DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Water Supply and Wastewater Management

DOCUMENT NUMBER: 391-2000-023

TITLE: Design Stream Flows

EFFECTIVE DATE: September 14, 1998
Minor changes were made throughout (March 24, 2003).

AUTHORITY: Federal Clean Water Act, Pa. Code Title 25, Chapter 92, 93, and 95 the Clean Streams Law, 35 P.S. §§691.1 *et seq.*

POLICY: It is the policy of the Department of Environmental Protection (DEP) to use the best available data in the calculation or estimation of wasteload allocations and NPDES effluent limitations. This often involves the use of data that can only be collected in the field.

PURPOSE: The design flow helps establish the assimilation capacity in the mass balance equation of the PENTOXSD model.

APPLICABILITY: DEP will use this guidance to provide technical details on how the program carries out various calculations and applies the evaluated results in preparing NPDES permits for dischargers, based on water quality criteria published in Chapters 93 and 16 (Statement of Policy).

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: 6 pages

LOCATION: Volume 29, Tab 11

1. <u>Purpose and Scope</u>

In general, point source wasteload allocations (WLAs) and NPDES effluent limitations are established on the basis of steady state water quality analysis, using specific design stream flows. (An exception to this general statement is that for precipitation induced point sources, WLAs are determined on the basis of a combination of minimum technology based treatment requirements and dilution ratios.) WLAs are, therefore, significantly affected by the design stream flow that is used. At the present time, DEP uses the design flows listed below in Table 1. (Each of the flows listed is either specifically provided for in DEP regulations, or has been selected by DEP as the appropriate flow for the particular analysis indicated.)

Table 1
Design Flows Used by DEP

Flow	Application
Q_{1-10} (seasonal or annual):	Used to establish acute toxicity based WLAs for ammonia nitrogen.
Q_{30-10} (seasonal or annual):	Used to establish chronic toxicity based WLAs for ammonia nitrogen.
Harmonic Mean:	Used to establish WLAs for carcinogens.
Average Daily:	Used to establish WLAs for phosphorus discharges to lakes, ponds and impoundments.
Q_{90-10}:	Used to establish WLAs for wildlife criteria in the Lake Erie Basin and the Genesee Basin only.
Q_{7-10}:	Used to establish WLAs for all other situations and/or pollutants.

Each of these design flows is a statistically derived value, based on an analysis of daily flow records. Q_{7-10} flow is, for example, the lowest seven (7) day average daily flow that is expected to occur at a frequency of no more than once in ten (10) years.

This protocol presents recommended procedures for estimating the design flows listed in Table 1 at ungauged stream locations, including locations of existing and proposed point source wastewater discharges.

2. <u>USGS Gauging Stations</u>

2.1 Description

USGS has approximately 250 continuous record stream flow gauging sites in Pennsylvania. These gauges have the 30 years of continuous flow records recommended by USGS for the calculation of design flows. Calculation of design flows requires using computer programs because of the amount of information and the complexity of the calculations. The analyst can use the design flow computer programs at the National Computer Center (NCC) or request the local USGS Field Office to do the computations. The local USGS office must do the computations for streams regulated by impoundments or with significant water withdrawals, because the computer programs at NCC do not factor in stream regulation or water withdrawals. Bulletin B-12 Low Flow

Characteristics of Pennsylvania Streams, lists the low flow statistics and duration tables for many gauges, but USGS recommends not using this obsolete information.

Bulletin 12 - Low Flow Characteristics of Pennsylvania Streams is being updated. Flow statistics for this update were retrieved from STORET and are current to December, 1996. This information will be available on the IntraDEP. In addition, Bulletin 15 - Technical Manual for Estimating Low Flow Characteristics of Streams is also being updated. When complete Bulletin 15 will be a GIS-based application that will be installed on a workstation in the Water Supply Management Section in each regional office.

2.2 Use

Users can access the USGS flow gauging information in the WATTSTORE data base by connecting to NCC. All DEP Field Offices can access the NCC computer. DEP personnel should contact the STORET manager in the Bureau of Water Supply and Wastewater Management in Harrisburg for information on using the system, documentation, and training. Others should contact STORET user support at 800-424-9067.

The FLOSTAT computer program at NCC gives many flow recurrence intervals including Q_{7-10}, median flow, duration curves, and frequency tables. Use the interactive DFLOW program to obtain aquatic life and human health design flows.

3. <u>Field Sample</u>

The majority of discharge sites do not have a nearby flow gauge with an adequate historical record. So, we need methods to estimate the design flows at a discharge site without a gauge. One method involves collecting stream flows at the discharge point to correlate with the flows at a nearby USGS gauge. Before implementing this method, submit a short narrative study plan to the local DEP field office addressing each step of the method.

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1. Select an approved method of gauging flows at the discharge site. For wadeable streams DEP uses methods endorsed by USGS.

2. Select a nearby USGS stream gauge with watershed features similar to the study area. The ecoregion method described in *Water Quality Anti-Degradation Implementation Guidance,* DEP ID: 391-0300-002 available for viewing on DEP's website at <u>www.dep.state.pa.us</u> is a good starting point for selecting a surrogate gauging station.

3. Determine the design flow at the USGS stream gauge using either the FLOSTAT or the DFLOW program, and do the field sampling when the flows at the USGS gauge are close to these flows. Sample only when there is a stable hydrograph, no rapid rises or falls.

4. Measure the flow at the study area and USGS stream gauge at approximately the same time. Arrangements should be made with USGS to read the gauge and obtain the rating table for the gauge.

5. After taking five measurements, plot the flows to determine the amount of variability. If the relationship approximates a straight line, then only a few more field measurements may adequately define the relationship between the discharge site and the gauge. If the plot shows scatter, then many more field measurements are required. The discharger and DEP staff should agree on the number of additional field measurements needed after viewing the plot. The discharger may decide not to continue with this method if the scatter indicates a poor correlation between the gauge and the discharge site.

6. Go back into the field and collect the additional measurements.

7. Upon completion of the field measurements, correlate the flows from the USGS gauge and the discharge site using linear correlation or regression. The discharge site is the dependent variable. Flow often follows a logarithmic data distribution so the analyst may need to transform the data before doing the regressions. Many PC software packages, such as spreadsheets, can do the logarithmic transformations and regression. Plug the design flows of the USGS gauge into the regression equation to get the predicted design flows at the discharge site.

4. Low Flow Yield Method for $Q_{7\text{-}10}$

Measuring stream flows at a discharge site may be cost prohibitive or impractical, especially in large unwadeable streams and rivers. The low flow yield method of extrapolating $Q_{7\text{-}10}$ flows can be used in such cases.

4.1 Low Flow Yield

Another method for extrapolating $Q_{7\text{-}10}$ flows is the low flow yield method. Locate a USGS stream gauge in a watershed that has similar geology, physiography, and land use as the study site. The ecoregion method described in *Water Quality Anti-Degradation Implementation Guidance* is a good starting point for selecting a surrogate gauge. Divide the $Q_{7\text{-}10}$ flow for the $Q_{7\text{-}10}$ by the drainage area upstream of the gauge. This gives a $Q_{7\text{-}10}$ low flow yield in cubic feet per second per square mile of drainage. Compute the drainage area upstream of the discharge site and multiply it by the $Q_{7\text{-}10}$ low flow yield for the USGS gauge. This gives an estimate of the $Q_{7\text{-}10}$ at the discharge site.

4.2 Incremental Low Flow Yield

A variation of the low flow yield method is the incremental low flow yield method. In large watersheds, features such as geology may change as the stream flows to the discharge site. In such cases the analyst may choose to use several USGS gauges to estimate the $Q_{7\text{-}10}$ at the discharge site. Segment the watershed upstream of the discharge area of each segment. Match the features of each watershed segment to the features of the nearby gauged watersheds and calculate a low flow yield for each of these gauges.

Multiply the Q_{7-10} low flow yield of each matched gauge and segmented drainage area. The sum of the Q_{7-10} estimates for each segment is the Q_{7-10} of the discharge site.

5. Period of Record And Regulated Flows

This section considers the need to evaluate the period of record, STPs and associated flows, and minimum releases, all of which may have an affect on the "design stream flow." The period of record is important in evaluating whether or not there was a significant flow contribution during that period from another source such as a significant STP or mining discharge. Another factor is whether or not a minimum release structure upstream was operational during the period of record. As a general guideline, the Bureau of Watershed Management (WM) and the Fish and Boat Commission recommend flow protection downstream of an intake if the withdrawal will be greater than 10% of the Q_{7-10} flow. In keeping with this guideline, any form of flow regulation can be considered significant if it exceeds 10% of the Q_{7-10} flow. Examples of flow regulation would include a STP or mining discharge, a dam's conservation release, or an inter basin transfer. Note that STP discharges should not be considered regulation if the water originates within the drainage area; in such cases, the STP discharge is merely restoring the status quo. Likewise, withdrawals that are returned within the drainage area are not considered regulation.

If the flow regulation is considered significant, the adjustments to the NPDES design flow should be made as follows:

1) If the stream gauge selected for computing the design flow has a record free of regulation (either no upstream regulation or record already adjusted for any upstream regulation), then any flow values derived from that gauge, for the NPDES site, will be estimates of natural, unregulated conditions at the NPDES site.

2) If the selected stream gauge is subject to significant upstream regulation, then the net regulation value (total flow sources minus total unreturned withdrawals) must be subtracted from any flow values for the gauge. These adjusted values can then be used to estimate natural, unregulated conditions at the NPDES site.

3) If the NPDES site is subject to significant upstream regulation, then the net regulation value (total flow sources minus total unreturned withdrawals) must be added to any derived flow values for the site.

4) The resulting flow should then be divided by the drainage area at the gauging station to determine a true stream yield value for that basin. This flow, times the drainage area at the discharge point gives you a Q_{7-10} value at that point.

5) To arrive at the design flow for carcinogens, the Q_{7-10} value at the discharge point should be multiplied by the Harmonic Mean factor in PENTOXSD, to which the significant upstream flow can be added.

Downstream conservation releases from reservoirs are frequently a condition of the dam safety or water allocation permit and can be obtained either from the Bureau of Waterways Engineering or WM. Conservation release schedules may also be obtained from the Army Corps of Engineers for Corps projects. Measurements during low flows would be the only way to determine mine discharges, which are frequently interbasin transfers. STP discharge information should be available from plant records.

6. Extrapolating Other Design Stream Flows

The correlation method allows the analyst to develop an equation for any design flow once the relationship between the discharge site and the gauge is defined. The low flow yield method gives reasonable estimates of the Q_{7-10} but not for other design flows. Q_{7-10} is such an extremely low flow that the main factor determining the stream flow is the groundwater. Other factors such as the soil type and runoff characteristics complicate the extrapolation of design flows that are not associated with extreme low flows. So, we need different methods to extrapolate these higher design flows from a USGS gauge to the discharge site.

There is an equation for estimating harmonic mean flow from the estimated Q_{7-10} in "*Implementation Guidance Design Conditions*," DEP ID: 391-2000-006. We repeat the equation here for your convenience.

$Qr = 7.43 \times (Q_{7-10})^{0.874}$

The *Implementation Guidance of Section 93.7 Ammonia Criteria*, DEP ID: 391-2000-013, available electronically for viewing on DEP's website, contains equations for calculation of Q_{30-10} and Q_{1-10} from the estimated Q_{7-10}. We repeat the equations here for your convenience.

$Q_{30-10} = 1.36 \times (Q_{7-10})$

$Q_{1-10} = 0.64 \times (Q_{7-10})$

6.1 Default Equations for Design Stream Flow

The analyst should use either the correlation or the low flow yield and conversion formula methods to compute design flows. In the rare instances when we can not use any of these methods, we must use the default equations for design flows found in the PENTOXSD model. The PENTOXSD model default equations are:

Q_{7-10} = Drainage Area at point of discharge) - (Drainage Area at the previous reach) x (Groundwater Quality Yield Factor)

$Qr = 7.43 \times (Q_{7-10})^{0.874}$