

Technical Reference Guide (TRG)
PENTOXSD for Windows
PA Single Discharge Wasteload
Allocation Program for Toxics
Version 2.0



COMMONWEALTH OF PENNSYLVANIA
Department of Environmental Protection

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Water Supply and Wastewater Management

DOCUMENT NUMBER: 391-2000-011

TITLE: Technical Reference Guide (TRG) PENTOXSD for Windows PA Single Discharge Wasteload Allocation Program for Toxics Version 2.0

EFFECTIVE DATE: May 22, 2004

AUTHORITY: Federal Clean Water Act, Sections 301, 302, 303, PA Clean Streams Law, and Pa. Code Title 25 Chapters 93, 96 and 16 (Statement of Policy)

POLICY: DEP will use the computer program PENTOXSD to compute NPDES effluent limitations for toxics (and other substances) for discharges to free-flowing streams.

PURPOSE: The purpose of this Technical Reference Guide (TRG) is to describe how applicable regulatory requirements and technical methods are incorporated into PENTOXSD. It explains how these requirements and methods are applied to available data to determine recommended effluent limitations. It describes the mathematical relationships, default equations and values, and wasteload allocation procedures used in PENTOXSD. An appendix contains practical information on using the model.

This document and the associated model is an update to an existing document and model that performs the same function.

APPLICABILITY: DEP uses PENTOXSD to determine recommended NPDES effluent limitations for toxics and other substances based on water quality criteria and other instructions published in Chapters 93, 96 and 16 (Statement of Policy). Substances such as C-BOD5, NH3-N, D.O. and Total Residual Chlorine are not included in this analysis.

DISCLAIMER: The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 64 pages

LOCATION: Volume 29, Tab 5

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1 Preface

PENTOXSD for Windows uses a mass-balance water quality analysis model that includes consideration for mixing, first-order decay and other factors to determine recommended water quality-based effluent limits. The primary purpose of the model is to assist DEP permit engineers in determining appropriate NPDES permit limits for toxics and certain other substances. For each parameter evaluated, the program:

- Computes a Wasteload Allocation (WLA) on a single discharge basis (i.e., without the consideration of multiple source interactions) for each applicable criterion.
- Determines a recommended maximum water quality-based effluent limitation (WQBEL) for each parameter.
- Compares the recommended WQBEL with the entered discharge concentration to determine which is more stringent.
- Recommends average monthly and maximum daily effluent limitations.

The process described above is explained in further detail in this Technical Reference Guide (TRG). A list of the toxic substances that can be evaluated using PENTOXSD can be found in Pa. Code Title 25 Chapter 16. In addition, several other non-toxic or conservative substances can be evaluated. These can be found in Pa. Code Title 25 Chapter 93.

PENTOXSD for Windows is a Microsoft Access 2000/VBA application. It uses three external Access 2000 databases -- the WAT_QUAL database (WAT_QUAL_Y2K.mdb), which is used to store stream, discharge and parameter data; a water quality criteria database (WQCriteria_2000.mdb); where water quality criteria and associated information is stored; and a Stream File database (STREAMFILE_Y2K.mdb), where information on all named and unnamed streams in Pennsylvania is stored.

PENTOXSD for Windows can be used to:

- Import previously developed PENTOXSD for DOS files into the WAT_QUAL database.
- Export and then subsequently import temporary (*.ptw) files consisting of selected stream, discharge and parameter records.
- View, edit, add, delete, save and analyze selected stream, discharge and parameter records from the WAT_QUAL database or from a selected *.ptw file.
- Save and then later retrieve completed analysis from the WAT_QUAL database.

During a single analysis, PENTOXSD can analyze one or more discharge records, each of which may contain one or more associated parameter records.

PENTOXSD for Windows includes an on-line help file describing how to carry out major program operations. The help file should be used in conjunction with this TRG.

Compared to PENTOXSD for DOS, PENTOXSD for Windows contains the following major enhancements and modifications:

- Integrated Data Management – In the DOS version, input data for the model was stored in a series of ASCII text files, which were only available on the user's machine. In the Windows version, input data is stored in the WAT_QUAL database so that (in client/server installations) the data is available to all users.

In addition to the above, the Windows version uses an integrated Water Quality Criteria database that contains both Statewide and Great Lakes Initiative (GLI) Water Quality Criteria, thereby eliminating the need to maintain two separate versions of PENTOXSD.

- Consideration of Dissolved Metals Criteria for Fish and Aquatic Life – The DOS version of PENTOXSD did not include the dissolved metals criteria that were adopted by DEP in November 1995. Because of this, it was necessary to use the DEP Dissolved Metals Application to incorporate site-specific Water Effect Ratios (WER). The Water Quality Criteria database associated with PENTOXSD for Windows contains the necessary information and algorithms to use the published dissolved metals criteria.

This document describes the technical methods contained in PENTOXSD for performing wasteload allocation analyses and for determining recommended single discharge NPDES effluent limits. It contains a listing of the current input data (both required and optional) and describes how these data are used. It contains discussions of important technical considerations that are pertinent to the determination of effluent limits. The appendices contain additional information on some of the statistical and mathematical relationships described in the main body of the text.

This TRG is intended for those individuals who are interested in how DEP computes water quality-based effluent limits for toxics. The audience should have a background in engineering, water resources, chemistry, biology or other related sciences. Interested parties are invited to comment on its contents.

2 Important Technical Issues And Procedures

The methods used by PENTOXSD to determine recommended effluent limits are based on many technical issues and procedures. These are either required by regulation, taken from the DEP *Toxics Management Strategy*, DEP ID: 361-0100-003, available on DEP's website at www.dep.state.pa.us or from other guidance documents. These issues are discussed below.

2.1 Design Stream Flows

PENTOXSD uses two different design stream flows to compute the Wasteload Allocations (WLAs). They are the Q7-10 (lowest 7-day average flow that occurs once every ten years) and Qh (harmonic mean flow). The Q7-10 stream flow is specified in the Water Quality Standards, Pa. Code Title 25 Section 96.4(g) Table 1. This stream flow is used in the application of three of the four water quality criteria:

- Acute Fish Criteria (AFC), also referred to as Criteria Maximum Concentration
- Chronic Fish Criteria (CFC), also referred to as Criteria Continuous Concentration
- Threshold Human Health (THH)

The Qh flow is specified by regulation in the Water Quality Standards, Pa. Code Title 25 Section 96.4(g) Table 1. Section 93.8a(e) specifies that "...for carcinogens, the design conditions result in a lifetime – 70 years – average exposure..." DEP has determined that Qh meets this requirement. Refer to the *Implementation Guidance Design Conditions*, DEP ID: 391-2000-006, available on DEP's website for more information on how to develop this flow. Qh flow is used to evaluate the non-threshold human health

(carcinogen) criterion (CRL). In the absence of field data, the Qh flow is computed using a default equation that estimates this flow as a function of the Q7-10 flow.

2.2 Discharge Analysis Flow

PENTOXSD can accept several different discharge flows that are entered by the user. The possible flows include: Existing Flow, Permitted Flow and Design Flow. The program selects one of these flows when wasteload allocations are performed. This becomes the discharge analysis flow. If the flow selected is either the existing or permitted flow, then a reserve factor may also be applied.

2.3 Criteria Compliance Times

PENTOXSD does not assume that all discharges completely mix with the stream. Therefore, it is necessary to define the mixing characteristics of the discharge. In doing so, the point of compliance with the water quality criteria must be established. This is accomplished by assigning different criteria compliance times (CCTs) for each criterion. These compliance times establish the locations where compliance with the water quality criteria is expected to occur. The following subsections provide an explanation of each.

2.3.1 Acute Fish Criterion (AFC)

The U.S. EPA *Technical Support Document for Water Quality-Based Toxics Control, March 1991, EPA/505/2-90-001 (EPA TSD)* suggests that compliance with acute fish criterion be at the end-of-pipe. Taken literally, this means a WLA equal to the criterion. EPA, however, will tolerate a small instream area where the criterion may be exceeded. Such an area allows for a WLA greater than the criterion. Therefore, DEP allows for an area of mixing downstream of the discharge for this criterion by establishing a maximum criteria compliance time of 15 minutes travel time downstream of the current discharge. The criteria compliance time (used to compute the mix factor) is then either this maximum criteria compliance time or the complete mix time, whichever occurs first.

2.3.2 Chronic Fish Criterion (CFC)

Chronic analyses frequently assume “complete mix.” However, the actual application of complete mix can vary greatly from case to case. Sometimes less than 100 percent of the design stream flow will be assigned. Ambient mixing depends on several variables, such as stream width, depth, the location of the discharge outfall, stream velocity and stream slope. Application of the EPA ambient mixing equation suggests that mixing is:

- Relatively rapid for practically all stream flows of less than 50 cfs.
- Complete mixing will occur within 12 hours for stream flows between 50 to 250 cfs.
- Seldom complete for stream flows greater than 250 cfs.

These conclusions are based on ambient mixing. Other factors such as discharge diffusion, channel geometry and stream flow vs. discharge flow ratio can induce more rapid mixing.

Because of the uncertainties associated with mixing, DEP allows for an area of mixing downstream of the discharge for this criterion by establishing a maximum criteria compliance time of 12 hours travel time downstream of the current discharge. The criteria compliance time (used to compute the mix factor) is then either this maximum criteria compliance time or the complete mix time, whichever occurs first.

2.3.3 Human Health Criteria (THH & CRL)

DEP allows for an area of mixing downstream of the discharge for these criteria by establishing the maximum criteria compliance time of 12 hours travel time downstream of the current discharge or, for THH criteria, the estimated travel time downstream to the nearest potable water supply intake. The criteria compliance time (used to compute the mix factor) is then either this maximum criteria compliance time or the complete mix time, whichever occurs first.

The CCTs, discussed above, are used to compute the partial mix factor for each criterion. Before these partial mix factors can be determined, however, the complete mix time must be computed.

2.4 Complete Mix Times

PENTOXSD uses the U.S. EPA ambient mixing equation to estimate the time to complete mix. This equation can be found in the EPA TSD section, *Ambient-Induced Mixing*. It has been adapted for use in Pennsylvania. An explanation of how this equation has been adapted for use in Pennsylvania can be found in Appendix A, Derivation of Mixing Relationships.

The adapted version of the EPA ambient mixing equation is used to compute the complete mix time. It is used when the user does not enter complete mix times and partial mix factors. The adapted version solves for complete mixing time, based on entered or estimated stream velocity, width and depth. Each of these variables may be computed or entered by the user. Once complete mix time is determined, it is used in conjunction with the CCT for each criterion, to compute the partial mix factor. This is discussed in the next section.

2.5 Partial Mixing Factors

The Partial Mix Factor (PMF) is used to describe the fractional portion of the stream that mixes with the discharge at the CCT. A separate mix factor may be supplied directly by the user for each criterion or computed by dividing the criteria compliance time into the complete mix time (see Appendix C). The partial mix factor is a value between 0 and 1. A value of 1 represents complete mixing between the stream and the discharge plume. A value of less than 1 means that there is incomplete mixing between the discharge and the stream at the criteria compliance time. A more complete explanation of how complete

mix times and partial mixing factors are determined (when they are not provided by the user) may be found in Appendix A.

2.6 Background Pollutant Concentration

Background pollutant concentration is defined as the condition that occurs in the absence of controllable point source discharges. Background pollutant loadings can include loadings from nonpoint sources or other sources not covered by the NPDES program. Generally, at low-flow, nonpoint source loadings are not significant. Other point source loadings outside of the current analysis, on the same stream, or subject to control, would not be considered part of the background concentration. Users should refer to *Implementation Guidance for the Determination and Use of Background/Ambient Water Quality in the Determination of Wasteload Allocations and NPDES Effluent Limitations for Toxic Substances*, DEP ID: 391-2000-022, available on DEP's website for assistance in determining when and how to use this field. PENTOXSD is only able to handle single-source scenarios, so if there are overlapping effects from other point source contributors of a pollutant, the user should consider using a different model that considers loading contributions from multiple sources.

The background concentration entered should be the concentration expected to occur at the design stream flow condition (Q7-10 or Qh). If the data are not available to determine background at the design condition, then it may be necessary to compute the long-term average background concentration and, if necessary, apply a coefficient of variation. Also note that background pollutant loadings can be entered in one of two ways. These are: 1) directly for each reach being evaluated (stream concentration), or 2) as tributary concentrations. The first option provides for the input of Natural Quality as described in Section 93.1. In the latter case, the tributary concentrations are mass-balanced with additional tributary flows/loads and a simulation is performed from the beginning of the current stream segment up to the current discharge being evaluated. In addition, a first-order decay rate can be entered for each reach and this will be used to decay the tributary loads as the simulation takes place. Therefore, if it is necessary to keep the concentration constant throughout the stream (i.e., Natural Quality), it should be entered as the stream concentration instead of as the tributary concentration. The background concentration computed and/or entered for the current reach is used to determine the available assimilation capacity and the water quality objective.

2.7 Hardness, pH and Dissolved Water Quality Criteria

Some fish and aquatic life (FAL) water quality criteria are hardness dependent (e.g., most toxic metals) or pH dependent (e.g., pentachlorophenol). This means that before WLAs can be computed, the criteria, at the point of application, must be calculated. Generally, this is at the criteria compliance time. However, under certain conditions (when discharge hardness or pH is greater than stream background concentrations and mixing is incomplete) the criteria compliance time may not represent the most critical location in the stream. Therefore before the WLA is assigned to the discharge, PENTOXSD computes the instream concentration at the point of complete mix. This concentration is then compared to the criterion also at the point of complete mix. If the criterion is violated at this point, then a WLA is computed to meet the criterion at complete mix. Otherwise, the WLA assigned to the discharge is the one computed at the CCT.

FAL criteria for certain toxic metals are expressed in terms of dissolved rather than as total recoverable concentrations. Chemical translators must be applied to determine the water quality objective and NPDES effluent limitations, both of which are expressed in the total recoverable form. Pa. Code Title 25 Section 16.24 provides that chemical translators may be based on site-specific studies, or in the absence of site-specific information, on a series of default conversion factors. Where applicable, PENTOXSD checks to see if a site-specific chemical translator has been entered, and if it has, uses the entered value to determine the water quality objective and the resulting recommended wasteload allocations and effluent limitations. Where a site-specific value is not provided, a default value, consistent with the values and formulas presented in Section 16.24 is used. The reader should refer to Pa. Code Title 25 Chapter 16 for the specific parameters that have hardness-based criteria or that are expressed as dissolved concentrations.

PENTOXSD provides three different methods for determining instream hardness and pH. First, an analysis hardness and/or pH can be entered directly by the user. The analysis hardness and pH are the final values used to adjust the criteria for any hardness or pH-dependent criteria. Second, the user can input separate discharge and stream values, which are then mass balanced to determine the analysis values. The mass balance between the discharge values and the stream values considers how much mixing has occurred between the discharge and the stream at the criteria compliance time. Finally, the user can enter discharge and tributary flow values. In this case, the tributary flow values are used to determine (complete mix) stream values, which are then mass balanced with discharge values to determine the analysis hardness and/or pH values.

The three data input methods described above may be used independently of each other, so that for some reaches an analysis value may be entered, while in other reaches stream or tributary values may be entered.

If no analysis, discharge, stream or tributary values are entered, a default hardness of 100 mg/L and a default pH of 7 is assigned to the discharge and tributary flow.

All measurements of hardness and pH, entered by the user, should be representative of the values expected to occur at the design stream flow condition (i.e., Q7-10).

2.8 Potable Water Withdrawals

Pa. Code Title 25 Sections 93.7 and 96.3(d) specify that human health criteria for (total) Phenolics, Fluoride, Nitrite/Nitrate, and Total Dissolved Solids, Chloride and Sulfate only be applied at potable water supply intakes. This is an exception to the general rule that water quality criteria apply at all locations. PENTOXSD implements this special instruction, under the assumption that discharge flow completely mixes with the receiving stream at or before the (next) downstream potable water supply intake is encountered. The evaluation of human health criteria for the four parameters will always be at the nearest downstream water supply intake. Fate coefficients are not applicable for these four parameters. PENTOXSD uses the stream flow at the potable water supply intake to evaluate these parameters instead of the stream flow at the current discharge. In this case, the partial mix factor is equal to one, assuming complete mix.

2.9 Point of First Aquatic Life Use

Generally Fish and Aquatic Life (FAL) criteria apply to all surface waters. However, for specific situations, such as acid mine affected streams, PENTOXSD allows the user to indicate that FAL criteria should not be applied to a specific reach. When the user does this, the FAL criteria are applied at the first downstream reach where FAL criteria do apply. The stream flow used in this case will be the flow at the point where FAL criteria apply, instead of the stream flow at the discharge. The partial mix factors for the aquatic life criteria are set to one, assuming complete mix. If fate coefficients are entered, the travel time up to the point of first use is computed and used in the first order decay relationship.

2.10 Pollutant Fate

Instream pollutant fate can be an important consideration and application of fate has been incorporated into PENTOXSD. Tributary loads upstream of the discharge may be decayed, as well as the discharge load downstream to the criteria compliance time. PENTOXSD applies first-order decay kinetics.

2.11 Reserve Factor

This factor is used to account for projected wasteloads for the discharge being evaluated at some time in the future. It is applied to the effluent flow, as a percent, to account for this growth. A default value of zero (0) is used and can be adjusted by the user.

2.12 Factor of Safety

This factor is used to account for the uncertainties in the input data for the discharge being evaluated. It is applied to the final maximum WQBEL as a percent. A default value of zero (0) is used and can be adjusted by the user.

2.13 Water Quality Criteria

PENTOXSD is linked to a water quality criteria database which contains the FAL and human health criteria published in Chapters 93 and 16 for both statewide application and for application under the Great Lakes Initiative (GLI). For most parameters, there are FAL criteria (or formulas for determining the criteria) for both Continuous (Chronic) and Maximum (Acute) concentrations. In addition, for a majority of parameters there is at least one Human Health criterion. PENTOXSD uses these criteria to determine wasteload allocations and recommended NPDES effluent limitations for each parameter that is evaluated.

DEP regulations allow for the use of site-specific FAL water quality criteria that are derived on the basis of (1) bioassay-based laboratory studies, (2) recalculation of criteria, and/or (3) in the case of dissolved metals criteria, the determination of a water effects ratio (WER). PENTOXSD incorporates these provisions by allowing the user to enter a site-specific criteria modifier, which is derived by application of one or more of the listed

methods. In the absence of a user-supplied criteria modifier, a criteria modifier value of one (1) is used.

Finally, PENTOXSD allows users to input applicable water quality criteria for parameters that are not listed in Chapters 93 and 16. Once a new water quality criteria parameter record is created, all users with access to the water quality criteria database where the new record was created may use it.

2.14 Water Quality Objective

Normally, the water quality objectives DEP seeks to achieve through the development of wasteload allocations are the water quality criteria published in Chapters 16 and 93. There are, however, some exceptions where criteria are not applied directly. The exceptions include:

- When natural water quality exceeds the published criterion.
- Where the criteria is expressed as a dissolved rather than as a total recoverable value.

The first exception is based on Pa. Code Title 25 Chapter 96, Section 96.3(e) that states “ . . . *When a water quality criterion . . . cannot be attained at least 99 percent of the time due to natural quality . . . the natural quality that is achieved at least 99 percent of the time shall be the applicable water quality criterion for protection of fish and aquatic life.* ”

Because of these exceptions PENTOXSD carries out a comparison between the criterion and background water quality concentration to see which governs. Whenever background concentration exceeds the corresponding water quality criterion, the background concentration becomes the water quality objective.

Where criteria are expressed as a dissolved rather than as total recoverable values, PENTOXSD uses the Chemical Translator (either user supplied or default) to determine the water quality objective.

2.15 Background Pollutant Variability

There may also be variability in the background concentrations taken in the stream. If this is the case, then the background concentration (Stream Concentration) is entered as a long-term average. The variability is estimated by performing a statistical summary of the data provided that enough is available. Variability is used to adjust the background concentration so that it has the same duration as the criterion. When this adjustment is made, the statistical equations used are the same ones used for effluent variability, except that the 95th percentile probability basis is used. In addition, a background coefficient of variation (Stream CV) is used to make the adjustment from the long-term average background to the appropriate criterion duration. In the absence of enough data, the default background coefficient of variation is 0, meaning that background is constant over all criteria durations. The user may enter a coefficient of variation to reflect the variability of background concentration above the discharge.

2.16 Effluent Variability

PENTOXSD uses the effluent variability to translate wasteload allocations to average monthly and maximum daily permit limits. The procedures used are recommended by the U.S. EPA and are applied to FAL criteria only. They can be found in the EPA TSD Sections 5.4 and 5.5. A summary of the procedure used is described below.

PENTOXSD first translates each FAL wasteload allocation to a long-term average (LTA) and then to an average monthly concentration. These statistical translations are made using the 99th percentile probability basis, and in the case of average monthly concentrations, the number of samples per month selected by the user. PENTOXSD also computes the maximum daily limit using similar statistics and the same probability basis.

When PENTOXSD computes the LTA for acute fish criterion, an hourly coefficient of variation is used. The justification for using an hourly-CV is that this is consistent with the expression of the water quality criterion for AFC as a 1-hour average. PENTOXSD uses the daily-CV in all other circumstances. The discharge coefficient of variation (CV) is determined by assuming that effluent variability is log-normally distributed. In the absence of a site-specific CV, a default value of 0.5 is used for both the daily-CV and hourly-CV. However, the user has the option of overriding both default CVs, based on site-specific data.

Before a recommended NPDES effluent limitation is determined, a final comparison is made. PENTOXSD compares the entered discharge concentration with the average monthly water quality-based effluent limits for each criterion to see which is most restrictive. The entered discharge concentration entered by the user is treated as the average monthly concentration at the 99th percentile probability basis. The user-supplied value is assumed to be a BAT value, or in the absence of a BAT value, the existing discharge concentration. If the entered value is more restrictive than the calculated WQBELs, then the entered value becomes the effluent limitation, and the recommended NPDES effluent limitation is identified as being based on the "INPUT" value. Similarly, PENTOXSD compares the entered maximum discharge concentration (if any) with the computed maximum daily water quality-based limits for each criterion, and will select the more restrictive concentration as the recommended maximum daily effluent limit.

3 Data Input Requirements

Table 1
PENTOXSD for Windows Data Inputs

Data Field	Type	Default	Units	Notes	Section Reference
GENERAL DATA					
Stream Code	Required				
River Mile Index	Required		miles		
Elevation	Required		feet		
Drainage Area	Required		sq miles		
Slope	Optional	Calculated based on elevation	ft/ft		4.5.1
PWS Withdrawal	Optional	0.0	mgd		2.8, 4.3, 4.5.6
Apply Fish Criteria (FC)?	Optional	Yes	Yes/No		2.9
STREAM DATA – (Separate data inputs for each design flow condition, Q7-10 and Qh)					
Incremental Low Flow Yield (LFY)	Optional	0.1	cfs/sq mile	For Q7-10 Only	4.3, 4.3.1
Tributary Stream Flow	Optional		cfs		2.6, 4.1, 4.3
Stream Flow	Optional		cfs		2.1, 4.3
Reach Width/Depth Ratio	Optional				4.5.2, 4.5.3
Reach Width	Optional		feet		4.5.2, 4.5.3
Reach Depth	Optional		feet		4.5.2, 4.5.3
Reach Velocity	Optional		fps		2.4
Reach Travel Time	Optional		days		4.1
Tributary Hardness	Optional	100	mg/L		2.7, 4.8
Tributary pH	Optional	7	pH units		2.7, 4.8
Stream Hardness	Optional		mg/L		2.7, 4.8
Stream pH	Optional		pH units		2.7, 4.8
Analysis Hardness	Optional		mg/L	At point of criteria compliance	2.7, 4.8
Analysis pH	Optional		pH units	At point of criteria compliance	2.7, 4.8

DISCHARGE DATA – (Separate data inputs for each discharger)					
Discharge Name	Required				
NPDES Permit No.	Required				
Discharge Flows Existing Permitted Design	Required		mgd	Only one of these three values is required for an analysis	2.2
Reserve Factor	Optional	0.0	Decimal percent		2.11
AFC Partial Mix Factor	Optional	0.0	Decimal percent		2.5
CFC Partial Mix Factor	Optional	0.0	Decimal percent		2.5
THH Partial Mix Factor	Optional	0.0	Decimal percent		2.5
CRL Partial Mix Factor	Optional	0.0	Decimal percent		2.5
Discharge Hardness	Optional	100	mg/L		2.7
Discharge pH	Optional	7	pH Units		2.7
Q7-10 Complete Mix Time	Optional		minutes		2.4
Qh Complete Mix Time	Optional		minutes		2.4
Number of Samples	Optional	4	Number of discharge samples per month	User selects 4,8,12,20, or 30	5.5

Data Field	Type	Default	Units	Notes	Section Reference
PARAMETER DATA (Separate data inputs for each parameter)					
Parameter Name	Required			Pick list	
Discharge Concentration	Required		µg/L		2.16
Tributary Concentration	Optional	0.0	µg/L		2.6
Discharge Daily CV	Optional	0.5			2.16
Discharge Hourly CV	Optional	0.5			2.16
Stream Concentration	Optional	0.0	µg/L		2.6
Stream CV – Daily	Optional	0.0			2.15
Fate Coefficient	Optional	1	1/day	First Order Decay Coefficient	2.10
Factor of Safety	Optional	0.0	Decimal percent		2.12
Criteria Modifier	Optional	1			2.13, 4.2
Chemical Translator (Dissolved Metals)	Optional	Per Title 25 §16.24		Applies only to metals criteria	2.14, 4.2
Maximum Discharge Concentration	Optional	0.0	µg/L		2.16

Table 1 lists required and optional data inputs. Required data inputs are listed, and must be provided by the user since there are no default values or equations for them. As a minimum, the DEP stream code, river mile index, cumulative drainage area and elevation must be entered to define each record (node). The discharge name and NPDES permit number must be entered to define a discharge, and a parameter name and discharge concentration to define a parameter.

Where optional data inputs are not supplied, default values are used for some of them. The default values are listed in Table 1. For the other data, values are computed using one or more of the equations described in Sections 4 and 5.

To analyze a single-discharge, two records are required. The first record contains all of the input data associated with the stream reach and discharge. This includes the river mile, drainage area, elevation, discharge flow, stream flow, parameter concentrations, etc. The second record is used as a reference point. In this reach the user must include (at least) stream code, river mile, elevation and drainage area.

4 Determining Wasteload Allocations

The complete first-order decay mass-balance wasteload allocation equation is presented below. This equation computes a WLA for each criterion.

$$wla = \left(\frac{cx}{\exp[-k \times tc/1440]} + \frac{yc \times qs \times (cx - cb)}{qd \times \exp[-k \times tc/1440]} \right) \times (1 - fos) \quad (4)$$

where,

wla	=	Wasteload allocation (µg/L)
qd	=	Discharge analysis flow (cfs)
yc	=	Partial mixing factor (decimal percent)
qs	=	Design stream flow (cfs)
cx	=	Water quality objective (µg/L)
cb	=	Background concentration (µg/L)
k	=	Instream fate coefficient (1/day)
fos	=	User-supplied factor of safety(decimal percent)
tc	=	Criteria compliance time (minutes)

For AFC	=	Minimum of [15, cmt]
For CFC	=	Minimum of [720, cmt]
For THH	=	Minimum of [ttpws, 720, cmt]
For CRL	=	Minimum of [720, cmt]
where,		
cmt	=	Complete mix time (See Section 4.5.4, below)
ttpws	=	Travel time to nearest potable water supply intake

Special Condition:

For PWS parameters (see Section 2.8)

$$tc = ttpws * 1440$$

If FAL do not apply at the point of discharge (see Section 2.9)

$$tc = ttaq * 1440$$

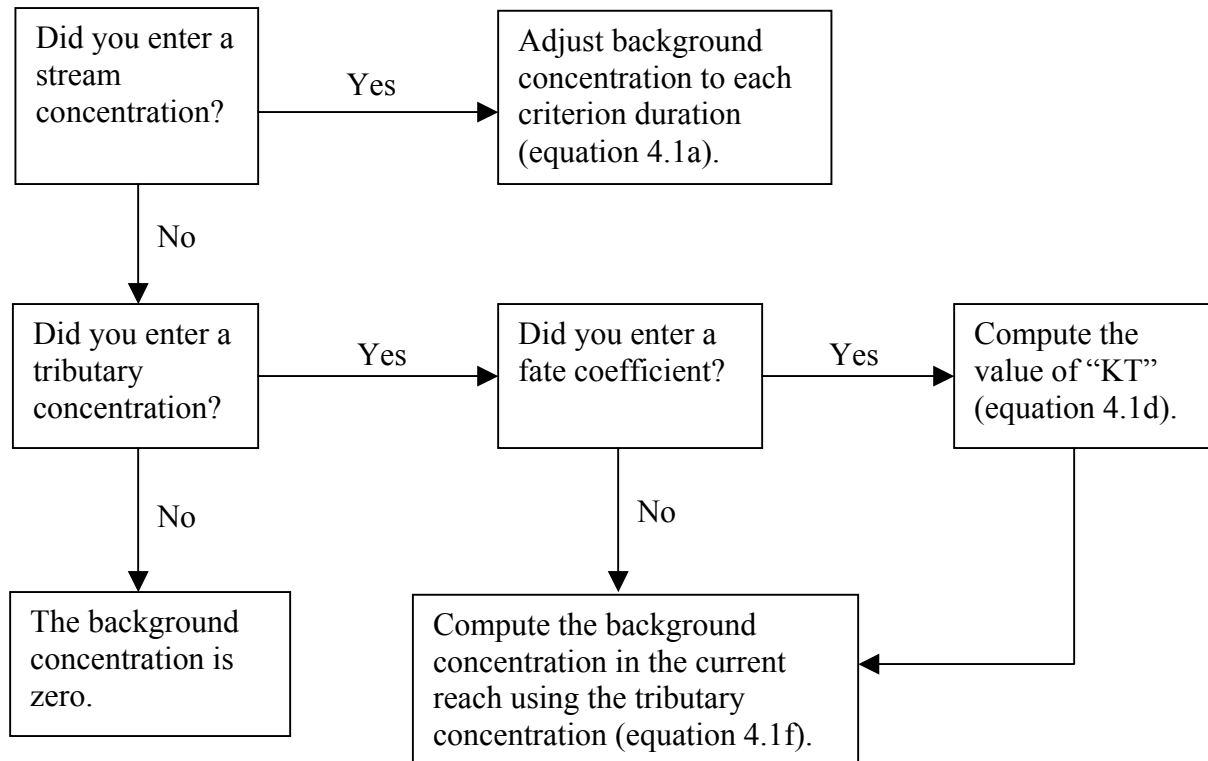
where,

ttpws	=	Travel time to nearest potable water supply intake
ttaq	=	Travel time to point of first aquatic life use

All of the variables listed on the right-hand side of this equation, except for the water quality objective, can be overridden with site-specific data. Methods and procedures for estimating each of the variables on the right side of this equation are described below. Depending on the data inputs supplied by the user, some of these equations require intermediate computations before the value can be determined. These intermediate computations must be performed first.

4.1 Background Concentration (cb)

Figure 1 Estimating Background Concentration



The background concentration is either the stream concentration entered directly by the user, or the concentration calculated by using the tributary concentrations measured at each reach above the current discharge.

When the user enters the stream concentration directly, the value may be adjusted to the criteria duration. This adjustment is made if the user also enters the stream coefficient of variation.

When the user enters tributary concentrations, they are mass-balanced up to the current reach to determine the background concentration in the stream. In a multi-reach stream segment, first-order decay rates are used to decay the tributary loads.

Two sets of equations are presented here. The first set covers the computations made when the user enters background (stream) concentration directly. The second set covers the computations made when tributary concentrations are entered.

If the user enters the stream concentration measured above the current discharge, then:

If the criterion being evaluated is AFC or CFC:

$$cb_crit = \left(\frac{cs}{\exp\left[0.5 \times \ln[cvb^2 / n + 1] - z \times \sqrt{\ln[cvb^2 / n + 1]}\right]} \right) \quad (4.1a)$$

where,

cs = User-supplied natural water quality, as defined in Section 2.6 (µg/L)
cvb = Background CV- daily (dimensionless)
n = 1 for AFC, 4 for CFC (criteria duration)
z = Z-Score = 1.645 @ 95th Percentile

If the criterion being evaluated is THH or CRL:

$$cb_crit = cs \quad (4.1b)$$

If the user enters one or more tributary concentrations (multi-reach analysis), then:

$$cb_crit_i = ct_i \quad (4.1c)$$

where,

ct_i = User-supplied tributary concentration at each reach (i) (µg/L)

If fate is applied in upstream reaches, then the cumulative fate coefficient kT_i is:

$$kT_i = \exp(-k_1 \times t_1) \times \exp(-k_2 \times t_2) \times \exp(-k_3 \times t_3) \dots \exp(-k_i \times t_i) \quad (4.1d)$$

where,

k_i = User-supplied decay coefficient for each upstream reach (1/days)

t_i = User-supplied travel time through each upstream reach: (days)

$$t_i = \left(\frac{rmi_i - rmi_{i+1}}{v_i \times 16.3636} \right) = (days)$$

rmi_i = User-supplied river mile index in the current reach (miles)

rmi_{i+1} = User-supplied river mile index in the next reach (miles)

v_i = Reach velocity (from DEP Velocity Equation or entered by the user at each reach (ft/sec)

16.36 = Conversion from ft/sec to miles/day

If fate is not applied in the upstream reaches, then:

$$kT_i = I \quad (4.1e)$$

Next, calculate the instream background concentration at the criteria compliance time

$$cb = \left(\frac{\sum_{i=1}^I (qt_i \times cb_crit_i \times KT_i) + qt_i \times cb_crit_i}{\sum_{i=1}^i (qt_i)} \right) \quad (4.1f)$$

where,

- cb_crit_i = User-supplied tributary concentration from Eq. 4.1c, above (µg/L)
- qt_i = Tributary flow in the current reach (from Eqs. 4.3b, 4.3c or 4.3d) (cfs)
- KT_i = Cumulative fate coefficient (dimensionless)

4.2 Water Quality Objective (cx)

For non-dissolved metals, the FAL water quality objective is:

$$cx = \max [wqx, cb] \quad (4.2a)$$

For dissolved metals, the FAL water quality objective is:

$$cx = \max [wqx / chem._trans, cb] \quad (4.2b)$$

where,

wqx = applicable water quality criterion.

$$wqx = wqc \times cm \quad (4.2c)$$

where,

- wqc = Chapter 16 or 93 water quality criterion (formula or value) (µg/L)
- cm = Site-specific criterion modifier (dimensionless – def. val. = 1)
- ch_trans = User-supplied or default chemical translator
- cb = Background water quality from Equation 4.1b or 4.1f at each criterion duration (µg/L)

max [] is the maximum of the two values separated by the comma.

For human health criteria:

$$wqx = \max [wqc, cb] \quad (4.2d)$$

4.3 Design Stream Flow (qs)

The design stream flow, q_s , is computed by taking either the stream flow entered directly or by using tributary flows entered for each reach above the current discharge. The latter is used in those situations where the current discharge is located in a multi-reach stream segment. If no data is entered, then the program computes the design flow at the current reach by using the drainage areas and groundwater yield factors. The equations below illustrate what the program does when the user enters either the flow directly, tributary flows or no flow at all.

4.3.1 Q7-10 Design Flow Condition

If Q7-10 is entered at the point of discharge, then:

$$q_s = q_{r(710)} \quad (4.3a)$$

where,

$q_{r(710)}$ = User-supplied Q7-10 design stream flow at the current discharge (cfs)

If Q7-10 is not entered at the point of discharge (multi-reach analysis), then:

$$q_s = \sum_{i=1}^i (q_{7_i}) - \left(\sum_{i=1}^i (pws_i) \times 1.547 \right) \quad (4.3b)$$

where,

$$q_{7_i} = qt_i \quad \text{or,} \quad (da_i - da_{i-1}) \times gwy_i$$

where,

qt_i = User-supplied incremental tributary flow at each reach (cfs)

pws_i = Potable water withdrawals up to the current reach (mgd)

da_i = User-supplied cumulative drainage area at the point of discharge (mi²)

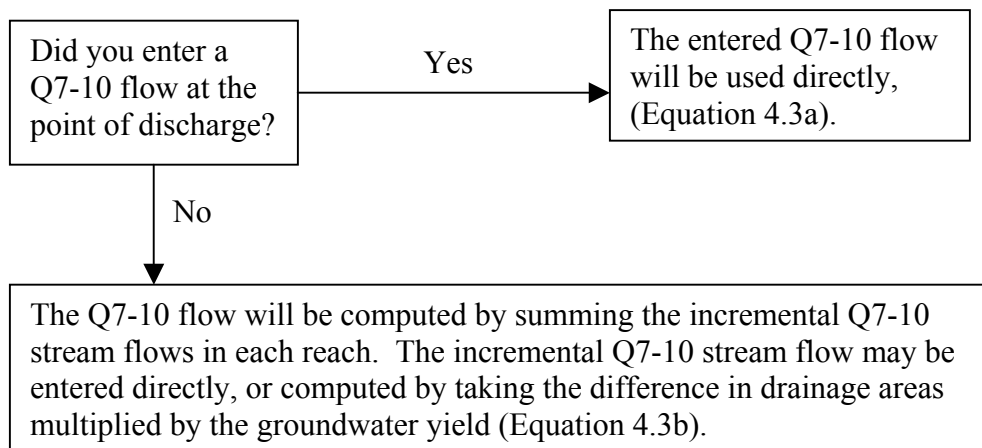
da_{i-1} = User-supplied cumulative drainage area at the previous reach (mi²)

gwy_i = User-supplied incremental low-flow yield factor (cfs/mi²)

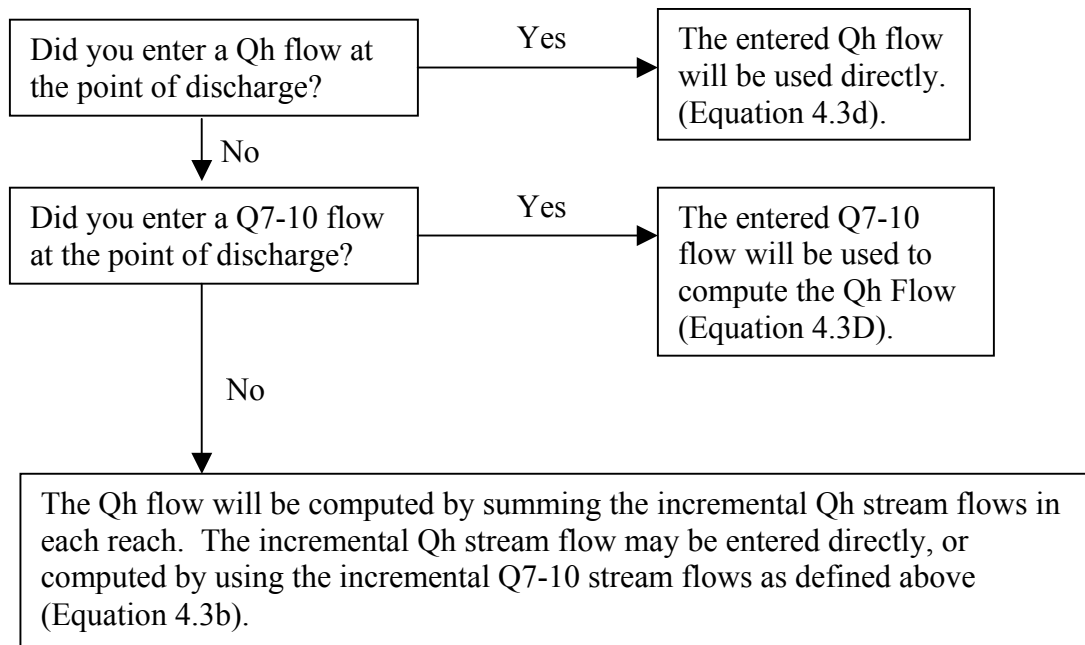
1.547 = Conversion from mgd to cfs

Figure 2 Design Stream Flow

Q7-10 Flow



Harmonic Mean Flow (Qh)



4.3.2 Harmonic Mean Design Flow

If Harmonic Mean Flow is entered at the point of discharge, then:

$$qs = qr(hm) \quad (4.3c)$$

where,

$qr(hm)$ = User-supplied harmonic mean design stream flow derived at the current discharge (cfs)

If Q7-10 is entered at the point of discharge, then:

$$qs = 7.43 \times (qr_{(7-10)})^{.874} \quad (4.3d)$$

If neither harmonic mean or Q7-10 Design Flows are not entered (multi-reach analysis), then:

$$qs = \sum_{i=1}^i qc_i - \left(\sum_{i=1}^i pws_i \times 1.547 \right) \quad (4.3e)$$

where,

$$qc_i = qt_i \quad \text{or} \quad 7.43 \times \left(\sum_{i=1}^i (q7_i)^{.874} - \sum_{i=1}^i (q7_i)^{.874} \right) \quad (4.3f)$$

where,

qt_i = User-supplied incremental harmonic mean flow at each reach (cfs)

$q7_i$ = Incremental Q7-10 tributary flow as defined above (cfs)

pws_i = Potable water withdrawals up to the current reach (mgd)

4.3.3 Special Conditions

If the user enters a potable water supply intake, or if the point of first aquatic life use is not the current reach, then:

Qs = Stream flow at the PWS or at the point of first aquatic use

The equations used to determine the stream flow are the same as shown above. However, the stream flow used for evaluation purposes is the stream flow at the specified RMI, instead of at the current discharge.

4.4 Discharge Analysis Flow (qd)

The discharge analysis flow, qd, is used to compute the allowable load for each parameter. This value can be either the design discharge flow, or can be based on an existing or permitted flow.

If the user enters the design discharge flow, then:

$$qd = qd_design \times 1.547 \quad (4.4a)$$

If the user enters existing and/or permitted discharge flow, then:

$$qd = \max [qd_existing , qd_permit] \times (1 + rf) \times 1.547 \quad (4.4b)$$

where,

qd_design = User-supplied design discharge flow (mgd)
qd_existing = User-supplied existing discharge flow (mgd)
qd_permit = User-supplied permitted discharge flow (mgd)
rf = User-supplied reserve factor (decimal percent)
max[] is the maximum of the two values separated by the comma.

4.5 Partial Mixing Factor (yc)

Depending on what data are entered by the user, partial mixing factors can be estimated in a variety of ways. If a mix factor is entered for each criterion, then the value is used directly. If complete mix times are entered instead of mix factors, then they are used to compute mixing factors. If neither are entered, then the partial mix factors are estimated by first determining the complete mix time. In this case, the complete mix time is computed using the width, depth and slope. The latter may be entered directly or computed using the default equations. The applicable equations are presented below assuming that no optional inputs are entered.

4.5.1 Reach Slope (sl)

The reach slope, sl, can be entered directly. Where not entered directly, it is calculated using the equation below.

If the user enters slope directly, then:

$$sl = slr \quad (4.5.1a)$$

where,

slr = User-supplied slope (ft/ft)

If the user does not enter the slope, then:

$$sl = \left(\frac{elev_i - elev_{i+1}}{[rmi_i - rmi_{i+1}] \times 5280} \right) \quad (4.5.1b)$$

where,

$elev_i$ = User-supplied elevation at the current reach (ft)
 $elev_{i+1}$ = User-supplied elevation at the next reach (ft)
 rmi_i = User-supplied river mile at the current reach (mi)
 rmi_{i+1} = User-supplied river mile at the next reach (mi)
5280 = Conversion from miles to feet

4.5.2 Reach Depth (d)

The reach depth, d, can be entered directly. If not, it is estimated in a number of ways, depending on what other information was entered. For example, if width is entered, then depth is computed based on the entered width.

For reach depth the possible combinations are presented below. Only one is selected.

If the user enters the depth, then:

$$d = dr \quad (4.5.2a)$$

where,

dr = User-supplied depth (ft)

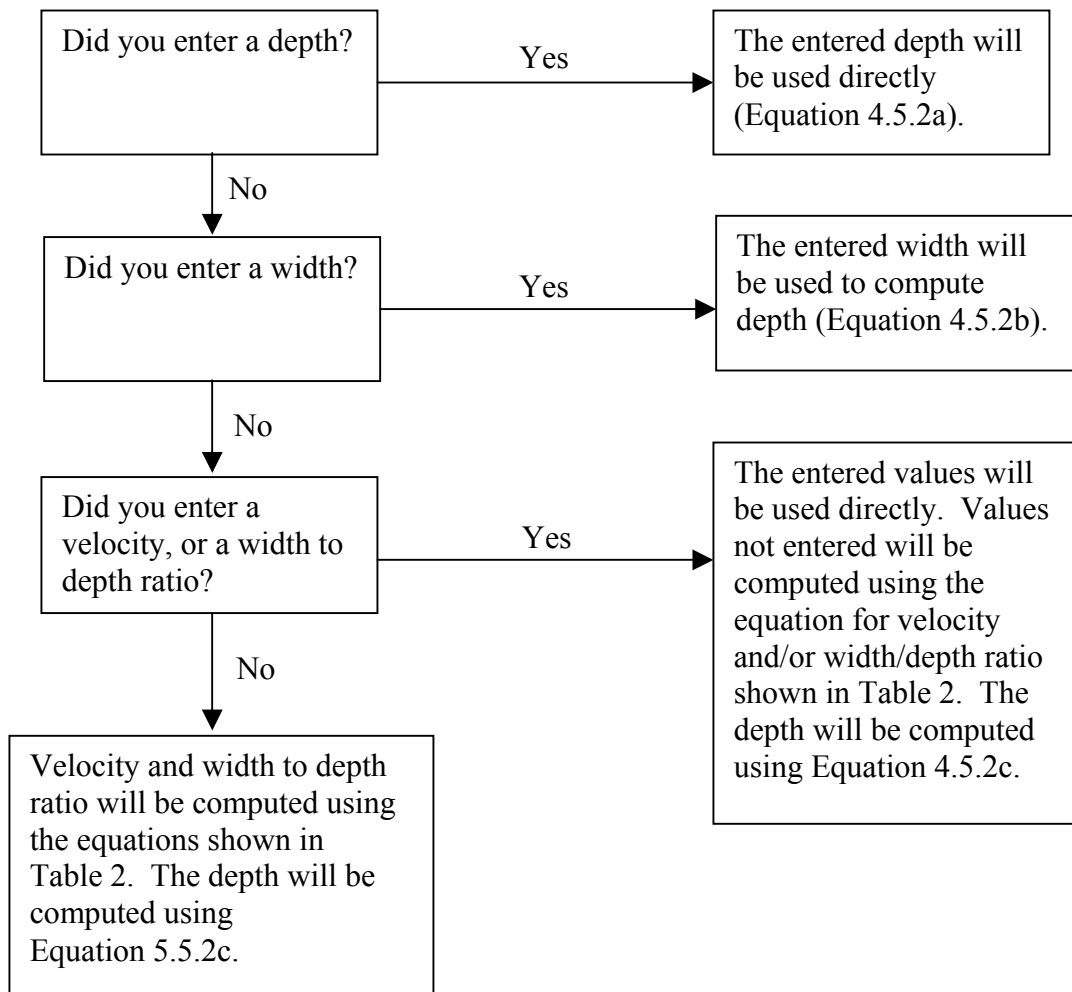
If the user enters reach width, then:

$$d = \left(\frac{qs + qd}{v \times w} \right) \quad (4.5.2b)$$

where,

qs = Design stream flow from equations in Box 4.3 (cfs)
 qd = Discharge analysis flow from equation 4.4a or 4.4b (cfs)
 v = DEP Velocity Equation or entered by the user (ft/sec)
 w = User-supplied width (ft)

Figure 3 Determining Reach Depth



If the user does not enter width, but enters velocity and/or width/depth ratio, then:

$$d = \sqrt{\left(\frac{[qs + qd]}{[v \times w_d]} \right)} \quad (4.5.2c)$$

where,

- qs = Design stream flow from equations in section 4.3 (cfs)
- qd = Discharge analysis flow from Equation 4.4a or 4.4b (cfs)
- v = DEP Velocity Equation or entered by the user (ft/sec)
- w_d = DEP Width/Depth Equation or entered by the user (dimensionless)

If the user does not enter any other optional data, then:

Use Equations 4.5.2c & 4.5.3d

4.5.3 Reach Width (w)

The reach width, w , can be entered directly. If it is not entered directly, it is estimated in a number of ways. This will depend on what other information was entered. For example, if the user enters depth, then width is computed based on the entered depth.

For reach width the possible combinations are presented below. Only one is selected.

If the user enters the width, then:

$$w = wr \quad (4.5.3a)$$

where,

wr = User-supplied width

If the user enters reach depth, then:

$$w = \frac{(qs + qd)}{(v \times d)} \quad (4.5.3b)$$

where,

qs	=	Design stream flow from equations in Section 4.3 (cfs)
qd	=	Discharge analysis flow from Equation 4.4a or 4.4b (cfs)
v	=	DEP Velocity Equation or entered by the user (ft/sec)
d	=	User-supplied depth (ft)

If the user does not enter depth, but enters velocity and/or width/depth ratio, then:

$$d = \sqrt{\left(\frac{[qs + qd]}{[v \times w_d]} \right)} \quad (4.5.3c)$$

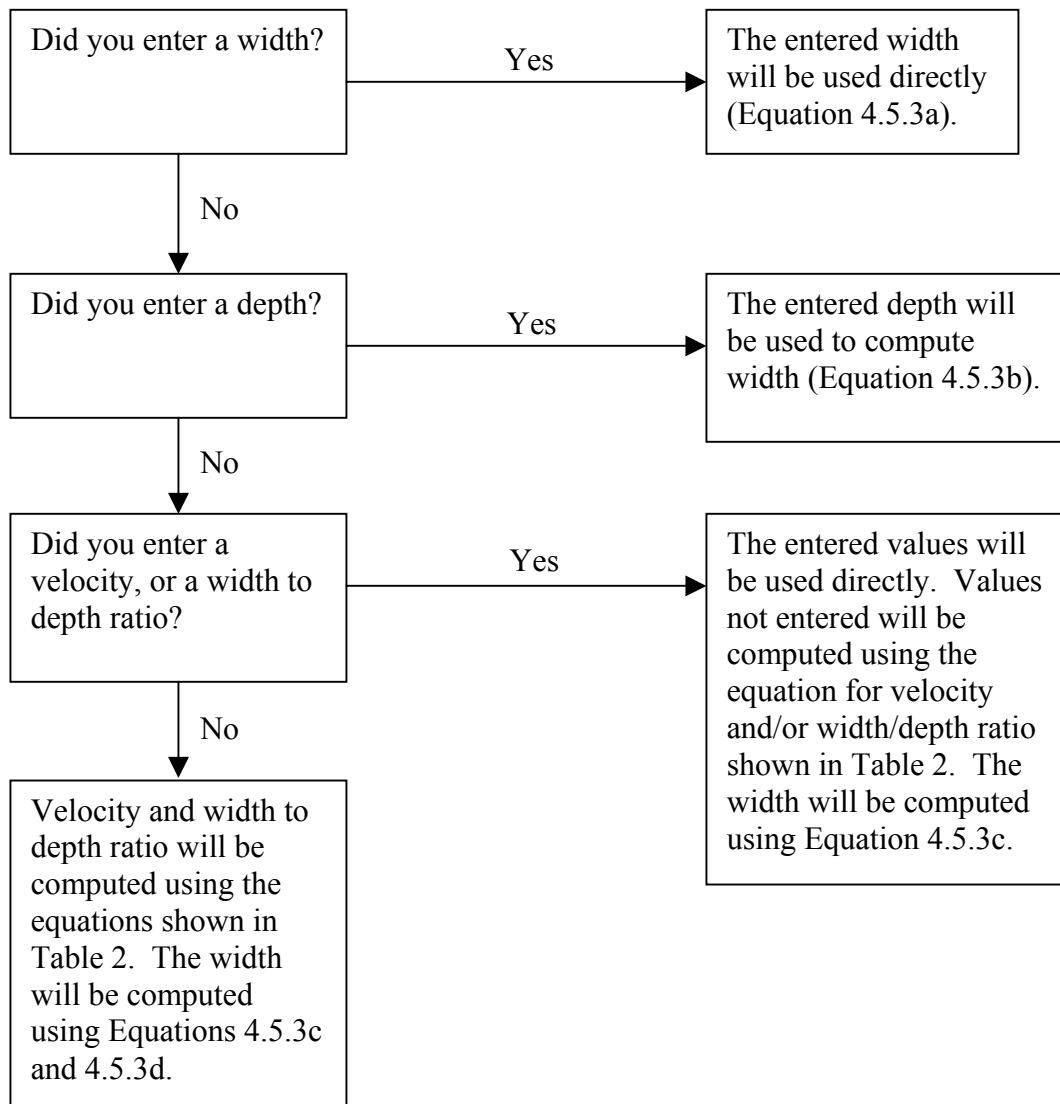
and

$$w = (d \times w_d) \quad (4.5.3d)$$

where,

qs	=	Design stream flow
qd	=	Discharge analysis flow
v	=	DEP Velocity Equation or entered by the user (ft/sec)
w_d	=	DEP Width/Depth Equation or entered by the user (dimensionless)

Figure 4 Determining Reach Width



If the user does not enter any other optional data, then:

Use Equations 4.3.3c & 4.3.3d

Table 2 Width, Depth, Width/Depth Ratio and Velocity Computations

When the user enters		Width (w)	Depth (d)	W/D Ratio (w_d)	Velocity (v)	Width (w) & Depth (d)	Nothing
PENTOXSD computes							
Velocity (v)	Velocity Equation (1)	Velocity Equation (1)	Velocity Equation (1)	Velocity Equation (1)	-	(qs + qd)/(w x d)	Velocity Equation (1)
W/D Ratio (w_d)	(w / d)	(w / d)	(w / d)	-	W/D Equation (2)	(w / d)	W/D Equation (2)
Depth (d)	(qs + qd) / (v x w)	(qs + qd) / (v x w)	-	(qs + qd) / (v x w_d) ⁵	(qs + qd) / (v x w_d) ⁵	-	(qs + qd) / (v x w_d) ⁵
Width (w)	-	(qs+qd)/(vx d)	(qs+qd)/(vx d)	(d x w_d)	(d x w_d)	-	(d x w_d)

Velocity Equation =
$$\frac{\left(A \times (qs + qd)^{0.56} \times (s / \times 5280)^B \times da^C \right)}{16.3636}$$

	da > 500 sq.mi.	da < 500 sq.mi.
A	1.64	2.62
B	0.055	0.083
C	-0.15	-0.22

and,

W/D Equation =
$$\left[-0.073 + 0.141 \times (qs + qd)^{-0.077} + 0.06 \times da^{-0.445} + 0.0001 \times (5280 \times sf)^{1.075} \right]^{-1.429}$$

where,

qs = design stream flow

qd = discharge analysis flow

sl = reach slope

da = cumulative drainage area

w_q7-10 = width computed at Q7-10 design flow

d_q7-10 = depth computed at Q7-10 design flow

v-q7-10 = velocity computed at Q7-10 design flow

q7-10 = design stream flow at Q7-10

qh = design stream flow at harmonic mean condition

(Note: The constant 16.3636 is used to change units from mi/day to feet/sec)

Note: Computing width, depth and velocity at the Qh flow condition
<div>If <u>width, depth and/or velocity are not entered at Harmonic Mean Flow, then:</u> Width = w_q7-10 Depth = d_q7 - 10 × (qh/q7 - 10)^{0.44} Velocity = v_q7 - 10 × (qh/q7 - 10)^{0.56} Note: The purpose of these equations is to maintain continuity with the relationship that Q = W x D x V, where some or all of these values may be entered by the user</div>

4.5.4 Complete Mix Time (cmt)

Complete mix time, cmt, can be entered directly, or estimated based on the width, depth, design stream flow, discharge analysis flow and slope of the stream at the point of discharge. If the user enters the complete mix time, then:

$$cmt = cmtr \quad (4.5.4a)$$

where,

cmtr = User-supplied complete mix time (minutes)

If the user does not enter the complete mix time, then:

$$cmt = \frac{0.28 \times (w \times (qs / (qs + qd)))^2}{0.6 \times d \times (\sqrt{32.2 \times d \times sl}) \times 60} \quad (4.5.4b)$$

where,

qs = Design stream flow
qd = Discharge analysis flow
sl = Stream slope
d = Stream depth
w = Stream width

Note: The constant 0.28 in Equation 4.5.4b represents the degree of uniformity expected in the channel that also produces a complete mix relationship with the variability in instream concentration of 20 percent. The value of 0.6 represents the amount of discharge diffusion associated with an average discharge.

If the user enters the partial mix factor, then a different equation is used to solve for the complete mix time. This equation is presented below.

$$cmt = \frac{tc}{yc^2} \quad (4.5.4c)$$

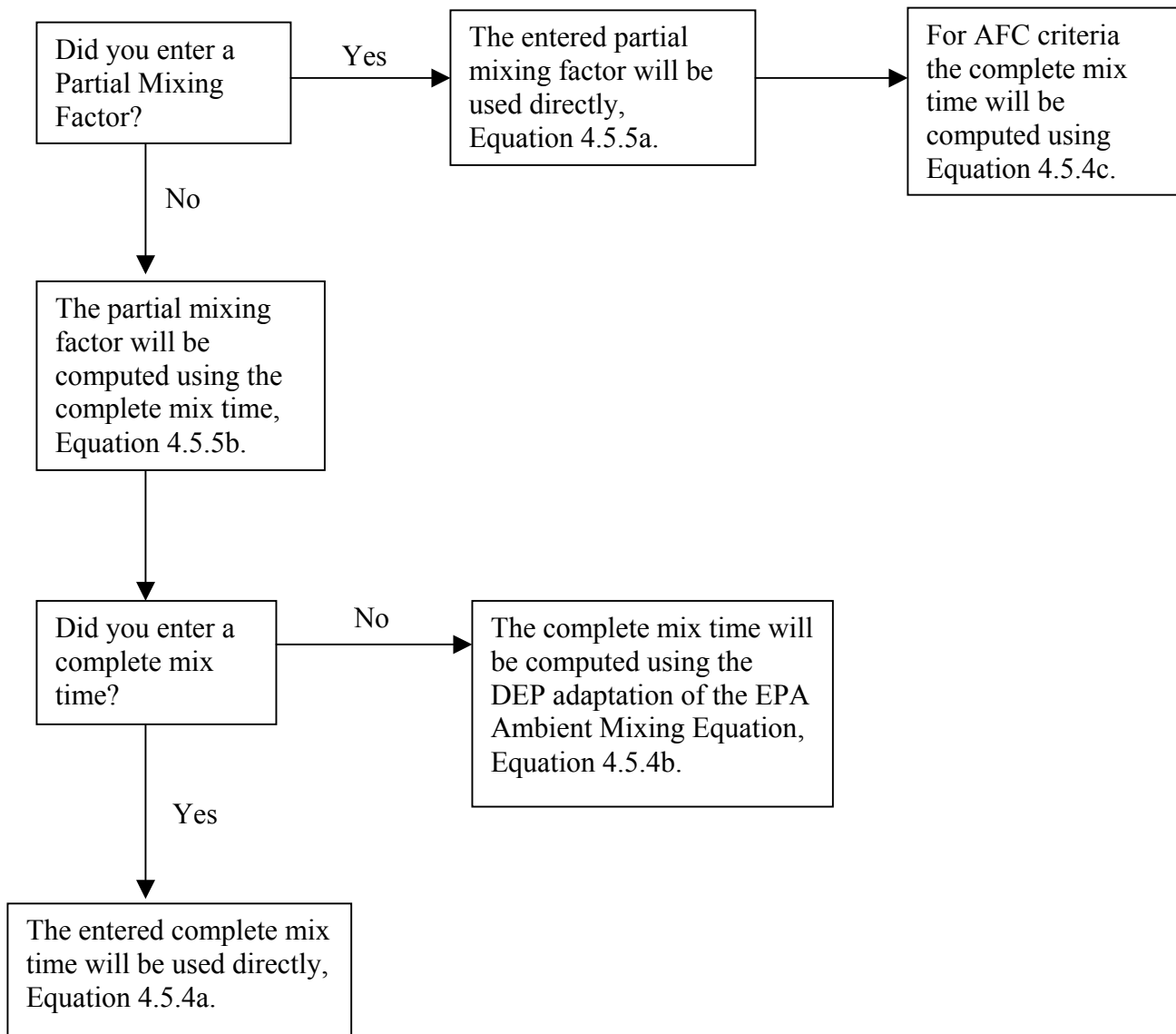
where,

tc = Criteria compliance time (minutes)
yc = User-supplied partial mix factor (decimal percent)

4.5.5 Partial Mixing Factor (yc)

The partial mix factor, yc, represents the fraction of design stream flow (qs) that mixes with the discharge at the criteria compliance time (tc). This factor may be estimated using results from an instream mixing study. Separate values are determined for each criterion and can be entered directly by the user.

Figure 5 Determining the Partial Mixing Factor



If the user enters the partial mix factor, then:

$$y_c = y_{cr} \quad (4.5.5a)$$

where,

y_{cr} = User-supplied partial mix factor (decimal percent)

If the user does not enter the partial mix factor, the equation for computing it is:

$$yc = \min\left[\sqrt{tc/cmt}, 1\right] \quad (4.5.5b)$$

where,

tc = Criteria compliance time (minutes)

cmt = Complete mix time (See Section 4.5.4) (minutes)

min[] is the minimum of the two values or expressions separated by a comma

4.5.6 Special Conditions

If the user enters a PWS withdrawal in a downstream reach, and for the six PWS parameters (phenolics, fluoride, NO₂-NO₃, total dissolved solids, sulfate and chloride), then for human health criteria:

$$yc = 1 \quad (4.5.6a)$$

If FAL criteria do not apply at the point of discharge, then at the point of first aquatic life use:

$$yc = 1 \quad (4.5.6b)$$

4.6 Instream Pollutant Fate Coefficient (k)

The instream pollutant fate, k, may be estimated by conducting the appropriate field surveys. If it is not entered, the program assigns the value of zero (0) for each decay coefficient.

4.7 Factor of Safety (fos)

The factor of safety, fos, may be entered into the program. If it is not entered, the program assigns the default value of 0.

4.8 Hardness & pH (Used for computing water quality criteria)

If the user enters the analysis hardness or pH then:

$$xc = csharcct \text{ or } cspHcct \quad (4.8a)$$

where,

csharcct = User-supplied analysis hardness

cspHcct = User-supplied analysis pH

If the user enters the discharge and stream conditions, then:

$$xc = \frac{((yc \times qs \times xs) + (qd \times xd))}{((yc \times qs) + (qd))} \quad (4.8b)$$

where,

qs = Net stream flow at current reach (cfs)
qd = Discharge analysis flow (mgd)
yc = Partial mix factor for each criterion
xs = User-supplied stream hardness (mg/L) or pH
xd = User-supplied discharge hardness (mg/L) or pH

If the user has not entered a stream hardness and/or pH, the stream value(s) are determined using tributary value(s) before equation 4.8b is applied, using the equation:

$$xs(i) = \frac{(qt(i) \times xt(i) + qs(i-1) \times xs(i-1))}{qs(i)} \quad (4.8c)$$

where,

qt(i) = Net tributary flow entering at the beginning of the current reach
qs(i-1) = Net stream flow in previous reach
xt(i) = User-supplied tributary hardness (mg/L) or pH
xs(i-1) = Stream hardness (mg/L) or stream pH in previous reach

Note: pH is converted to hydrogen ion concentration and the mass-balance is computed. The resulting value is then converted back to pH units.

5 Determining Final Effluent Limitations

In the previous section, the equations were presented that compute each Wasteload Allocation (WLA). These allocations have a specific duration associated with them. As can be seen from the box below, a separate allocation is done for each water quality criterion.

Criteria	Duration	Wasteload Allocation
AFC	1 hour	1-hour
CFC	4 days	4-day
THH	30 days	Long-term average
CRL	Long-term average	Long-term average

None of these can be placed directly in the NPDES permit. This is because the NPDES permit requires an average monthly and maximum daily effluent limit. Therefore, some of these allocations must be translated and compared at intermediate steps in the process so that the most stringent one can end up in the NPDES permit.

The recommended procedures involve the use of statistics and, particularly, include the effluent variability (coefficient of variation) for each parameter. These procedures are contained in the *Technical Support Document for Water Quality-Based Toxics Control* (EPA TSD). In particular, the reader is referred to EPA TSD Chapter 5, Pages 102-103 for determining the average monthly limit. The reader is referred to EPA TSD Chapter 5, Page 106 for determining the maximum daily limit.

Wasteload Allocations are determined for each applicable criterion using Equation 4. WLAs for AFC and CFC are first converted to long-term averages, and then to 30-day averages, while WLAs for THH and CRL are treated as 30-day averages directly. These four 30-day average values (or as many of them as are appropriate) are then compared to the entered discharge concentration to determine which value is the most stringent. This most stringent value is the recommended effluent limitation.

5.1 Determining the Average Monthly Effluent Concentration for Aquatic Life Criteria

If the wasteload allocation is for AFC, then:

$$LTAMULT = \exp\left(0.5 \times \ln(cvh^2 + 1) - z \times \sqrt{\ln(cvh^2 + 1)}\right) \quad (5.1a)$$

Compute the long-term average for acute fish criterion:

$$lta_afc = wla \times LTAMULT \quad (5.1b)$$

where,

wla = Wasteload allocation for AFC criterion (µg/L)
cvh = Discharge hourly coefficient of variation (dimensionless)
(Default = 0.5)
cvd = Discharge daily coefficient of variation (dimensionless) (Default = 0.5)
z = Z-Score = 2.326 @ 99th percentile

If the wasteload allocation is for CFC, then:

$$LTAMULT = \exp\left(0.5 \times \ln(cvd^2 / 4 + 1) - z \times \sqrt{\ln(cvd^2 / 4 + 1)}\right) \quad (5.1c)$$

And

$$lta_cfc = wla \times LTAMULT \quad (5.1d)$$

where,

wla = Wasteload allocation for CFC criterion (µg/L)
cvd = Discharge daily coefficient of variation (dimensionless) (Default = 0.5)
z = Z-Score = 2.326 @ 99th percentile

Determine More Stringent Long-Term Average

$$gov_lta = \min [lta_afc, lta_cfc] \quad (5.1e)$$

Convert to an Average Monthly Effluent Concentration

$$AMLMULT = \exp\left(z \times \left(\sqrt{\ln(cvd^2/n+1)}\right) - 0.5 \times \ln(cvd^2/n+1)\right) \quad (5.1f)$$

$$AML_{aquatic} = gov_lta \times AMLMULT \quad (5.1g)$$

where,

cvd = Discharge daily coefficient of variation (dimensionless) (Default = 0.5)

z = Z-Score = 2.326 @ 99th percentile

n = Number of samples per month in NPDES permit (4, 8, 12, 20, or 30)

5.2 Determining the Average Monthly Limit for Human Health Criteria

If the wasteload allocation is for THH or CRL then:

$$AMLMULT = 1.0 \quad (5.2a)$$

Convert to an Average Monthly Effluent Concentration

$$AML_{human} = wla \times AMLMULT \quad (5.2b)$$

5.3 Determining the “Governing” Water Quality-Based Effluent Limit (WQBEL)

$$WQBEL = \min[AML_{afc}, AML_{cfc}, AML_{thh}, AML_{crl}] \quad (5.3)$$

5.4 Determining the “Final” Effluent Limit

$$FinalLimit = \min[WQBEL, cd] \quad (5.4)$$

where,

WQBEL = Final water quality-based effluent limit from Equation 5.4 (µg/L)

cd = User-supplied effluent concentration (existing effluent quality, BAT or existing permit limit) (µg/L)

5.5 Calculate the Maximum Daily Effluent Limit

5.5.1 Calculate Ratio of MaxDaily/Final Limit

$$R = \frac{\exp\left[z \times \sqrt{\ln(cvd^2+1)} - 0.5 \times \ln(cvd^2+1)\right]}{\exp\left[z \times \sqrt{\ln(cvd^2/n+1)} - 0.5 \times \ln(cvd^2/n+1)\right]} \quad (5.5.1)$$

where,

cvd = Discharge daily coefficient of variation (Default = 0.5)
z = Z-Score = 2.326 @ 99th percentile
n = Number of samples per month in NPDES permit (4, 8, 12, 20, or 30)

5.5.2 Calculate Maximum Daily Limit

$$CMaxDaily = FinalLimit \times R \quad (5.5.2a)$$

where,

CmaxDaily = Calculated maximum daily effluent limit (µg/L)
Final Limit = Final average monthly effluent limit (µg/L)
R = Ratio of calculated maximum daily effluent limit to final average monthly effluent limit (dimensionless)

$$MaxDaily = \min[CMaxDaily, MaxDiscConc] \quad (5.5.2b)$$

where,

MaxDaily = Final maximum daily effluent limit (µg/L)
CMaxDaily = Calculated maximum daily effluent limit (µg/L)
MaxDiscConc = User-supplied maximum discharge concentration (µg/L)

6 Appendix A Derivation of Mixing Relationships

EPA's *Technical Support Document for Water Quality-Based Toxics Control*⁽¹⁾ contains the following general purpose equation for determining complete mix distance for a discharge to a free-flowing stream:

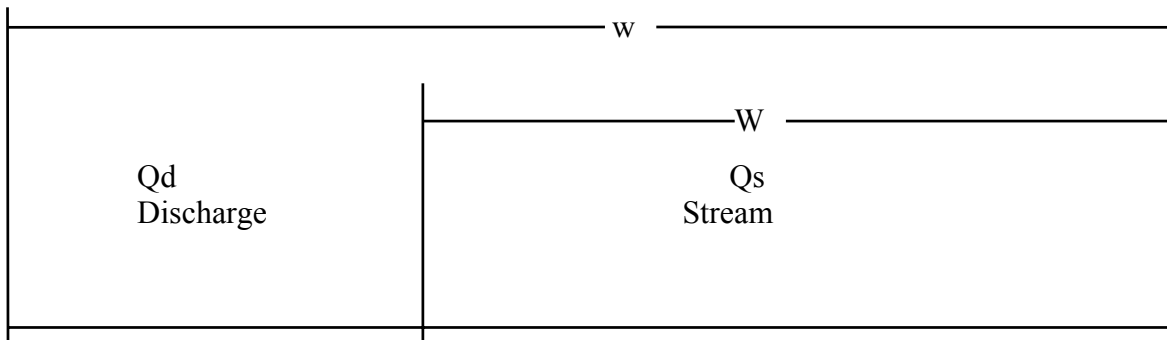
$$X_m = \frac{m \times w^2 \times u}{D_y} \quad (\text{A1a})$$

where,

X_m	=	Distance to complete mix
m	=	A parameter whose value defines the degree of uniformity used to define complete mix (set at 0.315 in PENTOXSD)
w	=	Stream width
u	=	Flow velocity for critical design condition
D_y	=	Lateral dispersion coefficient

The above equation is for ambient mixing only. It does not consider discharge induced mixing. It, therefore, provides a conservative estimate of complete mix time.

The EPA ambient mixing equation is an empirical relationship designed primarily for conditions where the discharge flow to stream flow ratio is very small.⁽²⁾ In many discharge situations found in Pennsylvania this is not the case. Because of this, an adjustment of stream width has been made to the mixing equation. In essence, this adjustment assumes that before ambient mixing begins, the discharge flow is within a defined rectangular channel, as illustrated in the figure below.



Thus the width of the stream is adjusted using the following relationship:

$$W = w \times (Q_s / (Q_s + Q_d)) \quad (\text{A1b})$$

where,

- W = Adjusted width of the stream channel
w = Actual/computed width of the effected stream channel
Qs = Total stream flow (cfs) including the addition of flow augmentation from upstream discharges
Qd = Analysis discharge flow (cfs) for the current discharge being evaluated.

This adjustment avoids obtaining overly long complete mix time for situations where the discharge flow represents a significant portion of the total system flow. The adjustment is made in Equation 4.5.4b of the PENTOXSD TRG.

For any set of design conditions, an estimate of complete mix time (i.e., travel time from point of discharge to point of complete mix) may be obtained by dividing distance by velocity. Therefore,

$$\frac{X_m}{u} = t_m = \frac{m \times W^2}{D_y} \quad (A2)$$

where,

t_m = complete mix time

In PENTOXSD, complete mix travel time is expressed in minutes. Another basic assumption made in PENTOXSD is that the free-flowing stream consists of a uniform rectangular channel, whose length is at least equal to X_m . In such a channel, the amount of flow Q is equal to:

$$Q = u \times W \times D \quad (A3)$$

where,

D = depth of channel

If it is assumed that velocity (u) and depth (D) are held constant, then the amount of flow (Q') in any portion of the channel (W') is:

$$Q' = u \times W' \times D \quad (A4)$$

where,

W' = portion of stream channel width

Q' = partial stream flow at width W'

By using equations (2) and (4), one can estimate the amount of time it takes a discharge to mix with a given portion of the stream, and the ratio of this (partial mix) time to the complete mix time.

$$t' = \frac{m \times W'^2}{D_y} \quad (A5)$$

$$\frac{t'}{t_m} = \frac{m \times W'^2}{D_y} \times \frac{D_y}{m \times W^2} = \frac{W'^2}{W^2} = \left(\frac{W'}{W} \right)^2 \quad (A6)$$

Since, based on equation (A4), W and W' are proportional to Q and Q' respectively, we have:

$$\frac{t'}{t_m} = \left(\frac{Q'}{Q} \right)^2 \quad (A7)$$

$$\frac{Q'}{Q} = \sqrt{\left(\frac{t'}{t_m} \right)} \quad (A8)$$

Equation (A8) is the basic equation used in PENTOXSD to determine the amount of stream flow (Q') which mixes with a discharge in a given time (t'). In PENTOXSD, (t') is set equal to the maximum criteria compliance times for each of the criteria being evaluated. These are listed in Figure C-2, below:

Criteria	Maximum Compliance Time Used in PENTOXSD
AFC	15 minutes
CFC	12 hours
THH	12 hours, or travel time to the nearest downstream water supply
CRL	12 hours

Since (Q') cannot be greater than Q, a boundary condition is added such that:

$$\frac{Q'}{Q} = \text{minimum} \left[\sqrt{\left(\frac{t'}{t_m} \right)}, 1 \right] \quad (A9a)$$

In PENTOXSD, this equation is modified slightly in order to solve for the analysis stream flow at the point of compliance. Thus, the equation is written:

$$Q' = Q \times \text{minimum} \left[\sqrt{\left(\frac{t'}{t_m} \right)}, 1 \right] \quad (A9b)$$

where,

Q' = Analysis stream flow at the point of compliance

The relationship: $\text{minimum} \left(\frac{t'}{t_m} \right)^{.5}, 1$ is known in PENTOXSD as the partial mix factor.

If the compliance time (t') for the criteria being evaluated is less than the complete mix time (tm), then the stream flow used in the analysis will be less than the total stream flow available for dilution. This

results in a partial mix analysis. If the compliance time (t') for the criteria being evaluated is greater than or equal to the complete mix time (t_m), then complete mix is assumed at the point of discharge.

References

- (1) Page 36, Technical Support Document for Water Quality-Based Toxics Control, U.S. EPA, September 1985.
- (2) Telephone Conversation with Professor G. Jirka, Cornell University, January 1988.

7 Appendix B Sample Problem

This appendix presents a sample problem. The input data for the problem is presented below.

First Reach:

Stream Code	RMI	Elevation	Drainage Area	Slope	PWS With.		Apply FC
28374	35.26	1400.00	48.30	0.00000	0.00		Y

	LFY:	Trib Flow	Stream Flow	WD Ratio	Rch Width	Rch Depth	Rch Vel.	Rch Trav Time	Stream Hard.	Stream pH	Back. Hard.	Back pH
Q710	0.100	0.000	0	0.000	0.000	0.0000	0.000	0.000	0.000	0.000	100.000	7.000
Qh			0			0.000	0.000	0.000				

Discharge Data												
4Name	Permit Number	Existing Disc. Flow	Permitted Disc. Flow	Design Disc. Flow	Reserve Factor	AFC PMF	CFC PMF	THH PMF	CRL PMF	Disc. Hard.	Disc. pH	
discharge 1	pa00001	0.700	0.700	0.000	0.000	0.000	0.000	0.000	0.000	100.000	7.000	

Parameter Data											
Parameter Name	Disc Conc	Trib Conc	Disc Daily CV	Disc Hourly CV	Back At Disc	Back CV	Fate Coef	FOS	Crit Mod	Max Disc Conc	
CADMIUM	1000.000	0.200	0.500	0.500	0.000	0.000	0.000	0.000	1.000	0.000	
COPPER	1000.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	1.000	0.000	
PENTACHLOROPHENOL	1000.000	0.000	0.500	0.500	0.000	0.000	1.000	0.000	1.000	0.000	
ZINC	10000.00	170.000	0.500	0.500	0.000	0.000	0.000	0.000	1.000	0.000	

Second Reach¹:

Stream Code	RMI	Elevation	Drainage Area	Slope	PWS With.	IWS With.	Apply FC
28374	31.00	1145.00	54.05	0.00000	0.00	0.00	Y

¹ Note: Although the PENTOXSD displays stream, discharge and parameter data for the second (reference) reach, the data are not shown here because they are not used in the calculation process.

Preliminary Calculations

PENTOXSD carries out calculations in two major phases – preliminary calculations, and parameter calculations. In preliminary calculations, hydrodynamic, as well as hardness and pH values are determined. The preliminary calculations for the sample problem are summarized below.

Variable	Q7-10 design conditions	Qh design conditions
Discharge Analysis Flow	Since a Design Discharge Flow was not entered, equation 4.4b is used. $qd = \max [qd_existing, qd_permit] \times (1 + rf) \times 1.547 =$ $.700 \times (1 + 0) \times 1.547 = 1.829 \text{ cfs}$	
Net Stream Flow	Since no Design Q7-10 flow and no tributary flow was entered, equation 4.3b is used. $qs = \sum_{i=1}^i (q7_i) - \left(\sum_{i=1}^i (pws_i) \times 1.547 \right)$ $= 0.1 \times 48.30 - 0 = 4.83 \text{ cfs}$	Since no Design Qh flow and no tributary Qh flow was entered, equation 4.3f is used. $qh = 7.43 \times \left(\sum_{i=1}^i (q7_i) \right)^{.874} - \left(\sum_{i=1}^i (q7_i) \right)^{.874}$ $= 7.43 \times 4.83^{.874} = 29.428 \text{ cfs}$
Reach Slope	Since no slope was entered, equation 4.5.1b is used. $sl = \left(\frac{elev_i - elev_{i+1}}{[rmi_i - rmi_{i+1}] \times 5280} \right) = \left(\frac{1400 - 1145}{[35.26 - 31.00] \times 5280} \right) = 0.0113 \text{ ft/ft}$	
Reach Velocity	Since no velocity @ Q7-10 flow and no Q7-10 reach travel time were entered, the DEP velocity equation from Table 2 is used. $Vel = \frac{\left(A \times (qs + qd)^{0.56} \times (sl \times 5280)^B \times da^C \right)}{16.3636}$ $\frac{\left(2.62 \times (4.83 + 1.829)^{0.56} \times (0.0113 \times 5280)^{0.083} \times 48.30^{-0.22} \right)}{16.3636}$ $= 0.259 \text{ fps}$	Since no velocity @ Qh flow and no Qh reach travel time were entered, the velocity is determined in accordance with the Qh velocity equation found in Table 2. $Vel = v_{q7-10} \times (qh/q7-10)^{0.56} =$ $0.259 \times (29.428/4.830)^{0.56}$ $= 0.713 \text{ fps}$
Reach Width/Depth Ratio	Since no Q7-10 W/D ratio, depth, and/or width were entered, the W/D ratio is determined using the W/D equation in Table 2. $WDRatio = \left[\frac{-0.073 + 0.141 \times (qs + qd)^{-0.077} + 0.06 \times da^{-0.445} + 0.0001 \times (5280 \times sl)^{1.075}}{1} \right]^{-1.429}$	Since no Qh W/D ratio, depth, and/or width were entered, the W/D ratio is determined by dividing the width by the depth after the Qh width and depth equations from Table 2 are applied (see below).

Variable	Q7-10 design conditions		Qh design conditions
	$= \left[\begin{aligned} &-0.073 + 0.141 \times (4.830 + 1.0829)^{-0.077} + \\ &0.06 \times 48.30^{-0.445} + 0.0001 \times (5280 \times 0.0113)^{1.075} \end{aligned} \right]^{-1.429}$ <p>= 45.8 (dimensionless)</p>		WD Ratio = (32.33/1.5624) = 21 (dimensionless)
Reach Depth	<p>Since no Q7-10 reach velocity, depth and/or width were entered, the reach depth is determined in accordance with the equation in Table 2.</p> <p>Depth = (qs + qd) / (v × w_d)⁵ = (4.830 + 1.0829) / (0.259v × 45.8)⁵ = 0.7055 ft.</p>		<p>Since no Qh reach velocity, depth, and/or width were entered, the reach depth is determined in accordance with the Qh depth equation in Table 2.</p> <p>Depth = d_q7-10 × (qh/q7-10)^{0.44} = 0.7055 × (29.428/4.830)^{0.44} = 1.5624 ft.</p>
Reach Width	<p>Since no Q7-10 reach velocity, depth and/or width were entered, the reach width is determined in accordance with the equation in Table 2.</p> <p>Width = d × w_d = (0.7055 × 45.8) = 32.33 ft.</p>		<p>Since no Qh reach velocity, depth, and/or width were entered, the reach width is determined in accordance with the Qh width equation in Table 2.</p> <p>Width = w_Q7-10 = 32.33 ft.</p>
Complete Mix Time	<p>Since no Q7-10 complete mix time was entered, the complete mix time is determined using equation 4.5.4b.</p> $cmt = \frac{0.28 \times (w \times (qs / (qs + qd)))^2}{0.6 \times d \times (\sqrt{32.2 \times d \times sl}) \times 60}$ $\frac{0.28 \times (32.33 \times (4.830 / (4.830 + 1.0829)))^2}{0.6 \times 0.7055 \times (\sqrt{32.2 \times 0.7055 \times 0.0113}) \times 60}$ <p>= 15.155 min.</p>		<p>Since no Qh complete mix time was entered, the complete mix time is determined using equation 4.5.4b.</p> $cmt = \frac{0.28 \times (w \times (qs / (qs + qd)))^2}{0.6 \times d \times (\sqrt{32.2 \times d \times sl}) \times 60}$ $\frac{0.28 \times (32.33 \times (29.428 / (29.428 + 1.082)))^2}{0.6 \times 1.5624 \times (\sqrt{32.2 \times 1.5624 \times 0.0113}) \times 60}$ <p>= 6.41 min.</p>
Partial Mixing Factor	Since no PMFs were entered, they are determined using Equation 4.5.4b.		
	AFC	CFC & THH	CRL
	$yc = \min \left[\sqrt{tc/cmt}, 1 \right]$ $= \min \left[\sqrt{15/15.51}, 1 \right]$ <p>= 0.994</p>	$yc = \min \left[\sqrt{tc/cmt}, 1 \right]$ $= \min \left[\sqrt{720/15.51}, 1 \right]$ <p>= 1.0</p>	$yc = \min \left[\sqrt{tc/cmt}, 1 \right] =$ $\min \left[\sqrt{720/6.41}, 1 \right]$ <p>= 1.0</p>

Variable	Q7-10 design conditions			Qh design conditions
Criteria	AFC	CFC	THH	CRL
Compliance Time	min [15, cmt] = min [15, 15.51] = 15 minutes	min [720, cmt] = min [720, 15.51] = 15.51 minutes	min [ttpws, 720, cmt] = min [720, 15.51] = 15.51.minutes ²	min [720, cmt] = min [720, 6.41] = 6.41 minutes
Design Hardness	<p>Since no stream hardness was entered, analysis hardness @ Q7-10 is determined using equation 4.8b. Note: a similar calculation is carried out for CFC, but is not shown here.</p> $x_c = \frac{((y_c \times q_s \times x_s) + (q_d \times x_d))}{((y_c \times q_s) + (q_d))} = \frac{((0.994 \times 4.830 \times 100) + (1.082 \times 100))}{((0.994 \times 4.830) + (1.082))} = 100 \text{ mg/L}$			<p>Although PENTOXSD carries out analysis hardness and pH calculations for Qh design conditions, the results are not used in the analysis and are not shown here.</p>
Design pH	<p>Since no stream pH was entered, analysis pH @ Q7-10 is determined using equation 4.8b. Note: a similar calculation is carried out for CFC, but is not shown here.</p> $x_c = \frac{((y_c \times q_s \times x_s) + (q_d \times x_d))}{((y_c \times q_s) + (q_d))} = \frac{((0.994 \times 4.830 \times 10^{-\log(7.0)}) + (1.082 \times 10^{-\log(7.0)}))}{((0.994 \times 4.830) + (1.082))} = 7.0$			<p>Although PENTOXSD carries out analysis hardness and pH calculations for Qh design conditions, the results are not used in the analysis and are not shown here.</p>

Parameter Calculations

Once all preliminary calculations are completed, parameter calculations are performed for each parameter selected by the user. Parameter calculations for cadmium are presented below, beginning with the determination of the applicable water quality criteria.

Strictly speaking, this determination is not actually calculation. Rather, the criteria are “looked-up” and retrieved from the water quality criteria database that is associated with PENTOXSD. However, FAL criteria for dissolved metals and for pentachlorophenol are hardness-based (dissolved metals) and pH-based (Pentachlorophenol) formulas. Therefore, the criteria determination is shown as a “calculation” below.

² In this example, no PWS has been entered

Variable	Criterion	Calculation
Water Quality Criterion	AFC	Dissolved criterion coefficients from WQC Database $[1.136672 - (\ln(xc) \times 0.041838) \times \exp^{(1.128 \times \ln(sc) - 3.6867)}] =$ $[1.136672 - (\ln(100) \times 0.041838) \times \exp^{(1.128 \times \ln(100) - 3.6867)}]$ $= 4.264 \text{ } \mu\text{g/L (dissolved)}$
	CFC	Dissolved criterion coefficients from WQC Database $[1.136672 - (\ln(xc) \times 0.041838) \times \exp^{(1.128 \times \ln(sc) - 3.6867)}] =$ $[1.136672 - (\ln(100) \times 0.041838) \times \exp^{(1.128 \times \ln(100) - 3.6867)}]$ $= 2.237 \text{ } \mu\text{g/L dissolved}$
	THH	There is no THH criterion for cadmium. Therefore the criterion = “NA”
	CRL	There is no CRL criterion for cadmium. Therefore the criterion = “NA”
Background Concentration	ALL	Calculated using equations 4.1a – 4.1f. Since no instream or tributary concentrations were entered, the background concentration for all conditions is zero.
Water Quality Objective	AFC	Since this is a dissolved metal, equation 4.2a is used. Since no chemical translator was entered, the default translator is used. The translator coefficients are from the WQC Database. $cx = \max [cc \times cm / chem_trans, cb] =$ $\max [4.264 * 1.0 / (1.136672 - (\ln(100) \times 0.041838), 0)$ $= 4.517 \text{ } \mu\text{g/L (total)}$
	CFC	Since this is a dissolved metal, equation 4.2a is used. Since no chemical translator was entered, the default translator is used. The translator coefficients are from the WQC Database. $cx = \max [cc \times cm / chem_trans, cb] =$ $\max [2.237 * 1.0 / (1.136672 - (\ln(100) \times 0.041838), 0)$ $= 2.462 \text{ } \mu\text{g/L (total)}$
	THH	Since there is no THH Criterion, the Water Quality Objective is “NA”

Variable	Criterion	Calculation
	CRL	Since there is no CRL Criterion, the Water Quality Objective is “NA”
Wasteload Allocation		$wla = \left(\frac{cx}{\exp[-k \times tc/1440]} + \frac{yc \times qs \times (cx - cb)}{qd \times \exp[-k \times tc/1440]} \right) \times (1 - fos)$ <p>Equation 4</p>
	AFC	$wla = \left(\frac{4.157}{\exp[-0 \times 15/1440]} + \frac{0.994 \times 4.830 \times (4.157 - 0.0)}{1.082 \times \exp[-0 \times 15/1440]} \right) \times (1 - 0)$ <p>= 24.562 µg/L (total)</p>
	CFC	$wla = \left(\frac{2.462}{\exp[-0 \times 720/1440]} + \frac{1.0 \times 4.830 \times (2.462 - 0)}{1.082 \times \exp[-0 \times 720/1440]} \right) \times (1 - 0)$ <p>= 13.443 µg/L (total)</p>
	THH	Since there is no THH Water Quality Objective, the WLA = “NA”
	CRL	Since there is no CRL Water Quality Objective, the WLA = “NA”
Long-Term Average	AFC	<p>Use equations 5.1a and 5.1b.</p> $LTA = wla \times \exp\left(0.5 \times \ln\left(cvh^2 + 1\right) - z \times \sqrt{\ln\left(cvn^2 + 1\right)}\right)$ $= 24.562 \times \exp\left(0.5 \times \ln\left(0.5^2 + 1\right) - 2.326 \times \sqrt{\ln\left(0.5^2 + 1\right)}\right)$ <p>= 9.161</p>
	CFC	<p>Use equations 5.1a and 5.1b.</p> $LTA = wla \times \exp\left(0.5 \times \ln\left(cvd^2/4 + 1\right) - z \times \sqrt{\ln\left(cvd^2/4 + 1\right)}\right)$ $= 13.443 \times \exp\left(0.5 \times \ln\left(0.5^{0.4}/4 + 1\right) - 2.326 \times \sqrt{\ln\left(0.5^2/4 + 1\right)}\right)$ <p>= 7.804</p>
Average Monthly Limit	AFC	<p>Use equations 5.2a and 5.2b.</p> $AML = LTA \times \exp\left(z \times \left(\sqrt{\ln\left(cvd^2/n + 1\right)}\right) - 0.5 \times \ln\left(cvd^2/n + 1\right)\right)$ $= 9.161 \times \exp\left(2.326 \times \left(\sqrt{\ln\left(0.5^2/4 + 1\right)}\right) - 0.5 \times \ln\left(4 + 1\right)\right)$ <p>= 15.757 µg/L (total)</p>

Variable	Criterion	Calculation
	CFC	<p>Use equations 5.2a and 5.2b.</p> $= 7.804 \times \exp\left(2.326 \times \left(\sqrt{\ln(0.5^2/4 + 1)}\right) - 0.5 \times \ln(4 + 1)\right)$ $= 13.443 \text{ } \mu\text{g/L (total)}$
	THH and CRL	<p>Use equations 5.2a and 5.2b.</p> $AML_{human} = wla \times AMLMULT$ <p>Since there is no human health-based WLA for this parameter, the AML = “NA”</p>
WQBEL		<p>Use Equation 5.3.</p> $WQBEL = \min[AML_{afc}, AML_{cfc}, AML_{thh}, AML_{crl}]$ $= 13.433 \text{ } \mu\text{g/L (total)}$
Final Effluent Limit		<p>Use Equation 5.4.</p> $FinalLimit = \min[WQBEL, cd] = \min[13.433, 1000] = 13.433 \text{ } \mu\text{g/L (total)}$
Maximum Daily Limit		<p>Use Equations 5.5.1 and 5.5.2a.</p> $MaxDaily = FinalLimit \times \frac{\exp\left[z \times \sqrt{\ln(cvd^2 + 1)} - 0.5 \times \ln(cvd^2 + 1)\right]}{\exp\left[z \times \sqrt{\ln(cvd^2/n + 1)} - 0.5 \times \ln(cvd^2/n + 1)\right]}$ $= 13.433 \times \frac{\exp\left[2.326 \times \sqrt{\ln(0.5^2 + 1)} - 0.5 \times \ln(0.5^2 + 1)\right]}{\exp\left[2.326 \times \sqrt{\ln(0.5^2/n + 1)} - 0.5 \times \ln(0.5^2/n + 1)\right]}$ $= 20.973 \text{ } \mu\text{g/L (total)}$

8 Appendix C

PENTOXSD for Windows (Version 2.0)

Supplemental Information

This document is intended to assist users in using the PENTOXSD for Windows software, which is the Pennsylvania Single-Discharge Wasteload Allocation Program for Toxics. Information in this document is guidance only. Basic concepts and terminology for the PENTOXSD model are reviewed in a PowerPoint file that should be on the CD.

MAIN MENU

The model gives you 5 choices after you start it up and reach the main menu:

- 1) Import a PENTOXSD for DOS File - PENTOXSD for DOS (Revision 1.30) was the DOS-based version of this model. PENTOXSD for Windows is backward compatible with PENTOXSD for DOS, and the DOS datasets may be imported into PENTOXSD for Windows using this control button. Any PENTOXSD for DOS dataset consists of 4 files with the following extensions: PTX, _TD, _TQ, _TR. All four files are required to make a complete PENTOXSD for DOS dataset, but the model will prompt you only for the file name and path of the PTX file. The other three files must be in the same path as the PTX file. After you import a PENTOXSD for DOS dataset, the PENTOXSD for Windows input data forms will display and be populated with the data from the DOS dataset. You may edit these data. Next, hit "Finish" to complete the process of importing the data to PENTOXSD for Windows. These data may now be selected as a WAT_QUAL record (see below). NOTE: In some cases, PENTOXSD for Windows may not import all the parameters from the DOS files. For example, Total PCBs would not be imported since PENTOXSD for Windows requires that you input the specific PCB chemicals, which the model will then summarize in a PCB, Total criterion.
- 2) Retrieve a Temporary (*.ptw) File - Normally, all input data on dischargers, stream reaches, hydrodynamics and parameters would be saved in MS Access tables within the model, but sometimes you may not want to do this. The model allows you to export input data for a project to an external dataset in ASCII format, and this button allows you to retrieve (load) this external dataset back into the model. Any external dataset consists of three files with the following extensions: PTW, TDW, TQW. All three files are required to make a complete PENTOXSD external dataset, but the model will prompt you only for the file name and path of the PTW file. The other two files must be in the same path as the PTW file.
- 3) Select WAT_QUAL Records - Data on dischargers, stream reaches, hydrodynamics and parameters is stored in Microsoft Access tables (WAT_QUAL) that are linked to the model. This is the main method by which input data are saved in the model. If you are beginning a new analysis from scratch, hit this button to initiate the analysis. If you want to access an analysis that has already been performed on the stream code that you are interested in, and if this work has been saved to the WAT_QUAL that you are linked to (depending on whether you have a DEP network installation or a standalone installation), then this control button will allow you to load those input data for the stream code. After you hit this button, the model will prompt you for a stream code. Every sizeable stream in Pennsylvania has a basin number and a stream code – see the discussion below under General Input Data. You may either enter your stream code directly or hit the drop-down

arrow to see a list of stream codes that already have data stored in WAT_QUAL. If any data exists for that stream code, they will be displayed as RMIs (River Mile Indexes – see below), and you may select your upstream RMI and downstream RMI, representing the bounds of the analysis. The drop-down list of stream codes available will only show those stream codes created by you or others that are in your DEP region.

If there are no data for your stream code, you need to enter your stream code directly. The model will then prompt you to create new records for that stream code by asking for your RMIs. The control button labeled with a Binoculars graphic allows you to look up the stream code of a stream by basin number and stream name. This feature is useful for named streams, but not for unnamed tributaries.

- 4) Retrieve Archived Results - The model allows you to archive (save) the results of an analysis to WAT_QUAL, and you use this button to retrieve (load) those results back into the model. After you hit this button, the model will prompt you for a stream code, and display a pull-down menu of all previously archived results, if any, for that stream code. You may not edit these data, as they have been archived as a permanent record of official DEP work -- when an archived record is retrieved, it may only be viewed. The reason you may want to archive data is to save the results of an analysis in one location that may not be edited or deleted, while different or additional analyses may be performed on the same discharger or stream segment. Unless you are interested in viewing a record of previous work, use the “Select WAT_QUAL Records” control button to initiate or continue work on a discharger or stream code.
- 5) Exit PENTOXSD for Windows - Hit this control button to exit the model to the desktop.

INPUT DATA

General Input Data

General Information: Each record defines a **stream node**, which is a point on the river or stream defined by an RMI (river mile index). Two nodes make up the top and bottom of a **stream reach**. At least one stream reach (two nodes) is required for any PENTOXSD analysis.

Stream Code - Stream code is a required input. Every stream in Pennsylvania has a stream code associated with it. Stream codes are most easily obtained from the *Pennsylvania Gazetteer of Streams* (3900-BK-DEP2929) or from GIS software. The model requires the user to select the stream code before entering the input data form. Once entered, the Stream Code may not be edited – the record must be deleted and reentered if the stream code is wrong. To select a different stream code, exit to the main menu dialog box and enter a new stream code or select a different WAT_QUAL record. NOTE: You should find copies of the *Pennsylvania Gazetteer of Streams* and the DEP Stream File on the PENTOXSD CD.

RMI (River Mile Index) - RMI is a required input for each node. RMIs typically start at 0.0 at the mouth of each stream, and proceed upstream to the source of the stream. RMIs typically are set at points of interest (such as a discharger or where a tributary joins the stream) or hydrodynamic change (sudden change in slope, width, depth, etc.). The model requires the user to input or select the RMI before you enter the input data form, and the model will not let the user change it directly. To change the RMI, delete the node (record) and then add a node with the desired RMI (all data associated with the deleted node will be lost). Typically, the user will need to determine the RMI of the point where the discharge flow enters the receiving water. This RMI will define the top of the reach to be modeled. The downstream node may be set to any other downstream RMI where the user knows or can measure the elevation and drainage area. Generally, the model will use only the flow, drainage area and elevation data from the discharge node to the next downstream node when calculating important hydrodynamic parameters. RMIs may be measured using GIS (Geographic Information System) software, a map wheel or dividers. RMIs should not be set to very small or very precise values – round off RMIs to the nearest 0.01 river mile. Unlike previous versions of this model, an RMI of zero (0.0) will be accepted by the model, and can be used to describe the mouth of the stream. Nodes may be added or deleted from the analysis readily. The user should distinguish between nodes that have been created and saved in the WAT_QUAL database, and the nodes that are currently loaded in the model for analysis. The user may delete a node from the analysis, but it will still be available in the WAT_QUAL database for the next analysis. The user may also delete the node from the analysis and the WAT_QUAL database if desired.

Elevation - Elevation is a required input for each node, and is expressed in feet above mean sea level. Any positive value is a valid input. Note that elevations typically decrease as you travel downstream. If you enter an elevation at a downstream node that is higher than one at an upstream node, the model will accept it but then will generate an error when you try to perform an analysis. An accurate input for elevation at each node is important, because the model normally will calculate the slope of the stream channel based on the elevation that you input. Stream channel slope will have a direct effect on the mixing calculations and the recommended effluent limits that are output. The slope calculated based on elevation inputs can be overridden by directly inputting the channel slope on this General Input Data form, but even if you input the slope of the channel as an override, the model will still require that you input the elevation. The elevation of a stream node may be determined using a topographic map or GIS software.

Drainage Area - Drainage Area is a required input for each node, and is expressed in square miles. Each point in a stream has an associated drainage area – the geographical area that drains to (is uphill of) that point in the stream. Any positive value is a valid input. Note that drainage areas typically increase as you travel downstream, so each succeeding downstream node should have a higher drainage area than the node above. An accurate input for Drainage Area at each node is important, because the model may use your input of drainage area to estimate the stream flow at low-flow (Q7-10) and normal flow (Qh) conditions. It is important that the model get the best estimate of the stream flows under these conditions as you can manage, because stream flow is important in determining effluent limits. The Q7-10 and Qh flows that the model calculates based on drainage area inputs may be overridden by directly entering the stream flow or the tributary flow in the “Stream” data input form. But the model will still require that you input the drainage area for each stream node, because even though the model will allow you to override the calculation of stream flow, the drainage area values normally will still be used to configure the stream channel and satisfy continuity (i.e., width, depth, velocity). This process can affect the wasteload allocation results. The drainage area of a stream node may be determined using a topographic map and planimeter, or GIS software.

Slope - Slope is an optional input. Slope is the slope of the stream channel expressed in feet of vertical descent per foot of horizontal travel downstream. The model will accept any positive value, but slopes typically are numbers in the range 0.01 to 0.0001. The default value is 0, which tells the model to calculate the slope for each reach based on the elevations that you entered for each node. If you enter the slope directly, the model will use this slope instead of the calculated value. Note that, while RMI, elevation and drainage area refer to conditions at the upstream node of a reach, the slope refers to the stream channel slope along the length of the reach until the next downstream node.

PWS Withdrawal (Potable Water Supply Withdrawal) - PWS Withdrawal is an optional input expressed in units of millions of gallons per day (mgd). PWS Withdrawal refers to a point on the stream where water is withdrawn for human consumption. Any positive value is a valid input. When you enter a positive value for PWS Withdrawal at a node, you are saying that potable water is removed from the stream at that RMI, and the model will balance the stream flow to account for the consumptive water use. PWS Withdrawal must be entered at a node downstream of the node containing the discharge – otherwise it will have no effect. If a downstream PWS exists within 12 hours travel time (at Q7-10), it should always be entered into the analysis.

The model treats THH criteria differently when a downstream PWS is entered. THH criteria will be evaluated at the first downstream PWS, the point at which CMT occurs, or 12 hours, whichever occurs first. If the PWS occurs first, the travel time between the discharge and the PWS becomes the CCT, and the PMF will be calculated based on this CCT (for THH criteria only). The model will use the stream flow at the discharge node as the flow available for mixing. Under some conditions, it may be appropriate to override this default method for determining the PMF. For example, if the PWS intake is on the opposite bank from the discharge, and the CMT is downstream of the PWS, the user should consider forcing complete mix at the PWS (for THH criteria only). To accomplish this, the user could set the THH PMF to 1 to force complete mixing at the point of discharge, or run the parameters with THH criteria in a separate analysis and set the CMT for Q7-10 or Qh equal to the travel time to the PWS. The results would then be compared to those produced by leaving that PWS out of the analysis, in case normal mixing or another downstream PWS is the limiting condition. On a large river with the PWS intake located on the opposite bank from and just downstream of the discharger, it may be obvious that the discharge plume could not impinge upon the intake. In this case, the user may justify leaving the PWS out of the analysis altogether. The presence of a PWS has no effect on AFC, CFC or CRL criteria.

Another purpose of this input field is to allow for the evaluation of certain water quality criteria that appear in Title 25 §96.3 (d), with numeric criteria listed in §93.7 Table 3. These are fluoride, phenolics, total dissolved solids (TDS), nitrite plus nitrate (NO₂-NO₃), sulfate and chloride. These water quality criteria for these six parameters are evaluated only at PWS withdrawal points. The water quality criteria for all other parameters apply anywhere in the river or stream, based on the computed CCT. If your discharge flow contains any of these six parameters in concentrations exceeding the associated water quality criteria, the user should determine where the nearest downstream PWS withdrawal is and create a downstream node at that point. PENTOXSD will then be able to evaluate the concentration of the pollutant at the PWS withdrawal and recommend effluent limits accordingly. Note that almost any discharge will contain TDS, and you should consider adding TDS to your analysis only if the concentration in the discharge exceeds the §93.7 limit of 500,000 µg/L for TDS. For these six parameters only, the model will use the stream flow minus the PWS flow to determine the net stream flow available for mixing (complete mixing between the discharge flow and the net stream flow will be forced).

PENTOXSD will always look at all downstream nodes included in an analysis for the presence of a PWS. This is an exception to the general rule that the model usually is only concerned with the first reach downstream of the discharge.

Apply FC? (Apply Fish Criteria?) - This is an on/off switch that allows you to turn off aquatic life criteria, AFC and CFC, for a stream reach. The default value is checked (aquatic life criteria do apply). If you clear this checkbox, you are telling the model it is OK to exceed aquatic life criteria in that reach. The model will then calculate AFC and CFC WLAs based on the first downstream node in which aquatic life criteria do apply. The model sets PMF to 1 for AFC and CFC at the first downstream node in which aquatic life criteria do apply. The model will use the stream flow from the first downstream node rather than the stream flow at the discharge when calculating AFC and CFC WLAs. NOTE: There is a bug in the PENTOXSD for DOS model that, under some conditions, would set the AFC/CFC WLA equal to the AFC/CFC water quality objective at the downstream node when aquatic life criteria were waived. This bug has been corrected in the Windows version.

You need a firm basis to turn off water quality criteria for a stream segment, and most likely this will involve Title 25 §95.5. This section provides for stream segments that are so impacted by acid mine drainage that aquatic life essentially is excluded from that stream segment. DEP Water Quality Assessment staff would need to concur with any determination to disregard water quality criteria in a stream segment.

Stream Input Data

General Information: These data describe the hydrodynamic characteristics of the stream at two flow conditions Q7-10 (7-day, 10-year flow, which represents low flow conditions), and Qh (harmonic mean flow, which represents normal flow conditions). The model needs to calculate how much stream flow is available for mixing with the discharge flow, and then how much of the available stream flow does mix with the discharge flow at the point where the various water quality criteria are evaluated. **All of the inputs in the Q7-10 and Qh Stream Input Data forms are optional.** If you don't enter anything in these forms, the model will use or calculate default values based on the RMI, drainage area and elevation data that you have entered. But if you do have data on the measured or previously established Q7-10, Qh, or any of the channel characteristics (width, depth, velocity, etc.) you should enter them in this form. Since mixing and dilution are the primary processes that affect the WLA process in PENTOXSD, it is important to assure that you have a good estimate of the Q7-10 flow, especially. The

default Low Flow Yield value of 0.1 cfs/sq mi should be used only as a last resort. Be careful that the data that you enter is representative of the applicable flow condition. You don't want to enter the depth of the stream channel that was measured under normal stream flow conditions as the Q7-10 depth.

PENTOXSD for Windows will first estimate the flow, velocity, stream width and stream depth at Q7-10, and then estimate the flow, velocity, stream width and stream depth at Qh based on the Q7-10 values. You may override any of these values based on known data, and the model will make everything else fit. For example, if you enter the Q7-10 flow or the LFY as a known value, you will affect the determination of all the other hydrodynamic characteristics at both Q7-10 and Qh, and you will affect all recommended effluent limits produced by the model. If you enter the Qh flow as a known value, you will affect only the other Qh hydrodynamic characteristics, and you will affect only recommended effluent limits based on CRL as the governing criteria.

Acute Fish Criteria (AFC), Chronic Fish Criteria (CFC) and Threshold Human Health (THH) criteria are evaluated at Q7-10. Cancer Risk Level (CRL) is evaluated at Qh. Refer to the *Technical Reference Guide for PENTOXSD Windows*, DEP ID: 391-2000-011, available on DEP's website, for details on how water quality criteria are evaluated.

RMI (River Mile Index) - This field is carried forward from the General Input Data and cannot be edited in this form (see discussion of RMI in General Input Data).

LFY (Low Flow Yield) - Low Flow Yield is the amount of river flow per square mile of drainage area that the model will use to estimate the Q7-10 in the absence of any other flow inputs. It is expressed in cubic feet per second per square mile (cfs/sq mile), and the default value is 0.1. LFY is an input for Q7-10 only, since it only applies to low stream flow conditions as represented by Q7-10. The recommended effluent limits that the model produces are sensitive to Q7-10, so it is important to enter a site-specific LFY if available for your stream or river. Any value entered for Tributary Flow or Stream Flow (see below) will override the calculation of Q7-10 based on LFY at that stream node. Any time the model encounters a node where the user has not entered Stream Flow or Tributary Flow, it will automatically add flow to the stream based on the increase in drainage area between the upstream node and the downstream node.

Tributary Flow - Tributary Flow is the incremental amount of flow in cubic feet per second (cfs) that is known to enter the stream at a stream node. It may be entered for Q7-10, Qh, or both. The typical use of this field allows you to provide for a tributary adding flow at a certain point in the stream, and you want to account for this additional stream flow. The value that you enter for Tributary Flow will be added to the flow that would have been present otherwise (from upstream reaches or dischargers). However, PENTOXSD uses the flow at the point of discharge when calculating CCT and PMF, so adding additional flows or concentrations downstream of the stream node containing the discharge normally does not affect these calculations. The main application of Tributary Flow field is upstream of the node containing the discharge. The model allows you to input upstream flows and concentrations from the main stem and any tributaries, and the model will sum these on a flow-weighted basis to determine flow and concentration in the stream immediately upstream of the discharge.

Stream Flow - Stream Flow is the absolute amount of stream flow in cubic feet per second (cfs) that is known to exist at a stream node. If you make an entry in this field, the model will ignore all other sources of flow (such as Tributary Flow or LFY), and the stream flow will be set to your input value for that reach. Note, however, that discharge flow is considered separately and is not included in stream flow. Stream Flow and Tributary Flow represent different ways of quantifying the Q7-10 or Qh, and

you would not normally enter both values for a given stream node. For the first stream node in an analysis (the upstream node), entering a value as Stream Flow is equivalent to entering it as Tributary Flow. Typically, the user would input Stream Flow at the upstream node of the analysis if there is no need to sum tributary flows.

Width/Depth Ratio, Reach Width (feet), Reach Depth (feet), Reach Velocity (feet per second), Reach Travel Time (days) - Input values of stream width, depth, velocity and travel time define conditions along the entire length of the reach. For example, if you input a width of 100 feet and a depth of 2 feet, the model considers the stream channel to be a rectangular section with those dimensions between the upstream node and the downstream node. It will calculate what the velocity and travel time would have to be based on the flow that has been input or calculated, and these values will apply along the length of the reach. At the end of the reach, the model will reset the section of the stream channel based on the data input for the downstream node. If there are no width, depth, velocity or travel time data input for the downstream node, the model will revert to default calculations for these characteristics, and these values will apply for the length of the downstream reach (stream flow, however, is modeled continuously from reach to reach and is not reset to default values between reaches). Be careful that the data that you enter is representative of the applicable flow condition. You don't want to enter the depth of the stream channel that was measured under normal stream flow conditions as the Q7-10 depth. Also, recognize that you are entering the average value for these characteristics assuming a rectangular cross-section of the stream. You don't want to enter the maximum depth at the center of the stream channel as the average depth.

Tributary Hardness (mg/L)/ Tributary pH - These fields allow you to override the default hardness of 100 mg/L and pH of 7. The model will consider these values as representative of natural background conditions, and will set the hardness and pH of any additive flow into the analysis to these values. Various tributary flows may be mixed together upstream or downstream of the discharge to produce a resultant hardness and pH representative of background conditions. The model will then calculate the resultant instream hardness and pH (Analysis Hardness/pH) after mixing with the discharge hardness and pH on a flow-weighted basis. Any entry in the Stream Hardness/pH or Analysis Hardness/pH input data fields would override this flow-weighted calculation of hardness and pH.

Stream Hardness (mg/L)/ Stream pH - Similar to the way tributary and stream flow may be entered as either additive or absolute values, background hardness and pH may be handled the same way. Values entered into these fields will be considered the absolute value of all stream flow at that node, regardless of any upstream values or mixing based on Tributary Hardness/pH values. The model will still consider mixing between the Discharge Hardness/pH and the Stream Hardness/pH in determining the Analysis Hardness/pH. Any entry in the Analysis Hardness/pH input data fields would override this flow-weighted calculation of hardness and pH.

Analysis Hardness (mg/L)/ Analysis pH - These fields allow you to override the default mixing calculation of the Analysis Hardness/pH, which are the values used to determine hardness and pH-dependent water quality criteria. Normally, the model will consider mixing between the Discharge Hardness/pH and the Tributary (or Stream) Hardness/pH in determining the Analysis Hardness/pH. But when you enter data in these fields, you are forcing the instream (Analysis) hardness and pH to these values for the entire reach. Analysis hardness and pH is important for certain parameters whose toxicity varies with hardness or pH (most toxic heavy metals and pentachlorophenol). Note that it is the Analysis Hardness/pH values at the discharge node that determine the values that will be used to calculate the toxicity and water quality criterion that will apply for that discharge and parameter. Entries

of different hardness/pH values in nodes downstream of the discharge will have no effect under most conditions.

Discharge and Parameter Input Data

Discharge Input Data

RMI (River Mile Index) - This field is carried forward from the General Input Data and cannot be edited in this form (see discussion of RMI in General Input Data).

Name - This is the name of the discharger, industry, sewage treatment plant or site that is the source of the pollutants. It is a required input. Any alphanumeric characters may be input, up to the field limit of 15 characters. Make sure that you input the discharger at the correct node RMI, and that there is at least one node downstream of the node where the discharge is located. Otherwise, the model will run fine but will produce no results for recommended effluent limits.

Permit Number - The NPDES permit number should be entered in this field, in the format PA1234567 (PA followed by seven numeric characters). Please ensure that you follow this format, including any zeros needed after “PA” to form seven numeric characters. This field, however, will accept any combination of alphanumeric characters up to the field limit of 15 characters. **It is critical that any entry in this field represent a unique identifier for the site you are analyzing!** If you attempt to enter the exact same alphanumeric characters as has been previously entered, the program will generate an error, because the same permit number cannot exist in two different places. This can cause problems if, for instance, the user tries to use “None” more than once in evaluating Act 2 scenarios.

Existing Discharge Flow, Permitted Discharge Flow, Design Discharge Flow - These fields allow you to enter the flow rate of the discharge (source of the pollution) in millions of gallons per day (mgd). All default values for these fields are 0, but if you don’t enter a positive value in at least one of these three fields, the model will not recommend effluent limits. The model uses only one discharge flow rate to calculate recommended effluent limits, and it will use any flow rate that you enter into any of these three fields. If you enter a flow rate into more than one of these three fields, it will choose one flow in this order of preference: Design Discharge Flow, Permitted Discharge Flow, Existing Discharge Flow. The only other difference between these three discharge flows involves the Reserve Factor (see below).

Reserve Factor - The Reserve Factor is intended to provide for anticipated future growth in the discharge flow of the discharger being evaluated. The default value is 0. Positive values expressed as decimal fractions are valid inputs. Positive reserve factors artificially increase the discharge flow, which lowers recommended effluent limits. A Reserve Factor of 0.10 will increase whatever discharge flow has been input by 10 percent, and reduce recommended effluent limits against all water quality criteria by some amount. Note that the Reserve Factor will not be applied if the Design Discharge Flow is entered, as the source is already considered to be at its maximum flow rate. It will only be applied if the Existing or Permitted Discharge Flow is entered, and the Design Discharge Flow remains at its default value of 0.

Partial Mix Factors (AFC, CFC, THH, CRL, PMFs) - The partial mix factor tells you how much of the stream has mixed with the discharge flow at the CCT, which is the point at which compliance with water quality criteria is evaluated. A higher PMF means that there has been more dilution of the discharge flow, which will result in higher recommended effluent concentrations. An input to any of these fields overrides the normal mixing calculations and forces the partial mix factor to the input value for the applicable water quality criterion. These input values should be used with caution. Any input to

these fields forces the PMF for those criteria to the input value at the point of discharge. The PMF remains at the input value for the entire simulation – no further downstream mixing is calculated. For instance, entering a THH PMF of 1 will force complete mixing at the point of discharge for THH criteria only. This renders any reported values of CCT and CMT for THH criteria irrelevant (since the only purpose of these values is to calculate the PMF). AFC, CFC and CRL calculations would be unaffected.

Generally, it is best to let the model determine the appropriate PMF, and you should override these values only if site-specific data exist or you want to perform “what-if” calculations. The default value for each PMF is 0, which means the model will calculate the appropriate PMF. Only positive decimal values between 0 and 1 should be entered. A PMF of 1 means complete mix of the discharge and stream, and 0.01 means that the discharge has mixed with only 1 percent of the stream. For all water quality criteria, recommended effluent limits are sensitive to changes in PMF. If the governing criterion is CRL or THH, there is a direct linear relationship between PMF and recommended effluent limits (i.e., doubling the PMF results in doubling of the recommended effluent limits). If the governing criterion is AFC or CFC, increasing the PMF normally results in a lesser increase in effluent limits.

The model always assumes complete mix at the PWS for the six special PWS parameters (phenolics, fluoride, NO₂-NO₃, and TDS, sulfate and chloride), and any PMF input value will not override this.

Discharge Hardness (mg/L)/ Discharge pH - These fields contain the hardness/pH of the discharge flow. Normally, the model will consider mixing between the Discharge Hardness/pH, and the Tributary (or Stream) Hardness/pH in determining the Analysis Hardness/pH. This calculation may be overridden by entering the Analysis Hardness/pH directly (see previous discussion). Analysis hardness and pH is important for certain parameters whose toxicity varies with hardness or pH (most toxic heavy metals, and pentachlorophenol).

Parameter Input Data

General Information: For this section, you access a drop-down menu and select one or more parameters for analysis. If the parameter is not listed, then PENTOXSD is not able to evaluate it and recommend an effluent limit. Three situations may apply:

- 1) Your parameter is on the drop-down menu, so you select it for analysis.
- 2) Your parameter is not on the drop-down menu, or is in brackets. In this case, you should contact the Water Quality Standards and Implementation Section in Harrisburg to determine if a criterion should be applied or if the parameter may be discharged in any concentration.
- 3) Your parameter is not on the drop-down menu, or is in brackets, but you have good reason to think that it should be listed in PENTOXSD. Maybe you have a new parameter or a basin-specific parameter. In this case, you can use the option to add a user-defined parameter to PENTOXSD. This option is available when the main menu is displayed – select the “Water Quality” option from the “Tools” pull-down menu. One or more water quality criteria may be added along with associated AFC, CFC, THH or CRL criteria. The user must be familiar with the details of how the model handles the different criteria in order to make an appropriate selection. Refer to the PENTOXSD Technical Reference Guide. Note that, if you export a file containing a user-defined parameter, and another user loads it on a PC that does not have the new parameter defined, the analysis will not

be able to produce results for the user-defined parameter until the second user adds the parameter and the associated water quality criteria to his or her database.

The model lets you select parameters to associate with the discharge and then will ask you which of these parameters you want to analyze. Separating the parameters this way allows you to restrict the analysis calculations and report output to whichever parameters you select.

The parameters listed in the model mostly are from Title 25 §93.7 and Chapter 16. However, a few additional parameters have been included based on requests from DEP regions, or to be consistent with other regulatory criteria. Within Chapter 16, the Great Lakes (GLI) criteria from §16.61 are integrated into the model, and will be applied in preference to statewide criteria whenever stream codes in basins 14 or 15 are selected. If you select a stream code in basin 14 or 15, and you select a parameter for which both GLI and statewide criteria exist, the GLI criteria will be applied. If you select a stream code in basin 14 or 15, and you select a parameter for which only statewide criteria exist, the statewide criteria will be applied. If you select a stream code not in basin 14 or 15, and you select a parameter for which both GLI and statewide criteria exist, the statewide criteria will be applied. If you select a stream code not in basin 14 or 15, and you select a parameter for which only GLI criteria exist, the GLI criteria will be applied (in this case, any recommended effluent limits are only guidance).

If you select any of the special PWS parameters (fluoride, phenolics, NO₂-NO₃, TDS, sulfate or chloride), you need to input a PWS Withdrawal at some downstream node. Otherwise, the model has no basis to evaluate the parameter and will report the Discharge Concentration as the recommended effluent limit. These parameters are handled differently than other parameters in PENTOXSD because Title 25 §93.7 stipulates that the water quality criteria for these parameters apply only at PWS intakes.

Osmotic Pressure is handled differently than any other parameter in PENTOXSD. The correct units of Osmotic Pressure are milliosmoles per kilogram (mOs/kg), so for this parameter all of the fields labeled as µg/L in PENTOXSD will be incorrect. The user should input the discharge concentration for Osmotic Pressure in mOs/kg, and interpret the recommended permit limits in the same units. The model handles Osmotic Pressure and Total Iron as CFC-governed parameters. However, for these two parameters only, the effluent limits are set equal to the WLA (any statistical adjustments that might normally be made to a CFC-governed parameter, based on the number of samples, are not applied).

Selecting some parameters will trigger a summary parameter to become active. For instance, if you select 2,4 Dinitrotoluene as a parameter, the model will automatically produce recommended effluent limits for both 2,4 Dinitrotoluene and Total Dinitrotoluene. The model will consider any other isomers of dinitrotoluene that you input in producing a recommended limit for Total Dinitrotoluene. Note that it would not be unusual for the model to produce a lower limit for Total Dinitrotoluene than for any one isomer of dinitrotoluene. In this case, the recommended effluent limit for Total Dinitrotoluene would be the controlling limit for the permit.

Discharge Concentration - Discharge Concentration is a required input in µg/L. Any positive value is a valid input. This value is designed to allow you to set an upper limit on the recommended average monthly effluent limit that the model will produce. Before the model recommends an effluent limit for a parameter, it will compare the water quality-based effluent limit that it has just calculated (based on flow and mixing) to whatever value has been entered in this field. The model will recommend the minimum of these two values as the average monthly effluent limit for this parameter. Typically, you would enter the effluent limit in the current permit as Discharge Concentration unless you intend to allow this limit to increase. Or if there is no effluent limit in the current permit, but a technology-based limit applies,

enter the technology-based limit in this field. If you want to allow the model to recommend a water quality-based limit with no constraints, enter a large number in this field. If no positive value is entered in this field for a parameter, the model will not recommend an effluent limit for that parameter.

The ideal situation is if the discharger has provided actual discharge data so that the actual monthly average and CV of a given parameter is known. Discharge Concentration may be used in combination with the Discharge CV field to generate the lowest effluent limit that the discharger can still meet.

NOTE: You do not enter the known average value as Discharge Concentration, because then the model would produce an unnecessarily restrictive permit limit that the discharger cannot meet consistently. Instead, the average concentration must be converted to the 99th percentile value before entering it as the Discharge Concentration.

Tributary Concentration - This is an optional input expressed in $\mu\text{g/L}$. The Tributary Concentration is one way to express the background concentration, and the other way is to input a value for Background at Discharge (see below). Tributary Concentration provides a mechanism to enter incremental flow/concentration inputs that the model will balance to determine the flow-weighted background concentration at the discharge node. The default Tributary Concentration is 0. Only positive values should be input. This value is subject to decay if a Fate Coefficient is entered. If a positive value is input for Tributary Concentration, recommended effluent limits will decrease as compared to a Tributary Concentration of 0. For the first stream node in an analysis (the upstream node), entering a value as Tributary Concentration is equivalent to entering it as Stream Concentration. Note that it is the Tributary Concentration (or Stream Concentration) at the discharge node that determines the values that will be used to calculate the recommended effluent limit. Entering Tributary Concentration values in nodes downstream of the discharge normally will have no effect.

Discharge Daily CV/Discharge Hourly CV - This is the coefficient of variation of the concentration of a given parameter in the discharge flow. These data normally would be available only if the discharger has provided them. If known, the site-specific CV for each parameter should always be used, because it will allow the model to recommend a more accurate limit for that parameter. Otherwise, the default value is 0.5. Mathematically, changing the discharge CV will affect recommended (average monthly) effluent limits only if the governing criterion is AFC or CFC. Usually, a noticeable effect on recommended effluent limits occurs only when the governing criterion is AFC. For AFC-governed parameters, recommended effluent limits are very sensitive to changes in discharge CV. When the Discharge Daily CV is reduced below the default 0.5, the recommended effluent limit for AFC-governed parameters will decrease. When the Discharge Hourly CV is reduced below the default 0.5, the recommended effluent limit for AFC-governed parameters will increase. NOTE: Changing the Discharge Daily CV will affect the recommended daily maximum effluent limits for all parameters, even when it has no effect on the recommended (average monthly) effluent limit. NOTE: Changing the Discharge Daily CV or the Discharge Hourly CV from the default value may change the governing criterion, so these CVs should always be used if available. NOTE: PENTOXSD cannot handle a CV of zero. If you enter a Discharge Daily CV or a Discharge Hourly CV of zero, the model will automatically reset it to 0.5. If you want to minimize the CV, enter a very small number such as 0.01.

Stream Concentration - This is the background concentration of a given parameter in the stream in $\mu\text{g/L}$ at the upstream node. These data normally are not available unless instream sampling has been performed previously. The default Stream Concentration is zero. Only positive values should be input. The value input as Stream Concentration will override any background concentration that is calculated by the model based on mass balancing the tributary concentrations. The Stream Concentration value will be modeled as a steady-state background concentration unless a Stream CV also is entered. This Stream

Concentration value is subject to decay if a Fate Coefficient is entered. If a positive value is input for Stream Concentration, recommended effluent limits typically will decrease as compared to a Stream Concentration of zero.

Stream CV - This is the coefficient of variation of the stream concentration of a given parameter in the stream at the upstream node, before any mixing between the stream and the discharge. The default Stream CV is 0. Only positive values should be input. If a value > 0 is input, and assuming that some positive Stream Concentration for that parameter has been entered (either through the Stream Concentration field or the Tributary Concentration field), recommended effluent limits based on a governing criterion of AFC or CFC may decrease as compared to a Stream CV of 0. The Stream CV value will have no effect on recommended effluent limits based on a governing criterion of THH or CRL.

Fate Coefficient - This is an optional input, expressed in units of day^{-1} , with a default value of 0. In the model, the Fate Coefficient provides for first-order decay of a parameter in the stream. Positive fate coefficients will result in increased recommended effluent limits because the parameter is decayed (reduced in concentration) in the stream before it reaches the CCT. Fate coefficients should not be entered unless the parameter is subject to natural degradation or volatilization within the time frame defined by the CCT for the applicable criterion (a maximum of 12 hours). A site-specific study or published studies may provide a basis to enter a decay coefficient for a given parameter. NOTE: Fate coefficients may not be applied against special PWS parameters (fluoride, phenolics, $\text{NO}_2\text{-NO}_3$, TDS, sulfate or chloride).

FOS (Factor of Safety) - This is an optional input expressed as a decimal fraction, with a default value of 0. This factor provides a mechanism to guard against uncertainties in the input data for the discharge being evaluated. If you input 0.10 as an FOS, the water quality-based effluent level calculated by the model will be ten percent lower than it would have been with the default FOS of 0. The FOS will reduce the calculated water quality-based effluent limit for any governing criterion. This reduced water quality-based effluent limit may still be superseded by a lower effluent limit, if an entry in the Discharge Concentration field supports a lower recommended effluent limit.

Criteria Modifier - This is an optional input expressed as a decimal fraction, with a default value of 1. This factor provides a mechanism to increase or decrease the AFC or CFC criteria for a given parameter based on site-specific data or studies. The Criteria Modifier field will only modify AFC or CFC criteria -- the model will not allow you to modify THH or CRL criteria. If you enter 2 as the Criteria Modifier, the normal AFC and CFC criteria will be doubled, and the water quality-based effluent limits calculated for that parameter will increase by some proportion. There are two primary ways to justify a change in AFC or CFC criteria. The first way involves a recalculation of the original EPA basis for the criterion, based on changes to the data used to produce the criterion. For example, if trout are not viable in the stream, you might delete the portion of the data based on trout studies and then recalculate the criterion based on a subset of the original data. The second way involves a Water Effects Ratio (WER) study, which is a biological study of the toxicity of the effluent to designated species. In a WER, you are trying to show that the toxicity of a parameter in your effluent differs from the toxicity demonstrated under the conditions used to produce the criterion. For example, you might show that the copper in your effluent may not be as toxic as it usually is because it is being bound up somehow. WER studies usually involve toxic metals, but the model will allow you to apply this field to any parameter.

Chemical Translator - This is an optional input expressed as a decimal fraction less than one, with a default value of “NA.” This factor provides a mechanism to modify the calculations used to determine the wasteload allocation for a toxic metal. This may be justified if a laboratory study of the effluent indicates that the dissolved portion of the total recoverable metal is different than the default values in the model (which are from Title 25 §16.24). The dissolved portion of the metal generally is the portion that is available and toxic to fish and aquatic life, so if there is a lower dissolved portion than that used by the model, toxicity should be reduced. For example, the model uses 0.960 as the proportion of dissolved metal to total recoverable metal for copper for both AFC and CFC. If site-specific studies determined that 0.800 of the metal exists in the dissolved phase instead of 0.960, you would enter 0.800 as the Chemical Translator. In this case, this would result in a 20 percent increase (.960/.800 is 1.2, which represents a 20 percent increase over default values) in the recommended effluent limit for copper. The Chemical Translator field will only affect AFC and CFC-based calculations for the metals listed in Title 25 §16.24. The default value of “NA” means that the model will use the Chemical Translator values listed in Title 25 §16.24.

Maximum Discharge Concentration - This is an optional input in µg/L. Any positive value is a valid input. This value is designed to allow you to set an upper limit on the recommended maximum daily effluent limit that the model will produce. The default value of 0 signifies that no limit is set. The model generates the recommended maximum daily effluent limit based on a statistical conversion of the recommended average monthly effluent limit. The Discharge Daily CV normally drives the magnitude of this conversion, but this field allows you to override that conversion. The user should ensure that any value input as Maximum Discharge Concentration is greater than the recommended average monthly effluent limit produced by the model.

Discharge Mixing Data

Complete Mix Times (CMT) - These fields allow you to override the calculated CMT for Q7-10 or Qh conditions with an input value. This value is expressed in minutes, and defines the time at which the discharge has completely mixed with the stream. Normally, you would need the results of a site-specific mixing study to justify entering an override value for CMT. Dischargers may want to perform such a study, because PENTOXSD does not consider turbulent mixing effects at the point of discharge, and the discharger can get credit for additional mixing if it can be quantified. But it may be difficult to translate the results of a mixing study at typical flow conditions to Q7-10 (low flow) conditions. Input values of Q7-10 CMT will affect only AFC, CFC and THH-governed parameters, and input values of Qh CMT will affect only CRL-governed parameters. Input values of CMT directly influence the model's calculation of PMF. If you input a CMT that is less than that calculated by the model, the model would calculate higher PMFs for affected criteria and parameters, typically resulting in higher recommended effluent limits. Note that if the PMF is manually input as an override in the Discharge Input Data, this PMF value will be used without regard to CMT inputs.

Use of Control Buttons for Input Data

The **Print** control button will print a summary of the input data. The model will print to whichever printer is attached to LPT1, whether network connected or locally connected. It doesn't matter which form you are viewing when you hit **Print** – you will get the same summary. The **<Back** and the **Next>** control buttons will navigate you between the input data forms. The **Save** control button will save all of your input data to WAT_QUAL, and is the normal way to preserve your work. Any changes to input variables will not be preserved until you hit **Save**. The **Analyze** control button tells the model to generate analysis results (recommended effluent limits) based on the input data. If the input data is complete, and parameters selected and discharge concentrations input, the model will calculate recommended effluent limits and display the output data forms. The **Cancel** control button will exit you

to the main menu. The **Export** control button allows you to export input data for a project to an external dataset in ASCII format. There is an option on the main menu to retrieve (load) data in this format. Normally, all input data on dischargers, stream reaches, hydrodynamics and parameters would be saved in MS Access tables (WAT_QUAL) within the model by hitting **Save**, but sometimes you may not want to do this. The **Export** button allows you to save alternate scenarios outside of the main database, or to make a portable dataset that can be copied to a floppy disk or CD and transferred to another user.

OUTPUT DATA (Analysis Results)

Effluent Limits

This form shows PENTOXSD's recommended average monthly and maximum daily NPDES effluent limits in µg/L (the "Effluent Limit" reported is the recommended 30-day permit limit). If there are no limits or limits are "NA," check to ensure that the input data reflect the following:

- The discharger has at least one stream node downstream of it.
- There are positive inputs for Discharge Concentration at the same stream node as the discharge.
- There is a positive discharge flow (either Existing, Permitted or Design).

If you are getting errors that prevent the model from completing an analysis, especially errors involving an "invalid use of null," check to ensure that you haven't deleted any input values completely. For many fields, deleting the default value (usually zero) will prevent the model from completing the analysis.

The model evaluates all parameters for all applicable criteria and then selects the criterion that results in the most restrictive effluent limit. This criterion is called the Governing Criterion, and is reported in this form. Normally, there are five candidates for Governing Criterion: AFC, CFC, THH, CRL and INPUT. Acute Fish Criteria (AFC), Chronic Fish Criteria (CFC), Threshold Human Health (THH) and Cancer Risk Level (CRL) are all water quality-based criteria. If one of these is reported as the Governing Criterion, it means that the model has determined that the recommended effluent limit shown for that parameter is the maximum allowable discharge concentration that is permissible while still meeting water quality criteria, and the water quality criterion displayed is the most limiting of the four criteria. If the Governing Criterion is reported as "INPUT," this means that the Discharge Concentration that you input for that parameter is more restrictive than any of the limits calculated based on the water quality-based criteria. The Governing Criterion may also be reported as "INPUT" for a PWS parameter when no downstream PWS Withdrawal has been input. Another possible display for Governing Criterion is the background variant for water quality-based criteria. For example, if your background concentration of a carcinogen is already higher than the CRL limit, the model will display "CRL - Background" and will set all recommended effluent limits to the background concentration. This means that the stream already does not meet water quality criteria and can accept no additional loading of that parameter.

Wasteload Allocations

This form shows all the intermediate results of the calculations used to support the recommended effluent limits. This information is useful if you need to see detailed results on the various criteria-specific calculations: how much mixing has occurred, how much time has elapsed to the CCT (Criteria Concentration Time), the time required for complete mix at Qh, etc. These data would help you isolate the problem if there is something obviously wrong with the results. The CCT and PMF (Partial Mix Factor) is reported for each water quality criterion, if applicable.

Analysis Hardness (mg/L)/ Analysis pH - These are the flow-weighted values for hardness and pH that exist in the stream and are used to correct for the variable toxicity of certain parameters (most toxic heavy metals and pentachlorophenol). PENTOXSD does this by calculating water quality criteria for each reach in the analysis based on the Analysis Hardness and Analysis pH. Unless the user has entered override values for Analysis Hardness and Analysis pH, the model will take the discharge flow, hardness and pH and mix it with the stream/tributary flow, hardness and pH to produce these values. The amount of stream /tributary flow used in this calculation depends on the PMF. Note that Analysis Hardness and Analysis pH are never reported for CRL criteria, since there are no parameters that are hardness or pH sensitive and also have CRL criteria.

Water Quality Criterion (µg/L), Water Quality Objective (µg/L), and Wasteload Allocation (µg/L) - The difference between the Water Quality Criterion and the Water Quality Objective reflects any adjustments that are required. For instance, if a Water Quality Criterion of 4.264 µg/L for cadmium has been calculated based on the Analysis Hardness, the Water Quality Objective may be adjusted to 4.517 µg/L based on the determination that only 94.4 percent of cadmium is biologically available (existing in the dissolved state). The Water Quality Objective is then used to determine the WLA. The WLA is then used to determine the recommended effluent limits for that parameter. The WLA may or may not be the same as the recommended effluent limit for that parameter. The model will report the nature of any adjustments between the Water Quality Criterion and the Water Quality Objective in the “Notes” field in this form.

Hydrodynamics

These data forms show the hydrodynamic data that the model used to produce the recommended effluent limits. Calculated values as well as override values that have been input by the user are shown. Most of these data are self-explanatory and have been addressed earlier, but it is a good idea to scan these data to ensure they are consistent with your understanding of the size and flow of the stream. For most of these parameters, a value is reported for both Q7-10 and Qh design flow conditions.

Stream Flow (cfs), PWS Withdrawal (mgd) and Net Stream Flow (cfs) - The only difference between Stream Flow and Net Stream Flow is that, if there is a PWS Withdrawal at this node, this will be subtracted from the Stream Flow to produce the Net Stream Flow. Net Stream Flow is the value used in mixing calculations used to produce the recommended effluent limits. Net Stream Flow does not include the discharge flow, however.

Discharge Analysis Flow (cfs) - This value is the flow of the discharge effluent that was used by the model to produce the recommended effluent limits. Normally, it is equal to the discharge flow input by the user (and converted from mgd to cfs), but in some cases it will be adjusted. For example, if the user has entered a positive Reserve Factor as input data, this will cause the Discharge Analysis Flow to be higher than the discharge flow that the user input.

Reach Slope (ft/ft), Depth (ft), Width (ft), Width/Depth Ratio, Velocity (fps), Reach Travel Time (days) - These values define how the model sees the receiving water at Q7-10 and Qh flow. If the model reports that your stream is 60 feet wide at Q7-10, but you know that it is no more than 25 feet wide at Q7-10, you should rerun the analysis after editing the input data.

CMT (Complete Mix Time) - This value is what the model predicts is the amount of time in minutes required for the discharge flow and the stream flow to completely mix. Mixing is nearly instantaneous

for very small streams (less than 2 cfs), and relatively rapid for small streams (less than 25 cfs). But for larger streams complete mix will not occur within the time frame defined by the CCT for the applicable criterion (a maximum of 12 hours, or 720 minutes). The model will report CMT only up to 1000 minutes. The model will report CMT only for nodes that contain a discharger.

Use of Control Buttons for Analysis Results (Output Data)

The **Print** control button will allow you to specify which of four reports that you wish to print. Printing all four reports will produce all input and output data as well as important hydrodynamic characteristics that the model used to produce the recommended effluent limits. The **<Back** and the **Next>** control buttons will navigate you between the output data forms. The **Cancel** control button will exit the output data forms, and present you with the option to return to the input data or the main menu. The **Archive** control button is used to permanently save the results of your analysis to an archive file. Generally, you should only use this control button when you have completed the analysis and wish to archive the results as official. There is no point in archiving the results of an analysis unless you want to create an official DEP record of it. Saving the input data normally is adequate, since you can quickly rerun any analyses. If you want to preserve a “what-if” analysis, but don’t want to save the input data to WAT_QUAL or archive the results to WAT_QUAL, use the “Export” control button on the input data form. If you do wish to archive your results, hit the **Archive** button and the model will prompt you for an archive title and archive comment field to describe the analysis.

Notes:

CMT: Complete Mix Time, the time required for the discharge flow to mix completely with the receiving stream flow.

CCT: Criteria Compliance Time, the amount of time allowed for mixing before the model will apply the relevant water quality criterion (AFC, CFC, THH, CRL). For instance, the CCT for an AFC for benzene may be applied after 15 minutes of mixing has occurred.

AFC, CFC, THH, CRL: These are the possible water quality criteria that may be applied by PENTOXSD: Acute Fish Criterion, Chronic Fish Criterion, Threshold Human Health, Cancer Risk Level. These correspond to the *Criteria Continuous Concentrations*, *Criteria Maximum Concentrations* and *Human Health Criteria* contained in Title 25 Chapter 16.

PMF: Partial Mix Factor, the amount of mixing on a scale between 0.0 and 1.0 that represents how much of the receiving water has mixed with the discharge flow at a given point in time. For instance, a PMF of 0.4 would indicate that the discharge flow has mixed with 40 percent of the receiving water at that point in time.