IMPLEMENTATION POLICIES AND PROCEDURES: PHASE I TMDLs FOR TOXIC POLLUTANTS IN THE DELAWARE RIVER ESTUARY

Basis and Background Document

DELAWARE RIVER BASIN COMMISSION
WEST TRENTON, NEW JERSEY

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This report was prepared by the Delaware River Basin Commission staff: Gerald M. Hansler, Executive Director. Dr. Thomas J. Fikslin was the principal author. Substantial contributions, technical recommendations and comments were provided by the Water Quality Advisory Committee, the Estuary Toxics Management Subcommittee and the Implementation Workgroup. Pauline Ditmars provided word processing support.

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EXECUTIVE SUMMARY

This document contains the recommended policies and procedures for establishing wasteload allocations and effluent limitations for toxic pollutants which will be uniformly applied to all NPDES discharges to the estuary. These policies and procedures along with water quality criteria developed for the Delaware River Estuary are the essential components of a management strategy to control the release of substances toxic to humans and aquatic life.

The strategy utilizes a phased approach based upon the principle that a waterbody can assimilate a maximum daily loading of a toxic pollutant which still assures that water quality criteria for the pollutant are not exceeded. This loading is called the Total Maximum Daily Load or TMDL. The approach is phased such that loadings from point sources are the focus of Phase 1 with loadings from both point and non-point sources being considered in later phases.

Two levels of control are proposed for toxic pollutants for point sources. These controls will only be imposed if a discharge contains or has a reasonable potential to contain a pollutant for which water quality criteria for the estuary have been adopted. The first level specifies minimum standards of performance for both industrial and municipal sources. The second level specifies the loading necessary to meet water quality criteria for four specific endpoints: acute and chronic toxicity to aquatic life, and carcinogenic and non-carcinogenic (or systemic) effects on human health. Parameter-specific wasteload allocation procedures are described for each of these endpoints. The more stringent of these control levels will be imposed on a discharge if it is included in the wasteload allocation exercise.

The recommended procedure for developing wasteload allocations is called Equal Marginal Percent Reduction (EMPR). EMPR is a two step process in which a discharge is first considered independently of all other discharges. In this step called the Baseline Analysis, the discharge is assigned a load based upon either the minimum performance standard or water quality considerations. In the second step called the Multiple Discharge Analysis, the cumulative impact of all discharges, discharging at their respective baseline load, is evaluated against the water quality objectives. If the analysis indicates that a water quality objective will be violated, then the baseline discharge loads of all discharges significantly contributing to the violation are reduced by an equal percentage until the violation is eliminated.

Procedures are also presented for translating the four wasteload allocations developed by Commission staff for each endpoint into a single effluent limitation. These procedures will be utilized by permit-issuing authorities to select the most stringent wasteload allocation, and establish average monthly and maximum daily effluent limitations for NPDES permits.

I. INTRODUCTION

The Delaware Estuary Toxics Management Program is an interstate, cooperative effort coordinated by the Delaware River Basin Commission to develop a strategy to control the release of substances toxic to humans and aquatic life in point source discharges to the tidal portion of the Delaware River from the head of the tide at Trenton, NJ to Delaware Bay. The strategy will be an integrated approach which will consider both specific toxic chemicals and whole effluent toxicity. One of the principal objectives of the program is the development and adoption of policies and procedures for establishing wasteload allocations and effluent limitations for toxic pollutants which will be uniformly applied to all NPDES discharges to the estuary.

Water quality criteria for this portion of the Delaware River have been developed by the program and were presented at a public briefing held in June 1992 (DRBC, 1992a). The implementation policies and procedures are the second major output of the program. This portion of the strategy utilizes the concept of Total Maximum Daily Loads (TMDLs). A TMDL is the maximum daily loading of a pollutant from all sources which still assures that water quality criteria are not exceeded. Section 303(d) of the Clean Water Act requires states to identify those waters for which existing controls are not stringent enough to meet water quality standards, and develop TMDLs for those waters on a priority basis.

The strategy represents a phased TMDL approach to controlling toxic pollutants entering the tidal Delaware River. A phased TMDL approach is necessary since data are not available on the non-point source contribution of toxic pollutants to the river. In Phase 1, the focus is on the loading from point sources, with the development of wasteload allocations (WLAs) which consider the loading of toxic pollutants from background sources. In Phase 2, the loading from both point and non-point sources will be considered, and load allocations for non-point sources will be developed along with revised WLAs. Lack of data on the loading contributed by non-point sources limits the inclusion of these sources in Phase 1. The Delaware Estuary Program is currently involved in identifying and quantifying the loading of toxic pollutants from non-point sources. This information should provide the basis for increased monitoring and control of non-point sources in Phase 2. Under this approach, water quality criteria for all toxic pollutants will be achieved at the completion of the second phase of the process. At that time, TMDLs may be formally adopted by the Commission as part of their water quality regulations.

The implementation policies and procedures are based upon the principle that point source discharges must, in and of themselves and in conjunction with other point source discharges, meet the water quality objective for toxic pollutants. Provisions have been incorporated in the implementation procedures for Phase 1 to assure that point sources are not penalized for impacts on water quality attributable to non-point sources. The strategy also incorporates two levels of controls for toxic pollutants for point sources. The first level is the specification of minimum standards of performance for both industrial and municipal point sources. The second level involves the specification of additional reductions in the loading of toxic pollutants which may be necessary to meet water quality objectives. Use of uniform water quality criteria and implementation procedures by the states adjoining the estuary will assure that effluent limitations for discharges to the estuary are both technically-sound and equitable.

This document contains policies and procedures to control impacts to aquatic biota and human health for four specific endpoints. With respect to aquatic life, the strategy addresses acute toxicity (short-term effects on the survival of free-swimming, drifting and benthic aquatic organisms) and chronic toxicity (longer-term effects on the survival, growth and reproduction of aquatic organisms). The combined effects of toxic chemicals on aquatic life is also addressed in the strategy through the use of toxicity tests. With respect to human health, the strategy addresses controls to minimize the promotion and induction of carcinogenicity, and to prevent the occurrence of non-carcinogenic or systemic effects by specific chemicals. Parameter-specific wasteload allocations for each of these endpoints will be developed using the policies and procedures described in this document. The four wasteload allocations will be converted to a common base and compared to determine the most stringent wasteload allocation. This wasteload allocation will be used by the permitting authority to establish effluent limitations for the NPDES permit using the principles recommended by the U.S. EPA in the Technical Support Document for Water Quality-Based Toxics Control (TSD) (U.S. EPA, 1991).

Current regulations of the Delaware River Basin Commission relating to the discharge of toxic pollutants are contained in Section 3.10.4 and Section 4.30 of the Water Quality Regulations (DRBC, 1992b). These regulations require that discharges not contain more than negligible amounts of toxic substances, and require the allocation of the assimilative capacity among discharges where necessary to maintain water quality criteria or designated uses. Further, Interpretative Guideline No. 1 which was adopted by the Commission on January 26, 1972, directs the staff to use defined numerical limits for nine metals, acute toxicity and chronic toxicity as guidelines in administering the above-cited sections. The purpose was to provide quantitation of descriptive criteria contained in the water quality standards.

The Water Quality Advisory Committee recommends that the Commission formally adopt the policies and procedures presented in this report in Article 4 of the Water Quality Regulations with a requirement for a review of the Total Maximum Daily Load for each toxic pollutant and the resulting wasteload allocations at least once every five years. The policies and procedures would also replace the effluent quality requirements for toxic substances [Section B(2)(b)] presently contained in Interpretive Guideline No. 1 only for Zones 2 through 5 of the Delaware River (River Miles 48.2 to 133.4).

In order to provide for the maintenance of the TMDL process and achieve the goals of the Estuary Toxics Management Program, it is further recommended that the Commission commit to maintain and update the toxic substance data base for the Delaware River Estuary, update the TMDLs for any toxic pollutant established in Phase 1 and later phases of this program, and foster coordination on issues related to toxic pollutants through periodic meetings of the Estuary Toxics Management Subcommittee. Phase 2 of this process should be completed 5 years after the adoption of the Phase 1 TMDLs, with subsequent updates performed at five year intervals. The estuary states should commit to utilize the implementation policies and procedures and TMDLs developed by the Commission staff to establish effluent limitations for NPDES permits, participate in subsequent TMDLs phases, and coordinate with the Commission on general issues and specific permits with respect to toxic pollutants for estuary discharges.

The policies and procedures presented in this report were developed by a workgroup of the Estuary Toxics Management Subcommittee, and have been approved by the Water Quality Advisory Committee.

II. GENERAL POLICIES

The toxic management strategy incorporates two levels of control: a requirement to meet minimum performance standards, and a requirement to meet any additional water quality-based controls. This approach is modeled after the Clean Water Act which requires discharges to achieve effluent limitations which reflect the best technology available (BAT), and any more stringent limitation required to meet water quality standards. For all parameters for which there are water quality criteria for toxic pollutants, the more stringent of these control levels will be imposed on a discharge if one of the following criteria are met:

1. The discharge has an existing permit limit for the parameter,

2. Effluent data indicates the presence of the parameter, or

3. The reasonable potential exists for the parameter to occur in the discharge.

Factors to be considered in determining the reasonable potential for a toxic pollutant to occur in a discharge include discharge type (industrial or municipal), presence of pollutant in similar discharges to the estuary, raw materials used and products produced for industrial discharges, industrial loadings for municipal facilities, and treatment practices.

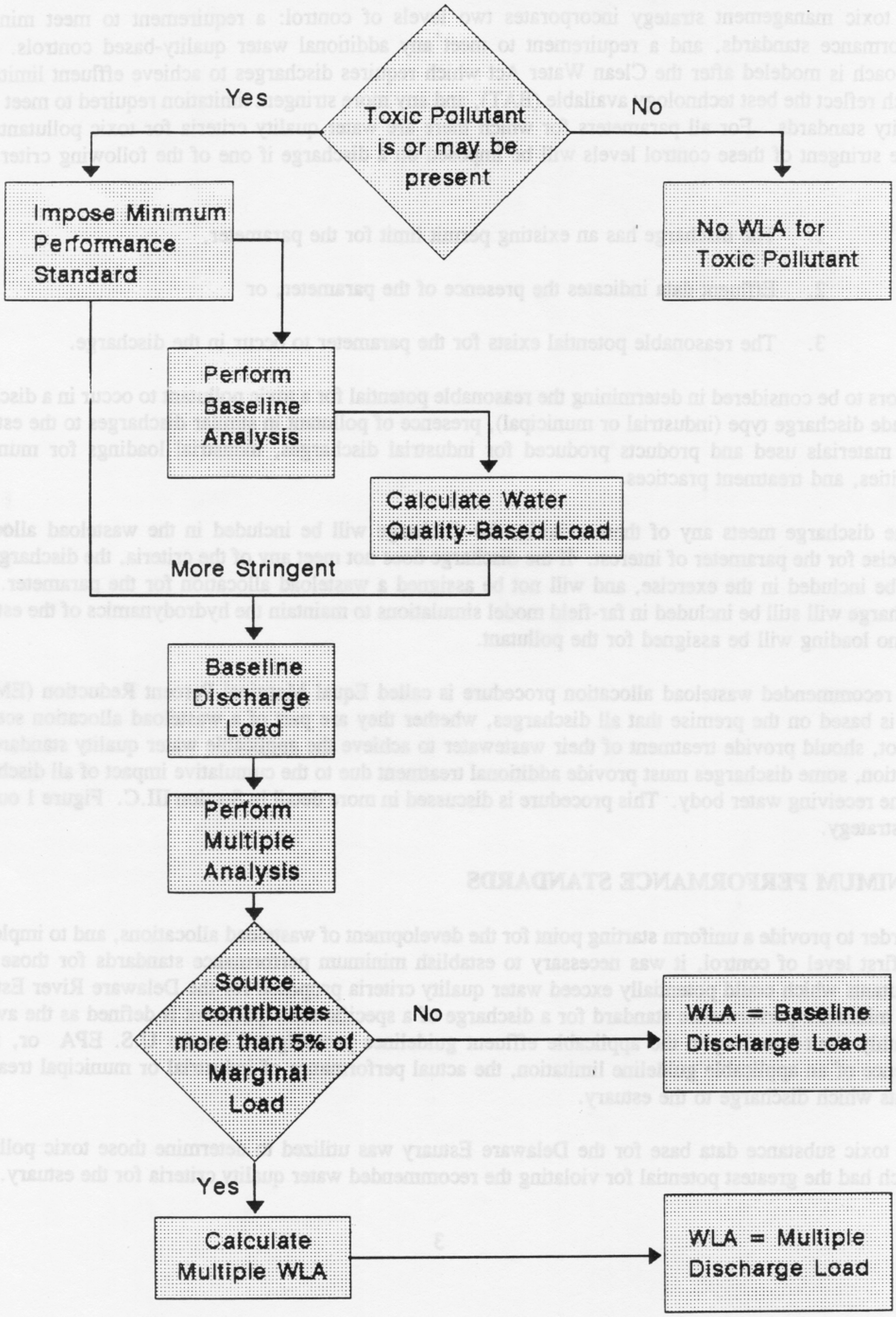
If the discharge meets any of these criteria, the discharge will be included in the wasteload allocation exercise for the parameter of interest. If the discharge does not meet any of the criteria, the discharge will **not** be included in the exercise, and will not be assigned a wasteload allocation for the parameter. The discharge will still be included in far-field model simulations to maintain the hydrodynamics of the estuary, but no loading will be assigned for the pollutant.

The recommended wasteload allocation procedure is called Equal Marginal Percent Reduction (EMPR), and is based on the premise that all discharges, whether they are part of a wasteload allocation scenario or not, should provide treatment of their wastewater to achieve the applicable water quality standard. In addition, some discharges must provide additional treatment due to the cumulative impact of all discharges on the receiving water body. This procedure is discussed in more detail in Section III.C. Figure 1 outlines the strategy.

MINIMUM PERFORMANCE STANDARDS

In order to provide a uniform starting point for the development of wasteload allocations, and to implement the first level of control, it was necessary to establish minimum performance standards for those toxic pollutants which could potentially exceed water quality criteria proposed for the Delaware River Estuary. The minimum performance standard for a discharge of a specific toxic pollutant is defined as the average monthly limit based upon the applicable effluent guidelines promulgated by the U.S. EPA or, in the absence of an applicable guideline limitation, the actual performance of industrial or municipal treatment plants which discharge to the estuary.

Figure 1: Strategy for developing wasteload allocations for toxic pollutants.



The toxic substance data base for the Delaware Estuary was utilized to determine those toxic pollutants which had the greatest potential for violating the recommended water quality criteria for the estuary. This evaluation indicated that metals, volatile organics, and pesticides/PCBs had the greatest potential for violating water quality criteria. In addition, fish consumption advisories have been issued and remain in effect for channel catfish and white perch due to elevated levels of PCBs and chlordane. Minimum standards of performance were established for these groups of toxic pollutants for both industrial and municipal and industrial discharges.

The methodology used to establish minimum performance standards was similar to the approach used by the New Jersey Department of Environmental Protection & Energy (NJDEPE, 1993). Minimum performance standards for volatile and non-volatile organic pollutants were obtained from the effluent guideline limitations for the Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) industrial category, and the U.S. EPA's Water Engineering Research Laboratory (WERL) data base. The maximum for a monthly average for a parameter listed in the guidelines was assumed to represent the long-term average performance. For thirteen (13) pollutants not listed in the OCPSF guidelines, the highest reported effluent value for activated sludge treatment contained in the WERL data base, was assumed to represent the long-term average performance. The OCPSF limitations represent technologically-achievable limits using biological treatment. These minimum performance standards apply to discharges from both industrial and municipal facilities.

Minimum performance standards for chlorinated pesticides and total polychlorinated biphenyls were obtained from the toxic substance data base and practical quantitation limits (PQLs) established by the New Jersey Department of Environmental Protection & Energy (NJDEPE, 1993). Since few facilities reported detectable limits of these compounds, the maximum reported concentration of each compound detected in treatment plant discharges was assumed to represent the long-term average performance. For those compounds which were not detected, the PQL was assumed to represent the long-term average performance. These minimum performance standards apply to discharges from both industrial and municipal facilities.

Minimum performance standards for metals for discharges from both industrial and municipal wastewater treatment plants were obtained from the toxic substance data base. Data from 42 industrial facilities representing several industrial categories including OCPSF, petroleum refining, inorganic chemicals manufacturing, and iron and steel manufacturing were available for analysis. Data from 31 municipal facilities having biological treatment with design capacities ranging from 0.22 to 210 MGD were available for analysis. The reported detection limit was utilized if the parameter was reported as undetected. For each category, the average discharge concentration for each metal was calculated, and assumed to represent the long-term average performance for industrial and municipal facilities discharging to the estuary.

Appendix A contains the minimum standards of performance that will be used in the baseline analysis portion of the wasteload allocation.

WATER QUALITY-BASED REQUIREMENTS

GENERAL APPROACH

Policies and procedures were developed to ensure compliance with water quality criteria currently being proposed to protect the designated uses of the tidal Delaware River for aquatic life and human health.

Criteria have been proposed for both specific chemicals and whole effluent toxicity (Appendix B). Since the criteria are expressed in two forms (acute and chronic toxicity for aquatic life, and protection against carcinogenic and systemic effects for human health), four sets of policies and procedures were necessary. The sets are as follows:

1. Protection of aquatic life from acute toxicity.
2. Protection of aquatic life from chronic toxicity.
3. Protection of human health from carcinogenic chemicals.
4. Protection of human health from non-carcinogenic or systemic effects of chemicals.

Three alternative approaches were identified for addressing the potential impact to aquatic life and human health of toxic pollutants discharged by point sources to the Delaware Estuary. These alternative approaches were:

1. Allow exceedances of water quality criteria at any time anywhere within the estuary.

2. No exceedances of water quality criteria allowed at any time anywhere within the estuary.

3. Allow exceedances of water quality criteria under design conditions and for periods of time less than the appropriate criteria duration.

The first approach would conflict with the objective of the Clean Water Act which is to restore and maintain the chemical, physical and biological integrity of the Nation's waters, and the national policy contained in Section 101(a)(3) of the Act which states that it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited. Furthermore, selection of this alternative would contravene the current water quality regulations of the Commission which contain a narrative standard requiring the waters of the basin to be "free from … substances in concentrations or combinations which are toxic or harmful to human animal, plant or aquatic life." Allowing exceedances of acute or chronic aquatic life criteria at any time and place in the estuary would potentially result in toxicity to at least the most sensitive species depending on the duration of the exceedance. Exceedances in habitats essential for the survival and reproduction of a pelagic or benthic species could present a significant challenge to the biological integrity of the estuary. Allowing exceedances of human health criteria at any time and place in the estuary would potentially result in impacts to segments of the population which ingest water and fish taken from the Delaware River.

The second approach would prohibit exceedances of water quality criteria in estuary waters. This alternative would allow no dilution of wastewater by the estuarine waters, and would require that criteria be applied to wastewater "in the pipe". This alternative would conflict with Section 4.20.3 of the water quality regulations of the Commission which provide for the measurement of water quality "outside of mixing areas" where such areas have been designated. The Technical Support Document for Water Quality-Based Toxics Control states that it is sometimes appropriate to allow for ambient concentrations which exceed acute water quality criteria in small areas near outfalls (U.S. EPA, 1991). Chronic mixing zones may also be established if the ecology of the waterbody as a whole is protected. Within these zones (also referred to as regulatory mixing zones), exceedances of chronic criteria are permitted and sensitive taxa will be prevented from establishing long-term residence (U.S. EPA, 1991). These zones should not be permitted to impair critical resource areas. For human health criteria, the TSD states that mixing zones may be established if there are no significant health risks, provided that they do not encroach on drinking water intakes. The establishment of mixing zones should not, however, result in significant health risks to average consumers of fish and shellfish when the duration of exposure of target species and fisheries use of the receiving water are considered (U.S. EPA, 1991).

The recommended approach therefore follows the third alternative of allowing exceedances of water quality criteria under design conditions and for periods of time less than the criteria duration. Such a policy will meet the objectives of the Clean Water Act to restore and maintain the chemical, physical and biological integrity of the Nation's waters, be consistent with current Commission water quality regulations, and is consistent with the recommendations contained in the Technical Support Document for Water Quality-Based Toxics Control.

The implementation of this approach for each set of water quality criteria is described below.

CONTROLLING ACUTE TOXICITY TO AQUATIC LIFE

A. Rationale

Acute toxicity is defined as a stimulus severe enough to rapidly induce an adverse effect in an aquatic organism. Acute toxicity results from exposure to a given level of a toxic pollutant (referred to as the magnitude) over a specified duration of exposure. Minimizing either the magnitude or duration will reduce or eliminate the toxicity. Thus, the magnitude of an acute water quality criterion may be exceeded as long as the average concentration of the pollutant over the specified criteria duration does not exceed the magnitude.

The recommended approach for controlling acute toxicity would allow exceedances of acute aquatic life criteria under design conditions, and for periods of time less than the criteria duration. In addition, small areas near each outfall called acute toxicity dispersion areas may be permitted. Within these dispersion areas, pollutant concentrations may exceed acute criteria.

The TSD contains several recommendations regarding the designation of dispersion areas. The total area of a water body assigned to dispersion areas should be small relative to the total area of the water body in order to have minimal effect on the integrity of the water body as a whole. Dispersion areas may be allowed only if there is no lethality to free-swimming and drifting aquatic organisms which encounter the area. In addition, the areal extent of and dilution isopleths within the dispersion area must assure that the one-hour average exposure of organisms drifting or swimming through this area is less than the Criterion Maximum Concentration (CMC). Acute toxicity dispersion areas should not be allowed if the area will impinge upon sensitive or critical habitat for fish and benthic organisms. Acute toxicity dispersion areas should also be restricted or denied to compensate for uncertainties in the degree of protection afforded by a criteria or uncertainties in the assimilative capacity of the water body.

Two levels of control are recommended for determining the size of acute toxicity dispersion areas. The first level is based upon the goal of achieving a high degree of mixing of the discharge with the receiving water by optimizing the outfall structure design. This level of control would be implemented through a "minimum performance standard" would require the area to be based upon the most stringent of the distance scales presented in the TSD. The second level is based upon ecological goals such as the maintenance of a zone of passage for free-swimming and drifting organisms and the protection of sensitive or critical habitat.

In order to minimize the cumulative area assigned to acute toxicity dispersion areas, it is recommended that no more that a small percentage (such as 5%) of the total area of the Delaware River Estuary be allocated for point source dispersion areas, and that this area be allocated to point sources discharging a specific toxic pollutant using a procedure based upon the principles of the Equal Marginal Percent Reduction procedure.

B. Specific Policies

1. Design Conditions - In order to prevent acutely toxic conditions to aquatic life, the average exposure over the criteria duration should not exceed the Criterion Maximum Concentration (CMC) for toxic pollutants specified in the document entitled "Recommended Water Quality Criteria for Toxic Pollutants for the Delaware River Estuary (DRBC, 1992a). The frequency of exceedance of the criteria will be determined by the hydrological processes that affect the dilution of the effluent. In the tidal river, tidal velocity and freshwater flow are the principal influences, with tidal flows the dominant factor. Despite the secondary influence of freshwater flow, a specified freshwater flow is needed to describe the ambient tidal velocities that occur in any portion of the estuary, and tributary flows must be specified in the model runs that will be used to establish reference pollutant concentrations. It is therefore recommended that a flow of 2500 cfs at Trenton with tributary flows set to the respective 7Q10 flow be used for these purposes (DRBC, 1992a). Tables of the design freshwater flows for tributaries are contained in Appendix C.

Preliminary evaluations of several discharges to the estuary indicate that minimal dilution of effluents is not always associated with the low water, slack tide condition during spring tides (U.S. EPA, 1991). Rather minimal dilution will vary depending on the outfall structure and location within the estuary. Since a complete tidal cycle occurs every 12.53 hours, there is a high frequency of occurrence of design tidal velocities, and the potential for these velocities to persist for significant periods of time. This potential requires procedures which provide strict control on the allowable dimensions of the acute toxicity dispersion areas.

2. Impingement on Critical Habitat - Critical habitat for a species is any area identified under the Endangered Species Act or specific areas within the tidal Delaware River which are or could be occupied by the species absent the toxic effect of pollutants; and which have those physical, chemical and biological features which are essential to the conservation and maintenance of the Delaware Estuary population. Protection of critical habitat is essential to maintain the integrity of the Delaware Estuary ecosystem. At the present time, however, critical habitat areas in the estuary have not been identified or mapped. The Delaware Estuary Program is currently planning an effort to identify the important species within the estuary, their habitat requirements, and publish maps of suitable habitat within the estuary (Delaware Estuary Program, 1992). This or other scientific efforts may result in the identification of critical habitat for important estuarine species. Until a consensus is reached on the location of such critical areas, it is recommended that dispersion areas be restricted by the permitting authority on a case-by-case basis at this

time. Future wasteload allocations to protect against acute toxicity to aquatic life should incorporate this general provision by prohibiting acute toxicity dispersion areas from impinging upon critical habitat which has been officially designated by federal or state resource agencies.

The protection of benthic organisms which may reside within the acute toxicity dispersion areas is also of concern. Depending upon the location and depth of the outfall structure, and the density of the effluent plume, benthic organisms may be directly exposed to the effluent plume. Appropriate location of outfall structures can minimize impacts to the benthic community by allowing mixing to occur with the receiving water beginning at the point of discharge. In order to protect the benthic community from the direct impacts of effluent discharges, it is recommended that acute toxicity dispersion areas not be allowed where the effluent is discharged directly to exposed benthic habitat. In such cases, the acute aquatic life criteria must be met prior to dilution with the receiving water (i.e., "in the pipe").

3. Limitation on the Total Estuarine Area Allocated to Dispersion Areas - Within the boundaries of acute toxicity dispersion areas, the concentration of a pollutant will exceed the acute water quality criterion. This may result in impacts to those species which reside within the area such as benthic species, and those mobile species which choose to remain within the area due to the present of more favorable temperatures and the presence of food particles. The cumulative area allocated must therefore be limited to ensure that the functions of the ecosystem are preserved. The Technical Support Document for Water Quality-Based Toxics Control (U.S. EPA, 1991) recommends that the size of the mixing zones be evaluated for their effect on the overall biological integrity of the waterbody. If the "total area affected by elevated concentrations is small compared to the total area of a waterbody", little effect on the integrity of the waterbody is likely. It is therefore recommended that the total surface area allocated to dispersion areas be limited to a small percentage of the total surface area of the estuary (approximately 260 km^2). Since 62% of the total estuary surface occurs between the Pennsylvania - Delaware border and the head of Delaware Bay (River Miles 48.2 - 78.8), it is further recommended that this small percentage be applied separately to this area and the upper tidal river (River Miles 78.8 - 133.4). Pending scientific consensus on the maximum percentage that could be allocated to dispersion areas without impacting critical estuary functions, it is recommended that the percentage allocated to dispersion areas be no more than five per cent (5%).

4. Restrictions on the Dimensions of the Dispersion Area - The size of dispersion areas need to be restricted to ensure that the uses of the water body by aquatic life are protected. Consistent with a two control level approach that requires minimum performance standards followed, if necessary, by water quality or "ecologically-based" requirements, the dispersion area will be limited to the most stringent of the distance scales presented in the TSD. The applicable distance scales are that:

> a. the area will be limited to a distance of 50 times the discharge length scale in any direction from the outfall structure, and
>
> b. the area will be limited to a distance of 5 times the local water depth in any direction from the outfall structure.

Ecological objectives that must be considered in this process include the prevention of lethality to drifting organisms which encounter the dispersion area, and the provision for a zone of passage for free-swimming and drifting organisms. The latter objective can be addressed by limiting the area to a fixed percentage of the surface width at the point of discharge. It is recommended that dispersion areas be limited to 50% of the surface width at the point of discharge to meet this objective. In order to prevent lethality within the dispersion area, the average exposure of organisms to toxicants over the criteria duration within the area should not exceed the acute water quality criterion. The above recommendations that dispersion areas be limited to the more stringent of the TSD distance scales and the ecologically-based requirements should ensure that aquatic life uses are protected.

CONTROLLING CHRONIC TOXICITY TO AQUATIC LIFE

A. Rationale

Chronic toxicity is defined as a stimulus which produces adverse effects in an aquatic organism over an extended time period. Adverse effects of chronic exposure to a toxicant include effects on growth, reproduction, survival, and behavior as well as biochemical and histological changes. Chronic aquatic life criteria are established to ensure that the survival, growth and reproduction of $>95\%$ of the species tested with a toxic pollutant would not be affected if the four day average concentration of the pollutant did not exceed the established value.

The policy for controlling chronic toxicity allows exceedances of chronic aquatic life criteria under design conditions for periods of time less than the criteria duration of four days. Compliance with the criteria would be evaluated by comparing the tidally-averaged concentration over the criteria duration at steady-state design conditions to the applicable criterion. Use of a one-dimensional water quality model for this comparison assumes complete vertical and lateral mixing in the tidal river. Since the criteria are applied as a time-averaged value rather than at a specified distance scale, it is unnecessary to designate a regulatory mixing zone.

It should be noted that this policy may result in the chronic criteria being exceeded during the four day averaging period under design conditions. The tidally-averaged concentration of the toxic pollutant over the four day period will not, however, exceed the chronic criteria. This policy may also not be sufficiently protective where lateral mixing is not complete within the criteria duration of four days. Therefore, site-specific factors will be applied to the criterion value where data are available to refute the assumption of complete lateral mixing.

B. Specific Policies

1. Design Flows - In order to prevent chronic toxicity to aquatic life, the average exposure over the criteria duration should not exceed the Criterion Continuous Concentration (CCC) for toxic pollutants specified in the document entitled "Recommended Water Quality Criteria for Toxic Pollutants for the Delaware River Estuary (DRBC, 1992a). The frequency of exceedance of the criteria will be determined by the hydrological processes that affect the dilution of the effluent. In the tidal river, freshwater flow, tidal velocity and effluent flow are the principal influences. Since the criteria will be applied as a tidally-averaged value, only the freshwater and effluent design flows need to be specified. The recommended design freshwater flow is a flow of 2500 cfs at Trenton with tributary flows set to the respective 7Q10 flow (DRBC, 1992a).

Tables of the design freshwater flow for tributaries which will be used to develop wasteload allocations are contained in Appendix C.

2. Assumption of Complete Vertical and Lateral Mixing - The recommended policy results in the application of chronic criteria as a four day, tidally-averaged value assuming complete vertical and lateral mixing. This policy may not be sufficiently protective if this assumption is not valid. Several authors have reported that the Delaware Estuary is considered to be a vertically well-mixed estuary, particularly during low freshwater inflows (Sharp et al, 1986; Smullen et al, 1983). Data collected by the Commission in the fall of 1992 indicated no statistically significant differences between concentrations of metals and volatile organics collected at twelve transects in the tidal river. This data supports the assumption of complete lateral mixing in the tidal river. The wasteload allocation procedure will therefore incorporate a lateral mixing factor of 1.0 which will be applied to the respective chronic criterion for the purposes of assessing compliance. This factor will be reduced on a site-specific basis if data obtained in future studies does not support this assumption.

CONTROLLING EFFECTS ON HUMAN HEALTH

A. Rationale

Potential effects on human health from toxic pollutants discharged from point sources are related to the uses of the estuary which expose the population to these substances. The principal exposure routes include recreational contact, ingestion of drinking water, and ingestion of contaminated fish tissue. Human health criteria are intended to minimize the risk of deleterious effects based upon ingestion of drinking water and the consumption of fish. Criteria are established for both carcinogens and non-carcinogens (systemic toxicants) to ensure that a risk level of 10^{-6} or one additional cancer case in one million people exposed is not exceeded, and that the concentration of a pollutant does not exceed the level that will result in systemic effects.

The recommended policy for controlling effects on human health allows exceedances of human health criteria under design conditions for periods of time less than the criteria duration. The duration for carcinogens is a lifetime exposure of 70 years, while the duration for non-carcinogens is a much shorter time frame. It is recommended that human health criterion for both carcinogenic and non-carcinogenic (systemic) effects be applied as a tidally-averaged concentration at steady state design conditions assuming complete vertical and lateral mixing. Since the criteria are applied as a time-averaged value rather than at a specified distance scale, it is unnecessary to designate a regulatory mixing zone.

B. Specific Policies

1. Design Flows - The frequency of exceedance of the criteria will be determined by the hydrological processes that affect the dilution of the effluent. In the tidal river, freshwater flow, tidal velocity and effluent flow are the principal influences. Since the criteria will be applied as a tidally-averaged value which will include a number of tidal cycles, only the freshwater flow and effluent flow design conditions need to be specified. The recommended design freshwater flow for the Delaware River and all tributaries for protection against carcinogenic effects is the harmonic mean flow. The recommended design freshwater flow for the

Delaware River and all tributaries for protection against systemic effects is 30Q5 extreme value flow statistic (DRBC, 1992a).

Tables of the design freshwater flows for tributaries which will be used to develop wasteload allocations are contained in Appendix C.

III. TOTAL MAXIMUM DAILY LOAD PROCEDURES

A. INTRODUCTION

The term "wasteload allocation" (WLA) refers to a specific set of circumstances in which two or more point source discharges are in sufficiently close proximity to one another to influence the level of treatment each must provide to comply with water quality standards (PADER, 1987). A WLA provides a quantitative relationship between the wasteload and the achievement of an instream concentration which is represented by the respective water quality criteria. The establishment of a WLA requires a fundamental understanding of the factors affecting water quality in the receiving water in question, and the representation of the significant processes in a conceptual or mathematical model which will determine the appropriate allocation of load.

The U.S. EPA has listed 19 procedures that may be used to establish wasteload allocations (U.S. EPA, 1991; Chadderton et al, 1981). A governing principal for most of these procedures is the concept of fairness or equity such that each of the dischargers contributing to an impairment of water quality receive an equal burden of the additional treatment requirements. The most commonly used allocation procedures reported by the U.S. EPA have been equal percent removal or equal effluent concentrations. Under certain conditions, both of these procedures may penalize dischargers. Examples include dischargers that have low levels of the pollutant in their influent or have aggressively improved the treatment efficiency of their treatment plant (in the case of equal percent removal), or that have high levels of a pollutant in their influent (in the case of equal effluent concentrations).

B. RATIONALE

There are several terms that can be applied to the sources of toxic pollutants. Point sources are generally industrial or municipal facilities that discharge to the estuary through outfall structures (or pipes) located in or adjacent to the estuary. These sources are usually regulated through the National Pollutant Discharge Elimination System (NPDES) permits issued by state agencies. Control of point sources is the focus of the Estuary Toxics Management Program. Non-point sources include stormwater runoff from urban, agricultural, and industrial areas; groundwater infiltration and runoff from Superfund sites; atmospheric deposition; combined sewer overflows (CSOs); groundwater infiltration and natural background. Some of these sources may discharge via an outfall structure and have an NPDES permit (such as a CSO, landfill or Superfund site), but are still considered non-point sources for the purposes of this strategy. Pollutant sources can also be classified as controllable or not subject to control. These terms refer to the degree to which a source is currently required to reduce its contribution of toxic pollutants through technology. Some sources which are not controlled at the present time, may be controlled in the future (industrial, urban and agricultural stormwater runoff).

The recommended strategy for allocating the loading of toxic pollutants to the Delaware Estuary is a two phased approach based upon the concept of Total Maximum Daily Loads (TMDLs). The TMDL process considers four components: WLAs for point sources, "load allocations" (LAs) for non-point sources, a specified margin of safety, and a reserve capacity for future growth. This approach would follow the standard TMDL process required by Section 303(d) of the Clean Water Act. Section 303(d) requires that each state identify those waters for which existing required pollution controls are not stringent enough to implement State water quality standards. For these waters, states are required to establish TMDLs. The TMDL would quantify the maximum allowable loading of a pollutant to the estuary, and allocate this loading to point and non-point sources including natural background. The TMDL must also include a margin of safety to reflect scientific uncertainty. The margin of safety may be incorporated through the use of conservative design conditions.

Phase 1 of the strategy focuses on the loading of toxic pollutants from point sources. Loading from non-point sources would be limited in Phase 1 to the contributions from the tributaries and sediments of the estuary. The loading from tributaries would be set to actual data or the respective water quality criterion, whichever is lower. Sediment concentrations attributable to non-point sources would be established as the difference between actual sediment concentrations and concentrations attributable to point sources which will be obtained from model runs.

In Phase 1, the water quality objective would be set to the higher of the water quality criterion for a pollutant or the background concentration of the pollutant. The latter objective is needed in order not to penalize point sources for impacts attributable to non-point sources.

Lack of data on the loadings of toxic pollutants from non-point sources limits their inclusion in Phase 1. Completion of an initial inventory and loading estimates by the Delaware Estuary Program will permit incorporation of load allocations for non-point sources in Phase 2 and future TMDL evaluations.

C. RECOMMENDED WASTELOAD ALLOCATION PROCEDURE

The selected wasteload allocation procedure should achieve three major objectives:

1. To assure compliance with applicable water quality criteria;
2. To provide maximum equity, or fairness, between competing discharges; and
3. To minimize, within institutional and legal constraints, the overall cost of compliance.

The first objective is fundamental to the protection of water quality and public health, and is mandated by the federal Clean Water Act and the statutes of the basin states. The second objective is a social statement that embodies the governing principle of wasteload allocation procedures. The desirability of equity among individual (and potentially competing) members of society, especially in a regulatory program, is a reasonably well-accepted goal of society. The third objective is a statement of the desirability of economic efficiency. An effective water quality management program should attempt to achieve water quality management goals with maximum economic efficiency (i.e., least cost).

The recommended wasteload allocation procedure was developed by the Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management with goal of achieving the above objectives (PADER, 1987). Other wasteload allocation procedures may be considered which achieve the above-stated objectives within the time frame specified for developing of wasteload allocations for point sources. In addition, submittals of alternative wasteload allocation procedures must include the consent of all permittees affected by the alternative procedure.

The recommended procedure is called Equal Marginal Percent Reduction (EMPR), and is based on the premise that all discharges, whether they are part of a wasteload allocation scenario or not, should provide treatment of their wastewater to achieve the applicable water quality standard. In addition, some discharges must provide additional treatment due to the cumulative impact of all discharges on the receiving water body. EMPR is thus a two-step process incorporating both minimum performance standards (such as applicable technology-based requirements) and, where necessary, water quality-based requirements. In the first step, known as the Baseline Analysis, each discharge included in the wasteload allocation process is evaluated independently, as if it was the only point source discharge to the estuary. If the quality of the discharge at the minimum performance standard will cause a violation of water quality criteria (or other policy constraints), the discharge is assigned a baseline water quality-based allocation. If the quality of the discharge at the minimum performance standard does not cause a violation, the baseline load is set equal to the minimum performance standard.

In the second step, Multiple Discharge Analysis, the cumulative impact of all discharges, discharging at the minimum performance standards or water quality-based levels established during Baseline Analysis, is evaluated. If the analysis indicates the water quality criteria (or other policy constraint) will be violated, then the Baseline Discharge loads of all discharges significantly contributing to the violation are reduced by an equal percentage until the violation is eliminated.

D. APPLICATION OF WASTELOAD ALLOCATION PROCEDURE

Separate procedures have been developed, incorporating the EMPR wasteload allocation algorithm, to address acute aquatic life protection, chronic aquatic life protection and both carcinogenic and systemic toxicants. Each of these procedures will be conducted separately for each toxic pollutant, and the most stringent wasteload allocation for each discharge will be selected for translation into permit limitations.

The criteria-specific procedures are described below.

ACUTE AQUATIC LIFE CRITERIA

The procedure for establishing dispersion areas (where allowed) and wasteload allocations based upon acute aquatic life protection is outlined below. It is designed to assure that, at design conditions, all but a minimal area of the estuary meets or exceeds acute fish and aquatic life criteria for toxic substances, that critical habitat areas and exposed benthic substrates in the estuary are not adversely affected, and that a continuous channel or zone for the passage of fish and other aquatic species is maintained at all times throughout the estuary. In performing this procedure, the existing outfall configuration and location will be utilized. The existing configuration and location are defined as the structure currently in-place, required by Administrative Consent Order, or required in a permit compliance schedule.

This procedure is a two step process. In the first step, called the BASELINE ANALYSIS, each point source discharge is evaluated independently, as if it were the only point source discharge to the estuary. For each discharge and parameter evaluated, BASELINE ANALYSIS can result in the assignment of a water quality based wasteload allocation and effluent limitation, or the determination that the minimum performance standard is sufficient to meet acute criteria.

The second step, called MULTIPLE DISCHARGE ANALYSIS, evaluates the cumulative impact of discharges, discharging at the levels established during BASELINE ANALYSIS. If MULTIPLE DISCHARGE ANALYSIS indicates that an acute criteria violation will occur or that the cumulative area assigned to mixing areas exceeds the maximum available area, the BASELINE DISCHARGE LOADS of all discharges that significantly contribute to the violation are reduced by an equal percentage until the violation is eliminated.

Baseline Analysis

1. For all parameters for which there are acute aquatic life criteria, evaluate all discharges that have effluent limitations for the parameter, or for which effluent data indicates the presence of the parameter, or that have a reasonable potential to discharge the pollutant of concern.

2. For each discharge and parameter, establish reference pollutant concentration profiles using the far-field model for the estuary. This reference profile will include loadings from tributaries and the bay; sediment loadings, if applicable; and loadings from all other discharges with the effluent concentration set to the water quality criteria for the parameter. (Note: The discharge being evaluated is <u>not</u> part of the reference concentration.)

3. Using the CORMIX model appropriate to the outfall design for each discharge, describe the wastefield (isopleths of dilution factors) for each discharge using the tidal velocities which occur in the vicinity of the discharge location over a complete tidal cycle. Construct a graph of area versus dilution factor for each discharge.

4. For each discharge, determine the dilution factor that corresponds to the most stringent of the minimum performance standard distance scales presented in Section B.4. on page 7.

5. Assess whether the wastefield impinges on critical habitat or exposed benthic substrate, and meets the requirements for zones of passage for free-swimming and drifting organisms. Dischargers whose plumes impinge on exposed benthic habitat will have their wasteload allocations for all parameters set equal to the respective acute water quality criterion. Determine the dilution factor which corresponds to the most stringent of ecologically-based requirements.

6. For each discharge and parameter of concern, determine the maximum allowable discharge load for the minimum performance standards and ecologically-based requirements, using the corresponding dilution factor and reference pollutant concentration.

7. For each parameter of concern, select the more stringent of the minimum performance standard or ecologically-based load as the *BASELINE DISCHARGE LOAD*.

Multiple Discharge Analysis

8. For each parameter of concern, determine the estuary pollutant concentrations at all critical points with each discharge discharging at their respective *BASELINE DISCHARGE LOAD*.

9. Using mass balance techniques, identify (any) locations where the estuary pollutant concentration is expected to exceed acute criteria at the edge of the allocated acute criteria dispersion area.

10. Beginning with the location that shows the most significant violation, determine which discharges are significantly contributing to the violation. Make appropriate adjustments to the discharge loads of the contributing discharges. (Note: Discharge significance will be determined on the basis of the baseline discharge loads.)

11. Repeat steps 9 through 10 until all violations have been eliminated for all parameters of concern.

12. For each parameter of concern, determine the cumulative allocated acute criteria dispersion area. If the allocated areas exceed the maximum allowable total dispersion area for the estuary, make further adjustments to the significant discharges to assure overall compliance.

13. Convert Acute Wasteload Allocations (WLAs) to equivalent long-term averages (LTAs) for comparison with the LTAs for chronic aquatic life criteria.

CHRONIC AQUATIC LIFE CRITERIA

The procedure for establishing chronic toxicity-based wasteload allocations is a two step process utilizing the one-dimensional water quality model of the tidal Delaware River (DELTOX) and the equal marginal percent reduction (EMPR) wasteload allocation procedure discussed above.

In the first step, called the BASELINE ANALYSIS, each point source discharge is evaluated independently, as if it were the only point source discharge to the estuary. For each discharge and parameter evaluated, BASELINE ANALYSIS can result in the assignment of a water quality-based wasteload allocation and effluent limitation, or the determination that the minimum performance standard is sufficient to meet chronic aquatic life criteria.

The second step, called MULTIPLE DISCHARGE ANALYSIS, evaluates the cumulative impact of discharges, discharging at the levels established during BASELINE ANALYSIS. If MULTIPLE DISCHARGE ANALYSIS indicates that a chronic criteria violation will occur, the BASELINE DISCHARGE LOADS of all discharges that significantly contribute to the violation are reduced by an equal percentage until the violation is eliminated.

Baseline Analysis

1. For all parameters for which there are chronic aquatic life criteria, evaluate all discharges that have effluent limitations for the parameter, or for which effluent data indicates the presence of the parameter, or that have a reasonable potential to discharge the pollutant of concern.

2. For each discharge and parameter, establish reference pollutant concentration profiles using the far-field model of the estuary. This reference profile will include loadings from tributaries and the bay; sediment loadings, if applicable; and loadings from all other discharges with the effluent concentration set to the water quality criteria for the parameter. (Note: The discharge being evaluated is <u>not</u> part of the reference concentration.)

3. For each discharge and parameter of concern, determine the maximum allowable discharge load for the minimum performance standard using the reference pollutant concentration.

4. Using the four day average loading of the toxic pollutant of concern, the design conditions for chronic aquatic life criteria and the DELTOX model, determine the maximum allowable discharge load for each discharge that will meet the applicable chronic criterion or other water quality objective for the pollutant.

5. For each parameter of concern, select the more stringent of the minimum performance standard load or water quality-based load as the *BASELINE DISCHARGE LOAD*.

Multiple Discharge Analysis

6. For each parameter of concern, determine the estuary pollutant concentrations at all critical points with each discharge discharging at their respective *BASELINE DISCHARGE LOAD*; or, for those discharges not evaluated in the baseline analysis, a load corresponding to the applicable water quality criterion.

7. Using the DELTOX model, identify (any) locations where the estuary pollutant concentration is expected to exceed the chronic criteria.

8. Beginning with the location that shows the most significant violation, determine which discharges are significantly contributing to the violation. Make appropriate adjustments to the discharge loads of the contributing discharges. (Note: Discharge significance will be determined on the basis of the baseline discharge loads.)

9. Repeat steps 7 through 8 until all violations have been eliminated for all parameters of concern.

10. Convert the Chronic Wasteload Allocations (WLAs) to equivalent long-term averages (LTAs) for comparison with the LTAs for acute aquatic life criteria.

HUMAN HEALTH CRITERIA

The procedure for establishing human health-based wasteload allocations is a two step process utilizing the one-dimensional water quality model of the tidal Delaware River (DELTOX) and the equal marginal percent reduction (EMPR) wasteload allocation procedure discussed above. This procedure must be performed for both the criteria for carcinogens and the criteria for systemic toxicants.

In the first step, called the BASELINE ANALYSIS, each point source discharge included in the wasteload allocation process is evaluated independently, as if it were the only point source discharge to the estuary. For each discharge and parameter evaluated, BASELINE ANALYSIS can result in the assignment of a water quality-based wasteload allocation and effluent limitation, or the determination that the minimum performance standard is sufficient to meet human health criteria.

The second step, called MULTIPLE DISCHARGE ANALYSIS, evaluates the cumulative impact of discharges, discharging at the levels established during BASELINE ANALYSIS. If MULTIPLE DISCHARGE ANALYSIS indicates that a human health criteria violation will occur, the BASELINE DISCHARGE LOADS of all discharges that significantly contribute to the violation are reduced by an equal percentage until the violation is eliminated.

Baseline Analysis

1. For all parameters for which there are human health criteria, evaluate all discharges that have effluent limitations for the parameter, or for which effluent data indicates the presence of the parameter, or that have a reasonable potential to discharge the pollutant of concern.

2. For each discharge and parameter, establish reference pollutant concentration profiles using the DELTOX model. This reference profile will include loadings from tributaries and the bay; sediment loadings, if applicable; and loadings from discharges with the effluent concentration set to the water quality criteria for the parameter. (Note: The discharge being evaluated is <u>not</u> part of the reference concentration.)

3. For each discharge and parameter of concern, determine the maximum allowable discharge load for the minimum performance standard using the reference pollutant concentration.

4. Using the average loading of the toxic pollutant of concern for the appropriate criteria duration (long-term average for carcinogenic criteria and 30 day average loading for systemic toxicants), the design conditions for the type of human health criteria and the DELTOX model, determine the maximum allowable discharge load for each discharge that will meet the applicable water quality criterion or other water quality objective for the pollutant.

5. For each parameter of concern, select the more stringent of the minimum performance standard load or water quality-based load as the *BASELINE DISCHARGE LOAD*.

Multiple Discharge Analysis

6. For each parameter of concern, determine the estuary reference pollutant concentrations at all critical points with each discharge discharging at their respective *BASELINE DISCHARGE LOAD*; or, for those discharges not evaluated in the baseline analysis, a load corresponding to the applicable water quality criterion. (Note: The discharge being evaluated is <u>not</u> part of the background concentration.)

7. Using the DELTOX model, identify (any) locations where the estuary pollutant concentration is expected to exceed the human health criterion.

8. Beginning with the location that shows the most significant violation, determine which discharges are significantly contributing to the violation. Make appropriate adjustments to the discharge loads of the contributing discharges. (Note: Discharge significance will be determined on the basis of the baseline discharge loads.)

9. Repeat steps 7 through 8 until all violations have been eliminated for all parameters of concern.

E. MATHEMATICAL MODELING

Given the hydrodynamic complexity of the estuary, the numerous point source discharges, and the various fate processes affecting toxic pollutants, mathematical models are needed to allocate wasteloads under the appropriate design conditions. The model selected for use in allocating wasteloads for the protection of aquatic life from chronic toxicity and the protection of human health is the Water Quality Analysis Simulation Program (WASP4) developed by the U.S. Environmental Protection Agency (U.S. EPA, 1988a). This model has been adapted for the tidal Delaware River between Trenton, NJ (River Mile 133.4) and the head of Delaware Bay (RM 48.2) by specifying physical, hydrodynamic and chemical characterist
ics for the estuary.

The DELTOX model consists of 90 nodes, and incorporates 11 tributaries, the headwaters of the Delaware River, the C&D Canal and a seaward boundary. The model also incorporates applicable fate processes for toxic substances which may include sorption, settling, resuspension, scour, volatilization, ionization, photolysis, oxidation, hydrolysis and bacterial degradation. The specific fate processes included in the model runs is dependent on the toxic pollutant being simulated. Loadings from tributaries and the seaward boundary are included in the model, and the concentration of toxic pollutants (e.g., metals) in the river sediments is also specified in the model.

Another family of models is utilized in developing wasteload allocations for the protection of aquatic life from acute toxicity. The CORMIX models are a series of expert system programs designed to predict the trajectory and dilution of submerged single port, submerged multi-port, and surface discharges into the ambient environment (Doneker and Jirka, 1991). These models are used to describe the wastefield or dispersion area of estuary discharges (including dilution isopleths) under the varying conditions that occur over a tidal cycle. These varying conditions include the direction and velocity of the ambient current, and water depth. Due to the short travel time of pollutants within the dispersion area or mixing zone, no fate processes are considered.

F. EFFLUENT DATA BASE FOR DEVELOPING WLAs

Accurate data on the loading of toxic pollutants from point source discharges to the estuary are essential if the wasteload allocations are to meet the objectives discussed in Section D. For each discharge, this data must include the concentration of each toxic pollutant, the variability of the concentration in the effluent, the effluent design flow, and the minimum performance standard for the toxic pollutant.

In the spring of 1990, the Commission required 83 NPDES permittees to monitor their discharges to the tidal Delaware River for priority toxic pollutants and whole effluent chronic toxicity. The discharges generally consisted of process wastewater or were currently monitored for one or more toxic pollutants. Data from this effort was assembled into a data base which currently resides on the IBM mainframe computer at the U.S. EPA Nation Computer Center (NCC). The data base is accessible by state and federal agencies or other organizations with access to the this computer. Instructions on accessing and sorting the data base are contained in the document entitled "Toxic Substance Data Base for the Delaware River Estuary" (DRBC, 1991). The data base will be sorted and used with any additional data that may be available to develop the mean concentration (long-term average) and associated coefficient of variation (CV) of each toxic pollutant of concern in each discharge. NPDES permittees will be notified of the CV values that will be used in the development of wasteload allocations, and will be given the opportunity to submit additional data. A default value of 0.6 will be used for the coefficient of variation if less than 10 values are available for the calculation of a discharge-specific CV.

Effluent concentration data will be used to establish minimum standards of performance for metals, and determine if a discharge should be included in the wasteload allocation. Discharges will be included in a wasteload allocation if the toxic pollutant or parameter of interest is detected in their effluent, or their NPDES permit contains a limit for the parameter, or there is a reasonable potential for the discharge to contain the pollutant of concern.

IV. TRANSLATION OF WLAs TO PERMIT LIMITATIONS

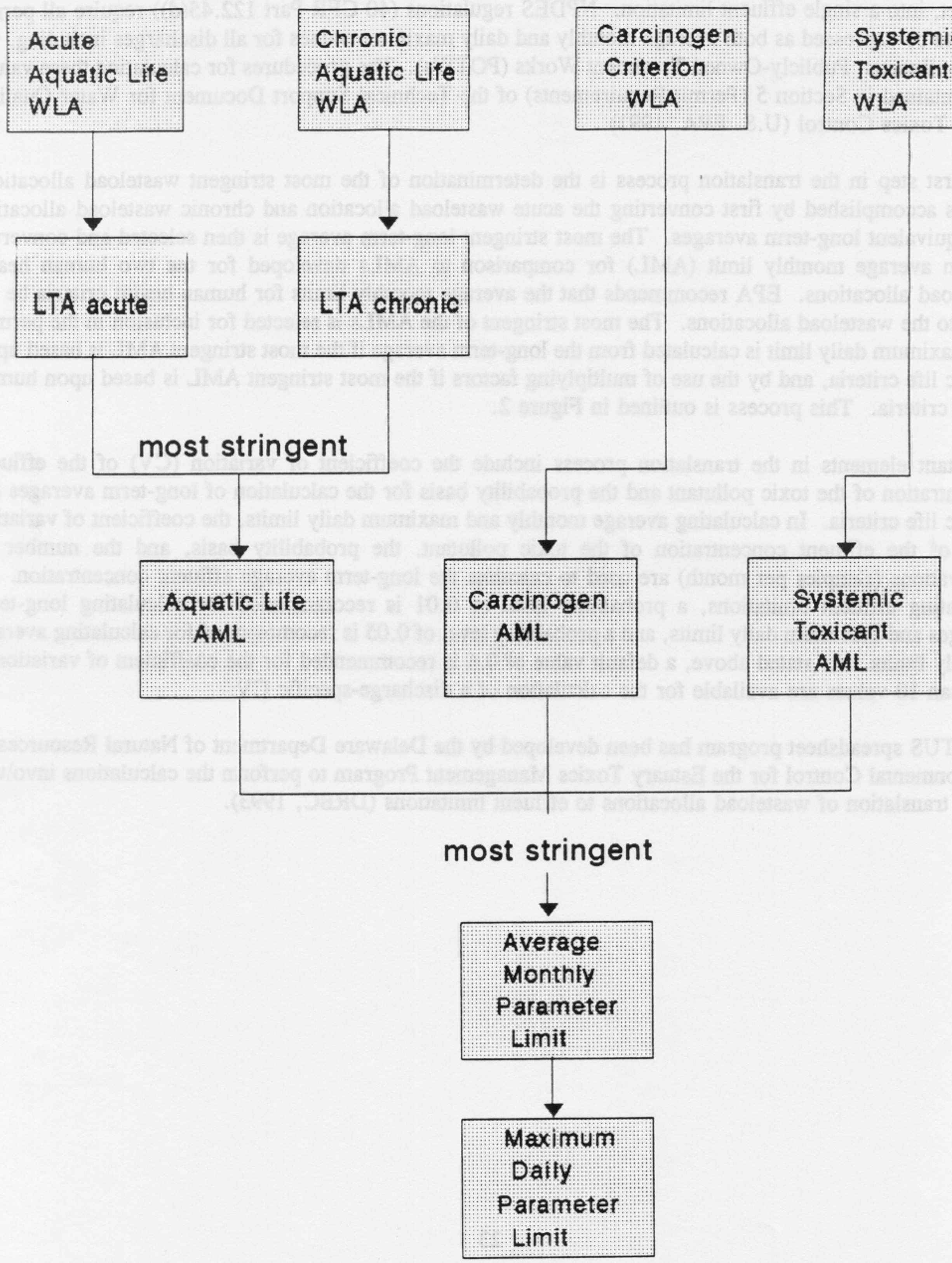
The final step in establishing effluent limitations for toxic pollutants is the translation of the four wasteload allocations developed to assure that aquatic and human health water quality criteria for a toxic pollutant are met, into a single effluent limitation. NPDES regulations (40 CFR Part 122.45(d)) require all permit limits to be expressed as both average monthly and daily maximum values for all discharges including, for toxic pollutants, Publicly-Owned Treatment Works (POTWs). The procedures for calculating these values are contained in Section 5 (Permit Requirements) of the Technical Support Document for Water Quality-Based Toxics Control (U.S. EPA, 1991).

The first step in the translation process is the determination of the most stringent wasteload allocation. This is accomplished by first converting the acute wasteload allocation and chronic wasteload allocation into equivalent long-term averages. The most stringent long-term average is then selected and converted into an average monthly limit (AML) for comparison to AMLs developed for the two human health wasteload allocations. EPA recommends that the average monthly limits for human health criteria be set equal to the wasteload allocations. The most stringent of the AMLs is selected for inclusion in the permit. The maximum daily limit is calculated from the long-term average if the most stringent AML is based upon aquatic life criteria, and by the use of multiplying factors if the most stringent AML is based upon human health criteria. This process is outlined in Figure 2.

Important elements in the translation process include the coefficient of variation (CV) of the effluent concentration of the toxic pollutant and the probability basis for the calculation of long-term averages for aquatic life criteria. In calculating average monthly and maximum daily limits, the coefficient of variation (CV) of the effluent concentration of the toxic pollutant, the probability basis, and the number of observations (samples per month) are used to calculate the long-term average effluent concentration. In calculating effluent limitations, a probability level of 0.01 is recommended for calculating long-term averages and maximum daily limits, and a probability level of 0.05 is recommended for calculating average monthly limits. As stated above, a default value of 0.6 is recommended for the coefficient of variation if less than 10 values are available for the calculation of a discharge-specific CV.

A LOTUS spreadsheet program has been developed by the Delaware Department of Natural Resources & Environmental Control for the Estuary Toxics Management Program to perform the calculations involved in the translation of wasteload allocations to effluent limitations (DRBC, 1993).

Figure 2: Procedure for selection of the most stringent wasteload allocation and establishing effluent limitations



V. SPECIFIC POLICIES AND OTHER CONSIDERATIONS

This section contains the rationale for specific policies and procedures that will be utilized to develop wasteload allocations for point sources discharging to the estuary. A discussion of each policy is as follows.

1. Margin of Safety - A margin of safety is a factor that takes into account any lack of knowledge or uncertainty related to the development of water quality-based controls. Uncertainties may be related to pollutant loadings, the model used, or ambient conditions. A margin of safety can be provided for by either allocating a portion of the loading capacity, or through the use of conservative design conditions (U.S. EPA, 1991). The principal design condition for protecting aquatic life from acute toxicity is the ambient velocity of the receiving water. The ~ 12.4 hour periodicity of the tides indicates the potential for a high frequency of occurrence of the design condition. The principal design condition for protecting aquatic life from chronic toxicity is freshwater inflow. This flow is not based upon extreme value flow statistics such as the 7Q10, but upon a regulated target flow of 2500 cfs which is slightly greater than the biologically-based flow (4Q3). These factors suggest that a margin of safety is not incorporated in the recommended design conditions, and it is therefore recommended that a margin of safety be incorporated as a proportion of the Total Maximum Daily Load during each allocation or reallocation.

2. Allocation Reserve - A portion of the loading capacity may be set aside in a reserve for future growth. Section 4.30.7(A.4) of the Commission's Water Quality Regulations allows the Commission to set aside a portion of the waste assimilative capacity of a water body to accommodate new discharges or major changes which occur subsequent to the initial allocation or any reallocation (DRBC, 1992b). It is recommended that a small reserve (5%) be included during the allocation process. This will be implemented by increasing the effluent design flow by 5%.

3. Sediment Interactions - The bed sediment of the estuary plays an important role in the transport and fate of toxic pollutants. The importance of sediment to the fate of a specific pollutant is directly related to the degree to which it is adsorbed to particulates. Pollutants such as metals and hydrophobic organic chemicals readily adsorb to the surface of suspended particulates. Volatile organic chemicals do not readily adsorb, and other mechanisms are more significant in determining their fate.

Sediment loading to the estuary derives primarily from erosion from tributary watersheds and shore erosion. Biggs et al (1983) estimated that 68% of the sediment loading to the estuary was from tributaries and 9% was from shore erosion. Pollutants sorbed to sediments may be buried in the bed by deposition and sedimentation, or they may be released to the water column by resuspension.

An important aspect of the modeling of toxic pollutants is the capability to simulate sediment transport, sediment/water, and sediment/toxicant interactions. In the DELTOX model, sediment/water interactions are specified in terms of settling, resuspension and deep burial rates. Sorption of the toxic pollutant is specified by means of a partition coefficient. The bed sediment is divided into a surface bed portion and a sub-surface bed portion. For simplicity, the depths of both beds are considered constant, and the sediment concentration of a bed changes according to the net flux of sediment through deposition, scour and sedimentation.

In order to determine the concentration of a toxic pollutant in the sediment which results from non-point sources only, the initial concentration in the estuary sediments were set to zero, and the model was run for

30 days using current loading estimates for point sources. The resulting sediment concentrations in the model output will then be subtracted from data on sediment concentrations of the toxic pollutant to obtain an estimate of the sediment concentrations attributable to sources not subject to control (i.e., non-point sources in Phase 1). These concentrations will then be used in model runs for the WLA procedures.

4. Reference Concentrations - Sources of toxic pollutants not subject to control such as natural sources, sources upstream of the segment, and atmospheric deposition represent loadings to a specific water body segment and result in background or reference concentrations of the pollutant for the water body. In the case of the estuary, reference pollutant concentrations of toxic pollutants must be developed in the baseline analysis for each toxic pollutant, each water quality criterion, and each discharge included in the wasteload allocation procedure. All reference pollutant concentrations will be determined using the DELTOX model. In developing the reference concentrations, loadings not subject to control will include tributary and seaward boundary loadings as well as projected sediment concentrations from non-point sources only. In the baseline analysis, loadings for discharges included in the wasteload allocation exercise (with the exception of the discharge being evaluated) are set to the applicable water quality criterion. Loadings for discharges not included in the exercise are set to zero.

5. Tributary Loadings of Toxic Pollutants - There are two options for establishing the contribution of toxic pollutants from tributaries at the head of the tide. The first option is to use actual data on the current loadings from the tributaries. Data are available for most of the tributaries that are included in the model. In some cases, this data indicates that the concentration of a toxic pollutant is above the water quality criterion. This may be due to the lag between the imposition of new effluent limitations for toxic pollutants, and the completion and operation of treatment facilities. Alternatively, it may be due to non-point sources of toxic pollutants. The second option is to use either the lower of the median value of the available data at the appropriate criteria duration, or the water quality criterion, whichever is lower. It is recommended that the second option be employed in developing wasteload allocations. Monitoring of the tributaries during the implementation period of the initial wasteload allocations is also recommended to determine if water quality criteria are being achieved above the head of tide.

6. Design Effluent Flows - The recommended effluent design flow for industrial wastewater treatment plants is dependent upon whether or not the discharge is covered by Effluent Limitations Guidelines (ELG) promulgated by the U.S. EPA. If ELGs are applicable to a discharge, the recommended effluent design flow shall be the average daily flow associated with:

a) the month having the highest monthly production rate of the previous twelve months or, if greater,

b) the year having the highest annual production rate of the previous five (5) years.

If a discharge is not covered by ELGs, is mixed with stormwater or cooling water or production data are not available, the recommended effluent design flow shall be the average daily flow for:

a) the month with the highest monthly flow rate of the previous twelve months, or if greater,

b) the year having the highest annual flow rate of the previous five (5) years.

The recommended effluent design flow for municipal wastewater treatment plants shall be the higher of the average daily flow of the plant for the previous three (3) years including a growth factor based upon a 5 year projection, or the design capacity of the plant expressed as the annual average flow. In the absence of data to derive a site-specific growth factor, a default value of 5% will be used.

Design effluent flows for industrial discharges were established using these policies and applicable data for the years 1988 to 1992. Design effluent flows for discharges from municipal wastewater treatment plants were established using these policies and data for the years 1990 to 1992. Tables of the design effluent flows which will be used to develop wasteload allocations are contained in Appendix C.

7. Definition of Discharge Significance - During the multiple discharge analysis, discharge loads of all discharges significantly contributing to a water quality violation are reduced by an equal percentage until the violation is eliminated. In order to achieve the maximum economic efficiency, discharges contributing a small percentage of the marginal loading should not receive an additional reduction during this phase of the wasteload allocation. It is recommended that discharges contributing a small proportion of the marginal loading not be included in the multiple discharge analysis.

8. Hydraulic Conditions for Baseline Allocations - During the baseline analysis step of the wasteload allocation procedure, each point source is evaluated independently as if it was the only discharge to the estuary. Different hydrodynamic conditions would exist, however, if each discharge were the only discharge to the estuary. For example, the withdrawal of water above the head of tide on the Schuylkill River results in less dilution flow in the tidal portion of the Schuylkill River. This water is returned to the basin in the form of discharges from the Philadelphia wastewater treatment plants, but at different locations in the Delaware River. In addition, discharges from point sources also provide assimilation capacity if they contain low levels of the pollutant of interest. It is therefore recommended that the effluent design flows for other point sources be included in the baseline analysis. The loading for these sources will be set to the product of the design effluent flow and the applicable water quality criterion if they are included in the wasteload allocation exercise. If they are not included in the wasteload allocation exercise, the loading will be set to zero.

9. Pollutant Fate - After discharge to a water body, pollutants may undergo varying transport and transformation processes which affect their distribution, concentration and impact. These processes include sorption, settling, resuspension, sedimentation, ionization, volatilization, hydrolysis, photolysis, oxidation and biological transformation. The number and type of processes which apply to a given pollutant vary depending on its chemical structure and characteristics. Each of these processes may be incorporated in the DELTOX model.

Due to the short duration associated with the application of the acute aquatic life criteria, fate processes are not explicitly considered in establishing wasteload allocations for the protection of aquatic life from acute toxicity. Fate processes are implicitly incorporated in both the baseline and multiple discharge analysis through the consideration of reference concentrations of the toxic pollutant due to sources not subject to control or other point sources. The appropriate fate processes are considered in the application of chronic aquatic life criteria and human health criteria by incorporation of the rates and/or constants in the DELTOX model runs for the pollutant of interest.

10. Bioavailability of Metals - The toxicity of metals is dependent on several factors including the partitioning between dissolved and particulate forms; the ionic speciation of the metal; the binding of the metal to organic ligands; competition with other ions such as calcium, magnesium and carbonates; and the physical and chemical characteristics of the effluent and the receiving water. The toxic form of most metals has generally been attributed to the ionic species and inorganic complexes such as metal hydroxides. Ideally, aquatic life criteria for metals should be expressed as bioavailable metal. Lack of toxicological data on the different ionic species of the metals and site-specific data on the quality and quantity of ligands prevents the implementation of bioavailable metal criteria. Recent guidance from the U.S. EPA, dated October 1, 1993, on the interpretation and implementation of aquatic life criteria for metals recommends that criteria be expressed as dissolved, and that adjustment factors be used to convert criteria currently expressed as total recoverable to dissolved values. This general recommendation does not consider the differing modes of action or the basis for the aquatic life criteria for several metals. The criteria for mercury also considers bioaccumulation as well as lethality and effects on reproduction or growth. Selenium as selenite and selenate has the potential to bioconcentrate to levels which may impact fish populations (Reidel and Sanders, 1993). Aluminum toxicity has been attributed to soluble and insoluble hydroxide complexes and flocs which may impact small invertebrates and bottom-dwelling organisms (U.S. EPA, 1988b).

It is therefore recommended that the aquatic life criteria for seven cationic metals be expressed as dissolved and that adjustment factors be applied to convert national criteria to dissolved values. The best available scientific information will be used to develop the adjustment factors for each metal. In the absence of data to develop a factor for a specific metal, an adjustment factor of 1.0 will be assumed. Aquatic life criteria for mercury, selenium and aluminum would still be expressed as total recoverable.

This recommendation would also require ambient partition coefficients and a translator mechanism to convert dissolved wasteload allocation to total recoverable for the purposes of establishing permit limitations. Site-specific partition coefficients for the ambient waters of the estuary would be used where this data is available. The discharge-specific partition coefficients would need to be developed using the translator mechanism by the permittees or regulatory agencies. Where discharge-specific data are unavailable, a coefficient of 1 would be used.

11. Stormwater Discharges and Combined Sewer Overflows - Stormwater discharges from active and inactive industrial facilities are potential sources of toxic pollutants to the estuary. These discharges are frequently intermittent in nature and may receive little or no treatment prior to release. In the initial phases of the Estuary Toxics Management Program, emphasis was placed on discharges from industrial and municipal wastewater treatment plants which are generally continuous. Monitoring requested of NPDES permittees by the Commission in the spring of 1990 placed less emphasis on stormwater discharges in terms of both frequency and parameters. It is recommended that stormwater discharges not be included in Phase 1 of the TMDL process. Monitoring of these discharges for both flow and toxic pollutants should be required, however, to permit their inclusion in future TMDL evaluations.

Discharges of stormwater and partially-treated industrial and municipal waste from combined sewer overflows (CSOs) are also potential sources of toxic pollutants. The Commission is currently involved in an effort to determine the transport, fate and effect of conventional pollutants discharged from CSOs, and this effort will eventually extended to toxic pollutants. Pending the completion of this effort and in view of the sparsity of information on the loading of toxic pollutants from CSOs, it is recommended that CSOs not be included in Phase 1 of the TMDL process. Monitoring of these discharges to determine the loading of toxic pollutants should be required, however, to permit their inclusion in future TMDL evaluations.

12. Cooling Water Discharges - Discharges of non-contact cooling water can contain toxic pollutants from several sources including the corrosion of components of the system; products applied continuously or intermittently to retard corrosion; and leakage of raw materials, intermediates or product being cooled by the system. In the initial phases of the Estuary Toxics Management Program, emphasis was placed on discharges from industrial and municipal wastewater treatment plants. Little or no monitoring of non-contact cooling water discharges was requested of NPDES permittees in the Commission's spring 1990 survey. It is recommended that non-contact cooling water discharges not be included in Phase 1 of the TMDL process. Studies to determine the net contribution of toxic pollutants such as metals from these discharges should be required, however, to permit their inclusion in future TMDL evaluations.

13. Hardness - Recommended water quality criteria for seven metals for the Delaware River Estuary to protect aquatic life are related to hardness of the receiving water for chronic criteria, and both the receiving water and effluent for acute criteria (DRBC, 1992a). Criteria for these metals are expressed in terms of a formula relating hardness to the criterion value. In order to facilitate implementation of these six chronic aquatic life criteria, twenty years of historical flow and hardness data (1970 to 1989) were analysis to determine a representative hardness value for the estuary, and whether the hardness values varied between different zones of the estuary under design conditions. This analysis indicated that hardness values were not significantly different between the zones of the estuary at flows less than 3500 cfs. A distribution-free measure of the central tendency (i.e., the median or 50^{th} percentile) of the 59 observations available for flows less than 3250 cfs was selected to represent the hardness of the estuary at design conditions. This value corresponded to 74 mg/l hardness as $CaCO_3$. Appendix D contains the values of the chronic aquatic life criteria for the six metals prior to applying adjustment factors which result from the implementation of this policy.

For acute aquatic life criteria, the appropriate hardness value that should be used to establish the discharge-specific criterion value is the hardness at the point where the criterion is applied. As discussed in the acute aquatic life wasteload allocation procedure, this point is established as the most stringent of the minimum performance standard distance scales or the ecologically-based requirements, and corresponds to an effluent dilution factor. It is recommended that this dilution factor and the median hardness value of the effluent be used to establish discharge-specific acute aquatic life criteria for the seven metals. In the absence of discharge-specific data, it is recommended that the receiving water hardness value of 74 be used.

14. pH - Recommended water quality criteria for pentachlorophenol for the Delaware River Estuary to protect aquatic life are related to the pH of the receiving water for chronic criteria, and both the receiving water and effluent for acute criteria (DRBC, 1995). Criteria for this parameter is expressed in terms of a formula relating pH to the criterion value. An analysis of pH values from the period 1970 to 1989 was also performed to determine the median pH value for the estuary, and whether the pH values varied between different zones of the estuary under design conditions. This analysis indicated that pH values were not significantly different between the zones of the estuary at flows less than 3000 cfs. A distribution-free measure of the central tendency (i.e., the median or 50^{th} percentile) of the 58 observations available for flows less than 3000 cfs was selected to represent the pH of the estuary at design conditions. A median pH value of 7.1 is therefore recommended for calculating the chronic aquatic life criteria for pentachlorophenol.

For acute aquatic life criteria, the appropriate pH value that should be used to establish the discharge-specific criterion value is the pH at the point where the criterion is applied. It is recommended that the dilution factor at the point of compliance and the median pH value of the effluent be used to establish discharge-specific acute aquatic life criterion for prntachlorophenol. In the absence of discharge-specific data, it is recommended that the receiving water pH value of 7.1 be used.

15. Other Design Conditions for Applying Criteria - In addition to river flow, hardness and pH, it is recommended that other design conditions such as temperature be evaluated where such conditions are necessary to establish effluent limitations based upon the water quality criteria for the estuary.

16. Adjustment for Pollutants in Intake Water - Loadings of toxic pollutants from industrial discharges may be adjusted to account for pollutants originating in the intake water for the facility which are beyond the control of the permittee provided that the permittee can demonstrate that:

a. In the absence of pollutants in the intake water, there would be no violation of any water quality criteria,

b. Pollutants present in the intake water are not the result of any other activity, operation or materials used or produced at the facility,

c. No statistically significant difference can be detected between the intake and effluent concentrations or loadings of a toxic pollutant based upon a rigorous analysis of data representative of operating and ambient conditions at the facility,

d. No practicable alternative source of intake water is available, and

e. Where a significant percentage of the effluent consists of water obtained from a water purveyor, well water, or water pumped from a stream basin other than the basin receiving the discharge; no adverse impact on the designated uses of the receiving water is expected.

REFERENCES

Biggs, R.H., J.H. Sharp and B.A. Howell. 1983. Suspended Sediments. *In:* The Delaware Estuary: Research as a Background for Estuarine Management and Development. J.H. Sharp, ed. pp. 107-116. University of Delaware, College of Marine Studies and New Jersey Marine Sciences Consortium.

Chadderton, R.A., A.C. Miller and A.J. McDonnell. 1981. Review and Evaluation of Wasteload Allocation Procedures. Institute for Research on Land and Water Resources. Pennsylvania State University. University Park, PA. Report to the Bureau of Water Quality Management. Pennsylvania Department of Environmental Resources.

Delaware Estuary Program. 1992. Preliminary Conservation and Management Plan. U.S. Environmental Protection Agency, Region III. Philadelphia, PA. October 1992.

Delaware River Basin Commission. 1986. Water Code, Delaware River Basin. West Trenton, NJ. October 1988.

Delaware River Basin Commission. 1991. Toxic Substance Data Base for the Delaware River Estuary. Estuary Toxics Management Program. West Trenton, NJ. October 1991.

Delaware River Basin Commission. 1992a. Recommended Water Quality Criteria for Toxic Pollutants for the Delaware River Estuary. Estuary Toxics Management Program. West Trenton, NJ. January 1992.

Delaware River Basin Commission. 1992b. Administrative Manual - Part III, Water Quality Regulations. West Trenton, NJ. December 9, 1992.

Delaware River Basin Commission. 1993. Calculating Water Quality and Technology-Based Effluent Limits and Monitoring Requirements with LOTUS. Estuary Toxics Management Program. West Trenton, NJ. December 1993.

Doneker, R.L. and G.H. and Jirka. 1991. Expert systems for mixing zone analysis and the design of pollutant discharges. Jour. Water Res. Plan. & Manag. 117(6):679-697.

New Jersey Department of Environmental Protection & Energy. 1993. Draft Basis and Background Document: Regulation of Toxics in NJPDES/DSW Permits. Wastewater Facilities Regulation Program. Trenton, NJ.

Pennsylvania Department of Environmental Resources. 1987. Equal Marginal Percent Reduction Wasteload Allocation Policy. Bureau of Water Quality Management, Division of Assessment and Standards. Harrisburg, PA.

Riedel, G.F. and J.G. Sanders. 1993. Trace metal speciation and behavior in the tidal Delaware River. Final Report to the Delaware Estuary Program. Academy of Natural Sciences Report No. 93-1. Benedict, MD.

Sharp, J.H., L.A. Cifuentes, R.B. Coffin, J.R. Pennock and K. Wong. 1986. The influence of river variability on the circulation, chemistry and microbiology of the Delaware Estuary. Estuaries 9(4A):261-269.

Smullen, J.T., J.H. Sharp, R.W. Garvine and H.H. Haskin. 1983. River Flow and Salinity. *In:* The Delaware Estuary: Research as a Background for Estuarine Management and Development. J.H. Sharp, ed. pp. 9-25. University of Delaware, College of Marine Studies and New Jersey Marine Sciences Consortium.

U.S. Environmental Protection Agency. 1988a. WASP4, A Hydrodynamic and Water Quality Model - Model Theory, User's Manual and Programmer's Guide. Environmental Research Laboratory - Athens, GA. EPA 600/3-87-039.

U.S. Environmental Protection Agency. 1988b. Ambient Water Quality Criteria for Aluminum. Office of Water Regulations and Standards. Washington, D.C. EPA 440/5-86-008.

U.S. Environmental Protection Agency. 1991. Technical Support Document for Water Quality-Based Toxics Control. Office of Water, Washington, DC. March 1991. EPA 505/2-90-001.

U.S. Environmental Protection Agency. 1993. The Determination and Use of Water-Effect Ratios for Metals. Office of Water, Washington, DC. Scheduled for Fall 1993.

DEFINITIONS

Average Daily Flow - The average flow emanating from an industrial or municipal facility in a day in million gallons per day or cubic meters per second during a specified time period.

Criterion Maximum Concentration - The magnitude of a pollutant that will not cause an adverse effect in aquatic organisms exposed for a brief period.

Criterion Continuous Concentration - The magnitude of a pollutant that will not cause an adverse effect in aquatic organisms which are exposed for an indefinite period.

Discharge length scale - The square root of the cross-sectional area of any discharge outlet.

Effluent Limitation Guidelines - Effluent limitations for pollutants for categories and classes of point sources promulgated by the U.S. Environmental Protection Agency under Section 301 of the Clean Water Act which reflect the best available treatment technology.

Harmonic mean flow - The number of daily flow measurements divided by the sum of the reciprocals of the flows.

Long-term Average Concentration - The mean concentration of a toxic pollutant in the effluent that represents the desired performance of a wastewater treatment plant.

Marginal Loading - The portion of the loading of a pollutant that contributes to an exceedance of a water quality criterion when the cumulative loading from all point sources is considered.

7Q10 Flow - The flow value corresponding to the lowest annual 7 day average flow that occurs at a frequency of once every 10 years.

30Q5 Flow - The flow value corresponding to the lowest annual 30 day average flow that occurs at a frequency of once every 5 years.

4Q3 Flow - The flow value corresponding to the lowest annual 4 day average flow that occurs at a frequency of once every 3 years.

ACRONYMS

CV - Coefficient of Variation

DNREC - Delaware Department of Natural Resources & Environmental Control

ELG - Effluent Limitation Guidelines

EMPR - Equal Marginal Percent Reduction

EPA - U.S. Environmental Protection Agency

LA - Load Allocation

LTA - Long-term Average Concentration

MGD - Million gallons per day

NJDEP - New Jersey Department of Environmental Protection

NPDES - National Pollutant Discharge Elimination System

OCPSF - Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) Industrial Category

PQL - Practical Quantitation Limit

TMDL - Total Maximum Daily Load

TSD - Technical Support Document for Water Quality-Based Toxics Control

WLA - Wasteload Allocation

APPENDICES

A. Minimum Performance Standards for Discharges to the Delaware River Estuary.

B. Water Quality Criteria for Toxic Pollutants for the Delaware River Estuary.

C. Design Flows for Wasteload Allocations.

D. Water Quality Criteria for Protection from Chronic Effects for Six Metals for the Delaware River Estuary.

APPENDIX A

Minimum Performance Standards for Discharges to the Delaware Estuary

TABLE 1: Minimum Performance Standards for Organic Compounds for Discharges from Industrial and Municipal Wastewater Treatment Facilities on the Delaware River Estuary.

PARAMETER	LONG-TERM AVERAGE CONCENTRATION[a] (µg/l)
Acrolein	50[b]
Acrylonitrile	96
Benzene	37
Bromoform	29[b]
Carbon tetrachloride	18
Chlorobenzene	15
Chlorodibromomethane	7[b]
Chloroform	21
Dichlorobromomethane	6[b]
1,2 - Dichloroethane	68
1,1 - Dichloroethene	16
Ethylbenzene	32
Methyl bromide	20[b]
Methylene chloride	40
Tetrachloroethene	22
Toluene	26
1,2 - trans-Dichloroethene	21
1,1,2,2 - Tetrachloroethane	3[b]
1,1,1 - Trichloroethane	21
1,1,2 - Trichloroethane	21
Trichloroethene	21
Vinyl chloride	104
Acenaphthene	22
Anthracene	22
Benzo[a]anthracene	22
Benzo[a]pyrene	23
Benzo[b]fluoranthene	23
Benzo[k]fluoranthene	22
Bis (2-chloroisopropyl) ether	301[b]

PARAMETER	LONG-TERM AVERAGE CONCENTRATION[a] (µg/l)
Bis (2-ethylhexyl) phthalate	103
Butyl benzyl phthalate	12[b]
Chrysene	22
Dibenzo[a,h]anthracene	10[b]
1,2 - Dichlorobenzene	77
1,3 - Dichlorobenzene	31
1,4 - Dichlorobenzene	15
Diethyl phthalate	81
Dimethyl phthalate	19
Di-N-butyl phthalate	27
2,4 - Dinitrotoluene	113
2,6 - Dinitrotoluene	255
Fluoranthene	25
Fluorene	22
Hexachlorobenzene	15
Hexachlorobutadiene	20
Hexachloroethane	21
Indeno[1,2,3-cd]pyrene	0.017[b]
Isophorone	10[b]
Nitrobenzene	27
N-Nitrosodimethylamine	73[b]
N-Nitrosodiphenylamine	3.8[b]
Phenanthrene	22
Pyrene	25
2 - Chlorophenol	31
2,4 - Dichlorophenol	39
2,4 - Dimethylphenol	18
2,4 - Dinitrophenol	71
Phenol	15

[a] Except as noted, source is BAT Effluent limitation Guidelines for the Organic Chemicals, Plastics and Synthetic Fibers Category, 40 CFR Part 414.91.

[b] Highest reported value for activated sludge treatment in the U.S. EPA's Water Engineering Research Laboratory treatability data base.

TABLE 2: Minimum Performance Standards for Chlorinated Pesticides and PCBs for Discharges from Industrial and Municipal Wastewater Treatment Facilities on the Delaware River Estuary.

PARAMETER	**LONG-TERM AVERAGE CONCENTRATION (µg/l)**
Aldrin	0.19
Alpha - BHC	0.20
Beta - BHC	2.60
Gamma - BHC (Lindane)	1.40
Chlordane	2.25
4,4' - DDT	0.06[b]
4,4' - DDE	0.07
4,4' - DDD	0.50
Dieldrin	0.03[b]
Endosulfan	0.09
Endrin	0.42
Heptachlor	0.60
Heptachlor epoxide	0.40[b]
PCBs (Total)	0.50[b]
Toxaphene	1.00[b]

[b] Based upon the Practical Quantitation Limit (PQL).

TABLE 3: Minimum Performance Standards for Total Recoverable Metals for Discharges from Industrial Wastewater Treatment Facilities on the Delaware River Estuary.

PARAMETER	**LONG-TERM AVERAGE CONCENTRATION (µg/l)**
Aluminum	850.0
Arsenic	10.0
Cadmium	6.0
Chromium (Total)	52.0
Copper	50.0
Lead	37.0
Mercury	2.3
Nickel	80.0
Selenium	15.0
Silver	22.0
Zinc	94.0

TABLE 4: Minimum Performance Standards for Total Recoverable Metals for Discharges from Municipal Wastewater Treatment Facilities on the Delaware River Estuary.

PARAMETER	LONG-TERM AVERAGE CONCENTRATION (μg/l)
Aluminum	300.0
Arsenic	13.0
Cadmium	8.0
Chromium (Total)	39.0
Copper	39.0
Lead	34.0
Mercury	0.8
Nickel	47.0
Selenium	9.0
Silver	21.0
Zinc	65.0

APPENDIX B

Water Quality Criteria for Toxic Pollutants
for the Delaware River Estuary
(February 1995)

TABLE 5: Water Quality Criteria for Toxic Pollutants for the Protection of Aquatic Life in the Delaware River Estuary.

Parameter	Freshwater Criteria (µg/l)		Marine Criteria (µg/l)	
	Acute	**Chronic**	**Acute**	**Chronic**
Metals				
Aluminum	750	87	-	-
Arsenic (trivalent)	360	190	69	36
Cadmium	$e^{(1.128*LN(Hardness)-3.828)}$	$e^{(0.7852*LN(Hardness)-3.49)}$	43	9.3
Chromium (trivalent)	$e^{(0.8190*LN(Hardness)+3.688)}$	$e^{(0.8190*LN(Hardness)+1.561)}$	-	-
Chromium (hexavalent)	16	11	1,100	50
Copper	$e^{(0.9422*LN(Hardness)-1.464)}$	$e^{(0.8545*LN(Hardness)-1.465)}$	2.9	2.9
Cyanide (total)	22	5.2	1.0	-
Lead	$e^{(1.273*LN(Hardness)-1.460)}$	$e^{(1.273*LN(Hardness)-4.705)}$	220	8.5
Mercury	2.4	0.012	2.1	0.025
Nickel	$e^{(0.846*LN(Hardness)+3.3612)}$	$e^{(0.846*LN(Hardness)+1.1645)}$	75	8.3
Selenium	20	5.0	300	71
Silver	$e^{(1.72*LN(Hardness)-6.52)}$	-	2.3	-
Zinc	$e^{(0.8473*LN(Hardness)+0.8604)}$	$e^{(0.8473*LN(Hardness)+0.7614)}$	95	86
Pesticides/PCBs				
Aldrin	1.5	-	0.65	-
gamma - BHC (Lindane)	1.0	0.08	0.08	-
Chlordane	1.2	0.0043	0.045	0.004
Chlorpyrifos (Dursban)	0.083	0.041	0.011	0.0056
DDT and metabolites (DDE & DDD)	0.55	0.001	0.065	0.001
Dieldrin	1.25	0.0019	0.355	0.0019
Endosulfan	0.11	0.056	0.017	0.0087
Endrin	0.09	0.0023	0.019	0.0023
Heptachlor	0.26	0.0038	0.027	0.0036
PCBs (Total)	2.0	0.014	10.0	0.03
Parathion	0.065	0.013	-	-
Toxaphene	0.73	0.0002	0.21	0.0002
Acid Extractable Organics				
Pentachlorophenol	$e^{(1.005*pH-4.83)}$	$e^{(1.005*pH-5.29)}$	13	7.9
Indicator Parameters				
Whole Effluent Toxicity	0.3 Toxic Units $_{acute}$	1.0 Toxic Units $_{chronic}$	0.3 TU_a	1.0 TU_c

TABLE 6: Water Quality Criteria for Carcinogens for the Delaware River Estuary.

PARAMETER	EPA CLASS.	FRESHWATER CRITERIA (μg/l)		MARINE CRITERIA (μg/l)
		FISH & WATER INGESTION	FISH INGESTION ONLY	FISH INGESTION ONLY
Arsenic*	A	0.018	0.144	0.0253
Beryllium	B2	0.00767	0.132	0.0232
Aldrin	B2	0.00189	0.0226	0.00397
alpha - BHC	B2	0.00391	0.0132	0.00231
Chlordane	B2	0.000575	0.000588	0.000104
DDT	B2	0.000588	0.000591	0.000104
DDE	B2	0.00554	0.00585	0.00103
DDD	B2	0.00423	0.00436	0.000765
Dieldrin	B2	0.000135	0.000144	0.0000253
Heptachlor	B2	0.000208	0.000214	0.0000375
Heptachlor epoxide	B2	0.000198	0.000208	0.0000366
PCBs (Total)	B2	0.0000444	0.0000448	0.0000079
Toxaphene	B2	0.000730	0.000747	0.000131
Acrylonitrile	B1	0.0591	0.665	0.117
Benzene	A	1.19	71.3	12.5
Bromoform	B2	4.31	164.0	28.9
Bromodichloromethane	B2	0.559	55.7	9.78
Carbon tetrachloride	B2	0.254	4.42	0.776
Chlorodibromomethane	C	0.411	27.8	4.88
Chloroform	B2	5.67	471.0	82.7
1,2 - Dichloroethane	B2	0.383	98.6	17.3
1,1 - Dichloroethene	C	0.0573	3.20	0.562
1,3 - Dichloropropene**	B2	87.0	14.1	2.48

PARAMETER	EPA CLASS.	FRESHWATER CRITERIA (μg/l)		MARINE CRITERIA (μg/l)
		FISH & WATER INGESTION	FISH INGESTION ONLY	FISH INGESTION ONLY
Methylene chloride	B2	4.65	1,580	277
Tetrachloroethene**	B2	0.80	8.85	1.55
1,1,1,2 - Tetrachloroethane	C	1.29	29.3	5.15
1,1,2,2 - Tetrachloroethane	C	0.172	10.8	1.89
1,1,2 - Trichloroethane	C	0.605	41.6	7.31
Trichloroethene**	B2	2.70	80.7	14.2
Vinyl chloride**	A	2.00	525.0	92.9
Benzidine	A	0.000118	0.000535	0.000094
3,3 - Dichlorobenzidine	B2	0.0386	0.0767	0.0135
PAHs				
Benz[a]anthracene	B2	0.00171	0.00177	0.00031
Benzo[b]fluoranthene	B2	0.000455	0.000460	0.000081
Benzo[k]fluoranthene	B2	0.000280	0.000282	0.000049
Benzo[a]pyrene	B2	0.0000644	0.0000653	0.0000115
Chrysene	B2	0.0214	0.0224	0.00394
Dibenz[a,h]anthracene	B2	0.0000552	0.0000559	0.0000098
Indeno[1,2,3-cd]pyrene	B2	0.0000576	0.0000576	0.0000101
Bis (2-chloroethyl) ether	B2	0.0311	1.42	0.249
Bis (2-ethylhexyl) phthalate	B2	1.76	5.92	1.04
Dinitrotoluene mixture (2,4 & 2,6)	B2	17.3	1420	249
1,2 - Diphenylhydrazine	B2	0.0405	0.541	0.095
Hexachlorobenzene	B2	0.000748	0.000775	0.000136
Hexachlorobutadiene	C	0.445	49.7	8.72
Hexachloroethane	C	1.95	8.85	1.56
Isophorone	C	36.3	2590	455
N-Nitrosodi-N-methylamine	B2	0.000686	8.12	1.43

PARAMETER	EPA CLASS.	FRESHWATER CRITERIA (μg/l)		MARINE CRITERIA (μg/l)
		FISH & WATER INGESTION	FISH INGESTION ONLY	FISH INGESTION ONLY
N-Nitrosodi-N-phenylamine	B2	4.95	16.2	2.84
N-Nitrosodi-N-propylamine	B2	0.00498	1.51	0.265
Pentachlorophenol	B2	0.282	8.16	1.43
2,4,6 - Trichlorophenol	B2	2.14	6.53	1.15
Dioxin (2,3,7,8 - TCDD)**	-	1.3×10^{-8}	1.4×10^{-8}	2.4×10^{-9}

* National criteria obtained from the Federal Register, Vol. 57, No. 246, pages 60848 - 60923).

** Criteria obtained from or calculated from data contained in the Water Quality Criteria documents for the parameter.

TABLE 7: Water Quality Criteria for Systemic Toxicants for the Delaware River Estuary.

PARAMETER	EPA CLASS.	FRESHWATER CRITERIA ($\mu g/l$)		MARINE CRITERIA ($\mu g/l$)
		FISH & WATER INGESTION	FISH INGESTION ONLY	FISH INGESTION ONLY
Antimony		14.0	4,310	757
Arsenic	A	9.19	73.4	12.9
Beryllium	B2	165	2,830	498
Cadmium		14.5	84.1	14.8
Chromium (Trivalent)		33,000	673,000	118,000
Hexavalent chromium	A	166	3,370	591
Mercury	D	0.530	0.560	0.144
Nickel		607	4,580	805
Selenium	D	100	2,020	355
Silver	D	175	108,000	18,900
Thallium		1.70	6.20	1.10
Zinc		9110	68700	12100
Aldrin	B2	0.96	11.5	2.03
gamma - BHC (Lindane)		7.38	24.9	4.37
Chlordane	B2	0.0448	0.0458	0.00805
DDT	B2	0.100	0.100	0.0176
Dieldrin	B2	0.108	0.115	0.020
Endosulfan		111	239	42.0
Endrin	D	0.755	0.814	0.143
Heptachlor	B2	0.337	0.344	0.060
Heptachlor epoxide	B2	0.0234	0.0246	0.00433
Total PCBs	B2	0.00839	0.00849	0.00149
Acrolein		320	780	137

PARAMETER	EPA CLASS.	FRESHWATER CRITERIA ($\mu g/l$)		MARINE CRITERIA ($\mu g/l$)
		FISH & WATER INGESTION	FISH INGESTION ONLY	FISH INGESTION ONLY
Ethylbenzene		3,120	28,700	5,050
Bromoform	B2	682	25,900	4,560
Bromodichloromethane	B2	693	69,000	12,100
Dibromochloromethane	C	690	46,600	8,190
Carbon tetrachloride	B2	23.1	402	70.6
Chloroform	B2	346	28,700	5,050
Chlorobenzene	D	677	20,900	3,670
1,1 - Dichloroethene	C	309	17,300	3,040
1,2 - trans - Dichloroethene		696	136,000	23,900
1,3 - Dichloropropene	B2	10.4	1,690	297
Methyl bromide		49.0	N/A	N/A
Methylene chloride	B2	2,090	710,000	125,000
1,1,2 - Trichloroethane	C	138	9,490	1,670
Tetrachloroethene		318	3,520	618
1,1,1,2 - Tetrachloroethane	C	1,000	22,400	3,940
Toluene		6,760	201,000	35,400
Acenaphthene		1,180	2,670	469
Anthracene	D	4,110*	6,760*	1,190*
Benzidine	A	81.8	369	64.9
Bis (2-chloroisopropyl) ether		1,390	174,000	30,600
Bis (2-ethylhexyl) phthalate	B2	492*	1,660*	291
Butylbenzl phthalate**	C	2,980	5,200	914
Diethyl phthalate	D	22,600	118,000	20,700
Dimethyl phthalate	D	313,000	2,990,000	526,000
Dibutyl phthalate	D	2,710	12,100	2,130
1,2 - Dichlorobenzene	D	2,670	17,400	3,060

PARAMETER	EPA CLASS.	FRESHWATER CRITERIA ($\mu g/l$)		MARINE CRITERIA ($\mu g/l$)
		FISH & WATER INGESTION	FISH INGESTION ONLY	FISH INGESTION ONLY
1,3 - Dichlorobenzene	D	414	3,510	617
1,4 - Dichlorobenzene		419	3,870	677
2,4 - Dinitrotoluene		69.2	5670	996
Fluoranthene		296*	375*	65.8
Fluorene	D	730	1,530	268
Hexachlorobenzene	B2	0.958	0.991	0.174
Hexachlorobutadiene	C	69.4	7,750*	1,360
Hexachlorocyclopentadiene		242	17,400*	3,050*
Hexachloroethane	C	27.3	124	21.7
Isophorone	C	6,900	492,000	86,400
Nitrobenzene	D	17.3	1,860	327
Pyrene	D	228*	291*	51.1
1,2,4 - Trichlorobenzene	D	255	945	166
2 - Chlorophenol		122	402	70.6
2,4 - Dichlorophenol		92.7	794	139
2,4 - Dimethylphenol		536	2,300	403
2,4 - Dinitrophenol		70	14,300	2,500
Pentachlorophenol	B2	1,010	29,400*	5,160
Phenol		20,900	4,620,000	811,000

* Recommended criterion is above the solubility of the compound in water at 25° C.

** Recommended criteria incorporate an additional safety factor of 10 since this compound is a Class "C" carcinogen and no criteria to protect against carcinogenic effects is recommended due to lack of data.

APPENDIX C

Design Flows for Wasteload Allocations

TABLE 8: Design Effluent Flows for Delaware Estuary Industrial Discharges.

PERMITTEE	NPDES #	DSN	PRODUCTION -BASED FLOW (MGD)	1992 MAXIMUM MONTHLY FLOW (MGD)	1988-1992 MAXIMUM ANNUAL FLOW (MGD)	EFFLUENT DESIGN FLOW (m^3/s)
STAR ENTERPRISES	DE0000256	001		402.0	320.0	17.608
STAR ENTERPRISES	DE0000256	601		9.80	10.77	0.472
FORMOSA PLASTICS	DE0000612	001		0.54	0.46	0.024
GEORGIA GULF	DE0000647	001		0.23	0.29	0.013
STANDARD CHLORINE	DE0020001	001		0.49	0.48	0.022
OCCIDENTAL CHEMICAL	DE0050911	001		0.30	0.23	0.013
DUPONT - CHAMBERS WORKS	NJ0005100	001		49.70	66.65	2.919
DUPONT - CHAMBERS WORKS	NJ0005100	009		0.03	0.03	0.001
DUPONT - CHAMBERS WORKS	NJ0005100	011		0.03	0.03	0.001
DUPONT - CHAMBERS WORKS	NJ0005100	013		9.80	-	0.429
DUPONT - CHAMBERS WORKS	NJ0005100	661		27.90	-	1.222
DUPONT-EDGEMOOR	DE0000051	001		4.30	4.13	0.188
DUPONT - CHERRY ISLAND	DE0050644	001		0.25	0.19	0.011
IKO MANUFACTURING	DE0050857	001		0.014	0.015	0.001
GENERAL CHEMICAL CORPORATION	DE0000655	001		30.10	26.62	1.318
B.F. GOODRICH	NJ0004286	001		0.91	0.95	0.042
MONSANTO	NJ0005045	001		1.19	0.95	0.052
BP OIL	PA0012637	001		57.15	-	2.503
BP OIL	PA0012637	201		3.31	-	0.145
PQ CORP.	PA0013021	001		0.235	-	0.010
NORTH AMERICAN SILICA	PA0051713	001		0.404	-	0.018
ROLLINS ENVIRONMENTAL	NJ0005240	001		0.27	0.22	0.012
BOEING HELICOPTERS	PA0013323	001		1.04	-	0.046
BOEING HELICOPTERS	PA0013323	002		0.072	-	0.003
DUPONT - REPAUNO	NJ0004219	001		31.30	20.25	1.371
AIR PRODUCTS & CHEMICALS	NJ0004278	001		0.18	0.1565	0.008
HERCULES - GIBBSTOWN	NJ0005134	001		0.32	0.3019	0.014
MOBIL OIL	NJ0005029	001		10.19	11.54	0.506
PENNWALT	NJ0005185	001		0.72	0.67	0.032
DEPT. OF NAVY	PA0036455	005		1.009	-	0.044
DEPT. OF NAVY	PA0036455	006		2.616	-	0.115

PERMITTEE	NPDES #	DSN	PRODUCTION -BASED FLOW (MGD)	1992 MAXIMUM MONTHLY FLOW (MGD)	1988-1992 MAXIMUM ANNUAL FLOW (MGD)	EFFLUENT DESIGN FLOW (m^3/s)
DEPT. OF NAVY	PA0036455	007		8.21	-	0.360
CHEVRON	PA0011533	015		9.13	8.15	0.400
SUN REFINING & MARKETING	PA0012629	002		3.75	3.21	0.164
PHILADELPHIA GAS - PASSYUNK	PA0046876	001		1.211	-	0.053
COASTAL EAGLE POINT	NJ0005401	001		3.90	3.6	0.171
MCANDREWS AND FORBES	NJ0004090	001		0.36	-	0.016
GEORGIA PACIFIC	NJ0004669	001		0.30	0.20	0.013
PHILADELPHIA GAS - RICHMOND	PA0012882	004		21.893	-	0.959
ALLIED-SIGNAL	PA0012017	001		0.028	-	0.001
ROHM & HAAS - PHILADELPHIA	PA0012777	001		5.62	4.51	0.246
ROHM & HAAS - PHILADELPHIA	PA0012777	003		1.67	1.34	0.073
ROHM & HAAS - PHILADELPHIA	PA0012777	004		1.96	1.58	0.086
ROHM & HAAS - PHILADELPHIA	PA0012777	005		0.83	0.61	0.036
ROHM & HAAS - PHILADELPHIA	PA0012777	007		0.64	0.51	0.028
OCCIDENTAL CHEMICAL	NJ0004391	001C		0.31	0.29	0.014
ROHM & HAAS - BRISTOL	PA0012769	009		1.78	1.57	0.078
HERCULES - BURLINGTON	NJ0005142	001		0.04	-	0.002
USX	PA0013463	005		21	26	1.139
USX	PA0013463	103		6.90	57.42	2.515
G.R.O.W.S.	PA0043818	001		0.067	-	0.003
PRE-FINISH METALS	PA0045021	001		0.214	-	0.009
RHONE-POULENC BASIC CHEMICALS	PA0011720	001		0.072	-	0.003

TABLE 9: Design Effluent Flows for Delaware Estuary Municipal Discharges.

PERMITTEE	NPDES #	DSN	GROWTH FACTOR (%)	DESIGN CAPACITY (MGD)	1990 - 1992 AVERAGE ANNUAL FLOW (MGD)	EFFLUENT DESIGN FLOW (m^3/s)
PORT PENN STP	DE0021539	001	5%	0.05	0.02	0.002
CITY OF SALEM	NJ0024856	001	5%	1.40	0.84	0.061
DELAWARE CITY STP	DE0021555	001	5%	0.55	0.39	0.024
PENNSVILLE SEWAGE AUTHORITY	NJ0021598	001	5%	1.875	1.59	0.082
CARNEYS PT. SEWAGE AUTHORITY	NJ0021601	001	5%	1.30	0.82	0.057
CITY OF WILMINGTON	DE0020320	001	5%	90.0	90.87	3.942
PENNS GROVE SEWAGE AUTHORITY	NJ0024023	001	5%	0.75	0.66	0.033
LOGAN TOWNSHIP MUA	NJ0027545	001	5%	1.00	0.59	0.044
DELCORA	PA0027103	001	5%	44.00	37.76	1.927
TINICUM TOWNSHIP	PA0028380	001	5%	1.40	0.98	0.061
GREENWICH TOWNSHIP	NJ0030333	001	5%	1.00	0.57	0.044
GLOUCESTER COUNTY UA	NJ0024686	001	5%	20.10	17.55	0.880
PHILADELPHIA - SOUTHWEST STP	PA0026671	001	5%	200.00	213.20	8.760
CAMDEN COUNTY MUA	NJ0026182	001	5%	80.00	52.95	3.504
PHILADELPHIA - SOUTHEAST STP	PA0026662	001	5%	112.00	117.46	4.906
PHILADELPHIA - NORTHEAST STP	PA0026689	001	5%	210.00	221.25	9.691
PALMYRA BOROUGH	NJ0024449	001	5%	1.05	0.57	0.046
RIVERTON BOROUGH	NJ0021610	001	5%	0.22	0.20	0.010
CINNAMINSON	NJ0024007	001	5%	2.00	1.52	0.088
DELRAN SEWAGE AUTHORITY	NJ0023507	001	5%	1.50	1.58	0.066
RIVERSIDE SEWAGE AUTHORITY	NJ0022519	001	5%	1.00	1.04	0.044
BEVERLY SEWAGE AUTHORITY	NJ0027481	001	5%	1.00	0.56	0.044
BURLINGTON TOWNSHIP	NJ0021709	001	5%	1.65	1.09	0.072
CITY OF BURLINGTON	NJ0024660	001	5%	3.20	1.70	0.140
BRISTOL TOWNSHIP	PA0026450	001	5%	2.25	1.67	0.099
BRISTOL BOROUGH	PA0027294	001	5%	2.70	2.44	0.118
LOWER BUCKS COUNTY JMUA	PA0026468	001	5%	10.00	8.38	0.438
HAMILTON TOWNSHIP	NJ0026301	001	5%	16.00	10.42	0.701
CITY OF TRENTON	NJ0020923	001	5%	20.00	17.28	0.876
MORRISVILLE BOROUGH	PA0026701	001	5%	7.10	4.14	0.311

TABLE 10: Design Freshwater Flows for the period 1970 to 1990 for the Delaware River at Trenton and Tributaries to the Estuary.

LOCATION	7Q10		30Q5		Harmonic Mean Flow	
	CFS	CMS	CFS	CMS	CFS	CMS
Delaware River at Trenton	-	-	3017.0	85.43	7402.0	209.60
Schuylkill River at Philadelphia[1]	98.00	2.78	322.9	9.14	1309.4	37.08
Brandywine Creek at Wilmington	95.01	2.69	127.39	3.61	306.36	8.68
Christina River[2]	35.98	1.02	54.29	1.54	127.33	3.61
Christina River at Coochs Bridge	1.68	0.05	3.79	0.11	9.67	0.27
Little Mill Creek at Elsmere[3]	0.45	0.01	1.38	0.04	3.18	0.09
Red Clay Creek at Wooddale	12.66	0.36	17.83	0.50	41.13	1.16
White Clay Creek near Newark	21.19	0.60	31.29	0.89	73.35	2.08
Salem River at Woodstown	1.26	0.04	4.15	0.12	9.35	0.26
Darby Creek at Waterloo Mills	1.64	0.05	2.58	0.07	5.19	0.15
Raccoon Creek	9.23	0.26	12.55	0.36	26.66	0.75
Cooper River	9.87	0.28	14.44	0.41	24.75	0.70
South Br. Pennsauken Cr. at Cherry Hill	3.73	0.11	5.30	0.15	9.58	0.27
Rancocas Creek[2]	46.07	1.30	66.60	1.89	167.75	4.75
South Br. Rancocas Creek at Vincentown[4]	8.40	0.24	14.72	0.42	46.03	1.30
North Br. Rancocas Creek at Pemberton	37.67	1.07	51.88	1.47	121.72	3.45
Neshaminy Cr.	19.65	0.56	35.66	1.01	107.82	3.05
Crosswicks Creek	27.92	0.79	38.98	1.10	86.56	2.45

[1] Values were determined by subtracting the average daily withdrawl by the City of Philadelphia (255 cfs) from the gage values. The 7Q10 value was recommended by the Pennsylvania Department of Environmental Resources.

[2] Sum of data from stations listed below.

[3] Gage terminated in 1981. Value includes data from 1970 - 1980.

[4] Available period of record: 1962 - 1975.

APPENDIX D

Water Quality Criteria for Protection from Chronic Effects for Six Metals for the Delaware River Estuary

TABLE 11: Numerical Values for Chronic Aquatic Life Freshwater Criteria for Six Metals for the Delaware River Estuary.

Parameter	Water Quality Criterion (μg/l)
Cadmium	0.9
Chromium (Trivalent)	160
Copper	9.1
Lead	2.2
Nickel	120
Zinc	82