$$300\ g/m^2/yr \times \frac{1\ yr}{365\ days} \times \frac{1}{0.01/day} \times [1 - \exp(-90 \times 0.01)] = 49\ g/m^2 \qquad \text{B-4}$$

This example shows that input data for the 90-day and steady-state accumulations are different. Consequently, Tables B-1 and B-2 should each be completed twice. Also, the accumulation over a critical 90-day period can exceed the steady-state accumulation. This is caused by short-term deposition rates that are considerably higher than the long-term average. In the example, the maximum 90-day deposition rate of 300 g/m^2/yr would eventually decrease to values below 100 g/m^2/yr so that on a yearly basis the deposition rate is 100 g/m^2/yr.

B-II. DISSOLVED OXYGEN CONCENTRATION FOLLOWING INITIAL DILUTION

When wastewater is discharged through a single port or a diffuser, the effluent forms a buoyant plume that entrains ambient water as it rises. Because the initial dilution process occurs rapidly (i.e., on the order of minutes), BOD exertion (a relatively slow process) is negligible during this period. However, an immediate dissolved oxygen demand (IDOD), which represents the oxygen demand of reduced substances that are rapidly oxidized (e.g., sulfides to sulfates), might not be negligible. The dissolved oxygen concentration following initial dilution can be predicted using the following expression:

$$DO_f = DO_a + \frac{DO_e - IDOD - DO_a}{S_a} \qquad \text{B-5}$$

where:

DO_f = Final dissolved oxygen concentration of receiving water at the plume trapping level, mg/L

DO_a = Affected ambient dissolved oxygen concentration immediately upcurrent of the diffuser averaged over the tidal period (12.5 hours) and from the diffuser port depth to the trapping level, mg/L

DO_e = Dissolved oxygen of effluent, mg/L

IDOD = Immediate dissolved oxygen demand, mg/L

S_a = Initial dilution (flux-averaged).

The applicant should use the least favorable combination of values for effluent dissolved oxygen, IDOD, affected ambient dissolved oxygen, and initial dilution. The effluent dissolved oxygen concentration at the point of discharge from the treatment plant is often 0.0 mg/L. Because the critical case is desired, a concentration of 0.0 mg/L is a reasonable value. However, if data show that dissolved oxygen concentrations in the effluent are greater than 0.0 mg/L during the critical periods, then these data may be used.

The IDOD values typically vary from 0 to 10 mg/L, but can be higher depending on the level of treatment and presence of industrial flows. Table B-3 can be used to select reasonable IDOD values. Alternatively, the IDOD can be measured as discussed below. The influence of the effluent IDOD on ambient dissolved oxygen can be estimated from the following table (calculated as $-IDOD/S_a$):

TABLE B-3. TYPICAL IDOD VALUES

Treatment Level	Effluent BOD_5 (mg/L)	Travel Time (min)[a]	IDOD (mg/L)
Untreated or less than primary		<60	5
		60-200	10
		200-300	15
		>300	20
Primary	50-100	0-100	2
	50-100	100-300	3
	50-100	>300	4
	100-150	0-100	3
	100-150	100-300	4
	100-150	>300	5
	150-200	0-100	5
	150-200	100-300	7
	150-200	>300	8
Advanced primary	<50	0-60	0
	<50	>60	1

[a] Travel time should include the total travel time from the treatment plant through the diffuser, including any land portion of the outfall.

Note: Information compiled from 301(h) applications.

	Initial Dilution			
IDOD (mg/L)	10	30	50	100
1	-0.1	-0.03	-0.02	-0.01
2	-0.2	-0.07	-0.04	-0.02
5	-0.5	-0.17	-0.1	-0.05
10	-1.0	-0.33	-0.2	-0.10
20	-2.0	-0.67	-0.4	-0.20

At high initial dilutions, the IDOD contribution is small. Thus, the expense of laboratory tests may be unwarranted. If IDOD is to be determined experimentally, the procedures in *Standard Methods* (American Public Health Association et al. 1985, p. 530) should be generally followed except that the dilution water should be seawater from the discharge site instead of distilled water and the effluent sample should be incubated anaerobically for a length of time equal to the travel times from the plant through the diffuser for minimum, average, and maximum flow conditions. The effluent sample should be mixed with the dilution water after incubation. The dissolved oxygen concentration of the effluent and dilution water should be measured separately after incubation and before mixing the samples. The dissolved oxygen of the mixture should be measured 15 minutes after preparation.

The IDOD is calculated using the following equation:

$$IDOD = \frac{(DO_D)(P_D) + (S)(P_S) - DO_M}{P_S} \quad \text{B-6}$$

where:

IDOD = Immediate dissolved oxygen demand, mg/L
DO_D = Dissolved oxygen of dilution water (seawater), mg/L
P_D = Decimal fraction of dilution water used
S = Dissolved oxygen of effluent after incubation, mg/L
P_S = Decimal fraction of effluent used
DO_M = Dissolved oxygen of mixture after 15 minutes, mg/L.

Several dilutions should be used, preferably close to the actual initial dilution, unless the difference between the initial and mixed concentrations is less than 0.1 mg/L. All data used in the above calculations, the incubation times, and the computed results for each test should be included in the application.

The lowest initial dilution (flux-averaged) should be used for the final dissolved oxygen calculation. Usually, this dilution will correspond to the maximum flow rate at the end of the permit term. Low initial dilutions can also occur at smaller effluent flow rates if stratification is sufficiently severe. Typically, dilutions during periods of maximum stratification should be used for the final dissolved oxygen calculation.

The affected ambient dissolved oxygen concentrations should also represent critical conditions. Usually, critical conditions will occur during the maximum stratification period in the late summer or in the spring when upwelling of deep ocean water occurs. For existing discharges, the affected ambient data should be collected at locations directly upcurrent of the diffuser, thereby incorporating the potential effects of recirculation. For proposed new or relocated discharges, affected ambient dissolved oxygen levels upcurrent of the diffuser should be estimated from mathematical models of the discharge or by extrapolation from similar situations. Dissolved oxygen data, as well as any ambient water quality constituent, may be averaged between the depth of the discharge ports and the plume trapping level, which corresponds to the lowest initial dilution that was used to predict the final dissolved oxygen concentrations. If applicants use a mathematical model that allows multiple vertical levels of input for ambient water quality instead of an average value, this should be noted.

The time period over which ambient data may be averaged may depend on specifications of intensity and duration factors in applicable water quality standards. For example, if certain numerical values should not be compromised over a period of 4 hours, a 4-hour average of input data may be reasonable. Absent any more stringent specification in locally applicable standards, an average over a half tidal cycle (approximately 12.5 hours) would provide a generally conservative estimate.

The affected ambient dissolved oxygen concentration can change substantially as a function of depth, depending on environmental characteristics and seasonal influences (e.g., upwelling). As the plume rises during initial dilution, water from deeper parts of the water column is entrained into the plume and advected to the plume trapping level. If the dissolved oxygen concentration is lower in the bottom of the water column than at the trapping level, the low-dissolved-oxygen water is advected to a region formerly occupied by water containing higher concentrations of dissolved oxygen. The result is an oxygen depression caused by entrainment.

This oxygen depression caused by the waste discharge and associated entrainment (ΔDO_1) should be computed as the difference between DO_f as defined in Equation B-5 and the affected ambient dissolved oxygen concentration at the trapping depth (DO_t).

$$\Delta DO_1 = DO_f - DO_t = DO_a - DO_t + \frac{(DO_e - IDOD - DO_a)}{S_a} \qquad \text{B-7}$$

The oxygen depression of the wastefield relative to the trapping depth, expressed in percent, is $(-\Delta DO_1/DO_t)100$.

For cases in which the effect of entraining low-dissolved-oxygen water can be neglected, the oxygen depletion (ΔDO_2) should be computed as the difference between the average affected ambient dissolved oxygen concentration (DO_a) in the entrained water and DO_f, as shown below.

$$\Delta DO_2 = DO_f - DO_a = \frac{(DO_e - IDOD - Do_a)}{S_a} \qquad \text{B-8}$$

The oxygen depletion of the wastefield relative to the average affected ambient dissolved oxygen concentration is $(-\Delta DO_2/DO_a)100$.

The equation of Baumgartner (1981) for the percentage depression is:

$$\frac{(DO_t - DO_e + IDOD)}{DO_t \times S_a} \times 100 \qquad \text{B-9}$$

This equation can be derived by assuming that $DO_a = DO_t$ in Equation B-7. Use of Equation B-9 has been allowed in the State of California.

These differences can be described as a percentage of the ambient concentration or as a numerical difference, depending on the requirements of the state. In some states, the final dissolved oxygen concentration must be above a specified limit or must be converted to percent saturation to determine whether the final concentration is above a prescribed limit. Dissolved oxygen saturation can be determined as a function of temperature and salinity using the method of Green and Carritt (1967) and Hyer et al. (1971), as tabulated in Table B-4. The applicant may want to consult with the state water quality agency to determine whether any other methods are used to determine compliance with the dissolved oxygen standards.

TABLE B-4. DISSOLVED OXYGEN SATURATION VALUES

Temperature (°C)	Dissolved Oxygen Saturation (mg/L)								
	Salinity (ppt)								
	20	22	24	26	28	30	32	34	36
0	12.8	12.6	12.5	12.3	12.1	12.0	11.8	11.7	11.5
1	12.5	12.3	12.2	12.0	11.8	11.7	11.5	11.4	11.2
2	12.1	12.0	11.9	11.7	11.5	11.4	11.2	11.1	10.9
3	11.8	11.7	11.5	11.4	11.2	11.1	10.9	10.8	10.7
4	11.5	11.4	11.3	11.1	11.0	10.8	10.7	10.5	10.4
5	11.3	11.1	11.0	10.8	10.7	10.6	10.4	10.3	10.1
6	11.0	10.9	10.7	10.6	10.4	10.3	10.2	10.0	9.9
7	10.7	10.6	10.5	10.4	10.2	10.1	9.9	9.8	9.7
8	10.5	10.3	10.2	10.1	9.9	9.8	9.7	9.6	9.4
9	10.2	10.1	10.0	9.8	9.7	9.6	9.5	9.3	9.2
10	10.0	9.9	9.7	9.6	9.5	9.4	9.2	9.1	9.0
11	9.6	9.6	9.5	9.4	9.3	9.2	9.0	8.9	8.8
12	9.5	9.4	9.3	9.2	9.1	9.0	8.8	8.7	8.6
13	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.5	8.4
14	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3
15	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1
16	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	8.0
17	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8
18	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6
19	8.2	8.1	8.0	8.0	7.9	7.8	7.6	7.6	7.5
20	8.1	8.0	7.9	7.7	7.7	7.6	7.6	7.5	7.4
21	7.9	7.9	7.7	7.7	7.6	7.5	7.5	7.4	7.3
22	7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2
23	7.7	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.1
24	7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1
25	7.5	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0
26	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0
27	7.2	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.9
28	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8
29	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8
30	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.8	6.7

B-III. FARFIELD DISSOLVED OXYGEN DEPRESSION

Subsequent to initial dilution, dissolved oxygen in the water column is consumed by the BOD in the wastefield. The effluent BOD_5 after initial dilution is needed to estimate farfield dissolved oxygen depletion. The final BOD_5 concentration can be estimated using the following expression:

$$BOD_f = BOD_a + \frac{(BOD_e - BOD_a)}{S_a} \qquad \text{B-10}$$

where:

BOD_f = Final BOD_5 concentration, mg/L

BOD_a = Affected ambient BOD_5 concentration immediately updrift of the diffuser averaged over one-half the tidal period (12.5 hours) and from the diffuser port depth to the trapping depth, mg/L

BOD_e = Effluent BOD_5 concentration, mg/L

S_a = Initial dilution (flux-averaged).

This equation provides an estimate of the total BOD_5 concentration in the receiving water. The maximum contribution due to the effluent alone can be determined by dividing the effluent BOD_5 concentration by the initial dilution. This value is used later to estimate farfield effects of the effluent. As a critical case, the maximum monthly average effluent BOD_5 concentration should be used with the monthly critical initial dilution. For existing plants, the previous 12 months of effluent BOD_5 data are used to support the selection of a BOD_5 concentration. For proposed or modified treatment plants where effluent data are not available, monthly average influent BOD_5 data should be provided along with the range of daily values. The average removal efficiency for the new or modified plant is also needed to compute estimated effluent BOD_5 concentrations.

Three approaches to assessing farfield dissolved oxygen demand are described below:

- Simplified mathematical models that predict dissolved oxygen depletion using calculation techniques that do not require computer support;
- Numerical models that predict dissolved oxygen depletion using a computer; and

- Evaluation of field data, using a data-intensive approach in which dissolved oxygen concentrations are measured in the water column and compared to ambient concentrations.

Before undertaking any analysis to determine whether farfield BOD exertion causes a violation of the dissolved oxygen standard, the applicant should first determine for critical conditions whether:

$$DO_{STD} \leq DO_f - BOD_{fu} \tag{B-11}$$

where:

DO_{STD} = Dissolved oxygen standard
DO_f = Dissolved oxygen concentration at the completion of initial dilution
BOD_{fu} = Ultimate BOD at the completion of initial dilution (= BOD_f x 1.46).

If the above inequality is true, then the discharge will not violate the dissolved oxygen standard due to BOD exertion and no further analysis of farfield BOD exertion is required. If the inequality is not true, then further analysis is required.

SIMPLIFIED MATHEMATICAL MODELS

Oxygen depletion due to coastal or estuarine wastewater discharges is primarily caused by exertion of BOD, although increased nutrient levels can affect oxygen concentrations indirectly by altering algal photosynthesis and respiration rates. BOD consists of a carbonaceous component (CBOD) and nitrogenous component (NBOD). Both components can contribute to oxygen depletion.

The first phase of the BOD reaction involves the oxidation of the carbonaceous organic material. The nitrogenous stage includes conversion of organic nitrogen to ammonia and the subsequent oxidation of ammonia to nitrite and then to nitrate. By U.S. convention, BOD measurements are typically conducted for 5 days. In addition, many of the tests are run with a nitrification inhibitor so that the test measures the oxidation of carbonaceous material only. When total BOD is measured after 5 days (an inhibitor is not used), these tests are designated as BOD_5. When the 5-day test employs a nitrification inhibitor, the results are designated as $CBOD_5$ (U.S. EPA 1992). Long-term tests are also employed to measure ultimate BOD (BOD_L) to reflect the potential strength of the oxygen consumption.

The effluent $CBOD_L$-to-$CBOD_5$ ratio is required in dissolved oxygen modeling analyses to estimate POTW $CBOD_L$ from effluent $CBOD_5$ data. For in-stream CBOD arising from a wastewater inflow, the degree of treatment of the wastewater is important. Thomann and Mueller (1987) summarize the $CBOD_L$-to-$CBOD_5$ ratios for municipal wastes as 1.2 for no treatment, 1.6 for primary/secondary, 3.2 for activated sludge, and 2.84 for advanced primary (U.S. EPA 1992). Some computer models (e.g., QUAL-II, QUAL2EU) specify this ratio as 1.46. The ratios are a function of the deoxygenation rate coefficients and are wasteload- and receiving-water-specific. In general, the higher the degree of treatment, the greater the degree of waste stabilization and the lower the deoxygenation rate. The range of values reported as in-stream deoxygenation rates or simply decay rates is wide, spanning more than two orders of magnitude (U.S. EPA 1985).

Before using $CBOD_5$ to predict oxygen depletion, the applicant should convert it to $CBOD_L$, the ultimate CBOD, by the following relationship:

$$CBOD_L = 1.46\ CBOD_5 \qquad \text{B-12a}$$

where the $CBOD_L$-to-$CBOD_5$ ratio of 1.46 is calculated using a 0.23 day^{-1} decay rate at 20 °C (U.S. EPA 1985) by the equation (Sawyer et al. 1978):

$$\frac{CBOD_5}{CBOD_L} = 1 - e^{-k_c t} \qquad \text{B-12b}$$

where:

k_c = the CBOD decay rate coefficient at T (°C)
t = Travel time corresponding to BOD_5 (5 days).

A number of factors, including temperature, are known to influence the rate at which CBOD is removed from the water column. The influence of these factors has been described by both theoretical and empirical formulations. Like all biochemical processes, CBOD decay occurs at a rate that increases with increasing temperature. Therefore, a temperature correction should be made to account for the temperature dependence of the rate constant as follows:

$$k_c = 0.23 \times \Theta^{(T - 20°C)} \qquad \text{B-13}$$

where:

k_c = CBOD decay rate at temperature T (°C)
0.23 = CBOD decay rate coefficient at 20 °C
Θ = Temperature correction factor.

Once the temperature-corrected decay rate, k_c, is calculated, the new $CBOD_L$-to-$CBOD_5$ ratio can be calculated using Equation B-12b. Studies indicate that the value of 1.047 for Θ is valid between 20 °C and 30 °C, but higher values are appropriate at lower temperatures (U.S. EPA 1985).

Data on the $CBOD_L$-to-$CBOD_5$ ratio can vary considerably, not only between different treatment levels but also between different sites with the same treatment levels. The consequence of using a ratio that has not been developed from field data could be to underestimate the effect of the wastewater on receiving water oxygen concentrations. Because of the importance of this parameter and the observed variability in the ratio from site to site, it is recommended that site-specific ratios be developed on a case-by-case basis (U.S. EPA 1984). In lieu of using average values for CBOD decay rates, the applicant can determine actual values by collecting data on effluent "bottle rates" using guidance found in *Rates, Constants, and Kinetics Formulations on Surface Water Quality Modeling* (U.S. EPA 1985).

The second phase of the BOD reaction involves the oxidation of the nitrogenous compounds in the waste or water body. The transformation of reduced forms of nitrogen to more oxidized forms (nitrification) consumes oxygen. Nitrification is a two-stage process facilitated by nitrifying bacteria. The first stage is the oxidation of ammonia to nitrite principally by *nitrosomonas* bacteria; the second stage is the oxidation of nitrite to nitrate principally by *nitrobacter* bacteria. NBOD might not always contribute to oxygen depletion. If the applicant discharges into open coastal waters where there are no other major discharges in the vicinity, the background population of nitrifying bacteria might be negligible. Under these circumstances, the NBOD will not be exerted immediately. In more enclosed estuarine waters, nitrification in the water column has been documented by numerous water quality studies. Applicants should analyze the potential impact of NBOD if they discharge into estuarine waters.

Although nitrification is a multistep process, a simplified approach to determining the oxygen demand uses an overall oxidation rate of the NBOD, k_N. The range of values of k_N is approximately the same as for the deoxygenation coefficient of the CBOD. For deep, large bodies of water, values of k_N of 0.1-0.5/day at 20 °C are typical (Thomann and Mueller 1987).

Assuming all reactions go to completion, the overall oxygen depletion can be estimated based on data for total Kjeldahl nitrogen (TKN is the sum of organic nitrogen and ammonia nitrogen) in the waste discharge using the following relationships:

$$NBOD_L = 4.57\ (TKN) \qquad \text{B-14a}$$

where $NBOD_L$ is the ultimate NBOD. As with carbonaceous BOD, if $NBOD_5$ is to be used to predict oxygen depletion, the applicant should convert it to $NBOD_L$, the ultimate NBOD, by the following relationship:

$$NBOD_L = 2.54\ NBOD_5 \qquad \text{B-14b}$$

where the $NBOD_L$-to-$NBOD_5$ ratio of 2.54 is calculated using a 0.1 day^{-1} nitrification rate at 20 °C (U.S. EPA 1985) by the equation (Thomann and Mueller 1987):

$$\frac{NBOD_5}{NBOD_L} = 1-e^{-k_N t} \qquad \text{B-14c}$$

where:

k_N = the nitrification rate coefficient at T (°C)
t = Travel time corresponding to BOD_5 (5 days).

A number of factors, including temperature, are known to influence the rate of nitrification. The influence of these factors has been described by both theoretical and empirical formulations. Like all biochemical processes, NBOD decay occurs at a rate that increases with increasing temperature. Therefore, a temperature correction should be made to account for the temperature dependence of the rate constant as follows:

$$k_N = 0.10 \times \Theta^{(T\ -20\ °C)} \qquad \text{B-15}$$

where:

k_N = Nitrification rate coefficient at temperature T (°C)
0.10 = Nitrification rate coefficient at 20 °C
Θ = Temperature correction factor.

Once the temperature-corrected decay rate, K_N, is calculated, the new $NBOD_L$-to-$NBOD_5$ ratio can be calculated using Equation B-14c. Although temperature correction factors are available for both ammonia oxidation and nitrate oxidation, typically only one temperature correction factor is used. Studies indicate that the value of 1.08 for Θ is valid between 10 °C and 30 °C; beyond this temperature the nitrification rate is inhibited by the high temperature, so the relationship no longer holds (U.S. EPA 1985). At temperatures below 10 °C, the nitrifying bacteria apparently do not multiply in any significant amount. Therefore, the rate k_N is usually set equal to zero at about 5-10 °C (Thomann and Mueller 1987).

The influence of pH on rates of nitrification is also quite important. If pH is outside the range of 7.0 to 9.8, significant reductions in nitrification rates occur. The optimal pH for nitrification is approximately 8.5; at pH values below approximately 6.0, nitrification is not expected to occur (U.S. EPA 1985).

Simplified mathematical models are an acceptable alternative to the more complex numerical models. In the simplest model of oxygen depletion, the following assumptions are generally made:

- The wastewater plume is submerged at the completion of initial dilution for critical conditions (so that direct reaeration of atmospheric oxygen into the wastefield does not occur).

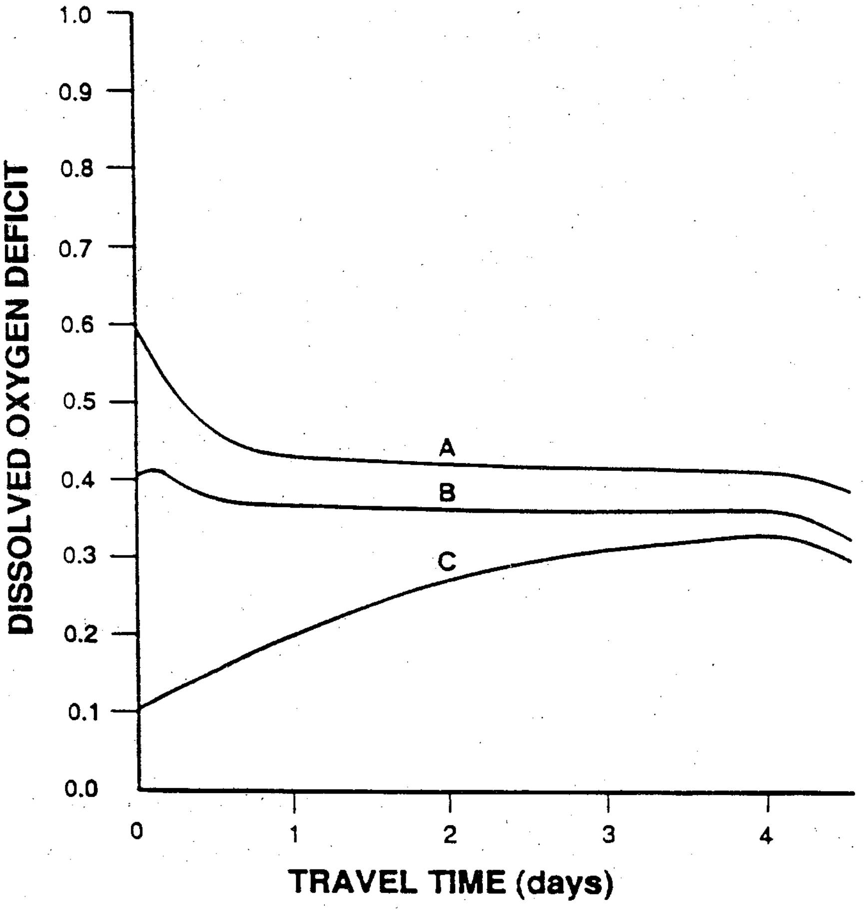
- Oxygen depletion is a function of distance from the discharge and is caused by carbonaceous oxygen demand and nitrogenous oxygen demand.

- The wastefield entrains ambient water as a function of travel time. Lateral dilution is the predominant mechanism of entrainment.

If the applicant demonstrates that the plume will always surface, then the effects of atmospheric reaeration can be included; otherwise, they should not be included.

When applying a model that predicts farfield oxygen depletion, it is suggested that the applicant plot dissolved oxygen depletion as a function of travel time so that the behavior of dissolved oxygen concentrations in the wastefield can be examined to locate minimum values.

Example oxygen depletion curves as a function of travel time are shown in Figure B-4. The depletion indicated at time, t = 0, denotes the depletion immediately following initial dilution. The dissolved oxygen deficits plotted in the figure are relative to the ambient concentration and tend to approach zero at travel times longer than those shown in the figure.



CURVE	BOD$_f$ (ultimate) (mg/L)	INITIAL DO DEMAND (mg/L)
A	3.5	66.
B	3.5	44.
C	3.5	0.

Figure B-4. Dissolved oxygen deficit vs. travel time for a submerged wastefield.

For the three cases, the maximum deficits occur at the following travel times:

- 0.0 days for Curve A;
- Approximately 0.2 day for Curve B; and
- Approximately 4.0 days for Curve C.

The primary reason for the difference in magnitude and time of occurrence of the maximum deficits is the IDOD, which varies from a high of 66 mg/L for Curve A to 0.0 mg/L for Curve C. When the IDOD is 66 mg/L (a high value, but one that could be associated with an unusual discharge), the maximum depletion is caused by initial mixing processes and not by farfield BOD exertion. Conversely, when IDOD is 0.0 mg/L, the maximum depletion is caused by BOD exertion and occurs at some distance from the discharge.

The simplified farfield oxygen depletion model for coastal waters suggested herein is based on an approach developed by Brooks (1960) for predicting wastefield dilution subsequent to initial dilution. The dissolved oxygen concentration in the receiving waters can be expressed as a function of travel time as follows:

$$DO(t) = DO_a + \frac{DO_f - DO_a}{D_s} - \frac{L_{fc}}{D_s}\left[1 - \exp(-k_c t)\right] - \frac{L_{fn}}{D_s}\left[1 - \exp(k_n t)\right] \qquad \text{B-16}$$

where:

$DO(t)$ = Dissolved oxygen concentration in a submerged wastefield as a function of travel time t, mg/L

DO_a = Affected ambient dissolved oxygen concentration immediately updrift of the diffuser, mg/L

DO_f = Dissolved oxygen concentration at the completion of initial dilution calculated using Equation B-5, mg/L

k_c = CBOD decay rate coefficient

k_n = NBOD nitrification rate coefficient

L_{fc} = Ultimate CBOD concentration above ambient at completion of initial dilution, mg/L

L_{fn} = Ultimate NBOD concentration above ambient at completion of initial dilution, mg/L

D_s = Dilution attained subsequent to initial dilution as a function of travel time.

The above equation expresses the dissolved oxygen deficit that arises because of an initial deficit at the completion of initial dilution (DO_a-DO_f) plus that caused by exertion of BOD in the water column. The last term in the equation estimates the exertion due to NBOD. The dissolved oxygen deficit tends to decrease at longer travel times as a result of subsequent dilution and to increase as a result of BOD exertion. Depending on the particular case being analyzed, one influence can dominate the other over a range of travel times so that a minimum dissolved oxygen level can occur either immediately following initial dilution or at a subsequent travel time, as previously shown in Figure B-4.

To predict farfield oxygen distribution, one must determine the dilution attained within the wastefield as a function of time following discharge. For open coastal areas, dilution is often predicted using the 4/3 law (Brooks 1960), which states that the lateral diffusion coefficient increases as the 4/3 power of the wastefield width. In mathematical form:

$$\varepsilon = \varepsilon_o \left(\frac{L}{b}\right)^{4/3} \qquad \text{B-17}$$

where:

ε = Lateral diffusion coefficient, ft^2/sec
ε_o = Diffusion coefficient when L = b
L = Width of sewage field at any distance from the ZID, ft
b = Initial width of sewage field (approximately as the longest dimension of the ZID), ft.

The initial diffusion coefficient can be predicted from:

$$\varepsilon_o = 0.001\ b^{4/3}\ ft^2/sec \qquad \text{B-18}$$

Based on the 4/3 law, the centerline dilution, D_S, is given by:

$$D_s = erf\left(\frac{1}{\left[\frac{1.5}{\left(1 + \frac{8\varepsilon_o t}{b^2}\right)^3} - 1\right]^{1/2}}\right) \qquad \text{B-19}$$

where:

t = Travel time, sec
erf = The error function.

The 4/3 law is not always applicable, especially in coastal areas or estuaries. In coastal areas, Grace (1978) suggests that the diffusion coefficient vary linearly with L. The subsequent dilution can be expressed as:

n=1

$$D_s = erf\left(\frac{1}{\left[\frac{1.5}{\left(1 + \frac{12\varepsilon_o t}{b^2}\right)^2 - 1}\right]^{1/2}}\right) \qquad \text{B-20}$$

A more conservative choice is to assume the diffusion coefficient is a constant. The subsequent dilution can then be expressed as:

n=0

$$D_s = erf\left[\frac{1}{\left(\frac{b^2}{16\varepsilon_o t}\right)^{1/2}}\right] \qquad \text{B-21}$$

These three equations are cumbersome to use, especially if repeated applications are needed. To facilitate predicting subsequent dilutions, values of D_s as a function of $12\varepsilon_0 t/b^2$ are shown in Figure B-5 for values of Brooks' n equal to 0, 1, and 4/3. For example, if b = 100 ft and t = 9,000 sec (2.5 h), then $\varepsilon_o = 0.464$ ft²/sec and $12\varepsilon_0 t/b^2 = 5.0$. Assuming that Brooks' n = 1, then use of Figure B-5 shows that $D_s = 4.3$ approximately.

The figure also reveals that the predicted dilutions are substantially different, depending on the relationship obeyed by the lateral diffusion coefficient. In some instances, the Brooks' n = 1 law might overestimate subsequent dilution, even if the outfall is in coastal waters. To attain the subsequent dilutions predicted at large travel times, a large amount of dilution water

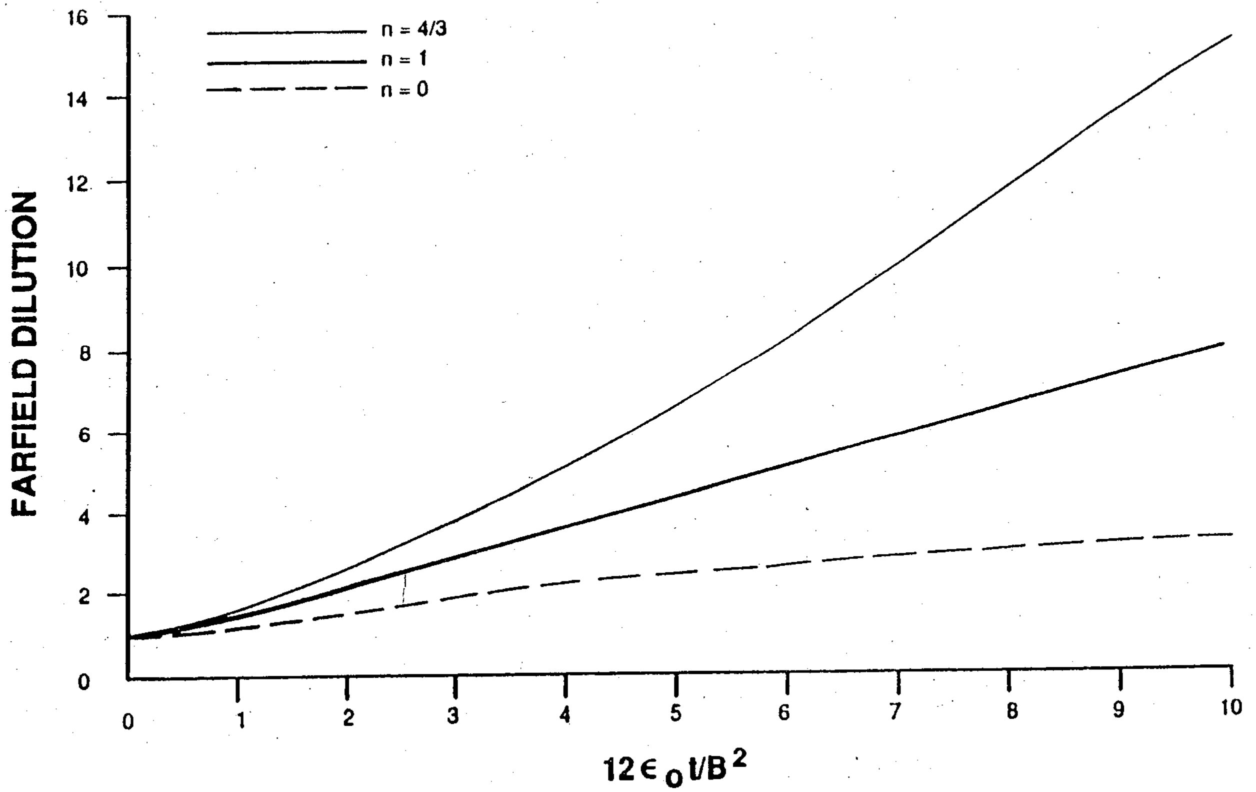


Figure B-5. Farfield dilution as a function of $12\varepsilon_o t/B^2$ (Brooks, 1960).

must be available. Because many outfalls, particularly small ones, are not far from shore, the entrainment rate of dilution water can be restricted by the presence of the shoreline and the depth of the water. As the wastefield widens substantially, the rate of entrainment could decrease, and neither the Brooks' n = 4/3 nor the Brooks' n = 1 law may be obeyed. It is suggested that applicants be conservative and base subsequent dilution on a constant lateral diffusion coefficient (i.e., Brooks' n = 0) rather than the Brooks' n = 1 or Brooks' n = 4/3 laws. However, if the applicant can show that the 4/3 law (or some other relationship) is applicable to the discharge site, then that relationship should be used.

If the applicant's discharge is near the mouth of a wide estuary, the approach just discussed can be used directly to predict oxygen depletion. If, however, the applicant discharges into a long, narrow estuary, then it is likely that the sides of the estuary will limit the lateral dilution that is attainable. Under these conditions, the maximum dissolved oxygen deficit with respect to saturation can be predicted as:

$$D = \frac{kw}{A(k_2-k)}\left[\frac{1}{\sqrt{4kE_L}} - \frac{1}{\sqrt{4K_2E_L}}\right] \qquad \text{B-22}$$

where:

D = Dissolved oxygen deficit
A = Cross-sectional area of the estuary near the discharge site
k = CBOD decay rate constant
k_2 = Reaeration rate constant
E_L = Longitudinal dispersion coefficient
W = Mass loading rate of CBOD.

The applicant can predict the deficits due to NBOD by using the appropriate k and W values and adding the two deficits to obtain the total. With reasonable values for the constants, the total dissolved oxygen deficit for discharge to narrow estuaries becomes:

$$D = \frac{(3.14\ W_c + 2.55\ W_n)\ 10^{-4}}{A} \qquad \text{B-23}$$

where:

A = Cross-sectional area in m^2

W_c = Mass emission rate of CBOD, g/day
W_n = Mass emission rate of NBOD, g/day
D = Dissolved oxygen deficit, mg/L.

The NBOD term can be added when data are available.

NUMERICAL MODELS

Numerical models are an acceptable method of predicting oxygen depletion caused by a discharge. Numerical models may consider the combined effect of farfield demand in the water column, as discussed above, and the oxygen demand associated with organic sediments. If not, the applicant may have to augment the numerical modeling analysis to address unanswered questions associated with sediment oxygen demand.

The applicant should try to isolate the impact of the outfall on dissolved oxygen concentrations by considering that the applicant's discharge is the sole source of oxygen depletion in the system being modeled. The applicant can then predict the dissolved oxygen depletion caused by the discharge by subtracting the background dissolved oxygen level from those predicted by the model. This approach also simplifies the applicant's analysis because data from other wastewater sources are not required.

Specific guidelines can be offered to applicants that choose to use numerical models. Typically, the most severe dissolved oxygen depletion due to BOD exertion occurs when the water column is density-stratified in the presence of tidally reversing currents and low nontidal currents, and the wastefield remains submerged following initial dilution. If such conditions occur at the applicant's outfall site, then the numerical model should be layered vertically, with a minimum of two layers. The plume should be discharged into the bottom layer to simulate the submerged discharge, with the consequence that direct atmospheric reaeration is not present in this layer.

The applicant should set up the grid system for the numerical model such that the smallest segments are located in the vicinity of the diffuser and gradually increase in size with distance from the diffuser. The volume of the segments in the immediate vicinity of the diffuser should approximate the volume of the ZID to prevent an initial dilution that is artificially high and that would cause the model to underestimate dissolved oxygen depletion. The applicant might choose to experiment with grid configuration by starting with a coarse grid and then decreasing grid size until the model results do not significantly change.

A steady-state numerical model is acceptable for the dissolved oxygen analysis because dynamic or unsteady analyses are generally more costly, are more difficult to implement, and require more data. The applicant should consider, however, whether intratidal variations can cause more severe depletions than are predicted by a steady-state model that calculates average oxygen depletions over a tidal cycle. Slack tide, for example, might be critical because oxygen-demanding materials can accumulate in the vicinity of the discharge. For existing discharges, the applicant might want to augment the steady-state modeling analysis by an abbreviated sampling program to determine dissolved oxygen depletions during slack-tide periods within a tidal cycle. Intratidal variations are likely to be more important in enclosed estuaries than along open coastal areas.

EVALUATION OF FIELD DATA

Extensive field data collection and analysis are required to fully implement this third approach. Limited samples of water column dissolved oxygen may be inadequate to demonstrate compliance with standards under critical conditions. Limited information should be supplemented with analyses based on numerical or simplified mathematical modeling.

These statements should not discourage applicants from collecting and submitting dissolved oxygen data from the vicinity of an existing discharge. To the contrary, such data, if available, should be submitted, particularly if the section 301(h) application is for a current discharge or for an improved or altered discharge at the same location. However, the data might reveal only a portion of the impact of the wastefield for the following reasons:

- The location of the maximum oxygen depletion might not be sampled.

- The sampling program could have been conducted during a period that was not critical with respect to the discharge or receiving water conditions. Critical discharge conditions are usually associated with high effluent BOD and high volumetric flow rates. Critical receiving water conditions are usually associated with minimum initial dilutions (maximum density stratification), maximum water temperatures, and possibly slack-tide or low nontidal current conditions.

- Ambient dissolved oxygen concentrations can vary spatially and temporally because of conditions unrelated to the discharge (e.g., upwelling effects). Consequently, dissolved oxygen depletions associated with the discharge can be masked by background variability.

Some applicants might have access to dissolved oxygen demand data collected adjacent to another outfall at a nearby coastal area and attempt to use those data to show that their own discharge will not violate dissolved oxygen standards. This approach can be, but is not always, reliable. The applicants should include in the application sufficient information such that the data collection program for the nearby area can be reviewed, and should then show that the predicted dissolved oxygen depletions are the maximum likely to be produced at the nearby discharge site. The applicant should also demonstrate that the results of the nearby discharge can be extrapolated to the applicant's discharge. Essentially, the dissolved oxygen depletion at the adjacent discharge (due to both BOD utilization and sediment oxygen demand) will need to be at least as severe as that at the applicant's discharge.

B-IV. SEDIMENT OXYGEN DEMAND

The oxygen depletion due to a steady sediment oxygen demand can be predicted by:

$$\Delta DO = \frac{\bar{S}_B X_M}{86{,}400\ UHD} = \frac{a\,\bar{S}\,k_d\,X_M}{86{,}400\ UHD} \qquad \text{B-24}$$

where:

ΔDO = Oxygen depletion, mg/L
$\bar{S}_B$ = Average benthic oxygen demand over the deposition area, g O_2/m^2/day
X_M = Length of deposition area (generally measured in longshore direction), m
H = Average depth of water column influenced by sediment oxygen demand, measured above bottom, m
U = Minimum sustained current speed over deposition area, m/sec
k_d = Sediment decay rate constant, 0.01/day
a = Oxygen:sediment stoichiometric ratio, 1.07 mg O_2/mg sediment
$\bar{S}$ = Average concentration of deposited organic sediments over the deposition area, g/m^2
D = Dilution caused by horizontal entrainment of ambient water as it passes over the deposition area (always $\geq$ 1).

Both $\bar{S}$ and X_M can be determined from the analysis performed in Chapter B-I, Suspended Solids Deposition. Figure B-3 in that chapter shows an example plot of seabed deposition. For that example, an estimate of $\bar{S}$ is the average of the maximum and minimum values, or

$$\frac{100 + 5}{2} = 52\ g/m^2 \qquad \text{B-25}$$

The distance X_M, measured parallel to the coast and within the 5-g/m^2 contour, is 8,000 m.

The depth of water affected by the sediment oxygen demand is not really a constant value (as suggested by the previous formula) but varies as a function of the travel time across the zone of deposition. The affected depth H (in meters) is chosen to represent the average depth influenced by the sediment oxygen demand and can be estimated as:

$$H = 0.8 \left(\frac{\varepsilon_Z X_M}{U} \right)^{1/2} \qquad \text{B-26}$$

where:

ε_z = Vertical diffusion coefficient (cm^2/sec).

For the example case where $U = 3$ cm/sec, $X_M = 8{,}000$ m, and $\varepsilon_z = 1$ cm^2/sec,

$$H = 0.8 \times \left(\frac{1 \times 8{,}000 \times 100}{3} \right)^{1/2} \times \frac{1}{100}\ m = 4.1\ m \qquad \text{B-27}$$

If the applicant desires to compute a value of vertical diffusivity, the following empirical expression can be used:

$$\varepsilon_Z = \frac{10^{-4}}{\frac{1}{\rho}\frac{d\rho}{dz}} \qquad \text{B-28}$$

where:

ε_z = Vertical diffusion coefficient, cm^2/sec
ρ = Ambient water density, kg/m^3 (1,024)
$\frac{d\rho}{dz}$ = Ambient density gradient, kg/m^4.

The density gradient used should reflect the most severe stratification condition that is likely to occur during the critical period.

The dilution D that is used in Equation B-24 can be obtained from Table B-5, where the field width is the width of the deposition area. For the appropriate travel time and field width, the smaller of the two estimates shown in the table should be used.

In Chapter B-I (Suspended Solids Deposition), the applicant is asked to compute the long-term accumulation and the critical 90-day accumulation. Because the critical 90-day accumulation might exceed the long-term average, the applicant should use the more critical case when predicting sediment oxygen demand.

TABLE B-5. SUBSEQUENT DILUTIONS[a] FOR VARIOUS INITIAL FIELD WIDTHS AND TRAVEL TIMES

Travel	Initial Field Width (ft)					
Time (h)	10	50	100	500	1,000	5,000
0.5	2.3/5.5	1.5/2.0	1.3/1.6	1.0/1.1	1.0/1.0	1.0/1.0
1.0	3.1/13	2.0/3.9	1.6/2.6	1.2/1.3	1.1/1.1	1.0/1.0
2.0	4.3/32	2.7/8.5	2.2/5.1	1.4/1.9	1.2/1.5	1.0/1.0
4.0	6.1/85	3.7/21	3.0/11	1.9/3.5	1.5/2.3	1.1/1.2
8.0	8.5/>100	5.2/53	4.1/29	2.5/7.3	2.0/4.4	1.4/1.7
12	10/>100	6.3/95	5.1/50	3.0/12	2.4/6.8	1.6/2.3
24	15/>100	8.9/>100	7.1/100	4.2/30	3.4/16	2.1/4.4
48	21/>100	13/>100	10/>100	5.9/80	4.7/41	2.8/10
72	26/>100	15/>100	12/>100	7.3/>100	5.8/73	3.4/17
96	29/>100	18/>100	14/>100	8.4/>100	6.6/100	3.9/24

[a] The dilutions are entered in the table as N_1/N_2, where N_1 is the dilution assuming a constant diffusion coefficient and N_2 is the dilution assuming the 4/3 law.

Oxygen Demand Due to Resuspension of Sediments

It is more difficult to accurately predict oxygen demand due to resuspension than that due to either farfield BOD decay or a steady sediment oxygen demand. To simplify the analysis, the approach here considers a worst-case situation. The amount of sediment to be resuspended is equal to the critical 90-day accumulation, which is found using the methods discussed in the above guidance on suspended solids deposition (Chapter B-I).

For the material to remain suspended, the ambient current speed has to be sufficiently great that the volume of water containing the resuspended material increases over time as ambient water is entrained. It is assumed that this process continues for up to 24 hours.

The applicant should compute the oxygen depletion as a function of time during this period. This can be done using the following relationship:

$$\Delta DO = \frac{\bar{S}_r}{DH}\left[\,1-\exp\left(\frac{-k_r t}{24}\right)\right] \tag{B-29}$$

where:

ΔDO = Oxygen depletion, mg/L
$\bar{S}_r$ = Average concentration (in g/m^2) of resuspended organic sediment (based on 90-day accumulation)
H = Depth of water volume containing resuspended materials, m
k_r = Decay rate of resuspended sediments, 0.1/day
t = Elapsed time following resuspension, h (t varies from 0 to 24 h)
D = Dilution as defined previously (generally set equal to 1).

The variable H is a function of travel time and can be predicted from:

$$H = \frac{1.6}{100}\left(3{,}600\ t\ \varepsilon'_z\right)^{1/2} \tag{B-30}$$

where:

ε'_z = Vertical diffusion coefficient when resuspension is occurring (5 cm^2/sec)
t = Elapsed time following resuspension, h.

The applicant should check to be sure that H does not exceed the water depth. If it does, H should be set equal to the water depth.

The concentration of resuspended sediments $\bar{S}_r$ can be approximated as the average concentration over the width of the zone of deposition. This can be determined directly from the contour plots of sediment accumulation, developed in response to the guidance on suspended solids deposition in Chapter B-I.

The applicant should calculate ΔDO for 3-hour increments for a period of up to 24 hours. The results can be tabulated as shown below. Data and calculations should be included in the application.

t (h)	DO (mg/L)
0	0
3	↓
6	
9	
12	
15	
18	
21	
24	predictions

Most often, a maximum depletion will occur somewhere in the 24-hour period, with depletions decreasing for larger travel times.

B-V. SUSPENDED SOLIDS CONCENTRATION FOLLOWING INITIAL DILUTION

The concentration of suspended solids at the completion of initial dilution should be calculated using the following equation:

$$SS_f = SS_a + \frac{SS_e - SS_a}{S_a} \qquad \text{B-31}$$

where:

SS_f = Suspended solids concentration at completion of initial dilution, mg/L
SS_a = Affected ambient suspended solids concentration immediately upcurrent of the diffuser averaged over one-half the tidal period (12.5 hours) and from the diffuser port depth to the trapping level, mg/L
SS_e = Effluent suspended solids concentration, mg/L
S_a = Initial dilution (flux-averaged).

The maximum change, DS, due to the effluent can be computed as follows:

$$\Delta S = SS_e/S_a \qquad \text{B-32}$$

where the terms are as defined above. Equation B-32 is appropriate as long as the effluent suspended solids concentration is much greater than the background concentration. During spring runoff in some estuaries, the background suspended solids concentration may exceed the effluent concentration. In these cases, the final suspended solids concentration will be below the background concentration.

EPA requires data for periods of maximum stratification and for other periods when discharge characteristics, oceanographic conditions, water quality, or biological seasons indicate that more critical situations exist. The critical period generally occurs when water quality standards are most likely to be violated. If the standard is expressed as a maximum numerical limit, the critical period would be when the background concentrations are highest and the initial dilution is low. If the standard is expressed as a numerical difference from background, the critical period would be when effluent concentrations are high and initial dilution low. When the standard is expressed as a percent difference from background, the critical period could occur when background concentrations are low.

Because effluent suspended solids concentrations can vary with discharge flow rate, the concentration at the completion of initial dilution should be computed for the minimum, average dry- and wet-weather, and maximum flow rates, using the associated suspended solids concentration. The range and average effluent concentrations should be provided in the application by month, unless locally applicable standards require compliance over shorter durations. This information should be available from operating records.

The selection of an appropriate background suspended solids concentration may be difficult because of a general lack of data. A common problem for coastal sites is that measurements may be available only at the mouths of large rivers. Concentrations are often higher at such locations than farther offshore because of the solids contribution from runoff. Selected values of background suspended solids concentrations are shown in Table B-6. Suspended solids background data should be obtained at control stations, at the ZID boundary of the existing discharges, and at stations between the ZID-boundary and control stations. Data should be collected over the tidal cycle and at several depths so the average concentration over the height-of-rise of the plume over the tidal cycle can be calculated. This value should be used in Equation B-31.

Compliance with the water quality standard can be determined directly if the standard is expressed in the form of suspended solids concentrations. If only a general standard exists, the

TABLE B-6. SELECTED BACKGROUND SUSPENDED SOLIDS CONCENTRATIONS

Water Body	Suspended Solids Concentration, mg/L
Cook Inlet, AK	250-1,280
Southern California Bight	0.7-60
Pacific Ocean near San Francisco, CA	1-33
Broad Sound, MA	18.6-25.2
Massachusetts Bay near South Essex	1.2-30.5
New Bedford Harbor, MA	0.4-6.1
East River, NY	6.0-25.6
Ponce, PR (near shore)	13.5
Puget Sound, WA	0.5-2.0
Outer Commencement Bay, Tacoma, WA	33-51
Commencement Bay near Puyallup River, WA	23-136
Tacoma Narrows, WA	33-63

Note: Data are from 301(h) applications.

maximum increase due to the effluent should be computed. If the increase is less than 10 percent, then no substantial effect in the water column is likely. However, seabed deposition could still be substantial, depending on the mass emission rate of suspended solids and ambient currents at the discharge site, and thus should be evaluated.

The water quality standards may also specify limitations on the level of suspended solids removal. For example, California has a requirement that 75 percent of the solids entering POTWs must be removed. Compliance with this standard can be determined by estimating the average removal efficiency for each month based on the average monthly influent and effluent suspended solids concentrations. The removal efficiency should be equal to or greater than the required percentage in all months. The applicant should include the monthly average influent and effluent suspended solids concentrations along with the computed removal efficiencies.

B-VI. EFFLUENT pH AFTER INITIAL DILUTION

The calculation of effluent pH following initial dilution is chemically more sophisticated than other chemical calculations in this document. This chapter details the basis for Table 1 in the main text showing the ranges of probable effluent pH following initial dilution. The method for calculating effluent pH following initial dilution, assuming that all of the required variables are known, is described herein. These variables include initial dilution and the temperature, salinity, pH, and alkalinity of the effluent and the receiving water. Effluent and receiving water temperature, salinity, and pH are normally measured. The initial dilution (usually critical) is routinely calculated as part of either the section 301(h) waiver application process or the section 301(h) permit renewal process; however, neither the alkalinity of the receiving water nor that of the effluent is usually measured. The alkalinity of seawater is relatively constant, however, at a value of 2.3 meq/L (Stumm and Morgan 1981). The alkalinity of effluent varies from 0.1 to 6.0 meq/L.

The method described herein predicts pH at the completion of initial dilution of an effluent-receiving water mixture. Because the initial dilution process occurs over a short time period, mixing is considered to occur in a closed system. Also, in stratified receiving waters, the wastewater plume is often trapped below the surface. Thus, the plume does not equilibrate with the atmosphere, and carbon dioxide exchange between the atmosphere and mixture is considered negligible. This method is useful for the calculation of pH, alkalinity, and total inorganic carbon concentration in the plume after initial dilution.

The pH of the effluent receiving water mixture is calculated using the equations for aqueous carbonate equilibrium in a closed system (Stumm and Morgan 1981). For this condition, the five equations that describe the relationships between pH, the carbonate species, and alkalinity are:

$$[H^+]\left[HCO_3^-\right] / \left[H_2CO_3^*\right] = K_1 \tag{B-33}$$

$$[H^+]\left[CO_3^{2-}\right] / \left[HCO_3^-\right] = K_2 \tag{B-34}$$

$$[H^+]\,[OH^-] = K_W \tag{B-35}$$

$$C_T = \left[H_2CO_3^*\right] + \left[HCO_3^-\right] + \left[CO_3^{2-}\right] \tag{B-36}$$

$$Alkalinity = \left[HCO_3^-\right] + 2\left[CO_3^{2-}\right] + \left[OH^-\right] - \left[H^+\right] \tag{B-37}$$

where:

$[H_2CO_3^*]$ = The sum of aqueous CO_2 and true H_2CO_3 concentrations
C_T = Total carbonate concentration.

The carbonate species can also be expressed in terms of ionization fractions α_0, α_1, and α_2:

$$\left[H_2CO_3^*\right] = C_T \, \alpha_0 \tag{B-38}$$

$$\left[HCO_3^-\right] = C_T \, \alpha_1 \tag{B-39}$$

$$\left[CO_3^{2-}\right] = C_T \, \alpha_2 \tag{B-40}$$

where:

$$\alpha_0 = \left[1 + \frac{K_1}{[H^+]} + \frac{K_1 K_2}{[H^+]^2}\right]^{-1} \tag{B-41}$$

$$\alpha_1 = \left[1 + \frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]}\right]^{-1} \tag{B-42}$$

$$\alpha_2 = \left[\frac{[H^+]^2}{K_1 K_2} + \frac{[H^+]}{K_2} + 1\right]^{-1} \tag{B-43}$$

Substituting the hydroxide-hydrogen ion relationship and ionization fractions into the alkalinity equation yields:

$$Alkalinity = C_T \left(\alpha_1 + 2\alpha_2\right) + \frac{K_W}{[H^+]} - [H^+] \tag{B-44}$$

Because total carbonate is conserved and α_1 and α_2 are functions solely of pH, the above equation has only one variable: hydrogen ion concentration. The model solves the equation to determine the pH of the effluent-receiving water mixture. The steps involved in the calculations are listed below:

- Determine input data.

- Calculate ion product of water, K_w, and carbonate dissociation constants, K_1 and K_2, of the effluent and receiving water based on temperature and salinity data.

- Check consistency between alkalinity and pH of both effluent and receiving water.

- Calculate total carbonate in effluent and receiving water separately.

- Calculate total carbonate, alkalinity, salinity, and temperature of the effluent-receiving water mixture following initial dilution (based on proportions of effluent and receiving water).

- Calculate K_w, K_1, and K_2 for the effluent-receiving water mixture following initial dilution.

- Use a stepping procedure to find pH based on the computed values for total carbonate and alkalinity of the effluent-receiving water mixture.

- Record results.

The ion product and dissociation constants are calculated for the appropriate temperature and salinity based on the equations given below. The equations for the receiving water have been revised so that salinity (in ppt) can be used.

For effluent:

$$pK_1 = \frac{3{,}407.7}{T} + 0.03279T - 14.8435 \quad \text{(Kelts and Hsu 1978, p. 300)} \qquad \text{B-45}$$

$$pK_2 = \frac{2{,}902.4}{T} + 0.02379T - 6.498 \quad \text{(Kelts and Hsu 1978, p. 300)} \qquad \text{B-46}$$

$$pK_w = \frac{4{,}471.0}{T} + 0.01706T - 6.0875 \quad \text{(Stumm and Morgan 1981, p. 127)} \qquad \text{B-47}$$

For receiving water and the effluent-receiving water mixture:

$$pK_1 = \frac{3,404.7}{T} + 0.03279T - 14.712 - 9.1575S^{1/3}$$

(Stumm and Morgan 1981, p. 205) B-48

$$pK_2 = \frac{2,902.4}{T} + 0.02379T - 6.471 - 0.3855S^{1/3}$$

(Stumm and Morgan 1981, p. 206) B-49

$$pK_w = \frac{3,441.0}{T} + 2.241 - 0.0925S^{1/2}$$

(Dickson and Riley 1979, p. 97) B-50

where:

T = Temperature in degrees Kelvin
S = Salinity in ppt.

The receiving water equations are valid for salinities down to about 10 ppt.

B-VII. LIGHT TRANSMITTANCE

Increased suspended solids concentrations associated with municipal discharges can cause a decrease in light penetration within the water column. Reductions in light penetration can result in a decrease in phytoplankton productivity, as well as a reduction in the areal distribution of attached macroalgae such as kelp. Therefore, several states have enacted regulations governing the allowable levels of interference with light transmittance.

The evaluation of light transmittance may require the measurement of one or more water clarity variables and a comparison of values recorded in the vicinity of the outfall with those recorded in control areas. Variables that are widely measured to assess light transmittance include turbidity, Secchi disc depth, beam transmittance, and downward irradiance. While many of the state requirements are very specific in terms of the light transmittance measurements, others leave the selection of the sampling methods to the discretion of the applicant.

Turbidity is a measure of the optical clarity of water, and many standards are written in terms of nephelometric turbidity units (NTU). Measurements are made with a nephelometer, which provides a comparison of the light-scattering characteristics of the sample with a standard reference. Differences in the optical design of nephelometers can cause differences in measured values even when calibrated against the same turbidity standard. For this reason, caution must be exercised when comparing measurements of turbidity made from different field sampling programs.

A Secchi disc is used to make visual observations of water clarity. Records of the depth at which the Secchi disc is just barely visible can be used to make comparisons of light transmittance among sampling sites. Measurements of Secchi disc depth are probably the most widely used means of estimating light penetration. The Secchi disc is easy to use, is accurate over a wide range of conditions, and can be used to estimate the attenuation coefficients for collimated and diffuse light and, therefore, to estimate the depth of the euphotic zone. Since a wastewater plume can be held below the upper regions of this zone during periods of stratification, however, Secchi disc measurements may not be appropriate under all conditions.

Beam transmittance is measured with a transmissometer and is a measure of the attenuation of a collimated beam of artificial light along a fixed path length (usually 1 m). The attenuation is caused by suspended and dissolved material as well as the water itself. These measurements, therefore, provide information about both the absorption and scattering properties of the water. The attenuation of a collimated beam of light in a water path is described by the Beer-Lambert law:

$$T_d = e^{-\alpha d} \qquad \text{B-51}$$

where:

T_d = The proportion of light transmitted along a path of length d, m
α = Light attenuation coefficient, m^{-1}.

Measurements of beam transmittance are made *in situ* at any depth.

The intensity and attenuation of daylight penetration are measured with an irradiance meter, which uses a photovoltaic cell to record incident light levels. Measurements are made just below the surface and at selected depth intervals throughout the water column so that light attenuation over specific depths can be determined. Unlike beam transmittance measurements, irradiance measurements are influenced by sunlight as well as surface conditions.

Empirical relationships can be derived among the light transmittance variables measured by these methods, which permits the estimation of one based on recorded values of another. These values can also be predicted from suspended solids concentrations. The derivation of these relationships from existing data, in some instances, may be sufficient to allow for the demonstration of compliance with state standards. Existing data can also be used to predict the transparency characteristics in the vicinity of an improved discharge. Alternatively, a sampling program can be designed to assess compliance with light transmittance standards based on such empirical relationships.

Where standards are written in terms of maximum allowable turbidity or turbidity increase, predicted turbidity in the receiving water at the completion of initial dilution can be used to demonstrate compliance. By treating turbidity as a conservative variable, the turbidity in the receiving water at the completion of initial dilution can be predicted as:

$$T_f = T_a + \frac{T_e - T_a}{S_a} \qquad \text{B-52}$$

where:

T_f = Turbidity in receiving water at the completion of initial dilution, typically NTU or Jackson turbidity units (JTU)
T_a = Ambient or background turbidity

T_e = Effluent turbidity
S_a = Initial dilution.

Initial dilution can be predicted based on the methods presented in Appendix A. Equation B-52 can be used, then, to directly evaluate compliance with standards written in terms of maximum allowable turbidity or a turbidity increase.

Laboratory experimental work can also be used in lieu of field sampling to demonstrate compliance with standards written in terms of an allowable turbidity increase. These analyses consist of determining the turbidity of a seawater-effluent mixture prepared in proportions corresponding to the predicted concentrations following initial dilution. Experiments should be conducted to simulate worst-case conditions. Simulations of expected receiving water turbidity should be made for periods of highest effluent turbidity (greatest suspended solids concentrations) as well as lowest initial dilutions. Values of the initial turbidity of the seawater, the effluent mixture, and the simulated dilution should accompany all test results.

By deriving a relationship between turbidity and Secchi depth and using the method of prediction for turbidity in the receiving water following initial dilution (Equation B-52), compliance with state standards written in terms of Secchi depth can be evaluated. Secchi depth and turbidity can be related in the following manner. Assume that the extinction coefficient of visible light (α) is directly proportional to turbidity (T) and inversely proportional to Secchi depth, or:

$$\alpha = k_1 T \qquad \text{B-53}$$

and

$$\alpha = \frac{k_2}{SD} \qquad \text{B-54}$$

where k_1 and k_2 are constants that need not be specified since they cancel out in further calculations. These two relationships have theoretical bases, as discussed in Austin (1974) and Graham (1966). Combining those two expressions, the relationship between Secchi depth and turbidity becomes:

$$T = \left(\frac{k_2}{k_1}\right)\left(\frac{1}{SD}\right) \qquad \text{B-55}$$

When state standards are written in terms of Secchi depth, it is convenient to combine Equations B-52 and B-55 to yield:

$$\frac{1}{SD_f} = \frac{1}{SD_a} + \frac{\frac{1}{SD_e} - \frac{1}{SD_a}}{S_a} \qquad \text{B-56}$$

or

$$SD_e = \left[\left(\frac{1}{SD_f} - \frac{1}{SD_a}\right) S_a + \frac{1}{SD_a}\right]^{-1} \qquad \text{B-57}$$

where:

SD_f = Minimum allowable Secchi disc reading in receiving water such that the water quality standard is not violated

SD_a = Ambient Secchi disc reading

S_a = Minimum initial dilution that occurs when the plume surfaces

SD_e = Critical Secchi disc depth of effluent.

In this manner, the critical effluent Secchi depth (SD_e) can be calculated. An effluent reading higher than this value indicates that standards will not be violated. This method of predicting the final Secchi depth in the receiving water can be used to provide an estimate of the effect of the wastewater discharge on the receiving water. This method should be used only where the standard is exclusively in terms of the acceptable decrease in the Secchi depth.

Values of the critical effluent Secchi depth (SD_e) calculated using Equation B-57 are presented in Table B-7. In this example, the water quality standard for the minimum Secchi visibility is 1 m (3.3 ft). Effluent having a Secchi depth greater than those presented for the selected ambient conditions and initial dilution will not violate the clarity standard of the example receiving water. Primary effluents typically have Secchi disc values of 5-30 cm (2-12 in). For this case, with an initial dilution greater than 40 and an ambient Secchi depth of 2 m (6.6 ft) or greater, these calculations indicate that the standard would not be violated.

TABLE B-7. CALCULATED VALUES FOR THE CRITICAL EFFLUENT SECCHI DEPTH (cm) FOR SELECTED AMBIENT SECCHI DEPTHS, INITIAL DILUTIONS, AND A WATER QUALITY STANDARD FOR MINIMUM SECCHI DISC VISIBILITY OF 1 m

Initial Dilution	Ambient Secchi Depth (m)				
	2	3	4	5	10
10	18	14	13	12	11
20	10	7	7	6	6
40	5	4	3	3	3
60	3	2	2	2	2
100	2	1	1	1	1

Since Secchi disc measurements are made from the water surface downward, critical conditions (in terms of the Secchi disc standard) will occur when the initial dilution is just sufficient to allow the plume to surface. It is notable that maximum turbidity or light transmittance impacts of a wastewater plume will occur when the water column is stratified, the plume remains submerged, and initial dilution is at a minimum. Under these same conditions, however, Secchi disc readings might not be altered at all if the plume is trapped below the water's surface at a depth exceeding the ambient Secchi disc depth.

The ability to relate measurements of turbidity to the attenuation coefficient (α) for collimated light has been demonstrated by Austin (1974). The attenuation coefficient can be expressed in terms of turbidity as:

$$\alpha = k \times JTU \qquad \text{B-58}$$

where:

JTU = Turbidity, JTU
k = Coefficient of proportionality.

Combining Equations B-51 and B-58, turbidity can be expressed as:

$$JTU = \frac{-\ln T_d}{kd} \qquad \text{B-59}$$

where:

T_d = Fraction of beam transmittance over distance d.

The coefficient of proportionality (k) takes on values 0.5-1.0. Therefore, to use these relationships to demonstrate compliance with a turbidity standard based on existing light transmittance data, the value of k must be determined empirically. This requires simultaneous measurements of beam transmittance and determination of turbidity covering the complete range of existing light transmittance records. If data are not available, the k value can be set equal to 1 as a conservative estimate.

Where a relationship between suspended solids concentration and beam transmittance data at a particular site can be derived, the suspended solids concentration at the completion of initial dilution from Equation B-31 can be used to predict compliance with standards written in terms of light transmittance.

B-VIII. OTHER WATER QUALITY VARIABLES

Other variables for which water quality standards may exist include total dissolved gases, coliform bacteria, chlorine residual, temperature, salinity, radioactivity, and nutrients. Variables concerned with aesthetic effects that also may be included are color, floating material, taste and odor, and hydrocarbons (i.e., grease and oil). For most dischargers, temperature, salinity, and radioactivity standards are unlikely to be violated. Aesthetic effects are more likely to occur when the plume surfaces and the dilution is low. Compliance with aesthetic standards can best be checked by field observations at the discharge site and along the shore.

TOTAL DISSOLVED GASES

Several states have a limit for total dissolved gases of 110 percent of saturation. Supersaturation of dissolved gases is not considered to be a likely problem for municipal wastewater discharges to the marine environment and is not discussed further.

CHLORINE RESIDUAL

Chlorine residual standards may be expressed as a concentration limit in the effluent or as a maximum concentration in the receiving water at the completion of initial dilution. If the effluent is not chlorinated, no further information is required. If the standard is expressed as an effluent limit, chlorine residual data from treatment plant operating reports, or other sources, should be presented in the application. If no data are available, then the procedure for chlorination, including the compound used, quantity, and occurrence of any operational problems, should be described. If the standard is expressed as a maximum limit at the completion of initial dilution, the concentration in the receiving water, assuming the ambient concentration is 0.0 mg/L, can be estimated as follows:

$$Cl_f = Cl_e / S_a \qquad \text{B-60}$$

where:

Cl_f = Chlorine residual at completion of initial dilution, mg/L
Cl_e = Chlorine residual in effluent, mg/L
S_a = Lowest flux-averaged initial dilution.

As a worst-case approach, the maximum observed chlorine residual in the effluent should be used with the lowest dilution. If violations are predicted, the applicable water quality standard may require information on the frequency of occurrence.

NUTRIENTS

Standards can be expressed as maximum receiving water concentrations of total nitrogen or total phosphorus or as a general prohibition on amounts that would cause objectionable aquatic life. In general, for small discharges when the initial dilution is large, nutrients are not likely to cause problems. Appropriate state agencies should be contacted to ascertain whether algal blooms, red tides, or other unusual biological activity has occurred near the discharge site in the past.

Receiving water and effluent nutrient data can be used to estimate concentrations at the completion of initial dilution. For screening purposes, the nutrients can be treated as conservative variables. The concentration is estimated as follows in a manner similar to that used for suspended solids:

$$C_f = C_a + \frac{C_e - C_a}{S_a} \qquad \text{B-61}$$

where:

C_a = Affected ambient concentration immediately upcurrent of diffuser, mg/L
C_e = Effluent concentration, mg/L
S_a = Initial dilution (flux-averaged)
C_f = Concentration at the completion of initial dilution, mg/L.

The predicted concentration can then be compared to the state standard.

Because water quality criteria are often prescribed as maximum values not to be exceeded following initial dilution, it is useful to rearrange the above equation to express the maximum allowable effluent concentration as follows:

$$(C_e)\max = C_a + (S_a)\min\,(C_c - C_a) \qquad \text{B-62}$$

where:

$(C_e)_{max}$ = Maximum allowable effluent concentration such that water quality criteria are not exceeded
C_c = Applicable water quality criterion
$(S_a)_{min}$ = Minimum expected initial dilution.

The maximum observed effluent concentration can then be compared to the predicted allowable concentration. This approach can be used for any conservative constituent. Thus, if other specific limits exist such as for color, effects due to the discharge can be determined as shown in Equations B-61 and B-62.

COLIFORM BACTERIA

Standards may exist for total or fecal coliform bacteria or enterococci and are usually expressed as a mean or median bacteria count and a maximum limit that cannot be exceeded by more than 10 percent of the samples. If the effluent is continuously disinfected using chlorination or an equivalent process, analyses for coliform bacteria may be needed only to verify the effectiveness of disinfection. If disinfection is done part of the year, analyses should be representative of conditions when the effluent is not so treated. The chemicals used, quantities, and frequency of use should be provided along with a discussion of the reliability of the system.

The coliform bacteria count at the completion of initial dilution due to the discharge can be estimated as follows:

$$B_f = B_e / S_a \qquad \text{B-63}$$

where:

B_e = Effluent coliform bacteria count, MPN/100 mL
S_a = Initial dilution.

As a conservative approach, the maximum effluent count and the lowest initial dilution should be used. If onshore currents occur only during a particular season, the coliform count at the completion of initial dilution can be estimated using the lowest initial dilution appropriate for that season. Effluent coliform data should be submitted to support the applicant's values. The predicted value can be compared with the appropriate standard at the ZID boundary. This value can also be used to estimate the bacteria concentration at specific locations away from the ZID.

Because different limits may apply to specific areas (e.g., shellfish-harvesting areas, beaches, diving areas), the maximum bacteria count at a specified distance from the discharge may be of concern. This bacteria count can be estimated in a manner analogous to the estimation of the BOD exerted as the wastefield spreads out from the ZID. The maximum bacteria count at the centerline of the wastefield can be estimated as a function of distance from the discharge as follows:

$$B_x = B_a + \frac{B_f - B_a}{D_s D_b} \tag{B-64}$$

where:

B_x = Bacteria count at distance x from ZID, #/100 mL
B_a = Affected ambient bacteria count immediately upcurrent of diffuser, #/100 mL
B_f = Bacteria count at completion of initial dilution, #/100 mL
D_s = Dilution attained subsequent to initial dilution at distance x
D_b = "Dilution" due to dieoff of bacteria caused by the combined effects of exposure to seawater and sunlight.

When $x = 0$, $B_x = B_f$. In cases where the background bacteria count is negligible or the effect of the discharge alone is desired, the terms for the ambient bacteria count can be dropped, simplifying Equation B-64 to:

$$B_x = \frac{B_f}{D_s D_b} \tag{B-65}$$

Values for subsequent dilution as a function of $12\varepsilon_o t/B^2$ are shown in Figure B-5. Guidance on methods for estimating subsequent dilution for sites located in narrow estuaries or bays is included in Chapter B-III (Farfield Dissolved Oxygen Demand).

The decay rate of bacteria in the ocean is influenced by water temperature, incident light, salinity, and other factors. As a conservative estimate, the minimum decay rate should be used.

If no violations would occur, then further calculations are not needed. Flocculation and sedimentation can cause an apparent decrease in the coliform count in the water column, but the bacteria are retained in the sediment. Thus, this process is not included in the above approach. If the applicant has information indicating that the decay rate at the discharge site should be a different value, the revised decay rate may be used. The evidence for the revised decay rate, including any data or results of laboratory tests, should be included in the application.

In this report, dieoff due to the combined effects of exposure to saltwater and exposure to sunlight only are considered. The dieoff due to exposure to saltwater, D_{sw}, and the dieoff due to exposure to sunlight, D_{sl}, are (Gameson and Gould 1975):

$$D_{sw} = \exp(k_{sw} t) \tag{B-66}$$

$$D_{sl} = \exp[\alpha I(t)] \tag{B-67}$$

where:

k_{sw} = Bacteria decay rate due to exposure to saltwater, 1/h
α = Constant, m^2/MJ
I(t) = Total intensity of sunlight received by bacteria during the travel time, MJ/m^2
t = Travel time, h.

The bacteria dieoff due to the combined effects of saltwater and sunlight is $D_b = D_{sw} D_{sl}$. Gameson and Gould (1975) indicate that $\alpha = 1.24\ m^2/MJ$ *in situ* for Dorset, England, seawater. The total intensity of sunlight received at the water surface can be measured or can be estimated using site-specific data or general methods (Wallace and Hobbs 1977). If the wastefield is submerged, then the calculation of the total sunlight received should reflect the effect of turbidity on light transmission from the sea surface to the top of the wastefield.

The bacteria decay rate due to exposure to saltwater is known for both coliform bacteria and enterococcus bacteria. For coliform bacteria,

$$k_{sw} = 2.303 \exp[(0.0295T - 2.292)2.303] \ / \ h \tag{B-68}$$

where

T = water temperature (in degrees Celsius), based on-field measurements at Bridport (Dorset, England) (Gameson and Gould 1975).

The enterococcus bacteria dieoff rate due to exposure to saltwater is:

$$k_{sw} = 0.5262 \;/\; (24\ h) \qquad \text{B-69}$$

at a temperature of 20 °C (Hanes and Fragala 1967). [It should be noted that Hanes and Fragala (1967) determined that k_{sw} for coliform bacteria is 0.0424/h at 20 °C, a value slightly smaller than the value of 0.0457/h at 20 °C based on the formula from Gameson and Gould (1975).]

The estimated coliform count at the location of interest should be compared to the applicable standard. If a violation is predicted, the water quality standards may require that the approximate frequency should be discussed based on the percentage or likelihood of currents transporting the wastefield in the direction of interest.

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APPENDIX C
BIOLOGICAL ASSESSMENT

BIOLOGICAL ASSESSMENT

Because benthic infauna are sedentary and must adapt to pollutant stresses or perish, this assemblage is often used to define the spatial extent and magnitude of biological impacts in the vicinity of sewage discharges. The general changes in benthic community structure and function that occur under conditions of organic enrichment of the sediments (e.g., due to municipal sewage effluent) have been well documented (Pearson and Rosenberg 1978). Table C-1 lists biological assessment documents developed to support the activities of the 301(h) program. Slight to moderate enrichment results in slight increases in number of species, abundance, and biomass of benthic communities (see Figure 3 in main text), while species composition remains unchanged. As enrichment increases, the number of species declines because less tolerant species are eliminated. The total abundance of organisms increases as a few species adapted to disturbed environments or organically enriched sediments become very abundant. When enrichment levels are optimal for those few species, they become extremely abundant and overwhelmingly dominate the benthic community (corresponding to the "peak of opportunists" shown in Figure 3). Biomass generally decreases, however, because many of those opportunistic species are small. Further organic enrichment of the sediments drastically reduces the number of species and the abundance of benthic organisms as conditions become intolerable for most taxa.

TABLE C-1. TECHNICAL SUPPORT AND GUIDANCE DOCUMENTS FOR BIOLOGICAL ASSESSMENT

Document	EPA Document Number
Recommended biological indices for 301(h) monitoring programs.	EPA 430/9-86-002
Bioaccumulation monitoring guidance: 1. Estimating the potential for bioaccumulation of priority pollutants and 301(h) pesticides discharged into marine and estuarine waters.	EPA 503/3-50-001
Bioaccumulation monitoring guidance: 2. Selection of target species and review of available bioaccumulation data. Volume I.	EPA 430/9-86-005
Bioaccumulation monitoring guidance: 2. Selection of target species and review of available bioaccumulation data. Volume II.	EPA 430/9-86-006
Bioaccumulation monitoring guidance: 3. Recommended analytical detection limits.	EPA 503/6-90-001
Bioaccumulation monitoring guidance: 4. Analytical methods for U.S. EPA priority pollutants and 301(h) pesticides in tissue from estuarine and marine organisms.	EPA 503/6-90-002
Bioaccumulation monitoring guidance: 5. Strategies for sample replication and compositing.	EPA 430/9-87-003

Because the model developed by Pearson and Rosenberg (1978) has been shown to be valid in many benthic environments, it is often instructive to examine the abundance of species that the authors identify as opportunistic or pollution-tolerant. Those data, in conjunction with the applicant's data on numbers of species, total abundance, and biomass at stations in the vicinity of the outfall, are often sufficient to determine the relative degree of impact within and beyond the ZID.

Comparable models that describe changes in the structure and function of plankton and demersal fish communities in organically enriched receiving environments have not yet been developed. However, it may be instructive to examine the scientific literature that is available for the biogeographic region in which the outfall is located. That literature often contains information describing the responses of the local fauna and flora to organic materials and other pollutants, and identifying opportunistic and pollution-tolerant species. Such information is extremely useful for interpreting data collected in the vicinity of the outfall.

A variety of analytical tools can be used to conduct biological comparisons for section 301(h) applications. Applicants can analyze the data graphically or statistically or can use other mathematical tools such as multivariate analyses (e.g., classification and ordination procedures). Graphical analyses can be especially useful for presenting data in an easily understood format.

In Figure C-1, data on numbers of species in each replicate sample at stations in the vicinity of an outfall have been plotted to show the range of reference values in comparison with values at within-ZID, ZID-boundary, nearfield, and farfield stations. These data may be tested statistically to determine those test stations at which mean values differ from mean values at either reference station or both. Even without such tests, however, the data in Figure C-1 clearly indicate that a gradient of effects occurs near the outfall. Relative to reference conditions, numbers of species are depressed at the within-ZID and downcurrent ZID-boundary stations, and may be depressed at the nearfield and upcurrent ZID-boundary stations.

Graphical analyses are especially useful for presenting data on the physical characteristics of the habitat. For example, it is often instructive to plot water column or substrate characteristics in relation to distance from the outfall (see Figures C-2 and C-3). Gradients of effects (as in Figure C-3) are often revealed in such simple presentations. An especially useful method for presenting data on sediment grain size distributions that has proven useful in analyses of 301(h) data was developed by Shepard (1954). Sediments are classified by the proportions of their three major grain-size categories (Figure C-4). Sand, silt, and clay are often the most useful categories. However, the gravel, sand, and mud (silt plus clay) categories are useful where sediments are relatively coarse. [See Shepard (1963) for information on sediment grain size scales.]

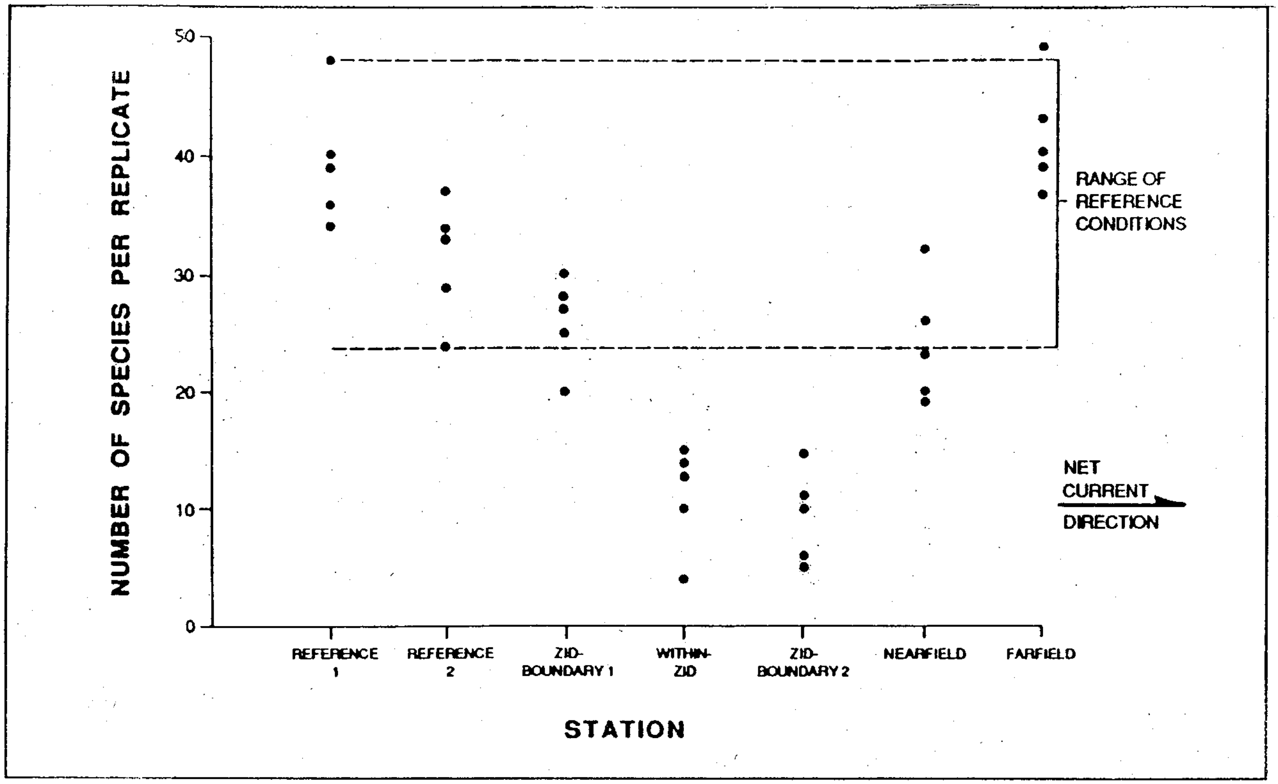

Figure C-1. Number of species collected in replicate grab samples at stations in the vicinity of the outfall.

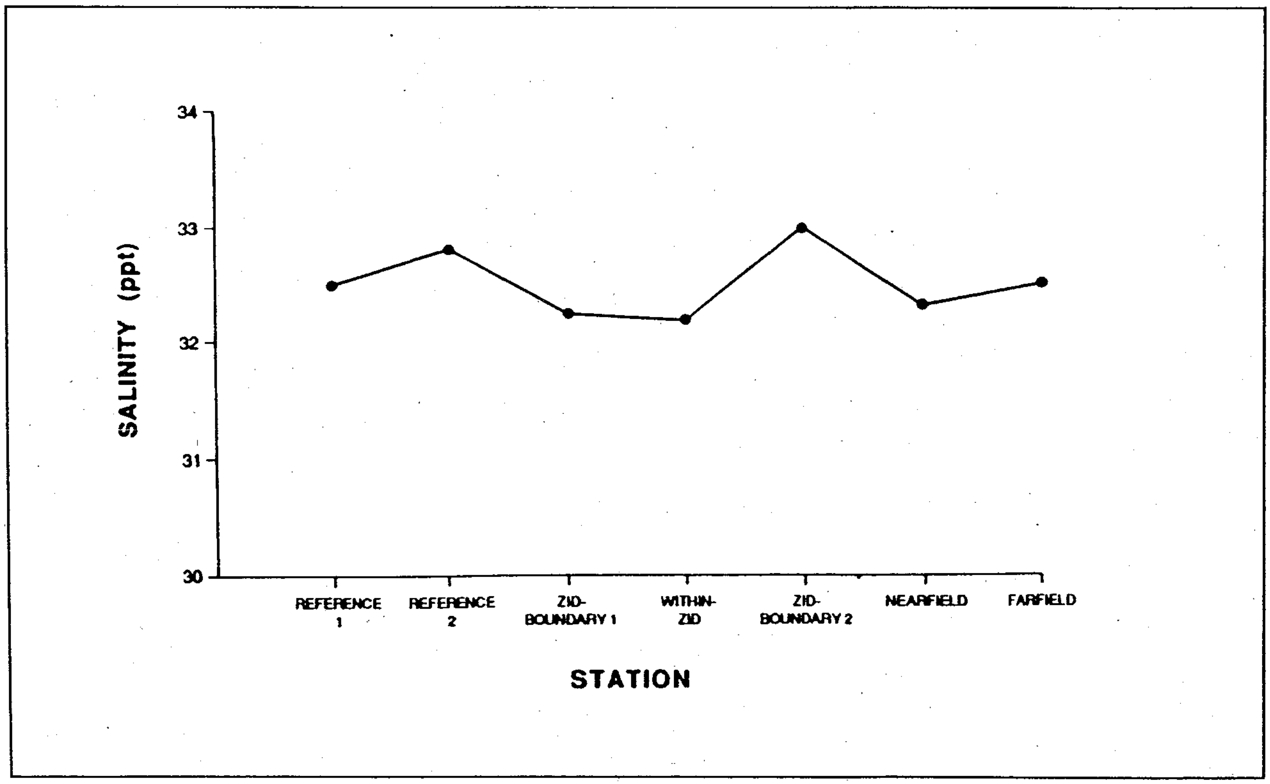

Figure C-2. Salinity at stations in the vicinity of the outfall.

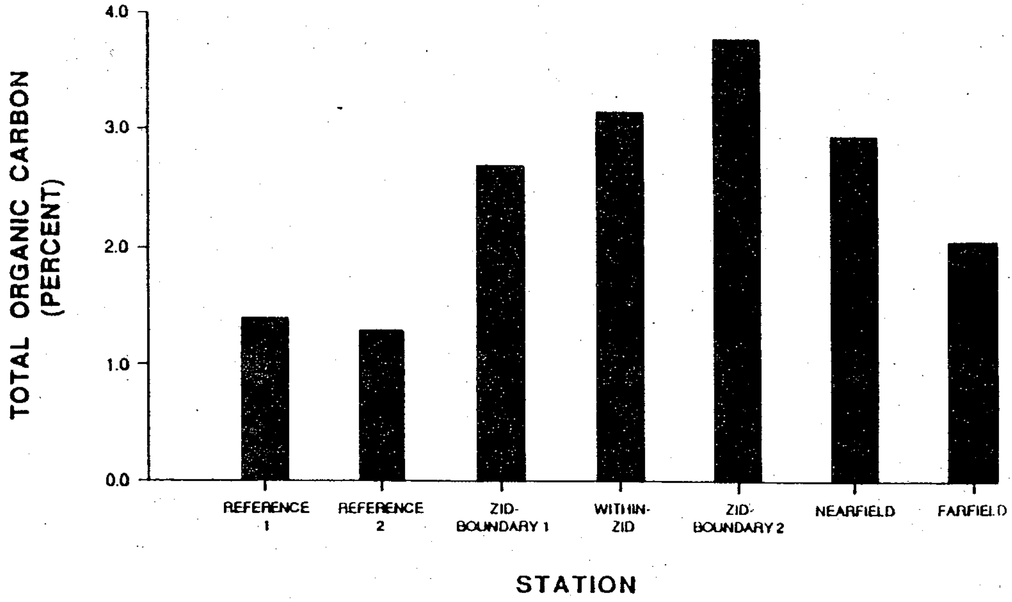

Figure C-3. Total organic carbon content of the sediments at stations in the vicinity of the outfall.

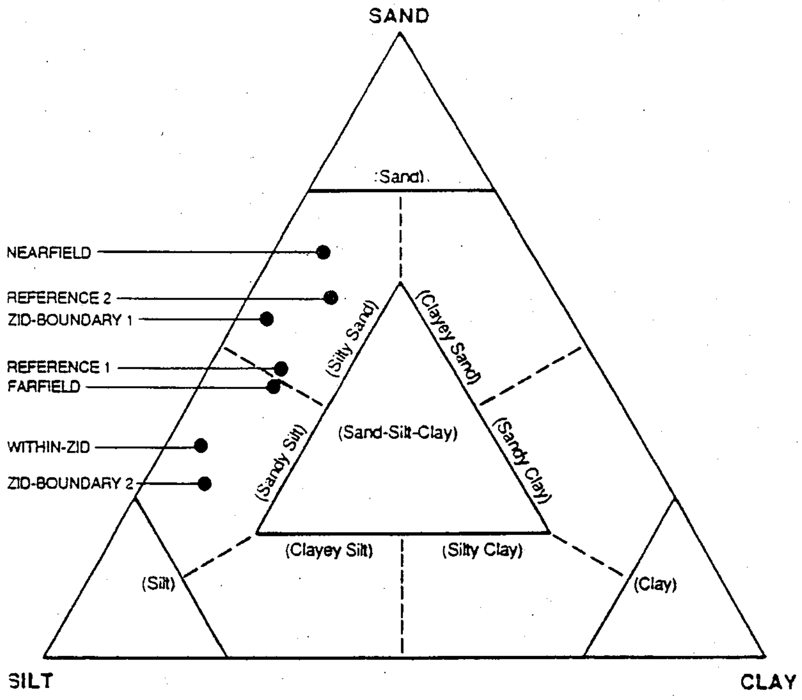

Figure C-4. Sediment grain size characterization at stations in the vicinity of the outfall.

Statistical tests are among the most effective tools for comparing biological communities among stations. A variety of statistical tests are available, the most widely used of which is one-way analysis of variance (ANOVA). ANOVA and other statistical tests have been used extensively for biological comparisons in the 301(h) program, but they have often been used improperly. For this reason, procedures for conducting statistical comparisons using biological data are discussed briefly below. Applicants are encouraged to consult references on biostatistics (e.g., Zar 1974, Sokal and Rohlf 1981) for more specific guidance on the application of these procedures.

The use of one-way ANOVA for biological comparisons is preferred because ANOVA is an efficient and robust test. ANOVA compares the mean values of a given variable among stations (or groups of stations) for the purpose of detecting significant differences at a predetermined probability level. ANOVA requires a minimum of three replicate values at each station to estimate the mean value and associated variance.

ANOVA is a parametric test based on three assumptions: (1) the error of an estimate is a random normal variate, (2) the data are normally distributed, and (3) the data exhibit homogeneous variances. Corrections for the first are not easily achieved, and an erroneous assumption can greatly affect the results of the test. Fortunately, error estimates in survey data are usually independent.

ANOVA is relatively robust with respect to the assumption that the data are normally distributed. Substantial departures from normality can occur before the value of the F-statistic is affected greatly (Green 1979). For this reason, tests for normality are not usually conducted before data are analyzed using ANOVA.

The third assumption, that variances are homogeneous, is critical to execution of ANOVA. Heterogeneous variances can greatly affect the value of the F-statistic, especially in cases where the statistical design is unbalanced (i.e., where numbers of replicate values vary among the stations or station groups being tested).

Several tests are available to determine whether variances are homogeneous. The Fmax test (see Zar 1974, Sokal and Rohlf 1981) and Cochran's C test (Winer 1971) are both appropriate, although the latter is preferred because it uses more of the information in the data set. Bartlett's test is not recommended because it is overly sensitive to departures from normality (Sokal and Rohlf 1981).

When sample variances are found to differ significantly ($P<0.01$), a transformation should be applied to the data. [A more conservative probability level (e.g., $P<0.05$) should be used when the statistical design is unbalanced. ANOVA is sensitive to unbalanced statistical designs.] Sokal and Rohlf (1981) describe several transformations that may be used. Because ANOVA on transformed data is usually a more efficient test for detecting departures from the null hypothesis than is the Kruskal-Wallis test (the nonparametric analog of ANOVA), the Kruskal-Wallis test should be used only when the appropriate transformation fails to correct for heterogeneous variances (Sokal and Rohlf 1981). The Kruskal-Wallis test requires a minimum of five replicate values per station because it is a test of ranks.

When ANOVA or a Kruskal-Wallis test is performed, significant differences ($P<0.05$) among individual stations or groups of stations may be determined using the appropriate *a posteriori* comparison. Of most importance in 301(h) demonstrations are differences among reference stations and stations within the ZID, at the ZID boundary, and beyond the ZID. It is primarily these comparisons on which determination of the presence or absence of a balanced indigenous population is based.

Classification analyses (e.g., cluster analyses) have also been used extensively in the 301(h) program. In the normal classification mode, stations are grouped by the attributes of the assemblages that occur there (e.g., species composition and abundance). This type of analysis is very useful for identifying the stations that are the most similar and least similar to one another in fauna and/or flora. Because biological communities respond to organic materials and other pollutants, stations at which pollutant impacts are occurring typically cluster together in interpretable groups. Inverse classification analysis, in which taxa are grouped by the stations at which they co-occur, is also helpful because it defines assemblages that are characteristic of different levels and types of pollutant impacts.

Classification analysis involves two analytical steps: (1) calculation of a matrix of similarity values for all possible station pairs and (2) grouping of stations based on those between-station similarity values. Many similarity indices and clustering strategies are available to perform these two tasks (see Boesch 1977, Green 1979, Gauch 1982, Pielou 1984, Romesburg 1984). However, only the Bray-Curtis similarity index and either the group average clustering strategy (i.e., the unweighted pair-group method using arithmetic averages) or the flexible sorting strategy has been used commonly in 301(h) demonstrations. Their continued use is recommended. The Bray-Curtis index is easily understood and has been used widely in ecological studies. Moreover, two comparisons of similarity indices (i.e., Bloom 1981, Hruby 1987) have shown it to be superior to many of the other commonly used resemblance measures. Both the group average clustering strategy and the flexible sorting strategy are recommended because they produce little distortion of the original similarity matrix. [See U.S. EPA (1985) for additional rationale on the use of these three indices.]

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APPENDIX D
NAVIGATIONAL REQUIREMENTS AND METHODS

CONTENTS

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NAVIGATIONAL REQUIREMENTS AND METHODS

The information presented below addresses navigational requirements and methods for section 301(h) dischargers. It summarizes more detailed discussions in U.S. EPA (1987, 1988).

MONITORING STATION LOCATIONS

Compliance with conditions of a secondary treatment variance requires monitoring at a site-specific array of sampling locations. The types of stations usually specified in 301(h) monitoring programs are depicted in Figure D-1. Positioning accuracy is most critical for the within-ZID and ZID-boundary stations (Stations Z_0, Z_1, Z_2 in Figure D-1). Applicants must be able to sample at a specific boundary location on any given occasion and to return to nearly the same location on subsequent trips. At gradient (G_1, G_2, G_3, G_4) and control or reference (C_1) stations, initial accurate location is not as critical. However, it is important to relocate these stations accurately during subsequent surveys to enable quantification of temporal changes in the variables sampled (e.g., benthic community characteristics). This requirement for high repeatable accuracy also applies to stations in or near special habitats (H_1, H_2). The ability to conduct sampling at the appropriate depth contour is also very important. Sampling programs for 301(h) typically include the requirement that a bottom sampling station can be relocated to within 10 m (32.8 ft).

ACCURACY LIMITATIONS

Both the procedures and equipment used to establish a navigational position contribute errors that affect the overall accuracy of a fix. Absolute or predictable accuracy is a measure of nearness to which a system can define a position by latitude and longitude (Bowditch 1984). Repeatable or relative accuracy is a measure of a system's ability to return the user to a given position with coordinates that were previously measured with the same system. The difference between these two accuracies can be substantial. For example, depending on one's location in the coverage area, Loran-C has a repeatable accuracy in offshore areas of 15-90 m (49-295 ft), but an absolute accuracy of 185-463 m (607-1,519 ft) (Dungan 1979). In many instances, repeatable accuracy is more important than absolute accuracy (e.g., retrieval of crab pots, return to desirable fishing grounds, avoidance of underwater obstructions, and reoccupation of reference stations).

For coastal outfall monitoring, both repeatable and absolute accuracy can be important, depending on the type of sampling site. For within-ZID and ZID-boundary stations, both accuracies are important because sampling stations must be located within or very near the

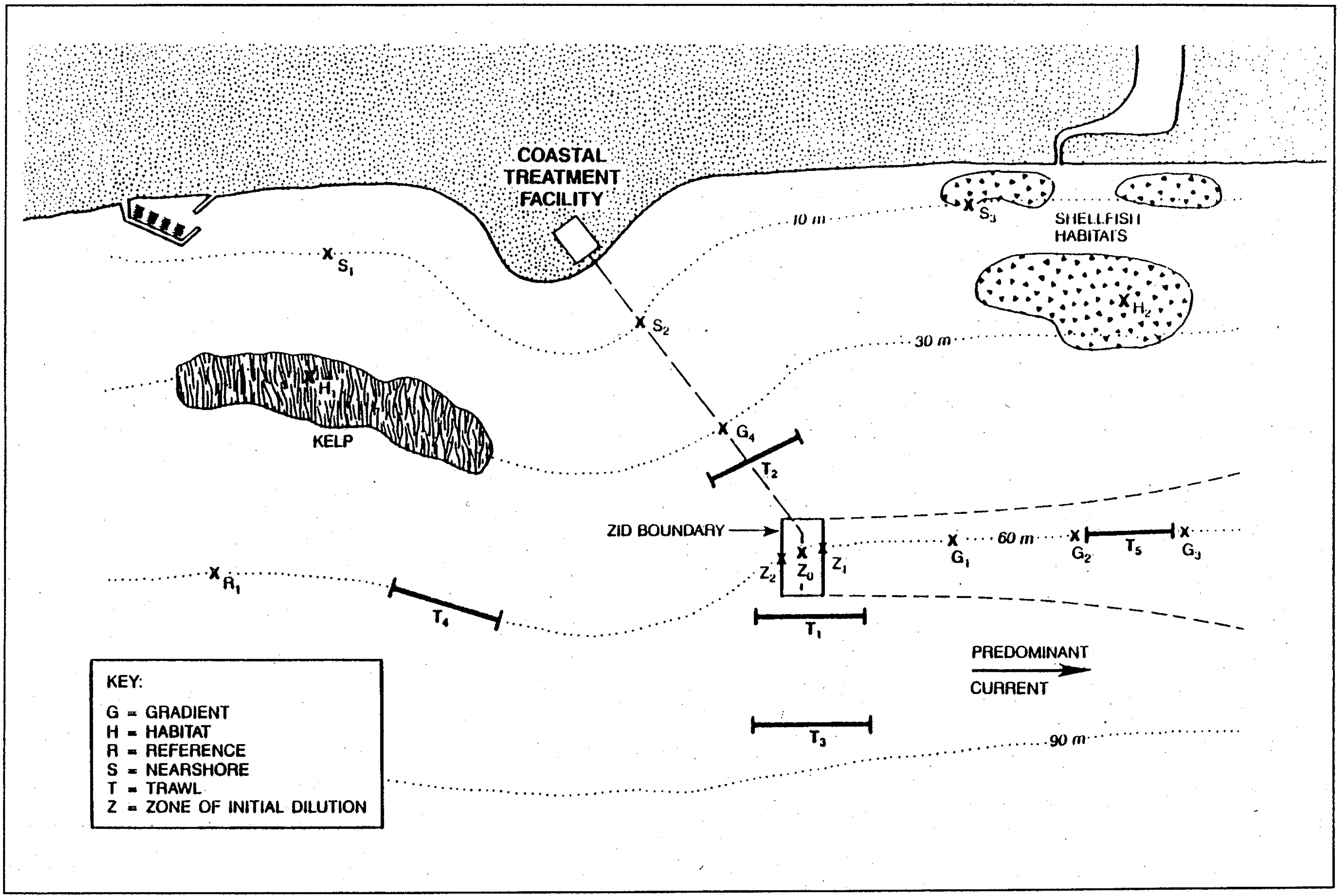

Figure D-1. Examples of some key 301(h) monitoring station locations for a medium-large marine municipal discharge.

boundary and must be repeatedly occupied during the program. For gradient, special habitat, and reference stations, repeatable accuracy is more important than absolute geographic location. Once such a station is established within a special habitat, it is often necessary to return to the same site to identify temporal variations in the previously sampled biological community. Thus, it is important to select navigational procedures and equipment with both the absolute and repeatable accuracies needed to meet the monitoring program objectives.

Because repeatable accuracy of navigational equipment is usually at least 1 order of magnitude better than absolute accuracy, the latter frequently limits the overall positioning accuracy of a sampling vessel during coastal monitoring programs. Therefore, the following discussion focuses on absolute accuracies that can be achieved by various procedures and associated equipment.

Practical considerations also limit the accuracy of an offshore positional fix. Resolution of a position to better than 1-2 m (3.3-6.6 ft) becomes meaningless when measuring the location of a moving vessel (e.g., during trawling) or a vessel that is on station but pitching and rolling. Antenna movement alone usually precludes higher resolution in position coordinates. Exceptions to this rule can occur when conditions are unusually calm.

POSITIONING ERROR

Many factors contribute to the total error in position of the water column or benthic sampling point. These factors include movement or drift of the "on-station" vessel, offsets between the deployment point of sampling equipment and the navigational system antenna, offsets between the deployment point and the subsurface location of the sampling or profiling equipment, and error in the ship's initial location. Most of these factors are site- or operationally specific and can be estimated with varying degrees of confidence. Because the accuracy to which the actual sampling point is known is highly dependent on all these factors, they should be carefully considered in both the design and conduct of monitoring programs.

A ZID-boundary error proportional to some percentage of the ZID dimension has been selected as the controlling parameter for 301(h) navigational requirements. Because ZID size is proportional to water depth, the allowable error in position is also proportional to depth. For example, ZID-boundary stations can be located at a distance from the diffuser axis equal to one-half the ZID width plus 20 percent of the water depth at mean tide level. The allowable maximum error in the location of these stations can then be ±20 percent of the water depth. As a result, the closest to the diffuser that sampling would occur is at the ZID boundary, and the farthest from the diffuser that sampling would occur is 40 percent of the water depth beyond this boundary. Nominally, however, sampling would be performed within a distance from the ZID boundary equal to 20 percent of the water depth. Example ZID-boundary station locations using this approach for a variety of ZID sizes are listed in Table D-1. The ZID-boundary and sampling station locations for discharges at the 100-, 60-, and 20-m (328-, 197-, and 66-ft) depths are shown in Figure D-2.

When discharge depths are less than approximately 15 m (49 ft), the 20 percent error allowance results in an overly restrictive positional error [i.e., less than ±3 m (9.8 ft)]. Therefore, a positioning error of ±3 m (9.8 ft) is considered to be more appropriate when sampling station depths are less than 15 m (49 ft). Although the percent error as a function of water depth increases at shallower depths, this minimum error is considered reasonable given available navigating techniques for small sampling vessels in other than extremely calm waters. Stations beyond the ZID may be similarly located using the 20 percent of depth rule beyond the 15-m (49-ft) contour and the ±3-m (9.8-ft) error limitation for shallower locations. As indicated earlier, it is recognized that the ability to reoccupy a given site can be as important as knowing its exact geographical location. However, relocation beyond the ZID probably will not be a problem if the same navigational equipment used to locate ZID-boundary stations is also used elsewhere.

TABLE D-1. EXAMPLE ZID-BOUNDARY STATION LOCATIONS

Average Diffuser Depth (m)	Average Diffuser Diameter (m)	ZID Width (m)	Recommended Station Location[a] (m)	Recommended Allowable Error[b] (m)
100	4.0	204.0	122.0	±20
90	3.6	183.6	109.8	±18
80	3.4	163.4	87.7	±16
70	3.2	143.2	85.6	±14
60	3.0	123.0	73.5	±12
50	2.5	102.5	61.3	±10
40	2.2	82.2	49.1	±8
30	2.0	62.0	37.0	±6
20	1.8	41.8	24.9	±4
15	1.5	31.5	18.8	±3
10	1.5	21.5	13.8	±3
5	1.0	11.0	8.5	±3
3	0.5	6.5	6.3	±3

[a] Distance from the zone of initial dilution centerline to the station, based on 0.5 times the ZID width plus 20 percent of the average water depth of the diffuser when over 15 m (49 ft).

[b] Error magnitude is equal to ±20 percent of the average diffuser depth when over 15 m (49 ft).

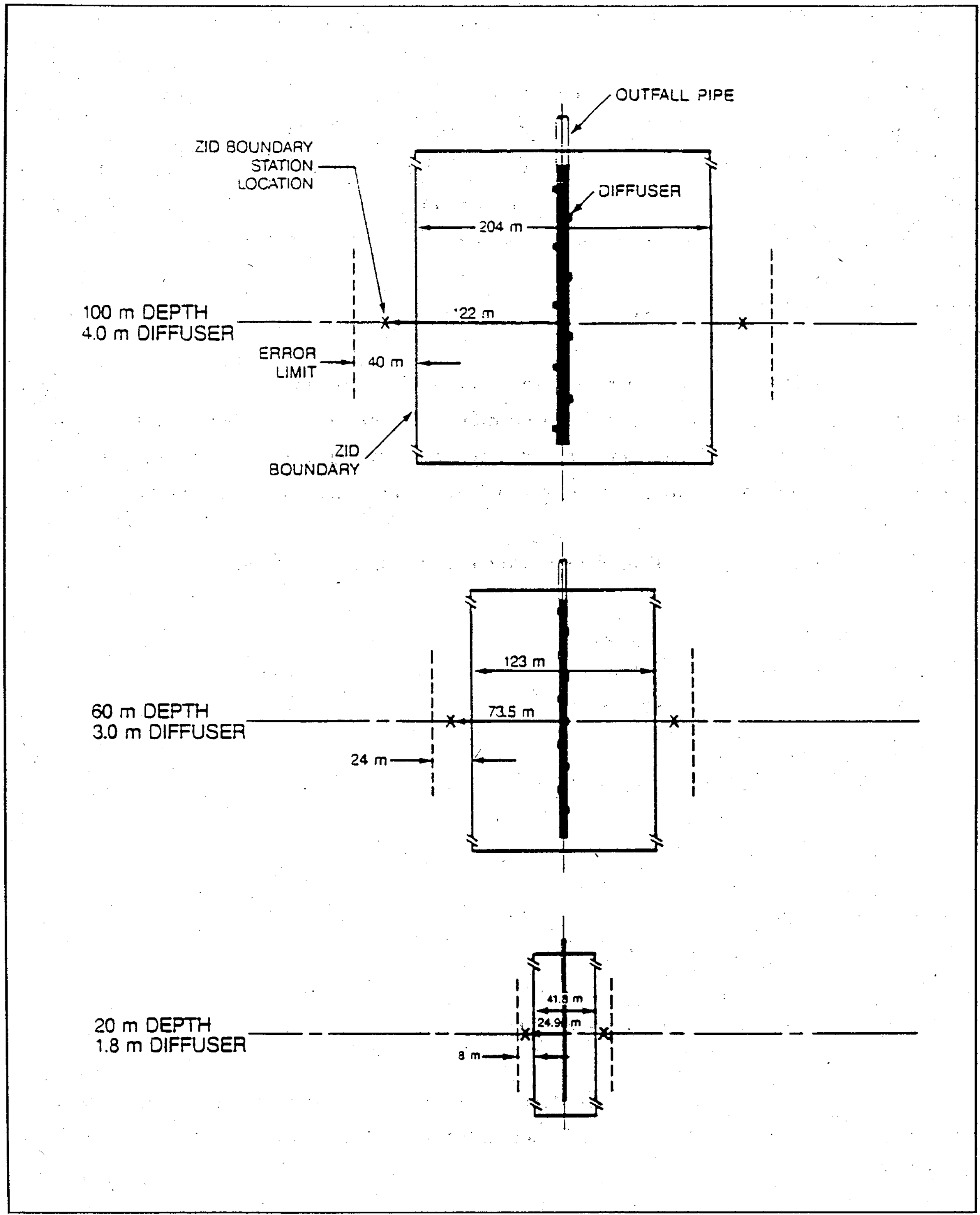

Figure D-2. Locations of ZID-boundary stations for selected ZID sizes.

SUMMARY OF RECOMMENDED PROCEDURES AND EQUIPMENT

Based on the U.S. EPA's evaluation of optional positioning methods, the systems recommended for coastal positioning include theodolites, sextants, electronic distance measuring instruments (EDMIs), total stations, and microwave and range-azimuth systems. Although satellite systems offer adequate accuracy (when used in a differential mode), their use may be limited because a sufficient number of satellites might not always be available.

CANDIDATE SYSTEM SELECTION

The details of positioning techniques and associated equipment are described in U.S. EPA (1988). No single system is best for all coastal monitoring purposes. Needs vary according to the size and complexity of the planned monitoring program, the nature of the immediate and surrounding areas, and other navigational or surveying requirements of a municipality.

Positioning techniques fall into three principal measurement categories:

- Multiple horizontal angles
    - Theodolite intersection
    - Sextant angle resection
- Multiple electronic ranges
    - Distance-measuring instruments
    - Range-range mode
    - Hyperbolic mode
    - Satellite ranging
- Range and angle
    - Theodolite and EDMI
    - Total station
    - Range-azimuth navigation systems

Systems within these categories that will meet or exceed the positional accuracy recommended herein are summarized in Table D-2. Additional information on the recommended categories is provided below.

TABLE D-2. SUMMARY OF RECOMMENDED SYSTEMS

Category	Representative Equipment[a]	Accuracy	Advantages	Disadvantages
Theodolite	Table B-1 Table B-2	10-30 sec ±1 m (3.3 ft)	Traditional method. Inexpensive. High accuracy. Successfully applied. Restricted areas.	Line-of-sight. Two manned shore stations. Simultaneous measurements. Limits on intersection angles. Area coverage; station movement.
Sextant	Table B-3	±10 ±2 m (6.6 ft)	Rapid. Easy to implement. Most widely used. Low cost. No shore party. High accuracy.	Simultaneous measurement of two angles. Target visibilities location, maintenance. Line-of-sight. Best in calm conditions. Limits on acceptable angles.
EDMI	Table B-4	1.5-3.0 cm	Extremely accurate. Usable for other surveying projects. Cost. Compact, portable, rugged.	Motion and directionality of reflectors. Visibility, unless microwave. Two shore stations Ground wave reflection.
Total stations	Table B-5	5-7 cm	Single onshore station. Other uses. Minimum logistics.	Reflector movement and directionality. Prism costs.
Microwave navigation systems	Table B-6	±1-3 m	No visibility restrictions. Multiple users. Highly accurate. Radio line-of-sight.	Cost. Multiple onshore stations Logistics. Security.
Range-azimuth systems	Table B-10	0.01° and 0.5 m	High accuracy. Single station. Circular coverage.	Single user. Cost.
Satellite systems	Table B-9	1-10 m	High accuracy. Minimum (initial units)logistics. Use in restricted/congested areas. Future cost. No shore stations.	Current coverage. Initial development cost.

[a] Table references refer to U.S. EPA (1987).

Multiple Horizontal Angles

In the multiple horizontal angles category, theodolites were found to have the angular accuracies required for the maximum ranges anticipated. They are relatively inexpensive, and they are readily available because they are widely used as a surveying instrument. At least two theodolites, two operators, a vessel siting target, and a three-way communications link to coordinate fixes are required. Visibility can be a limiting factor.

By comparison, sextant angle resection can be performed using one instrument if the vessel is stationary or using two instruments simultaneously if the vessel is moving. Achievable angular accuracy of ±10 seconds is adequate, and relatively inexpensive sextants are readily available. Again, visible range can be limiting. Shooting an accurate fix from a nonstationary platform in any significant sea or swell could be more difficult than shooting with theodolites from shore. A distinct advantage of sextant angle resection is location of the navigators on the survey vessel. The method usually requires highly visible shore targets and a three-arm protractor for plotting positions.

Multiple Electronic Ranges

Positioning using multiple ranges can be accomplished with two staffed EDMI stations. Accuracies were found to be more than adequate, but ranges were found to be marginal [if needed beyond 3 km (1.9 mi)] unless multiple prisms are used. Because such prisms are directional, procurement of multiple clusters for more than one direction could result in substantial additional costs. Limitations include geometry of shore stations; position of the vessel in the coverage area (i.e., crossing angle limitations); and possible interferences due to line-of-sight obstructions, sea-surface reflective nulls, and land-sea boundaries. The hyperbolic mode provides multiple user capability, but at the cost of an additional shore station.

Satellite ranging holds promise because required accuracies should be achievable in the near future. Transit satellite-based systems do not offer sufficient accuracy, except with multiple passes, and multiple passes are impractical when a given sampling station is occupied only briefly. Accuracies needed will undoubtedly be achievable in the future using differential global positioning system (GPS) techniques.

Range and Angle

Systems in the range-azimuth category show great promise. Required angular and range accuracies are available, only one shore station is needed, and costs depend on system refinements. At the low end of the scale, an EDMI and theodolite could be paired with a communication link. Optical and infrared range limitations apply to these systems. The three range-azimuth navigational systems examined provide sufficient positional accuracy with a single station.

SHALLOW-WATER POSITIONING METHODS

When sampling stations are located in relatively shallow water, they can be identified by relatively inexpensive methods (in addition to those discussed earlier in this report). Provided the center of the ZID over the outfall can be located (e.g., by diver-positioned surface float), an optical range finder can be used to establish the required distances to nearby water quality or biological sampling stations. An optical range finder is used by simply focusing a split image on the target float, enabling the slant distances to the target to be read from the instrument scale. When combined with a careful compass reading, this distance reading allows positioning of the sampling vessel.

A survey of accuracies claimed for commercially available instruments suggests that the ±3-m (9.8-ft) recommended minimum accuracy can be achieved for ranges up to approximately 100 m (328 ft) from the surface target. The Lietz Model 1200, for example, provides an accuracy of ±1 m (3.3 ft) at 100 m (328 ft). Beyond this distance, instrumental errors increase rapidly. For the instrument cited, a ±9 m (29.5 ft) accuracy is quoted at 300 m (984 ft).

An acceptable alternative method for collecting bottom samples from desired locations in shallow water is to use divers. If visibility is adequate, divers can measure radial distances to desired locations by holding a tape at the outfall and traversing the appropriate distance over the bottom in the proper direction.

Visual ranges have sometimes been used to establish a station position. This method requires that a minimum of two objects are in alignment, enabling the vessel to be placed on a common axis extending to the vessel's position. Simultaneous siting on a second set of at least two objects places the vessel at the intersection of the two common axes. The accuracy of each visual range is highly dependent on the quality of the visual range (e.g., alignment), the distance from the alignment objects to the vessel, and the angle between the ranges. Also, the number of visual ranges used affects the magnitude of the positional error. Although this technique is frequently used for positioning single sampling stations in bays, harbors, and other areas in which two or more conveniently alignable targets can be selected, the method is not considered acceptable for coastal monitoring at ZID-boundary stations. Also, it is not likely that a sufficient number of alignment target pairs will be present for all desired locations. In addition, the unpredictability of repeatable position error detracts from the value of this method.

Permanent installation of a marker buoy at the outfall terminus or midpoint of the diffuser allows easy return to this point on subsequent sampling trips. Using the previously discussed range-finder technique or a line of desired length enables positioning at desired distances from the marker buoy. It is not uncommon, however, to lose such a buoy due to vandalism, impact, or severe weather conditions. Therefore, it is necessary that the sampling party be prepared to relocate the outfall (e.g., by diver, sonar, or pinger mounted on the outfall itself) if location of stations is dependent on knowledge of the outfall location.

Because the techniques described here are inexpensive to implement (as is use of the sextant resection or theodolite intersection method), they are attractive to small coastal municipalities. However, use of more sophisticated and less labor-dependent techniques may be achievable at moderate costs by renting or leasing, rather than buying, such equipment.

USE OF LORAN-C

In its evaluation of positioning methods, U.S. EPA (1987) concluded that Loran-C did not provide the absolute and repeatable accuracies needed for the 301(h) program. However, because Loran-C is in such wide use and is relatively inexpensive, use of Loran-C in a special operating mode was reexamined in *Evaluation of Differential Loran-C for Positioning in Nearshore Marine and Estuarine Waters* (U.S. EPA 1988). The special operating mode, called differential Loran-C, requires an additional Loran-C receiver onshore at a known geographic location. At this location, the Loran-C signals are received, and a correction is generated and transmitted to the survey vessel, allowing the correction to be applied to signals received by the ship's Loran-C unit.

Use of differential Loran-C was found to significantly improve the positional accuracies achievable with Loran-C in the normal mode. During a simulated monitoring program near Newport Beach, California, normal Loran-C positional errors of 40-50 m (131-164 ft) were reduced to 7-15 m (23-49 ft) using differential Loran-C in conjunction with special vessel-operating procedures, a video display, and data-averaging techniques. Higher accuracies are expected in other coastal areas where improved lattice line crossing angles occur. Acceptability may depend on relative orientations of the diffuser and the error ellipse axes (Figure D-3, Table D-3). For those considering use of differential Loran-C, a procedure for determining the error in a ZID-boundary station location is provided in U.S. EPA (1988).

SYSTEM SELECTION PROCEDURE

A procedure for selecting an appropriate navigation system is described in detail in U.S. EPA (1987). The procedure involves definition of positioning requirements, establishment of screening criteria (e.g., range, accuracy, availability, and costs), review of candidate systems, and evaluation of purchase/lease options. As indicated in Figure D-4, a stepwise screening technique is recommended to identify an optimal system for a given monitoring program. At each step in the screening process, systems that cannot achieve the required criterion are removed from further consideration.

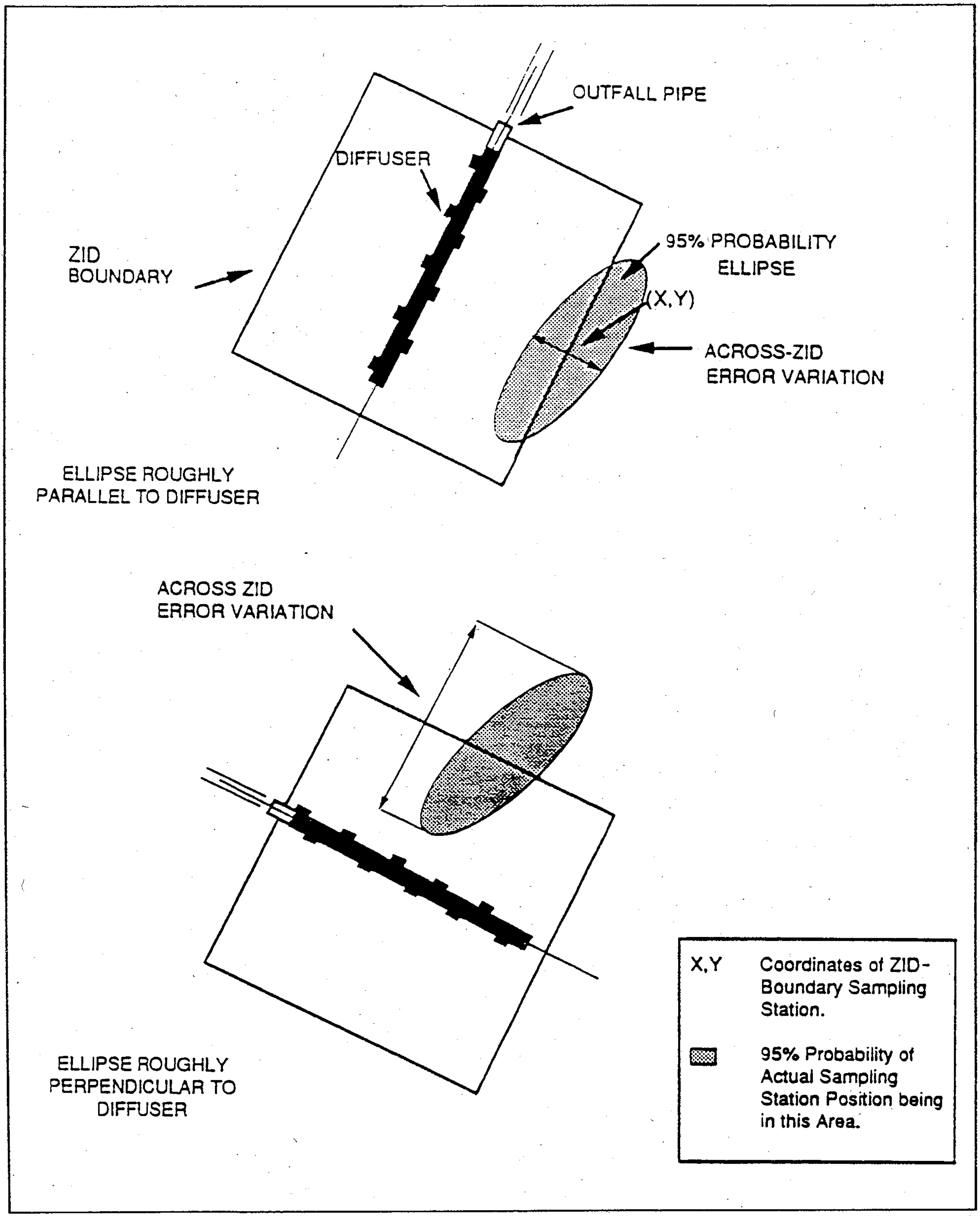

Figure D-3. Examples of differential Loran-C error ellipse orientation at a ZID-boundary sampling station.

TABLE D-3. THEORETICAL ERROR ELLIPSES OF DIFFERENTIAL LORAN-C FOR VARIOUS U.S. LOCATIONS

Location	Approximate Direction of Major Axis	Length of Major Axis[a]	Length of Minor Axis[a]
Anchorage, AK	NW/SE	70	20
Puget Sound, WA	NW/SE	180	40
San Francisco, CA	NE/SW	60	30
Los Angeles, CA	NE/SW	90	30
San Diego, CA	N/S	90	20
Mississippi Delta, LA	NW/SE	50	20
Panama City, FL	N/S	30	20
Chesapeake Bay, VA	W/E	40	20
Boston, MA	N/S	30	20

[a] Lengths are given to the nearest 10 m based on 95 percent confidence level error ellipses. Standard deviation of time differences is 25 nsec (achievable with differential Loran-C).

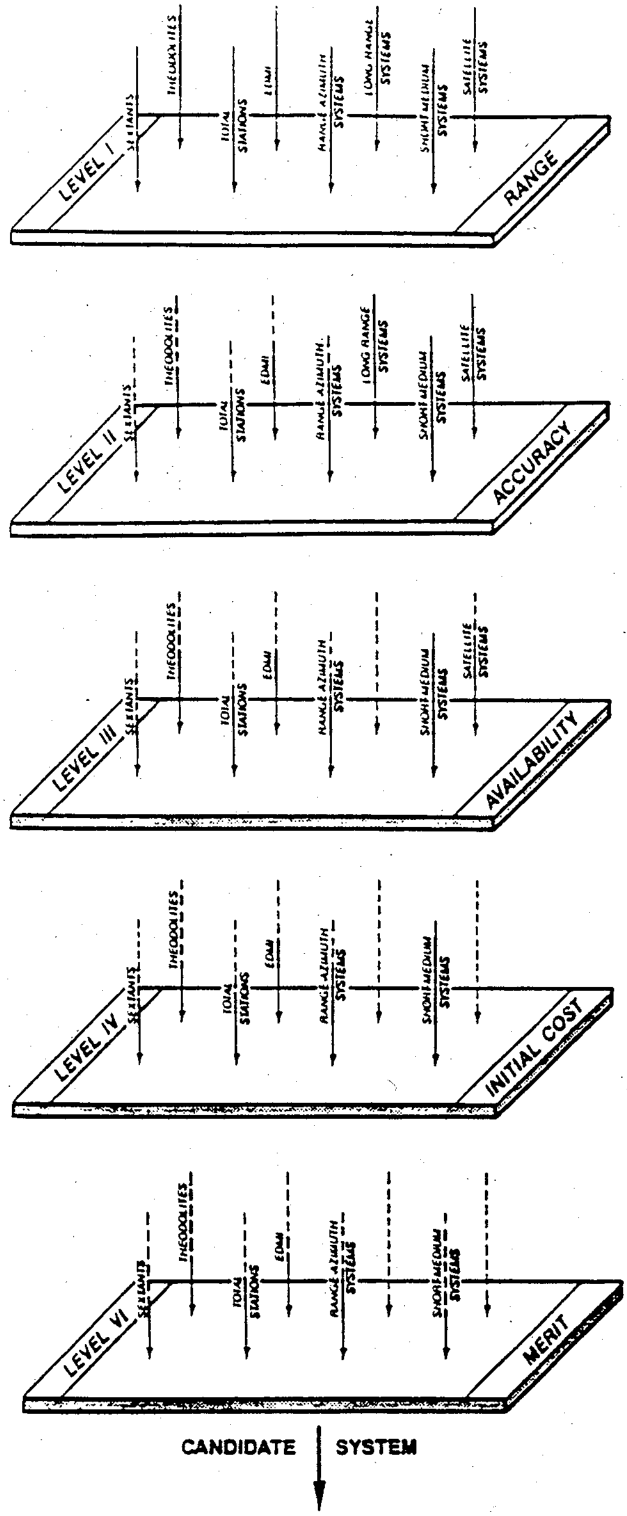

Figure D-4. Navigation system preliminary screening criteria.

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APPENDIX E
URBAN AREA PRETREATMENT REQUIREMENTS

CONTENTS

CONTENTS (continued)

ATTACHMENT 1: INDUSTRIAL USER MANAGEMENT PRACTICES

ATTACHMENT 2: LOCAL LIMITS DERIVATION EXAMPLE

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INTRODUCTION

Section 303(c) of the Water Quality Act of 1987 amended section 301(h) of the 1977 Clean Water Act by adding the "urban area pretreatment requirements." These requirements apply only to POTWs serving a population of at least 50,000 and only to toxic pollutants introduced by industrial dischargers. For each toxic pollutant introduced by an industrial discharger to an affected POTW, the applicant must demonstrate that it meets one of the following two conditions:

- It has an "applicable pretreatment requirement in effect."
- It achieves "secondary removal equivalency."

This new statutory requirement (§125.65) complements the toxics control program requirements in the section 301(h) regulations (§125.66) and other pretreatment requirements in 40 CFR Part 403.

The purpose of this appendix is to help 301(h) applicants interpret and comply with the new requirement. For site-specific reasons, concepts and procedures recommended herein may not necessarily apply to all 301(h) applicants. Issues that are not addressed by this appendix should be directed to EPA Regional offices. Applicants should also check with appropriate state and local agencies for any explicit requirements (e.g., water quality standards) that apply to them. The procedures to demonstrate compliance with the urban area pretreatment requirements must be formulated and implemented by each applicant with approval from the appropriate EPA Regional office. Compliance with the urban area pretreatment requirements is required before a 301(h) modified permit can be issued by EPA, although tentative approval may be granted on demonstration of the applicant's good faith effort to comply.

When a review of the 301(h) application indicates noncompliance with pretreatment requirements and shows that the applicant is not taking effective steps to ensure compliance, EPA may deny the permit. Factors relevant to such a decision include the number of noncomplying industrial sources, the nature of their toxic pollutant contribution to the POTW, and potential or actual POTW interference or pass-through.

For urban area POTWs with significant numbers of industrial users, at any given time it is reasonable to expect that at least one or more of those users might be out of compliance. EPA intends to determine a POTW's continuing eligibility for a 301(h) waiver under section 301(h)(6) by measuring industrial user compliance and POTW enforcement activities against existing criteria in the Agency's National Pretreatment Program. In 1989, EPA established criteria for determining POTW compliance with pretreatment implementation obligations. One element of those criteria is the level of significant noncompliance of the POTW's industrial users. The General Pretreatment Regulations (40 CFR Part 403) identify the circumstances when industrial user noncompliance is significant. The industrial user significant noncompliance (SNC) criteria are set out in 40 CFR 403.8(f)(2)(vii) and address both effluent and reporting violations.

In enforcing the pretreatment programs, POTWs are expected to respond to industrial user noncompliance using local enforcement authorities in accordance with an approved enforcement response plan (ERP), which is required of all approved pretreatment programs (see 40 CFR 403.5). POTWs, including 301(h) POTWs, with greater than 15 percent of their users in SNC, or which fail to enforce appropriately against any single industrial user causing pass-through or interference, are deemed to be failing to enforce their pretreatment programs. Thus, the POTW is also deemed to be in SNC.

EPA will base its determination on data collected during site visits to the POTW and from the POTW's pretreatment program performance report required by 40 CFR 403.12(i). This report includes compliance information on industrial users gathered by the POTW as well as a description of the enforcement activities of the POTW. EPA believes that the combination of industrial user compliance and POTW enforcement provides an appropriate measurement of the POTW's eligibility for the 301(h) waiver under section 301(h)(6).

The process that an applicant must follow to achieve compliance is based on guidelines established by EPA's pretreatment program. The U.S. EPA Office of Wastewater Management (OWM) and Office of Science and Technology (OST) have issued the following guidance manuals to assist POTWs in implementing pretreatment regulations and developing technically based local limits:

- *Fate of Priority Toxic Pollutants in Publicly Owned Treatment Works* (U.S. EPA 1982d);
- *Guidance Manual for POTW Pretreatment Program Development* (U.S. EPA 1983a);
- *Procedures Manual for Reviewing a POTW Pretreatment Program Submission* (U.S. EPA 1983b);

- *NPDES Compliance Inspection Manual* (U.S. EPA 1984a);
- *Guidance Manual for Implementing Total Toxic Organics (TTO) Pretreatment Standards* (U.S. EPA 1985a);
- *Guidance Manual for the Use of Production-Based Pretreatment Standards and the Combined Wastestream Formula* (U.S. EPA 1985b);
- *Pretreatment Compliance Monitoring and Enforcement Guidance* (U.S. EPA 1986a);
- *Guidance Manual for Preventing Interference at POTWs* (U.S. EPA 1987a);
- *Guidance for Reporting and Evaluating POTW Noncompliance with Pretreatment Implementation Requirements* (U.S. EPA 1987b);
- *Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program* (U.S. EPA 1987c);
- *Supplemental Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program: Residential and Commercial Toxic Pollutant Loadings and POTW Removal Efficiency Estimation* (U.S. EPA 1991a); and
- *Training Manual for NPDES Permit Writers* (U.S. EPA 1993a).

CHARACTERIZATION OF DISCHARGE AND SELECTION OF APPROACH

Figure E-1 presents an overview of the process and decision points that the applicant should follow to comply with the urban area pretreatment requirements. Next to each step in the process are page numbers indicating sections in this appendix that explain the procedures for that step. Under the urban area pretreatment provisions, the applicant must select one of two basic approaches to demonstrate compliance:

- The Applicable Pretreatment Requirement Approach or
- The Secondary Removal Equivalency (Pilot Plant) Approach.

Figure E-1 presents the Applicable Pretreatment Requirement Approach in detail. Figures illustrating the details of the Pilot Plant Approach will be presented later in this appendix. There is a first step common to both approaches. Prior to making the selection, the applicant should adequately *characterize the industrial users* discharging waste to the POTW, as well as conduct representative sampling of the POTW *influent, effluent*, and *sludge* to identify any and all toxic pollutants introduced by industrial sources.

INDUSTRIAL WASTE SURVEY

A comprehensive survey of industrial users is critical to characterizing the types and concentrations of toxic pollutants being discharged to the POTW. All industrial users, including major or significant industries (including categorical users) and minor industries, including noncategorical users (small industries and some commercial users), should be included in the industrial waste survey (IWS). A typical IWS may require submission of some or all of the following information from each industrial user:

- Name
- Address
- Standard Industrial Classification (SIC) code
- Wastewater flow
- Types and concentrations of pollutants in discharge(s)

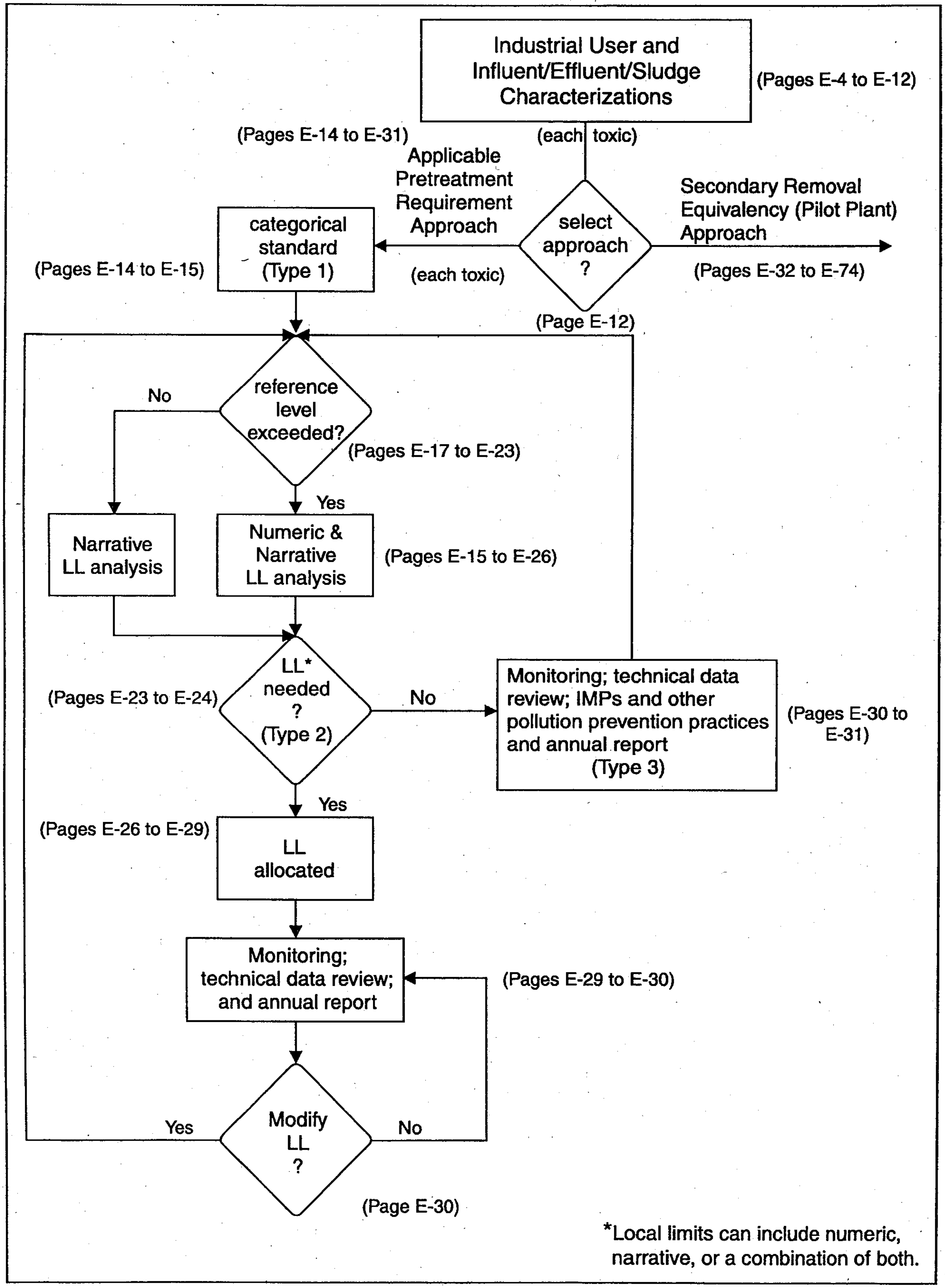

Figure E-1. Urban area pretreatment requirements.

- Major products manufactured and/or services rendered
- Locations of discharge points
- Process diagram and/or descriptions
- An inventory of raw feedstocks, including periodically used solvents, surfactants, pesticides, etc.
- Results of inspections, including documentation of spills, compliance history, general practices
- Treatment processes and management practices, such as spill prevention plans and solvent management plans, employed
- Discharge practices, such as batch versus continuous, variability in waste constituent concentrations and types, discharge volume
- Pollutant characteristics data (i.e., including carcinogenicity, toxicity, mutagenicity, neurotoxicity, volatility, explosivity, treatability, biodegradability, bioaccumulative tendency).

It is likely that this information has already been developed as part of the POTW's industrial pretreatment program. The IWS should be comprehensive and up-to-date, however, at the time the 301(h) application is submitted for review. Guidance on conducting an IWS is provided in Chapter 2 of EPA's *Guidance Manual for POTW Pretreatment Program Development* (U.S. EPA 1983a) and in Chapter 2 of *Guidance on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program* (U.S. EPA 1987c). IWS data may be reviewed in conjunction with the pollutant occurrence matrix provided in Table E-1. This table relates specific industries with the toxic pollutants commonly expected to occur with them. Other sources of information that will aid the POTW in identifying pollutants of concern are provided in the EPA guidance manuals listed on pages E-2 and E-3.

A classification scheme should be developed to assist in establishing a monitoring plan and conducting any local limits analyses. Industrial users can be initially grouped according to the following three broad categories (U.S. EPA 1983a):

TABLE E-1. POLLUTANT OCCURRENCE IN INDUSTRIAL WASTEWATER

	Adhesives	Aluminum Forming	Auto & Other Laundries	Battery Manufacturing	Coal Mining	Coil Coating	Copper Forming	Dye Manufacturing	Electrical & Electronic Components	Electroplating/Metal Finishing	Explosives Manufacturing	Foundries	Gum & Wood Chemicals	Hospitals	Inorganic Chemicals	Iron & Steel	Laboratories	Leather Tanning & Finishing	Mechanical Products	Non-Ferrous Metals	Ore Mining & Dressing	Organic Chemicals	Paint & Ink	Pesticides	Petroleum Refining	Pharmaceuticals	Photographic Supplies	Plastics & Synthetics	Plastics Processing	Porcelain Enameling	Printing & Publishing	Pulp, Paper, & Fiberboard	Rubber Manufacturing	Soaps & Detergents	Steam Electric	Stone, Clay, Glass, & Concrete Products	Textile Mills	Timber Products
Acenaphthene																				●		●			●													●
Acenaphthylene																●																			●			●
Acrylonitrile																						●		●					●								●	
Aldrin																								●														
Anthracene			●		●				●		●					●			●	●	●	●			●							●						●
Antimony	●			●	●			●			●			●	●	●	●	●		●							●						●			●	●	
Arsenic					●				●					●	●		●	●		●			●	●	●	●		●									●	●
Barium							●				●									●			●					●				●	●			●		
Benzo(a)anthracene																●			●						●													●
Benzene					●			●	●				●	●			●		●	●		●	●		●	●	●	●			●		●	●				●
Benzo(b)fluoranthene																									●													
Benzo(k)fluoranthene																●																						●
Benzo(a)pyrene																				●					●													
Benzo(g,h,i)perylene																																						
Beryllium									●		●								●																	●		
Bis(2-chloroethoxy)methane																		●															●					
Bis(2-ethylhexyl)phthalate	●	●			●							●						●	●	●		●		●				●				●	●		●		●	
Bromoform																																						
Bromomethane (methyl bromide)																						●		●														
Butyl benzyl phthalate	●											●							●	●		●						●				●						
Cadmium		●		●			●	●	●	●		●			●				●	●		●				●	●	●	●	●							●	
Carbon disulfide									●													●		●		●		●										
Carbon tetrachloride	●																		●			●	●															
Chlordane																								●														
p-Chloro-m-cresol																																						●
Chlorobenzene					●				●													●		●														
Chlorodibromomethane																												●										
Chloroethane (ethyl chloride)									●					●			●					●		●	●													

TABLE E-1. (Continued)

	Adhesives	Aluminum Forming	Auto & Other Laundries	Battery Manufacturing	Coal Mining	Coil Coating	Copper Forming	Dye Manufacturing	Electrical & Electronic Components	Electroplating/Metal Finishing	Explosives Manufacturing	Foundries	Gum & Wood Chemicals	Hospitals	Inorganic Chemicals	Iron & Steel	Laboratories	Leather Tanning & Finishing	Mechanical Products	Non-Ferrous Metals	Ore Mining & Dressing	Organic Chemicals	Paint & Ink	Pesticides	Petroleum Refining	Pharmaceuticals	Photographic Supplies	Plastics & Synthetics	Plastics Processing	Porcelain Enameling	Printing & Publishing	Pulp, Paper, & Fiberboard	Rubber Manufacturing	Soaps & Detergents	Steam Electric	Stone, Clay, Glass, & Concrete Products	Textile Mills	Timber Products
Chloroform	●	●			●				●								●	●				●		●		●		●	●			●	●					
Chloromethane (methyl chloride)									●					●			●					●		●				●					●		●			
2-Chlorophenol								●	●					●	●							●				●												
Chromium	●	●			●	●	●	●	●	●		●	●		●	●		●	●	●		●	●		●	●	●	●		●				●			●	●
Cobalt																																						
Copper	●	●	●		●		●		●	●		●	●		●			●	●	●	●	●	●					●	●	●				●	●		●	●
Cyanide	●					●				●					●	●		●		●	●			●	●	●	●										●	
DDE (dichlorodiphenyl dichloroethylene)																								●														
DDT (dichlorodiphenyl trichloroethane)																								●														
Di-n-butyl phthalate	●	●	●		●				●	●										●		●	●								●	●			●			
Di-n-octyl phthalate																				●		●							●									
Dibromomethane (methylene bromide)																						●																
1,2-Dichlorobenzene								●	●	●				●	●			●				●		●													●	
1,3-Dichlorobenzene									●									●																				
1,4-Dichlorobenzene									●						●			●				●																
Dichlorobromoethane																				●		●																
Dichlorodifluoroethane									●																			●										
1,1-Dichloroethane																			●	●		●																
trans-1,2-Dichloroethylene					●														●																			
2,4-Dichlorophenol														●								●		●								●	●					
2,4-Dichlorophenoxyacetic acid (2,4-D)																								●									●					
1,2-Dichloropropane																																						
1,3-Dichloropropene																						●		●														
Dieldrin																								●														
Diethyl phthalate	●				●										●				●	●								●				●						
Dimethyl phthalate	●																						●					●										
2,4-Dimethylphenol (2,4-xylenol)																●						●			●								●					
2,4-Dinitrotoluene								●			●				●							●																

TABLE E-1. (Continued)

	Adhesives	Aluminum Forming	Auto & Other Laundries	Battery Manufacturing	Coal Mining	Coil Coating	Copper Forming	Dye Manufacturing	Electrical & Electronic Components	Electroplating/Metal Finishing	Explosives Manufacturing	Foundries	Gum & Wood Chemicals	Hospitals	Inorganic Chemicals	Iron & Steel	Laboratories	Leather Tanning & Finishing	Mechanical Products	Non-Ferrous Metals	Ore Mining & Dressing	Organic Chemicals	Paint & Ink	Pesticides	Petroleum Refining	Pharmaceuticals	Photographic Supplies	Plastics & Synthetics	Plastics Processing	Porcelain Enameling	Printing & Publishing	Pulp, Paper, & Fiberboard	Rubber Manufacturing	Soaps & Detergents	Steam Electric	Stone, Clay, Glass, & Concrete Products	Textile Mills	Timber Products
1,2-Diphenylhydrazine																																						
Endosulfan																								●														
Endrin																								●														
Ethyl benzene	●		●		●				●				●		●			●	●			●	●		●			●				●	●				●	●
Ethylene dibromide (EDB)																						●		●	●													
Ethylene dichloride																																						
Fluoranthene																●			●	●		●			●													●
Fluorene																●				●		●			●													●
Heptachlor																								●														
Heptachlor epoxide																								●														
Hexachloro-1,3-butadiene									●															●	●													
Hexachlorobenzene																				●		●		●														
Hexachlorocyclohexane (Lindane)																								●														
Hexachloroethane											●			●								●		●				●						●				
Indeno(1,2,3-cd)pyrene																									●													
Isobutyl alcohol																	●					●	●					●										
Isophorone																							●	●				●										
Lead	●	●	●	●	●		●		●	●	●			●	●	●		●	●	●	●	●	●		●	●	●	●	●	●			●	●			●	
Malathion																								●														
Mercury	●			●	●				●	●				●	●		●			●		●	●		●	●									●		●	
Methoxychlor																								●														
Methyl ethyl ketone																						●						●			●					●		
Methylene chloride	●	●			●				●									●		●		●	●			●	●	●										
4,4-Methylenebis(2-chloroaniline)																												●										
Naphthalene			●		●				●		●	●			●	●		●	●	●	●	●	●		●							●	●					
Nickel		●		●	●				●	●			●		●	●		●	●	●			●			●	●	●		●				●	●		●	
Nitrobenzene															●							●			●									●				
2-Nitrophenol									●													●					●											

TABLE E-1. (Continued)

	Adhesives	Aluminum Forming	Auto & Other Laundries	Battery Manufacturing	Coal Mining	Coil Coating	Copper Forming	Dye Manufacturing	Electrical & Electronic Components	Electroplating/Metal Finishing	Explosives Manufacturing	Foundries	Gum & Wood Chemicals	Hospitals	Inorganic Chemicals	Iron & Steel	Laboratories	Leather Tanning & Finishing	Mechanical Products	Non-Ferrous Metals	Ore Mining & Dressing	Organic Chemicals	Paint & Ink	Pesticides	Petroleum Refining	Pharmaceuticals	Photographic Supplies	Plastics & Synthetics	Plastics Processing	Porcelain Enameling	Printing & Publishing	Pulp, Paper, & Fiberboard	Rubber Manufacturing	Soaps & Detergents	Steam Electric	Stone, Clay, Glass, & Concrete Products	Textile Mills	Timber Products
PCB (polychlorinated biphenyls)																				●									●				●					
Pentachloroethane					●																																	
Pentachlorophenol	●																	●	●			●	●	●													●	●
Phenanthrene					●			●	●		●			●		●				●		●	●		●	●						●						●
Phenol	●	●	●						●			●	●			●		●	●	●	●	●	●	●	●	●	●	●				●					●	●
Pyrene														●		●			●	●		●										●						
Pyridine								●						●	●							●		●		●							●					●
Selenium							●		●						●	●				●							●						●			●	●	
Silver									●	●				●	●		●		●	●							●										●	
1,1,1,2-Tetrachloroethane									●						●							●																
1,1,2,2,-Tetrachloroethane																						●	●				●	●										
Tetrachloroethylene (perchloroethylene)			●		●		●											●	●	●		●	●	●	●			●			●	●	●	●			●	●
Tetrachlorophenol									●										●			●	●	●														
Thallium					●				●						●					●				●												●		
Toluene			●		●			●	●		●		●		●			●	●			●	●		●	●	●	●	●				●				●	
Toxaphene																								●														
1,2,4-Trichlorobenzene								●	●											●		●		●							●						●	
1,1,1-Trichloroethane					●				●										●					●								●					●	
1,1,2-Trichloroethane																			●			●						●										
Trichloroethylene	●	●	●											●								●	●	●		●											●	
Trichlorofluoromethane					●			●						●								●																
2,4,5-Trichlorophenol									●						●			●				●		●								●						
2,4,6-Trichlorophenol																		●			●	●		●														
Trichlorophenoxy-2-propionic acid																								●														
Vinyl chloride (chloroethylene)																						●						●										
Vinylidene chloride																			●																			
Zinc	●	●	●	●	●	●	●		●	●		●	●		●	●		●	●	●	●		●	●	●	●	●	●		●			●	●	●		●	

Source: U.S. EPA (1987c).

- Group 1: Major or significant industries, defined as:
  - All categorical industrial users;
  - Noncategorical industrial users that discharge a nondomestic waste stream of 25,000 gallons per day (0.025 MGD) or more;
  - Noncategorical industrial users that contribute a nondomestic waste stream that makes up 5 percent or more of the average dry-weather hydraulic or organic (BOD, TSS, etc.) capacity of the treatment plant; or
  - Noncategorical industrial users that have a reasonable potential, in the opinion of the POTW applicant, to adversely affect the POTW treatment plant (inhibition, pass-through of toxic pollutants, sludge contamination, or endangerment of POTW workers).

  These industries would be regulated individually and would most likely have specific effluent limitations (categorical standards, numeric local limits, or both) placed on their discharges. They should also be monitored and inspected periodically to ensure compliance with their limitations.

- Group 2: Minor industrial users, defined as small industries (all noncategorical) and some commercial users (restaurants, auto repair shops, car and truck washes, etc.), as well as any hauled waste and/or landfill leachate, whose individual discharges are not likely to significantly impact the POTW treatment system, degrade receiving water quality, or contaminate sludge, but which have the potential as a group or as subgroups to represent a significant source of toxic pollutants to the POTW. The POTW may choose to apportion numeric local limits among minor industrial users when these industries as a group represent a significant source of toxic pollutants to the POTW; otherwise, the POTW should determine the need to set narrative local limits, which may include industrial management practices and best management practices (such as through a sewer ordinance or general permit) to control and reduce levels of toxic pollutants.

  Industries in this classification should be monitored and inspected periodically to determine whether their status as minor industrial users has changed. EPA's *Supplemental Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program: Residential and Commercial Toxic Pollutant Loadings and POTW*

Removal Efficiency Estimation (U.S. EPA 1991a) provides data on toxic pollutant types and levels for a variety of minor industrial users.

- Group 3: Insignificant industrial users, defined as those industries which do not discharge to the POTW or do not have any reasonable likelihood of discharging a nondomestic waste stream to the POTW. These industries would be randomly monitored to ensure their status has not changed.

REPRESENTATIVE SAMPLING PROGRAM AT POTW

At this point the applicant must conduct sufficient monitoring at the treatment plant to identify and characterize influent, effluent, and sludge concentrations of toxic pollutants. Monitoring of the treatment plant influent, effluent, and sludge should represent a minimum of 5 consecutive days (Monday through Friday), preferably under dry weather conditions (U.S. EPA 1987c). Guidance on sampling techniques and QA/QC requirements are provided later in this appendix. Results of these analyses, along with historic data (if available) and data and information gathered during the IWS, should be tabulated in a summary form that allows the toxic quality of the discharge to be evaluated. The applicant must report all toxic pollutants (40 CFR 401.15) that are identified in any analysis at or above detection limits in the influent, effluent, and sludge as well as toxic pollutants known or suspected to be discharged by industry to the POTW (based on historic data and information collected during the IWS). Sources of detected and/or known or suspected toxic pollutants must be identified and, to the extent practicable, categorized according to industrial and nonindustrial origins, using the results of the IWS.

SELECTION OF APPROACH

Once the toxic pollutants being introduced by industrial sources have been identified, the applicant can choose between two methods to comply with the urban area pretreatment requirements for each toxic pollutant introduced by an industrial source. In the first method, called the Applicable Pretreatment Requirement Approach, the applicant would demonstrate that it has in effect applicable pretreatment requirements for each toxic pollutant discharged to the POTW from an industrial source. Applicable pretreatment requirements may take the form of (1) federal categorical pretreatment standards or (2) local limits developed in accordance with 40 CFR Part 403, or a combination of (1) and (2). A third applicable pretreatment requirement exists where it is determined that local limits are not necessary for a toxic pollutant. In this case, the POTW should implement a program of periodic monitoring and/or technical review of data on industrial discharges and require industrial management practices plans (IMPs) and other pollution prevention practices where appropriate. The POTW should also determine on an annual basis over the permit term the need to revise local limits and/or demonstrate that there is no need for a local limit for each specific toxic pollutant.

In the second method, called the Secondary Removal Equivalency Approach (Pilot Plant Approach), the applicant would demonstrate that the POTW's treatment process, in combination with pretreatment, removes at least the same amount of that toxic pollutant as would have been removed by secondary treatment (as defined in 40 CFR Part 133) without industrial pretreatment for that toxic pollutant. These methods are detailed in the following sections. The applicant should review these procedures fully prior to selecting the method for addressing the urban area pretreatment requirements for each toxic pollutant introduced by industrial discharges.

APPLICABLE PRETREATMENT REQUIREMENT APPROACH

BACKGROUND AND GENERAL APPROACH

Applicable pretreatment requirements for each toxic pollutant may take the form of categorical standards, local limits (numeric or narrative), or a combination of both. They should include periodic monitoring and technical review of industrial discharges and POTW influent/effluent/sludge to determine the need for revising local limits and/or to demonstrate that there is no need for a local limit for a specific toxic pollutant. When an industrial discharger is subject to both a categorical standard (Type 1) and a local limit for a specific toxic pollutant (Type 2), the more stringent of the two limits applies. For toxic pollutants for which the POTW determines that a local limit is not needed (Type 3), the POTW can show that it has an applicable pretreatment requirement in effect by the following:

(1) Implement a periodic monitoring program and annual technical review of industrial discharges.

(2) Institute industrial management practices plans (IMPs), best management practices (BMPs), and other pollution prevention activities, where appropriate.

(3) Provide a determination on an annual basis of the need to develop local limits and/or to demonstrate that there is no need for a local limit for those toxic pollutants.

Categorical standards (see 40 CFR 403.6) are nationally uniform, technology-based limits developed for specific industries and for specific toxic pollutants. All categorical industries must comply with categorical standards, even if they discharge to a POTW without a federally approved local pretreatment program. By contrast, local limits are developed by the POTW, among other purposes, to prevent interference with the treatment works or pass-through of toxic pollutants, as required by 40 CFR 403.5(b).

A specific categorical industry may be subject to categorical standards for some pollutants and local limits for other pollutants. When both local limits and categorical standards address a particular pollutant for a specific industry, the more stringent requirement applies. Furthermore, local limits for specific toxic pollutants found in the POTW waste stream can apply to both categorical and noncategorical industries when the toxic pollutants cannot be entirely attributed to categorical industries and/or when categorical standards alone are not sufficient to satisfy the requirements of 40 CFR Part 403.

Local limits (see 40 CFR 403.5) are requirements developed by a POTW based on local conditions and unique requirements at the POTW. These limits are primarily intended to protect the treatment plant from industrial discharges that could interfere with POTW treatment processes or pass through the treatment plant to receiving waters and adversely affect water quality. Local limits are also designed to prevent sludge contamination and protect workers at the treatment POTW.

Under the Applicable Pretreatment Requirement Approach, the applicant must address each toxic pollutant introduced by industry. After conducting a local limits analysis, the POTW may apportion the allocation of the *numeric local limit* (if any) to any number of industrial sources of the toxic pollutant (categorical and/or noncategorical) that the POTW deems appropriate, subject to the approval of the applicable EPA Regional office. Moreover, when it is not appropriate or practical to develop and implement numeric local limits to prevent pollutant pass-through or interference, the EPA pretreatment program has provided for *narrative local limits* (i.e., industrial management and best management practices) as useful supplements to numeric limits. Narrative local limits are most appropriate where management plans are needed to help control or eliminate chemical spills or leaks, slug discharges, or the handling of hazardous or toxic materials from both categorical and noncategorical industries.

For toxic pollutants for which the POTW determines that neither numeric nor narrative local limits are necessary (e.g., categorical or noncategorical industries where not all toxic pollutants discharged require a categorical standard or local limit), a program of periodic POTW monitoring and annual technical review of data on industrial discharges would be conducted by the POTW and, where appropriate, would include industrial management practices plans (IMPs) and other pollution prevention activities. The permit for this latter case will require the applicant to demonstrate on an annual basis over the permit term that a local limit is not necessary and where appropriate will require the applicant to institute IMPs. If such monitoring and technical review of data indicate that a local limit is needed, the POTW shall establish and implement a local limit.

IMPs are intended to minimize the discharge of toxic pollutants to the sewer, or reduce the impact of toxic pollutant discharges by avoiding short-term, high-concentration discharges. IMPs can be applied to all classes of industrial users, e.g., major and minor industrial users. Examples of appropriate uses of IMPs include control of chemical spills and slug discharges to the POTW through formal chemical or waste management plans (including BMPs), solvent management plans, batch discharge policies, waste recycling, and waste minimization. It would also be appropriate to consider IMPs in cases where the POTW does not include biological treatment processes, or provides less treatment, e.g., primary treatment. In these cases, IMPs can be tailored for industrial sources of toxic pollutants that might otherwise interfere with biological treatment or would be degraded or removed through additional treatment.

POTWs must demonstrate that the local limits developed are adequate and enforceable. Section 301(h)(6) and §125.65(b)(2) also require POTWs to demonstrate that industrial sources are in compliance with all of their pretreatment requirements, including numerical standards set by local limits, and that those requirements will be enforced (see previous discussion regarding compliance and enforcement).

U.S. EPA PROCEDURES FOR DEVELOPING TECHNICALLY BASED LOCAL LIMITS

Details on the various approaches for developing technically based local limits are provided in U.S. EPA's *Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program* (December 1987) (hereafter called "EPA's Local Limits Guidance"). Questions about this guidance should be directed to the U.S. EPA Regional Pretreatment Coordinators or to EPA's Office of Wastewater Management in Washington, DC.

Several methods are available to develop local limits, including the Maximum Allowable Headworks Loading (MAHL) Method, the Collection System Approach, Industrial User Management Practice Plans, and Case-by-Case Permitting (U.S. EPA 1987c). The Collection System Approach is most appropriate to address pollutants that may cause air releases or explosive conditions or may otherwise endanger POTW worker health and safety. Case-by-Case Permitting is based on best professional judgment and is most appropriate where data on pollutant effects are insufficient to use other methods (e.g., the MAHL method or Collection System Approach). It largely relies on pollutant removal efficiencies and economic achievability data for pollution control from comparable industries/discharges.

The predominant approach used by POTWs and advocated in EPA's Local Limits Guidance is a chemical-specific approach known as the Maximum Allowable Headworks Loading (MAHL) Method. This method involves back-calculating from environmental and plant protection criteria to a maximum allowable headworks loading. This is accomplished pollutant by pollutant for each environmental criterion or plant requirement, and the lowest or most limiting value for each pollutant serves as the basis for allocation to industry and ultimate numeric local limits. Industrial User Management Practices Plans may be used in conjunction with the MAHL method through narrative local limits to address toxic pollutants and/or industries for which numeric local limits may not be applicable or adequate alone to achieve control of toxic chemical discharges. Narrative local limits may be required because the nature of the industrial activity (slug discharges, chemical handling, etc.) requires pollution prevention activities to ensure adequate control of accidental or haphazard toxic chemical releases. Narrative local limits are discussed later and in Attachment 1 to this appendix. The steps of the MAHL method are discussed below.

Maximum Allowable Headworks Loading Method

a) Determine Pollutants of Concern (U.S. EPA 1987c)--

The first step of the MAHL method is to determine the pollutants of concern. Prior to this step, the applicant will have completed the IWS and will have identified the toxic pollutants that its industrial users are reasonably expected to be discharging to the POTW. The applicant should then design a sampling and monitoring program that is thorough enough to verify the actual concentration levels of toxic pollutants expected to be discharged in significant quantities and broad enough to detect any toxic pollutants that were not detected by the IWS or representative sampling activities. Before designing the sampling program, the POTW may want to review environmental quality criteria/effects data for pollutants that are potentially of concern (U.S. EPA 1987c). The applicant should perform at least one priority pollutant scan and one RCRA Appendix 9 scan (refer to Tables E-2 and E-3, respectively) to identify potential pollutants of concern in the influent, effluent, and sludge.

Figure E-2 is a detailed decision diagram of one possible approach for determining pollutants of concern that may require numeric local limits through the MAHL method (U.S. EPA 1987c). This approach is based primarily on analysis of the POTW's influent, with limited effluent and sludge sampling to screen for pollutants that may not be detectable in the influent but may have been concentrated in the effluent or sludge. Figure E-2 provides a series of reference levels that POTWs can use in assessing influent wastewater data and determining the need to proceed with a headworks analysis. These reference levels, provided as guidance for each of the protection criteria, are intended to be conservative in order to account for the daily fluctuations in pollutant loadings experienced by POTWs and for the fact that decisions are usually made on the basis of limited data. The reason for emphasizing the use of influent data in this example in which only limited effluent and sludge data are used is to conserve resources

TABLE E-2. LIST OF PESTICIDES AND TOXIC POLLUTANTS

Pesticides

- Demeton
- Guthion
- Malathion
- Methoxychlor
- Mirex
- Parathion

Toxic Pollutants[a]

- Chlorinated Benzenes
    - Chlorobenzene
    - 1,2-Dichlorobenzene
    - 1,3-Dichlorobenzene
    - 1,4-Dichlorobenzene
    - 1,2,4-Trichlorobenzene
    - Hexachlorobenzene
- Chlorinated Ethanes
    - Chloroethane
    - 1,1-Dichloroethane
    - 1,2-Dichloroethane
    - 1,1,1-Trichloroethane
    - 1,1,2-Trichloroethane
    - 1,1,2,2-Tetrachloroethane
    - Hexachloroethane
- Chlorinated Phenols
    - 2-Chlorophenol
    - 2,4-Dichlorophenol
    - 2,4,6-Trichlorophenol
    - 4-Chloro-3-methyl phenol
- Other Chlorinated Organics
    - Chloroform (trichloromethane)
    - Carbon tetrachloride (tetrachloromethane)
    - bis(2-chloroethoxy)methane
    - bis(2-chloroethyl)ether
    - 2-Chloroethyl vinyl ether (mixed)
    - 2-Chloronaphthalene
    - 3,3-Dichlorobenzidine
    - 1,1-Dichloroethylene
    - trans-1,2-dichloroethylene
    - 1,2-Dichloropropane
    - 1,2-Dichloropropylene (1,3-dichloropropene)
    - Tetrachloroethylene
    - Trichloroethylene
    - Vinyl chloride (chloroethylene)
    - Hexachlorobutadiene
    - 2,3,7,8-Tetrachloro-dibenzo-p-dioxin (TCDD)
- Haloethers
    - 4-Chlorophenyl phenyl ether
    - 2-Bromophenyl phenyl ether
    - bis(2-Chloroisopropyl) ether
- Halomethanes
    - Methylene chloride (dichloromethane)
    - Methyl chloride (chloromethane)
    - Methyl bromide (bromomethane)
    - Bromoform (tribromomethane)
    - Dichlorobromomethane
    - Chlorodibromomethane
- Nitrosamines
    - N-Nitrosodimethylamine
    - N-Nitrosodiphenylamine
    - N-Nitrosodi-n-propylamine
- Phenols (other than chlorinated)
    - 2-Nitrophenol
    - 4-Nitrophenol
    - 2,4-Dinitrophenol
    - 4,6-Dinitro-o-cresol (4,6-dinitro-2-methylphenol)
    - Pentachlorophenol
    - Phenol
    - 2,4-dimethylphenol
- Phthalate Esters
    - bis(2-Ethylhexyl)phthalate
    - Butyl benzyl phthalate
    - Di-n-butyl phthalate
    - Di-n-octyl phthalate
    - Diethyl phthalate
    - Dimethyl phthalate
- Polynuclear Aromatic Hydrocarbons (PAHs)
    - Acenaphthene
    - 1,2-Benzanthracene (benzo(a)anthracene)
    - 3,4-Benzo(a)pyrene (benzo(a)pyrene)

TABLE E-2. (Continued)

PAHs (continued)
- 3,4-Benzofluoranthene (benzo(b)fluoranthene)
- 11,12-Benzofluoranthene (benzo(k) fluoranthene)
- Chrysene
- Acenaphthalene
- Anthracene
- 1,12-Benzoperylene (benzo(g,h,i)perylene)
- Fluorene
- Fluoranthene
- Phenanthrene
- 1,2,5,6-Dibenzanthracene (dibenzo(a,h) anthracene)
- Indeno(1,2,3-cd)pyrene (2,3-o-phenylene pyrene)
- Pyrene

Pesticides and Metabolites
- Aldrin
- Dieldrin
- Chlordane (technical mixture and metabolites)
- alpha-Endosulfan
- beta-Endosulfan
- Endosulfan sulfate
- Endrin
- Endrin aldehyde
- Heptachlor
- Heptachlor epoxide (BHC-hexachlorocyclohexane)
- alpha-BHC
- beta-BHC
- gamma-BHC (Lindane)
- delta-BHC
- Toxaphene

DDT and Metabolites
- 4,4-DDT
- 4,4-DDE (p,p-DDX)
- 4,4-DDD (p,p-TDE)

Polychlorinated Biphenyls (PCBs)
- PCB-1242 (Arochlor 1242)
- PCB-1254 (Arochlor 1254)
- PCB-1221 (Arochlor 1221)
- PCB-1232 (Arochlor 1232)
- PCB-1248 (Arochlor 1248)
- PCB-1260 (Arochlor 1260)
- PCB-1016 (Arochlor 1016)

Other Organics
- Acrolein
- Acrylonitrile
- Benzene
- Benzidine
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- 1,2-Diphenylhydrazine
- Ethylbenzene
- Isophorone
- Naphthalene
- Nitrobenzene
- Toluene

Inorganics
- Antimony
- Arsenic
- Asbestos
- Beryllium
- Cadmium
- Chromium
- Copper
- Cyanide, total
- Lead
- Mercury
- Nickel
- Selenium
- Silver
- Thallium
- Zinc

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[a] Source: U.S. EPA 1993b.

TABLE E-3. RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) APPENDIX 9 CONSTITUENTS

Acenaphthene
Acenaphthylene
Acetone
Acetonitrile
2-Acetylaminofluorene
Acrolein
Acrylonitrile
Aldrin
alpha-BHC
4-Aminobiphenyl
Aniline
Anthracene
Antimony (6010)
Aramite
Arsenic (7061)
Barium (6010)
Benzene
Benzo[a]anthracene
Benzo[a]pyrene
Benzo[b]fluoranthene
Benzo[g,h,i]perylene
Benzo[k]fluoranthene
Benzyl alcohol
Beryllium (6010)
beta-BHC
bis(2-Chloroethoxy)methane
bis(2-Chloroethyl)ether
bis(2-Chloroisopropyl)ether
bis(2-Ethylhexyl)phthalate
Bromodichloromethane
Bromoform
Bromomethane
4-Bromophenyl phenyl ether
Butyl benzyl phthalate
2-sec-Butyl-4,6-dinitrophenol
Cadmium (6010)
Carbon disulfide
Carbon tetrachloride
4-Chlorophenyl phenyl ether
Chlordane
2-Chloro-1,3-butadiene
p-Chloro-m-cresol
p-Chloroaniline
Chlorobenzilate
Chlorodibromomethane
Chlorobenzene
Chloroethane
Chloroform
2,4-Dimethylphenol
4,6-Dinitro-o-cresol
Chloromethane
2-Chloronaphthalene
2-Chlorophenol
3-Chloropropene
Chromium (6010)
Chrysene
Cobalt (6010)
Copper (6010)
o, m, p-Cresol
Cyanide (9010)
2,4-D
4,4-DDD
4,4-DDE
4,4-DDT
Di-n-butyl phthalate
Di-n-octyl phthalate
Di-n-propylnitrosamine
Diallate
Dibenzofuran
Dibenz[a,h]anthracene
1,2-Dibromo-3-chloropropane
Dibromoethane
Dibromomethane
trans-1,4-Dichloro-2-butene
3,3-Dichlorobenzidine
m-Dichlorobenzene
o-Dichlorobenzene
p-Dichlorobenzene
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
trans-1,2-Dichloroethene
1,1-Dichloroethylene
Dichloromethane
2,4-Dichlorophenol
2,6-Dichlorophenol
1,2-Dichloropropane
cis-1,3-Dichloropropene
trans-1,3-Dichloropropene
Dieldrin
Diethyl phthalate
Dimethoate
3,3-Dimethyl benzidine
Dimethyl phthalate
p-(Dimethylamino)azobenzene
7,12-Dimethylbenz[a]anthracene
α,α-Dimethylphenethylamine
m-Dinitrobenzene
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,4-Dioxane
Diphenylamine
Disulfoton
Endosulfan I
Endosulfan sulfate
Endosulfan II
Endrin

TABLE E-3. (Continued)

Endrin aldehyde
Ethyl benzene
Ethyl cyanide
Ethyl methacrylate
Ethyl methanesulfonate
Famphur
Fluoranthene
Fluorene
Heptachlor epoxide
Heptachlor
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Hexachloropropene
Hexachlorophene
2-Hexanone
Hexchlorobenzene
Indeno(1,2,3-cd)pyrene
Isobutyl alcohol
Iodomethane
Isodrin
Isophorone
Isosafrole
Kepone
Lead (7421)
Lindane
Mercury (7470)
Methacrylonitrile
Methapyrilene
Methoxychlor
Methyl parathion
Methyl ethyl ketone
Methyl methanesulfonate
Methyl methacrylate
4-Methyl-2-pentanone
3-Methylcholanthrene
2-Methylnaphthalene
Naphthalene
1,4-Naphthoquinone
1-Naphthylamine
2-Naphthylamine
Nickel (6010)
o-Nitroaniline
5-Nitro-o-toluidine
m-Nitroaniline
p-Nitroaniline
Nitrobenzene
o-Nitrophenol
p-Nitrophenol
4-Nitroquinoline-1-oxide
N-Nitrosodi-n-butylamine
N-Nitrosodimethylamine
N-Nitrosodiethylamine
N-Nitrosodiphenylamine
N-Nitrosomethylethylamine
N-Nitrosomorpholine
N-Nitrosopiperidine
N-Nitrosopyrrolidine
Parathion
PCBs
Pentachlorobenzene
Pentachloroethane
Pentachloronitrobenzene
Pentachlorophenol
Phenacetin
Phenanthrene
Phenol
p-Phenylenediamine
Phorate
2-Picoline
Polychlorinated Dibenzofurans (PCDFs)
Polychlorinated Dibenzo-p-dioxins (PCDDs)
Pronamide
Pyrene
Pyridine
Safrole
Selenium (7741)
Silver (6010)
Styrene
Sulfide (9030)
2,4,5-T
2,3,7,8-TCDD
1,2,4,5-Tetrachlorobenzene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrachloroethene
2,3,4,6-Tetrachlorophenol
Tetraethyldithiopyrothosphate
Thallium (7841)
Thionazin
Tin (6010)
Toluene
o-Toluidine
Toxaphene
2,4,5-TP (Silvex)
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethene
Trichlorofluoromethane
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
1,2,3-Trichloropropane
O,O,O-Triethyl phosphorothioate
sym-Trinitrobenzene
Vanadium (6010)
Vinyl Chloride
Vinyl Acetate
Xylene
Zinc (6010)

Source: 40 CFR Part 264.

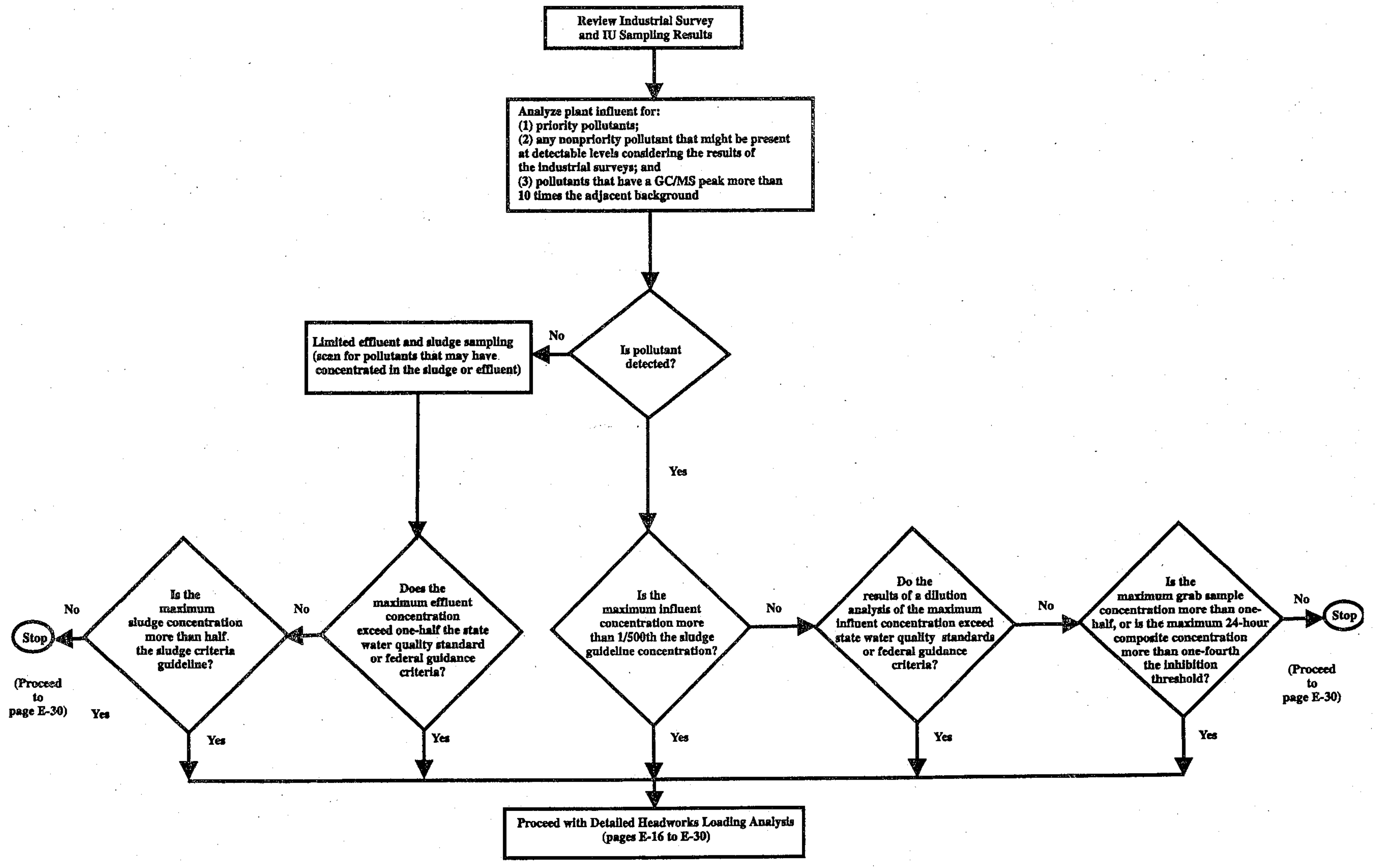

Figure E-2. Detailed flow sheet for a chemical-specific approach to identifying pollutants of concern to treatment plant operations (U.S. EPA 1987c).

during the preliminary screening and allow more resources to be used for the detailed headworks analysis of specific pollutants. The need to proceed with a headworks analysis for particular pollutants is indicated when:

- The maximum concentration of the pollutant in the POTW's effluent is more than one-half the allowable effluent concentration required to meet water quality criteria/standards or the maximum sludge concentration is more than one-half the applicable sludge criteria guidelines or

- The maximum concentration of the pollutant in a grab sample from the POTW's influent is more than half the inhibition threshold or the maximum concentration of the pollutant in a 24-hour composite sample from the POTW's influent is more than one-fourth the inhibition threshold.

- The maximum concentration of the pollutant in the POTW's influent is more than 1/500th of the applicable sludge use criteria [with the use of a "1/500th" reference level being suggested based on a review of POTW data (*Fate of Priority Toxic Pollutants in Publicly Owned Treatment Works*, U.S. EPA 1982d) indicating that a 500-fold concentration of pollutants can occur in digested sewage sludges as compared to the wastewater influent to the treatment plant] or

- The concentration of the pollutant in the plant influent exceeds water quality criteria adjusted through a simple dilution analysis.

Decisions as to whether to conduct a detailed headworks loading analysis are represented by the diamonds in Figure E-2. If a pollutant level exceeds the reference levels, the POTW should conduct a detailed headworks loading analysis for that pollutant to assess whether a numeric and/or narrative *local limit is needed.* The headworks loading analysis should be based on comprehensive influent, effluent, and sludge sampling and industrial contribution as discussed in the following section. If the reference-level analysis above does not point to the need for a detailed headworks loading analysis, the POTW should evaluate the need to set narrative limits (i.e., industrial management practices plans and best management practices) to control and reduce levels of these toxic pollutants from industrial sources, and determine on an annual basis the need to revise local limits and/or to demonstrate that there is no need for a local limit for a specific toxic pollutant.

Furthermore, for toxic pollutants for which the POTW determines [after completing the IWS, screening analysis, and MAHL (if applicable)] that neither numeric nor narrative local limits are necessary (e.g., insignificant industrial contribution), a program of periodic POTW monitoring and annual technical review of data on industrial discharges would be conducted by the POTW and, where appropriate, would require industrial users to institute industrial management practices plans and other pollution prevention activities. For these toxic pollutants, the POTW would report annually to EPA on the status of the need for development of local limits. (For further discussion of these requests, see section below entitled Ongoing Analysis of Other Toxic Pollutants Not Addressed by Local Limits).

b) Characterize Existing Loadings (U.S. EPA 1987c)--

Industrial Users--During the local limits development process, the POTW must characterize existing loadings to the treatment plant. Local limits should be based on site-specific monitoring data. This is especially important where a discharge makes up a large percentage of the total industrial pollutant loading to the system, or when toxic pollutants are known or suspected to be discharged in large quantities or concentrations. This loading characterization can be accomplished by conducting monitoring of all industrial users. Either POTW monitoring or self-monitoring data are acceptable, and information from the POTW's industrial waste survey may also be of use.

Hauled Waste--If hauled wastes are accepted at the POTW, they may be a significant source of toxic pollutant loadings. In such a case the POTW should consider them as a significant nondomestic source in the determination of local limits.

Domestic Loadings--The POTW must also characterize domestic loadings. Site-specific monitoring of a representative portion of the POTW's collection system should form the basis for loadings from domestic/background sources. Use of literature values must be justified by the POTW.

Treatment Plant Monitoring--The POTW must conduct sufficient monitoring at the treatment plant to characterize influent, effluent, and sludge loadings. Treatment plant influent and effluent sampling must be conducted to obtain data for use in calculating overall POTW removal efficiencies. The POTW should also monitor its sludge at the influent to the sludge digesters and at the point of disposal of the processed sludge. The resulting sludge monitoring data are used to derive digester removal efficiencies and sludge partitioning constants necessary for converting of sludge disposal criteria/standards and digester inhibition threshold data into corresponding headworks loadings. Specific guidance on sludge sampling and analysis can be found in *POTW Sludge Sampling and Analysis Guidance Document* (U.S. EPA 1989).

The initial monitoring program should include (as a minimum) at least 5 consecutive days of sampling for both metals and toxic organics. A minimum of 5 consecutive days (Monday through Friday) is necessary to adequately characterize the typical short-term range and variability in toxic quality of the POTW and industrial user wastewater discharge activity. Preferably, longer-term monitoring should also be conducted to include data for at least 1 day of sampling per month over at least 1 year for metals and other inorganic pollutants and 1 day of sampling per year for toxic organics to assess long-term variations in wastewater composition. To ensure valid data, representative measurements of flow rates must be taken at the point and time of sample collection. Flow measurements and sampling can be conducted either manually or with automatic devices.

The method for analysis of a toxic pollutant should be selected according to the type of pollutant to be analyzed (i.e., grab samples over 24 hours for volatile organic compounds, total recoverable phenolic compounds, and cyanide and flow-proportioned 24-hour composite samples for all other toxic pollutants). Guidance on sampling techniques and QA/QC requirements are provided later in this appendix.

c) Determine Applicable Environmental Criteria (U.S. EPA 1987c)--

Environmental criteria usually include NPDES permit limits, water quality standards or criteria, sludge disposal requirements, and unit process inhibition values. The POTW should use all applicable environmental criteria when developing local limits. Other appropriate requirements may include worker health and safety criteria; collection system effects; incinerator emission requirements; or other applicable federal, state, or local environmental protection requirements. Further information on how to incorporate applicable environmental criteria into the local limits development process is contained in EPA's Local Limits Guidance.

Another environmental criterion is biological toxicity of whole effluents. POTWs that have conducted biological toxicity testing indicating toxicity of whole effluents should develop local limits to correct the toxicity. Although there is no method in EPA's Local Limits Guidance for calculating maximum allowable headworks loadings based on the results of toxicity testing, the manual provides guidance and additional references on the Toxicity Reduction Evaluation (TRE) process. (Also, refer to U.S. EPA 1988 and U.S. EPA 1991b for additional information.)

d) Calculate Maximum Headworks Loadings (U.S. EPA 1987c)--

The POTW must calculate the maximum amount (lb/day) of each toxic pollutant contributed by an industrial user or received at the headworks of the treatment plant that will allow the POTW to achieve all of the above applicable environmental criteria. Figure E-3 presents the formulas and data elements necessary to perform these calculations. In addition, Attachment 2 to this appendix presents a sample local limits headworks loading calculation. If the POTW does not calculate the maximum allowable headworks loading to the POTW for each toxic pollutant, it must provide justification why it has not done so. The nonconservative pollutants (volatiles) require special consideration when conducting headworks analysis (e.g., alternative formulas and allocation methods). All calculations should be consistent with the approach outlined in EPA's Local Limits Guidance.

During this step of the local limits development process, the POTW should demonstrate that an acceptable mass balance exists between the actual loadings of pollutants at the headworks and the estimated loadings of pollutants from specific source discharges. This mass balance can be determined by calculating the actual loading of each pollutant from influent monitoring data and comparing this value with the sum of the estimated loadings from all individual sources (e.g., domestic, industrial, hauled waste). The resulting calculated loadings from various sources should be within 80 to 120 percent of the actual total influent loading and flow.

e) Calculate Allowable Industrial Loadings (U.S. EPA 1987c)--

Once the POTW has calculated the maximum allowable headworks loading, a safety factor must be applied and the value discounted for domestic/background loadings in order to determine the maximum allowable allocation available for industrial users. A safety factor is incorporated into the calculations to allow for future industrial growth and other discrepancies that may enter into the calculations because of the use of default data or variations in analytical procedures. The POTW should provide justification for the selected safety factor, which will usually range from 10 to 30 percent.

f) Allocate Allowable Industrial Loading (*allocation of local limits*) (U.S. EPA 1987c)--

After the POTW has calculated the allowable industrial loading, the method chosen to allocate this loading depends on the number and types of industrial users and the method of application (permits, contract, or sewer use ordinance) employed by the POTW. Where the

In-Plant Criterion	**Mass Balance Equation**
NPDES permit limit	$L_{IN} = \frac{(8.34)(C_{CRIT})(Q_{POTW})}{(1-R_{POTW})}$
Water quality standard	$L_{IN} = \frac{(8.34)[C_{WQ}(C_{STR}+Q_{POTW})-(C_{STR})(Q_{STR})]}{(1-R_{POTW})}$
Secondary treatment (e.g., activated sludge) threshold inhibition level	$L_{IN} = \frac{(8.34)(C_{CRIT})(Q_{POTW})}{(1-R_{PRIM})}$
Tertiary treatment (e.g., nitrification) threshold inhibition level	$L_{IN} = \frac{(8.34)(C_{CRIT})(Q_{POTW})}{(1-R_{SEC})}$
Sludge digester threshold inhibition level	$L_{IN} = \frac{(8.34)(C_{CRIT})(Q_{DIG})}{(R_{POTW})}$
Sludge disposal criterion/standard	$L_{IN} = \frac{(8.34)(C_{SLCRIT})(PS/100)(Q_{DISP})}{(R_{POTW})}$

where:

L_{IN} = Allowable influent loading, lb/day
C_{CRIT} = In-plant criterion, mg/L
C_{SLCRIT} = Sludge disposal criterion/standard, mg/kg dry sludge
Q_{POTW} = POTW flow, millions of gallons per day (mgd)
R_{POTW} = Removal efficiency across POTW, as a decimal
Q_{STR} = Receiving stream (upstream) flow, mgd
C_{STR} = Receiving stream background level, mg/L
C_{WQ} = Receiving stream water quality standard, mg/L
R_{PRIM} = Removal efficiency across primary treatment, as a decimal
R_{SEC} = Removal efficiency across secondary treatment, as a decimal
Q_{DIG} = Sewage sludge flow rate to digester, mgd
Q_{DISP} = Sewage sludge flow rate to disposal, mgd
PS = Percent of sludge to disposal

Uniform concentration local limits can be derived through the use of the following equation:

$$C_{LIM} = \frac{(1-SF)(L_{IN})-L_{DOM}}{(8.34)(Q_{IND})}$$

where:

C_{LIM} = Uniform concentration local limit, mg/L
L_{IN} = Maximum allowable influent loading, lb/day
SF = Safety factor, as a decimal
L_{DOM} = Loading for domestic/uncontrollable sources, lb/day
Q_{IND} = Total industrial flow, mgdlevel). The discharge limit derived is applied only to those industrial users which contribute the pollutant.

Figure E-3. Equation for deriving allowable POTW influent loadings from in-plant criteria.

current loading of a pollutant exceeds the MAHL, the POTW must establish a numeric local limit to reduce loadings to within the range of the MAHL. Where the current loading is below the MAHL, the POTW is encouraged, but not required, to set industrial discharge limits at current loadings to provide a safety factor.

A variety of procedures for the allocation of the allowable industrial loading exist. The four allocation methods most frequently used by POTWs are:

- Uniform concentration — The MAHL for each pollutant is divided by the total flow for *all* industrial users (even those which do not discharge the pollutant). The resultant discharge concentration for each pollutant is applied to all industrial user discharges.

- Concentration based on industrial contributory flow — The MAHL for each pollutant is divided by the flow from only those industrial users which actually have the pollutant in their untreated wastewaters (in concentration greater than the background concentration.

- Mass production — The ratio of the MAHL to the current loading for each industrial user contributing a particular pollutant is calculated, and the mass loading limit is derived by multiplying this ratio by the industry's current pollutant loading. The limit derived is unique for each industry, and limits are developed and applied only to industries that contribute the pollutant.

- Selected industrial reduction — Individual pollutant loading reductions for each industry are determined; typically the loading reductions are based on the treatability of the industrial wastewater for each pollutant.

The POTW should ensure that it has selected local limits that are reasonable (i.e., they incorporate appropriate safety factors, account for domestic/background loadings, and consider appropriate environmental and plant protection criteria). All numeric local limits should be at or above detection limits and should not be so lenient as to provide industry additional opportunity to pollute or encourage discharge of hazardous waste to the POTW. Under the applicable pretreatment requirement approach, the applicant must address each toxic pollutant introduced by industry. After conducting the local limits analysis, the POTW may allocate the allowable industrial loading among any number of industrial sources of the toxic pollutant (categorical and/or noncategorical) that the POTW deems appropriate, subject to the approval of the applicable EPA Regional office. Local limits could be allocated, for example, according to the classification scheme developed under the industrial waste survey. For the major or significant industries, the POTW would most likely set specific effluent limitations (categorical standards, numeric local limits, or both). For the minor industries, the POTW may choose to apportion numeric local limits among minor industrial users when these industries as a group represent a significant source of toxic pollutants to the POTW; otherwise, the POTW should determine the need to set narrative local limits (i.e., industrial management practice plans and best management practices; see Attachment 1 to this appendix) where appropriate to control and reduce levels of toxic pollutants. Narrative local limits may also be implemented in conjunction with numeric local limits for the same industry, if deemed appropriate.

If the initial screening process described in step (a) of the MAHL process (see Figure E-2) does not point to the need for a detailed headworks loading analysis for a specific toxic pollutant, the POTW should evaluate the need to set narrative local limits (i.e., industrial management practices plans and best management practices) where appropriate to control and reduce levels of these toxic pollutants from selected industries. Guidance on how to identify industries for which narrative local limits may be appropriate is given in Attachment 1 to this appendix.

Once local limits have been developed for a toxic pollutant (numeric, narrative, or a combination of both), they must be effectively implemented. Local limits should be incorporated into the sewer use ordinance or some form of individual control mechanism.

g) Ongoing Review/Revision of Local Limits (numeric/narrative)(U.S. EPA 1987c)--

Local limits must be revised on a periodic basis to reflect changes in conditions or assumptions. Conditions that might require that local limits be revised include, but are not limited to, changes in environmental criteria, changes in the industrial users, availability of additional monitoring data, changes in plant processes, and changes in POTW capacity or configuration.

For those toxic pollutants for which numeric or narrative local limits were developed through the MAHL analysis (or other method as appropriate), the POTW must demonstrate to EPA on an annual basis, through *annual monitoring* and appropriate *technical review of data* on discharges from industrial sources, that levels of these toxic pollutants in the POTW influent do not exceed the maximum allowable headworks loading (MAHL) determined in the analysis of local limits described above. Annual monitoring should follow the guidelines discussed previously in this appendix for long-term treatment plant monitoring.

The results of the monitoring and data review must be made available in the annual report required under 40 CFR 403.12. If the POTW determines, based on results of annual monitoring of the POTW influent/effluent/sludge and/or technical review of data on discharges from industrial sources (also updated annually), that the level of a toxic pollutant is expected to exceed the maximum allowable level determined through the local limits analysis, the POTW should *modify the local limit* and the individual control mechanism or sewer use ordinance, as appropriate, to implement the new local limit. Furthermore, the POTW should update the initial screening of toxic pollutants based on results of the same technical review to determine the need for inclusion of any new toxic pollutants/industries in the local limits analysis (either numeric or narrative).

Ongoing Analysis of Other Toxic Pollutants Not Addressed by Local Limits

For those toxic pollutants which the POTW determines that neither numeric nor narrative local limits are necessary (e.g., insignificant industrial contribution) the POTW must continue to conduct periodic *monitoring* of the POTW influent and effluent and conduct annual *technical reviews* of data on discharges from industrial sources during the term of the permit, to determine any change in status of the toxic quality of the POTW wastewater and industrial sources. Further, where appropriate the POTW should require industrial users to institute industrial management practices plans (*IMPs*) and *other pollution prevention activities* such as through individual control mechanisms or local sewer ordinances, to reduce or control the levels of these toxic pollutants from industrial sources. These plans and activities could include best management practices (BMPs). For more information, see Attachment 1 to this appendix and EPA's *Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program* (U.S. EPA 1987c) and *Supplemental Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program: Residential and Commercial Toxic Pollutant Loadings and POTW Removal Efficiency Estimation* (U.S. EPA 1991a). If such monitoring and technical review of data indicate that a local limit is needed, the POTW would establish and implement a local limit. The monitoring program should follow the guidelines discussed previously in this appendix.

The basic philosophy of instituting management practices (IMPs) is to minimize the discharge of toxic or hazardous pollutants to the sewer, or reduce the impact of toxic/hazardous pollutant discharges by avoiding short-term, high-concentration discharges. Examples of appropriate uses of IMPs include the control of chemical spills and slug discharges to the POTW through formal chemical or waste management plans, including BMPs, solvent management plans, batch discharge policies, waste recycling, and waste minimization. It would also be appropriate to consider IMPs in cases where the POTW does not include biological treatment processes, or provides less treatment, e.g., primary treatment. In these cases, IMPs can be tailored for industrial sources of toxic pollutants that might otherwise interfere with biological treatment or would be degraded or removed through additional treatment.

SECONDARY REMOVAL EQUIVALENCY APPROACH

The second approach that 301(h) applicants may use to satisfy the new urban area pretreatment requirements is to demonstrate secondary removal equivalency. As noted in §125.65(d):

> An applicant shall demonstrate that it achieves secondary removal equivalency through the use of a secondary treatment pilot plant at the applicant's facility which provides an empirical determination of the amount of a toxic pollutant removed by the application of secondary treatment to the applicant's discharge, where the applicant's influent has not been pretreated. Alternatively, an applicant may make this determination using influent that has been pretreated, notwithstanding §125.58(w).

In effect, the applicant's existing treatment processes and industrial pretreatment program must remove at least as much of a toxic pollutant as would be removed if the applicant applied secondary treatment and did not have an industrial pretreatment requirement for that pollutant.

To demonstrate secondary removal equivalency, an applicant would need to use a secondary treatment pilot plant. By diverting part of its primary effluent (secondary influent) to the pilot plant (see Figure E-4), the applicant would empirically determine the incremental amount of each toxic pollutant that would be removed from the primary effluent (secondary influent) if secondary treatment were applied. Having determined the amount of each toxic pollutant removed, the applicant would then demonstrate that its existing less-than-secondary treatment plus existing industrial pretreatment removes at least the same amount of each toxic pollutant as did the secondary treatment pilot plant (including removals in the primary effluent) without any industrial pretreatment.

Figure E-4 schematically represents how the secondary removal equivalency test would work for a POTW that has an existing industrial pretreatment program. Toxic pollutant scans would be conducted on the effluent from the existing POTW (SCAN E1) and from the secondary pilot plant (SCAN E2). To achieve secondary removal equivalency for a toxic pollutant, the following must hold:

$$\text{E1 concentration} \quad \leq \quad \text{E2 concentration}$$

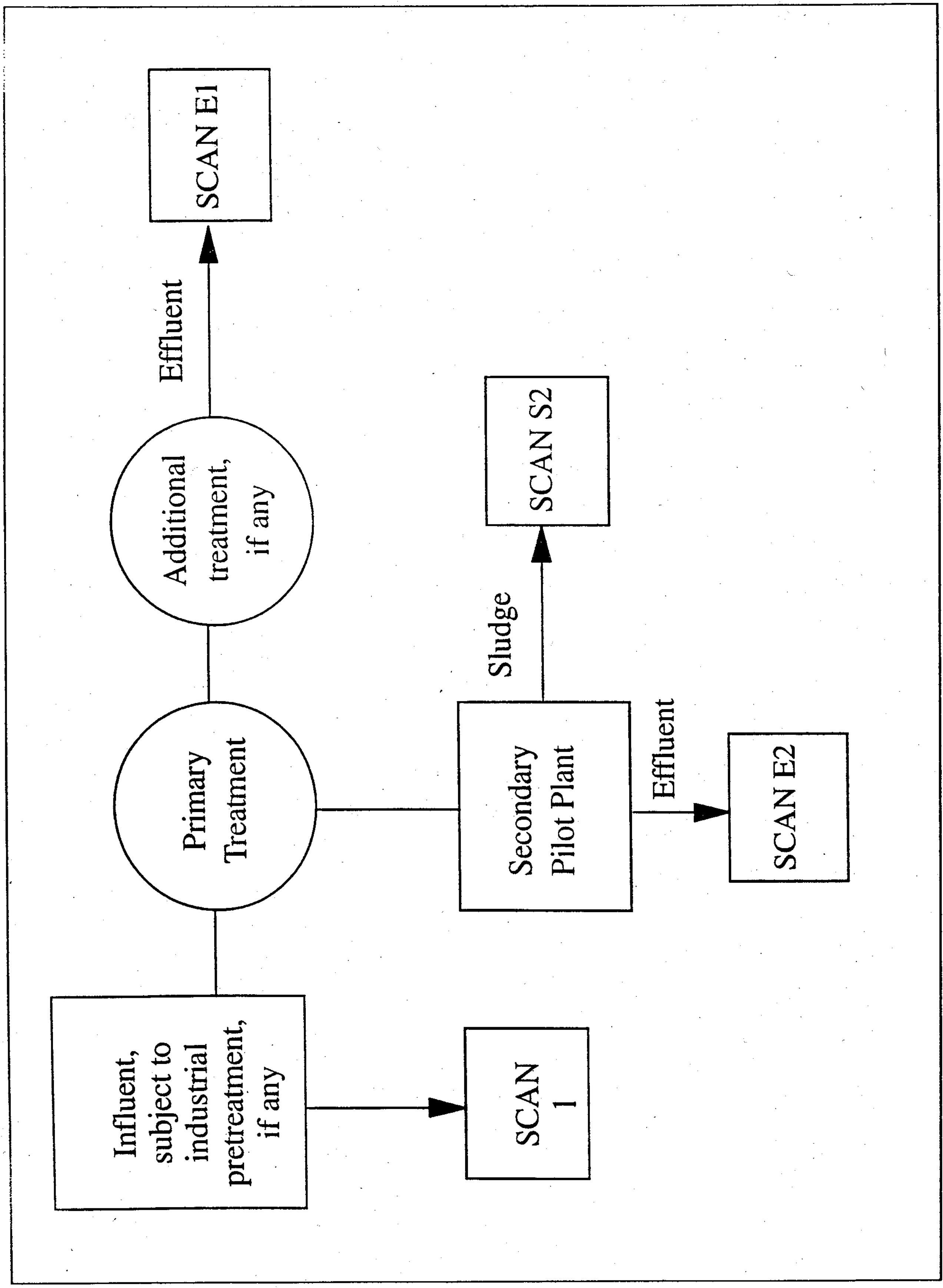

Figure E-4. Secondary pilot plant demonstration.

The above relationship is equivalent to the following, restated in terms of removals of a toxic pollutant:

$$\overbrace{\begin{matrix}\text{removals by any}\\ \text{existing industrial}\\ \text{pretreatment}^{*}\end{matrix} + \begin{matrix}\text{removals by existing}\\ \text{primary and any}\\ \text{existing additional}\\ \text{POTW treatment}\end{matrix}}^{\text{Removals by Existing Treatment}} \geq \overbrace{\begin{matrix}\text{removals by any}\\ \text{existing POTW}\\ \text{primary treatment}\end{matrix} + \begin{matrix}\text{removals by}\\ \text{secondary pilot}\\ \text{plant treatment}\\ \text{(scaled up)}\end{matrix}}^{\text{Removals by Secondary Treatment (and no industrial pretreatment)}}$$

If the POTW is able to estimate the amount of a toxic pollutant removed by its existing industrial pretreatment (*), then secondary equivalency demonstration using the above formula is straightforward. In many instances, however, the POTW will not have the necessary data with which to estimate removals of toxic pollutants by existing industrial pretreatment. In those instances, the above equation is revised as follows:

$$\overbrace{\begin{matrix}\text{removals by}\\ \text{any existing}\\ \text{industrial}\\ \text{pretreatment}\end{matrix} + \begin{matrix}\text{removals by}\\ \text{existing primary}\\ \text{and any}\\ \text{existing}\\ \text{additional}\\ \text{POTW}\\ \text{treatment}\end{matrix}}^{\text{Removals by Existing Treatment}} \geq \overbrace{\boxed{\begin{matrix}\text{removals by}\\ \text{any existing}\\ \text{industrial}\\ \text{pretreatment}\end{matrix}}^{\,*} + \begin{matrix}\text{removals by}\\ \text{any existing}\\ \text{POTW}\\ \text{primary}\\ \text{treatment}\end{matrix} + \begin{matrix}\text{removals by}\\ \text{secondary}\\ \text{pilot plant}\\ \text{treatment}\\ \text{(scaled up)}\end{matrix}}^{\text{Removals by Secondary Treatment (with existing industrial pretreatment)}}$$

Ideally the (*) term should not appear on the right side of the equation, but this cannot be avoided unless the POTW can factor out this term by knowing, through independent means (e.g., a rigorous industrial wastewater pretreatment survey) the amount of a toxic pollutant removed by existing industrial pretreatment. Otherwise, the POTW may choose to perform the empirical (pilot plant) secondary removal equivalency demonstration using influent that has been subject to that existing industrial pretreatment. Such a demonstration may then be conservative because it may overstate the amount of toxic pollutant that would be removed by applying only primary and secondary treatment.

If the POTW's above demonstration fails to demonstrate attainment of secondary removal equivalency, then the POTW must evaluate the need for additional industrial pretreatment, additional POTW treatment, or a combination of the two to achieve the necessary additional removals, as defined in the revised equation shown below:

Removals by Existing Plus Any New Additional Treatment				Removals by Secondary Treatment (with existing industrial pretreatment)				
removals by any existing industrial pretreatment	+	removals by existing primary and any existing additional POTW treatment	≥	removals by any existing industrial pretreat-ment	+	removals by any existing POTW primary treatment	+	removals by secondary pilot plant treatment (scaled up)
+ new additional pretreatment **		+ new additional POTW treatment **						

The "new" removals shown on the left side of the equation (**) represent additional future removals by any new industrial pretreatment or new POTW treatment added to achieve secondary equivalency. The applicant will be required to develop effluent limits based on data from the secondary removal equivalency demonstration when these values are more stringent than effluent limits based on state water quality standards or water quality criteria or will be required to ensure that all applicable environmental protection criteria are met. Once the effluent limits are established, the applicant may either develop local limits (as described earlier) or perform additional treatment at the POTW, or combine the two to achieve the permit limit.

Secondary treatment at POTWs typically involves biological processes that remove organic matter through biochemical oxidation, usually variations of the activated sludge process. Other physical-chemical secondary treatment processes (e.g., coagulation, filtration, carbon adsorption) may also be used, particularly for nonbiodegradable wastewaters. The specific secondary treatment process used by a POTW is dependent on numerous factors such as wastewater quantity, waste biodegradability, and available space at the POTW site. Each POTW must determine the best strategy and the most applicable treatment process for complying with the secondary removal equivalency requirements.

The level of effluent quality attainable through the application of secondary treatment is defined in 40 CFR Part 133 (Table E-4). Treatment processes that are considered equivalent to secondary treatment (e.g., trickling filter, waste stabilization pond) are discussed in 40 CFR 133.105. Minimum levels of effluent quality attainable from these equivalent treatment processes differ from those shown in Table E-4.

Because secondary treatment levels were defined only for BOD, suspended solids, and pH, POTWs were usually not required to institute technology specifically to control toxic pollutants. Under the 1977 Clean Water Act, toxic pollutants in the POTW effluents were

TABLE E-4. EFFLUENT WATER QUALITY VALUES THAT SHALL NOT BE EXCEEDED UNDER SECONDARY TREATMENT

Variable[a]	30-Day Average	7-Day Average	30-Day Average (Percent Removal)
BOD_5	30 mg/L	45 mg/L	>85
$CBOD_5$[b]	25 mg/L	40 mg/L	>85
SS	30 mg/L	45 mg/L	>85
pH	6.0 to 9.0		

[a] BOD_5 = 5-day measure of biochemical oxygen demand; $CBOD_5$ = 5-day measure of carbonaceous biochemical oxygen demand; SS = suspended solids.
[b] At the option of the NPDES permitting authority, $CBOD_5$ may be substituted for BOD_5.

controlled predominantly through pretreatment programs, categorical standards, and local POTW limits required by the issuance of NPDES permits.

SECONDARY TREATMENT PILOT PLANT DESIGN CRITERIA

A secondary treatment pilot plant should be designed for an average flow of approximately 150 GPD. The flow rate should remain constant over a 24-hour period. The pilot plant should require minimum operation and maintenance time and must be able to operate unattended for 16-24 hours. The organic loading will vary with the diurnal and seasonal fluctuations in the BOD_5 concentration in the existing POTW effluent. Design criteria for the secondary treatment pilot plant are shown in Table E-5.

A conventional activated sludge system (Figure E-5) for a POTW includes the following related components:

- Single or multiple reactor basins (i.e., aeration tanks) in which microorganisms consume the organic wastes. These basins are designed to allow for complete mixing of their contents, which are defined as mixed liquor suspended solids (MLSS). Each basin must provide typical hydraulic retention times of 2-24 hours.

- Pressurized or atmospheric oxygen-containing gases that are dispersed into the reactor basin.

TABLE E-5. SECONDARY TREATMENT PILOT PLANT DESIGN CRITERIA

Reactor Basin (Aeration Tank)	
Volume	50 gal (189 L)
Detention time	8 h
Organic loading	25-60 lb BOD/1,000 ft^3/day (0.4-1.0 kg/m^3/day)
Air requirement	0.20-0.44 ft^3/min (0.33-0.75 m^3/h)
Settling Basin (Final Clarifier)	
Volume	20 gal (76 L)
Surface area	0.375 ft^2 (0.035 m^2)
Overflow area	400 gal/ft^2/day (16.3 m^3/m^2/day)
Solids loading	14 lb/ft^2/day (68.4 kg/m^2/day)
Weir length	0.5 ft (0.152 m)
Detention time	3 h
Influent Feed Pump	
Capacity	0-290 gal/day (0-12.7 L/sec)
Type	Peristaltic
Return Activated Sludge Pump	
Capacity	0-130 gal/day (0-5.7 L/sec)

- Settling basin (i.e., final clarifier) to separate the MLSS from the treated wastewater.

- Equipment to collect the solids in the settling basin and to recycle the active biological solids (i.e., activated sludge) to the reactor basin.

- Equipment to remove excess active biological solids from the system.

Typical design variables for the conventional activated sludge process are shown in Table E-6. Additional information on activated sludge systems is provided by the Water Pollution Control Federation, or WPCF (1976, 1987) and WPCF/American Society for Civil Engineers (1977).

SECONDARY TREATMENT PILOT PLANT START-UP

In the activated sludge process, microorganisms metabolize nearly all soluble organic matter in the influent. The microorganisms (i.e., active biological solids) must be removed from

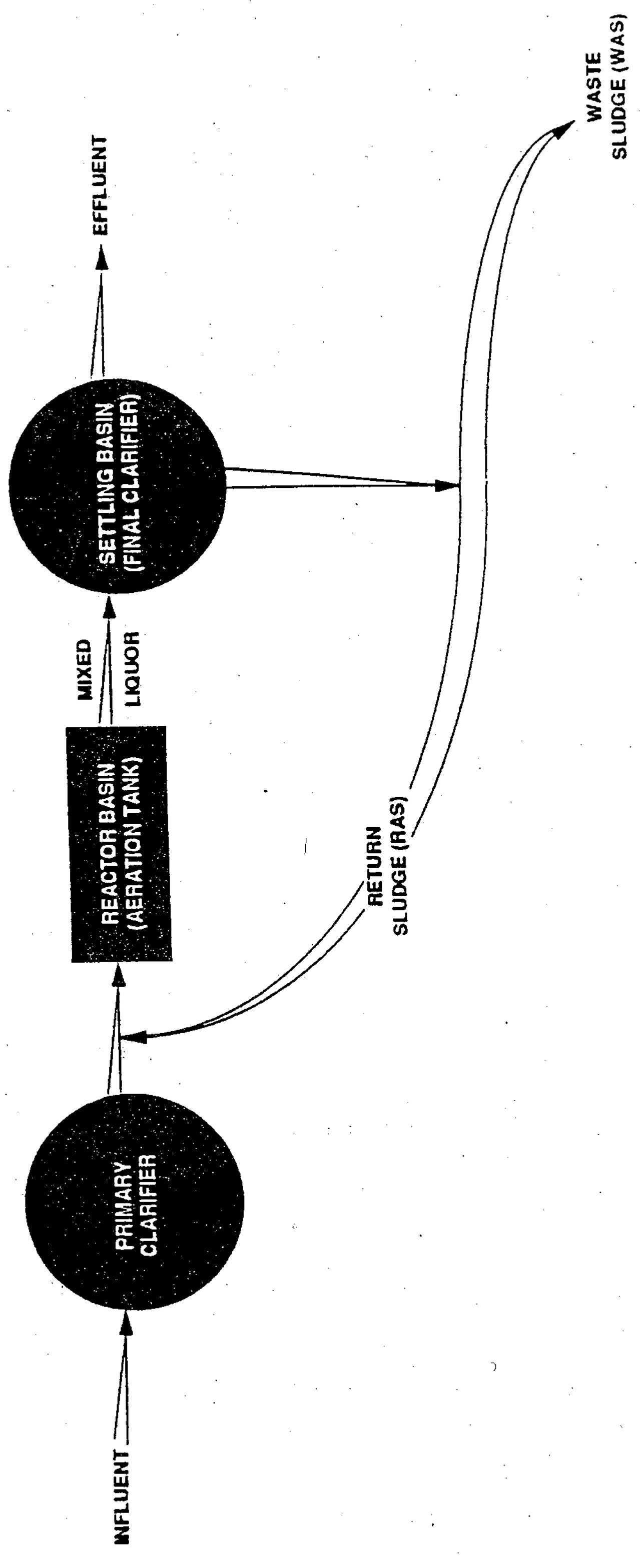

Figure E-5. Components of a conventional activated sludge system.

TABLE E-6. CONVENTIONAL ACTIVATED SLUDGE DESIGN PARAMETERS

Food-to-microorganism ratio	0.15-0.4 lb BOD_5/lb MLSS/day
Mean cell residence time	5-15 days
Aeration detention time	4-8 h
Oxygen requirements	0.8-1.1 lb (kg) 0_2/lb (kg) BOD_5 removed
Return activated sludge flow rate	30-100 percent influent flow
Mixed liquor suspended solids (MLSS)	1,500-4,000 mg/L
Organic loading at 3,000 mg/L MLSS	20-60 lb BOD/1,000 ft^3 (0.3-1.0 kg BOD/m^3)
Respiration (oxygen uptake) rate at 3,000 mg/L MLSS	15-45 mg oxygen/L/h
Sludge volume index	90-150
Waste activated sludge	0.4-0.6 lb (kg)/lb (kg) BOD removed

the settling basin to produce an acceptable effluent, and the proper operation of the settling basin is critical. The following process control parameters should be monitored to ensure proper operation of the activated sludge system:

- Mixed liquor suspended solids (MLSS);
- Mixed liquor volatile suspended solids (MLVSS);
- Dissolved oxygen;
- Sludge volume index (SVI);
- Sludge density index (SDI);
- Organic loading;
- Return activated sludge (RAS) flow rate;

- Waste activated sludge (WAS) flow rate;
- Mean cell residence time (MCRT)/solids retention time (SRT);
- Food-to-microorganism (F/M) ratio;
- Temperature;
- Hydrogen ion concentration (pH); and
- Respiration rate (RR).

In addition to monitoring these process control parameters, microscopic examination of the MLSS should be performed.

An initial food-to-microorganism (F/M) ratio of 0.2 should be achieved. Field operators should adjust the F/M ratio by changing the MLSS concentration in the reactor basin if the required 30-day average effluent quality (i.e., 30 mg/L BOD, 30 mg/L suspended solids) cannot be achieved. If temperature varies substantially between summer and winter, the F/M ratio will probably need to be lowered during winter to achieve the required effluent quality.

The pilot plant should be seeded with MLSS from a local domestic wastewater treatment facility. Acclimation of the pilot plant will require about 4-6 weeks. If there is no local source of MLSS, the pilot plant may be started using the POTW's effluent. An additional 4-6 weeks may be needed to ensure that the MLSS meets the desired design concentration.

The MLSS should be fed with domestic wastewater for the first 2-3 days. The volumetric proportion of the effluent should then be adjusted to 10 percent of the total feed for 4-5 days. After the initial week of operation, the volumetric proportion of the regular POTW effluent in the pilot plant feed can be increased approximately 5 percent per day until the system is receiving 100 percent POTW effluent.

Sampling for BOD_5 and suspended solids should be conducted daily during and after the acclimation period. Sampling for toxic pollutants should not be started until 2 weeks after the pilot plant is receiving 100 percent POTW effluent.

SECONDARY TREATMENT PILOT PLANT OPERATING CRITERIA

The process control parameters identified in the preceding section should be monitored to provide information for process control and to determine treatment efficiency. A monitoring schedule is shown in Table E-7. The frequency of sample collection and analysis may vary for each POTW, however, depending on the size of the POTW, available laboratory facilities, available staff, and the technical skills of the personnel. Additional sampling and analysis may be required for abnormal conditions or during periods of process upsets. Implementation of the monitoring program, data interpretation, and pilot plant operation and maintenance is estimated to require about 5 labor hours per day. Each process control parameter is discussed below.

TABLE E-7. PILOT PLANT MONITORING SCHEDULE

Sampling Point	Parameters[a]	Frequency
Primary Effluent	Temperature	1 grab daily
	pH	1 grab daily
	SS	4 grabs weekly and 3 24-h composites weekly
	BOD_5	3 24-h composites weekly
	Overflow rate	1 grab daily
	$CBOD_5$	1 24-h composite weekly
MLSS	Temperature	1 grab daily
	pH	1 grab daily
	Dissolved oxygen	2 grabs daily
	Respiration rate	2 grabs daily
	Sludge volume index	2 grabs daily
	SS	1 grab daily
	VSS	1 grab daily
	Microscopic examination	1 grab daily
WAS/RAS	SS	1 grab daily
Secondary Clarifier	Sludge blanket depth	2 grabs daily
Final Effluent	Temperature	1 grab daily
	pH	1 grab daily
	Settleable solids	1 grab daily
	SS	4 grabs weekly and 3 24-h composites weekly
	BOD_5	3 24-h composites weekly
	$CBOD_5$	1 24-h composite weekly

[a] SS = Suspended solids; BOD_5 = 5-day biochemical oxygen demand; $CBOD_5$ = 5-day carbonaceous biochemical oxygen demand; VSS = volatile suspended solids.

Mixed Liquor Suspended Solids (MLSS)

Samples of MLSS should be collected from the effluent end of the reactor basin twice daily and analyzed for suspended solids. This analysis will measure the total amount of solids in the aeration system. The concentration of the MLSS, which depends on the influent BOD_5 concentration, should be adjusted based on the daily average.

Mixed Liquor Volatile Suspended Solids (MLVSS)

Each MLSS sample should be analyzed for MLVSS. This analysis indirectly measures the living biological percentage of the MLSS. The concentration of MLVSS is normally 70 to 80 percent of the concentration of the MLSS.

Dissolved Oxygen

The concentration of dissolved oxygen in the reactor basins should be measured twice daily to ensure that a concentration of 1-3 mg/L is maintained. Samples should be collected about 2 ft below the surface of the reactor basin, near the effluent weir. The plant operator should adjust the air supply to provide more air if the dissolved oxygen concentration is less than 1 mg/L and less air if it is greater than 3 mg/L.

Sludge Volume Index (SVI)

The rate at which the MLSS settles in the settling basin depends on the sludge characteristics. These characteristics are described by a simple settling test: 1,000 mL of the MLSS effluent is collected and allowed to settle for 30 minutes in a Mallory settleometer. At the end of 30 minutes, the volume of the settled sludge is measured. The SVI (mL/g) is calculated as follows:

$$SVI = \frac{\textit{sludge volume after settling } (mL/L) \times 1{,}000}{MLSS\ (mg/L)}$$

The lower the SVI, the more dense the sludge. An SVI of 150 or less is usually considered good.

Sludge Density Index (SDI)

The SDI test is also used to indicate the settling characteristics of the sludge, and it is arithmetically related to the SVI:

$$SDI = \frac{100}{SVI}$$

The SDI (g/mL) of a "good settling sludge" is about 1.0. A value of less than 1.0 indicates light sludge that settles slowly, and a value greater than 1.5 indicates dense sludge that settles rapidly.

Organic Loading

From routine laboratory BOD_5 analysis, the plant operator can determine organic loading in the reactor basin.

$$Organic\ loading\ (lb\ BOD/1{,}000\ ft^3/day) =$$

$$POTW\ effluent\ BOD\ (mg/L) \times \frac{POTW\ effluent\ flow\ (MGD) \times 0.0624}{reactor\ basin\ volume\ (MG)}$$

Return Activated Sludge (RAS) Flow Rate

To properly operate the activated sludge process, MLSS that settle adequately must be achieved and maintained. The MLSS are settled in the settling basin and then returned to the reactor basin as RAS. The RAS allows the microorganisms to remain in the treatment system longer than the flowing wastewater. Changes in the activated sludge quality and settling characteristics will require different RAS flow rates.

Two basic approaches can be used to control the RAS flow rate. One approach establishes a constant RAS flow rate, independent of the influent flow. This approach is simple (i.e., maximum solids loading in the settling basin occurs at the start of the peak flow periods), and less operator attention is needed. A disadvantage of this approach is that the F/M ratio is constantly changing. However, because of short-term variation in the MLSS due to hydraulic loading, the range of fluctuation in the F/M ratio is usually small enough to ensure that no significant problems arise.

A second approach establishes the RAS flow rate as a constant percentage of the influent flow. This approach reduces variations in the MLSS concentration and the F/M ratio, and the MLSS remain in the settling basin for shorter time periods (which may reduce the possibility of denitrification in the basin). The most significant disadvantage of this approach is that the settling basin is subjected to maximum solids loading when the basin contains the maximum amount of sludge, which produces excessive solids in the effluent.

Two methods are commonly used to determine the RAS flow rate. The settleability method uses the settled sludge volume from the SVI test to calculate the RAS flow rate:

$$\textit{RAS Flow Rate (MGD)} =$$

$$\textit{Volume of Settled Sludge (mL/L)} \times \frac{[\textit{POTW Effluent Flow (MGD)}]}{1{,}000\ \textit{mL/L}}$$

The second and more direct method is to monitor the depth of the sludge blanket in the settling basin. The depth of the sludge blanket should be less than one-fourth the water depth of the settling basin sidewall. The operator must check the sludge blanket depth twice daily, adjusting the RAS flow to control the blanket depth. If the depth of the sludge blanket is increasing, increasing the RAS flow is only a short-term solution. Increases in sludge blanket depth may result from too much activated sludge in the treatment system, a poorly settling sludge, or both. If the sludge is settling poorly, increasing the RAS flow may cause even more problems by further increasing the flow through the settling basin. The long-term corrections noted below must be made to improve the settling characteristics of the sludge or remove the excess solids from the treatment system:

- If the sludge is settling poorly because of bulking, the environmental conditions for the microorganisms must be improved.

- If there is too much activated sludge in the treatment system, the excess sludge must be wasted.

The best time to measure RAS flow is during the period of maximum daily flow, because at that time the clarifier is operating under the highest solids loading rate. Adjustments in the RAS flow rate should be needed only occasionally if the activated sludge process is operating properly.

Waste Activated Sludge (WAS) Flow Rate

The increase of activated sludge is a cumulative process that eventually produces surplus WAS. This surplus has to be permanently removed from the treatment process and collected for ultimate disposal. The WAS flow rate should be determined and adjusted daily to maintain the desired mean cell residence time (MCRT), based on the MLSS in the entire secondary system, and RAS suspended solids concentration:

$$\text{WAS flow rate (MGD)} = \text{MLSS (mg/L)} \times \frac{[\text{aeration tank volume (MG)} + \text{clarifier volume (MG)}]}{[\text{desired MCRT (days)}] \times [\text{RAS suspended solids (mg/L)}]}$$

Mean Cell Residence Time (MCRT)/Solids Retention Time (SRT)

The MCRT, which is also called the SRT, is a measure of the age of sludge. Under normal conditions, the MCRT is 5-15 days. MCRT is defined as:

$$MCRT = \frac{\text{Suspended solids in total secondary system (lb)}}{\text{Solids wasted (lb/day)} + \text{effluent solids (lb/day)}} =$$

$$\frac{[\text{MLSS (mg/L)} \times [\text{aeration tank volume (MG)} + \text{secondary clarifier volume (MG)}]}{[\text{WAS suspended solids (mg/L)} \times \text{WAS flow (MGD)}] + [\text{Effluent suspended solids (mg/L)} \times \text{effluent flow (MGD)}]}$$

The MCRT is the best process control technique available to the plant operator. By using the MCRT, the operator can control the quantity of food available to the microorganisms and calculate the amount of activated sludge that should be wasted.

Food-to-Microorganism (F/M) Ratio

The F/M ratio is the ratio of BOD in the POTW effluent to the MLVSS. An F/M ratio of 0.15 to 0.4 is desirable. F/M is defined as:

$$F/M = \frac{\text{POTW effluent BOD (mg/L)}}{\text{MLVSS (mg/L)}}$$

To control the F/M ratio, the operator must adjust the MLSS by wasting more or less sludge.

Temperature

In process control, accurate temperature measurements are required to predict and evaluate process performance, thereby enhancing microbial growth. Typically, the rate of microbial growth doubles for every 10 °C increase in temperature within the specific temperature range of the microbe.

Hydrogen Ion Concentration (pH)

The activity and health of microorganisms are affected by pH. Sudden changes or abnormal pH values may indicate an adverse industrial discharge. A pH drop also results when nitrification is occurring in a biological process; alkalinity is destroyed and carbon dioxide is produced during the nitrification process.

Respiration Rate (RR)

The efficiency of the activated sludge process depends primarily on the activity of bacteria that use organic compounds in sewage for energy and reproduction. When in contact with an adequate food supply, viable bacteria have a respiration rate (i.e., oxygen uptake rate) of 5-15 mg oxygen/h/g MLSS. Respiration rate data provide immediate information concerning viability, nitrification, organic loading, nutrient levels, and toxicity in the activated sludge.

The respiration rate, or oxygen uptake rate, is monitored with a dissolved oxygen meter over a time interval (t) (e.g., 6-10 minutes). The respiration rate is a measure of the decrease in dissolved oxygen (DO) concentration:

$$RR\ (mg\ oxygen/h/g\ MLSS) = \frac{[DO\ change\ over\ \ t\ (mg/L)] \times [60{,}000]}{[MLSS\ (mg/L)] \times [t\ (\mathrm{min})]}$$

Microscopic Examination

Microscopic examination of the MLSS can be used to evaluate the effectiveness of the activated sludge process. The most important microorganisms are the protozoa, heterotrophic bacteria, and autotrophic bacteria responsible for purifying the wastewater. Both protozoa (e.g., ciliates) and rotifers are indicators of treatment performance, and large numbers of these organisms in the MLSS indicate good-quality sludge. Large numbers of filamentous organisms and certain ciliates indicate poor sludge quality, a condition commonly associated with a sludge that settles poorly (i.e., the sludge floc is usually light and fluffy because it has a low density). Many other organisms (e.g., nematodes, waterborne insect larvae) may be found in the sludge, but these organisms are not significant to the activated sludge process.

TOXIC POLLUTANT MONITORING PROGRAM, TESTING PROCEDURES, AND QUALITY ASSURANCE/QUALITY CONTROL

A sampling strategy must be developed to estimate the difference between toxic pollutant concentrations in the existing discharge and those in the secondary treatment pilot plant discharge. Samples must be collected using proper techniques and analyzed using appropriate analytical methods. Both field and laboratory methods must be performed under defined QA/QC procedures.

Applicants are referred to the following documents for guidance on specific topics relevant to the design and execution of 301(h) monitoring programs:

- Sampling/Monitoring Program:
    - *NPDES Compliance Sampling Manual* (U.S. EPA 1979a);
    - *Design of 301(h) Monitoring Programs for Municipal Wastewater Discharges to Marine Waters* (U.S. EPA 1982a); and
    - *Handbook for Sampling and Sample Preservation of Water and Wastewater* (U.S. EPA 1982c);
- Chemical Analytical Methods:
    - *Methods for Chemical Analysis of Water and Wastes* (U.S. EPA 1979b, revised 1983);
    - *Guidelines Establishing Test Procedures for the Analysis of Pollutants* (40 CFR Part 136);
    - *Standard Methods for the Examination of Water and Wastewater*, 16th ed. (American Public Health Association et al. 1985);
    - *Analytical Methods for EPA Priority Pollutants and 301(h) Pesticides in Estuarine and Marine Sediments* (U.S. EPA 1986d); and
    - *Analytical Methods for EPA Priority Pollutants and 301(h) Pesticides in Tissues from Estuarine and Marine Organisms* (U.S. EPA 1986e).

- Quality Assurance/Quality Control (QA/QC):

  - *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (U.S. EPA 1979c) and

  - *Quality Assurance/Quality Control (QA/QC) for 301(h) Monitoring Programs: Guidance on Field and Laboratory Methods* (U.S. EPA 1987d).

Information from these documents is summarized below.

SAMPLING FREQUENCY

The frequency of sampling is dependent on the characteristics of the discharge (e.g., influent and effluent toxic pollutant variability, flow, size and location of the discharge). For example, large applicants with substantial quantities of toxic pollutants should conduct more frequent sampling than small dischargers with fewer toxic pollutants. Also, if existing toxic pollutant data are minimal, and estimates of periods of maximum pollutant loadings and peak concentrations are not known, then more frequent monitoring is needed.

The concentrations of toxic pollutants in the discharge may vary in response to periodic peak inflows. If a fixed periodic trend is observed (e.g., a sine curve), then the sampling plan could be designed to collect samples during the peak period.

If a fixed sampling interval that is equal to or a multiple of the period is chosen, every sample would be taken at the same inflow condition and the estimate of the mean difference in toxic pollutant concentrations between samples would not take into account all possible inflows. The most favorable sampling situation occurs when the fixed sampling interval is an odd multiple of the half-period (i.e., successive deviations above and below the mean inflow would mathematically cancel one another, and the mean difference in concentration between samples would take into account the mean inflow). However, toxic pollutant effluent data from the applicant may not be sufficient to identify the odd multiple of the half-period. In this case, a fixed sampling interval would not be recommended.

Assuming that the toxic pollutant limits for the POTW will be based on the pollutant concentrations measured in the secondary treatment effluents, a flexible sampling scheme for secondary treatment pilot plant effluents may involve sample collection for 1 day/week (over

24 hours) on different days of the week over a 1-year period of pilot plant operation. This flexible sampling frequency would generate a data set that represents an acclimated biological treatment system. It would also address the day/night, weekday/weekend, and seasonal variations in domestic, industrial/commercial, and wet- and dry-weather discharges.

SAMPLE COLLECTION AND ANALYSIS

Representative samples must be collected to ensure that data are reliable. Care must be taken to select appropriate sampling devices and procedures. Depending on the toxic pollutant to be analyzed, three types of samples may be collected:

- Grab sample — A discrete sample volume is collected. (This type of sample will not always provide an accurate measure of wastewater characteristics, particularly when the flow or pollutants are heterogeneous or vary with time.)

- Simple composite sample — Equal sample volumes are collected sequentially over time and combined in a single reservoir. (This type of sample does not measure the mass of pollutants discharged because pollutant loading is a flow-related value.)

- Flow-proportioned composite sample — Incremental samples are collected over time and sample volumes are proportional to flow. Incremental samples are combined in a single reservoir. (This type of sample provides the most accurate measurement of wastewater quality and pollutant loading.)

The methods to be used for the analysis of toxic pollutants are summarized in Tables E-8, E-9, and E-10. Grab samples for volatile organic compounds, total recoverable phenolic compounds, and cyanide should be collected manually at least four times during the discharging period of the POTW during a 24-hour period (e.g., at least every 6 hours within a 24-hour period, assuming continuous discharge). Samples for all other variables should be collected using an automatic sampler. The automatic sampler should collect a selected number of sample aliquots (minimum of 100 mL each) during the discharging period of the POTW. Recommended sample sizes, containers, preservation techniques, and holding times are shown in Table E-11. Sample analyses will generally be completed by the analytical laboratory within 4-6 weeks; data analyses will generally require an additional week. Interpretation of all data collected at the pilot plant during 1 year will require about 2 weeks.

TABLE E-8. LIST OF TEST PROCEDURES APPROVED BY U.S. EPA FOR INORGANIC COMPOUNDS IN EFFLUENT

NOTE: This table is an exact reproduction of Table 1B in 40 CFR 136.3.

Parameter, units, and method	Reference (method No. or page)				
	EPA 1979	Standard methods 16th Ed.	ASTM	USGS [1]	Other
1. Acidity, as $CaCO_3$ mg/L: Electrometric end point or phenolphthalein end point.	305.1	402(4.a)	1067–82(E)		
2. Alkalinity, as $CaCO_3$ mg/L:					
Electrometric or colorimetric titration to pH 4.5, manual, or.	310.1	403	D1067–82(B)	I–1030–84	33.014[2].
Automated	310.2			I–2030–84	
3. Aluminum—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	202.1	303C		I–3051–85	
AA furnace	202.2	304			
Inductively coupled plasma (ICP)					200.7.[4]
Direct current plasma (DCP) or					Note 33.
Colorimetric (Eriochrome cyanine R)		306B			
4. Ammonia (as N), mg/L: Manual distillation (at pH 9.5) [5] followed by:	350.2	417A			33.057.[2]
Nesslerization	350.2	417B	D1426–79(A)	I–3520–84	33.057.[2]
Titration	350.2	417D			
Electrode	350.3	417 E or F	D1426–79(D)		
Automated phenate or	350.1	417G	D1426–79(C)	I–4523–84	
Automated electrode					Note 6.
5. Antimony—Total [3], mg/L: Digestion [3] followed by:					
AA direct aspiration	204.1	303A			
AA furnace, or	204.2	304			
Inductively coupled plasma					200.7.[4]
6. Arsenic—Total [3], mg/L: Digestion [3] followed by	206.5				
AA gaseous hydride	206.3	303E	D2972–84(B)	I–3062–84	
AA furnace	206.2	304			
Inductively coupled plasma, or					200.7.[4]
Colorimetric (SDDC)	206.4	307B	D2972–84(A)	I–3060–84	
7. Barium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	208.1	303C		I–3084–85	
AA furnace	208.2	304			
ICP, or					200.7.[4]
DCP					Note 33.
8. Beryllium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	210.1	303C	D3645–84(A)	I–3095–85	
AA furnace	210.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (aluminon)		309B			
9. Biochemical oxygen demand (BOD_5), mg/L:					
Dissolved Oxygen Depletion	405.1	507		1–I578–78 [7]	33.019 [2], p. 17.[8]
10. Boron—Total, mg/L;					
Colorimetric (curcumin)	212.3	404A		I–3112–85	
ICP, or					200.7.[4]
DCP					Note 33.
11. Bromide, mg/L: Titrimetric	320.1		D1246–82(C)	I–1125–84	p. S44.[9]
12. Cadmium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	213.1	303 A or B	D3557–84 (A or B).	I–3135–85 or I–3136–85.	33.089.[2] p. 37.[8]
AA furnace	213.2	304			
ICP					200.7.[4]
DCP					Note 33.
Voltametry,[10] or			D3557–84(C)		
Colorimetric (Dithizone)		310B			

TABLE E-8. (Continued)

Parameter, units, and method	Reference (method No. or page)				
	EPA 1979	Standard methods 16th Ed.	ASTM	USGS [1]	Other
13. Calcium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	215.1	303A	D511–84(B)	I–3152–85	
ICP					200.7.[4]
DCP, or					Note 33.
Titrimetric (EDTA)	215.2	311C	D511–84(A)		
14. Carbonaceous biochemical oxygen demand (CBOD$_5$), mg/L [11]: Dissolved Oxygen Depletion with nitrification inhibitor.		507(5.e.6)			
15. Chemical oxygen demand (COD), mg/L:					
Titrimetric, or	410.1 410.2, or 410.3	508A	D1252–83	I–3560–84 or I–3562–84.	33.034 [2], p. 17.[8]
Spectrophotometric, manual or automated.	410.4			I–3561–84	Notes 12 or 13.
16. Chloride, mg/L:					
Titrimetric (silver nitrate)		407A	D512–81(B)	I–1183–84	
or (Mercuric nitrate), or	325.3	407B	D512–81(A)	I–1184–84	33.067.[2]
Colorimetric, manual or			D512–81(C)	I–1187–84	
Automated (Ferricyanide)	325.1, or 325.2	407D		I–2187–84	
17. Chlorine—Total residual, mg/L:					
Titrimetric:					
Amperometric direct	330.1	408C	D1253–76(A)		
Starch end point direct	330.3	408A	D1253–76(B) Part 18.3		
Back titration either end point [14], or.	330.2	408B			
DPD–FAS	330.4	408D			
Spectrophotometric, DPD	330.5	408E			
Or Electrode					Note 15.
18. Chromium VI dissolved, mg/L: 0.45 micron filtration followed by:					
AA chelation-extraction, or	218.4	303B		I–1232–84	
Colorimetric (Diphenylcarbazide)				I–1230–84	307B.[16]
19. Chromium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	218.1	303A	D1687–84(D)	I–3236–85	33.089.[2]
AA chelation-extraction	218.3	303B			
AA furnace	218.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Diphenylcarbazide)		312B	D1687–84(A)		
20. Cobalt—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	219.1	303 A or B	D3558–84 (A or B).	I–3239–85 or I–3240–85b.	p. 37.[8]
AA furnace	219.2	304			
ICP, or					200.7.[4]
DCP					Note 33.
21. Color platinum cobalt units or dominant wavelength, hue, luminance purity:					
Colorimetric (ADMI), or	110.1	204D			Note 17.
(Platinum cobalt), or	110.2	204A		I–1250–84	
Spectrophotometric	110.3	204B			
22. Copper—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	220.1	303 A or B	D1688–84 (D or E).	I–3270–85 or I–3271–85.	33.089.[2] p. 37.[8]
AA furnace	220.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Neocuproine), or (Bicinchoninate).		313B	D1688–84(A)		Note 18.

TABLE E-8. (Continued)

Parameter, units, and method	Reference (method No. or page)				
	EPA 1979	Standard methods 16th Ed.	ASTM	USGS [1]	Other
23. Cyanide—Total, mg.L: Manual distillation with $MgCl_2$ followed by		412B			
Titrimetric, or		412C			p. 22.[9]
Spectrophotometric, manual or	335.2	412D	D2036–82(A)	I–3300–84	
Automated.[10]	335.3		D2036–82(A)		
24. Cyanide amendable to chlorination, mg/L: Manual distillation with $MgCl_2$ followed by titrimetric or spectrophotometric.	335.1	412F	D2036–82(B)		
25. Fluoride—Total, mg/L: Manual distillation[5] followed by:		413A			
Electrode, manual or	340.2	413B	D1179–80(B)		
Automated.				I–4327–84	
Colorimetric (SPADNS),	340.1	413C	D1179–80(A)		
Or Automated complexone	340.3	413E			
26. Gold—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	231.2	303A			
AA furnace, or	231.2	304			
DCP					Note 33.
27. Hardness—Total, as $CaCO_3$ mg/L:					
Automated colorimetric,	130.1				
Titrimetric (EDTA), or Ca plus Mg as their carbonates, by inductively coupled plasma or AA direct aspiration. (See Parameters 13 and 33.).	130.2	314B	D1126–80	I–1338–84	33.082.[2]
28. Hydrogen ion (pH), pH units:					
Electrometric, measurement, or	150.1	423	D1293–84 (A or B).	I–1586–84	33.006.[2]
Automated electrode					Note 20.
29. Iridium—Total[3], mg/L; Digestion[3] followed by:					
AA direct aspiration, or	235.1	303A			
AA furnace	235.2	304			
30. Iron—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	236.1	303 A or B	D1068–84 (C or D).	I–3381–85	33.089.[2]
AA furnace	236.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Phenanthroline)		315B	D1068–84(A)		Note 21.
31. Kjeldahl nitrogen—Total, (as N), mg/L: Digestion and distillation followed by:	351.3	420 A or B	D3590–84(A)		
Titration	351.3	417D	D3590–84(A)		33.051.[2]
Nesslerization	351.3	417B	D3590–84(A)		
Electrode	351.3	417 E or F			
Automated phenate	351.1			I–4551–78 [7]	
Semi-automated block digestor, or	351.2		D3590–84(A)		
Potentiometric	351.4		D3590–84(A)		
32. Lead—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	239.1	303 A or B	D3559–84 (A or B).	I–3399–85	33.089.[2]
AA furnace	239.2	304			
ICP					200.7.[4]
DCP					Note 33.
Voltametry,[10] or			D3559–85(C)		
Colorimetric (Dithizone)		316B			
33. Magnesium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	242.1	303A	D511–84(B)	I–3447–85	33.089.[2]
ICP					200.7.[4]
DCP, or					Note 33.
Gravimetric		318B	D511–77(A)		

TABLE E-8. (Continued)

Parameter, units, and method	Reference (method No. or page)				
	EPA 1979	Standard methods 16th Ed.	ASTM	USGS [1]	Other
34. Manganese—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	243.1	304 A or B	D858–84 (B or C).	I–3454–85	33.089.[2]
AA furnace	243.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Persulfate) or		319B	D858–84(A)		33.126.[2]
(Periodate)					Note 22.
35. Mercury—Total [3], mg/L:					
Cold vapor, manual or	245.1	303F	D3223–80	I–3462–84	33.095.[2]
Automated	245.2				
36. Molybdenum—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	246.1	303C		I–3490–85	
AA furnace	246.2	304			
ICP, or					200.7.[4]
DCP					Note 33.
37. Nickel—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	249.1	303 A or B	D1886–84 (C or D).	I–3499–85	
AA furnace	249.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Heptoxime)		321B			
38. Nitrate (as N), mg/L: Colorimetric (Brucine sulfate), or Nitrate-nitrite N minus Nitrite N (See parameters 39 and 40).	352.1		D992–71		33.063 [2], 419D [16], p. 28.[9]
39. Nitrate-nitrite (as N), mg/L: Cadmium reduction, Manual or	353.3	418C	D3867–85(B)		
Automated, or	353.2	418F	D3867–85(A)	I–4545–84	
Automated hydrazine	353.1				
40. Nitrite (as N), mg/L: Spectrophotometric:					
Manual or	354.1	419	D1254–67		Note 24.
Automated (Diazotization)				I–4540–84	
41. Oil and grease—Total recoverable, mg/L: Gravimetric (extraction).	413.1	503A			
42. Organic carbon—Total (TOC), mg/L: Combustion or oxidation.	415.1	505	D2579.85 (A or B).		33.044 [2], p. 4.[22]
43. Organic nitrogen (as N) mg/L: Total Kjeldahl N (Parameter 31) minus ammonia N (Parameter 4.).					
44. Orthophosphate (as P), mg/L: Ascorbic acid method:					
Automated or	365.1	424G		I–4601–84	33.116. [2]
Manual single reagent	365.2	424F	D515–82(A)		33.111. [2]
or Manual two reagent	365.3				
45. Osmium—Total [3], mg/L: Digestion [3] followed by:					
AA direct aspiration, or	252.1	303C			
AA furnace	252.2	304			
46. Oxygen dissolved, mg/L: Winkler (Azide: modification), or	360.2	421B	D888–81(C)	I–1575–78 [7]	33.028. [2]
Electrode	360.1	421F		I–1576–78 [7]	
47. Palladium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	253.1				p. S27.[9]
AA furnace	253.2				p. S28.[9]
DCP					Note 33.
48. Phenols, mg/L:					
Manual distillation [25]	420.1		D1783–80 (A or B).		Note 26.
Followed by:					
Colorimetric (4AAP) manual, or	420.1				Note 26.
Automated [19]	420.2				

TABLE E-8. (Continued)

Parameter, units, and method	Reference (method No. or page)				
	EPA 1979	Standard methods 16th Ed.	ASTM	USGS[1]	Other
49. Phosphorus (elemental) mg/L: Gas-liquid chromatography.					Note 27.
50. Phosphorus—Total, mg/L: Persulfate digestion followed by	365.2	424C(III)			33.111.[2]
Manual or	365.2 or 365.3.	424F	D515–82(A)		
Automated ascorbic acid reduction, or.	365.1	424G		I–4600–84	33.116.[2]
Semi-automated block digestor	365.4				
51. Platinum—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	255.1	303A			
AA furnace	255.2	304			
DCP					Note 33.
52. Potassium—total [3], mg/L: Digestion followed by:					
AA direct aspiration	258.1	303A		I–3630–84	33.103.[2]
Inductively coupled plasma					200.7.[4]
Flame photometric, or		322B	D1428–82(A)		
Colorimetric (Cobaltinitrate)					317B.[16]
53. Residue—Total, mg/L: Gravimetric, 103–105°C.	160.3	209A		I–3750–84	
54. Residue—filterable, mg/L: Gravimetric, 180°C.	160.1	209B		I–1750–84	
55. Residue—nonfilterable, (TSS), mg/L: Gravimetric, 103–105°C post washing of residue.	160.2	209C		I–3765–84	
56. Residue—settleable, mg/L: Volumetric, (Imhoff cone) or gravimetric.	160.5	209E		1	
57. Residue—Volatile, mg/L: Gravimetric, 550°C.	160.4	209D		I–3753–84	
58. Rhodium—Total [3], mg/L: Digestion [3] followed by:.					
AA direct aspiration, or	265.1	303A			
AA furnace	265.2	304			
59. Ruthenium—Total [3], mg/L: Digestion [3] followed by:					
AA direct aspiration, or	267.1	303A			
AA furnace	267.2	304			
60. Selenium—Total [3], mg/L: Digestion [3] followed by:					
AA furnace	270.2	304			
Inductively coupled plasma, or					200.7[4]
AA gaseous hydride	270.3	303E	D3859–84(A)	I–3667–84	
61. Silica—Dissolved, mg/L: 0.45 micron filtration followed by:					
Colorimetric, Manual or	370.1	425C	D859–80(B)	I–1700–84	
Automated (Molybdosilicate), or				I–2700–84	
Inductively coupled plasma					200.7.[4]
62. Silver—Total,[28] mg/L; Digestion [3] followed by:					
AA direct aspiration	272.1	303 A or B		I–3720–85	33.089.[2] p. 37.[9]
AA furnace	272.2	304			
Colorimetric (Dithizone)					319B.[16]
ICP, or					200.7.[4]
DCP					Note 33.
63. Sodium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	273.1	303A		I–3735–85	33.107.[2]
ICP					200.7.[4]
DCP, or					Note 33.
Flame photometric		325B	D1428–82(A)		
64. Specific conductance, micromhos/cm at 25°C: Wheatstone bridge	120.1	205	D1125–82(A)	I–1780–84	33.002.[2]
65. Sulfate (as SO_4), mg/L:					
Automated colorimetric (barium chloranilate).	375.1				
Gravimetric, or	375.3	426 A or B	D516–82(A)		33.124.[2]
Turbidimetric	375.4		D516–82(B)		426C.[29]

TABLE E-8. (Continued)

Parameter, units, and method	Reference (method No. or page)				
	EPA 1979	Standard methods 16th Ed.	ASTM	USGS [1]	Other
66. Sulfide (as S), mg/L:					
Titrimetric (iodine) or	376.1	427D		I-3840-84	228A.[30]
Colorimetric (methylene blue)	376.2	427C			
67. Sulfite (as SO_3), mg/L: Titrimetric (iodine-iodate).	377.1	428A	D1339-84(C)		
68. Surfactants, mg/L: Colorimetric (methylene blue).	425.1	512B	D2330-82(A)		
69. Temperature, °C.: Thermometric	170.1	212			Note 31.
70. Thallium—Total [3], mg/L: Digestion [3] followed by:					
AA direct aspiration	279.1	303A			
AA furnace, or	279.2	304			
Inductively coupled plasma					200.7.[4]
71. Tin—Total [3], mg/L: Digestion [3] followed by:					
AA direct aspiration, or	282.1	303A		I-3850-78 [7]	
AA furnace,	282.2	304			
72. Titanium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	283.1	303C			
AA furnace	283.2	304			
DCP					Note 33.
73. Turbidity, NTU: Nephelometric	180.1	214A	D1889-81	I-3860-84	
74. Vanadium—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	286.1	303C			
AA furnace	286.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Gallic acid)		327B	D3373-84(A)		
75. Zinc—Total,[3] mg/L; Digestion [3] followed by:					
AA direct aspiration	289.1	303 A or B	D1691-84 (C or D).	I-3900-85	33.089.[2] p. 37.[9]
AA furnace	289.2	304			
ICP					200.7.[4]
DCP, or					Note 33.
Colorimetric (Dithizone) or		328C			
(Zincon)					Note 32.

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[1] "Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments," U.S. Department of the Interior, U.S. Geological Survey, Open-File Report 85-495, 1986, unless otherwise stated.

[2] "Official Methods of Analysis of the Association of Official Analytical Chemists," methods manual, 14th ed. (1985).

[3] For the determination of total metals the sample is not filtered before processing. A digestion procedure is required to solubilize suspended material and to destroy possible organic-metal complexes. Two digestion procedures are given in "Methods for Chemical Analysis of Water and Wastes, 1979." One (section 4.1.3), is a vigorous digestion using nitric acid. A less vigorous digestion using nitric and hydrochloric acids (section 4.1.4) is preferred; however, the analyst should be cautioned that this mild digestion may not suffice for all sample types. Particularly, if a colorimetric procedure is to be employed, it is necessary to ensure that all organo-metallic bonds be broken so that the metal is in a reactive state. In those situations, the vigorous digestion is to be preferred making certain that at no time does the sample go to dryness. Samples containing large amounts of organic materials would also benefit by this vigorous digestion. Use of the graphite furnace technique, inductively coupled plasma, as well as determinations for certain elements such as arsenic, the noble metals, mercury, selenium, and titanium require a modified digestion and in all cases the method write-up should be consulted for specific instruction and/or cautions.

NOTE: If the digestion included in one of the other approved references is different than the above, the EPA procedure must be used.

Dissolved metals are defined as those constituents which will pass through a 0.45 micron membrane filter. Following filtration of the sample, the referenced procedure for total metals must be followed. Sample digestion for dissolved metals may be omitted for AA (direct aspiration or graphite furnace) and ICP analyses provided the sample solution to be analyzed meets the following criteria:

a. has a low COD (<20)
b. is visibly transparent with a turbidity measurement of 1 NTU or less.
c. is colorless with no perceptable odor, and
d. is of one liquid phase and free of particulate or suspended matter following acidification.

[4] The full text of Method 200.7, "Inductively Coupled Plasma Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes," is given at Appendix C of this Part 136.

[5] Manual distillation is not required if comparability data on representative effluent samples are on company file to show that this preliminary distillation step is not necessary; however, manual distillation will be required to resolve any controversies.

TABLE E-8. (Continued)

[6] Ammonia, Automated Electrode Method, Industrial Method Number 379–75 WE, dated February 19, 1976, Technicon AutoAnalyzer II, Technicon Industrial Systems, Tarrytown, NY. 10591.

[7] The approved method is that cited in "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments", USGS TWRI, Book 5, Chapter A1 (1979).

[8] American National Standard on Photographic Processing Effluents, Apr. 2, 1975. Available from ANSI, 1430 Broadway, New York, NY 10018.

[9] "Selected Analytical Methods Approved and Cited by the United States Environmental Protection Agency," Supplement to the Fifteenth Edition of *Standard Methods for the Examination of Water and Wastewater* (1981).

[10] The use of normal and differential pulse voltage ramps to increase sensitivity and resolution is acceptable.

[11] Carbonaceous biochemical oxygen demand ($CBOD_5$) must not be confused with the traditional BOD_5 test which measures "total BOD." The addition of the nitrification inhibitor is not a procedural option, but must be included to report the $CBOD_5$ parameter. A discharger whose permit requires reporting the traditional BOD_5 may not use a nitrification inhibitor in the procedure for reporting the results. Only when a discharger's permit specifically states $CBOD_5$ is required, can the permittee report data using the nitrification inhibitor.

[12] OIC Chemical Oxygen Demand Method, Oceanography International Corporation, 512 West Loop, P.O. Box 2980, College Station, TX 77840.

[13] Chemical Oxygen Demand, Method 8000, Hach Handbook of Water Analysis, 1979, Hach chemical Company, P.O. Box 389, Loveland, CO 80537.

[14] The back titration method will be used to resolve controversy.

[15] Orion Research Instruction Manual, Residual Chlorine Electrode Model 97-70, 1977, Orion Research Incorporated, 840 Memonal Drive, Cambridge, MA 02138.

[16] The approved method is that cited in *Standard Methods for the Examination of Water and Wastewater*, 14th Edition, 1976.

[17] National Council of the Paper Industry for Air and Stream Improvement, (Inc.) Technical Bulletin 253, December 1971.

[18] Copper, Biocinchoinate Method, Method 8506, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, P.O. Box 389, Loveland, CO 80537.

[19] After the manual distillation is completed, the autoanalyzer manifolds in EPA Methods 335.3 (cyanide) or 420.2 (phenols) are simplified by connecting the re-sample line directly to the sampler. When using the manifold setup shown in Method 335.3, the buffer 6.2 should be replaced with the buffer 7.6 found in Method 335.2.

[20] Hydrogen Ion (pH) Automated Electrode Method, Industrial Method Number 378–75WA, October 1976, Technicon Auto-Analyzer II, Technicon Industrial Systems, Tarrytown, NY 10591.

[21] Iron, 1,10-Phenanthroline Method, Method 8008, 1980, Hach Chemical Company, P.O. Box 389, Loveland, CO 80537.

[22] Manganese, Periodate Oxidation Method, Method 8034, Hach Handbook of Wastewater Analysis, 1979, pages 2–113 and 2–117, Hach Chemical Company, Loveland, CO 80537.

[23] Goerlitz, D., Brown, E., "Methods for Analysis of Organic Substances in Water," U.S. Geological Survey Techniques of Water-Resources Inv., book 5, ch. A3, page 4 (1972).

[24] Nitrogen, Nitrite, Method 8507, Hach Chemical Company, P.O. Box 389, Loveland, CO 80537.

[25] Just prior to distillation, adjust the sulfuric-acid-preserved sample to pH 4 with 1 + 9 NaOH.

[26] The approved method is that cited in *Standard Methods for the Examination of Water and Wastewater*, 14th Edition. The colorimetric reaction is conducted at a pH of 10.0±0.2. The approved methods are given on pp. 576–81 of the 14th Edition: Method 510A for distillation, Method 510B for the manual colorimetric procedure, or Method 510C for the manual spectrophotometric procedure.

[27] R. F. Addison and R. G. Ackman, "Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography," *Journal of Chromatography*, vol. 47, No. 3, pp. 421–426, 1970.

[28] Approved methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/L and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to a pH of 12. Therefore, for levels of sliver above 1 mg/L, 20 mL of sample should be diluted to 100 mL by adding 40 mL each of 2 M $Na_2S_2O_3$ and 2M NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/L the approved method is satisfactory.

[29] The approved method is that cited in *Standard Methods for the Examination of Water and Wastewater*, 15th Edition.

[30] The approved method is that cited in *Standard Methods for the Examination of Water and Wastewater*, 13th Edition.

[31] Stevens, H. H., Ficke, J. F., and Smoot, G. F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation," U.S. Geological Survey, Techniques of Water Resources Investigations, Book 1, Chapter D1, 1975.

[32] Zinc, Zincon Method, Method 8009, Hach Handbook of Water Analysis, 1979, pages 2–231 and 2–333, Hach Chemical Company, Loveland, CO 80537.

[33] "Direct Current Plasma (DCP) Optical Emission Spectometric Method for Trace Elemental Analysis of Water and Wastes, Method AES0029." 1986, Applied Research Laboratones, Inc., 24911 Avenue Stanford, Valencia, CA 91355.

TABLE E-9. LIST OF TEST PROCEDURES APPROVED BY U.S. EPA FOR NON-PESTICIDE ORGANIC COMPOUNDS

NOTE: This table is an exact reproduction of Table 1C in 40 CFR 136.3.

Parameter [1]	EPA Method Number [2, 7]			Other
	GC	GC/MS	HPLC	
1. Acenaphthene	610	625, 1625	610	
2. Acenaphthylene	610	625, 1625	610	
3. Acrolein	603	[4]624, 1624		
4. Acrylonitrile	603	[4]624, 1624		
5. Anthracene	610	625, 1625	610	
6. Benzene	602	624, 1624		
7. Benzidine		[5]625, 1625	605	Note 3, p. 1;
8. Benzo(a)anthracene	610	625, 1625	610	
9. Benzo(a)pyrene	610	625, 1625	610	
10. Benzo(b)fluoranthene	610	625, 1625	610	
11. Benzo(g,h,i)perylene	610	625, 1625	610	
12. Benzo(k)fluoranthene	610	625, 1625	610	
13. Benzyl chloride				Note 3, p. 130; Note 6, p. S102.
14. Benzyl butyl phthalate	606	625, 1625		
15. Bis(2-chloroethoxy) methane	611	625, 1625		
16. Bis(2-chloroethyl) ether	611	625, 1625		
17. Bis(2-ethylhexyl) phthalate	606	625, 1625		
18. Bromodichloromethane	601	624, 1624		
19. Bromoform	601	624, 1624		
20. Bromomethane	601	624, 1624		
21. 4-Bromophenylphenyl ether	611	625, 1625		
22. Carbon tetrachloride	601	624, 1624		Note 3, p. 130;
23. 4-Chloro-3-methylphenol	604	625, 1625		
24. Chlorobenzene	601, 602	624, 1624		Note 3, p. 130;
25. Chloroethane	601	624, 1624		
26. 2-Chloroethylvinyl ether	601	624, 1624		
27. Chloroform	601	624, 1624		Note 3, p. 130;
28. Chloromethane	601	624, 1624		
29. 2-Chloronaphthalene	612	625, 1625		
30. 2-Chlorophenol	604	625, 1625		
31. 4-Chlorophenylphenyl ether	611	625, 1625		
32. Chrysene	610	625, 1625	610	
33. Dibenzo(a,h)anthracene	610	625, 1625	610	
34. Dibromochloromethane	601	624, 1624		
35. 1,2-Dichlorobenzene	601, 602, 612	624, 625, 1625		
36. 1,3-Dichlorobenzene	601, 602, 612	624, 625, 1625		
37. 1,4-Dichlorobenzene	601, 602, 612	625, 1624, 1625		
38. 3,3'-Dichlorobenzidine		625, 1625	605	
39. Dichlorodifluoromethane	601			
40. 1,1-Dichloroethane	601	624, 1624		
41. 1,2-Dichloroethane	601	624, 1624		
42. 1,1-Dichloroethene	601	624, 1624		
43. trans-1,2-Dichloroethene	601	624, 1624		
44. 2,4-Dichlorophenol	604	625, 1625		
45. 1,2-Dichloropropane	601	624, 1624		
46. cis-1,3-Dichloropropene	601	624, 1624		
47. trans-1,3-Dichloropropene	601	624, 1624		
48. Diethyl phthalate	606	625, 1625		
49. 2,4-Dimethylphenol	604	625, 1625		
50. Dimethyl phthalate	606	625, 1625		
51. Di-n-butyl phthalate	606	625, 1625		
52. Di-n-octyl phthalate	606	625, 1625		
53. 2,4-Dinitrophenol	604	625, 1625		
54. 2,4-Dinitrotoluene	609	625, 1625		
55. 2,6-Dinitrotoluene	609	625, 1625		
56. Epichlorohydrin				Note 3, p. 130; Note 6, p. S102.

TABLE E-9. (Continued)

Parameter[1]	EPA Method Number[2, 7]			Other
	GC	GC/MS	HPLC	
57. Ethylbenzene	602	624, 1624		
58. Fluoranthene	610	625, 1625	610	
59. Fluorene	610	625, 1625	610	
60. Hexachlorobenzene	612	625, 1625		
61. Hexachlorobutadiene	612	625, 1625		
62. Hexachlorocyclopentadiene	612	[5]625, 1625		
63. Hexachloroethane	612	625, 1625		
64. Ideno(1,2,3-cd)pyrene	610	625, 1625	610	
65. Isophorone	609	625, 1625		
66. Methylene chloride	601	624, 1624		Note 3, p. 130;
67. 2-Methyl-4,6-dinitrophenol	604	625, 1625		
68. Naphthalene	610	625, 1625	610	
69. Nitrobenezene	609	625, 1625		
70. 2-Nitrophenol	604	625, 1625		
71. 4-Nitrophenol	604	625, 1625		
72. N-Nitrosodimethylamine	607	625, 1625		
73. N-Nitrosodi-n-propylamine	607	[5]625, 1625		
74. N-Nitrosodiphenylamine	607	[5]625, 1625		
75. 2,2'-Oxybis(1-chloropropane)	611	625, 1625		
76. PCB-1016	608	625		Note 3, p. 43;
77. PCB-1221	608	625		Note 3, p. 43;
78. PCB-1232	608	625		Note 3, p. 43;
79. PCB-1242	608	625		Note 3, p. 43;
80. PCB-1248	608	625		Note 3, p. 43;
81. PCB-1254	608	625		Note 3, p. 43;
82. PCB-1260	608	625		Note 3, p. 43;
83. Pentachlorophenol	604	625, 1625		Note 3, p. 140;
84. Phenanthrene	610	625, 1625	610	
85. Phenol	604	625, 1625		
86. Pyrene	610	625, 1625	610	
87. 2,3,7,8-Tetrachlorodibenzo-p-dioxin		[5a]613		
88. 1,1,2,2-Tetrachloroethane	601	624, 1624		Note 3, p. 130;
89. Tetrachloroethene	601	624, 1624		Note 3, p. 130;
90. Toluene	602	624, 1624		
91. 1,2,4-Trichlorobenzene	612	625, 1625		Note 3, p. 130;
92. 1,1,1-Trichloroethane	601	624, 1624		
93. 1,1,2-Trichloroethane	601	624, 1624		Note 3, p. 130;
94. Trichloroethene	601	624, 1624		
95. Trichlorofluoromethane	601	624		
96. 2,4,6-Trichlorophenol	604	625, 1625		
97. Vinyl chloride	601	624, 1624		

Table IC Notes

[1] All parameters are expressed in micrograms per liter (μg/L).

[2] The full text of Methods 601–613, 624, 625, 1624, and 1625, are given at Appendix A, "Test Procedures for Analysis of Organic Pollutants," of this Part 136. The standardized test procedure to be used to determine the method detection limit (MDL) for these test procedures is given at Appendix B, "Definition and Procedure for the Determination of the Method Detection Limit," of this Part 136.

[3] "Methods for Benzidine: Chlorinated Organic Compounds, Pentachlorophenol and Pesticides in Water and Wastewater," U.S. Environmental Protection Agency, September, 1978.

[4] Method 624 may be extended to screen samples for Acrolein and Acrylonitrile. However, when they are known to be present, the preferred method for these two compounds is Method 603 or Method 1624.

[5] Method 625 may be extended to include benzidine, hexachlorocyclopentadiene, N-nitrosodiumethyamine, and N-nitrosodiphenylamine. However, when they are known to be present, Methods 605, 607, and 612, or Method 1625, are preferred methods for these compounds.

[5a] 625, Screening only.

[6] "Selected Analytical Methods Approved and Cited by the United States Environmental Protection Agency," Supplement to the Fifteenth Edition of *Standard Methods for the Examination of Water and Wastewater* (1981).

[7] Each analyst must make an initial, one-time, demonstration of their ability to generate acceptable precision and accuracy with Methods 601–613, 624, 625, 1624, and 1625 (See Appendix A of this Part 136) in accordance with procedures each in section 8.2 of each of these Methods. Additionally, each laboratory, on an on-going bases must spike and analyze 10% (5% for Methods 624 and 625 and 100% for methods 1624, and 1625) of all samples to monitor and evaluate laboratory data quality in accordance with sections 8.3 and 8.4 of these Methods. When the recovery of any parameter falls outside the warning limits, the analytical results for that parameter in the unspiked sample are suspect and cannot be reported to demonstrate regulatory compliance.

NOTE: These warning limits are promulgated as an "interim final action with a request for comments."

TABLE E-10. LIST OF TEST PROCEDURES APPROVED BY U.S. EPA FOR PESTICIDES[1]

NOTE: This table is an exact reproduction of Table 1D in 40 CFR 136.3.

Parameter µg/L)	Method	EPA ^{2,7}	Standard Methods 15th Ed	ASTM	Other
1. Aldrin	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			
2. Ametryn	GC				Note 3, p. 83; Note 6, p. S68.
3. Aminocarb	TLC				Note 3, p. 94; Note 6, p. S16.
4. Atraton	GC				Note 3, p. 83; Note 6, p. S68.
5. Atrazine	GC				Note 3, p. 83; Note 6, p. S68.
6. Azinphos methyl	GC				Note 3, p. 25; Note 6, p. S51.
7. Barban	TLC				Note 3, p. 104; Note 6, p. S64.
8. α-BHC	GC	608	509A	D3086	Note 3, p. 7.
	GC/MS	[5] 625			
9. β-BHC	GC	608		D3086	
	GC/MS	625			
10. δ-BHC	GC	608		D3086	
	GC/MS	[5] 625			
11. γ-BHC (Lindane)	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			
12. Captan	GC		509A		Note 3, p. 7.
13. Carbaryl	TLC				Note 3, p. 94; Note 6, p. S60.
14. Carbophenothion	GC				Note 4, p. 30; Note 6, p. S73.
15. Chlordane	GC	608	509A	D3086	Note 3, p. 7.
	GC-MS	625			
16. Chloropropham	TLC				Note 3, p. 104; Note 6, p. S64.
17. 2,4–D	GC		509B		Note 3, p. 115; Note 4, p. 35.
18. 4,4′–DDD	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC-MS	625			
19. 4,4′–DDE	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			
20. 4,4′–DDT	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			
21. Demeton-O	GC				Note 3, p. 25; Note 6, p. S51.
22. Dementon-S	GC				Note 3, p. 25; Note 6, p. S51.
23. Diazinon	GC				Note 3, p. 25; Note 4, p. 30; Note 6, p. S51.
24. Dicamba	GC				Note 3, p. 115.
25. Dichlofenthion	GC				Note 4, p. 30; Note 6, p. S73.
26. Dichloran	GC		509A		Note 3, p. 7.
27. Dicofol	GC			D3086	
28. Dieldrin	GC	608	509A		Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			
29. Dioxathion	GC				Note 4, p. 30; Note 6, p. S73.
30. Disulfoton	GC				Note 3, p. ; Note 6, p. S51.
31. Diuron	TLC				Note 3, p. 104; Note 6, p. S64.
32. Endosulfan I	GC	608	509A	D3086	Note 3, p. 7.
	GC/MS	[5] 625			
33. Endosulfan II	GC	608	509A	D3086	Note 3, p. 7.
	GC/MS	[5] 625			
34. Endosulfan sulfate	GC	608			
	GC/MS	625			
35. Endrin	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	[5] 625			
36. Endrin aldehyde	GC	608			
	GC/MS	625			
37. Ethion	GC				Note 4, p. 30; Note 6, p. S73.
38. Fenuron	TLC				Note 3, p. 104; Note 6, p. S64.
39. Fenuron-TCA	TLC				Note 3, p. 104; Note 6, p. S64.
40. Heptachlor	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			

TABLE E-10. (Continued)

Parameter µg/L)	Method	EPA [2,7]	Standard Methods 15th Ed	ASTM	Other
41. Heptachlor epoxide	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30; Note 6, p. S73.
	GC/MS	625			
42. Isodrin	GC				Note 4, p. 30; Note 6, p. S73.
43. Linuron	TLC				Note 3, p. 104; Note 6, p. S64.
44. Malathion	GC		509A		Note 3, p. 25; Note 4, p. 30; Note 6, p. S51.
45. Methiocarb	TLC				Note 3, p. 94; Note 6, p. S60.
46. Methoxychlor	GC		509A	D3086	Note 3, p. 7; Note 4, p. 30.
47. Mexacarbate	TLC				Note 3, p. 94; Note 6, p. S60.
48. Mirex	GC		509A		Note 3, p. 7.
49. Monuron	TLC				Note 3, p. 104; Note 6, p. S64.
50. Monuron-TCA	TLC				Note 3, p. 104; Note 6, p. S64.
51. Neburon	TLC				Note 3, p. 104; Note 6, p. S64.
52. Parathion methyl	GC		509A		Note 3, p. 25; Note 4, p. 30.
53. Parathion ethyl	GC		509A		Note 3, p. 25.
54. PCNB	GC		509A		Note 3, p. 7.
55. Perthane	GC			D3086	
56. Prometron	GC				Note 3, p. 83; Note 6, p. S68.
57. Prometryn	GC				Note 3, p. 83; Note 6, p. S68.
58. Propazine	GC				Note 3, p. 83; Note 6, p. S68.
59. Propham	TLC				Note 3, p. 104; Note 6, p. S64.
60. Propoxur	TLC				Note 3, p. 94; Note 6, p. S60.
61. Secbumeton	TLC				Note 3, p. 83; Note 6, p. S68.
62. Siduron	TLC				Note 3, p. 104; Note 6, p. S64.
63. Simazine	GC				Note 3, p. 83; Note 6, p. S68.
64. Strobane	GC		509A		Note 3, p. 7.
65. Swep	TLC				Note 3, p. 104; Note 6, p. S64.
66. 2,4,5–T	GC		509B		Note 3, p. 115; Note 4, p. 35.
67. 2,4,5–TP (Silvex)	GC		509B		Note 3, p. 115.
68. Terbuthylazine	GC				Note 3, p. 83; Note 6, p. S68.
69. Toxaphene	GC	608	509A	D3086	Note 3, p. 7; Note 4, p. 30.
	GC/MS	625			
70. Trifluralin	GC		509A		Note 3, p. 7

Table ID Notes

[1] Pesticides are listed in this table by common name for the convenience of the reader. Additional pesticides may be found under Table IC, where entries are listed by chemical name.

[2] The full text of methods 608 and 625 are given at Appendix A, "Test Procedures for Analysis of Organic Pollutants," of this Part 136. The standardized test procedure to be used to determine the method detection limit (MDL) for these test procedures is given at Appendix B, "Definition and Procedure for the Determination of the Method Detection Limit", of this Part 136.

[3] "Methods for Benzidine, Chlorinated Organic Compounds, Pentachlorophenol and Pesticides in Water and Wastewater," U.S. Environmental Protection Agency, September, 1978. This EPA publication includes thin-layer chromatography (TLC) methods.

[4] "Methods for Analysis of Organic Substances in Water," U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 5, Chapter A3 (1972).

[5] The method may be extended to include α-BHC, δ-BHC, endosulfan I, endosulfan II, and endrin. However, when they are known to exist, Method 608 is the preferred method.

[6] "Selected Analytical Methods Approved and Cited by the United States Environmental Protection Agency," Supplement to the Fifteenth Edition of *Standard Methods for the Examination of Water and Wastewater* (1981).

[7] Each analyst must make an initial, one-time, demonstration of their ability to generate acceptable precision and accuracy with Methods 608 and 625 (See Appendix A of this Part 136) in accordance with procedures given in section 8.2 of each of these methods. Additionally, each laboratory, on an on-going basis, must spike and analyze 10% of all samples analyzed with Method 608 or 5% of all samples analyzed with Method 625 to monitor and evaluate laboratory data quality in accordance with Sections 8.3 and 8.4 of these methods. When the recovery of any parameter falls outside the warning limits, the analytical results for that parameter in the unspiked sample are suspect and cannot be reported to demonstrate regulatory compliance.

NOTE: These warning limits are promulgated as an "interim final action with a request for comments."

TABLE E-11. RECOMMENDED SAMPLE SIZES, CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR EFFLUENT SAMPLES

Measurement	Minimum Sample Size[a] (mL)	Container[b]	Preservative[c]	Maximum Holding Time
pH	25	P, G	None	Analyze immediately[d]
Temperature	1,000	P, G	None	Measure immediately[d]
Turbidity	100	P, G	Cool, 4 °C	48 h
Total suspended solids	1,000	P, G	Cool, 4 °C	7 days
Settleable solids	1,000	P, G	Cool, 4 °C	48 h
Floating particulates	5,000	P, G	None	Analyze immediately[d,e]
Dissolved oxygen				
Probe	300	G bottle and top	None	Analyze immediately[d]
Winkler	300	G bottle and top	Fix onsite; store in dark	8 h
Biochemical oxygen demand	1,000	P, G	Cool, 4 °C	48 h
Total chlorine residual	200	P, G	None	Analyze immediately[d]
Oil and grease	1,000	G only	Cool, 4 °C H_2SO_4 to pH<2	28 days
Nitrogen				
Ammonia-N	400	P, G	Cool, 4 °C H_2SO_4 to pH<2	28 days
Total Kjeldahl-N	500	P, G	Cool, 4 °C H_2SO_4 to pH<2	28 days
Nitrate+Nitrite-N	100	P, G	Cool, 4 °C H_2SO_4 to pH<2	28 days
Phosphorus (total)	50	P, G	Cool, 4 °C H_2SO_4 to pH<2	28 days
Priority pollutant metals				
Metals, except mercury	100	P, G	HNO_3 to pH<2	6 mo
Mercury	100	P, G	HNO_3 to pH<2	28 days

TABLE E-11. (Continued)

Measurement	Minimum Sample Size[a] (mL)	Container[b]	Preservative[c]	Maximum Holding Time
Priority pollutant organic compounds				
Extractable compounds (includes phthalates, nitrosamines, organochlorine pesticides, PCBs, nitroaromatics, isophorone, polycyclic aromatic hydrocarbons, haloether, chlorinated hydrocarbons, phenols, and TCDD)	4,000	G only, TFE-lined cap	Cool, 4 °C 0.008% $Na_2S_2O_3$[f] Store in dark	7 days until extraction 40 days after extraction
Purgeable compounds	40	G only, TFE-lined septum	Cool, 4 °C 0.008% $Na_2S_2O_3$[f]	7 days[g]
Total and fecal coliform bacteria	250-500	P, G	Cool, 4 °C 0.008% $Na_2S_2O_3$[f]	6 h
Enterococcus bacteria	250-500	P, G	Cool, 4 °C 0.008% $Na_2S_2O_3$[f]	6 h

Source: Adapted from U.S. EPA (1979b), 40 CFR Part 136.

[a] Recommended field sample sizes for one laboratory analysis. If additional laboratory analyses are required (e.g., replicates), the field sample size should be adjusted accordingly.

[b] P = Polyethylene; G = Glass.

[c] Sample preservation should be performed immediately upon sample collection. For composite samples, each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, the samples should be maintained at 4 °C until compositing.

[d] Immediately means as soon as possible after the sample is collected, usually within 15 min (U.S. EPA 1984b).

[e] No recommended holding time is given by EPA for floating particulates. Analysis should therefore be made as soon as possible.

[f] Should be used only in the presence of chlorine residual.

[g] Holding time and preservation technique for purgeable compounds are based on the use of EPA Method 624 for screening all priority pollutant volatiles organic compounds, including acrolein and acrylonitrile. If analysis of acrolein and acrylonitrile is found to be of concern, a separate subsample should be preserved by adjusting the pH to 4-5 and the sample should then be analyzed by EPA Method 603.

QUALITY ASSURANCE/QUALITY CONTROL

QA/QC procedures should be detailed in the quality assurance project plan (U.S. EPA 1979c, 1987d). The following items should be discussed in the quality assurance project plan:

- Statement and prioritization of study objectives;
- Responsibilities of personnel associated with sample collection and analysis;

- Sampling locations, frequency, and procedures;
- Variables to be measured, sample sizes, sample containers, preservatives, and sample holding times;
- Equipment checklist;
- Sample splits or performance samples to be submitted with the samples;
- Sample handling, packaging, labeling, and shipping requirements; and
- Laboratories to which samples will be shipped.

U.S. EPA (1987d) provides QA/QC guidance for the following activities:

- Preparation for sampling program;
- Sample collection;
- Sample processing;
- Sample size;
- Sample containers;
- Sample preservation;
- Sample holding times;
- Sample shipping;
- Record keeping;
- Labeling;
- Custody procedures;

- Analytical methods;
- Calibration and preventive maintenance;
- Quality control checks;
- Corrective action; and
- Data reporting requirements.

Field Sampling Procedures

For the field sampling effort, the following procedures are recommended:

- Establish and implement chain-of-custody protocols to track samples from the point of collection to final disposition.
- Establish and implement protocols to prepare sample containers.
- Prepare field "blank" samples to assess potential sample contamination by the sampling devices.
- Prepare "trip blanks" to assess potential contamination by volatile organic analytes en route to the laboratory (one trip blank per sample shipment).
- Collect replicate samples to assess sample precision and the homogeneity of samples collected.
- Use appropriate sample collection procedures (see Table E-11).

Volatile organic samples and split composite samples should be collected carefully. Grab samples for volatile organic analyses should be collected in duplicate. Residual chlorine should be eliminated, and the volatile sample containers should be filled with a minimum of mixing and to capacity, leaving no headspace. When splitting composite samples into discrete aliquots for analyses, the composite sample should be mixed to provide a homogeneous mixture. A representative portion of any solids in the container should be suspended in the composite sample. Composite samples may be homogenized by hand stirring with clean glass rods or by mechanical stirring with Teflon-coated paddles. Metal mixing devices should not be used.

Laboratory Procedures

Laboratory analytical results must be accurate and reliable. Laboratory QA/QC procedures are generally specified for each different analytical method, and the level of QA/QC and associated deliverables vary among methods (Tables E-9 to E-11). The following documentation is required by the analytical laboratory for QA review of data on organic substances (see Tables E-10 and E-11):

- Initial multipoint calibration;
- Demonstration of method proficiency;
- Determination of method detection limit [usually 5-10 ppb for base, neutral, and acid organic compounds (U.S. EPA Method 625); 0.005-0.10 ppb for pesticide/PCB analysis (U.S. EPA Method 608); and 1-10 ppb for volatiles (U.S. EPA Method 624)];
- Daily checks of calibration and instrument tuning;
- Daily analysis of method blanks (1 blank/20 samples); and
- Analysis of duplicate samples (minimum of 5 percent of samples analyzed) and use of matrix spikes to determine organic recoveries.

The following documentation is required by the analytical laboratory for QA review of data on inorganic substances (see Table E-8):

- Multipoint calibration;
- Analysis of reagent blanks;
- Use of matrix spikes of 0.5-5 times the sample concentration;
- Determination of method detection limits;

- Analysis of full method blanks at a minimum frequency of every 20 samples, rather than reagent water blanks;
- Verification of calibration by analysis of standards (daily or with every 10 sample batches);
- Performance of duplicate analyses for a minimum of 5 percent of the total number of samples analyzed; and
- Use of the method of standard additions for samples demonstrating interferences.

Data Evaluation

Data generated from the monitoring program should be evaluated using the stepwise approach discussed below.

1. Assemble the original raw data reports and the associated QA/QC data. The analytes and analytical methods used will determine the types of QA/QC data generated and may include the following:

    - Sample results;
    - Blank sample results;
    - Instrument calibrations (initial and continuing);
    - Matrix spike/matrix spike duplicate results;
    - Surrogate recovery data;
    - Instrument tuning data;
    - Chain-of-custody records;
    - Analytical request forms;

- Gas chromatograms;
- Mass spectra;
- Instrument detection limit determinations;
- Serial dilution results;
- Clean-water precision and accuracy studies;
- Furnace atomic absorption quality control data;
- Interference check data;
- Laboratory control sample results; and
- Holding time documentation.

2. Because the resulting data will be used to determine regulatory compliance of the discharge, the following sequence is recommended to conduct a QA review of the data:

    - Confirm the sample identifier, container, and preservation with chain-of-custody records.
    - Confirm the analytical procedure (e.g., extraction or digestion) used with the procedure requested.
    - Confirm that an acceptable instrument detection limit was achieved.
    - Confirm that the analysis proceeded in the manner specified.
    - Confirm that all quality control data deliverables specified by the analytical protocol have been submitted.
    - Confirm that the analysis was performed within the specified sample holding time.

- Confirm that the instrumentation used was properly calibrated initially and that the method was validated.
- Confirm detection limits, precision, and accuracy for each substance and review duplicate analysis results.
- Confirm that blank samples were analyzed and that the field sampling and analytical procedures did not contaminate the data.
- Evaluate the presence of matrix interferences through the use of surrogate recoveries and matrix spikes.
- Annotate the data with appropriate qualifiers, and note deviations from prescribed methods.
- Detail problems associated with the analyses.

UPGRADING TO A FULL-SCALE SECONDARY TREATMENT FACILITY

Data obtained from the monitoring program described above will be used to determine the mean and peak concentrations and site-specific toxic pollutant removal capabilities for secondary treatment. The performance of the secondary treatment pilot plant will be closely related to the attention and expertise of the operator controlling the plant. If the pilot plant is not properly operated, the data will not approximate the removals that could be achieved with a full-scale facility. Conventional pollutant data (e.g., suspended solids, BOD) can be used to determine when the pilot plant is operating within the expected design removal efficiencies. The most important factor in performing site-specific toxic pollutant removal investigations is to ensure that an acclimated biological seed exists before initiating sample collection for pollutant analyses.

Plant operators should be aware that activated sludge microorganisms are susceptible to biological and chemical effects that may kill the organisms or severely inhibit their effectiveness. Accumulations of toxic waste components (via gradual concentration from continuous discharges, or sudden slugs) could limit the ability of the activated sludge system to achieve design effluent quality (see Tables E-12 and E-13). Disruptions or changes could be found by reviewing operating records (e.g., settling characteristics of secondary sludge, species populations in the MLSS). If inhibition or upset conditions are found, the concentration and source of each pollutant of concern should be determined. Concentrations shown in Tables E-12 and E-13 are not absolute and should be used only for comparison purposes and preliminary investigations.

Toxic pollutant removal efficiencies at the secondary treatment pilot plant may differ from than those expected in a full-scale secondary treatment facility. For example, the pilot plant will be operated at a constant flow rate and will not be subject to the diurnal and seasonal flow fluctuations normally experienced at treatment facilities or to the slug loadings and batch discharges that POTWs can experience in daily operation. Also, at the relatively higher aeration rates of the pilot plant system, higher degrees of volatile organics stripping may occur, thereby implying higher levels of removal of biodegradable material than might actually happen under full-scale conditions.

TABLE E-12. REPORTED VALUES FOR ACTIVATED SLUDGE BIOLOGICAL PROCESS TOLERANCE LIMITS OF ORGANIC PRIORITY POLLUTANTS

Pollutant	Threshold of Inhibitory Effect (mg/L)[a]
Acenaphthene	NI[b] at 10
Acrolein	NI at 62
Acrylonitrile	NI at 152
Benzene	125
Benzidine	5
Carbon tetrachloride	NI at 10
Chlorobenzene	NI at 1
1,2,4-Trichlorobenzene	NI at 6
Hexachlorobenzene	5
1,2-Dichloroethane	NI at 258
1,1,1-Trichloroethane	NI at 10
Hexachloroethane	NI at 10
1,1-Dichloroethane	NI at 10
1,1,2-Trichloroethane	NI at 5
1,1,2,2-Tetrachloroethane	NI at 201
bis(2-Chloroethyl)ether	NI at 10
2-Chloroethyl vinyl ether	NI at 10
2-Chloronaphthalene	NI at 10
2,4,6-Trichlorophenol	50
4-Chloro-3-methyl phenol	NI at 10
Chloroform	NI at 10
2-Chlorophenol	NI at 10
1,2-Dichlorobenzene	5
1,3-Dichlorobenzene	5
1,4-Dichlorobenzene	5
1,1-Dichloroethylene	NI at 10
trans-1,2-Dichloroethylene	NI at 10
2,4-Dichlorophenol	NI at 75
1,2-Dichloropropane	NI at 182
1,3-Dichloropropylene	NI at 10
2,4-Dimethylphenol	NI at 10
2,4-Dinitrotoluene	5
2,6-Dinitrotoluene	5
1,2-Diphenylhydrazine	5
Ethylbenzene	NI at 10
Fluoranthene	NI at 5
bis(2-Chloroisopropyl)ether	NI[b] at 10
Chloromethane	NI at 180
Bromoform	NI at 10
Dichlorobromomethane	NI at 10
Trichlorofluoromethane	NI at 10
Chlorodibromomethane	NI at 10
Hexachlorobutadiene	NI at 10
Hexachlorocyclopentadiene	NI at 10
Isophorone	NI at 15.4
Naphthalene	500
Nitrobenzene	500

TABLE E-12. (Continued)

Pollutant	Threshold of Inhibitory Effect (mg/L)[a]
2-Nitrophenol	NI at 10
4-Nitrophenol	NI at 10
2,4-Dinitrophenol	1
N-Nitrosodiphenylamine	NI at 10
N-Nitrosodi-n-propylamine	NI at 10
Pentachlorophenol	0.95
Phenol	200
bis(2-Ethylhexyl)phthalate	NI at 10
Butyl benzyl phthalate	NI at 10
Di-n-butyl phthalate	NI at 10
Di-n-octyl phthalate	NI at 16.3
Diethyl phthalate	NI at 10
Dimethyl phthalate	NI at 10
Chrysene	NI at 5
Acenaphthylene	NI at 10
Anthracene	500
Fluorene	NI at 10
Phenanthrene	500
Pyrene	NI at 5
Tetrachloroethylene	NI at 10
Toluene	NI at 35
Trichloroethylene	NI at 10
Aroclor-1242	NI at 1
Aroclor-1254	NI at 1
Aroclor-1221	NI at 1
Aroclor-1232	NI at 10
Aroclor-1016	NI at 1

Source: U.S. EPA (1986c).

[a] Unless otherwise indicated.

[b] NI = no inhibition at tested concentrations. No concentration is listed if reference lacked concentration data.

TABLE E-13. REPORTED VALUES FOR ACTIVATED SLUDGE BIOLOGICAL PROCESS TOLERANCE LIMITS OF INORGANIC PRIORITY POLLUTANTS

Pollutant	Threshold of Inhibitory Effect (mg/L)
Arsenic	0.1
Cadmium	1
Chromium (VI)	1
Chromium (III)	10
Copper	1
Cyanide	0.1
Lead	0.1
Mercury	0.1
Nickel	1
Silver	5
Zinc	0.03

Source: U.S. EPA (1986c).

DEMONSTRATING COMPLIANCE USING PILOT PLANT DATA

The purpose of operating a secondary treatment pilot plant is to determine the concentrations of toxic pollutants in the effluent that would be realized if the applicant were providing secondary treatment rather than less-than-secondary treatment, as requested in the 301(h) application. Effluent from the secondary treatment pilot plant is then analyzed to determine the concentration of each toxic pollutant in the effluent. If these concentrations are more stringent than effluent limits based on state water quality standards or 304(a)(1) water quality criteria, if applicable, or are otherwise required to ensure that all environmental protection criteria are met, then these concentrations define the maximum allowable concentrations in the discharge of less-than-secondary treated effluent.

To demonstrate secondary equivalency, the applicant must demonstrate that the concentration of each toxic pollutant in the effluent of the section 301(h) modified discharge is equal to, or less than, the concentration achieved using the secondary treatment pilot plant. For toxic pollutants whose concentration in the section 301(h) modified discharge is greater than the concentration in the secondary treated effluent, the applicant must lower the concentration using either or both of two approaches. The first approach is to establish local limits for such pollutants, in accordance with the guidance given earlier. These would be in the form of numeric local limits, allocated according to one of the approaches outlined previously in this appendix. As discussed in this section of the appendix, local limits allocations can be based on concentration limits or on flow-corrected mass loading limits, depending on the type of toxic pollutant (conservative vs. nonconservative) and the type and mix of industrial sources of that toxic pollutant. The second approach is to upgrade the treatment process within the POTW. Having implemented either or both of these approaches, the applicant must then provide results of additional effluent analyses to demonstrate that the maximum allowable concentrations of toxic substances are not being exceeded after the proposed controls have been implemented.

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ATTACHMENT 1 TO APPENDIX E
U.S. EPA GUIDANCE MANUAL ON THE DEVELOPMENT AND IMPLEMENTATION OF LOCAL DISCHARGE LIMITATIONS UNDER THE PRETREATMENT PROGRAM
(DECEMBER 1987)

CHAPTER 5 - INDUSTRIAL USERS MANAGEMENT PRACTICES

5. INDUSTRIAL USER MANAGEMENT PRACTICES

5.1 INTRODUCTION

The development and implementation of numeric local limits is not always the only appropriate or practical method for preventing pollutant pass through and interference, or for protecting POTW worker health and safety. Control of chemical spills and slug discharges to the POTW through formal chemical or waste management plans can go a long way toward preventing problems. A local requirement for an IU to develop and submit such a plan can be considered as a type of narrative local limit and can be a useful supplement to numeric limits.

The basic philosophy of instituting management practices is to minimize the discharge of toxic or hazardous pollutants to the sewer, or at least to reduce the impact of toxic/hazardous pollutant discharges by avoiding short-term, high concentration discharges. Management practice plans generally are developed to prevent or control the discharge of hazardous or toxic materials, such as acids, solvents, paints, oils, fuels and explosives by means of appropriate handling procedures, possibly in addition to pretreatment. Slug discharges of process wastewater (including high BOD/COD wastes) can also be effectively controlled through the use of management practices.

In the NPDES permitting program for direct dischargers, industries can be required under 40 CFR Part 125, Subpart K to implement best management practices (BMPs) to minimize the discharge of toxicants to surface waters. These plans are meant to address:

- Toxic and hazardous chemical spills and leaks
- Plant site run-off
- Sludge and waste disposal
- Drainage from material storage areas
- Other "good housekeeping" practices.

While direct discharger BMPs address only activities which are ancillary to manufacturing or treatment processes, IU management practices under a local pretreatment program can also include:

- Solvent management plans
- Batch discharge policies
- Waste recycling
- Waste minimization.

The first step a POTW must take in implementing its program is to be certain that the POTW has the requisite legal authority. This involves ensuring that proper language regarding IU management practices are contained in the sewer use ordinance (at a minimum) and in IU permits. The sewer use ordinances or regulations of most POTWs may already include provisions for requiring IUs to develop management practice plans.

When evaluating the need for IU management plans, POTWs may follow the following steps:

- Evaluation of the potential for toxic and hazardous chemicals onsite to reach the sewer system
- Assessing the adequacy of any industry management plans and practices already in place, and requiring revisions to these as necessary.

1. <u>Evaluation of the Potential for Toxic and Hazardous Chemicals Onsite to Reach the Sewer System</u>. The primary concern on the part of the POTW when evaluating the adequacy of IU management practices is the likelihood of slugs/spills of chemicals reaching the sewer system. Inspectors need to focus on: (1) the types of and quantities of chemicals that are handled (e.g., transferred), stored, or disposed onsite; and (2) the location(s) of all chemical handling, storage and disposal activities with respect to sewer access. The chemicals managed in areas of highest risk of being discharged to the sewers (through spills, slug loading, or accidents) should be of the highest priority to be addressed in management plans.

2. <u>Assessing the Adequacy of Existing Management Plans and Practices</u>. POTW officials should carefully evaluate any existing industry management plans. Receiving particular scrutiny should be:

- The practices that are proposed (and whether they are currently being followed)

- Whether the plan is reflective of current operations at the industry
- Whether the plan was designed to prevent discharges to the sewers
- Whether plant personnel are required to follow the plan
- The familiarity of personnel with the plan
- Any conditions that must be met before a response/corrective action can be taken
- Whether all toxic chemicals managed in areas with access to sewers are addressed.

If deficiencies are found in the existing plans, the IU should be required to correct them before submitting a revised plan to the POTW for approval. Further details of recommended plan specifics are discussed later in this section.

The following sections of this chapter outline the elements of three types of industry management practice plans; chemical management plans, spill contingency, and best management practices plans. POTWs should be aware that hybrids of the plans presented may be appropriate for a particular situation and that some overlap of management practice requirements exists. Key to each of these plans is the continued training of staff and proper implementation.

5.2 CHEMICAL MANAGEMENT PLANS

Chemical management plans differ from the other two types of management plans introduced above because they target specific chemicals or groups of chemicals that are considered to be of concern. One example of a chemical management plan that is widespread is the solvent management plan required of metal finishers by federal categorical standards.

POTWs may wish to pay special attention to certain groups of chemicals that have historically caused management problems. Examples of such chemical groups are:

Strong acids (e.g., hydrochloric acid, sulfuric acid, nitric acid, and chromic acid)

Strong bases (e.g., caustic soda, lye, ammonia, lime, etc.)

Noxious/fuming chemicals (e.g., phosphorus pentachloride, hydrofluoric acid, benzene, chloroform)

Flammable chemicals (e.g., acetone, naptha, hexane, cyclohexane)

Explosive chemicals (e.g., nitroglycerine, metallic sodium, picric acid, and lead azide)

Oxidants (e.g., chlorine dioxide, phosphorus pentoxide, potassium permanganate, sodium chlorate)

Reductants (e.g., sodium borohydride, phosphine, methyl hydrazine)

Oils and fuels (e.g., diesel oil, gasoline, bunker fuel oil)

Toxic wastes (e.g., pesticides)

Solvents

Radioactive materials

Foaming Materials (e.g., surfactants).

It is impossible to present an all encompassing list of chemicals that might suitably be addressed under chemical management plans as the needs and concerns of any specific POTW and its industries will be different. However, much attention has recently been paid to one particular group of chemicals, the frequently used solvents. Table 5-1 presents a list of frequently used solvents and their regulatory status. In presenting this table, it is not the intention to suggest that the solvents on this list will always be a problem. Rather, this list is a recognition of the fact that solvents are ubiquitous to sewer systems and can make up a large portion of the usually uncontrolled organic loadings to treatment plants. Concerns regarding these chemicals may be less familiar to POTW personnel than concerns regarding other chemicals such as acids and bases.

As part of the assessment of an industry's chemical management plan, the POTW must first determine the following: the nature of chemical usage at the IU, chemical handling practices, specific process streams containing the chemical, and locations where the chemicals might (intentionally or unintentionally) enter the sewers. An analysis of the chemical's concentration at potential as well as known release points should be obtained as part of this data gathering effort. These data should be gathered through onsite inspections whenever possible. Once this basic information is compiled, its accuracy should be verified with the IU and should subsequently provide the basis for assessing the need for, and adequacy of, chemical management plans submitted by the industry. Elements of the industry's chemical management plan should address each of the potential release points. Whenever possible, the industry should be provided with specific language indicating the acceptable levels of the chemical in the sewer so that a clear yardstick is established against which the success or failure of the management plan can be measured. An example of this is again provided by the metal finishing industry's solvent management plans which attempt to achieve a total toxic organic (TTO) pollutant limit of 2.13 mg/l.

Examples of plan components that would target specific release points are: prevent access through floor drains to sewers in areas of possible chemical spillage; the installation of sumps in floor drains providing a capacity that exceeds the largest projected potential spill volume by a safety margin of perhaps 10 percent; and the education of plant workers handling the chemicals of concern in areas with access to sewers.

POTW staff could also discuss the feasibility of possible chemical substitution, process modifications, and/or waste segregation as means of source control.

- Chemical substitution may be possible if there are other compounds that will fulfill the same function demanded of the chemical of concern; assuming that the substitute itself does not exhibit any properties with the potential to cause problems for the POTW. Key factors in the feasibility of this option will be the cost and availability of the substitute chemical; the chemical and physical properties of the substitute and whether these properties will have a substantive effect on the manufacturing process or subsequent wastes handling operations/liabilities.

- Process modifications that would reduce or eliminate the presence of the chemicals of concern would be an attractive option if feasible. It is likely that industry officials will have a better understanding of the limitations to such modifications than POTW personnel, but this should not inhibit inspectors from raising this option as a possibility. Examples of process modification are the use of different, more effective polymers during wastewater treatment, resulting in an improved removal efficiency for the target pollutant; and changing the degreasing procedures utilized in cleaning product components, possibly from immersion in solvent baths and subsequent rinsing with water, to the wiping of the components manually with the solvent, and air drying under a vacuum hood.

- Waste segregation may be an effective means for improving wastewater treatment efficiency. If the presence of more than one wastewater component acts to limit the efficiency of a treatment process, it may be possible to undertake some form of waste segregation (possibly by distillation) that would separate the components sufficiently to allow for efficient subsequent treatment.

In some instances the institution of formal procedures for the handling, transfer, and storage of chemicals will be useful. For example, if a specific chemical is only used in the manufacturing process in small quantities, the dispensing of the chemical in bulk quantities could be discouraged. This action would reduce the quantities potentially spilled during transfer and also reduce the quantity of "left-over" chemicals that might be carelessly discarded. In some instances the centralized storage of chemicals could improve the logistics of chemical use supervision and provide a principle point of focus for chemical management efforts.

The chemical management plan for each facility should be endorsed by a responsible official at the facility and include a written commitment that the practices described will be followed as a matter of company policy. In instances where industries appear reluctant to implement the procedures delineated in the management plans, POTWs may wish to withhold formal approval of the management plan until a trial period illustrates that the procedures are indeed being implemented.

5.3 SPILL CONTINGENCY PLANS

Many industries with large storage tanks onsite may already have spill contingency plans in place, sometimes as a matter of company policy. This kind of familiarity with planning and response procedures is a definite plus from the POTW's point of view. However, existing spill plans may address only a portion of the potential pollutant sources of concern to the POTW and may not be as sensitive to protection of the sewer system as needed. Also, the quantity and types of materials spilled that would initiate a spill response under existing contingency plans may be inconsistent with pretreatment concerns and needs. With this in mind, POTW inspectors should carefully review any existing plans for their adequacy as opposed to accepting them at face value. The items which should be focused upon in reviewing a spill contingency plan are the same as those considered in the design of a new plan and include:

- Identification of high risk chemicals
- Identification of high risk handling and storage procedures and plant locations
- Identification and mapping of potential release points relative to sewer access points
- Identification of and preparation for possible spill containment and/or countermeasures
- Identification of individuals responsible for implementation of the spill plan, individuals with the authority to commit additional resources to a response action, if necessary; and designation of a predetermined chain of command for coordinating spill response activities--depending on the type of spill
- Documentation of the entire spill contingency plan, including:
    - Maps of key area
    - Equipment lists, and equipment storage and in-plant staging locations
    - Names and functions of all plant officials with a role in spill contingency planning and implementation
    - Names and phone numbers of POTW officials who should be contacted in the event of a spill (the industry may choose to also include local fire department, police, and emergency rescue information)
    - A commitment to provide the POTW with a written notification or report within a short period (3 days) following an incident, explaining the cause of the spill, and steps that are being taken to prevent recurrence
    - An endorsement of the spill plan by responsible industry officials, including a commitment to implement the plan as per the facility's permit requirement
    - An indication as to the date when the plan was last updated, and a commitment to update the plan periodically, or following a spill incident.

Inspectors should carefully review all the details of the plan and be satisfied that it is adequate from the POTW's perspective before recommending formal approval. Additional information on spill contingency plans may be found in "EPA Region X Guidance Manual for the Development of Accidental Spill Prevention Programs," U.S. EPA Region X, Seattle, WA, February 1986. An example is also provided in Appendix K. In addition, EPA is currently developing a guidance manual to help identify the need and methods for developing slug control plans.

5.4 BEST MANAGEMENT PRACTICES PLANS

The concept of best management practices plans (BMPs) is well accepted in the NPDES program, and many of the same principles apply equally well to indirect dischargers. In this section, the types of requirements that could be required of an IU under the provisions of a BMP are discussed. As in the case of the other types of management plans, the actual requirement imposed on any particular industry will vary depending on site-specific needs.

Much of the focus of BMPs is on good housekeeping and proper operation and maintenance measures. While these items may at first seem obvious or trivial, experience has shown that the documentation of proper procedures and a requirement that the procedures be followed are very effective in reducing the number of (preventable) breakdowns in equipment, and miscommunication that can lead to unwanted discharges to the sewers. In considering the need for BMPs and in reviewing the design of BMPs proposed by industry, the following should be considered:

- Equipment O & M. While most facilities will make every effort to take care of the equipment that they have purchased and installed for waste management purposes, this cannot be assumed to always be the case. Where equipment is at a level of sophistication that is beyond the comprehension of its operators, or when the equipment is simply old, attention paid to operation and maintenance practices becomes all the more important. In such cases, BMP requirements should be directed at ensuring that necessary routine maintenance is performed and that equipment failures are not due to neglect. Where sophisticated electronics are a part of a treatment system the manufacturers of such equipment frequently provide either technical training or the option of equipment maintenance contracts. These services should be encouraged by POTW staff wherever appropriate.

- Reduction of contaminated runoff. The potential exists for contaminated runoff from any process operation, chemical transfer area, or raw materials, product, or waste storage area that is exposed to rainfall. Walk through inspections of a facility may reveal telltale stains on the ground in problem areas. Depending on the nature of the contamination, this type of runoff may be of concern. If the contaminated runoff is readily treated by the IU's pretreatment processes and does not contribute to hydraulic overloading of the system, then it may be of little consequence. However, if pollutants (or the flow) resulting from runoff appear to be a problem, then some form of mitigation should be considered by the IU. After discussing the problems and possible solutions with industry staff, the POTW inspectors should leave the selection of remedial measures to industry management. Mitigative measures might include the construction of berms and/or diversion structures, the shifting of operations to covered areas, recontouring of surfaces, or even the modification of pretreatment systems onsite. The ongoing maintenance and implementation of runoff control measures are appropriately contained in the facility's BMP.

- Segregation of wastes for reclamation. In some instances, opportunities will exist to segregate wastes within a facility for the purpose of reclamation. This practice also reduces the quantities of possibly hazardous waste that must be disposed and may even reduce pollutant loadings in the wastewater. Contaminated oils and spent solvents are examples of wastes for which a substantial reclamation market exists.

- Routine cleaning operations. Many industries will schedule routine cleaning of plant areas and equipment. This may come at the end of every few shifts, on specified days of the week, or possibly at the end of seasonal operations. While these cleaning activities are necessary for the continued efficient (and perhaps sanitary) nature of plant operations, the use of large quantities of detergents and solvents, and the pollutants carried by these chemicals, can be of concern. In some instances, it is possible for industries to reduce the loadings to the sewers through the substitution of dry methods of cleaning or modification of cleaning procedures. For instance, it is often possible to achieve highly efficient cleaning of surfaces while reducing chemical usage by using high pressure application wands. This type of chemical application also allows for more direct application and more efficient chemical usage. When reviewing routine cleaning operations, POTWs should also endeavor to ensure that required cleaning of grease traps are indeed conducted with necessary frequency. Once again, the use of formal procedures, and perhaps even operations log books could be of help.

- Chemical storage practices. A walk through of a facility's process operations may reveal that chemicals and fuels are being stored adjacent to, and perhaps directly over floor drains (so that leaks and drips do not make a mess). This kind of practice should be discouraged and is perhaps the simplest type of preventive measure. Also, if a facility acknowledges routine amounts of chemical spillage and leaks (perhaps during dispensing chemicals) with the use of drip pans, it is probably worth inquiring as to the frequency with which these pans are emptied, whose responsibility it is, and where and how the spilled substances are disposed.

5.5 LEGAL AUTHORITY CONSIDERATIONS

All POTWs must have the minimum legal authority required by 40 CFR 403.8(f)(i), to deny or condition discharges of pollutants that could violate local or Federal pretreatment standards and requirements. The goals of management practice requirements are the same as those of numerical local limits -- to prevent pass through, interference, and violations of the specific prohibitions. However, the imposition of the management plans described in this chapter may or may not be within the scope and authority of some local ordinances. Therefore, it is suggested that each POTW specifically evaluate its legal ability to impose these requirements. Once verified or obtained, specific requirements for industrial users to submit a management plan should be included in the user's control mechanism (i.e., industrial user permit).

5.6 APPROVAL OF INDUSTRIAL USER MANAGEMENT PLANS

Once the need for a chemical management plan, spill prevention plan or BMP is determined, the POTW may require the plan(s) to be submitted in conjunction with the industrial user's permit application and approved in conjunction with issuance of the permit. The industrial user permit should be reissued to include the requirements of the management plan if necessary. Satisfactory implementation of the plans should then be verified during the periodic industrial inspections by the POTW.

TABLE 5-1. LIST OF COMMONLY USED SOLVENTS

Solvent	RCRA Ignitability	RCRA Toxicity	Proposed TCLP	CWA Priority Pollutant
Acetone	Yes	No	No	No
Benzene	Yes	Yes	Yes	Yes
n-Butyl alcohol	Yes	No	No	No
Carbon disulfide	Yes	Yes	Yes	No
Carbon tetrachloride	No	Yes	Yes	Yes
Chlorobenzene	No	Yes	Yes	Yes
Cresols (o-m-p isomers)	No	Yes	Yes	No
Cyclohexanone	Yes	No	No	No
1,2-Dichlorobenzene	No	Yes	Yes	Yes
Dichlorodifluoromethane	No	Yes	No	No
2-Ethoxyethanol	Yes	Yes	No	No
Ethyl acetate	Yes	No	No	No
Ethyl benzene	Yes	No	No	Yes
Ethyl ether	Yes	No	No	No
Isobutanol	Yes	Yes	Yes	No
Methanol	Yes	No	No	No
Methylene chloride	No	Yes	Yes	Yes
Methyl ethyl ketone	Yes	Yes	Yes	No
Methyl isobutyl ketone	Yes	No	No	No
Nitrobenzene	No	Yes	Yes	Yes
2-Nitropropane	Yes	Yes	No	No
Pyridine	Yes	Yes	Yes	No
Tetrachloroethylene	No	Yes	Yes	Yes
Toluene	Yes	Yes	Yes	Yes
1,1,1-Trichloroethane	No	Yes	Yes	Yes
1,1,2-Trichloroethane	No	Yes	Yes	Yes
Trichloroethylene	No	Yes	Yes	Yes
Trichlorofluoromethane	No	Yes	No	No
1,1,2-Trichloro-1,2,2-trifluoroethane	No	Yes	No	No
Xylene (o-m-p isomers)	Yes	No	No	No

ATTACHMENT 2 TO APPENDIX E
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APPENDIX I - LOCAL LIMITS DERIVATION EXAMPLE

APPENDIX I

LOCAL LIMITS DERIVATION EXAMPLE

In this appendix, local limits for a hypothetical POTW are derived. This POTW is a conventional activated sludge plant, with anaerobic sludge digestion. POTW characteristics are as follows:

- POTW influent flow = 3.35 MGD
- POTW sludge flow to disposal = 0.01 MGD
- POTW sludge flow to digester = 0.015 MGD
- Percent solids of sludge to disposal = 7.5%
- Receiving stream flow = 47 MGD (7Q10)
  26 MGD (1Q10)

In the first section of this appendix, local limits will be derived for four metals. The second section of this appendix discusses the identification of organic pollutants of concern, and details the calculation of local limits for these organic pollutants.

DERIVATION OF LOCAL LIMITS FOR METALS

The derivation of local limits for metals (cadmium, chromium, copper and lead have been selected as representative) is demonstrated in this section. The methodology for deriving local limits for these metals entails:

- Acquisition of representative removal efficiency data
- Identification of applicable treatment plant/environmental criteria and conversion of criteria into allowable headworks loadings
- Allocation of maximum allowable headworks loadings to domestic and industrial sources, thereby setting local limits

Representative Removal Efficiency Data

Representative removal efficiency data are crucial to the development of allowable headworks loadings. In this section, the acquisition of representative metal pollutant removal efficiencies for the hypothetical POTW is discussed.

The POTW has monitored its effluent and sludge for the metals cadmium and copper on a monthly basis over the past year. Tables I-1 and I-2 present these monthly effluent and sludge monitoring data, respectively. Corresponding monthly removal efficiency data can be derived from the monthly effluent and sludge monitoring data shown in Tables I-1 and I-2. In order to derive removal efficiencies from the Table I-1 and I-2 data, the following equation can be used:

$$R_{EFF} = \frac{(C_{SLDG})\ (PS/100)\ (Q_{SLDG})\ (100)}{(C_{SLDG})\ (PS/100)\ (Q_{SLDG}) + (C_{EFF})\ (Q_{POTW})}$$

where: R_{EFF} = POTW removal efficiency, percent

C_{SLDG} = Sludge level, mg/kg dry sludge

PS = Percent solids of sludge to disposal

Q_{SLDG} = Sludge flow to disposal, MGD

C_{EFF} = POTW effluent level, mg/l

Q_{POTW} = POTW flow, MGD

This removal efficiency expression was derived from the removal efficiency equation for metals presented in Section 3.2.4. The above equation is based upon the assumption for metals that the POTW influent pollutant loading is equal to the sum of the POTW's effluent and sludge pollutant loadings.

Table I-3 presents site-specific removal efficiencies derived from the above removal efficiency equation, the Table I-1 and I-2 data, and the following POTW operational data:

- POTW flow = 3.35 MGD
- Sludge flow to disposal = 0.01 MGD
- Percent solids of sludge to disposal = 7.5%

TABLE I-1. MONTHLY POTW EFFLUENT MONITORING DATA FOR METALS (MG/L)

Pollutant	Detection Limit*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cd	0.001	ND**	ND	ND	ND	0.03	ND	ND	0.02	ND	ND	0.27	ND
Cu	0.001	0.10	0.06	0.09	0.02	0.14	0.02	0.05	0.06	0.03	0.06	0.13	0.07

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*From "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," USEPA Environmental Monitoring and Support Laboratory, Cincinnati, OH, July 1982 (EPA 600/4-82-057).

**ND = Not detected.

TABLE I-2. MONTHLY DIGESTED SLUDGE MONITORING DATA FOR METALS (MG/KG DRY SLUDGE)

Pollutant	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cd	55.	50.	35.	44.	60.	65.	26.	30.	30.	11.	42.	26.
Cu	205.	185.	200.	340.	325.	340.	150.	120.	410.	80.	240.	16.

TABLE I-3. MONTHLY REMOVAL EFFICIENCY DATA FOR METALS (PERCENT)

Pollutant	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cd	96	96	94	95	31	97	92	25	93	83	3	92
Cu	31	41	33	79	34	79	40	31	75	23	29	5

Notes: Calculated using data in Tables I-1 and I-2. Pollutant levels indicated in Table I-1 as below detection were set equal to one-half the detection limit.

As surrogates for Table I-1 pollutant levels designated as below detection, pollutant levels corresponding to one-half the analytical detection limit (i.e., Cd = 0.0005 mg/l) were used in the removal efficiency calculations.

Section 3.2.4.2 of the manual suggests the use of removal efficiency deciles in deriving allowable headworks loadings. Following these procedures, the second and eighth removal efficiency deciles for cadmium and copper can be obtained from the Table I-3 removal efficiency data. Table I-4 presents second and eighth decile removal efficiency data for these two pollutants, as well as literature decile removal efficiency data for the additional metals chromium and lead. The removal efficiencies shown in this table will be used in deriving allowable headworks loadings for the four metals.

Removal efficiencies for the four metals across primary treatment will also be needed, to derive allowable headworks loadings based on activated sludge inhibition threshold data. The POTW conducted an additional monitoring effort to obtain representative primary removal efficiencies for the four metals. The result of this effort is the median primary removal efficiency data shown in Table I-5. Primary removals varied only slightly from month to month; as a consequence, the POTW elected to use median primary removals and did not consider the use of the removal efficiency decile approach to be necessary.

Derivation of Allowable Headworks Loadings

Having obtained removal efficiency data, allowable headworks loadings are now derived, based on the following treatment plant/environmental criteria:

- NPDES permit limits
- Water quality standards
- Activated sludge inhibition data
- Anaerobic digester inhibition data
- Sludge disposal criteria

TABLE I-4. REPRESENTATIVE REMOVAL EFFICIENCIES FOR THE HYPOTHETICAL POTW

Pollutant	Second Decile Removal	Eighth Decile Removal
Cd	29%	96%
Cr	68%*	91%*
Cu	27%	77%
Pb	39%*	76%*

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*Literature value from Table 3-9.

TABLE I-5. REPRESENTATIVE PRIMARY TREATMENT REMOVAL EFFICIENCES FOR THE HYPOTHETICAL POTW

Pollutant	Median Removal Across Primary Treatment
Cd	21%
Cr	31%
Cu	23%
Pb	12%

The derivation of allowable headworks loadings on each of the above-listed bases are discussed in this section.

NPDES Permit Limits

The following equation is used to derive allowable headworks loadings based on NPDES permit limits (from Section 3.2.1.1 of the manual):

$$L_{IN} = \frac{(8.34)(C_{CRIT})(Q_{POTW})}{(1-R_{POTW})}$$

where:

L_{IN} = Allowable headworks loading, lbs/d

C_{CRIT} = NPDES permit limit, mg/l

Q_{POTW} = POTW flow, MGD

R_{POTW} = Removal efficiency across POTW based on second decile

The hypothetical POTW has only one metal pollutant NPDES permit limit, a 0.5 mg/l limit for cadmium. To calculate the corresponding allowable headworks loading of cadmium for the hypothetical POTW, the following values have been established: C_{CRIT} = 0.5 mg/l, Q_{POTW} = 3.35 MGD, and R_{POTW} = 0.29 (from Table I-4). Thus, the allowable headworks loading for cadmium, based on the NPDES permit limit, is:

$$L_{IN} = \frac{(8.34)(0.5)(3.35)}{(1-0.29)} = 19.7 \text{ lbs/d}$$

Water Quality Standards

The following equations are used to derive allowable headworks loadings based on water quality standards (from Section 3.2.1.2 of the manual):

$$L_{IN/C} = \frac{(8.34)[C_{CWQ}(Q_{7Q10} + Q_{POTW})-(C_{STR}Q_{7Q10})]}{(1-R_{POTW})}$$

$$L_{IN/A} = \frac{(8.34)[C_{AWQ}(Q_{1Q10} + Q_{POTW})-(C_{STR}Q_{1Q10})]}{(1-R_{POTW})}$$

where:

$L_{IN/C}$ = Allowable headworks loading based on chronic toxicity standard, lbs/d

$L_{IN/A}$ = Allowable headworks loading based on acute toxicity standard, lbs/d

C_{CWQ} = Chronic toxicity standard, mg/l

C_{AWQ} = Acute toxicity standard, mg/l

Q_{7Q10} = Lowest 7-day average receiving stream flow over the past 10 years, MGD

Q_{1Q10} = Lowest single day receiving stream flow over the past 10 years, MGD

Q_{POTW} = POTW flow, MGD

C_{STR} = Background (upstream) pollutant level in receiving stream, mg/l

R_{POTW} = Removal efficiency across POTW based on second decile

The POTW contacted the State environmental agency and obtained the following receiving stream flow data for deriving allowable headworks loadings based on water quality standards:

Q_{7Q10} = 47 MGD

Q_{1Q10} = 26 MGD

The POTW also obtained from the State agency the applicable water quality standards and receiving stream background level data presented in Table I-6. The Table I-6 water quality standards are converted into corresponding allowable headworks loadings, by means of the above equations. These calculations are illustrated below for cadmium:

$$L_{IN/C} = \frac{(8.34)[(0.001)(47 + 3.35)-(0)(47)]}{(1-0.29)} = 0.59 \text{ lbs/d}$$

$$L_{IN/A} = \frac{(8.34)[(0.005)(26 + 3.35)-(0)(26)]}{(1-0.29)} = 1.72 \text{ lbs/d}$$

TABLE I-6. WATER QUALITY STANDARDS AND RECEIVING STREAM BACKGROUND LEVELS FOR THE HYPOTHETICAL POTW

Pollutant	Chronic Water Quality Standard, mg/l	Acute Water Quality Standard, mg/l	Receiving Stream Background Level, mg/l
Cd	0.001	0.005	0.0*
Cr	0.012	0.025	0.002
Cu	0.015	0.05	0.003
Pb	0.005	0.008	0.001

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*Assumed. No data available.

The chronic toxicity-based allowable headworks loading (0.59 lbs/d) is more stringent and is selected as the POTW's overall water quality standard-based allowable headworks loading for cadmium.

The water quality standard-based allowable headworks loadings for the remaining three metals are calculated in an identical fashion. The water quality standard-based allowable headworks loadings for all four metals are listed in Table I-8.

Biological Treatment Process Inhibition

The following equations are used to derive allowable headworks loadings based on biological treatment process inhibition (from Section 3.2.2.1 of the manual):

$$L_{IN/AS} = \frac{(8.34)(C_{IN/AS})(Q_{POTW})}{(1-R_{PRIM})}$$

$$L_{IN/AD} = \frac{(8.34)(C_{IN/AD})(Q_{DIG})}{R_{POTW}}$$

where:

$L_{IN/AS}$ = Allowable headworks loading based on activated sludge process inhibition, lbs/d

$C_{IN/AS}$ = Activated sludge inhibition threshold level, mg/l

Q_{POTW} = POTW flow, MGD

R_{PRIM} = Median primary removal efficiency (Table I-5)

and:

$L_{IN/AD}$ = Allowable headworks loading based on anaerobic digester inhibition, lbs/d

$C_{IN/AD}$ = Anaerobic digester inhibition threshold level, mg/l

Q_{DIG} = Sludge flow to digester, MGD

R_{POTW} = Removal efficiency across POTW based on eighth decile (Table I-4)

The inhibition threshold levels provided in Tables 3-4 and 3-6 of the text are used in these calculations. The sludge flow to the digester (Q_{DIG}) is 0.015 MGD.

Demonstrating the use of the above equations in calculating allowable headworks loadings for cadmium:

- From Table 3-3, $C_{IN/AS} = 1$ mg/l
- From Table 3-6, $C_{IN/AD} = 20$ mg/l
- $Q_{POTW} = 3.35$ MGD
- $Q_{DIG} = 0.015$ MGD
- $R_{PRIM} = 0.21$ (Table I-5)
- $R_{POTW} = 0.96$ (Table I-4)

$$L_{IN/AS} = \frac{(8.34(1)(3.35)}{(1-0.21)} = 35.4 \text{ lbs/d}$$

$$L_{IN/AD} = \frac{(8.34)(20)(0.015)}{(0.96)} = 2.6 \text{ lbs/d}$$

The activated sludge and anaerobic digester inhibition-based allowable headworks loadings for all four metals are presented in Table I-8.

Sludge Disposal Criteria

The POTW land-applies 0.01 MGD of sludge (7.5% consistency) to 500 acres of cropland (soil pH = 7.0, cation exchange capacity = 12 meq/100g). The site life is estimated at 20 years. The POTW contacted the State environmental agency, which advised the POTW that the sludge disposal criteria presented in Table I-7 apply to the POTW's current sludge disposal practices.

Two sludge disposal criteria must be compared for each pollutant: 1) the sludge disposal limit taken directly from Table I-7, and 2) the corresponding sludge disposal limit based on the cumulative application limit from Table I-7. The latter sludge disposal limit is calculated from the following equation (from Section 3.2.2.2 of the manual):

$$C_{LIM(C)} = \frac{(CAR)(SA)}{(SL)(Q_{SLDG})(PS/100)(3046)}$$

where:

$C_{LIM(C)}$ = Sludge disposal limit based on cumulative application rate limit, mg/kg dry sludge

CAR = Cumulative application rate limit, lbs/acre over the site life

TABLE I-7. SLUDGE DISPOSAL CRITERIA FOR LAND APPLICATION OF SLUDGE BY THE HYPOTHETICAL POTW

Pollutant	Sludge Limit, mg/kg dry weight	Cumulative Application Limit, lbs/acre
Cd	25	8.92
Cu	1000	223.1
Pb	1000	892.2

SA = Site area, acres

SL = Site life, years

Q_{SLDG} = Sludge flow to disposal, MGD

PS = Percent solids of sludge to disposal

Demonstrating the use of this equation for cadmium:

- From Table I-7, CAR = 8.92 lbs/acre
- SA = 500 acres
- SL = 20 years
- Q_{SLDG} = 0.01 MGD
- PS = 7.5%

$$C_{LIM(C)} = \frac{(8.92)(500)}{(20)(0.01)(7.5/100)(3046)} = 97.6 \text{ mg/kg dry sludge}$$

Since the sludge disposal limit listed in Table I-7 (25 mg/kg) is more stringent than the above-calculated limitation, the 25 mg/kg limit should be used in deriving the sludge disposal-based allowable headworks loading for cadmium. Similar calculations show that the sludge disposal limits listed in Table I-7 are more stringent for the other two metals as well.

In order to convert a sludge disposal criterion into an allowable headworks loading, the following equation is used (from Section 3.2.2.2 of the manual):

$$L_{IN} = \frac{(8.34)(C_{SLCRIT})(PS/100)(Q_{SLDG})}{R_{POTW}}$$

where:

L_{IN} = Allowable headworks loading, lbs/d

C_{SLCRIT} = Sludge disposal criterion, mg/kg dry sludge

PS = Percent solids of sludge to disposal

Q_{SLDG} = Sludge flow to disposal, MGD

R_{POTW} = Removal efficiency across the POTW, based on eighth decile

For cadmium:

- From above, $C_{SLCRIT} = 25$ mg/kg
- PS = 7.5%
- $Q_{SLDG} = 0.01$ MGD
- From Table I-4, $R_{POTW} = 0.70$

$$L_{IN} = \frac{(8.34)(25)(7.5/100)(0.01)}{(0.70)} = 0.16 \text{ lbs/d}$$

Allowable headworks loadings based on sludge disposal criteria are listed in Table I-8 for the three metals.

Table I-8 presents a comparison of allowable headworks loadings for the four metals, derived on all five bases. As can be seen from Table I-8, the smallest loading for each pollutant is selected as the pollutant's maximum allowable headworks loading. Local limits are to be derived from these maximum allowable headworks loadings.

Allocating Maximum Allowable Headworks Loadings

The allocation of maximum allowable headworks loadings entails:

- Incorporation of a safety factor and subtraction of domestic/ background wastewater loadings
- Allocation of resulting maximum allowable industrial loadings to individual industrial users

Four methods for allocating allowable industrial loadings are demonstrated in this section:

- Uniform concentration method
- Industrial contributory flow method
- Mass proportion method
- Selected industrial reduction method

TABLE I-8. COMPARISON OF ALLOWABLE HEADWORKS LOADINGS FOR METALS

		Allowable Headworks Loading (lbs/d) Based on:				
Pollutant	NPDES Limit	Water Quality Standard	Activated Sludge Inhibition	Anaerobic Digester Inhibition	Sludge Disposal Criterion	Maximum Allowable Headworks Loading, lbs/d
Cd	19.7	0.59	35.4	2.6	0.16	0.16
Cr	-	13.3	40.5	15.1	-	13.3
Cu	-	7.0	36.3	6.5	8.1	6.5
Pb	-	2.8	3.2	56.0	8.2	2.8

The uniform concentration method derives limits which apply to all industrial users, whereas the other three methods are IU-specific, in that derived limits only apply to those industrial users known to be discharging a given pollutant at greater than the domestic/background level.

Incorporation of a Safety Factor/Subtraction of Domestic Loadings

The following equation is used to convert maximum allowable headworks loadings into maximum allowable industrial loadings, through 1) the incorporation of a safety factor, and 2) the subtraction of the total pollutant loading from domestic/background sources:

$$L_{ALL} = (1-SF)L_{MAHL} - L_{DOM}$$

where:

L_{ALL} = Maximum allowable industrial loading, lbs/d

L_{MAHL} = Maximum allowable headworks loading, lbs/d

SF = Safety factor, decimal

L_{DOM} = Domestic/background wastewater pollutant loading, lbs/d (uniform concentration method)

or,

L_{DOM} = Domestic/unregulated wastewater pollutant loading, lbs/d (IU-specific methods)

It can be seen from the above equation that the domestic/background loading (L_{DOM}) for each pollutant depends on the allocation method selected. For the IU-specific allocation methods, IUs which do not discharge the particular pollutant are considered as background sources, discharging at normal domestic/background pollutant levels. Therefore for the IU-specific allocation methods, L_{DOM} for each pollutant includes background pollutant loadings from these IUs. As a result, L_{DOM} for the IU-specific allocation methods is greater than L_{DOM} for the uniform concentration allocation method.

Table I-9 presents a summary of industrial user and domestic/background wastewater flow, concentration, and pollutant loading data for the hypothetical POTW. The distinction between the two types of domestic/background

TABLE I-9. INDUSTRIAL USER MONITORING DATA FOR METALS

Industrial Uses	Flow, MGD	Cd mg/l	Cd lbs/d	Cr mg/l	Cr lbs/d	Cu mg/l	Cu lbs/d	Pb mg/l	Pb lbs/d
Chemical Manufacturer	0.5	0.0018*	-	0.023*	-	0.40	1.67	0.011*	-
Equipment Rebuilder	0.085	0.010	0.007	2.24	1.59	0.20	0.14	3.75	2.66
Ceramic Manufacturer	0.155	0.0015*	-	0.85	1.10	0.05*	-	1.25	1.62
Total Industrial	0.74		0.007		2.69		1.81		4.28
Domestic Wastewater	2.61	0.002	0.044	0.075	1.63	0.080	1.74	0.015	0.33
Domestic Plus			0.054		1.95		1.84		0.39
Unregulated Wastewater									

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*Pollutant level less than domestic wastewater level. IU discharge flow is considered part of the unregulated wastewater flow for the pollutant.

wastewater loadings is evident from the Table I-9 data; the domestic/background loadings for the IU-specific method are increased to account for industrial user background loadings. The amount of this increase equals the flow from those industries not discharging the pollutant times the domestic wastewater background concentration.

The calculation of maximum allowable industrial loadings, using domestic/background pollutant loading data from Table I-9, is demonstrated below for cadmium:

- From Table I-8, $L_{MAHL} = 0.16$ lbs/d
- From Table I-9, $L_{DOM} = 0.044$ lbs/d (Uniform Concentration Method)
- From Table I-9, $L_{DOM} = 0.054$ lbs/d (IU-specific methods)
- SF = 0.10 (ten percent safety factor assumed)

$$L_{ALL} = (1-0.10)(0.16) - 0.044 = 0.10 \text{ lbs/d (Uniform Concentration Method)}$$

$$L_{ALL} = (1-0.10)(0.16) - 0.054 = 0.09 \text{ lbs/d (IU-specific methods)}$$

Table I-10 presents maximum allowable industrial loadings for the four metals. These loadings were derived from the above equation, incorporating a ten percent safety factor and using the domestic/background pollutant loading data presented in Table I-9.

Allocation of Maximum Allowable Industrial Loadings

Table I-11 to I-13 present local limits for each of the hypothetical POTW's industrial users, derived by application of the four industrial loading allocation methods discussed in Chapter 3 of the manual. The equations and calculations pertinent to the derivation of these local limits are discussed in the following sections.

Uniform Concentration Allocation Method

The uniform allocation method derives local limits which apply to all three of the hypothetical POTW's industrial users. The equation for this method is (from Figure 3-2 of the manual):

$$C_{LIM} = \frac{L_{ALL}}{(8.34)(Q_{IND})}$$

TABLE I-10. MAXIMUM ALLOWABLE INDUSTRIAL LOADINGS, LBS/D

Pollutant	Uniform Concentration Method	IU-Specific Allocation Methods
Cd	0.10	0.09
Cr	10.34	10.02
Cu	4.11	4.01
Pb	2.19	2.13

TABLE I-11. LOCAL LIMITS FOR THE HYPOTHETICAL CHEMICAL MANUFACTURER

	Local Limit, mg/l			
Pollutant	Uniform Concentration	Industrial Contributory*	Mass Proportion*	Selected Industrial Reduction**
Cd	0.02	-	-	-
Cr	1.68	-	-	-
Cu	0.67	0.82	0.89	-
Pb	0.35	-	-	-

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*Local limits not derived for pollutants discharged by the IU at levels below the domestic sewage background concentration. The IU would be notified that it is not allowed to increase its discharge above the domestic sewage background level.

**Calculation of limits by the selected industrial reduction method is illustrated for lead only.

TABLE I-12. LOCAL LIMITS FOR HYPOTHETICAL EQUIPMENT REBUILDER

	Local Limit, mg/l			
Pollutant	Uniform Concentration	Industrial Contributory*	Mass Proportion*	Selected Industrial Reduction**
Cd	0.02	0.13	0.13	-
Cr	1.68	5.01	8.35	-
Cu	0.67	0.82	0.44	-
Pb	0.35	1.06	1.87	1.0

---

*Local limits not derived for pollutants discharged by the IU at levels below the domestic sewage background concentration. The IU would be notified that it is not allowed to increase its discharge above the domestic sewage background level.

**Calculation of limits by the selected industrial reduction method is illustrated for lead only.

TABLE I-13. LOCAL LIMITS FOR HYPOTHETICAL CERAMIC MANUFACTURER

Industrial User:

	Local Limit, mg/l			
Pollutant	Uniform Concentration	Industrial Contributory*	Mass Proportion*	Selected Industrial Reduction**
Cd	0.02	-	-	-
Cr	1.68	5.01	3.17	-
Cu	0.67	-	-	-
Pb	0.35	1.06	0.62	1.0

---

*Local limits not derived for pollutants discharged by the IU at levels below the domestic sewage background concentration. The IU would be notified that it is not allowed to increase its discharge above the domestic sewage background level.

**Calculation of limits by the selected industrial reduction method is illustrated for lead only.

where:

C_{LIM} = Uniform concentration limit, mg/l

L_{ALL} = Maximum allowable industrial loading, lbs/d

Q_{IND} = Total industrial flow, MGD

As an example, for chromium:

L_{ALL} = 10.34 lbs/d (See Table I-10)

Q_{IND} = 0.74 MGD (Table I-9)

$$C_{LIM} = \frac{(10.34)}{(8.34)(0.74)} = 1.68 \text{ mg/l}$$

This limit applies to all three industrial users of the hypothetical POTW (See Tables I-11 to I-13).

<u>Industrial Contributory Flow Method</u>

The industrial contributory flow method derives local limits which apply only to those industrial users discharging the particular pollutant at greater than the normal background concentration in domestic sewage. The equation for this method is (from Figure 3-2 of the manual):

$$C_{LIM} = \frac{L_{ALL}}{(8.34)(Q_{CONT})}$$

where:

C_{LIM} = Industrial contributory flow-based limit, mg/l

L_{ALL} = Maximum allowable industrial loading, lbs/d

Q_{CONT} = Industrial contributory flow, MGD

As an example, for chromium:

L_{ALL} = 10.02 lbs/d (See Table I-10)

Q_{CONT} = flow from chromium dischargers = 0.085 + 0.155 = 0.24 MGD (See Table I-9)

$$C_{LIM} = \frac{10.02}{(8.34)(0.24)} = 5.01 \text{ mg/l}$$

This limit applies only to the hypothetical equipment rebuilding and ceramic manufacturing industrial users. (See Tables I-11 to I-13).

Mass Proportion Method

The mass proportion method allocates allowable industrial loadings to individual IUs in direct proportion to each IU's current pollutant loading. This allocation method is also IU-specific. The equation for this method is (from Figure 3-2 of the manual):

$$C_{LIM(x)} = \frac{(L_{CURR(x)}/L_{CURR(t)})}{(8.34)(Q_{(x)})} \times L_{ALL}$$

where:

$C_{LIM(x)}$ = Local limit for industrial user (x), mg/l

L_{ALL} = Maximum allowable industrial loading, lbs/d

$L_{CURR(x)}$ = Current loading from industrial user (x), lbs/d

$L_{CURR(t)}$ = Total industrial loading, lbs/d

$Q_{(x)}$ = Industrial user (x) discharge flow, MGD

As an example, for chromium:

L_{ALL} = 10.02 lbs/d (Table I-10)

$L_{CURR(t)}$ = 2.69 lbs/d (Table I-9)

Equipment Rebuilder:

$L_{CURR(x)}$ = 1.59 lbs/d

$Q_{(x)}$ = 0.085 MGD

$$C_{LIM(x)} = \frac{(1.59/2.69)}{(8.34)(0.085)} \times (10.02) = 8.35 \text{ mg/l}$$

Ceramic Manufacturer:

$L_{CURR(x)}$ = 1.10 lbs/d

$Q_{(x)}$ = 0.155 MGD

$$C_{LIM(x)} = \frac{(1.10/2.69)}{(8.34)(0.155)} \times (10.02) = 3.17 \text{ mg/l}$$

The above limits apply only to the industrial users indicated (See Tables I-11 to I-13).

Selected Industrial Reduction Method

The selected industrial reduction method is based upon the reduction of current industrial user discharge loadings by the installation of treatment technologies. As an example of the application of this method, selected industrial reduction limits for lead will be derived in this section.

From Table I-9, the current total industrial loading of lead is 4.28 lbs/d. The maximum allowable industrial loading, from Table I-10, is 2.13 lbs/d. The required industrial loading reduction is:

4.28 lbs/d - 2.13 lbs/d = 2.15 lbs/d

Appendix L (Table L-1) and Table 6-1 in Chapter 6 document that a reduction of lead to less than 1.0 mg/l can be achieved through the installation of precipitation technologies. This concentration limit may be imposed upon the POTW's current lead dischargers as long as it results in the minimum required industrial loading reduction of 2.15 lbs/d. That this loading reduction can be achieved with a 1.0 mg/l limit is demonstrated as follows:

- For the equipment rebuilder, current lead loading = 2.66 lbs/d (from Table I-9)

  At 1.0 mg/l, the IU's lead loading is reduced to:

  (8.34)(1.0 mg/l)(0.085 MGD) = 0.71 lbs/d

  The lead loading reduction effected by the equipment rebuilder equals:

  2.66 lbs/d - 0.71 lbs/d = 1.95 lbs/d

- For the ceramic manufacturer, current lead loading = 1.62 lbs/d (from Table I-9)

  At 1.0 mg/l, the IU's lead loading is reduced to:

  (8.34)(1.0 mg/l)(0.155 MGD) = 1.29 lbs/d

The lead loading reduction effected by the ceramic manufacturer equals:

1.62 lbs/d - 1.29 lbs/d = 0.33 lbs/d

- The combined lead loading reduction brought about by the two industrial users equals:

1.95 lbs/d + 0.33 lbs/d = 2.28 lbs/d

Since this lead loading reduction of 2.28 lbs/d exceeds the required loading reduction of 2.15 lbs/d, the 1.0 mg/l lead limit may be imposed upon the equipment rebuilder and the ceramic manufacturer (see Tables I-11 to I-13).

DERIVATION OF LOCAL LIMITS FOR ORGANICS

The derivation of organic pollutant local limits for the hypothetical POTW entails:

- Identification of organic pollutants of concern for which local limits may be needed
- Derivation of maximum allowable headworks loadings
- Allocation of maximum allowable headworks loadings
- Establishing local limits to address pollutant flammability/ explosivity and fume toxicity concerns

Each of the above tasks are discussed in the following sections.

Identification of Organic Pollutants of Concern

The first step in deriving organic pollutant local limits for the hypothetical POTW will be to identify organic pollutants of concern for which local limits may be needed. As discussed in Chapter 2 of this manual, the first step involves completion of a thorough industrial user survey which identifies chemicals used, produced, stored, or disposed by the IUs. Then, sampling of IU discharges and at the POTW is performed to screen for the presence of those pollutants reasonably expected to be present in significant quantities. Based on the results of this preliminary sampling, some quick rules of thumb may be used to determine whether more extensive coordinated influent/effluent/sludge sampling for particular pollutants is needed to provide data necessary for calculation of local limits. For example, the following conservative rules of thumb could be used to decide which pollutants would warrant further consideration:

- Water quality-based local limits - Does the result of a receiving stream dilutional analysis based on maximum POTW effluent concentration exceed State water quality standards?

- Inhibition-based local limits - Does the maximum POTW influent grab sample concentration exceed one-half, or the maximum POTW influent 24-hour composite sample concentration exceed one-fourth, of the activated sludge inhibition threshold level?

  Does the maximum POTW influent concentration exceed one five-hundredth of the anaerobic digester inhibition threshold level?

- Sludge disposal criteria-based local limits - Does the maximum concentration of the pollutant in POTW sludge exceed one-half of the State sludge disposal criterion?

- Flammability/explosivity and fume toxicity-based local limits - Are IU discharge levels in excess of flammability/explosivity - and/or fume toxicity-based discharge screening levels?

The above pollutant evaluation scheme is based on the chemical-specific approach to identifying pollutant of concern, discussed in Section 2.3.3.1 and Figure 2-2 of the manual, and the flammable/explosive and fume toxic pollutant screening techniques discussed in Sections 4.1.1.5 and 4.2.3 of the manual. This evaluation scheme focuses on POTW influent and IU discharge data, but also incorporates the use of effluent and sludge data. As discussed in Section 2.3.3.1 of the manual, the POTW should perform at least a limited amount of effluent and sludge monitoring as part of its preliminary sampling program, in order to screen for pollutants which have concentrated to detectable levels in effluent or sludge even though not detectable in the influent.

Table I-14 and I-15 summarize organic pollutant monitoring data for the hypothetical POTW's influent and effluent, respectively, and Table I-16 summarizes organic pollutant monitoring data for the POTW's principal industrial user, an organic chemical manufacturing facility. The monitoring data presented in these tables will be used in demonstrating the above-described pollutant evaluation scheme. The application of each step of the pollutant evaluation scheme is demonstrated in the following sections.

TABLE I-14. POTW INFLUENT MONITORING DATA FOR ORGANIC POLLUTANTS

Pollutant	Number of Detections in Grab Samples	Concentration Range, mg/l	Number of Detections in Composite Samples	Concentration Range, mg/l
Priority Pollutant Organics:				
Chlorobenzene	2	0.24 - 1.16	6	0.04 - 0.74
Chloroform	1	0.06	6	0.002 - 0.38
Ethylbenzene	1	0.003	4	0.001 - 0.005
Methyl Chloride	1	3.48	7	0.001 - 0.69
Methylene Chloride	2	0.001 - 0.03	3	0.006 - 0.11
Nitrobenzene	0		2	0.087 - 0.28
Phenol	1	0.0002	1	0.036
Toluene	1	0.008	8	0.001 - 0.043
Non-priority Pollutant Organics:				
Acetone	1	0.1	1	2.62
Aniline	1	0.76	3	0.6 - 2.0
Benzoic Acid	0		2	0.27 - 0.7
3-(Dimethylamino) phenol	1	1.56	0	
N,N-Dimethylaniline	1	0.67	1	0.2
N,N-Dimethyl Formamide	1	1.4	0	
Quinaldine	1	2.7	2	0.4 - 1
Resourcinol Dimethyl Ether	0		3	0.1 - 0.47
Hydroquinone Monomethyl Ether	0		1	0.41
Methyl Isobutyl Ketone	1	0.018	1	0.12

TABLE I-15. POTW EFFLUENT MONITORING DATA FOR ORGANIC POLLUTANTS

Pollutant	Number of Detections in Grab Samples	Concentration Range, mg/l	Number of Detections in Composite Samples	Concentration Range, mg/l
Priority Pollutant Organics:				
Chlorobenzene	6	0.39 - 23.0	5	0.05 - 1.36
Chloroform	4	0.04 - 0.83	5	0.01 - 0.09
Ethylbenzene	2	0.002 - 4.6	5	0.001 - 0.008
Methyl Chloride	1	1.58	5	0.002 - 1.16
Methylene Chloride	2	0.007 - 0.014	1	0.021
Nitrobenzene	0		1	0.028
Phenol	0		2	0.001 - 0.037
Toluene	5	0.005 - 0.048	7	0.004 - 0.01
Non-priority Pollutant Organics:				
Acetone	1	0.1	1	9.73
Aniline	1	0.4	2	0.1 - 0.82
Benzoic Acid	0		1	0.55
3-(Dimethylamino) phenol	1	0.56	0	
N,N-Dimethylaniline	0		1	0.3
N,N-Dimethyl Formamide	1	0.15	0	
Quinaldine	1	0.53	1	0.4
Resourcinol Dimethyl Ether	0		1	0.2
Resourcinol Monomethyl Ether	0		1	0.1
Hydroquinone Monomethyl Ether	0		1	0.41

TABLE I-16. IU DISCHARGE MONITORING DATA FOR ORGANIC POLLUTANTS

Pollutant	Number of Detections in Grab Samples	Concentration Range, mg/l	Number of Detections in Composite Samples	Concentration Range, mg/l
Priority Pollutant Organics:				
Chlorobenzene	1	10.99	26	0.18 - 13.8
Chloroform	1	0.69	17	0.04 - 0.9
2,4-Xylenol	0		1	6.1
Ethylbenzene	0		1	12.2
Methyl Chloride	1	39.27	6	0.09 - 13.9
Methylene Chloride	1	0.73	4	0.016 - 2.4
Nitrobenzene	1	1.49	23	0.11 - 34.0
Phenol	0		10	0.01 - 17.0
Toluene	1	0.014	6	0.06 - 0.62
Non-priority Pollutant Organics:				
Aniline	0		22	0.18 - 108.0
Benzoic Acid	0		1	3.8
3-(Dimethylamino) phenol	0		4	0.088 - 6.0
4-(Dimethylamino)benzaldehyde	1	1.99	4	0.045 - 3.6
N,N-Dimethylaniline	1	1.89	4	0.2 - 4.0
N,N-Dimethyl Formamide	0		1	9.6
Hydroquinone Monomethyl Ether	0		1	2.2

TABLE I-16. IU DISCHARGE MONITORING DATA FOR ORGANIC POLLUTANTS (CONTINUED)

Pollutant	Number of Detections in Grab Samples	Concentration Range, mg/l	Number of Detections in Composite Samples	Concentration Range, mg/l
Non-Priority Pollutant Organics:				
3-(Hydroxyphenyl) Ethanol	1	0.78	0	
Methyl Acetate	0		3	0.01 - 1.7
Methyl Benzoate	0		2	0.085 - 0.64
Quinaldine	1	10.53	3	0.75 - 6.3
Resourcinol Dimethyl Ether	1	5.56	3	0.27 - 2.3
Resourcinol Monomethyl Ether	0		3	0.1 - 0.89
Tridecanol	1	2.72	0	
Methyl Ethyl Ketone	1	0.9	0	
Methyl Isobutyl Ketone	1	0.15	1	1.44

Screening of Organic Pollutants on the Basis of Water Quality Standards

The first step of the evaluation scheme consists of a receiving stream dilutional analysis to identify pollutants of potential water quality concern. The equation for conducting this dilutional analysis is as follows:

$$C_{PROJ} = C_{EFF} \times \left(\frac{Q_{POTW}}{Q_{STR} + Q_{POTW}}\right)$$

where:

C_{PROJ} = Projected downstream level, mg/l

C_{EFF} = Maximum POTW effluent level, from Table I-15, mg/l

Q_{POTW} = POTW flow, MGD

Q_{STR} = Receiving stream flow, MGD

- 7Q10 flow for comparison to chronic criteria
- 1Q10 flow for comparison to acute criteria

Projected downstream levels calculated from the above equation are compared with State water quality standards. Table I-17 presents organic pollutant State water quality standards for the POTW.

The screening technique is demonstrated below for chlorobenzene:

Q_{POTW} = 3.35 MGD

Q_{STR} = 47 MGD (7Q10)
26 MGD (1Q10)

C_{EFF} = 23 mg/l (Table I-15)

Chronic: $$C_{PROJ} = 23 \times \left(\frac{3.35}{3.35 + 47}\right) = 1.5 \text{ mg/l}$$

Acute: $$C_{PROJ} = 23 \times \left(\frac{3.35}{3.35 + 26}\right) = 2.6 \text{ mg/l}$$

Table I-17 indicates that the chronic water quality standard for chlorobenzene is 0.026 mg/l and the acute standard is 0.59 mg/l. Since the above-derived projected in-stream levels exceed these water quality standards, the development of water quality-based local limits for chlorobenzene is warranted.

TABLE I-17. ORGANIC POLLUTANT WATER QUALITY STANDARDS FOR THE POTW

Pollutant	Acute Water Quality Standard, mg/l	Chronic Water Quality Standard, mg/l
Acetone	550	78
Chlorobenzene	0.59	0.026
Chloroform	1.8	0.079
Ethylbenzene	1.4	0.062
Methylene Chloride	9.7	0.43
Phenol	5.3	0.37
Toluene	2.4	1.7
Nitrobenzene	27.0	-*

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*No standard available.

Based on this screening technique, the POTW determined that water quality-based local limits should be developed for the following organic pollutants:

- Chlorobenzene
- Ethylbenzene

Screening of Organic Pollutants on the Basis of Biological Process Inhibition

The second step of the pollutant evaluation scheme entails the comparison of POTW influent levels of organic pollutants with activated sludge and anaerobic digester inhibition threshold data, as follows:

- Maximum level in grab sample of POTW influent compared with one-half of the activated sludge inhibition threshold
- Maximum level in composite sample compared with one-fourth of the activated sludge inhibition threshold
- Maximum POTW influent level compared with one-five hundredth of the anaerobic digester inhibition threshold

Activated sludge inhibition data are provided in Table 3-2 of the manual. Comparing POTW influent data from Table I-14 with inhibition threshold cutoffs derived from the Table 3-2 data:

Pollutant	Maximum Grab Sample Level, mg/l	One-half of Inhibition Threshold, mg/l	Maximum Composite Sample Level, mg/l	One-fourth of the Inhibition Threshold, mg/l
Ethylbenzene	0.003	100	0.005	50
Nitrobenzene	Not detected	15	0.28	7.5
Phenol	0.002	25	0.036	12.5
Toluene	0.008	100	0.043	50

The above-listed organics are present in the POTW influent at levels well below their corresponding cutoffs. Local limits for these organics need not be developed from activated sludge process inhibition data.

Table 3-5 of the manual presents anaerobic digester threshold inhibition data. Comparing maximum POTW influent levels with anaerobic digester inhibition cutoffs derived from Table 3-5 data:

Pollutant	Maximum Influent Level, mg/l	One-five hundredth of the Digester Inhibition Level, mg/l
Chlorobenzene	1.16	0.002
Chloroform	0.38	0.002
Methyl Chloride	3.48	0.007

All three pollutants are present in the POTW influent at levels in excess of their cutoffs. Based on this screening analysis, local limits based on anaerobic digester inhibition may be needed for all three pollutants. The POTW should therefore perform the additional sampling necessary to perform a headworks loading analysis. It would also be wise for the POTW to sample for pollutants in the digester to determine whether inhibition threshold levels are currently exceeded.

Screening of Organic Pollutants on the Basis of Sludge Disposal Criteria

The hypothetical POTW contacted the State environmental agency to determine if any State sludge disposal guidelines had been established for organic pollutants in land-applied sludge. The POTW was informed that State sludge disposal guidelines for organic pollutants had not been established. The hypothetical POTW concluded that without sludge disposal criteria, no basis existed for a sludge disposal criteria analysis.

Screening of Organic Pollutants Based on Flammability/Explosivity and Fume Toxicity

The final step of the pollutant evaluation scheme is to compare industrial user discharge levels with IU discharge screening levels based on pollutant flammability/explosivity and fume toxicity. These screening levels are developed as per the methodologies presented in Sections 4.1.1.5 and 4.2.3 of the manual.

Table I-18 presents a comparison of IU discharge levels (from Table I-16) with discharge screening levels developed in accordance with the Section 4.1.1.5 and Section 4.2.3 methodologies. The comparison suggests that fume toxicity-based local limits may be needed for the following pollutants:

- Chlorobenzene
- Chloroform
- Ethylbenzene
- Methyl chloride
- Nitrobenzene

The comparison also suggests that flammability/explosivity-based local limits may be needed for methyl chloride.

Derivation of Maximum Allowable Headworks Loadings

The pollutant evaluation scheme identified the following pollutants for which allowable headworks loadings should be developed:

Water Quality-based Headworks Loadings

- Chlorobenzene
- Ethylbenzene

Anaerobic Digester Inhibition-based Headworks Loadings

- Chlorobenzene
- Chloroform
- Methyl chloride

Earlier in this appendix, allowable headworks loadings for metals were derived from State water quality standards. The same procedures can be followed here to derive water quality-based allowable headworks loadings for chlorobenzene and ethylbenzene. Based on the following data:

- Receiving stream flow, 7Q10 = 47 MGD
- Receiving stream flow, 1Q10 = 26 MGD
- POTW flow = 3.35 MGD

TABLE I-18. COMPARISON OF IU DISCHARGE LEVELS WITH IU DISCHARGE SCREENING LEVELS

Pollutant	Maximum IU Discharge Level, mg/l	Flammability/ Explosivity-Based Screening Level, mg/l	Fume Toxicity-Based Screening Level, mg/l
Chlorobenzene	13.8	403.	2.35
Chloroform	0.9	- *	0.42
Ethylbenzene	12.2	158.	1.59
Methyl Chloride	39.27	11.	0.007
Methylene Chloride	2.4	5760.	4.15
Nitrobenzene	34.0	98035.	5.41
Phenol	17.0	- *	688.4
Toluene	0.62	173.	1.35
Aniline	108.0	712086.	143.9
N,N-Dimethylaniline	4.0	- *	71.4
Methyl Acetate	1.7	21531.	140.0
Methyl Ethyl Ketone	0.9	24848.	249.0
Methyl Isobutyl Ketone	0.15	24601.	88.0

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*Screening level not developed (LEL data not available)

- Receiving stream background levels = 0 (i.e., not available)
- Chlorobenzene chronic standard = 0.026 mg/l
- Chlorobenzene acute standard = 0.59 mg/l
- Ethylbenzene chronic standard = 0.062 mg/l
- Ethylbenzene acute standard = 1.4 mg/l
- Chlorobenzene removal efficiency = 90%*
- Ethylbenzene removal efficiency = 67% (Table 3-10)

Allowable headworks loadings of 109.2 lbs/d chlorobenzene and 78.9 lbs/d ethylbenzene are derived.

The following equation is used to derive allowable headworks loadings for organic pollutants based on anaerobic digester inhibition data (from Section 3.2.2.1 of the manual):

$$L_{IN} = L_{INF} \times \left(\frac{C_{CRIT}}{C_{DIG}}\right) = \frac{(8.34)(Q_{POTW})(C_{INF})}{(C_{DIG})} \times C_{CRIT}$$

where: L_{IN} = Allowable headworks loading, lbs/d

L_{INF} = POW influent pollutant loading, lbs/d

C_{CRIT} = Anaerobic digester inhibition threshold level, mg/l

C_{DIG} = Pollutant level in sludge to digester, mg/l

Q_{POTW} = POTW flow, MGD

C_{INF} = POTW influent level, mg/l

Table 3-11 presents anaerobic digester inhibition levels (C_{CRIT}) for incorporation into the above expression; however, C_{INF}/C_{DIG} data must be obtained through site-specific monitoring. C_{DIG} data are not currently available for the hypothetical POTW. For the three pollutants of concern (chlorobenzene, chloroform, methyl chloride), the hypothetical POTW should perform coordinated monitoring of the POTW influent and the sludge to the digester, in order to obtain C_{INF}/C_{DIG} data for incorporation into the above expression.

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*From Reference [19].

Allocation of Maximum Allowable Headworks Loadings

Requisite pollutant loading reductions for nonconservative pollutants can be calculated from the following equation:

$$R = \frac{L_{INF} - L_{IN}}{L_{INF}} (100)$$

where:

R = Requisite pollutant loading reduction, percent

L_{INF} = Current POTW influent loading of the pollutant, lbs/d

L_{IN} = Maximum allowable headworks loading, lbs/d

Use of the above equation requires that the current POTW influent loading of the particular pollutant exceeds the maximum allowed ($L_{INF} > L_{IN}$).

The application of the above equation is demonstrated below for chlorobenzene:

- Recent composite sampling of the hypothetical POTW quantified the current POTW influent level of chlorobenzene at 4.50 mg/l. Therefore:

  $$L_{INF} = (8.34)(Q_{POTW})(C_{INF}) =$$
  $$(8.34)(3.35)(4.50) = 125.7 \text{ lbs/d}$$

- Uncontrollable sources of chlorobenzene have been assessed to be negligible

- The allowable headworks loading for chlorobenzene (water quality-based) is 109.2 lbs/d

- Required removal is:

  $$R = \frac{125.7 - 109.2}{125.7} (100) = 13.1\%$$

- The hypothetical POTW's chemical manufacturing IU is the only known discharger of chlorobenzene to the POTW. For this IU:

  - Discharge flow = $Q_{(X)}$ = 0.5 MGD
  - Discharge level = $L_{CURR(X)}$ = 13.8 mg/l (Table I-16)

  $$L_{CURR(T)} = (8.34)(Q_{(X)})(L_{CURR(X)})$$
  $$= (8.34)(0.5)(13.8) = 57.5 \text{ lbs/d}$$

- The IU's chlorobenzene discharge limit is derived as follows:

$$C_{LIM(X)} = \frac{L_{CURR(X)} - (1 - R)}{(8.34)(Q_{(X)})}$$

$$C_{LIM(X)} = \frac{57.5 - (1 - 0.131)}{(8.34)(0.5)} = 12.0 \text{ mg/l}$$

The above minimum discharge limit should be incorporated into the industrial user's permit.

This minimum industrial reduction may need to be increased further to account for domestic/background sources if the assumption that these sources are negligible is not accurate. These limits should be reassessed during routine evaluation of local limit effectiveness. If subsequent evaluation of the actual influent loading indicates insufficient reduction has been achieved, the POTW should consider whether the industrial reduction needs to be increased.

<u>Local Limits to Address Pollutant Flammability/Explosivity and Fume Toxicity Concerns</u>

The pollutant evaluation scheme determined that the hypothetical POTW's chemical manufacturing IU is discharging potentially fume toxic levels of the following five pollutants:

- Chlorobenzene
- Chloroform
- Ethylbenzene
- Methyl chloride
- Nitrobenzene

The POTW decided to adopt the Cincinnati MSD volatile organic pollutant local limit procedure (See Sections 4.1.1.2 and 4.2.1, and Appendix J) and impose a volatile organic pollutant local limit on the chemical manufacturer's discharge. The MSD volatile organic pollutant local limit consist of a 300 ppm hexane equivalent limit on volatile organics in headspace gases collected over an equilibrated wastewater sample.

In addition to imposing the volatile organic pollutant local limit, the POTW has planned a comprehensive inspection of the chemical manufacturer's industrial processes. This inspection is to identify IU chemical management practice deficiencies which might account for the presence of the above-listed volatile organics in the IU's discharge. The POTW plans to impose chemical management practice requirements on the IU to correct these deficiencies and prevent the IU from discharging flammable/explosive and fume toxic levels of the five organics.

APPENDIX F
WATER QUALITY-BASED TOXICS CONTROL

WATER QUALITY-BASED TOXICS CONTROL

In addition to compliance with section 301(h) of the Clean Water Act and its implementing regulations, permits issued to facilities with 301(h) waivers must also ensure compliance with other appropriate sections of the CWA. Among these is section 301(b)(1)(C), which requires, in part, the imposition of any conditions necessary to meet water quality standards. Regulations that implement section 301(b)(1)(C) are found at 40 CFR 122.44(d), and the following discussion highlights some of the requirements of those regulations. This appendix is not intended as a comprehensive statement of NPDES permitting requirements. Rather, the information is presented as an overview to advise the 301(h) applicant of some of the additional CWA requirements and to guide the applicant to requirements similar or complementary to the 301(h) requirements.

Under 40 CFR 122.44(d), NPDES permits must contain limitations to control all pollutants or pollutant parameters that *are or may be discharged at a level which will cause, have reasonable potential to cause, or contribute to an excursion above any state water quality standard, including state narrative criteria for water quality.* The regulations require these evaluations to be made using procedures that account for existing controls on point and nonpoint sources of pollution, the variability of the pollutant in the effluent, species sensitivity (for toxicity), and, where appropriate, dilution in the receiving water. The limits must be stringent enough to ensure that water quality standards are met and must be consistent with any available wasteload allocation.

The regulations also specifically address when toxicity and chemical-specific limits are required. A toxicity limit is required whenever toxicity has the reasonable potential to cause or contribute to an excursion above either a numeric or narrative standard for toxicity. The only exception is where chemical-specific limits will achieve the narrative standard. A chemical-specific limit is required whenever an individual pollutant is at a level of concern [as defined at 40 CFR 122.44(d)(1)] relative to the numeric standard for that pollutant.

40 CFR 122.44(d)(1)(vi) outlines the options to be used to interpret a state narrative criterion in the absence of a numeric criterion for a pollutant. Under the first option, the permitting authority [in the case of 301(h) modified NPDES permits, EPA] may use a criterion that is derived based on a proposed state criterion or an explicit state policy or regulation interpreting its narrative criterion, supplemented with other relevant information. The second option is to establish effluent limitations based on EPA's water quality criteria. Finally, the

permitting authority may establish limits on an indicator pollutant, provided that certain conditions are met.

EPA's *Technical Support Document for Water Quality-based Toxics Control* (U.S. EPA 1991a) provides guidance for evaluating "reasonable potential" and establishing water quality-based effluent limits for specific chemicals, as well as whole effluent toxicity. Although the whole-effluent toxicity discussions focus primarily on fresh water, the approach outlined in U.S. EPA (1991a) is appropriate for marine waters as well.

In addition to the *Technical Support Document for Water Quality-based Toxics Control*, EPA has published several manuals that provide guidance for conducting whole-effluent toxicity testing and for addressing any toxicity that is found. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*, 4th ed. (U.S. EPA 1991b) addresses acute (e.g., rapid response) toxicity. EPA's *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms* (U.S. EPA 1988a) provides protocols for conducting chronic (e.g., long-term) testing.

If toxicity is found in an effluent, the permittee will be required to conduct a toxicity identification evaluation (TIE) and, if appropriate, a toxicity reduction evaluation (TRE) to control toxicity. Two EPA manuals, *Toxicity Identification Evaluations: Characterization of Chronically Toxic Effluents, Phase 1* (U.S. EPA 1991c) and *Toxicity Reductions Evaluation Protocols for Municipal Wastewater Treatment Plants* (U.S. EPA 1988b), address TIE/TRE procedures for POTWs.

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