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USER HANDBOOK FOR THE ALLOCATION OF COMPLIANCE MONITORING RESOURCES

Office of Air, Land, and Water Use
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FOREWORD

A successful water quality management program requires not only thorough problem definition and prudent implementation of effective control methods, but also adequate monitoring and strict enforcement of the ambient and effluent quality standards upon which the program is based. The acquisition and analysis of adequate data for detection and enforcement of standards violations is a complex and costly process, and can be ineffective and inefficient unless due consideration is given to the statistics and economics of the system, and the monitoring program is designed and operated accordingly.

This report is the eighth in a series within the Environmental Management Research Program which addresses the management aspects of the design and operation of water quality monitoring and information management programs at the state or regional level, and develops user-oriented handbooks to assist personnel in program design and management. The other seven reports are available from GPO or NTIS, and are listed below:

"Design of Water Quality Surveillance Systems," 16090DBJ08/70, August 1970

"Quantitative Methods for Preliminary Design of Water Quality Surveilance Systems," EPA-R5-72-001, November 1972

"Data Acquisition Systems in Water Quality Management," EPA-R5-73-014, May 1973

"Michigan Water Resources Enforcement and Information System," EPA-R5-73-020, July 1973

"Design of Cost-Effective Water Quality Surveilance Systems," EPA-600/5-74-004, Janauary 1974

"Demonstration of a State Water Quality Management System," EPA-600/5-74-022, August 1974

"Quantitative Method for Effluent Monitoring Resource Allocation," EPA-600/5-75-015, August 1975

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ABSTRACT

This report is designed as a handbook specifically oriented to environmental planners and managers. It presents the development and successful demonstration of hand and computerized procedures for the design of effluent compliance monitoring systems. The procedures may help planners allocate compliance monitoring budgetary resources so as to minimize environmental damage. The original technical development of these procedures is given in a companion report, "Quantitative Methods for Effluent Compliance Monitoring Resources Allocation," EPA-600/5-75-015. Both the computerized and hand calculation procedures are demonstrated to function satisfactorily using data supplied by the State of Michigan.

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SECTION 1
INTRODUCTION

In response to increasing public awareness and concern for the quality of the environment, government agencies at all levels are taking steps to protect and enhance the quality of the nation's waters. Control of wastewaters is essential to the success of this initiative toward environmental quality. The Federal Water Pollution Control Act Amendments of 1972 require the establishment of wastewater (effluent) limitations for all joint sources by July 1, 1977. The Environmental Protection Agency, or designated state agency, is required to establish monitoring programs to ensure that the effluent sources are in compliance with the standards.

According to the Federal monitoring guidelines, there are three ways the monitoring agency must obtain information concerning the compliance of dischargers:

1. Self-Monitoring. The effluent dischargers are required to sample their own effluent levels and periodically transmit records of these samples to the monitoring agency.
2. Compliance Monitoring. The monitoring agency visits the effluent dischargers to ensure that the self-monitoring is being properly executed and reported.
3. Ambient Monitoring. The water quality of the receiving waters monitored by state and/or local agencies.

The self-monitoring reports are the principal source of compliance information used by monitoring agencies since the agency expense to acquire these data is minimal. Some check is, however, needed on the reliability of self-monitoring data. The compliance monitoring program is set up to provide that check. The compliance program also has other purposes associated with the permit program, such as verifying that the plant processes described in the permit are correct, evaluating new waste removal equipment, reviewing progress toward scheduled pollution control activities, and monitoring to aid in preparing enforcement actions. The ambient monitoring is primarily used to determine water quality, discern trends in water quality, and evaluate the overall effectiveness of pollution control in a region. Under certain conditions, however, ambient monitoring may flag effluent irregularities unmeasured by other means. Through knowledge of the effluent sources that could contribute to the decline in ambient quality, action can be initiated against possible violators.

This handbook is directed toward responsible monitoring agencies on the local, state and Federal levels, and specifically to the design of compliance monitoring programs. It is intended to extend the Resource Allocation Procedure of a previous Research and Development report [1] to include hand calculation procedures, and user oriented documentation. The handbook provides simple and concise procedures for the preliminary design of effluent compliance monitoring programs. It includes the option of using hand calculation or computer calculation techniques. It is intended to assist officials in developing efficient and effective compliance monitoring programs using a relatively simple, yet meaningful approach.

SECTION 2

DESCRIPTION OF COMPLIANCE MONITORING DESIGN PROCEDURE

This section presents a technical overview of the monitoring Resource Allocation Procedure, and how it relates to the governing laws and regulations.

2.1 REVIEW OF GOVERNING LAWS AND REGULATIONS

The Federal Water Pollution Control Act Amendments of 1972 shift the emphasis of the law from water quality standards to effluent limitations. These effluent limitations are asserted through the National Pollutant Discharge Elimination System (NPDES) permits. The Federal Environmental Protection Agency (EPA) or state agency designated by the EPA regional administrator must issue NPDES permits to all dischargers based upon certain criteria outlined as follows.

The basic limitations are based upon known effluent control technology. Permits for 28 industrial categories [2] are set according to the Best Practicable Control Technology Currently Available (by 1977), and Best Available Technology Economically Achievable (by 1983). Municipal sewage discharge permits are set according to the basic Secondary Levels of Treatment (by 1977), and Best Practicable Waste Treatment Technology (by 1983). However, in Water Quality Limited Segments* the permits must be based upon the level of additional treatment needed to assure maintenance of acceptable water quality. It is the responsibility of the state or regional administrators to set the permit levels in these areas based upon

*Areas of receiving waters where acceptable water quality levels are not always reached when the effluents of that area are held to the basic limitations.

studies such as those under Sections 303e and 208 of the Water Quality Act [3]. Once the permits are specified, it is the responsibility of each discharger to maintain their effluents within permit levels.

The Federal government has set out guidelines to officials issuing NPDES permits in the form of Effluent Limitations Guidelines [2,4-20]. The important aspects of these guidelines are listed below.

1. Only constituents of major significance should be limited and monitored. The full list of constituents recommended for effluent limitations in the 28 industrial categories is given in Table 2.1.

2. Limitations should be in terms of "production days," i.e., loads throughout a day.

3. Each permit should contain limitations on (monthly) average and daily maximum.

4. Permits should be based upon gross loads, unless the discharger has a strong argument to use limitations on net loads (i.e., outlet load minus the intake load). Where possible, the permits should be in units of kilograms per day.

The enforcement of these NPDES requirements requires certain specified monitoring procedures, as outlined in the next subsection.

Monitoring Guidelines

The Federal Water Pollution Control Act Amendments of 1972 and the accompanying regulations and guidelines specify a comprehensive set of monitoring programs for enforcement of the law. The major monitoring efforts to be required are shown in Figure 2.1.

Table 2.1 Constituents Recommended for Limitation by Industrial Category

INDUSTRY CATEGORY	BOD5	TSS	pH	COLOR	COD	PHENOLS	OIL & GREASE	SURFACTACTS	TOC	NH_3	SULFIDE	Cr TOTAL	Cr 6	ZINC	K. NITROGEN	FECAL COLIFORM	NO_3-N	ORGANIC N	T. PHOSPHOROS	FLOURIDE	HEAT	COPPER	ALLUMINUM	CYANIDE	MANGANESE	NICKEL	ARSENIC	CHLORINE	IRON	LEAD	MURCURY	T. DISOLVED SOLIDS
1 PULP, PAPER & PAPERBOARDS	X	X	X	X																												
2 BUILDERS PAPER AND BOARD	X	X	X																													
3. TIMBER PRODUCTS	X	X	X		X	X	X																									
4 SOAP AND DETERGENTS	X	X	X		X		X	X																								
5 DAIRY PRODUCTS	X	X	X																													
6 ORGANIC CHEMICALS	X	X	X		X	X																										
7 PETROLEUM REFINING	X	X	X		X	X	X		X	X	X	X	X																			
8 LEATHER TANNING & FISHING	X	X	X				X				X	X			X	X																
9 CANNED AND PRESERVED FRUITS AND VEGTABLES	X	X	X													X																
10 NONFERROUS METALS		X	X		X					X										X		X	X									
11 GRAIN MILLS	X	X	X																													
12 SUGAR PROCESSING	X	X	X													X					X											
13 FERTILIZERS		X	X				X			X							X	X	X	X												
14 ASBESTOS		X	X		X																											
15 MEAT PRODUCTS	X	X	X				X			X						X																
16 FERROALLOYS		X	X			X						X	X								X			X		X						
17 GLASS	X	X	X		X	X	X												X													
18 ELECTROPLATING		X	X									X	X	X								X		X		X						
19 PHOSPHATE MANUFACTURING		X	X																X	X							X					X
20 FEEDLOTS	X															X																
21 CEMENT MANUFACTURING		X	X																		X											X
22 RUBBER PROCESSING	X	X	X		X		X																									
23 PLASTICS AND SYNTHETICS	X	X	X		X	X						X		X																		
24 INORGANIC CHEMICALS		X	X		X				X			X	X							X				X					X	X	X	
25 IRON AND STEEL		X	X			X	X			X				X			X			X			X		X						X	
26 TEXTILES	X	X	X	X	X	X	X					X				X																
27 STEAM ELECTRIC GENERATING EQUIPMENT		X	X				X														X	X						X	X			
28 SEAFOOD PROCESSING	X	X	X				X																									

From References [2,4-20]

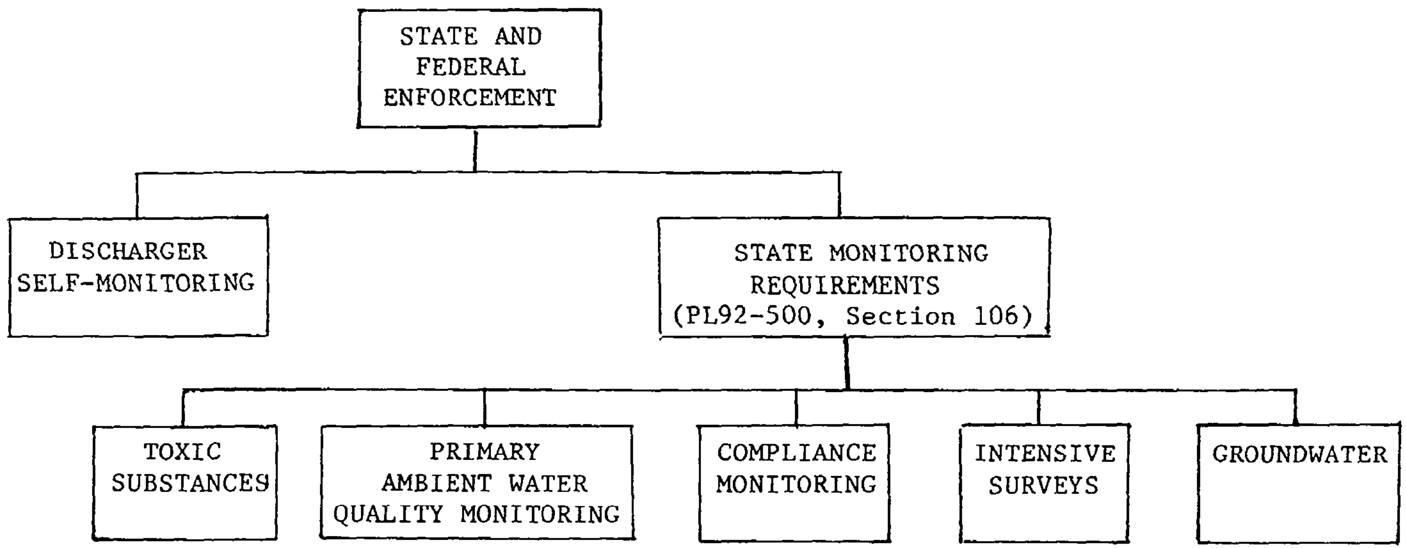

Figure 2.1 Major Monitoring Activities

The effluent discharger under an NPDES permit must monitor his effluent (self-monitor) at some minimum sampling frequency, maintain records of sample results, and periodically transmit these records to the state. In addition, state officials must have the authority to enter the premises of a permittee at any reasonable time to inspect records and instrumentation and to sample effluents, both to verify the quality of self-monitoring reports and to check for compliance with permit conditions.

The States have a number of monitoring responsibilities (shown in Figure 2.1) in order to be eligible for Federal wastewater control program grants. These responsibilities are described in regulations developed under Section 106e(1) of PL 92-500 [3]. In summary, these regulations require that monitoring systems include the following components:

- Compliance Monitoring to validate self-monitoring reports and support enforcement actions. This monitoring must include scheduled and random quality control inspection of permittees' monitoring reports and equipment to establish the credibility of self-monitoring reports, follow-up inspections when there is evidence of an effluent standard violation, and ad hoc intensive surveys when there is evidence of a water quality violation.
- Intensive surveys (scheduled in advance on a periodic basis) conducted "before and after implementing pollution controls in areas of significant pollution sources, clustered pollution sources, localized nonpoint sources of pollution, and in major bodies of water which are known or suspected to be accumulating pollutants." These surveys may include monitoring of both ambient and effluent levels.

- Primary ambient monitoring designed to give the long-term coverage necessary to describe trends in water quality and to establish a macroscopic view of the effectiveness of pollution control actions (see Section 305b, PL 92-500).
- Toxic pollutant monitoring including "studies and systematic sample collection from surface waters, groundwaters, sediments and biological communities" to define where toxic pollutants are entering the States' waters and to provide basis for control actions.
- Groundwater monitoring consisting of stations designed to "determine baseline conditions and provide early detection of pollution."

The procedures given in this handbook are concerned with the allocation of monitoring resources for compliance monitoring.

Self-Monitoring Requirements

The NPDES permit program guidelines [2] give detailed requirements for self-monitoring programs. They suggest that minimum self-monitoring frequencies be set according to the discharge flows and constituent nature for industrial and municipal effluents as given in Tables 2.2 and 2.3. Since the effluent standards must be set in terms of daily loads, the monitoring guidelines strongly recommend the use of composite samples. However, if it is only feasible to take grab samples, they can be used to represent daily composite samples.

The self-monitoring data must be reported on standard forms giving the maximum and minimum of production day loading samples over a month, and the monthly average of these samples. The dischargers with more than

Table 2.2 Recommended Minimum Sampling and Analysis Frequency for Process Effluent

Effluent Flow Volume (MGD)	Minimum Frequency for Major Constituents	Minimum Frequency for Other Constituents
< .05	Once per month	Semi-Annually
.05-1.0	Once per month	Quarterly
1.0-10.	Once per week	Once per Month
10. - 50.	Three times per week	Once per Month
>50.	Daily	Once per Month

Table 2.3 Municipal Wastewater Treatment Facilities Minimum Sampling Frequency

		EFFLUENT					
Plant Size (mgd)	Flow	BOD_5 (mg/l)	Suspended Solids (mg/l)	pH	Residual Chlorine (mg/l)[3]	Fecal Coliform (N per 100 ml)[1,3]	Settleable Solids (ml/l)[3]
Up to 0.99	Once each Wkday.[2]	Once per month					
1 - 4.99	Daily	Once per week					
5 - 14.99	Daily	Once per weekday[2]					
15 and greater	Daily	Once per day					

[1]In smaller plants, we should accept total coliform rather than fecal coliform at this time.

[2]Weekday = Monday - Friday

[3]Grab Sample

one discharge pipe are given the option of reporting on each discharge separately, or on the combined discharges. The self-monitoring data must be transmitted to the State at least quarterly -- semi-annually for very small industries.

2.2 COMPLIANCE MONITORING PROCEDURES

This handbook is concerned with the part of the compliance monitoring program that determines whether effluent sources are in compliance with the effluent standards. Since the state monitoring agency has limited resources available for compliance monitoring, it is important that these resources be used in an efficient manner. The procedure developed in the first SCI study [1], and presented in this handbook,determines how often to monitor each source in a region to obtain maximum benefit from the compliance monitoring program. The procedure uses information from past self-monitoring, ambient monitoring, and compliance monitoring reports.

As discussed earlier, an effluent source is in violation (i.e., does not comply with standards) if either the value of a daily composite measurement exceeds the maximum standard, or the average of the daily composites over the month exceeds the average standard. In order to determine whether an effluent source is in violation of the "average" standard, it is necessary to take measurements over a large percentage of the month, while to determine if the "maximum" standard is violated, it is only necessary to determine if the standard was exceeded over a single day. Since compliance monitoring is costly to the monitoring agency, and since most regions will contain many effluent sources, it is not expected, in general, that compliance monitoring resources will be available to determine whether the "average" standard is violated. Additionally, the chronic, long-term pollution effects resulting from the "average" violation can usually be sensed in both the primary monitoring network, and through a compliance monitoring scheme designed for the "maximum" standard. Therefore, the procedure given in this handbook is limited to determining whether the "maximum" standard is violated.

The Resource Allocation Procedure sets priorities on which effluent sources should be monitored and how often. The procedure determines the sampling rates so that sources that have a high probability of violating their standard, and (optionally) sources that may cause large environmental damage will be sampled with high priority. The objective in allocating monitoring resources then is to minimize the "cost" of undetected violations, or equivalently, the expected environmental damage that would result from undetected violations. The "cost" of undetected violations for a number of effluent sources may depend on:

1. The expected number of undetected violations;
2. The expected "environmental cost" due to undetected violations;
3. The expected magnitude of undetected violations.

Any one of these three factors can be used as the criterion for the allocation of monitoring resources.

The first allocation criterion depends on the probability that the various violating sources in the monitoring region will not be caught in violation once in the monitoring period (i.e., the probability of being an undetected violator). This quantity in turn depends on the sampling rates and single day probability that each of the sources will violate one of their standards. The other two criteria are also a function of the probability of being an undetected violator; however, they all depend on other factors. The second criterion depends on the environmental damage that is expected to result from a standard violation, while the third criterion depends on the degree or amount by which the standard is expected to be exceeded. These criteria are defined in more detail in Section 2.4.

All the above criteria are functions of the discharges or loadings from effluent sources. These effluent loads, due to their inherent variability, are modeled statistically by either a normal or lognormal probability density function. Allowing for two types of density functions results in the ability to model a wide range of effluent loadings with sufficient accuracy to determine sampling priorities. Both the normal and lognormal density functions can be defined by two parameters, a mean and a standard deviation. (For the lognormal case, the mean and standard deviation are those of the logs of the effluent values.) These parameters are obtained for each constituent of each source from historical data, including self-monitoring and compliance monitoring data. The procedure used to determine the statistical characteristics of the effluents is described in Section 2.5.

2.3 OVERVIEW OF RESOURCE ALLOCATION PROCEDURE

The basic task flow for the Resource Allocation Procedure is given in Figure 2.2. The various major functions of the procedure are briefly described below, and described in more detail in Sections 2.4 through 2.6.

1. Initialize Statistical Description

   Combine the raw self-monitoring and compliance monitoring data to obtain an initial statistical description (distribution, mean and standard deviation) for each pollutant of each source.

2. Calculate Probability and "Cost" of Violation (Allocation Criteria)

   Use the statistical description of the effluent loads, the effluent standards, and the stream parameters to obtain the

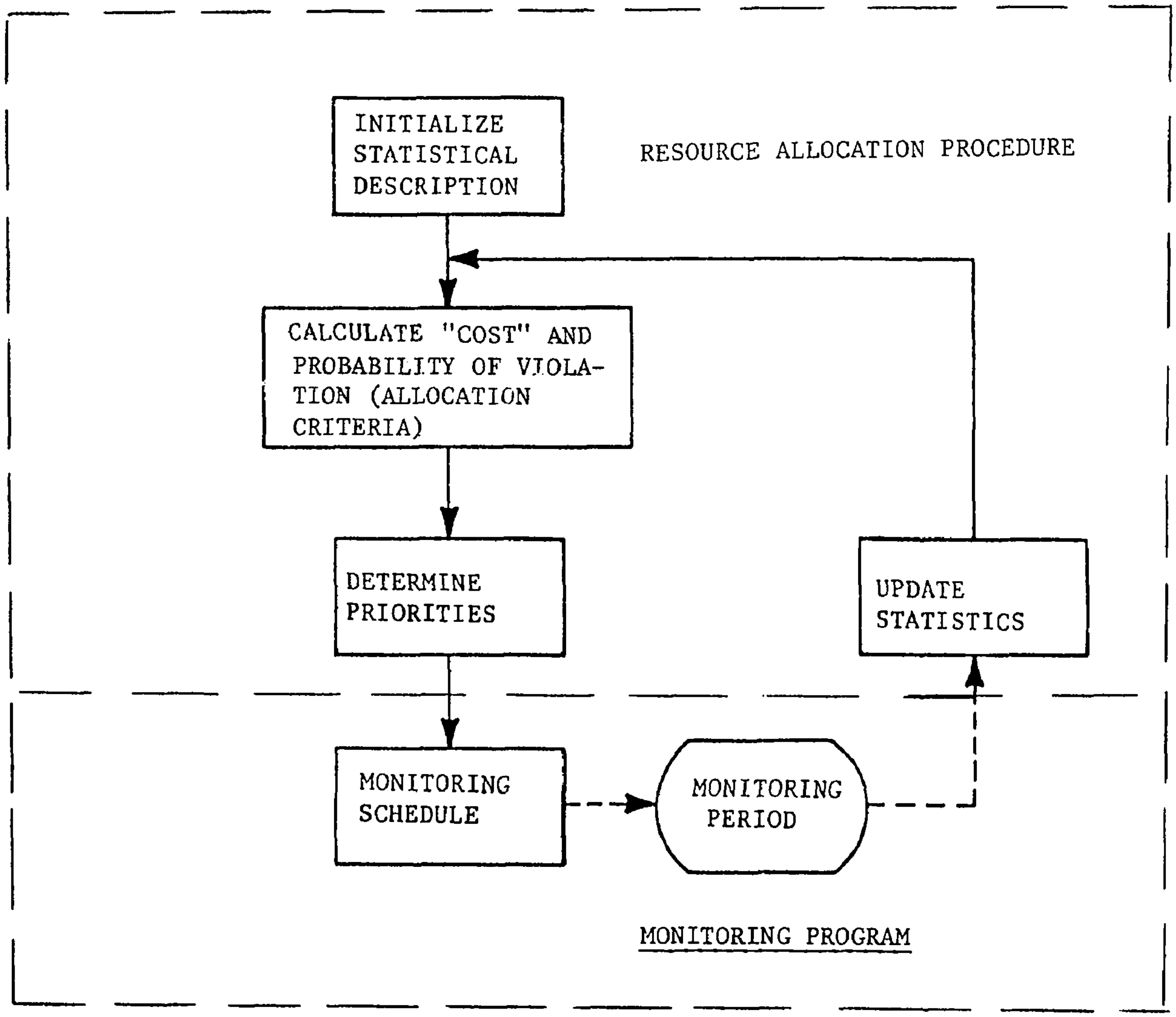

Figure 2.2 Flow of Resource Allocation Procedure

"cost" and probability of violation for each source. Use the appropriate option in this calculation as described in Section 2.4.

3. Determine Priorities

   Use the method of maximum marginal return to obtain the monitoring rates.

4. Monitoring Schedule

   Take the sampling rates obtained in the previous function and determine which date to sample which sources.

5. Monitoring Period

   This box represents the actual time spent monitoring the sources.

6. Update Statistics

   Combine new self-monitoring and compliance data with the initial statistics to obtain an updated statistical description of the effluents.

Functions 1, 2, 3, and 6 are performed by the Resource Allocation Procedure and will be described in Sections 2.4 through 2.6. The scheduling of the sampling (Function 4) depends on a number of factors which are difficult to quantify in an optimization framework, such as: the spatial location of the various effluent sources, the size of the monitoring agency's jurisdiction, and the availability of personnel. This scheduling is left to the individual monitoring agency. Function 5 simply denotes the passage of time.

2.4 RESOURCE ALLOCATION CRITERIA

The procedures presented in this handbook give users several optional criteria for resource allocation, as discussed in Section 2.2. This section discusses the mathematical definitions of these criteria. Those readers with non-mathematical background are encouraged to skip this section.

Number of Undetected Violators (Criterion #1)

The objective of this allocation criterion is to minimize the number of undetected violators, which is defined as the expected number of effluent sources which will not be caught in violation given that the i^{th} source is sampled s_i times.

Now $(p_i)^{s_i}$ is the probability that the i^{th} source will not be caught in violation if it is sampled s_i times, where p_i is the probability that it will not be caught in violation if it is sampled once. The number of undetected violators is then

$$\sum_{i=1}^{n_s} p_i^{s_i} \qquad (2.1)$$

where n_s is the number of sources.* The calculation of p_i is discussed in [1].

---

*Equation 2.1 should more accurately be called the "Number of Undetected Sources," since the probability that each source will be a violator is not included. The expected number of sources which will violate a standard but not be caught in violation given that the i^{th} source is sampled s_i times during a monitoring period of N days is

$$\sum_{i=1}^{n_s} \left[p_i^{s_i} - p_i^{N} \right] .$$

Since this formula differs from Equation 2.1 only by a constant, the same sampling rates, s_i, will minimize both functions. Therefore, the simpler formula has been presented.

"Cost of Undetected Violations" (Criterion #2)

The objective of this allocation criterion is to minimize the "environmental cost" of undetected violations, which is the damage to water quality in receiving waters due to the effluent constituents of the effluent sources. The environmental damage due to a given effluent constituent is related to the concentration of the constituent (or corresponding water quality indicator) in the receiving waters through a damage function. The damage function is defined as a piecewise linear function where a numerical value is given to each "level of damage" - the values 0, 2, 4, 6, 8 and 10 correspond to "none", "excellent", "acceptable", "slightly polluted", "polluted", and "heavily polluted", respectively. This type of subjective damage function closely follows the approaches used by Prati [22], Horten [23], and McCelland [24]. Using various references [22-27], appropriate damage function were specified for 26 water quality indicators as shown in Table 2.4. The user of this procedure may optionally modify the damage functions in this table based upon his own experience and particular needs. Figure 2.3 gives an example, in graphical form, of a damage function; the indicator considered is suspended solids. The computation of the cost of undetected violations using this approach is given in [1].

Magnitude of Undetected Violations (Criterion #3)

This allocation criterion serves as an alternative to the very complex "Cost of Undetected Violations" criteria. It accounts for severity of environmental damages, and yet is simple enough to be included in the hand calculation procedures. The "Magnitude of Undetected Violations" is defined as the severity of undetected violations (i.e., the amount by which effluent standards are exceeded). The degree of violation, for a loading M and a standard τ, is given by equation

$$DV(M,\tau) = \begin{cases} 0 & ; \quad M \leq \tau \\ \alpha(M-\tau); & M > \tau \end{cases} \qquad (2.2)$$

Table 2.4 Damage Functions

Constituent name	Units	Level of damage: None 0	Excellent 2	Acceptable 4	Slightly polluted 6	Polluted 8	Heavily polluted 10	Reference*
Aluminum	mg/l	0	0.01	0.05	0.10	.50	1.00	7
Ammonia	mg/l	0	0.1	0.3	0.9	2.7	3.0	2
Dissolved oxygen	mg/l	>9	8.0	6.8	4.5	1.8	0.9	5
Inorganic carbon	mg/l	<50	70	90	110	130	150	5
Chloride	mg/l	0	25	175	200	240	250	3
Chloroform extract	mg/l	0	0.04	0.15	0.25	0.35	0.40	3
Chromium	mg/l	0	0.02	0.05	1.0	10.0	50.0	6,7
Coliforms-total	MPN/100ml	0	100	2000	7500	15,000	150,000	3,6
Coliforms-fecal	MPN/100ml	0	20	200	800	3,000	50,000	4,5
Copper	mg/l	0	0.02	0.10	1.00	5.00	10.00	6,7
Cyanide	mg/l	0	0.01	0.02	0.05	0.10	0.50	6,7
Fluoride	mg/l	<0.7	0.8	0.9	1.2	3.0	8.0	7
Iron	mg/l	0	0.1	0.3	0.9	2.7	3.0	2
Lead	μg/l	0	5	50	100	250	350	6,7
Manganese	mg/l	0	0.05	0.17	0.50	1.00	1.50	2
Mercury	μg/l	0	1	5	10	20	50	7
Nickel	mg/l	0	0.01	1.0	3.0	9.0	20.0	7
Inorganic nitrogen	mg/l	<0.6	0.9	3.0	4.5	7.0	10.0	5
Oil-grease	mg/l	0	0.01	0.10	5	30	50	7
pH-MIN		7	6.5	6.0	5.0	4.0	3.9	2
pH-MAX		7	8.0	8.4	9.0	10.0	10.1	2
Phenol	μg/l	0	0.5	1.0	20	100	200	6,7
Phosphates	mg/l	0	0.1	0.2	0.5	1.6	10	4
Solids-dissolved	mg/l	<100	200	500	1000	1500	2300	5
Solids-suspended	mg/l	0	20	40	100	280	300	2
Temp. diff.	°C	0	1.0	2.5	3.0	4.0	10.0	4
Tin	mg/l	0	10	40	100	300	1000	6,7
Zinc	mg/l	0	0.1	1	5	15	40	7

*The references shown are those used to develop the damage function for each constituent.

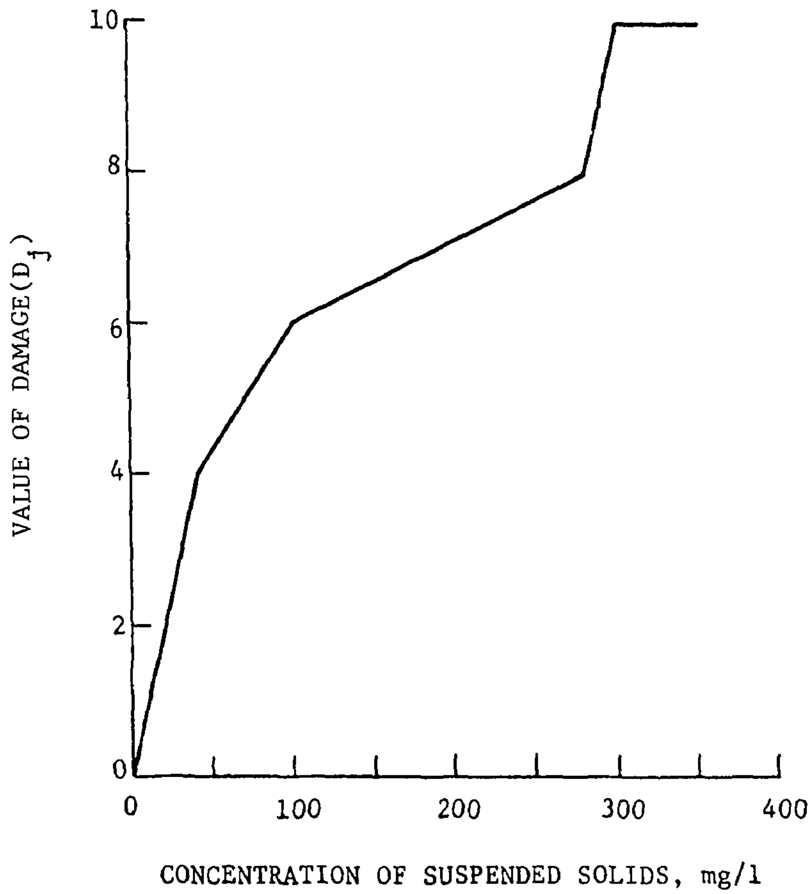

Figure 2.3 Example Damage Function

where α is a design constant discussed in detail in Section 4, Task 10.

The expected degree of violation for the j^{th} constituent of the i^{th} source is

$$DV_{ij} = \int_{o}^{\infty} DV(M,\tau_{ij})\ \phi_{ij}(M)dM = \int_{\tau_{ij}}^{\infty} \alpha_{ij}(M-\tau_{ij})\ \phi_{ij}(M)dM \qquad (2.3)$$

The expected degree of violation from all the constituents of the i^{th} source is then

$$DV_i = \underset{j}{\text{Max}}\ DV_{ij} \qquad (2.4)$$

where it is assumed that the user is interested in the worst degree of violation from the source. The derivation of the Degree of Undetected Violation now follows exactly the derivation of the "Cost of Undetected Violation" given in [1]. The Degree of Undetected Violation is therefore,

$$DV = \sum_{i=1}^{n_s} DV_i p_i^{s_i} . \qquad (2.5)$$

where, for the i^{th} source, DV_i is the expected degree of violation, p_i is the probability the source will not be found in violation if sampled once, and s_i is the number of times the source was monitored.

Summary of Resource Allocation Criteria

In examining the three optional resource allocation criteria, it is seen that they are all a function of the number of Undetected Violations given in Criteria #1. In fact, they are all of the form

$$\text{Allocation Criteria} = \sum_{i=1}^{n_s} (\text{weighting factor})(p_i)^{s_i} . \qquad (2.6)$$

In Criterion #1, the weighting factor is simply set to 1. In Criterion #2, the weighting factor is set to the expected "environmental cost" of undetected violation. In Criterion #3, the weighting factor is set to the relative severity or magnitude of undetected violations given by Equations 2.3 and 2.4

The manual calculation procedures presented in Section 4 gives the option of using Criteria #1 and #3. The computer calculation procedure givesthe option of using Criteria #1 and #2.

2.5 STATISTICAL CHARACTERISTICS OF EFFLUENT STREAMS

All three of the allocation criteria, discussed in the previous section, require knowledge of the probability of violation for each effluent source. Thus, the priority setting procedure for compliance monitoring requires that the daily composite effluent loads, due to their inherent variability, be modeled statistically. Among the questions that must be addressed in developing a statistical model are:

- What probability distributions adequately model the effluent data?
- What is the statistical correlation between the various constituents of the effluent?
- What is the time-varying nature of the statistics?

It has been shown in [1], for several example sets of data, that the normal and lognormal distributions adequately model the statistics of the daily composite effluent loadings. In order to decide whether to model a particular constituent by a normal or lognormal distribution, it is necessary to process a large amount of daily data. It is not expected that the individual monitoring agency will have the resources to analyze the daily data of each source in its jurisdiction. It is only postulated that the monitoring agency will have a monthly mean and maximum for each constituent of each source. It is, therefore, necessary to determine, using industry-wide studies of effluent characteristics, which distribution can be associated with a given industrial process. Since this information is unavailable at the publication of this report, several guidelines are specified in Section 4, Task 1, on how to choose between the normal and lognormal cases.

The normal and lognormal distributions are defined by a mean and a standard deviation. (For the lognormal distribution, the mean and standard deviation are of the logs of the data.) Since it is only assumed that the monthly mean and maximum, and not the sample standard deviation, are available to the monitor, the standard deviation of the normal process must be estimated using nonstandard estimation procedures. Approximate maximum likelihood estimates of the mean and standard deviation from the mean and maximum were developed in [1] for both the normal and lognormal cases. These estimates were tested on real data and it was shown that they, coupled with the associated distributions, adequately describe the statistical variations.

There has been little study into the statistical correlation of the constituents of an effluent. As with the problem of determining the appropriate distributions, it is not expected that the monitoring agency would be able to determine the correlation of the constituents of the sources in its jurisdiction. It is therefore necessary that the correlation coefficients be obtained from industry-wide studies. Since these are unavailable at the present time, it is assumed, unless other knowledge is available, that the constituents from a source are uncorrelated. The priority setting procedure also allows for the case where the constituents are completely correlated. In [1] a correlation study for a single municipal treatment plant was carried out. It is clear that no general conclusions can be reached from the analysis of one water treatment plant. The analysis has shown that variability in the correlation between constituents exists from month to month, and that there are some problems inherent in choosing between the hypotheses of uncorrelated constituents and correlated constituents.

The time-varying nature of effluent statistics comes from two sources: (1) periodic variations due to weekly, monthly, or seasonal variations and (2) trends due to changes in the plant processes. The weekly and monthly variations are averaged out in the input data (i.e., monthly mean and maximum). These variations, if known, should be taken into account when determining when, in a monitoring period, to monitor a particular source. The seasonal variations and trends are taken into account in the statistical characterization by discounting appropriate past information and updating the statistics as new data become available (see Section 4, Task 7).

The specific procedures used in the Resource Allocation Procedure to obtain the initial statistical description of the effluent sources and to update the statistics as new information becomes available are discussed below.

Initial Statistical Description

The monitoring agency will have two types of data available from which it can initially determine the statistical characteristics of the effluent discharges:

- Self-monitoring data
- Compliance data

The self-monitoring reports will typically be sent to the appropriate regulatory agency on a monthly or quarterly basis. The reports will at a minimum contain the monthly maximum and monthly sample mean of the daily measurements (usually composite) of those constituents for which standards have been set. The report will also state the number of samples which were used to obtain the sample mean and maximum. Compliance data will also be available on the sources the monitoring agency has inspected as part of its compliance monitoring program.

When using the Resource Allocation Procedure for the first time, it is necessary to obtain an initial statistical description of all the effluent source constituents. This statistical description will be a function of self-monitoring data and compliance monitoring data gathered over many months. The procedure required to obtain the initial statistical description in the computer implementation is shown in Figure 2.4. The changes made for the manual procedure are discussed at the end of this section. The various components of this procedure will now be discussed.

Aggregate Data. The procedure to obtain estimates of the mean and standard deviation from the sample mean and the maximum (given in Appendix A of [1]) requires that the number of measurements used to obtain the sample mean and the maximum be greater than three. If the number of measurements is three or less, the data over several months can be aggregated to obtain a sample mean and maximum based on more than three measurements. In this way, the estimation procedures, which have been shown to be applicable in describing the effluent statistics [1], can still be used. A theoretical description of the aggregation procedure is given in [1, Section 5].

Obtain Estimates of Mean and Standard Deviation From Monthly Self-Monitoring Data. The estimation procedures to obtain estimates of the mean and standard deviation for normal and lognormal processes are given in Appendix A of [1].

Combine Self-Monitoring and Compliance Monitoring Data. At this point in the procedure (see Figure 2.4), estimates of the mean and standard deviation, based on self-monitoring data, are available for each month or aggregated month. These will be combined with the compliance monitoring data to obtain new improved estimates. Since the monitoring agency will be collecting the compliance monitoring data, this data will be more

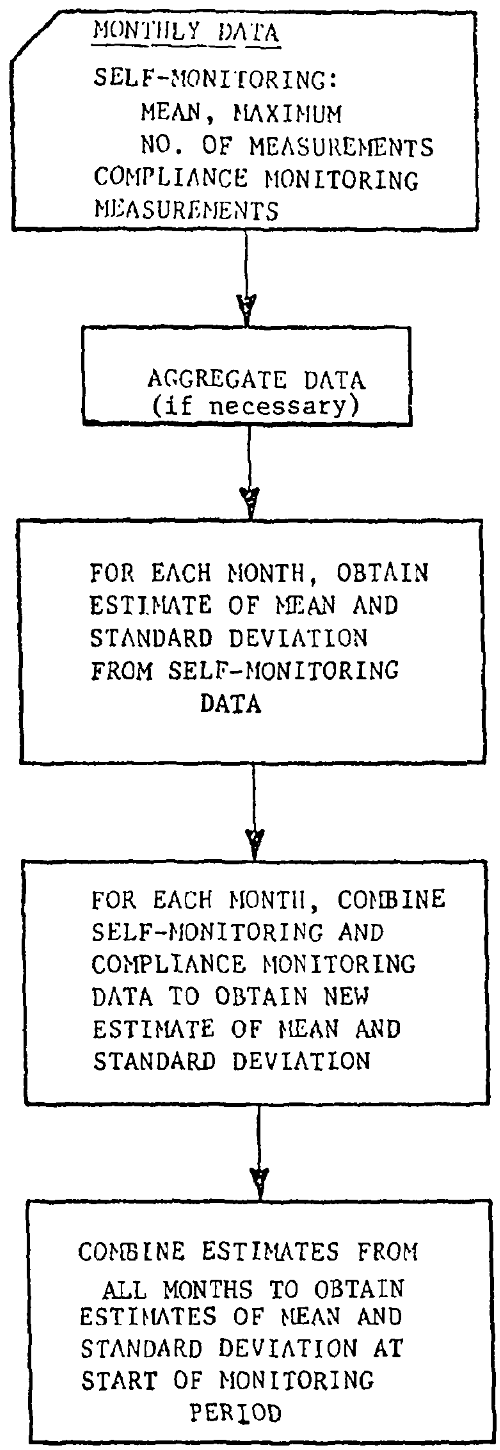

Figure 2.4 Initial Statistical Description Procedure

reliable than the self-monitoring data. This should be taken into consideration in the method of combination. The combination procedure is as follows. Let

$$z_1, z_2, \ldots, z_c$$

be c daily composite values obtained in the compliance monitoring program for a month. Let m and V be the estimated mean and variance (estimated standard deviation square d) for that month based on the self-monitoring data. Let n and ν be the parameters which express the confidence in the mean and variance respectively. n and ν are constants representing the equivalent number of measurements used to estimate m and V.* The values of n and ν are set proportionally to the number of measurements, N, used to calculate the monthly mean and maximum. That is,

$$n = h_n N \tag{2.7}$$

and

$$\nu = h_\nu (N-1) \tag{2.8}$$

where h_n and h_ν are design parameters.

The compliance data and the monthly estimates are combined sequentially, using the updating formula described in Appendix E of [1]. First, the compliance data z_1 from a given month are combined with the self-monitoring estimates (m, n, V, ν) for that month using the update formula (E.3) of [1], yielding the posterior estimates (m_1, n_1, V_1 ν_1). The second compliance data z_2 for that month are then combined with this estimate to yield a new estimate (m_2, n_2, V_2, ν_2). The process is repeated until all the compliance data are used to obtain a final monthly estimate for each month. In order to give the compliance monitoring data more weight (since

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*A discussion of these confidence parameters is given at the end of this section. They are also discussed in [1]. For further information see [28].

they will, in general, be more reliable), the values of ν and n' used in (E.3a) and (E.3b) of [1] should be replaced by ν/γ and n/γ where $\gamma > 1$ is a design constant.

As an example, consider the case where the estimate of the mean, from self-monitoring data, is m = 100, and the estimate of the standard deviation is $\sigma = 25$. The confidence parameters are assumed to be n = 15 and $\nu = 10$. Suppose compliance data for the month are also available with values $z_1 = 115$ and $z_2 = 145$. Let γ be equal to 2. [Recall n' = 1 and $\nu' = 0$.] Using (E.3), of [1], z can be combined with the estimates (m, n, V, ν) to yield

$$m_1 = \frac{(n/\gamma)m + z_1}{(n/\gamma) + 1} = 101.8$$

$$n_1 = n + 1 = 16$$

$$V_1 = \frac{[(\nu/\gamma)\ V + (n/\gamma)m^2] + z_1^2 - ((n/\gamma) + 1)m_1^2}{(\nu/\gamma) + 1} = 543.7$$

and

$$\nu_1 = \nu + 1 = 11. \qquad (2.9)$$

The new estimate of the standard deviation is $\sigma_1 = \sqrt{V_1} = 23.3$. The process is then repeated with (m_1, n_1, V_1, ν_1) replacing (m, n, V, ν) and z_2 replacing z_1 to yield

$$m_2 = 106.6$$

$$n_2 = 17$$

$$V_2 = 715.27$$

and

$$\nu_2 = 12. \qquad (2.10)$$

The new estimate of the standard deviation is $\sigma_2 = 26.7$.

Combine Estimates From Several Months. The final step in obtaining an initial statistical description is to combine the estimates from several months to obtain an estimate of the mean and standard deviation at the start of the monitoring period. The estimates are combined by sequentially using the Bayesian update formula (E.3) given in Appendix E of [1]. If the mean, m_t, and the variance, V_t, along with the confidence parameters, n_t, and ν_t, are available for months t = 1,2, ..., T, the final estimates would be obtained by first combining (m_1, n_1, V_1, ν_2) and (m_2, n_2, V_2, ν_2) using (E.3) of [1] yielding (m_2', n_2', V_2', ν_2'). Then (m_2', n_2', V_2', ν_2') would be combined with (m_3' n_3, V_3, ν_3) to yield (m_3', n_3', V_3', ν_3'). This process would be repeated until the estimate (m_T', n_T', V_T', ν_T') is obtained, which is the estimate to use in the priority setting procedure.

Confidence Parameters. In order to use the Bayesian update formula, it is necessary to specify the confidence parameters n and ν. These parameters describe one's confidence in the estimates of the mean and variance. A discussion of how to obtain these parameters is given in Section 5, of [1]. A detailed manual procedure for obtaining them is given in Section 4, Task 4.

Update of Statistics

In the previous section, a procedure was given to obtain the statistical characteristics of the effluent sources at the commencement of the use of the Resource Allocation Procedure. The Resource Allocation Procedure will be used on a periodic basis to obtain the sampling frequencies for the following monitoring period. At the same time the monitoring agency will continue to receive self-monitoring and compliance data. The purpose of this section is to describe how this data should be used to obtain an updated statistical description.

The update procedure is identical to the procedure for the Initial Statistical Description with the small exception that the old statistical characterization is used as a starting point in the procedure. To be precise, the statistical update procedure follows the Initial Statistical Description procedure (see Figure 2.2), in that first, the new monthly data are aggregated, if necessary, to obtain sample sizes greater than 3; estimates of monthly means and standard deviations based on the self-monitoring data are then obtained. The Bayesian update formulas (Appendix E of [1]) are then used to combine the compliance monitoring data and the monthly statistical description of the effluent and thus the new monthly statistical descriptions based on the new data are available. These are combined sequentially, starting with the original statistics, using the Bayesian update formula, therby obtaining an updated statistical description.

Manual Procedure

The manual procedure described in Section 4 is the same as the computer implementation except that the data from all the previous months are aggregated in the "Aggregate Data" step. This eliminates the need for computing the standard deviation for each month of data -- they only have to be estimated once per monitoring period -- and the need for combining the monthly estimates using the update formula. The tremendous reduction in computation far outweighs the loss of accuracy in the effluent statistics.

2.6 RESOURCE ALLOCATION PROBLEM

In Section 2.4, performance criteria for the procedure of allocating monitoring resources were defined. This section defines the complete resource allocation problem and describes the method of solution used in this handbook, the maximum marginal return method.

Formulation of The Problem

There are three resource allocation problems that the monitoring agency might want solved:

1. Given a certain amount of resources (i.e., budget), determine how the monitoring resources should be allocated to minimize the allocation criteria, (i.e., minimize the Probability of Undetected Violations, Cost of Undetected Violations, or Magnitude of Undetected Violations).

2. In setting up a monitoring program, determine what level of resources is needed to insure that an allocation criterion is below a given level.

3. Given an increment of monitoring resources, determine how to allocate these additional resources and the resulting improvement in the monitoring system performance.

In the remainder of this subsection, these problems are formulated mathematically.

The allocation criteria are all of the form

$$C(\underline{s}) = \sum_{i=1}^{n_s} C_i(s_i) \tag{2.11}$$

where

$$\underline{s} = (s_1, s_2, \ldots, s_{n_s}), \quad C_i(s_i) = c_i p_i^{s_i}, \tag{2.12}$$

and c_i is the "damage cost"* for the i^{th} source, p_i is the probability

*This cost is dependent on which allocation criteria from Section 2.4 is used. For Criteria #1, $c_i = 1$; Criteria #2, c_i = the environmental damage given by Equations 2.5 through 2.7; Criteria #3, c_i = magnitude of violation given by Equations 2.11 through 2.13.

no violation is observed at the i^{th} source, n_s is the number of sources, s_i is the number of times the i^{th} source is monitored, and C_i is defined by the criteria used as explained in Section 2.4. The total monetary cost to monitor all the sources, where the i^{th} source is monitored s_i times is

$$R(\underline{s}) = \sum_{i=1}^{n_s} r_i s_i \tag{2.13}$$

where r_i is the cost of monitoring source i once. r_i is made up of manpower, transportation, equipment and laboratory costs. The actual values of these costs will vary from agency to agency and as a function of time.

Upper and lower bounds on s_i may also be given, i.e.,

$$\ell_i \leq s_i \leq L_i \tag{2.14}$$

To see when a monitor may desire to specify bounds, consider the case where, from ambient monitoring, it has been observed that in a certain river section the level of a particular constituent is higher than usual. Then, one might want to check at least once during the next period all the effluent sources that might have caused this. In this case a lower bound of one is set on the corresponding sampling rates. Also, consider the case of an effluent having a small expected violation cost. Based upon the existing information, it will have a low priority for being monitored. In order to prevent information from becoming obsolete, one can stipulate that it has to be monitored at least once during a certain period of time. An upper bound might be desired if the monitor does not want to sample any source more than a given number of times. This should be true, for example, if the monitor were required to visit a certain number of sources. Another situation can occur when there is a known polluter (e.g., one against which there are sufficient data to initiate legal action or one which is improving its treatment according to an approved long-term plan);

the monitor may then decide not to survey this source frequently because the result is predictable. In this case, the upper bound for s_i would be set to some specified value.

The three optimization problems can now be specified.

Problem 1: minimize $C(\underline{s})$

subject to $R(\underline{s}) \le B$

$\underline{\ell} \le \underline{s} \le \underline{L}$

where B is the monitoring agency's budget and $\underline{\ell} = (\ell_1, \ldots, \ell_{n_s})$ and $\underline{L} = (L_1, \ldots, L_{n_s})$ are upper and lower bounds.

Problem 2: minimize $R(\underline{s})$

subject to $C(\underline{s}) \le A$

$\underline{\ell} \le \underline{s} \le \underline{L}$

where A is the maximum "cost" of undetected violations allowed.

Problem 3 is of the same form as Problem 1, except B includes the additional resources and $\underline{\ell}$ specifies the sampling frequencies under the original allocation. The decrease in "cost" between when the original budget is used and the new budget is used is the system improvement. The additional samples specify where to use the additional resources.

Method of Maximum Marginal Return - - Problem Solution

The optimization method used to solve the resource allocation problems is the method of maximum marginal return. It is particularly suited for these problems since it solves all of them in the same manner. It is based on the following intuitive idea: the best place to allocate one unit of resource is where the marginal return (the decrease in damage cost - in our case, undetected violation "cost" - accrued by using that unit of resource) is greatest. Therefore, by ordering the marginal returns in descending order, one obtains a priority list with the samples having highest priority on top.

To be precise, the marginal return accrued when the sampling rate on the i^{th} source is increased from s_i-1 to s_i is

$$\mu_i(s_i) = \frac{C_i(s_i-1) - C_i(s_i)}{r_i}$$

In view of the convexity of C_i, these marginal returns are monotonically decreasing with s_i, i.e.,

$$\mu_i(s_i) > \mu_i(s_i + 1) .$$

The priorities of allocation are obtained by simply ordering these marginal returns. If the ordering obtained is, for example

$$\mu_2(1) > \mu_1(1) > \mu_2(2) > \mu_3(1) \ldots$$

then effluent source 2 is sampled with highest priority, then effluent source 1, then again effluent source 2, then effluent source 3, etc. Following this, a relation between the minimized "cost" of undetected violations and the corresponding resource cost is obtained. Therefore, this method solves simultaneously the problem of minimizing the undetected violation "cost" subject to the total budget and the minimization of the budget subject to a given "cost" of undetected violations.

The problem of allocating an increment of resources to maximize the improvement in an existing monitoring system is solved as follows: set up the priority list as described above, and remove from the list those samples that have been allocated. The remaining items on the list are, in descending priority, the ones that should be monitored with an increase in resources.

2.7 SIMPLIFIED EXAMPLE

The performance of the Resource Allocation Program is demonstrated in this section, using a simplified example. Initially, it is assumed that there are four sources to be monitored, each having four months of self-monitoring data available from which to obtain the initial statistics. The initial self-monitoring data assumed are shown in Tables 2.5a through 2.5e. The data have been abstracted from real data that were used for the demonstration case of [1]. Using the procedure outlined in Section 2.5 and Section 2.3 of [1], Tables 2.5a through 2.5e present the initial statistics obtained from the data. The estimated mean and estimated standard deviation are the monthly estimates. For Source 4, the sample size of the effluent constituents for a single month is 2; therefore, the data in months 1 and 2 and months 3 and 4 have to be aggregated, as discussed in Section 2.5. Thus, only two estimates of the mean and two of the variance are given in Tables 2.5d and 2.5e. Tables 2.6a through 2.6e also show how the estimates of the mean and standard deviation are sequentially updated as the monthly estimates are combined to obtain the estimates to be used in the Resource Allocation Program. For this case the design parameters k_n and k_ν, which determine the degree of the discounting of past information, have been set to 3. The updated mean and variance for month 2 are therefore the combined estimates derived from the 1st and 2nd monthly estimates. The updated mean and variance for month 3 are the combination of the updated estimates for month 2 and monthly estimate for month 3. The same process is repeated for month 4, yielding the initial statistical description to be used in the program.

Table 2.5a SELF MONITORING DATA FOR SOURCE 1

Month	Mean source flow, Ml/day	Parameter: pH Max Eff. standard: 9 Distribution: Normal			Parameter: pH Min Eff. standard: 6 Distribution: Normal			Parameter: Lead Eff. standard: 2 kg Distribution: Normal		
		Mean	Max	Sample size	Mean	Min	Sample size	Mean, kg	Max, kg	Sample size
1	0.90	8.5	10.6	20	8.5	6.0	20	0.41	1.0	20
2	1.10	7.6	9.0	22	7.6	5.4	22	1.08	1.7	22
3	1.20	8.3	9.8	22	8.3	6.4	22	1.09	6.3	22
4	0.85	8.1	9.5	20	8.1	6.4	20	0.52	1.8	22

Table 2.5b SELF MONITORING DATA FOR SOURCE 2

Month	Mean source flow, Ml/day	Parameter: Chromium Eff. standard: 0.45 kg Distribution: Normal			Parameter: Copper Eff. standard: 1.5 kg Distribution: Lognormal			Parameter: Fluoride Eff. standard: 30 kg Distribution: Normal		
		Mean, kg	Max, kg	Sample size	Mean, kg	Max, kg	Sample size	Mean kg	Max, kg	Sample size
1	0.80	0.216	0.808	18	0.524	1.89	18	24.4	31.4	18
2	0.78	0.313	0.867	19	0.374	1.87	19	25.4	31.9	19
3	0.87	0.214	0.620	21	0.364	1.25	22	24.7	31.0	22
4	0.85	0.132	0.255	14	0.110	0.42	14	14.0	31.0	11

Table 2.5c SELF MONITORING DATA FOR SOURCE 3

Month	Mean source flow, Ml/day	Parameter: BOD_5 Eff. standard: 3500 kg Distribution: Normal			Parameter: Phosphate Eff. standard: 500 kg Distribution: Lognormal			Parameter: Sus. Solids Eff. standard: 4050 kg Distribution: Lognormal			Parameter: Dissolved oxygen	
		Mean, kg	Max, kg	Sample size	Mean, kg	Max, kg	Sample size	Mean, kg	Max, kg	Sample size	Mean, mg/l	Sample size
1	105	1165	2115	30	178	658	30	2430	6030	30	3.9	30
2	110	900	2115	31	171	338	31	1665	5130	31	3.8	31
3	109	1395	2880	30	171	500	30	3240	10935	30	4.2	30
4	108	1060	2385	31	68	275	31	2160	4590	31	4.1	31

Table 2.5d SELF MONITORING DATA FOR SOURCE 4, PIPE 1

Month	Mean source, flow Ml/day	Parameter: Phosphates Eff. standard: 0.6 kg Distribution: Normal			Parameter: Sus. Solids Eff. standard: 25 kg Distribution: Normal		
		Mean, kg	Max, kg	Sample size	Mean, kg	Max, kg	Sample size
1	0.35	0.15	0.24	2	12.0	18.9	2
2	0.26	0.30	0.36	2	14.6	18.9	2
3	0.29	0.31	0.36	2	16.4	18.0	2
4	0.30	1.20	2.56	2	11.0	15.3	2

Table 2.5e SELF MONITORING DATA FOR SOURCE 4, PIPE 2

Month	Parameter: Phosphates Distribution: Normal				Parameter: Suspended Solids Distribution: Normal			
	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg
1	-	-	-	-	-	-	-	-
2	3.20	0.526	-	-	88.0	156.3	-	-
3	-	-	-	-	-	-	-	-
4	4.35	4.096	3.78	2.719	62.0	62.3	75.0	108.2

Table 2.6a INITIAL STATISTICS FOR SOURCE 1

Month	Parameter: pH Max Distribution: Normal				Parameter: pH Min Distribution: Normal				Parameter: Lead Distribution: Normal			
	Est. mean	Est. st. dev.	Updated mean	Updated st. dev.	Est. mean	Est. st. dev.	Updated mean	Updated st. dev.	Est. mean, kg	Est. st. dev., kg	Updated mean, kg	Updated st. dev., kg
1	8.5	1.12	-	-	8.5	1.33	-	-	0.41	0.31	-	-
2	7.6	0.73	8.03	1.06	7.6	1.15	8.03	1.33	1.08	0.32	0.76	0.51
3	8.3	0.78	8.12	0.98	8.3	0.99	8.12	1.22	1.09	2.72	0.87	1.62
4	8.1	0.74	8.12	0.92	8.1	0.90	8.12	1.14	0.515	0.67	0.78	1.45

Table 2.6b INITIAL STATISTICS FOR SOURCE 2

Month	Parameter: Chromium Distribution: Normal				Parameter: Copper Distribution: Lognormal				Parameter: Fluoride Distribution: Normal			
	Est. mean, kg	Est. st. dev., kg	Updated mean, kg	Updated st. dev., kg	Est. mean, log kg	Est. st.dev., log kg	Updated mean, log kg	Updated st. dev., log kg	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st. dev., kg
1	0.216	0.321	-	-	-0.437	0.369	-	-	24.4	3.79	-	-
2	0.313	0.297	0.266	0.308	-0.685	0.474	-0.565	0.443	25.4	3.49	24.9	3.62
3	0.214	0.214	0.247	0.277	-0.570	0.337	-0.567	0.403	24.7	3.29	24.8	3.46
4	0.132	0.070	0.218	0.246	-1.146	0.404	-0.711	0.502	24.0	4.17	24.6	3.61

Table 2.6c INITIAL STATISTICS FOR SOURCE 3

Month	Parameter: BOD_5 Distribution: Normal				Parameter: Phosphate Distribution: Lognormal				Parameter: Suspended Solids Distribution: Lognormal				Parameter: Dissolved oxygen	
	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg	Est. mean, log kg	Est. st.dev., log kg	Updated mean, log kg	Updated st.dev., log kg	Est. mean, log kg	Est. st.dev., log kg	Updated mean, log kg	Updated st.dev., log kg	Est. mean, mg/l	Updated mean, mg/l
1	1165	470	---	---	2.12	0.339	---	---	3.33	0.218	---	---	3.90	---
2	900	598	1030	555	2.20	0.157	2.16	0.265	3.13	0.282	3.23	0.277	3.80	3.85
3	1395	734	1150	648	2.12	0.268	2.16	0.264	3.40	0.312	3.29	0.302	4.20	3.96
4	1080	642	1133	643	1.85	0.286	2.08	0.313	3.30	0.175	3.29	0.274	4.10	4.00

Table 2.6d INITIAL STATISTICS FOR SOURCE 4, PIPE 1

Month	Parameter: Phosphates Distribution: Normal				Parameter: Suspended Solids Distribution: Normal			
	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st. dev., kg
1	-	-	-	-	-	-	-	-
2	0.225	0.101	-	-	13.3	4.21	-	-
3	-	-	-	-	-	-	-	-
4	0.755	1.356	0.490	0.925	13.7	3.23	13.5	3.38

Table 2.6e INITIAL STATISTICS FOR SOURCE 4, PIPE 2

Month	Mean source flow, Ml/day	Parameter: Phosphates Eff. standard: 3.5 kg Distribution: Normal			Parameter: Sus. Solids Eff. standard: 80 kg Distribution: Normal		
		Mean, kg	Max, kg	Sample size	Mean, kg	Max, kg	Sample size
1	0.90	2.9	3.2	2	158	296	2
2	1.01	3.5	3.9	2	18	26	2
3	1.09	2.9	3.1	2	93	145	2
4	1.00	5.8	9.8	2	31	33	2

The expected damage and probability of violation obtained from the data are shown in Table 2.7, along with the estimated source flow and the stream flow. For this case, the upstream concentration was assumed to be at a level causing zero damage, and the distributions of the various parameters were assumed uncorrelated. Certain of the entries deserve some comment. Source 3 is a large sewage treatment plant. From the table, the impact of BOD_5 and phosphates is large; however, the standards are also large and therefore the probability of violation for the parameters is small. Source 4 has a relatively small impact on the stream (i.e., small expected damage); however, the standards have been set so that the probability of violation is very large. The resources required to sample the sources are given in Table 2.8, and the priority list is given in Table 2.9. For the purposes of this example, it was assumed that the sources could be sampled between 0 and 10 times. From the table, one sees that sources 1 and 3 should be sampled with higher priority than sources 2 and 4. This is due to the much larger expected damage from the former sources. Source 4 appears relatively early in the list, but most of the samples have low priority. This is because the probability of violation is very large and therefore the chances are that the source will be caught in violation after one or two visits. Further sampling is therefore not necessary. Source 2 has a small expected damage and a fairly large probability of no violation resulting in a low sampling priority. Table 2.9 also gives the marginal return, "cost" of undetected violations and resources used. The marginal returns are decreasing (the list has been ordered in just this manner). The "cost" of undetected violations is decreasing, and the resources required are increasing as more sources are sampled.

If only, say $10,000 were available for monitoring, then only the sources with priority 1 through 17 would be monitored. The sampling frequencies for this case are shown in Table 2.10. If, on the other hand, a maximum allowed "cost" of undetected violations of say, 100 were specified, then sources with priorities 1 through 10 would be sampled.

Table 2.7 EXPECTED DAMAGE AND PROBABILITY OF VIOLATION

Source	Pipe	Est. source flow, Ml/day	Stream flow, Ml/day	Parameter	Expected damage - D_{ij}	Probability of no violation - p_{ij},%	Expected damage for source - C_i	Probability of no violation for source - p_i,%
1	1	0.961	100	pH	0.29	80.0		
				Lead	1.60	80.0	1.60	64.0
2	1	0.845	320	Chromium	0.08	82.6		
				Copper	0.12	96.1		
				Fluoride	0.00	93.1	0.12	74.0
3	1	108	525	BOD_5	3.22	100.0		
				Phosphate	3.64	97.6		
				Suspended Solids	0.37	87.8	3.64	85.6
4	1	0.297	300	Phosphates	-	100.0		
				Suspended Solids	-	51.8		
	2	1.016		Phosphates	0.29	54.4		
				Suspended Solids	0.03	46.0	0.29	13.0

Table 2.8 RESOURCES NEEDED TO SAMPLE

Source	Field and office costs	Laboratory costs	Total Cost $-r_i$
1	\$525	\$10.50	\$535.50
2	\$525	\$23.00	\$548.00
3	\$525	\$38.00	\$563.00
4	\$525	\$30.00	\$555.00

Table 2.9 PRIORITY LIST OF SAMPLES FOR SIMPLIFIED EXAMPLE

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	1	.10774492	5.07571	535.50
2	3	.09326524	4.55342	1095.50
3	3	.07989130	4.10603	1655.50
4	1	.06899248	3.73658	2191.00
5	3	.06843515	3.35334	2751.00
6	3	.05862177	3.02506	3311.00
7	3	.05021559	2.74385	3871.00
8	4	.04526206	2.49264	4426.00
9	1	.04417806	2.25607	4961.50
10	3	.04301484	2.01519	5521.50
11	3	.03684665	1.80895	6081.50
12	3	.03156296	1.63209	6641.50
13	1	.02828861	1.48061	7177.00
14	3	.02703693	1.32920	7737.00
15	3	.02315992	1.19951	8297.00
16	1	.01511409	1.10251	8832.50
17	1	.01159902	1.04039	9368.00
18	1	.00742722	1.00062	9903.50
19	4	.00590250	.96786	10458.50
20	2	.00556719	.93735	11006.50
21	1	.00475588	.91158	11542.00
22	2	.00412025	.88931	12090.00
23	2	.00304938	.87260	12638.00
24	1	.00304534	.85629	13173.50
25	2	.00225693	.84392	13721.50
26	1	.00195003	.83348	14257.00
27	2	.00167027	.82432	14805.00
28	2	.00123616	.81755	15353.00
29	2	.00091486	.81254	15901.00
30	4	.00076974	.80426	16456.00
31	2	.00067710	.80455	17004.00
32	2	.00050112	.80181	17552.00
33	2	.00037087	.79978	18100.00
34	4	.00010038	.79922	18655.00
35	4	.00001309	.79915	19210.00
36	4	.00000171	.79914	19765.00
37	4	.00000022	.79914	20320.00
38	4	.00000003	.79914	20875.00
39	4	.00000000	.79914	21430.00
40	4	.00000000	.79914	21985.00

The sampling frequencies for this case are shown in Table 2.11. The priority list in Table 2.9 also shows when the return from monitoring (i.e., the marginal return) starts becoming negligible; the return, in this case, for monitoring more than 25 sources is very small.

Table 2.10 FINAL ALLOCATION GIVEN MONETARY BUDGET

FINAL ALLOCATION

BUDGET 10000.00

SOURCE	MIN NO. SAMPLES REQUIRED	MAX NO. SAMPLES ALLOWED	TIMES SAMPLED	RESOURCES USED	COST OF UNDETECTED VIOLATIONS
1	0	10	7	3748.50	.07081
2	0	10	0	.00	.11738
3	0	10	10	5600.00	.77476
4	0	10	1	555.00	.03767

TOTAL RESOURCES USED 9903.50
FINAL COST OF UNDETECTED VIOLATIONS 1.00062

Table 2.11 FINAL ALLOCATION GIVEN MAXIMUM ALLOWED COST OF UNDETECTED VIOLATIONS

FINAL ALLOCATION

MAXIMUM ALLOWED COST OF UNDETECTED VIOLATIONS 1.00000

SOURCE	MIN NO. SAMPLES REQUIRED	MAX NO. SAMPLES ALLOWED	TIMES SAMPLED	RESOURCES USED	COST OF UNDETECTED VIOLATIONS
1	0	10	7	3748.50	.07081
2	0	10	0	.00	.11738
3	0	10	10	5600.00	.77476
4	0	10	2	1110.00	.00491

TOTAL RESOURCES USED 10458.50
FINAL COST OF UNDETECTED VIOLATIONS .96786

SECTION 3

GENERAL REQUIREMENTS FOR MANPOWER, DATA, AND COMPUTERS

3.1 INPUT DATA REQUIREMENTS AND PROCEDURES

The types of input data required by both the hand calculation approach and the computer approach are indicated in Table 3.1. These data types have been classified into categories in this table, which also provides some indication of their relative availability. The data needs, availability, adequacy, and preparation procedures required are discussed below for each category.

Standards

Essentially, the same data on effluent standards is required by both approaches. The computer approach is somewhat limited in the range of units in which the data may be expressed (see Table 5.1). Therefore, conversions into such units must be completed, where necessary, before input to the computer, while the hand approach includes any needed conversions (units unlimited) as part of the procedure. The required data should be readily available since they provide the basis and incentive for the monitoring; the new National Pollutant Discharge Elimination System (NPDES) required to be initiated by 1 July 1977, should provide a strong added impetus to standard setting.

Data on ambient receiving water quality standards may be needed only by the hand calculation approach, and then only when a certain option is chosen. Under this option, the standard is only used to develop a

Table 3.1 Summary of Input Data Types

Data Type	Procedure Requiring Hand	Procedure Requiring Computer	Relative Availability
STANDARDS			
Effluent	√	√	High
Receiving Water	*		High
EFFLUENT CHARACTERISTICS			
Statistical Distribution Types	√	√	Low
Constituent Correlations	√	√	Low
MONITORING DATA			
Self-Monitoring	√	√	High
Compliance Monitoring	√	√	Medium
ENVIRONMENTAL CHARACTERISTICS			
Environmental Damage Functions		√	Medium
Upstream Constituent Concentrations		√	High
BOD-DO Transfer Coefficients		√	High
DO Saturation Concentrations		√	High
COMPLIANCE MONITORING COSTS			
Sample Collection	√	√	Medium
Sample Analysis	√	√	High
DESIGN PARAMETERS			
Discount Factors		√	User Determined

*Need depends upon options selected

weighting factor; therefore its value is less critical, and may be estimated if not legally established. For this purpose, there is probably sample information available on receiving water quality standards which have been established or recommended by various government agencies. Any preparation of the data needed will again be internal to the hand calculation approach.

Effluent Characteristics

Needed effluent information includes a determination of the statistical distribution types which best describe the daily constituent loading rates, limited to normal and lognormal, and the correlations (full or none), between the constituents at a given source. The requirements of both approaches are identical.

Very few determinations of such statistical distributions have been made to date. Therefore, while this would appear to be an area where availability could be greatly improved, the cost would clearly be great and the benefits small, since analysis and sensitivity studies have indicated that errors resulting from insufficient information will generally be quite small (see Section 4, Task 1: Discussion). Furthermore, a good approximation method has been developed.

Little information is also likely to be available on the correlations between the various constituents. A similar situation exists, where the results are not very sensitive to error in this area, where it would be very costly to reduce the errors, and where guidance for selection is provided (see Section 4, Task 9: Procedure, Step 2).

The guidance provided in the hand approach (Section 4, Tasks 1 and 9) may also be used to help the user prepare this input data for the computer approach.

Monitoring Data

Self-monitoring and compliance monitoring data are required by both the approaches. Self-monitoring data for the computer approach must have been preprocessed to yield the maximum (or minimum), mean, and sample size for each separate month of all data collected; data preprocessing is optional for the hand approach, which does not require separate monthly inputs, nor does it need to re-input data inputted to previous applications of this allocation procedure. Another difference between the two procedures is that water discharge rates in receiving streams are required only by the computer approach; effluent discharge rates are required in the computer approach, and in the hand approach only to determine the constituent loading rates.

Compliance monitoring data are entered only on an item-by-item basis for both approaches. However, the month corresponding to each item of data must be provided for the computer approach. With regard to updating and effluent discharge rates, the same difference between the two approaches apply as for self-monitoring data.

For both these types of data, the acceptable units of input data are more limited in the computer approach (see Table 5.5), than in the hand calculation approach; some preprocessing may be needed with the computer approach, while unit conversions form part of the hand approach.

The availability of self-monitoring data should of course, be as high as the surveillance agency wishes to make it, within reasonable and justifiable limits. The availability of compliance monitoring data will probably depend mostly upon the resources made available to the surveillance agency.

Environmental Characteristics

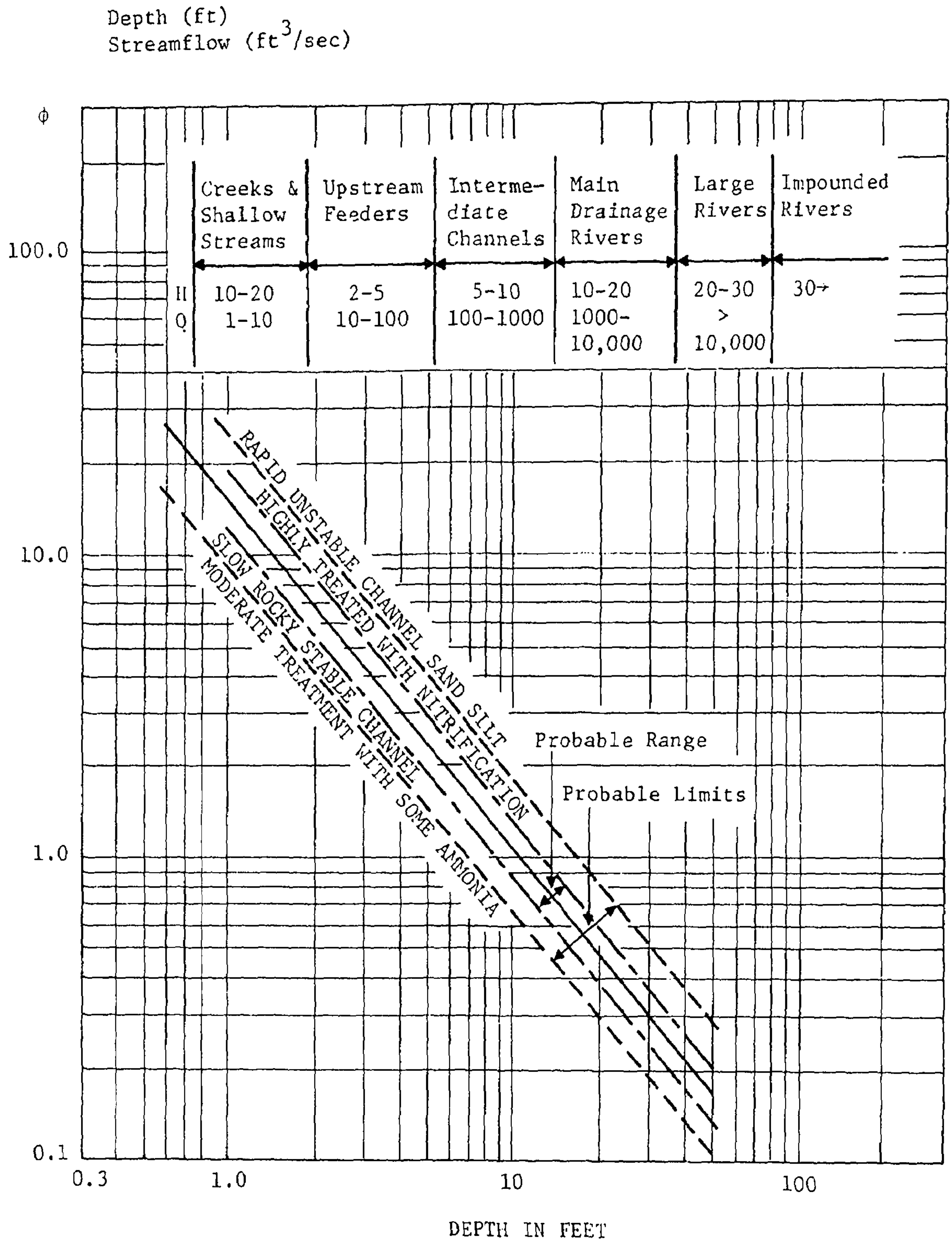
Receiving water data are required only by the computer approach, since the impact of discharged effluent constituents upon the receiving waters are considered directly only in that approach.

An estimate of streamflow immediately upstream of each effluent source is needed. Streamflow data is usually available from the U.S. Geological Survey on a daily basis. Since only one "design" streamflow can be used, a single worst case, low streamflow is suggested. For design purposes, the seven day, ten year low flow is often available, and is a reasonable design flow for this procedure.

Information on environmental damage functions for each constituent representing the variation of environmental damage with constituent concentration, has been collected and organized to a useful extent (see SCI's first report [1], Section VI.2). When improved damage/water quality information becomes available, and it is desired to input new damage function data (i.e., override the program's default values in Tables 5.2 and 5.3), some preparatory re-scaling may be needed. Both the concentration levels and the environmental damage values may be changed (input variables "DMG", "DAMAGE", "S", and "SSPH").

Some idea of the upstream environmental damage (or concentration) is necessary as input for the computer procedure. Since only one overall value is used, the user must examine his damage functions and pick that damage level which represents the "average" upstream damage for all constituents of all sources (input variable "ICOPT").

The selection of the required BOD-DO transfer coefficient may be readily achieved through the use of Figure 3.1 and Figure 3.2 (from [29]).



NOTE: H = Depth (ft.)
Q = Streamflow (ft^3/sec)

Figure 3.1 Assimulation Ratio (ϕ) as a Function of Depth

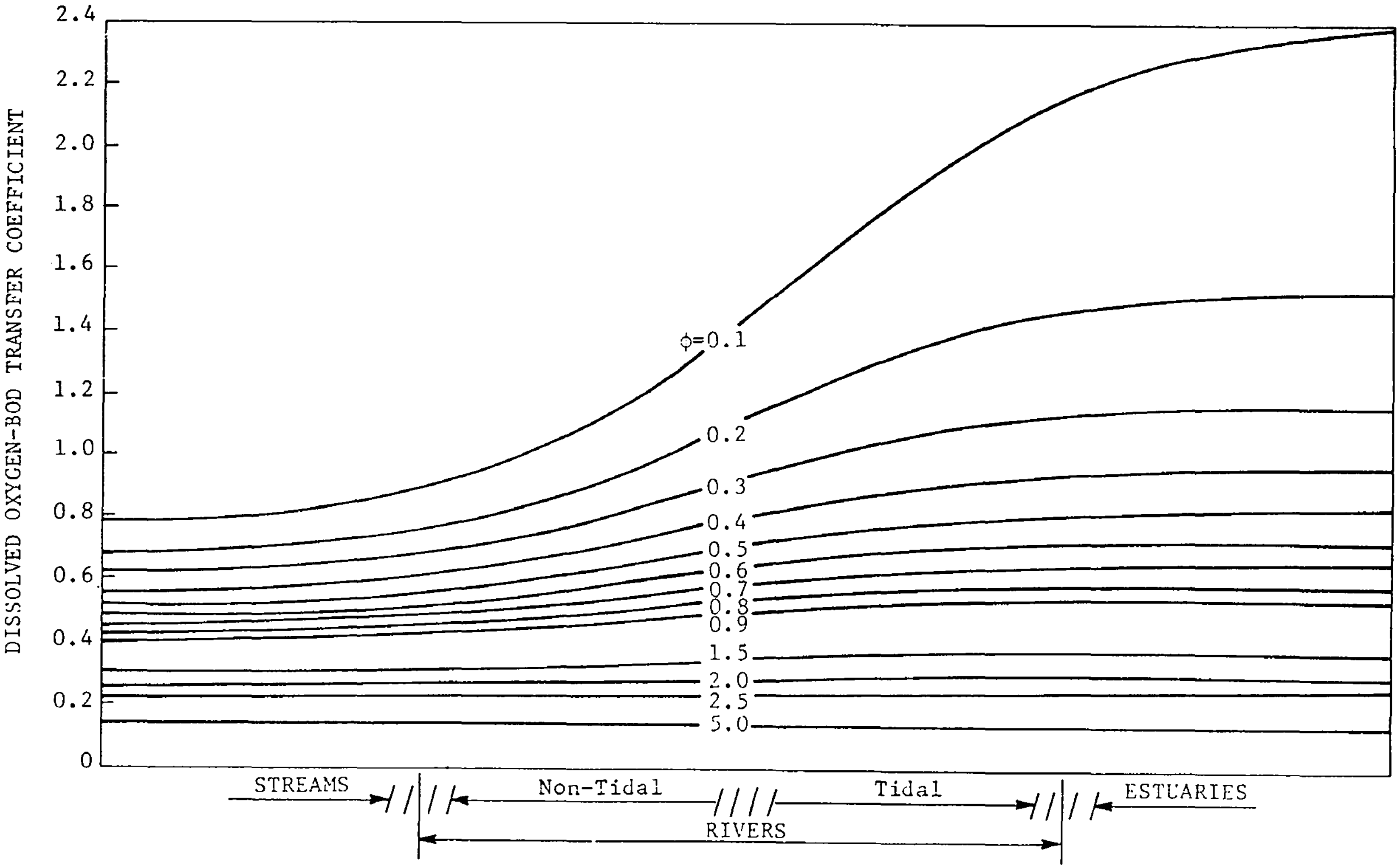


Figure 3.2 Dissolved Oxygen Response as a Function of Water Body Type and Assimilation Ratio (ϕ)

Likewise, the required dissolved oxygen saturation concentrations may be obtained from Figure 3.3 (also from [29]) given the water temperature and chlorides content (salinity).

Compliance Monitoring Costs

These costs are required in much the same way by both approaches; one minor difference is that the computer approach lumps together travel costs for samples taken from different pipes (outfalls) belonging to the same source, while the hand approach does not. The development of these cost data must remain the responsibility of the surveillance agency, which should be able to extract the information from records hopefully kept on past monitoring operations. Sample analysis costs for the various constituents should be easily available from the water quality laboratory which performs the analyses.

The hand approach (Section 4, Task 13) lists the various component costs required. These must be combined together into separate analysis costs (per constituent) and base costs (per number of pipes at a source) before input to the computer approach.

Design Parameters

There are several design parameters used in combining monitoring data for the computer procedure. First, there is a parameter used to exponentially smooth the monthly effluent discharges at a source into a single value. This parameter (input variable "ALPHA") should be between 0. and 1. where an ALPHA close to 0. represents the case where each new piece of data is heavily weighted with respect to older data and an ALPHA close to 1.0 represents the case where newer data is very lightly weighted with respect to older data.

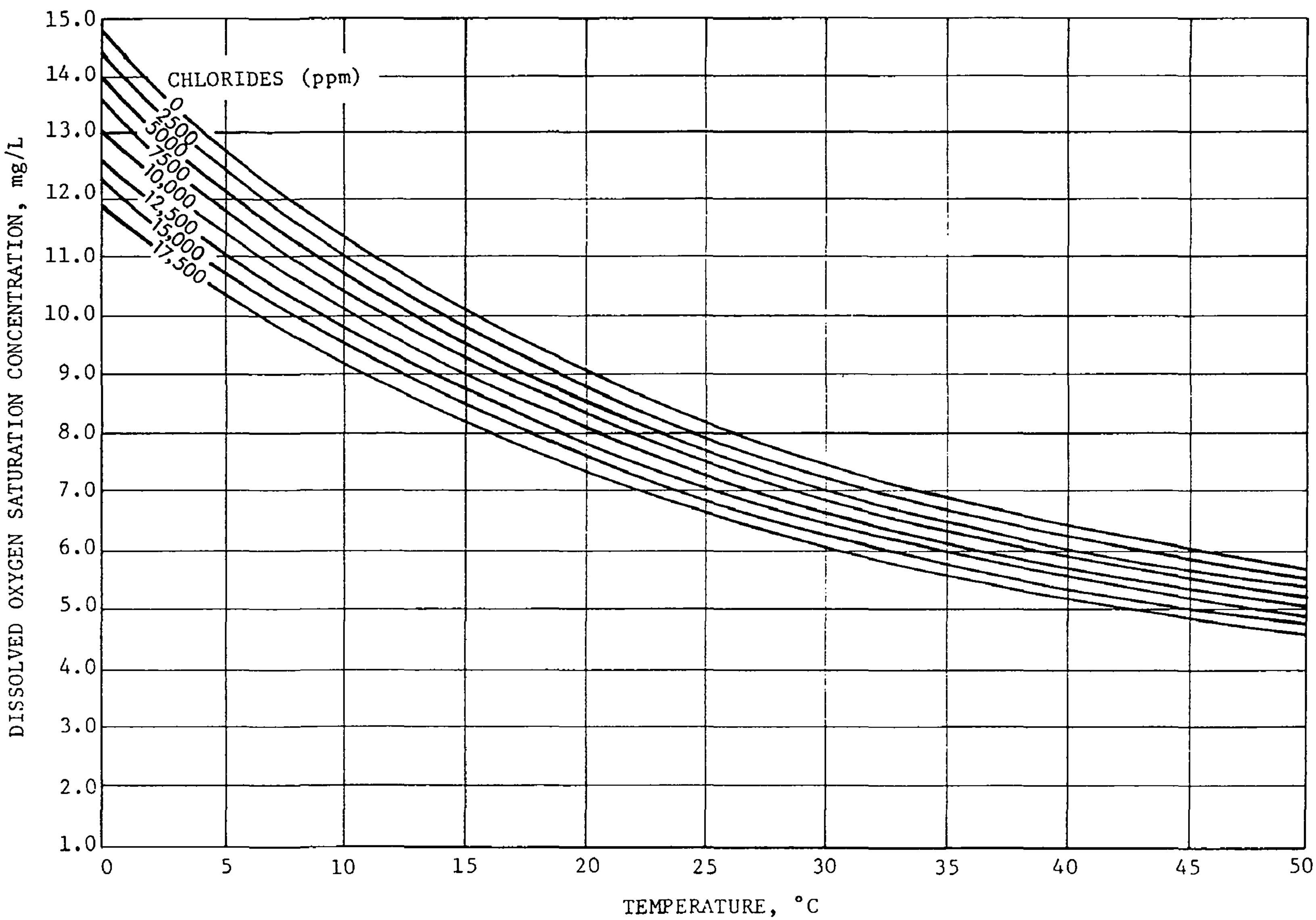


Figure 3.3 Dissolved Oxygen Saturation Versus Temperature and Chlorides

A second design parameter is the discount factor used in including compliance monitoring data. This factor, called "γ", was explained in SCI's first report ([1], Section V.2). The corresponding input variable is "GAMMA" and the value should be greater than 1. The larger the input value of "GAMMA" is, the more weight that is given to compliance monitoring data in comparison to self-monitoring data.

Other discount factors are "k_η" and "k_μ" (from [1], Section V.2), where the corresponding input variables are "KETA" and "KNU". The larger the values of these variables are, the more heavily weighted is past data with respect to the current month's data in combining monthly constituent self-monitoring data.

Finally, the values of "h_η" and "h_μ" must be considered (from [1], Section V.2). Since "h_η" is considered to be "1" and is not input, only "h_μ" need be considered. It was recommended that this be set according to Table A.3.3 in [1] (use an "average" sample size for the source in reading the table). The input variable is "ENU".

3.2 COMPUTER AND MANPOWER REQUIREMENTS

The requirements for manpower and hardware differ substantially between the hand and computer calculation techniques. Generally, the hand calculation option requires more person time to implement, but requires only an inexpensive hand calculator. On the other hand, the computer calculation option requires a large scale digital computer with marginally less person time for programming and interpretation of results. The computer calculation option becomes more cost-effective as the number of effluent sources and constituents to be considered increase. If the number of effluent sources is small, say less than 10, the hand calculation technique becomes less tedious and more cost-effective.

The hand calculation's efficiency depends more upon the efficiency of the tester than does the computer procedure. Numerous opportunities exist for errors to creep into the early calculations. It would be quite easy to carry these errors through the complete analysis only to discover the necessity of repeating much of the analysis.

The same opportunities for error exist with the computerized procedure, but correction is a simpler process which would require substantially less personnel time.

For the test case described in Section 6, seven effluent sources and seven constituents were used in both the hand and computer calculation options. Approximately 60 hours of professional man-time were spent performing the hand calculations and determining the final allocation of monitoring resources. Nearly half of this 60 hours was spent in initial data extraction and tabulation, which must also be done to derive inputs for the computer procedure. This was performed by an SCI staff member previously unfamiliar with the Resource Allocation Program.

Other Differences Between the Computerized and Hand Procedures

The two major areas of difference between the hand calculation approach and the computerized procedure (see Sections 5 and 7) are in the resource allocation criteria used and in the methods of using the newly entered self-monitoring and compliance monitoring data.

Among the resource allocation criteria used in the computerized procedure is the total expected environmental damage from undetected violation (see Section 2.4, Criterion Number 2). The expected environmental damage computation is quite a lengthy procedure, more appropriate for computers, based on the expected damage per source and the expected damage per constituent. This in turn is computed from a "damage function" for each constituent, which attempts to quantify environmental damage resulting from various concentrations of the constituent in the receiving waters. Thus, the receiving water concentrations caused by each constituent in an effluent must be determined, requiring a knowledge also of the volume flowrates of both the source and the receiving stream. This criterion is too complicated for use in the hand calculation procedures.

The resource allocation procedure is greatly simplified in the hand calculation approach by the use of a different resource allocation criterion: the total expected extent of undetected violation (discussed in Section 2.4 as Criterion Number 3). The extent of violations is computed from either the amount by which the effluent standards are exceeded, or the number of times by which they are exceeded, at the user's option. This has the effect of directing compliance monitoring towards those dischargers with the more serious violations of the standard, whose conviction is easier. It also eliminates all the calculations required to assess the impact on the receiving waters, and in particular, prevents consideration of the impact of BOD loads upon dissolved oxygen in the receiving waters.

Exclusion of the damage function criterion from the hand calculation approach also enables the treatment of sources with multiple outfall pipes, each with its own effluent standards, to be greatly simplified; the computerized procedure requires many more involved computations to determine the environmental damage caused by one source with multiple outfalls. For the purposes of this entire hand calculation approach, a source is defined as a separate outfall or discharge pipe, with its own set of effluent standards. This differs from the computerized procedure, in which a source may have a number of outfall pipes each with its own standards. The effect of this difference appears in the resulting sampling rates, since with the computerized approach, all pipes of one source would be sampled at the same time (economizing on travel costs), whereas in the hand calculation approach, each pipe will probably be assigned a different sampling rate (economizing on compliance monitoring with low marginal returns). Since actual monitoring programs have historically been implemented on a source basis rather than an individual pipe basis, this may be a slight deficiency in the hand calculation procedure.

Another major area of difference between the hand and computerized procedures is in the methods of using the newly entered monitoring data. In the computerized procedure, the self-monitoring data are entered monthly, aggregated across months if the number of data are too small, and then used to estimate monthly statistics. The compliance monitoring data are also entered monthly, incorporated into the monthly statistics, which are then combined into cumulative statistics. In the hand calculation approach the same general procedure is used, but the data are not divided up into monthly subsets. Thus, the sample sizes are much larger, and there is no need to aggregate across months or combine monthly statistics. The principal effect of this difference is in the time discounting of the data. In the hand procedure, only data prior to the last monitoring period may be discounted, or down-weighted, whereas, in the computerized procedure data as recent as that for the month before last, may be discounted if desired.

SECTION 4

USER MANUAL FOR HAND CALCULATION APPROACH

4.1 INTRODUCTION

Section 4 constitutes a stand-alone handbook for the hand application of resource allocation methods for effluent compliance monitoring.

Usage

This handbook is intended for use in determining for an effluent monitoring agency the rate (or frequency) with which it should sample each effluent source within its jurisdiction. This sampling rate will specify the number of samples to be taken at each source during a forthcoming monitoring period, but it will not allocate their timing within the period.

The criterion for determining the sampling rate is the "degree of undetected violations". This is explained further in Section 2.2 and Reference [1]. The sampling rate may be subject to constraints on the total resources available for monitoring and on the maximum and minimum sampling rates specified by the user for each source. The user may choose to either:

1. Expend the remaining monitoring resources so as to minimize the total degree of undetected violation from all sources; or
2. Bring the total degree of undetected violation from all sources below some specified limit while minimizing the monitoring resources spent.

Since conditions in the jurisdictional region will undoubtedly change with time, and since information on the dischargers may improve with time as more data is collected, the rate allocation should be redesigned from time to time in the future, each time incorporating all new information available. The user therefore selects a suitable length for the next compliance monitoring period, e.g., 3-, 6-, or 12-months. Since some time is required to analyze the data and design the allocation procedure for the next monitoring period, there must be a lag period between data collection and application of the new procedure. The timing of the various monitoring and analysis functions is illustrated in an example monitoring sequence in Figure 4.1. Some of the implications of seasonal variations in effluents upon the selection of monitoring periods are included in the discussion under Task 3.

The user may wish to apply this allocation procedure for any of several reasons, such as:

A. For the preliminary design of a new effluent compliance monitoring system.

B. To compare the effectiveness of an existing surveillance system against that produced by this procedure.

C. For program planning, to evaluate (on the basis of the resource allocation criterion) the overall level of surveillance required in a basin, region, or nation.

He may prefer the hand calculation procedure outlined in this Section to the alternative computerized procedure (see Sections 5 and 7), for such reasons as:

A. The lack of staff or facilities to operate the computerized procedure.

B. The wish to become intimately familiar with the procedure, before implementing it on a computer. (However, there are some differences, which will be discussed below.)

C. The small size of this surveillance operation does not justify the use of a computer.

Start Allocation Procedure — Start Compliance Monitoring Based on Allocation Procedure

	Month		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Collect Compliance Monitoring Data Set Number	'OLD'	D_1						D_2						
2a	Update Compliance Monitoring Statistics Through Set Number	'OLD'	'OLD'						D_1						D_2
2b	Design Compliance Monitoring Procedure Number	'OLD'	P_1						P_2						P_3
3	Apply Compliance Monitoring Procedure Number	'OLD'		P_1					P_2						

Figure 4.1 Example of Monitoring Sequence. This assumes: (1) a six month compliance monitoring period, and (2) a one month lag time to complete data analysis and to design the procedure for the next monitoring period.

The user should be familiar with basic engineering statistics and mathematics up to, but not including, calculus. He should also have available a desk calculator or similar computational device. Once the procedure is well understood, a programmable calculator could undoubtedly be used to provide added convenience with the repetitive computations.

Many of the technical terms used are explained in the Glossary at the back of this handbook.

Limitations

This hand procedure is limited to the preliminary design of effluent compliance monitoring systems for which the primary goal is the minimization of the total expected extent of undetected violations (or optionally, minimization of the number of undetected violations). The methods require that the effluent standards be expressed as simple thresholds for each constituent (maximum or minimum values, or both).

This hand procedure does not include considerations of monitoring system implementation costs, accessibility, maintainability, reliability, and other similar practical engineering factors.

Assumptions

The methods employed in this hand procedure are based on the following assumptions:

1. Only one set of effluent standards applies to each source.
2. Concentrations at various sampling times are independent.
3. The loading rates of the various constituents at one source may be taken to be completely dependent (correlated) or completely independent.

4. The frequency distributions of daily loading rates of each constituent may be represented by either a normal or a log-normal distribution.

5. Effluent standard violations are the only concern. Therefore, any damage to the receiving waters caused when source constituents do not violate the effluent standards cannot be considered.

These assumptions are explained in more detail in the areas of Section 4.2 where they are employed.

Other Requirements

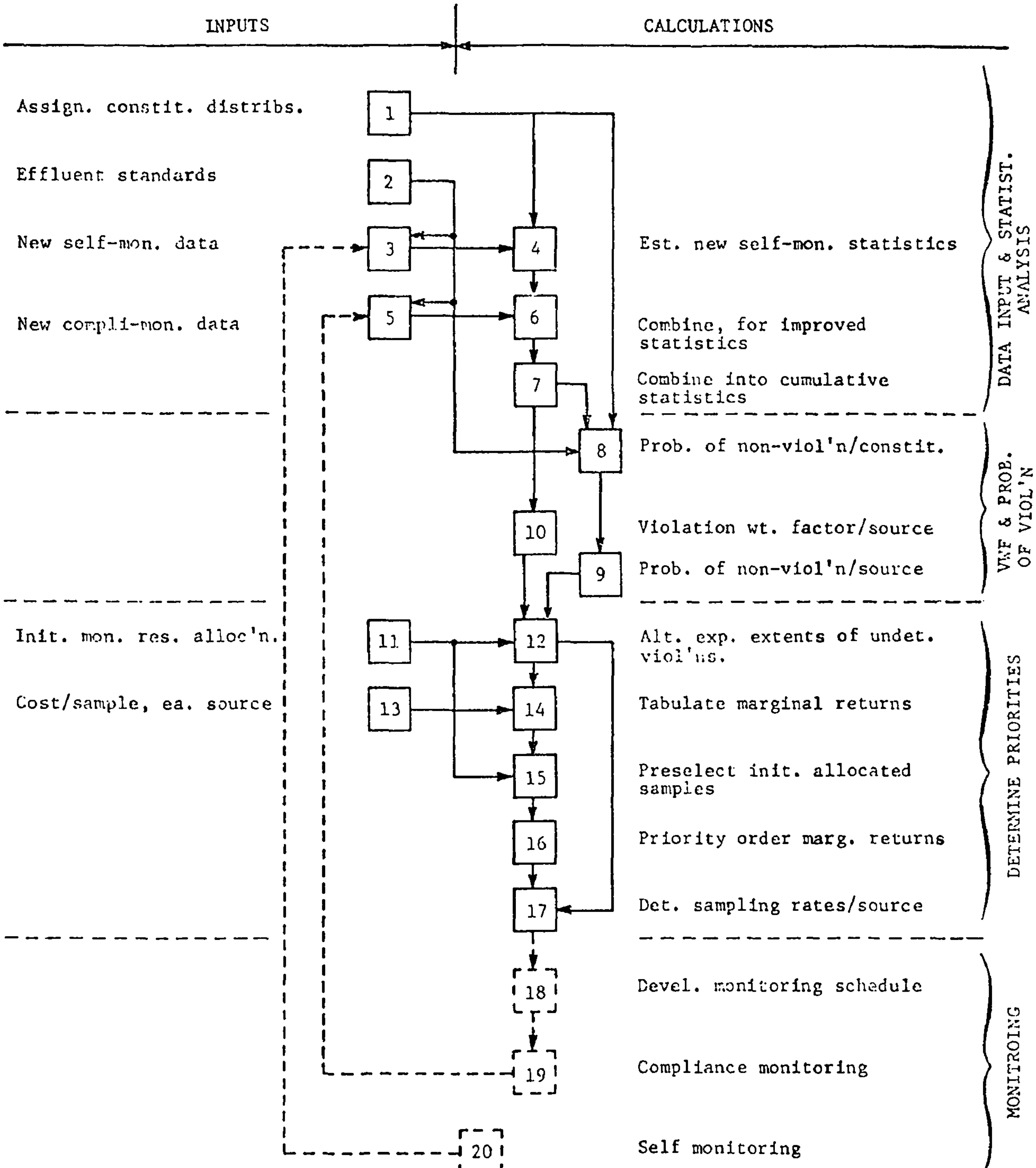
Another requirement of the hand procedure employed here is that:

- Data should be available on the component cost for transportation, sampling, materials, labor, analysis, and reporting which together comprise the total cost to take a 24-hour composite (compliance monitoring) sample at each source within the area of jurisdiction.

Overview of the Hand Calculation Approach

The quantitative preliminary design procedure used in the hand calculation approach consists of a number of individual tasks. These tasks are numbered, and their relationships indicated, in Figure 4.2. Each task is relatively self-contained; the objective, outputs, inputs, and procedure required for each are discussed separately in the following subsection.

The 20 tasks have been grouped in Figure 4.2, into the four principal activity areas identified in the original formulation of this monitoring resource allocation procedure (see [1], p. 97). The first three activities comprise the overall allocation procedure. The fourth



NOTE: The number in boxes indicate task numbers of the hand calculation procedure as described in Section 4.2.

Figure 4.2 Interralationships of Comprising Tasks (linking areas in present flow of effluents) activity represents the remaining tasks to be executed by the monitoring agency and the dischargers, which will provide additional inputs for the next allocation.

Organization

Following this introduction, the objectives, outputs, inputs, and the step-by-step procedure required for each task are discussed separately. Examples of the computational tables required are provided. For user convenience, each task begins on a fresh page. For clarification, task numbers are placed in boxes similar to those in Figure 4.2.

Units

For computational efficiency, an attempt has been made to use a consistent system of units throughout. The system used is the metric system (specifically, the CGS system). It is recognized that this system does not always reflect common practice and tables have been provided for rapid conversion from more common units.

Symbols

To the extent possible, the symbols used herein have the same meaning as they have in Section 2: Summary. The meanings are given in the list of symbols at the back of this handbook.

4.2 STEP-BY-STEP PROCEDURE

TASK [1]: ASSIGN CONSTITUENT DISTRIBUTIONS

Objective

For each water quality constituent of interest in the surveillance program and at each source where it occurs, assign a type of statistical distribution which best represents the frequency distribution of the daily loading rates of the effluent.

Output

The output for Task [1] is the completed Table 4.1 with the name of the frequency distribution type (must be either "Normal" or "Lognormal").

Inputs

Previous determinations of statistical distributions in the area of interest, if available.

Information Sources

- Reference [1], Section V.1
- References [2,3]

Discussion

Very few determinations of statistical distributions have been made to date (see [1], Recommendation 3). Sensitivity studies ([1], Section 8.3) indicate that an error in the specification of a distribution type would be small (approximately 10 percent), if not negligible, in effect. Therefore, the extensive studies of effluent data required to make a more accurate determination do not seem to be justified, especially when a good approximating alternative method is available (Alternative 2 of Step 6 below).

In the SCI first report [1], it was found that a large majority of effluent loading rates could be accurately represented by either normal or lognormal distributions. Therefore, candidate distributions are limited to these two.

Procedure

1. List all the sources of interest in the region and constituents of interest at each source, in columns 1-3 of Table 4.1, arranging them in source order (for convenience later). Choose a convenient ordering which will be repeated in many subsequent tasks. In column 1, assign a number to each source for convenient reference later.

2. At a given source, for a given constituent, assign constituent distributions as follows: if this is the first time this particular constituent at this source is being considered for assignment, (determine this from Table 4.1 for the most recent, previous application of this allocation procedure), then proceed to Step 4; otherwise go to Step 3.

3. Procedure has been applied previously. Copy the distribution assignment from Table 4.1 for the previous application into the new Table 4.1 for this application. (Note: Such assignments must not be changed after the first application of this procedure, since once "typed" normal or lognormal, the cumulative statistics cannot be later converted from one type to the other).

   Go to Step 7.

4. For first application of procedure. If the constituent is pH or coliform bacteria, go to Step 5; otherwise skip to Step 6.

5. For pH and coliforms only. Because specific assignments are the most reasonable for certain constituents, and they are also of help in subsequent tasks, this overall hand calculation procedure requires the following constituents, if present, to be always assigned the following distributions:

Constituent		Distribution
pH	always	Normal (N)
Coliforms	always	Lognormal (L)

Indicate the distribution assignment in column 4 of Table 4.1, and enter a dash in column 5 (not applicable).

Go to Step 7.

6. For all other constituents. Select one of the following two alternative methods to assign a distribution type (see Task [1], Discussion):

Alternative 1: Where available, use previous determinations of the statistical distribution type made for this specific constituent and source.

Alternative 2: Assume a normal distribution for all cases. (Note: This assumption may be modified later in Step 4g of Task [4]).

Enter the assignment and selection into columns 3 and 4 respectively on Table 4.1.

7. Repeat Steps 2-6 (as appropriate) for each constituent of interest at the same source.

8. Repeat Steps 2-7 (as appropriate) for each source of interest in the region.

Table 4.1 Statistical Distribution Types By Constituent and Source

Source No. (i)	Constituent Name	Distribution Type (N or L)	Task [1] Alternative Used (1 or 2)
(1)	(2)	(3)	(4)

Note: This table can be duplicated for use in the hand calculations.

TASK [2]: INPUT EFFLUENT STANDARDS

Objective

For each source and each constituent, prepare a list of the effluent standards.

Output

Task [2]'s output is Table 4.2 which lists by source the limiting loading rates or concentrations permitted for each constituent.

Inputs

- Effluent limitations stated on National Pollution Discharge Elimination System (NPDES) discharge permits (required by 1 July 1977).
- Pending the establishment of the above, equivalent limitations previously established by the responsible water quality control agency.

Discussion

In some cases, effluent standards may alternatively be specified as either (a) a maximum loading (e.g., kg/day, lb/day, MPN/day), or (b) a maximum concentration (e.g., mg/L, ppm) together with a maximum volumetric flow rate (e.g., ML/day, cfs, mgd). Assuming these maxima are synchronous, (a) can be computed from (b). In the last analysis, it is the loading rate which is the crucial quantity and which must be controlled to prevent environmental damage. Furthermore, for Task [10], Step 4 (see Subsection a), the allocation procedure requires that the effluent standard S be prescribed in the form of a loading rate wherever possible. pH is a special case, and is so treated in Task [10], Step 4, Subsection c.

The same units used to specify these effluent standards will be also specified for the monitoring data to be input in Tasks [3] and [5], in order to obtain consistency.

Procedure

Enter the applicable standards into Table 4.2, following the same source and constituent order established in Table 4.1 (Task 1). Whereever possible, enter the standard in the form of a loading rate (e.g., kg/day, MPN/day - see Discussion); use Table 4.3 to assist in making the conversions. Also, wherever possible, convert the units of the standard to CGS units; use Table 4.4 to assist in making these conversions.

For pH standards, make two separate entries: for pH MAX and pH MIN.

Table 4.2 Effluent Standards

Source	Constituent		
	Name	Units*	Standard Value, S
(1)	(2)	(3)	(4)

*Specify in the form of a loading rate, preferably kg/day, wherever possible (see Task [2] Discussion). For concentrations, only where unavoidable, preferably use mg/L.

Note: This table can be duplicated for use in the hand calculations.

Table 4.3 Conversion Factors

MASS

1 pound	(lb)	=	.4536 kilograms (kg)
1 kilogram	(kg)	=	2.205 pounds (lb)
1 kilogram	(kg)	=	1000 grams (g)
1 kilogram	(kg)	=	1,000,000 milligrams (mg)
1 kilogram	(kg)	=	1,000,000,000 micrograms (μg)

VOLUME

1 gallon	(g)	=	.13368 cubic feet (ft^3)
1 gallon	(g)	=	3.785 liters (L)
1 liter	(L)	=	.2642 gallons (g)
1 liter	(L)	=	.03532 cubic feet (ft^3)
1 cubic foot	(ft^3)	=	7.4805 gallons (g)
1 cubic foot	(ft^3)	=	28.3161 liters (L)

TIME

1 day	=	86,400 seconds
1 second	=	.0000115741 days

NOTE: Parts-per-million (ppm) is approximately equivalent to milligrams per liter (mg/L)

Table 4.4 Data and Standards Conversion

Unconverted Data or Standard	Unconverted Units	Conversion Factor	Converted Units	Converted Data or Standard

Note: This table can be duplicated for use in the hand calculations.

TASK [3]: INPUT NEW SELF-MONITORING DATA

Objective

For each constituent, and for each source, tabulate summary information on all the new self-monitoring data collected during the monitoring period just completed.

Output

The output, to be recorded in columns 1-7 of Table 4.5, will include:

- Listing of constituents of concern at each source in the region.
- Self-monitoring summary data on these constituents for the monitoring period just completed.

Inputs

Depending upon both the source and the constituents, the inputs may be either raw, grab sample and daily composite measurements, or they may be summaries for subintervals, such as monthly means, monthly maxima, and the number of measurements made during each interval.

References

- [1], Section III

Discussion

Input data from composite self-monitoring samples are clearly preferred to data from grab samples, because they are far more representative of the total pollutant load and they relate directly to the NPDES daily maximum effluent standard. However, there are likely to be many more grab sample data available, due to their lower acquisition cost. Unless there are ample composite sample data available, it is suggested that the grab sample data should be included in the input self-monitoring data for this task. The fact that the grab sample data are less reliable can be accounted for later in the reliability factor, γ, of Task 6, Step 1.

Where fairly strong seasonal variations in effluents are known to occur, as for example, in the food processing industry, possible measures to reduce misallocation would be:

1. to design for a one-year-long compliance monitoring period, and to then allocate the compliance monitoring samples to suit the seasonal operations;

2. to treat data from "peak season" and "off season" periods as though they came from two different regions, and to therefore design separate compliance monitoring programs for each period.

Since the surveillance agency can specify the units in which the self-monitoring data is to be reported, it is assumed in this task that these units will be the same as those used to define the effluent standards (see Task 2). Therefore, no conversions of self-monitoring input data should be needed; in the event they are needed, the user may refer to Task 2, Procedure.

For the purposes of this entire hand calculation approach, a source is defined as a separate outfall or discharge pipe, with its own set of effluent standards. In the case of the constituent pH, pH Max and pH Min are treated as separate constituents until Task 8. The mean (m) of pH Max and the mean (m) of pH Min (Table 4.5, Column 4) should be equal and represent the mean of all pH values.

Procedure

1. For the first constituent at the first source (outfall) listed in Table 4.1, enter the source name, constituent name and units in the first three columns of Table 4.5 (Task 3). The units to be used will be those with which the effluent standards are specified for this constituent (see Task 2).

2. Using all the self-monitoring data collected for this constituent during the most recent monitoring period, find the sample mean, maximum (and/or minimum), and sample size as described below. If no processing of raw daily measurements (into means, etc.) has been done, use Method A. If processing has been done, use Method B. (Note: In allocation procedures for previous monitoring periods, some data may not have been used because its sample size was less than four (see Task 4, Steps 1 and 2). This data can be conbined with data for the new monitoring period in this step.

Method A: (for raw data)

mean, m = $\frac{\text{sum of all values}}{\text{number of values}} = \frac{1}{n}\sum_{r=1}^{n} y_r$

maximum, ξ = maximum of the values = $\max_n (y_r)$

minimum, ω = minimum of the values = $\min_n (y_r)$
[for pH only]

sample size, n = number of values

where y_r is the r-th of n data values

Method B: (for processed data)

Suppose the data for the last monitoring period was divided up and summarized for R smaller reporting periods (e.g., months), and the input data consists of a mean, m_r, a maximum, ξ_r (or minimum, ω_r), and sample size, n_r, for each reporting sub-period number r. Then for the entire monitoring period:

$$\text{mean, } m = \frac{\sum_{r=1}^{R} m_r n_r}{\sum_{r=1}^{R} n_r}$$

$$\text{maximum, } \xi = \text{maximum of the } \xi_r \text{ values} = \max_R (\xi_r)$$

$$\text{minimum, } \omega = \text{minimum of the } \omega_r \text{ values} = \min_R (\omega_r)$$

$$\text{sample size, } n = \sum_{r=1}^{R} n_r$$

Enter the results in columns 4-7 of Table 4.5, Task [3].

NOTE: When this Task [3] is being done in a region for the first time, the "data collected during the monitoring period just completed," will include all the desired past self-monitoring data collected.

3. Repeat the preceding Steps 1 and 2 for each constituent of interest at the first source, following the constituent order established in Table 4.1, Task [1].

4. Repeat the preceding Steps 1-3 for each source of interest in the surveillance region, following the source order of Table 4.1.

Table 4.5 Effluent data, Statistics and Probabilities

γ(Task 6) = ____________ Discounting constant, h(Task 7) = ____________

TASK 3 Self-monitoring input data (record in source sequence)							TASK 4 Self-monitoring statistics					TASK 6 Self + compliance				TASK 7 New cum. statis.				TASK 8 Probabilities		
Source	Constituent Name	Units	Mean m	Max* ζ	Min** ω	Sample Size n	Est'd Mean μ	Est'd Std. Dev. σ	Distribution L or N	η	ν	$\tilde{\mu}$	$\tilde{\sigma}$	$\tilde{\eta}$	$\tilde{\nu}$	$\hat{\mu}$	$\hat{\sigma}$	$\hat{\eta}$	$\hat{\nu}$	Norm'd Effl't Std. x	$\Phi(x)$	Pr. non-viol'n./const. P_{ij}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)

*Not required for pH min.

**Required only for pH min.

Note: This table can be duplicated for use in the hand calculations.

TASK [4]: ESTIMATE SELF-MONITORING STATISTICS

Objective

To obtain for each constituent occurring at each source, an estimate of the mean and standard deviation of the newly entered self-monitoring data.

Output

Tabulation of the estimated means and standard deviations in columns 8-12 of Table 4.5

Inputs

- Distribution types (from Table 4.1, Task [1])
- Self-monitoring input data (from Table 4.5, Task [3])

References

- [1], Appendix A
- [1], Section V.1
- [1], Section IX.1
- [4], for the preparation of Figure 4.5

Discussion

The procedure employed in this task to obtain estimates of the source mean and standard deviation from the sample mean and the maximum requires that the number of measurements (sample size) upon which these are based be greater than three.

If the sample size for a constituent is greater than three, then the estimation procedure to be used differs between normal and lognormal distribution types.

Procedure

1. For the first constituent at the first source, determine from column 7 of Table 4.5, Task [3], whether the sample size n is less than 4.

   If n is less than 4, go to Step 2, otherwise proceed to Step [3].

2. For $n < 4$. In Table 4.5 write "INSUFFICIENT DATA" under Task 3. The insufficient data may be saved for incorporation with the data from the next monitoring period. Return to Step 1 and re-start the procedure for the next constituent.

3. Determine from Table 4.1, Task [1] whether the constituent's distribution type is Normal or Lognormal (N or L), and which Task [1] alternative was used for it (Alternative 1 or 2).

   If the distribution type is Normal (N), go to Step 4; if Lognormal (L), go to Step 5.

4. For normal distributions.

   a. Use the sample mean, m, from column 4 of Table 4.5, Task [3], as the best estimate of the source mean, μ.

   b. Use the sample size, n, from column 7 of Table 4.5, Task [3], to determine the scaling factor, G, from from Figure 4.3.

c. Compute the estimated standard deviation for the source σ, from

$$\sigma = \frac{\xi - m}{G} \quad \text{or} \quad \sigma = \frac{m - \omega}{G}$$

where m, ξ, and ω are obtained from columns 4-6 of Table 4.5, Task [3].

d. If this task has been performed previously to design a prior compliance monitoring program for this constituent and source, go to Step 4f; if not, go to Step 4e.

e. If both the following are true:

   A. Alternative 2 was used in Task [1] (see Step 6) and

   B. $\sigma > 1.5\mu$

then go to Step 4g; otherwise go to Step 4f.

NOTE: The factor of 1.5 used in condition B is somewhat arbitrary, but is near-best based on the limited known information. Even if it were sufficiently in error to yield the wrong distribution, the effect on the resource allocation would still be small -- see the Task [1], Discussion.

f. Enter the values of μ and σ obtained in Steps 4a and 4c above, into columns 8 and 9 respectively of Table 4.5, Task [4]. Enter an "N" in column 10 of Table 4.5, Task [4]. Go to Step 6.

g. Change the distribution type from normal (N) to log-normal (L) in column 4 of Table 4.1. Go to Step 5 immediately following and redetermine μ and σ as for lognormal distributions.

5. <u>For lognormal distributions</u>:

a. Compute the ratio of the maximum to the mean, $\rho = \frac{\xi}{m}$ where m and ξ are obtained from columns 4 and 5 of Table 4.5, Task 3.

b. Knowing the ratio, ρ, and the sample size, n, from column 7 of Table 4.5, determine the estimated standard deviation (of the logarithms of the measurements), σ, from Figure 4.4; interpolate carefully between curves for different sample sizes, where necessary.

c. Compute the estimated mean (of the logarithms of the measurements), μ, from

$$\mu = \log_{10} m - 1.1513\ \sigma^2$$

d. Enter the values of μ and σ obtained in Steps 5c and 5b above into columns 8 and 9 respectively of Table 4.5, Task [4]. Enter an "L" in column 10 of Table 4.5, Task [4].

6. Knowing the sample size n (from column 7 of Table 4.5), determine the confidence parameters. Prescribe η, the confidence parameter for the mean, to be

$$\eta = n$$

and obtain ν, the confidence parameter for the standard deviation from Figure 4.5.

Enter the results into columns 11 and 12 of Table 4.5, Task [4].

7. Repeat the preceding Steps 1-6 (as required) for each additional constituent of interest at the first source.

8. Repeat the preceding steps 1-7 (as required) for each source of interest in the surveillance region.

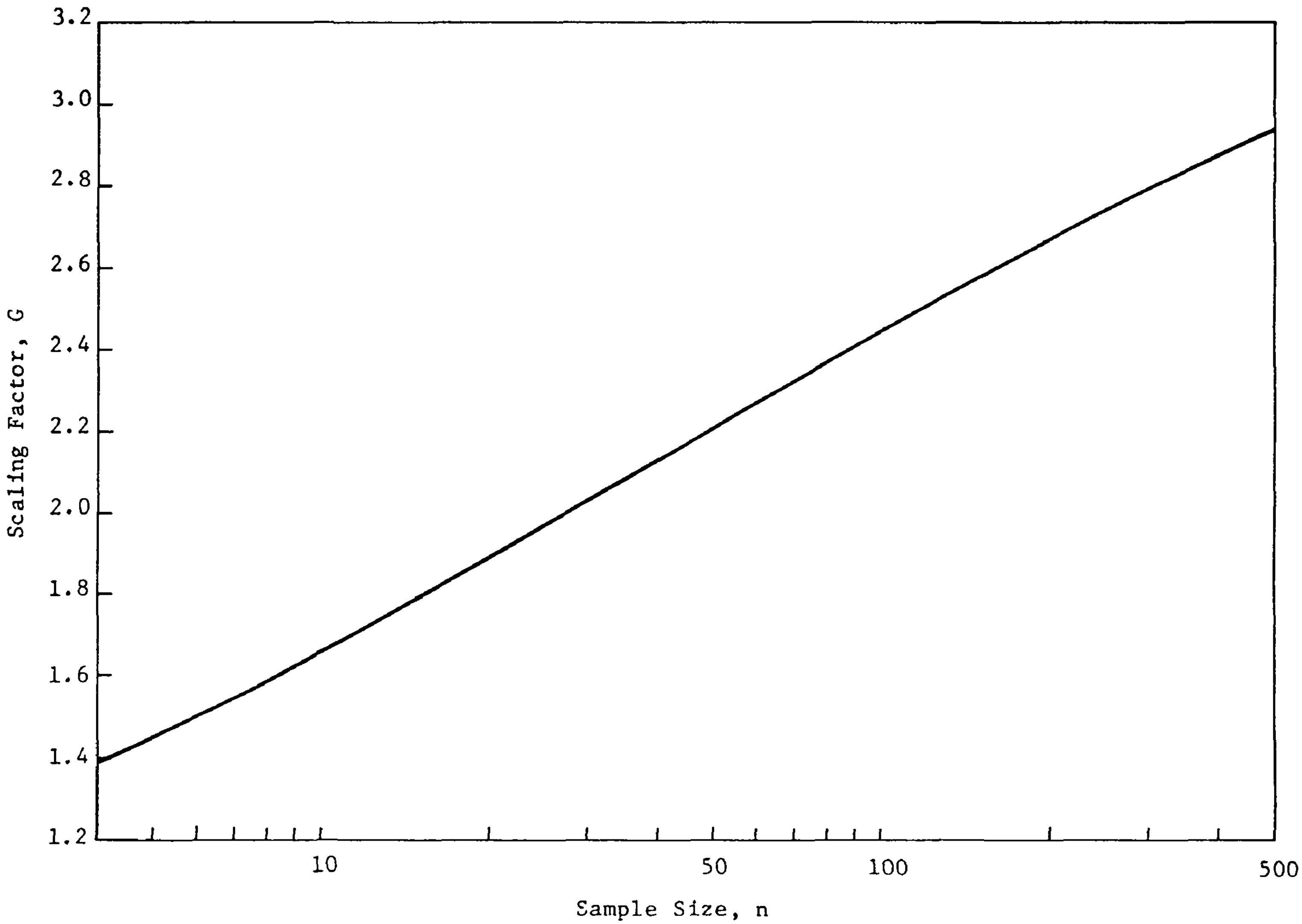


Figure 4.3 Variation of Scaling Factor, G, with Sample Size for Normal Distributions

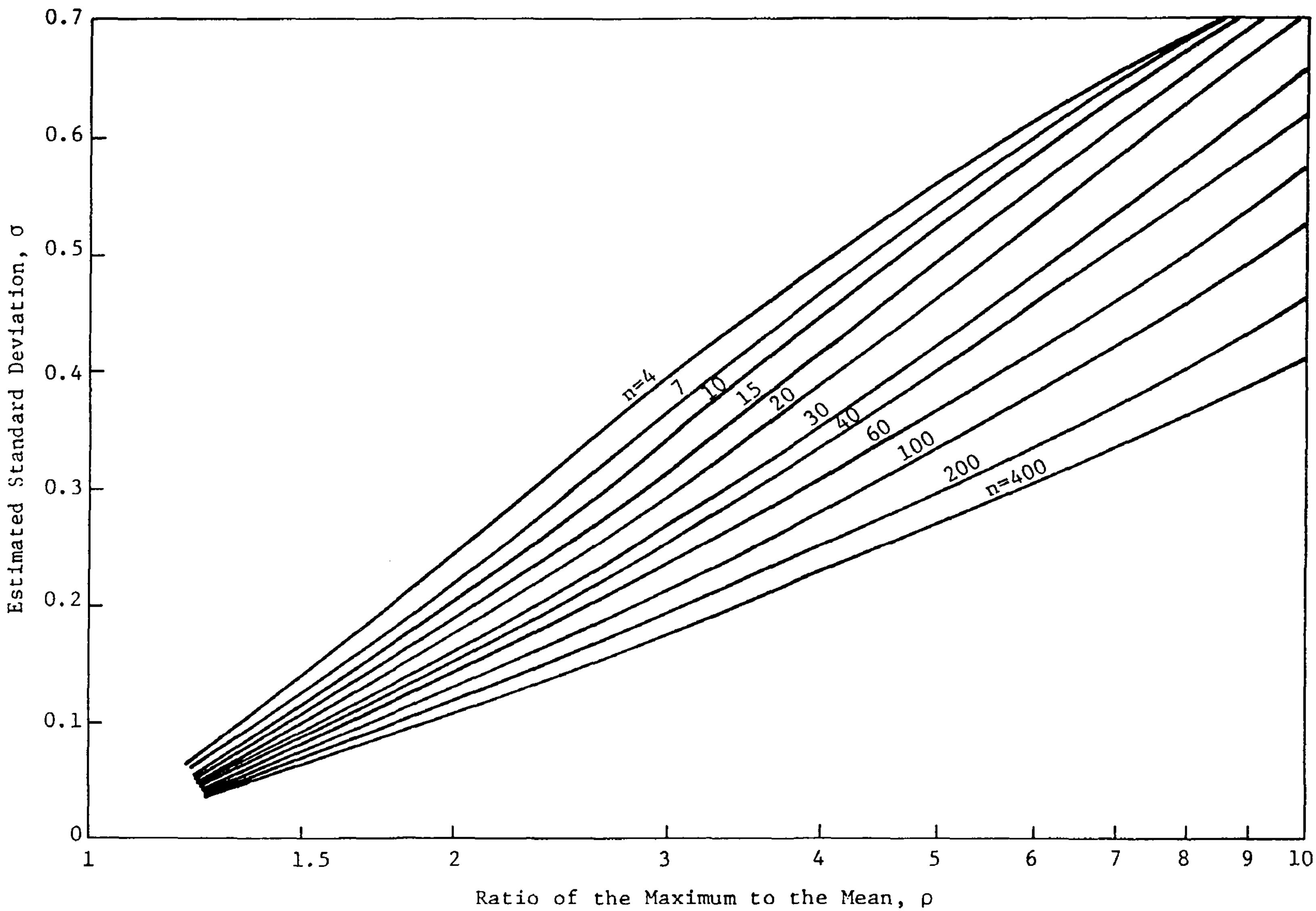


Figure 4.4 Standard Deviation Estimated from the Mean and Maximum of Lognormal Distributions, for Various Sample Sizes, n

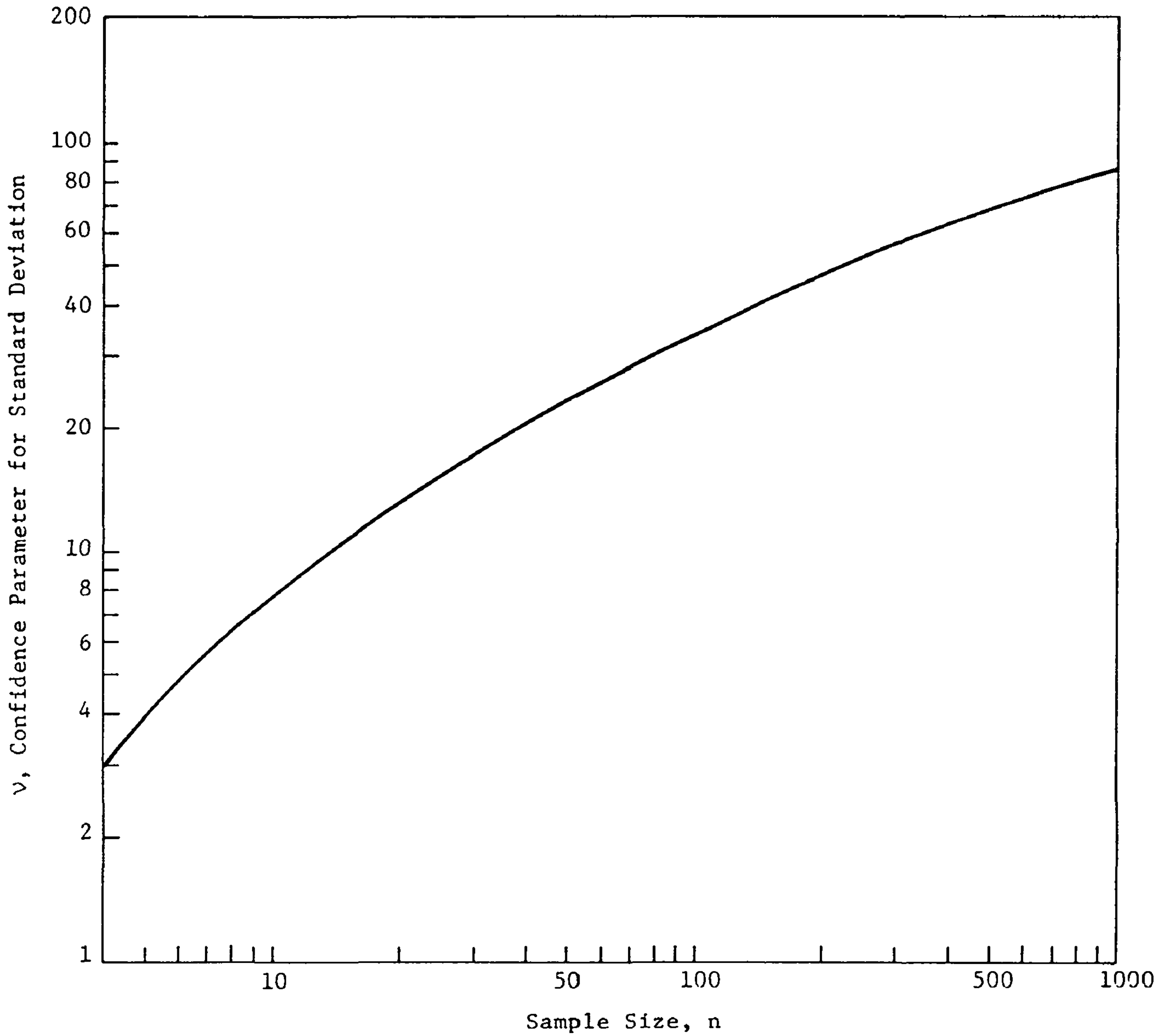


Figure 4.5 Variation of the Confidence Parameter for Standard Deviation with Sample Size

TASK 5: INPUT NEW COMPLIANCE MONITORING DATA

Objective

For each constituent, and for each source, tabulate all the new compliance monitoring data collected during the monitoring period just completed.

Output

Data on the constituents monitored by the surveillance agency at each source in the region.

Inputs

Daily composite data values obtained in the compliance monitoring program during the last monitoring period.

Discussion

It is assumed that grab sample data will not be included in compliance monitoring input data, since the objective of the surveillance exercise is to identiy violators, and violations are defined (via the NPDES daily maximum effluent standard) in terms of daily composite samples.

The computational procedure requires that the units of effluent standards and self-monitoring and compliance monitoring data are consistent for any one constituent at a given source. Therefore, it is required that the compliance monitoring data be converted, if necessary, before input, to have the same units as the corresponding effluent standards specified in Task 2. Information which may aid such conversions is provided in Tables 4.3 and 4.4.

Procedure

1. Follow the same source order as was established in Table 4.1, Task [1].

   At a given source with compliance monitoring data, copy or record all such data collected during the monitoring period just completed into Table 4.6. Ensure that the units of this data are the same as those specified for the effluent standards in Task [2]; if they are not, convert them as necessary (see Discussion above).

   > NOTE: When this task is being done for the first time, these input data will include all the past compliance monitoring data of interest which has been collected.

2. Repeat Step 1 for each source in the region having compliance monitoring data.

Table 4.6 Compliance Monitoring Input Data

	Constituent		
Source	Name	Units	Monitored Value z
(1)	(2)	(3)	(4)

Note: This table can be duplicated for use in the hand calculations.

TASK 6: COMBINE SELF-MONITORING STATISTICS AND COMPLIANCE MONITORING DATA

Objective

To obtain, for each constituent, and for each source, new improved estimates of the means and standard deviations of the data.

Output

Tabulation of improved means, standard deviations, and confidence parameters in columns 13-16 of Table 4.5.

Inputs

- Self-monitoring statistics from Table 4.5, Task 3.
- Compliance monitoring data from Table 4.6, Task 5.

References

- [1], Section V.2
- [1], Appendix E

Discussion

Compliance monitoring data are treated differently in this procedure from self-monitoring data, since the former may be considered more reliable and weighted accordingly.

Procedure

1. If only self-monitoring data is used, skip this task and go to Task 7, and write the words "same as Task 4," in columns 13-16 of Table 4.5. Otherwise, select for the region, a value

for γ, always greater than 1, and probably in the range of 1.5-3, but possibly much larger. This γ value will represent the greater weight (due to greater reliability) given to the compliance monitoring data than to the self-monitoring data. Therefore, one consideration might be the ratio of composite to grab sample data in the self-monitoring input data (see Task [3], Discussion). Enter the chosen γ value above Table 4.5.

> NOTE: Once the user becomes familiar with the intent and effect of γ, there is no reason why it could not be varied with the constituent, source, etc., treated.

2. For the first constituent and source with a compliance monitoring measurement, z, and with sufficient data from self-monitoring statistics (see Step 2, Task [4]):

   a. Compute the improved estimate of the process mean,

   $$\tilde{\mu} = \frac{z + \mu\eta/\gamma}{1 + \eta/\gamma}$$

   where z is obtained from Table 4.6, Task [5], and μ and η are obtained from Table 4.5, Task [4].

   b. Compute the improved estimate of the process standard deviation

   $$\tilde{\sigma} = \sqrt{\frac{z^2 + (\nu\sigma^2 + \eta\mu^2)/\gamma - (1 + \eta/\gamma)\tilde{\mu}^2}{1 + \nu/\gamma}}$$

   where σ and ν are also obtained from Table 4.5, Task [4].

   c. Compute the new confidence parameter for the estimated mean

   $$\tilde{\eta} = 1 + \eta$$

d. Compute the new confidence parameter for the estimated standard deviation

$$\tilde{\nu} = 1 + \nu$$

3. If more than one compliance monitoring measurement, z, was taken for the same constituent and source during the last monitoring period, then successively combine them into the statistics by repeating Step 2 above for each measurement.

4. Enter the final results for $\tilde{\mu}$, $\tilde{\sigma}$, $\tilde{\eta}$ and $\tilde{\nu}$ obtained from Step(s) 2 (and possibly 3), into columns 13-16 of Table 4.5, Task [6].

5. Repeat Steps 2-4 for each source and each constituent where compliance measurements were taken during the most recent monitoring period.

TASK [7]: COMBINE LATEST STATISTICS INTO CUMULATIVE STATISTICS FOR COMPLIANCE MONITORING PERIOD

Objective

To obtain, for each constituent and each source, estimates of the mean and standard deviation of the data based on all past measurements.

Output

Tabulation of cumulative means, standard deviations, and confidence parameters in columns 17-20 of Table 4.5.

Inputs

- Cumulative estimates (if any) of process statistics from previous allocation period.
- Latest improved estimates of process statistics from Table 4.5, Task [6].

References

- [1], Section V.2
- [1], Appendix E

Discussion

One or two of the formulas used in this task look rather complex. However, only straightforward substitution and computation are required to evaluate them, for which a hand calculator should be found very helpful. If the size of the formula is of concern to a user, it is suggested he develop a table for operating on the various terms in a step-by-step procedure.

Procedure

1. Determine whether this compliance monitoring allocation procedure has been used previously. If it has, go to Step 3; otherwise go to Step 2.

2. No previous statistical computations or monitoring allocations have been made with this procedure. Therefore, the cumulative statistics desired in this task will be derived entirely from the "latest" (all previous) data, summarized in Table 4.5, Task [6].

   In columns 17-20 of Table 4.5 (Task 7), write "VALUES SAME AS FOR TASK [6]."

   Go to TASK [8].

3. Keep at hand the cumulative statistics (in Table 4.5, Task [7]) from the most recent, previous application of this allocation procedure. These previous cumulative statistics will be representative of all data preceding the latest monitoring data used in Tasks 2-5.

4. Select a value for the data discounting constant, h, for the region. This value will probably be in the range 1-3, but may be less than one. It effectively discounts past data (relative to new data) by limiting their sample size to h times the size of the new sample. It should therefore be made smaller for longer monitoring periods.

   Enter the chosen h value over Table 4.5.

NOTE: Once the user becomes familiar with the intent and effect of h, there is no reason why it could not be varied with the constituent, source, etc., treated, or with the age of the data.

5. Update the cumulative statistics for one constituent at one source as follows: Let a "~" indicate a new statistic for the latest monitoring period (taken from columns 13-16 of Table 4.5, Task 6); a "^" without a subscript will indicate cumulative statistics obtained from the previous application of this allocation procedure (see Step 3). A "^" with a subscript "1" indicates statistics updated for this application. Then:

   a. Compute the new cumulative estimate of the process mean,

$$\hat{\mu}_1 = \frac{\tilde{\eta}\tilde{\mu} + \hat{\eta}\hat{\mu}}{\tilde{\eta} + \hat{\eta}}$$

   b. Compute the new cumulative estimate of the process standard deviation

$$\hat{\sigma}_1 = \sqrt{\frac{\tilde{\nu}\tilde{\sigma}^2 + \tilde{\eta}\tilde{\mu}^2 + \hat{\nu}\hat{\sigma}^2 + \hat{\eta}\hat{\mu}^2 - (\tilde{\eta}+\hat{\eta})\hat{\mu}_1^2}{\tilde{\nu} + \hat{\nu} + 1}}$$

   c. Compute the new confidence parameter for the cumulative estimated mean,

$$\hat{\eta}_1 = \min\left[(\tilde{\eta} + \hat{\eta}),\ h\tilde{\eta}\right]$$

   d. Compute the new confidence parameter for the cumulative standard deviation

$$\hat{\nu}_1 = \min\left[(\tilde{\nu} + \hat{\nu} + 1),\ h\tilde{\nu}\right]$$

e. Enter the values of $\hat{\mu}_1$, $\hat{\sigma}_1$, $\hat{\eta}_1$ and $\hat{\nu}_1$ obtained in Steps 5a-d above, into columns 17-20 of Table 4.5, Task [7].

6. Repeat Step 5 for each additional constituent of interest at the same source.

7. Repeat Steps 5-6 for each source of interest in the surveillance region.

TASK [8]: DETERMINE PROBABILITY OF NON-VIOLATION PER CONSTITUENT

Objective

To obtain, for each constituent at each source, its probability of non-violation.

Output

A tabulation of the probabilities of non-violation in columns 21, 22, and 23 of Table 4.5.

Inputs

- Distribution types (from Table 4.1, Task [1])
- The cumulative statistics for each constituent at each source (from Table 4.5, Task [7]).
- The effluent standards (from Table 4.2, Task [2])

References

- [1], Appendix C, Sections C.2 and C.4

Procedure

For a given source, i, and a given constituent, j:

1. Determine from Table 4.5, Task [4] whether the constituent's distribution type is normal (N) or lognormal (L). If it is type -N, go to Step 2; if it is type -L, go to Step 5.

2. Check whether or not the constituent is pH. If it is pH, go to Step 3; otherwise go to Step 4.

3. <u>For pH only</u>. During this step, statistics for pH Max and pH Min (columns 17-20 of Table 4.5) will be combined to produce a probability of no violation of the overall pH standards. Note that quantities such as $\bar{\hat{\sigma}}$ (standard deviation for pH Max) and $\underline{\hat{\sigma}}$ (standard deviation for pH Min) can both be required in one calculation of joint probability. In this step, pH Min and pH Max should be treated as one constituent.

   Compare the estimated mean $\hat{\mu}$ (from column 17 of Table 4.5) with the standards for maximum and minimum pH, $\bar{S}$ and $\underline{S}$ respectively (from column 4 of Table 4.2), and proceed as follows:

   If $\hat{\mu} < \underline{S}$, go to Section (i)

   $\underline{S} < \hat{\mu} < \bar{S}$, go to Section (ii)

   $\hat{\mu} > \bar{S}$, go to Section (iii)

   (i) <u>For $\hat{\mu} < \underline{S}$ (pH only).</u>

   Compute the normalized effluent standard

$$x = \frac{\underline{S} - \hat{\mu}}{\bar{\hat{\sigma}}}$$

   where

   $\underline{S}$ = pH Min standard from column 4 of Table 4.2

   $\hat{\mu}$ = estimated mean from column 17 of Table 4.5

   $\bar{\hat{\sigma}}$ = cumulative estimate of the standard deviation of <u>pH Max</u>, from column 18 of Table 4.5, Task 7

Enter the result for x into column 21 of Table 4.5, Task [8].

Determine $\Phi(x)$ from Table 4.7. Enter the result into column 22 of Table 4.5, Task [8].

Determine the constituent (pH) probability of non-violation at this source

$$p_{ij} = \frac{1}{2} - \Phi(x)$$

Enter the result into column 23 of Table 4.5, Task [8].

Go to Step 6.

(ii) <u>For $\underline{S} < \hat{\mu} < \bar{S}$ (pH only).</u>

Compute the normalized upper and lower effleunt standards

$$\underline{x} = \frac{\hat{\mu} - \underline{S}}{\hat{\underline{\sigma}}}, \quad \bar{x} = \frac{\bar{S} - \hat{\mu}}{\hat{\bar{\sigma}}}$$

where

$\hat{\bar{\sigma}}$ is as above,

$\hat{\underline{\sigma}}$ = cumulative estimate of the standard deviation of pH Min, from column 18 of Table 4.5, Task [7].

Enter the results for $\underline{x}$ and $\bar{x}$ into column 21 of Table 4.5, Task [8], using a row for each and identifying which is which.

Determine $\Phi(\underline{x})$ and $\Phi(\bar{x})$ from Table 4.7. Enter the results into column 22 and the corresponding rows of Table 4.5, Task [8].

Determine the probability of non-violation of pH at this source (overall, not separately for pH Max and pH Min) from

$$p_{ij} = \Phi(\underline{x}) + \Phi(\bar{x})$$

Enter the result into column 23 of Table 4.5, Task [8].

Go to Step 6.

(iii) For $\hat{\mu} > \bar{S}$ (pH only).

Compute the normalized effluent standard

$$x = \frac{\hat{\mu} - \bar{S}}{\hat{\underline{\sigma}}}$$

where

$\hat{\underline{\sigma}}$ is as above.

Enter the result for x into column 21 of Table 4.5, Task [8].

Determine $\Phi(x)$ from Table 4.7. Enter the result into column 22 of Table 4.5, Task [8].

Determine the probability of non-violation of pH at this source

$$p_{ij} = \frac{1}{2} - \Phi(x)$$

Enter the result into column 23 of Table 4.5, Task [8].

Go to Step 6.

4. For Normal Distributions (except pH). Compute the normalized effluent standard

$$x = \frac{S - \hat{\mu}}{\hat{\sigma}}$$

where $\hat{\mu}$ and $\hat{\sigma}$ are taken from Table 4.5, Task [7], and S is taken from Table 4.2.

NOTE: $\hat{\mu}$ and $\hat{\sigma}$ must have the same units as S, so check column 3 of Table 4.5 against column 3 of Table 4.2.

Enter the result for x into column 21 of Table 4.5, Task [8].

Determine $\Phi(x)$ from Table 4.7. Enter the result into column 22 of Table 4.5, Task [8].

Determine the constituent probability of non-violation at this source

$$p_{ij} = \frac{1}{2} + \Phi(x)$$

Enter the result into column 23 of Table 4.5, Task [8].

Go to Step 6.

5. For Lognormal Distributions. Compute the normalized effluent standard

$$x = \frac{\log_{10} S - \hat{\mu}}{\hat{\sigma}}$$

where $\hat{\mu}$, $\hat{\sigma}$, and S are obtained in the same way as for Step 4, and the same check on their units should be made.

Enter the result for x into column 21 of Table 4.5, Task [8].

Determine $\Phi(x)$ from Table 4.7. Enter the result into column 22 of Table 4.5, Task [8].

Determine the constituent probability of non-violation at this source

$$p_{ij} = \frac{1}{2} + \Phi(x)$$

Enter the result into column 23 of Table 4.5, Task [8].

Go to Step 6.

6. Repeat Steps 1-5 (as appropriate) for each constituent j at the same source i.

7. Repeat Steps 1-6 (as appropriate) for each source i in the region.

Table 4.7 The Standard Normal Cumulative Distribution Function, Φ(x)

x	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.00000	.00399	.00798	.01197	.01595	.01994	.02392	.02790	.03188	.03586
0.1	.03983	.04380	.04776	.05172	.05567	.05962	.06356	.06749	.07142	.07535
0.2	.07926	.08317	.08706	.09095	.09483	.09871	.10257	.10642	.11026	.11409
0.3	.11791	.12172	.12552	.12930	.13307	.13683	.14058	.14431	.14803	.15173
0.4	.15542	.15910	.16276	.16640	.17003	.17364	.17724	.18082	.18439	.18793
0.5	.19146	.19497	.19487	.21094	.20540	.20884	.21226	.21566	.21904	.22240
0.6	.22575	.22907	.23237	.23565	.23891	.24215	.24537	.24857	.25175	.25490
0.7	.25804	.26115	.26424	.26730	.27035	.27337	.27637	.27935	.28230	.28524
0.8	.28814	.29103	.29389	.29673	.29955	.30234	.30511	.30785	.31057	.31327
0.9	.31594	.31859	.23121	.32381	.32639	.32894	.33147	.33398	.33646	.33891
1.0	.34134	.34375	.34614	.34850	.35083	.35314	.35543	.35769	.35993	.36214
1.1	.36433	.36650	.36864	.37076	.37286	.37493	.37698	.37900	.38100	.38298
1.2	.38493	.38686	.38877	.39065	.39251	.39435	.39617	.39796	.39973	.40147
1.3	.40320	.40490	.40658	.40824	.40988	.41149	.41309	.41466	.41621	.41774
1.4	.41924	.42073	.42220	.42364	.42507	.42647	.42786	.42922	.43056	.43189
1.5	.43319	.43448	.43574	.43699	.43822	.43943	.44062	.44179	.44295	.44408
1.6	.44520	.44630	.44738	.44845	.44950	.45053	.45154	.45254	.45352	.45449
1.7	.45543	.45637	.45728	.45818	.45907	.45994	.46080	.46164	.46246	.46327
1.8	.46407	.46485	.46562	.46638	.46712	.46784	.46856	.46926	.46995	.47062
1.9	.47128	.47193	.47257	.47320	.47381	.47441	.47500	.47558	.47615	.47670
2.0	.47725	.47778	.47831	.47882	.47932	.47982	.48030	.48077	.48124	.48169
2.1	.48214	.48257	.48300	.48341	.48382	.48422	.48461	.48500	.48537	.48574
2.2	.48610	.48645	.48679	.48713	.48745	.48778	.48809	.48840	.48870	.48899
2.3	.48928	.48956	.48983	.49010	.49036	.49061	.49086	.49111	.49134	.49158
2.4	.49180	.49202	.49224	.49245	.49266	.49286	.49305	.49324	.49343	.49361
2.5	.49379	.49396	.49413	.49430	.49446	.49461	.49477	.49492	.49506	.49420
2.6	.49534	.49547	.49560	.49573	.49585	.49598	.49609	.49621	.49632	.49643
2.7	.49653	.49664	.49674	.49683	.49693	.49702	.49711	.49720	.49728	.49736
2.8	.49744	.49752	.49760	.49767	.49774	.49781	.49788	.49795	.49801	.49807
2.9	.49813	.49819	.49825	.49831	.49836	.49841	.49846	.49851	.49856	.49861
3.0	.49865									
3.1	.49903									
3.2	.49931									
3.3	.49952									
3.4	.49966									
3.5	.49977									
3.6	.49984									
3.7	.49989									
3.8	.49993									
3.9	.49995									
4.0	.499968									
4.5	.499997									
5.0	.49999997									

Note: Φ(-x) = -Φ(x)

TASK [9]: DETERMINE PROBABILITY OF NON-VIOLATION PER SOURCE

Objective

To obtain, for each source, its probability of non-violation.

Output

A tabulation of the probabilities of non-violation in columns 1, 2, and 3 of Table 4.8.

Inputs

- The probabilities of non-violation for each constituent at each source (from Table 4.5, Task [8]).

References

- [1], Section VI.3
- [1], Appendix B
- [1], Section VIII.3

Procedure

For a given source, i:

1. Indicate the source number in column 1 of Table 4.8.
2. Select whether the various constituents at the source as a group are to be described as statistically dependent (SD) or statistically independent (SI). If SD, all the constituents

vary together in time in the same way (are completely correlated) maintaining the same ratios to one another; if SI, there is zero statistical correlation between their variations.

> NOTE: Since sufficient data to ascertain the exact correlation between various constituents are not readily available, one of the above extremes must be assumed. Appendix B of [1] suggests SD is less likely to be true than SI. Sensitivity studies (Section 8.3 of [1] revealed that in many cases the resulting compliance monitoring priorities will be insensitive to this selection; however, cases could clearly be devised where the priorities would be very sensitive to the correlation assumption.

Indicate the type of dependence (SD or SI) chosen in column 2 of Table 4.8, Task [9].

3. Accordingly, knowing the probabilities of non-violation, p_{ij}, of the various constituents at source i, from column 23 of Table 4.5, Task [8], determine the source probability of non-violation, P_i, from either a or b below.

   a. <u>If dependent (SD)</u>, then

   $$P_i = \min_j(p_{ij})$$

   i.e., P_i is the smallest of the constituent probabilities at this source i.

   b. <u>If independent (SI)</u>, then

   $$P_i = \prod_j p_{ij}$$

i.e., P_i is the product of all the constituent probabilities at this source i.

Enter the result for P_i into column 3 of Table 4.8, Task [9].

4. Repeat Steps 1-3 for each source i in the region.

Table 4.8 Ranges of Sampling Rates and Expected Extents of Undetected Violations

Source No. i	Constituent Interdependence SD/SI	TASK 9	TASK 10	TASK 11		TASK 12							
		Prob. of Non-violation P_i	Violation Weighting Factor c_i	Min. No. Samples Required ℓ_i	Max. No. Samples Allowed L_i	Alternative Expected Extents of Undetected Violations, $C_i(s_i)$, for Various Sampling Rates, s_i							
						$s_i=1$	2	3	4	5	6	7	8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)

Note: This table can be duplicated for use in the hand calculations.

TASK [10]: DETERMINE THE VIOLATION WEIGHTING FACTOR PER SOURCE

Objective

To obtain, for each source, a quantitative factor representing the significance attached to violations which might occur there.

Output

A tabulation of violation weighting factors in column 4 of Table 4.8. These factors are found by completing an interim Table 4.9.

Inputs

- Effluent standards, from Table 4.2, Task [2].
- Constituent distribution type (normal and lognormal), from Table 4.5, Task [4].
- Cumulative estimates of constituent means and standard deviations, from Table 4.5, Task [7].
- x (normalized effluent standard), $\Phi(x)$, and p (probability of non-violation) for each constituent at each source, from Table 4.5, Task [8].
- Receiving water concentration standards for the region and the constituents of interest (need depends upon options chosen).

References

- [1], Section VI - Introduction
- [1], Section 6.3
- [1], Appendix C, Section C.1

- [1], Appendix C, Section C.2.1
- [1], Section VI.2

Discussion

The purpose of the Violation Weighting Factor is to make available to the user alternative ways in which he can weight the allocation of his surveillance resources. This is done by weighting the violations.

One obvious way to do this is to weight them in proportion to the environmental damage caused in the receiving waters, through the use of environmental damage functions (damage as a function of concentration) for each constituent. While desirable, this approach necessitates much detailed computation, and has therefore, been excluded from this hand calculation procedure. It is included in the computerized procedure, however. (See Sections 5 and 7 of this handbook, and [1], Section 6.)

Two simpler alternative weighting methods have been included in this hand calculation approach. One gives all violations equal weights, the other weights them by the amount by which the standards are exceeded. With these simpler methods, the effects of the effluents on the receiving waters are still taken into account indirectly, since the effluent standards should have been set with these effects in mind.

Since the second simpler method contains a number of options and since different procedures are required for different constituents, it has been necessary to break this task up into numerous components, many of which may turn out to be skipped in any one application.

Procedure

1. For the entire region, select one of the following two alternative methods for assigning violation weighting factors:

   Method 1: Set all the weighting factors to be equal. This has the effect that the sampling frequency then depends only upon the probability of violation, Task [9].

   Method 2: Make the weighting factors increase with the extent by which the standard is exceeded. This has the effect of directing compliance monitoring towards those dischargers with the more serious violations of the standards, where conviction is easier.

   Indicate the method selected above Table 4.9.

   If using Method 1, go to Step 2; if Method 2, go to Step 3.

2. Method 1. For all sources, set the source violation weighting factor, $c_i = 1$.

   Enter this result into column 4 of Table 4.8, Task [10].

   Go to Task [11].

3. Method 2. Copy, in the same order, the information from columns 1 and 2 (Task [3]) and 10 (Task [4]) of Table 4.5 into columns 1, 2, and 3 respectively of Table 4.9.

4. For each constituent at one source, select a weighting factor function (WFF) type from the following three types, (A, B or C) and select a WFF coefficient k for each:

a. <u>WFF Type A</u>: (General, for Normal or Lognormal constituents, excepting pH)

$$W = \begin{cases} k(M-S), & M > S \\ 0, & M \leq S \end{cases}$$

where

M = constituent mass loading rate or concentration in effluent, depending upon the form of S

S = applicable effluent standard for M

k = a WFF coefficient (see below)

With this type of WFF, the weighting factor, W, for a constituent is proportional to the amount by which M exceeds its standard.

The coefficient, k, may be chosen to specify the principle upon which the WFF is preferred to operate, such as:

1. $k \propto \frac{1}{\theta}$ for each constituent

   where θ is the receiving water concentration standard for the constituent. This will result in, W, varying as the <u>magnitude</u> of the exceedance.

   In the case of BOD, assume the in-stream standard to be as follows:

θ	Type of Streams
15.0	Fast flowing, shallow streams
10.0	Slow flowing, shallow streams and fast flowing, medium to deep streams
5.0	Slow flowing, deep rivers and estuaries

2. $k \propto \frac{1}{S}$ for each constituent at each source

This will result in W varying as the number of times by which the standard is exceeded.

The difference between these two alternatives for k is illustrated in Table 4.10. Alternative (1) is seen to penalize the larger dischargers, and is therefore, generally preferred; alternative (2) penalizes the smaller dischargers.

k may also be weighted to emphasize concern for any particular constituent, regardless of its source.

b. WFF Type B: (For Lognormal constituents only, e.g., coliforms)

The concentrations (and hence loading rates) of certain constituents, particularly coliform bacteria, vary so rapidly that their orders of magnitude are of more significance than their actual size. As a result, their type of frequency distribution in Task [1], will usually be lognormal (specifically required for coliforms), and the following Type B WFF is a more appropriate measure of standard exceedance.

$$W = \begin{cases} k(\log M - \log S), & M > S \\ 0, & M \le S \end{cases}$$

Here, k, would be either (1) $1/\log \theta$, or (2) $1/\log S$. W, M, S, and k are as defined in Subsection a above.

NOTE: A lognormal (L) distribution in Task [1], Table 4.1, is specifically required for constituents to be assigned a Type B WFF.

c. WFF Type C: (for pH only)

For pH, the logorithm of the hydrogen ion concentration has already been taken, and the possible range of values is very limited. With this constituent, therefore, the weighting factor is the amount by which the pH standard is exceeded (in either direction, since there are both upper and lower standards).

$$W = \begin{cases} \underline{k}(\underline{S} - M), & M < \underline{S} \\ 0, & M \geq \underline{S} \end{cases}$$

$$\bar{W} = \begin{cases} \bar{k}(M - \bar{S}), & M > \bar{S} \\ 0, & M \leq S \end{cases}$$

where

$\underline{S}$ = minimum pH standard

$\bar{S}$ = maximum pH standard

W = weighting factor for pH (Min or Max)

and commonly, $\bar{k} = \underline{k} \approx 1$.

Record the type of WFF selected for this constituent in column 4 of Table 4.9. If the selection is Type B, check that the corresponding distribution is lognormal (Type "L" in column 3 of Table 4.9) as is required. Record the magnitude chosen for the WFF coefficient, k, (or $\underline{k}$ and $\bar{k}$, identifying which is which) in column 5 of Table 4.9.

5. Repeat Step 4 for each constituent at the same source.

6. For each constituent at the same source, compute the expected extent of violation, D, from the appropriate section below,

depending upon the WFF type as follows:

For WFF Type A, go to Section a

For WFF Type B, go to Section b

For WFF Type C, go to Section c

a. For WFF Type A: $(W = k[M-S])$

If the constituent distribution is normal (N) (from column 3 of Table 4.9), go to Subsection (1); if lognormal (L), go to Subsection (2).

1. For Normal Distribution $(W = k[M-S])$

$$D = k\hat{\sigma}\left\{f(x) - x\ [1-p]\right\}$$

where

x = probability of non-violation per constituent, from column 23 of Table 4.5, Task [8]

$\hat{\sigma}$ = cumulative estimate of the standard deviation, from column 18 of Table 4.5, Task [7]

$f(x)$ is given by Table 4.11

k is recorded in column 5 of Table 4.9

2. For Lognormal Distribution $(W = k[M-S])$

$$D = k \exp\left(A\hat{\mu} + \frac{A^2\hat{\sigma}^2}{2}\right)$$

$$\left\{\frac{1}{2} - \Phi\left(\frac{\log S - [\hat{\mu}+A\hat{\sigma}^2]}{\hat{\sigma}}\right)\right\} - kS[1-p]$$

where

p, $\hat{\sigma}$, and k are as above, and

$\hat{\mu}$ = cumulative estimate of the mean from column 17 of Table 4.5, Task [7]

S = effluent standard, from Table 4.2, Task [2]

log S = $\log_{10} S$

A = ln10 = 2.3026

$\Phi(x)$ is given by Table 4.7

Go to Step 7.

b. <u>For WFF Type B</u> (W = k[log M-log S]

NOTE: This may be used only for constituents with distribution type L in Table 4.5, Task [3].

$$D = k\hat{\sigma}\left\{f(x) - x[1-p]\right\}$$

where

x, k, $\hat{\sigma}$, f and p are as above

Go to Step 7.

c. <u>For WFF Type C</u> ($\underline{W} = \underline{k}[S-M]$, $\bar{W} = \bar{k}[M-\bar{S}]$

For pH only, compare the estimated mean, $\hat{\mu}$ (from column 17 of Table 4.5, with the standards for maximum and minimum and minimum pH, $\bar{S}$ and $\underline{S}$ respectively (from column 4 of Table 4.2), and proceed as follows: if

$\hat{\mu} < \underline{S}$, go to Subsection (i).

$\underline{S} \leq \hat{\mu} \leq \bar{S}$, go to Subsection (ii).

$\hat{\mu} > \bar{S}$, go to Subsection (iii).

(i) <u>For $\hat{\mu} < \underline{S}$ (pH only)</u>

$$D = \underline{k}\left\{\frac{(\hat{\underline{\sigma}} - \bar{\hat{\sigma}})}{2\pi} + \frac{\underline{S} - \hat{\mu}}{2} + \bar{\hat{\sigma}}\left[f(x) + x\Phi(x)\right]\right\}$$

where

x = normalized effluent standard from column 21 of Table 4.5, Task [8]

$\hat{\underline{\sigma}}$ = cumulative estimate of the standard deviation of pH Min, from column 18 of Table 4.5, Task [6]

$\bar{\hat{\sigma}}$ = cumulative estimate of the standard deviation of pH Max, from same location

$\Phi(x)$ is obtained from column 22 of Table 4.5, Task [8]

$f(x)$ is given by Table 4.11

$\underline{k}$ is recorded in column 5 of Table 4.9

Go to Step 7.

(ii) <u>For $\underline{S} \leq \hat{\mu} \leq \underline{S}$ (pH only)</u>

$$D = \bar{k}\bar{\hat{\sigma}}\left\{f(\bar{x}) + \bar{x}[0.5-\Phi(\bar{x})]\right\} + \underline{k}\hat{\underline{\sigma}}\left\{f(\underline{x}) + \underline{x}[0.5-\Phi(\underline{x})]\right\}$$

where

$\hat{\underline{\sigma}}$, $\bar{\hat{\sigma}}$, and f are as above, and

$\bar{x}$ and $\underline{x}$ are obtained from column 21 of Table 4.5, Task [8]

$\Phi(\bar{x})$ and $\Phi(\underline{x})$ are obtained from column 22 of Table 4.5, Task [8]

$\bar{k}$ and $\underline{k}$ are recorded in column 5 of Table 4.9

Go to Step 7.

(iii) <u>For $\hat{\mu} > \bar{S}$</u> (pH only)

$$D = \bar{k}\left\{\frac{\bar{\hat{\sigma}} \quad \underline{\hat{\sigma}}}{2\pi} + \frac{\hat{\mu} - \bar{S}}{2} + \underline{\hat{\sigma}}[f(x) + x\Phi(x)]\right\}$$

where

$\underline{\hat{\sigma}}$, $\bar{\hat{\sigma}}$, and f are as above, and

x and $\Phi(x)$ are obtained from columns 21 and 22 of Table 4.5, Task [8]

$\bar{k}$ is recorded in column 5 of Table 4.9

Go to Step 7.

7. Record the value of D (just obtained in Step 6) in column 6 of Table 4.9.

8. Repeat Steps 6-7 for all constituents of interest at the same source.

9. Of the expected extents of violation, D, for the various constituents at this same source i, find the largest, to be the source violation weighting factor, c_i, i.e.,

$$c_i = \max(D)$$

Enter the result into column 4 of Table 4.8, Task [10].

10. Repeat Steps 4-9 (Method 2) for each source of interest in the region.

Table 4.9 Record of Task 10 Options and Calculations

Violation weighting factor assignment method (I or II):____________

Source No. i	Constituent Name	Distri-bution L or N	Type of WFF A/B/C	WFF Coefficient k	Expected Extent of Violation D
(1)	(2)	(3)	(4)	(5)	(6)

Note: This table can be duplicated for use in the hand calculations.

Table 4.10 Examples of Alternative Type of Weighting Factor Functions (WFF)
(Comparison for the same constituent, θ = 100)

		Source 1	Source 2	Source 3
Let S	=	100	10,000	10,000
Let M	=	600	10,500	12,000
Then (M-S)	=	500	500	2,000
(1) $k = 1/\theta$				
$W = (M-S)/\theta$	=	5	5	20
(2) $k = 1/S$				
$W = (M-S)/S$	=	5	0.05	0.2

Table 4.11 The Standard Normal Probability Density Function, f(x)

± x	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.3989	.3989	.3989	.3988	.3986	.3984	.3982	.3980	.3977	.3973
0.1	.3970	.3965	.3961	.3956	.3951	.3945	.3939	.3932	.3925	.3918
0.2	.3910	.3902	.3894	.3885	.3876	.3867	.3857	.3847	.3836	.3825
0.3	.3814	.3802	.3790	.3778	.3765	.3752	.3739	.3726	.3712	.3697
0.4	.3683	.3668	.3653	.3637	.3621	.3605	.3589	.3572	.3555	.3538
0.5	.3521	.3503	.3485	.3467	.3448	.3429	.4410	.3391	.3372	.3352
0.6	.3332	.3312	.3292	.3271	.3251	.3230	.3209	.3187	.3166	.3144
0.7	.3123	.3101	.3079	.3056	.3034	.3011	.2989	.2966	.2943	.2920
0.8	.2897	.2874	.2850	.2827	.2803	.2780	.2756	.2732	.2709	.2685
1.0	.2420	.2396	.2371	.2347	.2323	.2299	.2275	.2251	.2227	.2203
1.1	.2179	.2155	.2131	.2107	.2083	.2059	.2036	.2012	.1989	.1965
1.2	.1942	.1919	.1895	.1872	.1849	.1826	.1804	.1781	.1758	.1736
1.3	.1714	.1691	.1669	.1647	.1626	.1604	.1582	.1561	.1539	.1518
1.4	.1497	.1476	.1456	.1435	.1415	.1394	.1374	.1354	.1334	.1315
1.5	.1295	.1276	.1257	.1238	.1219	.1200	.1182	.1163	.1145	.1127
1.6	.1109	.1092	.1074	.1057	.1040	.1023	.1006	.0989	.0973	.0957
1.7	.0940	.0925	.0909	.0893	.0878	.0863	.0848	.0883	.0818	.0804
1.8	.0790	.0775	.0761	.0748	.0734	.0721	.0707	.0694	.0681	.0669
1.9	.0656	.0644	.0632	.0620	.0608	.0596	.0584	.0573	.0562	.0551
2.0	.0540	.0529	.0519	.0508	.0498	.0488	.0478	.0468	.0459	.0449
2.1	.0440	.0431	.0422	.0413	.0404	.0396	.0387	.0379	.0371	.0363
2.2	.0355	.0347	.0339	.0332	.0325	.0317	.0310	.0303	.0297	.0290
2.3	.0283	.0277	.0270	.0264	.0258	.0252	.0246	.0241	.0235	.0229
2.4	.0224	.0219	.0213	.0208	.0203	.0198	.0194	.0189	.0184	.0180
2.5	.0175	.0171	.0167	.0163	.0158	.0154	.0151	.0147	.0143	.0139
2.6	.0136	.0132	.0129	.0126	.0122	.0119	.0116	.0113	.0110	.0107
2.7	.0104	.0101	.0099	.0096	.0093	.0091	.0088	.0086	.0084	.0081
2.8	.0079	.0077	.0075	.0073	.0071	.0069	.0064	.0065	.0063	.0061
2.9	.0060	.0058	.0057	.0055	.0053	.0051	.0050	.0048	.0047	.0046
3.0	.0044	.0043	.0042	.0040	.0039	.0038	.0037	.0036	.0035	.0034
3.1	.0033	.0032	.0031	.0030	.0039	.0028	.0027	.0026	.0025	.0025
3.2	.0024	.0023	.0022	.0022	.0021	.0020	.0020	.0019	.0018	.0018
3.3	.0017	.0017	.0016	.0016	.0015	.0015	.0014	.0014	.0013	.0013
3.4	.0012	.0012	.0012	.0011	.0011	.0010	.0010	.0010	.0009	.0009
3.5	.0009	.0008	.0008	.0008	.0008	.0007	.0007	.0007	.0007	.0006
3.6	.0006	.0006	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0004
3.7	.0004	.0004	.0004	.0004	.0004	.0004	.0003	.0003	.0003	.0003
3.8	.0003	.0003	.0003	.0003	.0003	.0002	.0002	.0002	.0002	.0002
3.9	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0001	.0001

Note: f(-x) = f(x)

TASK [11]: ESTABLISH LIMITING SAMPLING RATES

Objective

To establish limits on the surveillance sampling rate desired at each source.

Output

A tabulation of the minimum and maximum number of samples required at each source listed in columns 5 and 6 of Table 4.8.

Inputs

Information on:

- Past sampling rates
- Established policy (if any), on minimum and maximum sampling rates
- Suspected trouble spots, based on self-monitoring or ambient receiving quality data
- Length of planned monitoring period

References

- [1], Section VII.1

Procedure

Based on the information provided by the inputs, assign a mininum and maximum number of samples required at each source. Enter these into columns 5 and 6 of Table 4.8.

TASK 12: DETERMINE ALTERNATIVE EXPECTED EXTENTS OF UNDETECTED VIOLATIONS

Objective

To obtain, for each source, expected extents of undetected violations for various sampling rates.

Output

A list of expected extents of undetected violations for each candidate sampling rate recorded in columns 7-14 of Table 4.8.

Inputs

- Minimum and maximum sampling rates (from Table 4.8, Task 11)
- Violation weighting factors (from Table 4.8, Task 10)
- Probabilities of non-violation (from Table 4.8, Task 9)

References

- [1], Section VI.3

Procedure

1. For each source i:

   In Table 4.8, Task 12, blank out spaces under s_i values less than ℓ_i or greater than L_i.

   NOTE: The user can extend the table for larger values of s_i, if necessary. The sampling rate limits, ℓ_i and L_i, are given in columns 5 and 6 of Table 4.8. If ℓ_i=0, no column is needed for s_i=0 because this eventually is considered later.

2. For a given source i:

   a. For the lowest s_i value, compute the corresponding expected extent of undetected violation, C_i, from

   $$C_i(s_i) = c_i p_i^{s_i}$$

   where

   p_i and c_i are taken from columns 3 and 4 (Tasks [9] and [10] of Table 4.8

   Enter the result in Table 4.8 appropriate s_i column under Task [12].

   b. For the next s_i value, compute C_i by multiplying the result of Step 2a again by p_i. Enter the result in Table 4.8, next column under Task [12].

   c. Repeat Step 2b for all s_i values of interest, i.e., not blanked out.

3. Repeat Step 2 for each source in the region.

TASK 13: DETERMINE COST TO SAMPLE EACH SOURCE ONCE

Objective

To obtain, for each source, the total cost of collecting, analyzing and reporting a surveillance monitoring sample.

Output

A list of component costs and a total sampling cost for each source. Output is recorded in Table 4.12.

Inputs

- Man-hours required to sample each source and process resulting data
- Unit cost of labor
- Travel distance to sample each source
- Unit cost of field transportation
- Cost of expended field equipment
- Laboratory analysis charge for each constituent of interest

References

- [1], Section IX.1 (Table 9.2)
- [1], Appendix D

Procedure

1. Enter names of constituents to be checked in headings of columns 10 through 15 in Table 4.12.

   NOTE: The user can increase the number of these columns as required by his list of constituents

2. For a given source i:

   a. Enter the above input information (input items a-e) into columns 2-5 and 8 respectively of Table 4.12.

3. Multiply contents of column 2 by column 3, and enter results in column 6 of Table 4.12.

4. Multiply column 4 by column 5, and enter the result in column 7 of Table 4.12.

5. Enter in columns 10-15 of Table 4.12, where appropriate, the constituent analysis cost for each constituent to be analyzed at an individual source. The constituents to be analyzed at any given source are listed in Table 4.5, Task [3].

   NOTE: The analysis costs will probably be quite small by comparison with the cost of the man-hours and travel, columns 6 and 7.

6. Add the contents of columns 6-8 to obtain total cost per sample. Enter the results in column 9. Add the contents of columns 9-14 in Table 4.12, to obtain the total cost of a sample at an individual source; enter the result in the last column.

7. Repeat Steps 2-6 for each source of interest in the region.

Table 4.12 Resources Needed to Monitor Each Source Once

Source No. i	Man Hours Per Sample	Cost Per Man Hours	Travel Miles Per Sample	Cost Per Mile	Per Sample Cost of:				Laboratory Analysis Charge/Constituent (add constituent names)						Total Cost
					Man Hours	Travel	Expend. Equip't.	Total Per Sample Cost	#1	#2	#3	#4	#5	#6	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	

Note: This table can be duplicated for use in the hand calculations.

TASK [14]: TABULATE MARGINAL RETURNS

Objective

To obtain, for each source, the marginal return from each additional surveillance monitoring sample collected there.

Output

A tabulation of marginal returns for each sample to be taken at each source. Output is recorded in Table 4.13.

Inputs

- Alternative expected extents of undetected violations, C_i, from Table 4.8, Task [12].
- Costs to sample each source once, r_i, from Table 4.12, Task [13].

References

- [1], Section VII.2

Discussion

The marginal return, μ_i, at a source i, varies with the sampling rate, s_i, there. As the source is sampled more frequently (s_i increases), the expected extent of undetected violations, C_i, decreases. Therefore, the marginal return for a given sample, $\mu_i(s_i)$, is defined to be the incremental decrease in C_i, resulting from taking that single sample, divided by the cost, r_i, to take that sample. The cost, r_i, includes the analysis of all constituents of interest in the sample.

Procedure

1. Enter the source numbers into Table 4.13, and for each source blank out spaces under μ_i which correspond to those blanked out in Table 3.8 under Task [12]. In addition, for each source also blank out in Table 4.13, the μ_i space under, $s_i = \ell_i$, where ℓ_i is given in column 5 of Table 4.8, Task [11].

2. For a chosen source, i, if the marginal return, μ_i, for sample $s_i = 1$, *has been blanked out, skip to Step 4, otherwise proceed* to Step 3.

3. For the same source, i, and for sample number 1 ($s_i = 1$), compute the marginal return

$$\mu_i(1) = \frac{c_i - C_i(1)}{r_i}$$

where c_i and $C_i(1)$ are taken from columns 4 and 7 of Table 4.8, and r_i is taken from Table 4.12. Enter $\mu_i(1)$ into the second column of Table 4.13.

4. For the next sample number, s_i, at the same source, if μ_i has been blanked out (i.e., if $s_i \leq \ell_i$), then increase s_i by 1 and restart this Step 4. Otherwise, compute the marginal return

$$\mu_i(s_i) = \frac{C_i(s_i-1) - C_i(s_i)}{r_i}$$

where the C's are taken from Table 4.8 and r_i is taken from Table 4.12. Enter the result, $\mu_i(s_i)$, into the appropriate s_i column of Table 4.13.

5. Repeat Step 4 for each subsequent sample, s_i, not blanked out (i.e., $s_i \leq L_i$) in Table 4.13.

NOTE: The user can extend the table for larger values of s_i, if necessitated by an extended Table 4.8.

6. Repeat Steps 2-5 for each source in Table 4.13.

Table 4.13 Marginal Returns for Each Source

Source No. i	Marginal return, $\mu_i(s_i)$, from one additional sample, number s_i							
	$s_i=1$	2	3	4	5	6	7	8

Note: This table can be duplicated for use in the hand calculations.

TASK [15]: PRESELECT INITIALLY ALLOCATED SAMPLES

Objective

To preselect those samples needed to meet the previously established minimum requirements for each source.

Output

A listing of the samples required to meet minimum requirements, with the resulting degrees of undetected violation and monitoring resources required. Table 4.14 is utilized.

Inputs

- Minimum sampling rates, ℓ_i, desired at each source (from Table 4.8, Task [11]).
- Violation weighting functions, c_i, for all sources (from Table 4.8, Task [10]).
- Expected extents of undetected violations, $C_i(s_i)$, for all sources (from Table 4.8, Task [12]).
- Resources needed to monitor each source once, r_i, for all sources (from Table 4.12, Task [13]).

Discussion

Since the initially allocated samples treated in this task must be included to meet the minimum requirements established in Task [11], no choice may be exercised as to whether or not they may be included. Therefore, their marginal returns and ordering are of no consequence, and so these computations have been omitted from this task to save labor.

Procedure

1. Complete the first line of Table 4.14 for the case when no surveillance monitoring samples would be collected. In that case

$$\sum C_i = \Delta C_i = \sum c_i$$

Obtain this quantity $\sum c_i$), by summing all the entries in column 4 of Table 4.8. Enter the result in both columns 5 and 6, row 1, of Table 4.14. Enter a "0" in column 8, row 1, of Table 4.14.

2. Find the first source in Table 4.8 with $\ell_i > 0$. If all $\ell_i = 0$, go to Task 16. In order to minimize the computations, all the ℓ_i samples required as a minimum at that source, will be treated together as follows:

   a. Enter a "0" for the priority order in column 1, row 2, Table 4.14.

   b. Enter the source number, i, in column 2, row 2.

   c. Enter the range of the number of samples, "1 to ℓ_i" where the value of ℓ_i is indicated, in column 3. Thus, if $\ell_i = 3$, we will write: 1 to 3.

   d. Write a dash for the marginal return in column 4 (since this quantity is not required subsequently).

   e. Compute ΔC_i for the ℓ_i samples from

$$\Delta C_i = C_i(\ell_i) - c_i$$

where $C_i(\ell_i)$ is the first entry for source, i, under Task [12] in Table 4.8, and c_i is obtained from column 4 of Table 4.8. Note that ΔC_i will be negative. Enter the result, ΔC_i, into column 5.

f. Add the latest $\Delta C_i(s_i)$ (from Step 2e above) into the cumulative total, $\sum C_i(s_i)$ in the previous row. Note that $\sum C_i(s_i)$ should decrease, since the $\Delta C_i(s_i)$ being added in is negative. Enter the new cumulative total in column 6.

g. Multiply the number of samples, ℓ_i, (see Step 2c) by the cost per sample, r_i, (obtained from Table 4.10) and enter the result in column 7.

h. Add the latest column 7 entry (Step 2g above) to the previous total in column 8, and enter the resulting new total in column 8.

3. Repeat Step 2 for each subsequent source in Table 4.8, with $\ell_i > 0$, entering the results into subsequent rows of Table 4.14.

4. Draw a line across Table 4.14, below the last entry, to indicate the end of Task [15].

Table 4.14 Sampling Priority List

Priority Order	Source No. i	Sample No.(s) s_i	Marginal Return $\mu_i(s_i)$	Degree of Undetected Violation: Incremental $\Delta C_i(s_i)$	Degree of Undetected Violation: Cumulative $\Sigma C_i(s_i)$	Monitoring Resources Required: Per Sample(s) r_i	Monitoring Resources Required: Cumulative $R=\Sigma r_i$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Note: This table can be duplicated for use in the hand calculations.

TASK 16: PRIORITY ORDER MARGINAL RETURNS

Objective

To order the marginal returns from all optional samples at all sources, in terms of their sizes.

Output

An ordered tabulation of marginal returns from each optional sample collected at each source, together with the resulting degrees of undetected violation and monitoring resources required. Output is recorded in Table 4.14.

Discussion

The term "optional sample" here refers to samples over and above the minimum requirement and below the maximum limit (both established in Task 11), and therefore, in the range where choice may be exercised.

Inputs

- The results of the preselection of the initially allocated samples (from Table 4.14, Task 15).
- The tabulation of marginal returns (not ordered) obtained in Task 13, Table 4.13.
- Resources needed to monitor each source once, r_i, for all sources (from Table 4.12, Task 13).

Procedure

1.

a. Locate the largest marginal return, $\mu_i(s_i)$, in Table 4.13. Enter its value into column 4 of the next available now in Table 4.14. Enter its corresponding source number, i, and sample number, s_i, into columns 2 and 3 of Table 4.14. Enter its priority order, "1", into column 1. Check it off in Table 4.13 as having been extracted.

b. Enter the cost, r_i, for this single sample (obtained from Table 4.12) into column 7 of the same row of Table 4.14.

c. Add the latest column 7, cost entry (Step 1b above) to the previous total cost in column 8, and enter the resulting new total cost in column 8.

d. Compute the incremental degree of undetected violation from either

(i) $\Delta C_i(s_i) = C_i(s_i) - C_i(s_i - 1)$

where the $C_i(s_i)$ are obtained from Table 4.8, Task 12 and where $C_i(0)$ is defined to be, c_i, (also from Table 4.8) or from

(ii) $\Delta C_i(s_i) = -r_i \mu_i(s_i)$

where the r_i and μ_i are obtained from Steps 1b and 1a above columns 7 and 4 of Table 4.14. Enter the result into column 5.

NOTE: $\Delta C_i(s_i)$ will be negative

e. Add the $\Delta C_i(s_i)$ from Step 1d above, to the cumulative total $\sum C_i(s_i)$ in column 6 of the previous now. Note that $\sum C_i(s_i)$ should decrease, since the $\Delta C_i(s_i)$ being added in is negative. Enter the new cumulative total into column 6.

2. Repeat Step 1 for the next largest marginal return, $\mu_i(s_i)$, in Table 4.13, increasing its priority order (column 1 of Table 4.14) by 1.

3. Repeat Step 2 until all the entries in Table 4.13 have been extracted, and entered in order in Table 4.14.

TASK 17: DETERMINE SAMPLING RATES

Objective

To determine and summarize for the chosen constraint, the sampling frequency for each source.

Output

A source-by-source tabulation of sampling rates, monitoring resources required, and resulting degrees of undetected violations.

Inputs

- Limiting sampling rates (from Table 4.8, Task [11]).
- Cumulative degrees of undetected violation and monitoring resources required for individual samples, rank ordered by marginal return (from Table 4.14, Task [16]).
- Resources required to monitor each source once (from Table 4.12, Task [13]).
- Degrees of undetected violation per source for various alternative sampling rates (from Table 4.8, Task [12]).
- The constraint on the surveillance monitoring funds available, or on the maximum acceptable degree of undetected violation.

Discussion

The two principal constraints most likely to limit the total number of surveillance samples to be collected during a monitoring period are: (i) the amount of funds (resources) available for surveillance monitoring, or (ii) the maximum acceptable degree of undetected violation (compare with column 6 of Table 4.14). The former obviously increases with more sampling, while a decrease in the latter requires more samples to be taken.

It is expected that the dollar constraint (i) will most commonly be used, particularly at first when the users of this allocation procedure are not very familiar with the concept of "degree of undetected violation." However, as familiarity with both this concept and the numbers which measure it grows, it is quite possible that improved effluent control by dischargers could lead to a type (ii) constraint requiring fewer surveillance samples than type (i).

When a compliance sample detects a violation during a monitoring period, the compliance monitoring program could be said (depending upon the extent of the violation) to have "achieved its objective" at the source in question. If further samples had been scheduled at the same source during the monitoring period, these may now be deemed unnecessary, depending upon the surveillance agency's policy. The funds from these saved samples, may be applied to samples at sources next in priority order (see Table 4.14) if the agency can reschedule in mid-period, or they may be saved for use in the following monitoring period.

<u>Procedure</u>

1. Copy the contents of columns 1, 5, and 6 of Table 4.8 into the first three columns of Table 4.15.

2. Determine which of the following two constraints will limit the total number of samples to be collected in the proposed monitoring (see Discussion above) period:

(i) The maximum monitoring resources (funds) available; or

(ii) the maximum acceptable degree of undetected violation.

3. Locate the position of the chosen constraint in relation to the contents of column 6 or 8 of Table 4.14, whichever is appropriate.

   Draw a second line across Table 4.14 immediately below the largest entry smaller than the constraint. (To meet the constraint, the samples below this line cannot or need not be taken.)

4. From the portion of Table 4.14 above, the cutoff line drawn in Step 3, determine the total number of samples to be taken at each source, and enter the results in column 4 of Table 4.15.

5. Determine the monitoring resources needed per source by (i) adding the individual resources, r_i, for that source listed in column 7 of Table 4.14 above the cutoff line, or by (ii) multiplying the number of times to be sampled (column 4 of Table 4.15) by the resources, r_i, required to monitor each source once (last column of Table 4.12). Enter the result for each source in column 5 of Table 4.15.

6. Determine the degree of undetected violations per source by finding the value of $C_i(s_i)$ in Table 4.8, Task [12], which corresponds to the sampling rate, s_i, specified in Table 4.15, column 4. If $s_i = 0$, for any source enter C_i, because $C(0)=C_i$. Enter the result for each source into the last column of Table 4.15.

7. Add up all the entries in columns 5 and 6 of Table 4.15 to obtain the two respective totals and enter them below those columns.

NOTE: The appropriate total should meet the constraint specified above Table 4.15.

Table 4.15 Sampling Rates

Maximum monitoring resources available, $\bar{R}$ = $______

Maximum acceptable degree of undetected violations = ______

Source No. i	Min. No. Samples Required ℓ_i	Max. No. Samples Allowed L_i	No. of Times to be Sampled s_i	Monitoring Resources Needed $	Degree of Undetected Violations $C_i(s_i)$
(1)	(2)	(3)	(4)	(5)	(6)
			Totals:		

Note: This table can be duplicated for use in the hand calculations.

TASK [18]: DEVELOP MONITORING SCHEDULE (Discussion)

Objective

To develop a time schedule for monitoring the sources to be sampled during the forthcoming monitoring period.

Output

A surveillance monitoring time schedule, indicating on which days which sources are to be sampled.

Inputs

The sampling rate determined for each source in Task [17], Table 4.15.

Discussion

The scheduling of the sampling depends on a number of factors which are difficult to quantify in an optimization framework, such as: the spatial location of the various effluent sources, the size of the monitoring agency's jurisdiction, the availability of personnel, and the desire for "random" timing within the monitoring period, to combat possible "gamesmanship" on the part of the dischargers. This scheduling must, therefore, be the responsibility of the surveillance agency; it is not part of the resource allocation procedure provided in this handbook.

SECTION 5

USER MANUAL FOR COMPUTER CALCULATION

5.1 MODE OF OPERATION

Purpose

The purpose of the Effluent Monitoring Program (EFFMON) is to aid the user in scheduling future compliance monitoring visits to effluent sources. The user of the program may specify up to 30 effluent sources which are of interest, inputting information about the sources, including up to two years of past self-monitoring and compliance monitoring data. The program uses this information to compute a "priority allocation", a listing of the effluent sources showing how often each should be sampled during the upcoming monitoring period in order to minimize environmental damage. The larger the amount of past effluent data which is input, the better EFFMON will perform. Likewise, the quality of information is also important.

Solution Technique and Model Usage

The algorithms used by EFFMON in the calculation of a priority allocation are described in detail in Section 2 and also in Reference [1]. Briefly, the procedure is as follows: for each distinct constituent of each effluent source, all given self-monitoring and compliance monitoring data are combined to yield overall estimates of the mean and standard deviation of the constituent loading. Using these statistics, and the effluent standard, a probability of not violating the standard is found for the constituent. From the constituent probabilities, a source probability of no violation is calculated.

Next, an expected damage of an undetected violation is calculated for each constituent of a source, which leads to the expected damage for that source. Expected damage is defined as the average environmental damage expected to be caused by the effluent; it is determined on the basis of damage functions (see Section 2.4, Criterion #2 for details). These damage functions relate environmental damage to constituent concentrations, and consist of six "breakpoints" (11 in the case of pH) which are assigned increasingly larger "damage values" as shown in Table 2.4 and Figure 2.3. Damage values are numerical values which indicate the relative environmental damage caused (i.e., 0, 2, 4, 6, 8 and 10) corresponding to "none", "excellent", "acceptable", "slightly polluted", "polluted", and "heavily polluted". The breakpoints are the associated levels of concentration for the constituent. The specific damage values and breakpoints used influence the determination of expected damages and hence, the priority allocation. The user can rely on the default values for these functions present in EFFMON, but should consult Section 3.1 for advice on inputting his own values. The user can optionally set all expected damages at 1.0 and compute the priority allocation solely on the basis of probabilities of no violation (as discussed in Section 2.4, Criterion #1) and monitoring costs.

Finally, the program uses the information about expected damage and probability of no violation for each source to compute monitoring allocations for all effluent sources. Other factors important in determining the allocation which the user has input control are the monitoring costs. Each source has a resource cost (cost to monitor) which is determined by adding a laboratory cost for each constituent of the source onto a base cost determined by the number of pipes at the source. Default values are present in the program, but these costs are highly variable, and the user should input his own (see Section 3.1).

As has been pointed out, the user has various ways of influencing the program results given a particular set of monitoring data. There are also other constants which affect the final results (i.e., the constants used in the combination of data to find the mean and standard deviation of each constituent). All such influential variables are marked by a "+" in the input description, Table 5.1, and the user is referred to Section 3.1 for assistance in determing input values.

The program works in standard units which are the same as those listed in Table 5.4. (Table 5.4 lists acceptable input units for compliance monitoring data and effluent standards.) Data which is input in other units is converted by the program.

General Model Inputs

The information which the user must have to input to the program consists of:

1. A list of effluent sources to be considered and the minimum and maximum number of samples for each, for the next monitoring period. If the user specifies "zero" as the minimum, and a large value as the maximum, the program makes the most optional allocation; however, the user may need to meet certain constraints and thus, specify other values.

2. A list of the discharge pipes present at each effluent source and the constituents to be considered from each pipe.

3. A decision for each constituent as to whether that constituent loading is distributed normally or lognormally. Note that pH is always considered to be distributed normally whereas coliforms are always considered to be lognormal (see Section 4, Task 1 for assistance in making decisions on other constituents).

4. A decision for each effluent source as to whether or not the various constituent loadings are correlated (see Section 3.1).

5. The stream flow immediately upstream of each effluent source.

6. Self-monitoring data (effluent measurements taken by the discharger and sent to the monitoring agency) for each constituent and flows for each pipe.

7. Any compliance monitoring data (measurements taken by the monitoring agency) which is available for the dischargers.

8. An effluent standard for each constituent (of each pipe of each effluent source) except DO. The constituent DO is different from all others in that it is only used to aid in calculating expected damage due to BOD_5 loads. No expected damages or violation probabilities are calculated for DO itself. Therefore, whenever possible, DO effluent data should be entered for sources containing BOD_5; in the event that no DO data is input, default values are used.

9. The "permit effluent flow" (as registered with the monitoring agency on a discharge permit) for each pipe of each source.

10. The saturation level of dissolved oxygen (DO) in the stream for effluent sources where BOD_5 is a considered constituent.

11. Various options and coefficients (as marked by a "+" in the input list of Table 5.1 and explained in Section 3.1).

Restrictions and Requirements

1. The maximum number of effluent sources which can be considered in the monitoring allocation procedure at one time is thirty.*

2. A maximum of four discharge pipes can be considered at each source.

3. All discharge pipes at a single source are assumed to empty into the same receiving water body.

4. No more than ten distinct constituents may be considered at one effluent source (there may be forty constituents if the same ten occur in each pipe).

5. The self-monitoring data must consist of measurements of the effluent levels and pipe flow made once, on several days, or daily during a calendar month. All self-monitoring data must be reducible to a monthly mean of each constituent's loadings,

*The limit of 30 sources was set for purposes of demonstration in this project. This capability could easily be expanded in the computer program by changing the appropriate numbers in the DIMENSION and COMMON statements of the program.

monthly maximum of each constituent's loadings, and a sample size for the month (except for the constituent pH, for which a monthly minimum must also be available and a monthly mean is not mandatory). The pipe flows must reduce to a monthly mean of the measured daily flows.

6. A minimum of one calendar month of self-monitoring effluent data must be available for each constituent of every pipe of every source. More than the minimum one month's data is mandatory if the sample size for that month is less than four; in that case as many months as is necessary for the sum of the monthly sample sizes to be four or larger is needed.

7. A maximum of twenty-four calendar months of self-monitoring data may be input for any pipe of a source. The months need not be consecutive months, but a monthly mean pipe flow and data for each constituent of the pipe (or zeros if no data is available for some of the constituents for a given month), must be entered.

8. Compliance monitoring data may be entered for any constituent for any month for which self-monitoring data (or zeros) was entered. Compliance monitoring consists of a single measurement, and a maximum of thirty of these compliance monitoring points may be entered for a constituent for any given month.

9. Compliance monitoring data must be entered in units as specified in Table 5.4. Likewise, self-monitoring data and effluent standards must also be entered in units as specified in Table 5.4. The user must convert the data in all other cases; assistance may be found in Section 4, Task 2.

10. The permit flow units must be Megaliters/day and a permit flow must be entered for each pipe of each source. This value is necessary for use in converting the effluent standards into proper units; the program has standard units (generally Kg) and does conversions of its own. The permit flow is also used in cases where all monthly pipe flows are 0.0 (no pipe flow data).

Preparation of Inputs

Before entering numbers on coding forms, the user should organize his data. He should have a list of all his sources which he should number as 1, 2, 3, 4 and so on (in whatever source order is convenient). The total number must be less than or equal to 30. He should number each pipe of each source as 1, 2, 3, and 4 (for a 4-pipe source), in whatever order is convenient. Finally, he should number each constituent of the pipes as 1, 2, 3, 4, and so on (maximum of 10).

Next, he should examine each pipe of each source and all of its constituents to find all months for which monitoring or flow data will be entered. These months should be ordered chronologically and numbered as 1, 2, 3, 4, and so on (to a maximum of 24). The numbers themselves mean nothing; they serve only for identification. Therefore, it does not matter if there are months skipped, or even larger gaps, so long as each month is numbered sequentially, larger numbers indicating more recent data. Even if some part of the data is missing for a particular month, assign a number (i.e., if only two constituents for a particular month have monitoring data and there is no flow data for the month, one can enter the data for the two constituents for that month and enter 0.0 for all other constituents and the flow).

All of the numbers assigned should be carefully recorded. They must be consistently used for identification throughout the input cards.

5.2 INPUT DESCRIPTION

The inputs required by EFFMON are described in Table 5.1. Any variable marked by a "+" is discussed in Section 3.1 and the user should refer to that Section for suggested input values. A sample input deck is illustrated in Figure 5.1.

All variables which require a decimal point are specified, and the user should be careful to insert a decimal point. For the other variables, no decimal point is allowed. For a given variable, the numerical data need not fill all the allowed columns, but the data must be placed in the

Table 5.1 EFFMON Inputs

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
DAMAGE FUNCTION/RESOURCE COST OPTIONS						
1	1	No	ICOSTS			= 0, Default values for monitoring costs (see variables PIPCST and CONCST) ≠ 0, Costs will be inputted
	3	No	IDMG			= 0, Default pH and pOH damage function break-points will be used (see DMG) = 1, Read in pH <u>or</u> pOH damage function break-points = 2, Read in both pH and pOH damage function break-points
	5	No	IDAMAG			= 0, Default damage function break-points for non-pH constituents (see DAMAGE)

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
						= X, Total number of constituents whose damage function break points will be replaced with inputted values ($\leq$30)
	7	No	ISS			= 0, Default damage function values will be used
						$\neq$ 0, Inputted damage function values will be used (see S and SSPH)
*****Cards 2-6 are included only if ICOSTS≠0***						
*BASE COST TO MONITOR						
* 2	1-10	Yes	PIPCST(1)+	$	$ 525	Base cost to monitor 1-pipe source
*	16-25	Yes	(2)	$	525	Base cost to monitor 2-pipe source
*	31-40	Yes	(3)	$	857	Base cost to monitor 3-pipe source
*	45-54	Yes	(4)	$	857	Base cost to monitor 4-pipe source
*LAB COSTS TO MONITOR						
* 3	1-5	Yes	CONCST(1)+	$	8.50	Lab cost to analyze aluminum
*	11-15	Yes	(2)	$	10.00	Lab cost to analyze ammonia
*	21-25	Yes	(3)	$	20.00	Lab cost to analyze BOD_5

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
*	31-35	Yes	CONCST (4)+	$	0.00	Not used-leave columns blank
*	41-45	Yes	(5)	$	10.00	Lab cost to analyze carbon
*	51-55	Yes	(6)	$	0.00	Not used-leave columns blank
*	61-65	Yes	(7)	$	5.00	Lab cost to analyze chloride
*	71-75	Yes	(8)	$	15.00	Lab cost to analyze chloroform
* 4	1-5	Yes	(9)	$	7.50	Lab cost to analyze chromium
*	11-15	Yes	(10)	$	15.00	Lab cost to analyze total coliforms
*	21-25	Yes	(11)	$	15.00	Lab cost to analyze fecal coliforms
*	31-35	Yes	(12)	$	7.50	Lab cost to analyze copper
*	41-45	Yes	(13)	$	15.00	Lab cost to analyze cyanide
*	51-55	Yes	(14)	$	8.00	Lab cost to analyze fluoride
*	61-65	Yes	(15)	$	7.50	Lab cost to analyze iron
*	71-75	Yes	(16)	$	7.50	Lab cost to analyze lead
* 5	1-5	Yes	(17)	$	7.50	Lab cost to analyze manganese
*	11-15	Yes	(18)	$	15.00	Lab cost to analyze mercury
*	21-25	Yes	(19)	$	7.50	Lab cost to analyze nickel
*	31-35	Yes	(20)	$	10.00	Lab cost to analyze nitrogen
*	41-45	Yes	(21)	$	10.00	Lab cost to analyze oil-grease

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
*	51-55	Yes	CONCST(22)+	$	3.00	Lab cost to analyze pH
*	61-65	Yes	(23)	$	0.00	Not used-leave blank
*	71-75	Yes	(24)	$	12.50	Lab cost to analyze phenol
* 6	1-5	Yes	(25)	$	10.00	Lab cost to analyze phosphorus
*	11-15	Yes	(26)	$	5.00	Lab cost to analyze dissolved solids
*	21-25	Yes	(27)	$	5.00	Lab cost to analyze suspended solids
*	31-35	Yes	(28)	$	0.00	Lab cost to analyze temperature difference
*	41-45	Yes	(29)	$	8.50	Lab cost to analyze tin
*	51-55	Yes	(30)	$	3.00	Lab cost to analyze DO (dissolved oxygen)
**						
******Cards 7 and 8 are included only if IDMG≠0**						
* pH/pOH DAMAGE FUNCTION BREAKPOINTS IN UNITS OF ION CONCENTRATION						
* 7	1	No	I1			=1 for pH damage function
*						=2 for pOH damage function
*	6-15	Yes	DMG(I1,1)+	See Table 5.2	See Table 5.2	1st damage function breakpoint
*	16-25	Yes	(I1,2)	"	"	2nd damage function breakpoint
*	26-35	Yes	(I1,3)	"	"	3rd damage function breakpoint
*	36-45	Yes	(I1,4)	"	"	4th damage function breakpoint
*	46-55	Yes	(I1,5)	"	"	5th damage function breakpoint
*	56-65	Yes	(I1,6)	"	"	6th damage function breakpoint
* 8	6-15	Yes	(I1,7)	"	"	7th damage function breakpoint

Table 5.1 Continued

	CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
*		16-25	Yes	DMG(I1,8)	As in Table 5.2	See Table 5.2	8th damage function breakpoint
*		26-35	Yes	(I1,9)	"	"	9th damage function breakpoint
*		36-45	Yes	(I1,10)	"	"	10th damage function breakpoint
*		46-55	Yes	(I1,11)	"	"	11th damage function breakpoint

****

*****Cards 9 and 10 are included only if IDMG=2***

* 9 Cards 9 and 10 correspond to 7 and 8 except that the other damage function must be inputted
10 (i.e., if 7 and 8 input pH, 9 and 10 must input pOH, or vice versa)

****

*****Card(s) 11 are included only if IDAMAG>0***

* NON-pH DAMAGE FUNCTION BREAKPOINTS

	CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
*	11	1-2	No	I1			Damage function identification number (i.e., 01 for aluminum, 15 for iron, and so on - see Table 5.3)
*		6-15	Yes	DAMAGE(I1.1)+	See Table 5.3	See Table 5.3	1st damage function breakpoint for I1
*		16-25	Yes	(I1,2)	"	"	2nd damage function breakpoint for I1
*		26-35	Yes	(I1,3)	"	"	3rd damage function breakpoint for I1
*		36-45	Yes	(I1,4)	"	"	4th damage function breakpoint for I1
*		46-55	Yes	(I1,5)	"	"	5th damage function breakpoint for I1
*		56-65	Yes	(I1,6)	"	"	6th damage function breakpoint for I1

* Repeat card 11 as many times as specified by the value of IDAMAG (one card for each damage function, in any order).

****

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
********Cards 12 and 13 are included only if ISS≠0**						
NON-pH BREAKPOINT DAMAGE VALUES						
*	1-5	Yes	S(1)+		0.	1st value of non-pH damage functions
*	6-10	Yes	(2)		2.	2nd value of non-pH functions
*	11-15	Yes	(3)		4.	3rd value of non-pH functions
*	16-20	Yes	(4)		6.	4th value of non-pH functions
*	21-25	Yes	(5)		8.	5th value of non-pH functions
*	26-30	Yes	(6)		10.	6th value of non-pH functions
* pH BREAKPOINT DAMAGE VALUES						
* 13	1-5	Yes	SSPH(1)+		0.	1st value of pH/pOH damage function
*	6-10	Yes	(2)		1.	2nd value of pH/pOH damage function
*	11-15	Yes	(3)		2.	3rd value of pH/pOH damage function
*	16-20	Yes	(4)		3.	4th value of pH/pOH damage function
*	21-25	Yes	(5)		4.	5th value of pH/pOH damage function
*	26-30	Yes	(6)		5.	6th value of pH/pOH damage function
*	31-35	Yes	(7)		6.	7th value of pH/pOH damage function
*	36-40	Yes	(8)		7.	8th value of pH/pOH damage function
*	41-45	Yes	(9)		8.	9th value of pH/pOH damage function
*	46-50	Yes	(10)		9.	10th value of pH/pOH damage function
*	51-55	Yes	(11)		10.	11th value of pH/pOH damage function

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
**						
OUTPUT OPTIONS						
14	1	No	NOUT			≠0, No tabled output (as in Figure 5.7) =0, Tabled output
	6	No	IOUT1			≠1, No type 1 output (as in Figure 5.2) =1, Output type 1
	11	No	IOUT2A			≠1, No type 2A output (as in Figure 5.3) =1, Output type 2A
	16	No	IOUT2B			≠1, No type 2B output (as in Figure 5.4) =1, Output type 2B
	21	No	IOUT3			≠1, No type 3 output (see Figures 5.5 and 5.6) =1, Output type 3
	26-35	Yes	B	$		Budget limit (used if IOUT3=1)
	36-45	Yes	D			Undetected-violation-cost limit (used if IOUT3=1)--for B and D, one allocation is made for each which is not 0.

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
SOURCE CONSTANTS						
15	1	No	ICOPT+			That damage function breakpoint n (n=1, 2,3,4,5,or 6) which represents the up-stream concentration of all non-coupled constituents (by the nth breakpoint of their respective damage function)
	6	No	IEXPD+			≠0, All expected damages in the allocation are set at 1.0 =0, All expected damages are calculated from the data
	11-12	No	NOSORS			Number of sources for which data will be read in
	16-17	No	NUSORS			Number of sources to be considered by the program for allocation (≤NOSORS)
UPDATING CONSTANTS						
16	1-10	Yes	ALPHA+			Exponential smoothing constant used in estimating a single monthly pipe flow
	11-20	Yes	GAMMA+			Updating constant
	21-30	Yes	KETA+			Updating constant
	31-40	Yes	KNU+			Updating constant
	41-50	Yes	ENU+			Updating constant

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
MAXIMUM NUMBERS OF SAMPLES TO BE ALLOCATED FOR EACH SOURCE						
17	1-2	No	ISFUP(1)			Maximum number of samples for each cource for which data is entered (sequentially by source)
	3-4	No	(2)			
	5-6	No	(3)			
	.	.	.			
	.	.	.			
	.	.	.			
	.	.	(NOSORS)			
MINIMUM NUMBERS OF SAMPLES TO BE ALLOCATED FOR EACH SOURCE						
18	1-2	No	ISFLOW(1)			Minimum number of samples for each source for which data is entered (sequentially by source)
	3-4	No	(2)			
	5-6	No	(3)			
	.	.	.			
	.	.	.			
	.	.	.			
	.	.	(NOSORS)			
SOURCE CONSTITUENT CORRELATION						
19	1	No	ICOR(1)			Correlation flag for each source for which data is entered (sequentially by source):
	2	No	(2)			
	3	No	(3)			ICOR(i) = 1, Source i constituents are correlated
	.	.	.			
	.	.	.			
	.	.	.			
	.	.	(NOSORS)			≠ 1 not correlated

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
SOURCES TO BE ALLOCATED						
20	1-2	No	INSORS(1)			Sources to be considered for priority allocation in sequential order (i.e., by source number)
	3-4	No	(2)			
	5-6	No	(3)			
	.	.	.			
	.	.	.			
	.	.	.			
	.	.	(NOSORS)			
SOURCE DESCRIPTION						
21	1-2	No	ID			Source number (between 1 and 30)
For variable NAME only, data must begin in column 4 and need not fill all columns.						
	4-55	No	NAME(I,J)			Source description as desired (i.e., XYZ COMPANY, RIVER CITY).
	57-62		QU(I)	Megaliters/day		Upstream flow for sources ID
	63-68		KBOD(I)			BOD transfer coefficient for source ID
	69-74		DOSAT(I)	Mg/liter		Saturation level of DO for source ID

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	77-78		IONESD(1)			= 0, if there is no for source ID or if for source ID has a minimum and mean. = 1, if pH data for source ID consists of only a maximum and minimum (no mean)
	79-80		NPIP			Number of discharge pipes for source ID
PIPE DESCRIPTIONS						
22	1-2		NPPARS(1)			Number of constituents discharged from 1st pipe to be entered as data
	4-5		NMNTHS(1)			Number of months of constituent and flow data from 1st pipe
Fill in the following if there is a 2nd pipe, otherwise leave remainder of card blank						
	7-8		NPPARS(2)			Number of constituents discharged from 2nd pipe
	10-11		NMNTHS(2)			Number of months of constituent and flow data from 2nd pipe
Fill in the following if there is a 3rd pipe, otherwise leave remainder of card blank						
	13-14		NPPARS(3)			Number of constituents discharged from 3rd pipe
	16-17		NMNTHS(3)			Number of months of constituent and flow data from 3rd pipe

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION

Fill in the following if there is a 4th pipe, otherwise leave remainder of card blank

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	19-20		NPPARS(4)			Number of constituents discharged from 4th pipe
	22-23		NMNTHS(4)			Number of months of constituent and flow data from 4th pipe

Cards 21 and 22 must be repeated for every source (i.e., 21 and 22 for the first souce, then 21 and 22 for the second source, then 21 and 22 for the third). Note that the number of times NPPARS(i) and NMNTHS(i) appears on card 22 is the number that was listed under NPIP on card 21; in counting constituents for NPPARS, pH (if present) must be counted twice.

PIPE FLOW DATA

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
23	1-2	No	ID			Source number (between 1 and 30)
	5-6	No	PIPNO			Pipe number (between 1 and 4)
	7-8	No	IQS			Enter "99" (signals computer that this is a flow card)
	9-10	No	QSUNIT(J)			Units that pipe-flow will be entered in (for this source and pipe J=PIPNO), = 8 for megaliters/day = 3 for million gal/day
	15-16	No	MNTHQS(J,1)			First month for which pipe J-PIPNO flow will be entered
	19-24	Yes	QSMEAN(J,1)	Megaliters/day or million gallons/day		Mean pipe flow for first month, pipe J=PIPNO
	29-30	No	MNTHQS(J,2)			Second month for which pipe J=PIPNO flow will be entered

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	33-38	Yes	QSMEAN(J,2)	Megaliters/day or Million gallons/day		Flow for second month
	43-44	No	MNTHQS(J,3)			Third month for which pipe J=PIPNO flow will be entered
	47-52	Yes	QSMEAN(J,3)	Megaliters/day or Million gallons/day		Flow for third month
	57-58	No	MNTHQS(J,4)			Fourth month for which pipe J=PIPNO flow will be entered
	61-66	Yes	QSMEAN(J,4)	Megaliters/day or Million gallons/day		Flow for fourth month
	71-72	No	MNTHQS(J,5)			Fifth month for which pipe J=PIPNO flow will be entered
	75-80	Yes	QSMEAN(J,5)	Megaliters/day or Million gallons/day		Flow for fifth month

Repeat columns 15-80 on as many cards as needed (up to 4 additional cards) to enter more months and flows for this pipe; at any point on any card when the end of the month/flows is reached, leave the remainder of the card blank and proceed to card 24. Note that the months must be placed sequentially on the cards (i.e., 1,2,3,5,6,8,10, ...) although some may be skipped if no data is available; but any month for which data is entered must appear. If for a certain month flow data is not available, enter 0. for QSMEAN for that month.

SELF-MONITORING CONSTITUENT DATA

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
24	1-2	No	ID			Source number (must be the same as on card 23)

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	5-6	No	PIPNO			Pipe number (must be the same as on card 23)
	7-8	No	IPARM(J,K,I)	See Table 5.4		Constituent identification number (see Table 5.4) for first constituent of source ID, Pipe J=PIPNO
	9-10	No	PRUNIT(J,K)	See Table 5.5		Units this constituent's data is in
	11-16	Yes	SMAX(J,K,1)	As in PRUNIT(J,K) above		Maximum of this constituent samples for first month
	17-22	Yes	SMEAN(K,K,1)	As in PRUNIT(J,K) above		Mean of this constituent samples for first month
	23-24	No	NSIZE(J,K,1)			Number of samples taken from this constituent for first month
	25-30	Yes	SMAX(J,K,2)	As in PRUNIT(J,K) above		Maximum for second month
	31-36	Yes	SMEAN(J,K,2)	As in PRUNIT(J,K) above		Mean for second month
	37-38	No	NSIZE(J,K,2)			Sample size for second month
	39-44	Yes	SMAX(J,K,3)	As in PRUNIT(J,K) above		Maximum for third month
	45-50	Yes	SMEAN(J,K,3)	As in PRUNIT(J,K) above		Mean for third month

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	51-52	No	NSIZE(J,K,3)			Sample size for third month
	53-58	Yes	SMAX(J,K,4)	As in PRUNIT(J,K) above		Maximum for fourth month
	59-64	Yes	SMEAN(J,K,4)	As in PRUNIT(J,K) above		Mean for fourth month
	65-66	No	NSIZE(J,K,4)			Sample size for fourth month
	67-72	Yes	SMAZ(J,K,5)	As in PRUNIT(J,K) above		Maximum for fifth month
	73-78	Yes	SMEAN(J,K,5)	As in PRUNIT(J,K) above		Mean for fifth month
	79-80	No	NSIZE(J,K,5)			Sample size for fifth month

Repeat columns 11-80 on as many cards as needed (up to 4 additional cards) to enter more months of data; at any point on any card when the end of the data is reached, leave the remainder of the card blank and proceed to the next step as detailed below. If no data is available for a constituent during a month, enter zeros for maximum, mean, and sample size for that month. Note that a maximum, mean, and sample size must be entered for each month that was listed on card 23 and that the maximum, mean, sample-size groups must be ordered as the months were. When the constituent being entered is pH, card 24 must be repeated twice. The first time, pH must be entered as constitutent 23 (pH max) and means, maximums, and sample sizes are listed as above. The second time, pH must be entered as constituent 22 (pH min) and the same means and sample sizes are listed but instead of sample maximums, sample minimums are listed. If, as may be the case for pH, no means are available, enter zeros in those columns.

After the first constituent has been completed, repeat card 24 for every other constituent of the pipe (that pipe listed on card 23). Once all constituents have been done, repeat cards 23 and 24 for pipe 2, pipe 3, and then pipe 4 (if they exist), of the source (that source listed on card 23). Then proceed to card 25.

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
EFFLUENT STANDARDS						
25	1-2	No	ID			Source number
	4-5	No	PIPNO			Pipe number (1 to 4)
	7-12	Yes	EFFLOW(J,I)	Megaliters/day		Permit flow for pipe J=PIPNO
	13-14	No	IP(1)			First constituent of pipe PIPNO (use identification number as in Table 5.4)
	15-20	Yes	XI(1)	As in IUNIT(1)		First constituents effluent standard
	22	No	IUNIT(1)	See Tables 5.4 and 5.5		Units that standard is expressed in
	23	No	M(1)			Distribution of constituent 0 = Normal 1 = Lognormal
	25-26	No	IP(2)			Second constituent
	27-32	Yes	XI(2)	As in IUNIT(2)		Second constituent's effluent standard
	34	No	IUNIT(2)			Units of standard

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	35	No	M(2)			Distribution of second constituent (0 or 1)
	37-38	No	IP(3)			Third constituent
	39-44	Yes	X1(3)	As in IUNIT(3)		Third constituent effluent standard
	46	No	IUNIT(3)			Units of standard
	47	No	M(3)			Distribution of third constituent (0 or 1)
	49-50	No	IP(4)			Fourth constituent
	51-56	Yes	X1(4)	As in IUNIT(4)		Fourth constituent effluent standard
	58	No	IUNIT(4)			Units of standard
	59	No	M(4)			Distribution of fourth constituent (0 or 1)
	61-62	No	IP(5)			Fifth constituent
	63-68	Yes	X1(5)	As in IUNIT(5)		Fifth constituent effluent standard
	70	No	IUNIT(5)			Units of standard
	71	No	M(5)			Distribution of fifth constituent (0 or 1)

Table 5.1 Continued

Repeat columns 13-71 on another card, if necessary, to list all constituents and their standards for the pipe. Then repeat card 25 for pipes 2, 3, and 4 of the source (if they exist). Once all pipes have been completed, repeat cards 23, 24 and 25 for the next source. Proceed until all sources have been completed, being careful to enter the sources in their proper order (source 1, source 2, source 3,...). Note that no standard is necessary if the constituent is DO (enter "0." under X1).

COMPLIANCE MONITORING DATA

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
26	1-2	No	ID			Source number
	5	No	J			Pipe number ("0" if there is no compliance monitoring for this source)
	7-8	No	IPAR			Constituent identification number (as in Table 5.4)
	11-12	No	NUM			Number of compliance monitoring points to be entered for this constituent
	14-19	Yes	X1(1)	See Table 5.4		Value of first compliance monitoring point
	20-21	No	M(1)			Month from which compliance monitoring point was taken
	23-28	Yes	X1(2)	See Table 5.4		Second CM point
	29-30	No	M(2)			Month of second CM point
	32-37	Yes	X1(3)	See Table 5.4		Third CM point
	38-39	No	M(3)			Month of third CM point

Table 5.1 Continued

CARD NUMBER	CARD COLUMN(S)	DECIMAL POINT?	VARIABLE NAME	UNIT MUST BE	DEFAULT VALUE	DESCRIPTION
	41-46	Yes	X1(4)	See Table 5.4		Fourth CM point
	47-48	No	M(4)			Month of fourth CM point
	50-55	Yes	X1(5)	See Table 5.4		Fifth CM point
	56-57	No	M(5)			Month of fifth CM point
	59-64	Yes	X1(6)	See Table 5.4		Sixth CM point
	65-66	No	M(6)			Month of sixth CM point
	68-73	Yes	X1(7)	See Table 5.4		Seventh CM point
	74-75	No	M(7)			Month of seventh CM point

Repeat columns 14-75 on as many cards as needed (up to 5 additional cards) to enter all compliance monitoring points the constituent. At any point on any card when the last CM point is recorded, leave the remainder of the card blank and proceed as below. Repeat card 26 for any other constituents in any of the pipes of the source for which there are compliance monitoring points (any order is acceptable and the number of CM points may vary with constituents where some constituents may not have any and need not be entered). Once a source has been completed, a final card for the source must be added which contains the source number under ID and "0" for J before going on to the next source. Repeat card 16 for all compliance monitoring data of the next source. Each source listed under variable INSORS on card 20 must be represented, and in the same order; if a source has no compliance monitoring data, enter the source number under ID and a "0" for J and proceed to the next source on the next card.

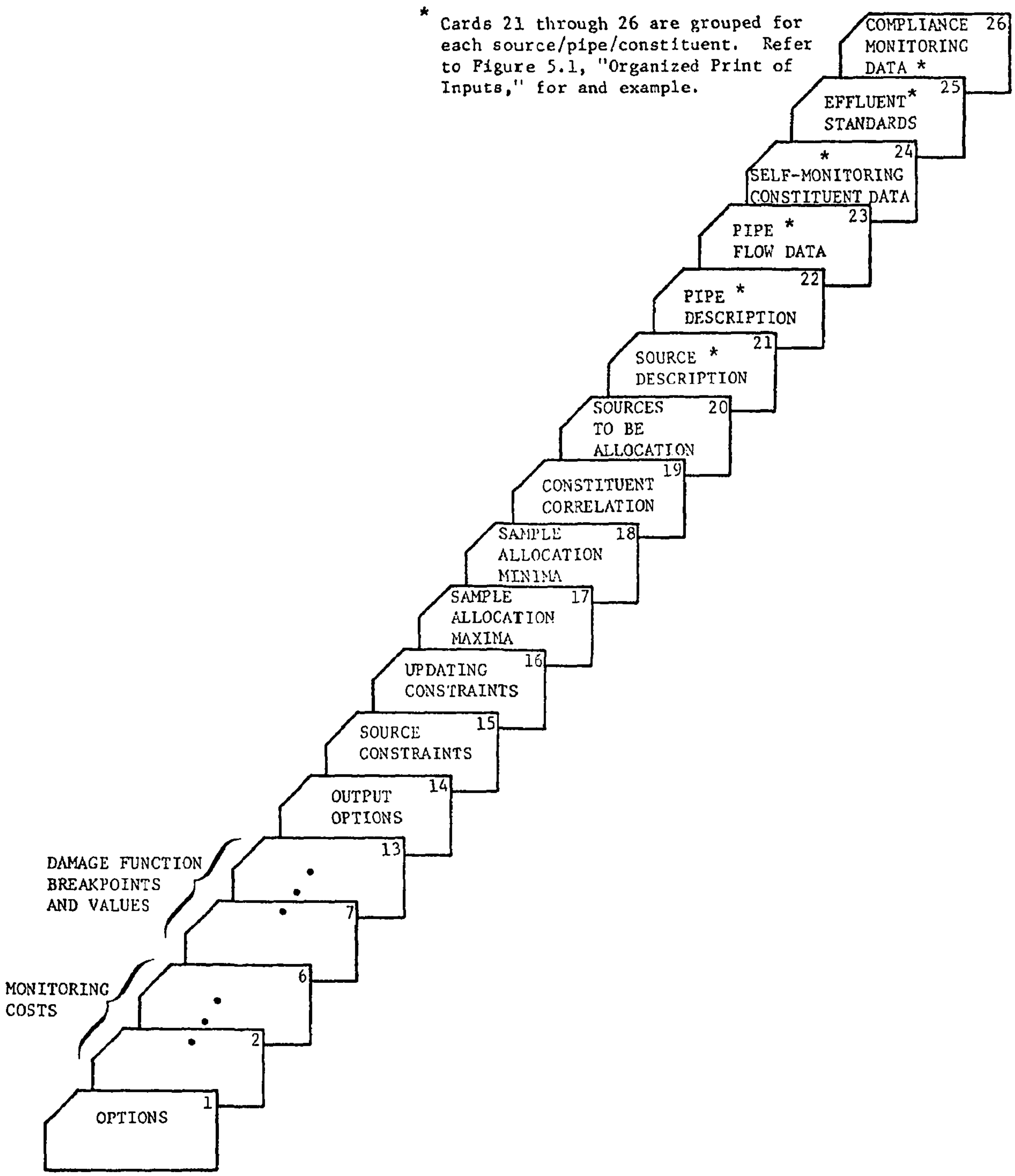


Figure 5.1 Organization of Input Deck

Table 5.2 pH/pOH Damage Function Breakpoints

	BREAKPOINTS	
Damage Function Point	pH Conc of H^+ ions	pOH Conc of OH^- ions
1	1.00×10^{-7}	1.00×10^{-7}
2	1.78×10^{-7}	3.16×10^{-7}
3	3.16×10^{-7}	1.00×10^{-6}
4	5.62×10^{-7}	1.58×10^{-6}
5	1.00×10^{-6}	2.51×10^{-6}
6	3.16×10^{-6}	5.01×10^{-6}
7	1.00×10^{-5}	1.00×10^{-5}
8	3.16×10^{-5}	3.16×10^{-5}
9	1.00×10^{-4}	1.00×10^{-4}
10	1.12×10^{-4}	1.12×10^{-4}
11	1.26×10^{-4}	1.26×10^{-4}

Table 5.3 Non-pH Damage Functions

DFIN*	Constituent Name	Units	Breakpoints 1	2	3	4	5	6
01	Aluminum	mg/l	0	0.01	0.05	0.1	0.5	1.
02	Ammonia	mg/l	0	0.1	0.3	0.9	2.7	3.
03	Dissolved Oxygen	mg/l	>9	8.0	6.8	4.5	1.8	0.9
04	Not Used	mg/l	0	0.	0.	0.	0.	0.
05	Inorganic Carbon	mg/l	<50	70.	90.	110.	130.	150.
06	Not Used	mg/l	0	0.	0.	0.	0.	0.
07	Chloride	mg/l	0	25.	175.	200.	240.	250.
08	Chloroform Extract	mg/l	0	0.04	0.15	0.25	0.35	0.4
09	Chromium	mg/l	0	0.02	0.05	1.	10.	50.
10	Coliforms-Total	MPN/100ml	0	100.0	2000.	7500.	15000.	150000.
11	Coliforms-Fecal	MPN/100ml	0	20.	200.	800.	3000.	50000.
12	Copper	mg/l	0	0.02	0.1	1.	5.	10.
13	Cyanide	mg/l	0	0.01	0.02	0.05	0.1	0.5
14	Fluoride	mg/l	<0.7	0.8	0.9	1.2	3.	8.
15	Iron	mg/l	0	0.1	0.3	0.9	2.7	3.
16	Lead	mg/l	0	0.005	0.05	0.1	0.25	0.35
17	Manganese	mg/l	0	0.05	0.17	0.5	1.	1.5
18	Mercury	mg/l	0	0.001	0.005	0.01	0.02	0.05
19	Nickel	mg/l	0	0.01	1.	3.	9.	20.
20	Inorganic Nitrogen	mg/l	<0.6	0.9	3.	4.5	7.	10.
21	Oil-Grease	mg/l	0	0.01	0.1	5.	30.	50.
22	Not Used	mg/l	0	0.	0.	0.	0.	0.
23	Not Used	mg/l	0	0.	0.	0.	0.	0.
24	Phenol	mg/l	0	0.0005	0.001	0.02	0.1	0.2
25	Phosphates	mg/l	0	0.1	0.2	0.5	1.6	10.
26	Solids-Dissolved	mg/l	<100	200.	500.	1000.	1500.	2300.
27	Solids-Suspended	mg/l	0	20.	40.	100.	280.	300.
28	Temp. Diff.	C°	0	1.	2.5	3.0	4.	10.
29	Tin	mg/l	0	10.	40.	100.	300.	1000.

*Damage Function Identification Number

Table 5.4 Constituent Identification Numbers and Input Units

Number	Constituent	Acceptable Units for Self-Monitoring Data and Effluent Standards							Acceptable Units for Compliance Monitoring Data
		ug/l	mg/l	lbs/day	Kg/day	°C	pH	MPN/day	
01	Aluminum	X	X	X	X				Kg/day
02	Ammonia	X	X	X	X				Kg/day
03	BOD_5	X	X	X	X				Kg/day
04	-								
05	Carbon	X	X	X	X				Kg/day
06	-								
07	Chloride	X	X	X	X				Kg/day
08	Chloroform	X	X	X	X				Kg/day
09	Chromium	X	X	X	X				Kg/day
10	Total Coliforms							X	MPN/100 ml.
11	Fecal Coliforms							X	MPN/100 ml.
12	Copper	X	X	X	X				Kg/day
13	Cyanide	X	X	X	X				Kg/day
14	Fluoride	X	X	X	X				Kg/day
15	Iron	X	X	X	X				Kg/day
16	Lead	X	X	X	X				Kg/day
17	Manganese	X	X	X	X				Kg/day
18	Mercury	X	X	X	X				Kg/day
19	Nickel	X	X	X	X				Kg/day
20	Nitrogen	X	X	X	X				Kg/day
21	Oil-grease	X	X	X	X				Kg/day
22	pH-min						X		pH
23	pH-max						X		pH
24	Phenol	X	X	X	X				Kg/day
25	Phosphorus	X	X	X	X				Kg/day
26	Dissolved Solids	X	X	X	X				Kg/day
27	Suspended Solids	X	X	X	X				Kg/day
28	Temperature Difference					X			°F
29	Tin	X	X	X	X				Kg/day
30	DO		X						mg/l

Table 5.5 Input Units

Identification Number	Units
1	mg/l
2	μg/l
3	MGD (Million Gallons/Day)
4	lbs/day
5	°C
6	pH
7	MPN/100ml
8	Ml/day (Megaliters/day)
9	Kg/day

right-most columns allowed (i.e., if the value 2 is to be placed in columns 60-62, specify "002" in columns 60-62 or simply place "2" in column 62).

If a decimal point number being entered as input data is too large to fit into the allowed columns, scientific notation should be used (i.e., 6,020,400 would be 6.02×10^6, which is entered into the columns as 6.02E6 and likewise, .0000005 would be entered as 5.0E-7). Make sure in this case also that the entry is in the right-most columns allowed, and has a decimal point.

All self-monitoring or flow data which is read in as 0.0 is considered to be "missing data". Therefore, if a sample value really is 0.0, a very small number (i.e., .00001) should be entered instead.

The variable INSORS on card 20 allows the user flexibility in specifying which sources to consider in the priority allocation. All sources must be numbered (1 to 30), their pipes numbered (1 to 4), and the months of data numbered (1 to 24) as described in Section 5.1. Suppose that all data has been entered on cards and the user decides that for some reason he wants to delete one or more sources. Rather than having to renumber and retype all cards, he simply specifies exactly which numbered sources he <u>does</u> want in his allocation and lists these under INSORS. If he does not wish to delete any sources, he lists <u>all</u> source numbers under INSORS.

Finally, the user should study the examples of input and output presented in Sections 5.3 and 5.4. These examples should help in resolving any questions arising out of the table of inputs.

5.3 SAMPLE INPUT DECK

Suppose that the available self-monitoring and compliance monitoring monthly data for sources of interest is as in Table 5.6. The card input would then resemble that of Figure 5.2, depending upon the rest of the data and the options which the user chooses.

5.4 OUTPUT DESCRIPTION

The output generated by EFFMON is printer output. Except for an initial printout of all the inputs which is always printed (see Figure 5.3), the output may consist of any or all of the following as desired by the user (the theoretical background for the various outputs is discussed in Section 2.6).

Output Option 1 : An initial allocation, including the minimum number of times each source must be sampled as specified by the user (see Figure 5.4).

Output Option 2a: A priority list of the samples, including the minimum required samples (see Figure 5.5).

Output Option 2b: A priority list of the samples, including only samples to be taken beyond the minimum number required for each source (see Figure 5.6).

Output Option 3 : A final allocation including the total number of times each source is to be sampled and other summary information based on a given budget limit (see Figure 5.7).

Output Option 4 : A final allocation including the same information as in 4 above, but based on a given maximum "cost of undetected violations" as defined below (see Figure 5.8).

Table 5.6 Sample Input Date

Source & Pipe	Constituent (or Pipe Flow)	Self-Monitoring: Monthly Max. or Min.	Self-Monitoring: Monthly Mean	Self-Monitoring: Sample Size	Units	Compliance Monitoring Points	Month and Year
Source 1							
Pipe 1	Flow	NA	.254	NA	MGD	NA	6/74
		NA	.148	NA		NA	7/74
	pH-max	10.6	-	6	pH	10.0,9.0,9.5	6/74
		9.0	-	7			7/74
	pH-min	6.0	-	6	pH	8.0,7.1,6.8	6/74
		5.4	-	7			7/74
	Lead	800.	760.	6	ug/l	.461,.202,.371*	6/74
		510.	400.	7			7/74
	Phosphorus	.017	.011	6	mg/l	.051,.023	6/74
		.066	.025	7			7/74
	Cyanide	.025	.020	6	mg/l	.052,.059,.071	6/74
		-	-	-			7/74
Source 2							
Pipe 1	Flow	NA	.04	NA	MGD	NA	2/74
		NA	.04	NA		NA	7/74
		NA	.05	NA		NA	8/74
	pH-max	10.0	9.0	10	pH	8.5	2/74
		9.9	9.2	12		9.1,8.9	7/74
		9.2	9.0	12		8.3,8.4,8.3, 8.7,8.5	8/74
	pH-min	7.6	9.0	10	pH	7.7	2/74
		7.4	9.2	12		8.0,7.7	7/74
		7.6	9.0	12		7.6,7.6,7.5 7.4,7.6	8/74
Source 3							
Pipe 1	Flow	NA	.430	NA	Megaliters/ day	NA	10/73
		NA	.437	NA		NA	11/73
		NA	.524	NA		NA	12/73
		NA	-	NA		NA	6/74
		NA	.491	NA		NA	7/74
		NA	.482	NA		NA	8/74
		NA	.554	NA		NA	12/74

* Note that units are kg as required.
NA-Not Applicable

Table 5.6 Continued

Source & Pipe	Constituent (or Pipe Flow)	Self-Monitoring: Monthly Max. or Min.	Self-Monitoring: Monthly Mean	Self-Monitoring: Sample Size	Self-Monitoring: Units	Compliance Monitoring Points	Month and Year
	Chloroform Extract	24.0	15.5	2	mg/l		10/73
		8.0	2.8	2			11/73
		23.6	7.6	3			12/73
		45.0	31.4	5			6/74
		56.8	30.1	7			7/74
		16.8	-	2			8/74
		13.2	6.0	1			12/74
Pipe 2	Flow	NA	.121	NA	Megaliters/ day	NA	10/73
		NA	.125	NA		NA	11/73
		NA	.131	NA		NA	12/73
		NA	.126	NA		NA	2/74
		NA	-	NA		NA	3/74
		NA	.133	NA		NA	8/74
	Chloroform Extract	8.4	3.5	2	mg/l		10/73
		19.2	5.8	2			11/73
		15.6	7.1	3			12/73
		20.0	8.1	7			2/74
		28.0	6.2	7			3/74
		19.2	8.9	7			8/74
		-	-	-			9/74
	Total Coliforms	1080.	1010.	2	MPN		10/73
		-	-	-			11/73
		1200.	-	3			12/73
		1210.	1050.	10			2/74
		1150.	1100.	10			3/74
		-	-	-			8/74
		-	-	-			9/74
	BOD_5	7.8	6.3	2	mg/l		10/73
		13.0	5.0	2			11/73
		18.0	12.0	3			12/73
		11.0	7.7	7			2/74
		-	-	-			3/74
		-	-	-			8/74
		-	-	-			9/74
	DO	5.7	5.0	2	mg/l		10/73
		7.0	6.7	2			11/73
		8.0	7.0	3			12/73
		6.7	6.3	7			2/74
		-	-	-			3/74
		5.4	5.2	2			8/74
		-	-	-			9/74

```
0 0 ^ 0
0    /    1    1    1         10000.        .25
1    O      3    3
.4                 1.5       1.5        .7
10100505
01020101
001
010203
01 JONES MANUFACTURING CO.                                             100.     0.     0.  0101
05 02
02 SAFE CHEMICAL CO.                                                   20.7     0.     0.  0001
02 03
03 SEWAGE TREATMENT                                                    525.     .5    9.0  0002
01 07 04 07
01  019903     01     .254     02     .148
01  012306  10.6    0.0 6    9.0    0.0 7
01  012206   6.0    0.0 6    5.4    0.0 7
01  011602  800.   760. 6  510.   400. 7
01  012501  .017   .011 6  .066   .025 7
01  011301  .025   .020 6   0.0   0.000
01 01   .52923   9.5 60 22   6.5 60 16     .1 10 25    2. 11 13   .25 11
02  019903     01      .04     02     .04     03     .05
02  012306  10.0    9.010    9.9    9.212    9.2    9.012
02  012206   7.6    9.010    7.4    9.212    7.6    9.012
02 01   1.4323   9.5 60 22   6.7 60
03  019908     01     .430     02     .437     03     .524     04     0.0     05     .491
               06     .482     07     .554
03  010801  24.0   15.502    8.0    2.802   23.6    7.603   45.0  31.405   56.8  30.107
            16.8    0.002   13.2    6.001
03  029908     01     .121     02     .125     03     .131     04     .126     05     0.0
               06     .133
03  020801    8.4   3.502   19.2    5.802   15.6    7.103   20.0   8.107   28.0   6.207
            19.2    8.907
03  021007 1080. 1010.02    0.0    0.000 1200.   0.003 1210. 1050.10 1150. 1100.10
             0.0    0.000
03  020301    7.8   6.302   13.0    5.002   18.0   12.003   11.0   7.707    0.0   0.000
             0.0    0.000
03  023001    5.7   5.002    7.0    6.702    8.0    7.003    6.7   6.307    0.0   0.000
             5.4    5.202
03 01   2.0008    10. 11
03 02   .46508    20. 11 10 1500. 70 03    15. 10 30       10
01   1 23   03    10.0 1    9.0 1    9.5 1
01   1 22   03     8.0 1    7.1 1    6.8 1
01   1 16   03    .461 1   .202 1   .371 1
01   1 25   02    .051 1   .023 1
01   1 13   03    .052 1   .059 1   .071 1
01
02   1 23   08     8.5 1     9.1 2     8.9 2     8.3 3     8.4 3     8.3 3     8.7 3
                   8.5 3
02   1 22   08     7.7 1     8.0 2     7.7 2     7.6 3     7.6 3     7.5 3     7.4 3
                   7.6 3
02
03
**
```

Figure 5.2 Organized Print of Inputs

```
05/30/75  12:56:09 WINK   000373D53   000373        S30   75                             DATE 053075

----------THE INPUT CARD DATA FOLLOWS----------

ICOSTS=0            IDMG=0               IDAMAG=0            ISS=0

PIPCST( 1)=    525.00        **IF PIPCST, CONCST, OR DAMAGE FUNCTIONS AND BREAKPOINTS WERE NOT READ IN,
      ( 2)=    525.00               VALUES PRINTED ARE THOSE EXISTING IN THE PROGRAM
      ( 3)=    857.00
      ( 4)=    857.00

CONCST( 1)=      8.50        ALUMINUM
      ( 2)=     10.00        AMMONIA
      ( 3)=     20.00        BOD5
      ( 4)=       .00
      ( 5)=     10.00        CARBON
      ( 6)=       .00
      ( 7)=      5.00        CHLORIDE
      ( 8)=     15.00        CHLOROFORM EXTRACT
      ( 9)=      7.50        CHROMIUM
      (10)=     15.00        COLIFORMS--TOTAL
      (11)=     15.00        COLIFORMS--FECAL
      (12)=      7.50        COPPER
      (13)=     15.00        CYANIDE
      (14)=      8.00        FLUORIDE
      (15)=      7.50        IRO N
      (16)=      7.50        LEAD
      (17)=      7.50        MANGANESE
      (18)=     15.00        MERCURY
      (19)=      7.50        NICKEL
      (20)=     10.00        NITROGEN
      (21)=     10.00        OIL-GREASE
      (22)=      3.00        PH-MIN
      (23)=       .00        PH-MAX
      (24)=     12.50        PHENOL
      (25)=     10.00        PHOSPHORUS
      (26)=      5.00        DISSOLVED SOLIDS
      (27)=      5.00        SUSPENDED SOLIDS
      (28)=       .00        TEMPERATURE DIFF
      (29)=      8.50        TIN
      (30)=      3.00        DO
```

Figure 5.3   Organized Print of Inputs

```
05/30/75  12:56:09 WINK   000373053    000373        S30   75                                   DATE 053075      PAGE    3

                 J= 1          2          3          4          5          6          7          8          9          10          11
--PW
DMG(1,J)     .0000001   .0000002   .0000003   .0000006   .0000010   .0000032   .0000100   .0000316   .0001000   .0001120   .0001260
--POM
DMG(2,J)     .0000001   .0000003   .0000010   .0000016   .0000025   .0000050   .0000100   .0000316   .0001000   .0001120   .0001260

                 J=    1              2              3              4              5              6

DAMAGE( 1,J)        .00000         .01000         .05000         .10000         .50000        1.00000
      ( 2,J)        .00000         .10000         .30000         .90000        2.70000        3.00000
      ( 3,J)       9.00000        8.00000        6.80000        4.50000        1.80000         .90000
      ( 4,J)        .00000         .00000         .00000         .00000         .00000         .00000
      ( 5,J)      50.00000       70.00000       90.00000      110.00000      130.00000      150.00000
      ( 6,J)        .00000         .00000         .00000         .00000         .00000         .00000
      ( 7,J)        .00000       25.00000      175.00000      200.00000      240.00000      250.00000
      ( 8,J)        .00000         .04000         .15000         .25000         .35000         .40000
      ( 9,J)        .00000         .02000         .05000        1.00000       10.00000       50.00000
      (10,J)        .00000      100.00000     2000.00000     7500.00000    15000.00000   150000.00000
      (11,J)        .00000       20.00000      200.00000      600.00000     3000.00000    50000.00000
      (12,J)        .00000         .02000         .10000        1.00000        5.00000       10.00000
      (13,J)        .00000         .01000         .02000         .05000         .10000         .50000
      (14,J)        .70000         .80000         .90000        1.20000        3.00000        8.00000
      (15,J)        .00000         .10000         .30000         .90000        2.70000        3.00000
      (16,J)        .00000         .00500         .05000         .10000         .25000         .35000
      (17,J)        .00000         .05000         .17000         .50000        1.00000        1.50000
      (18,J)        .00000         .00100         .00500         .01000         .02000         .05000
      (19,J)        .00000         .01000        1.00000        3.00000        9.00000       20.00000
      (20,J)        .60000         .90000        3.00000        4.50000        7.00000       10.00000
      (21,J)        .00000         .01000         .10000        5.00000       30.00000       50.00000
      (22,J)        .00000         .00000         .00000         .00000         .00000         .00000
      (23,J)        .00000         .00000         .00000         .00000         .00000         .00000
      (24,J)        .00000         .00050         .00100         .02000         .10000         .20000
      (25,J)        .00000         .10000         .20000         .50000        1.60000       10.00000
      (26,J)      100.00000      200.00000      500.00000     1000.00000     1500.00000     2300.00000
      (27,J)        .00000       20.00000       40.00000      100.00000      280.00000      300.00000
      (28,J)        .00000        1.00000        2.50000        3.00000        4.00000       10.00000
      (29,J)        .00000       10.00000       40.00000      100.00000      300.00000     1000.00000
      (30,J)        .00000         .00000         .00000         .00000         .00000         .00000

S(J)            .00        2.00        4.00        6.00        8.00       10.00

SSPH(J)         .00        1.00        2.00        3.00        4.00        5.00        6.00        7.00        8.00        9.00       10.00

NCUT=0              IOUT1=1              IOUT2A=1              IOUT2B=1              IOU13=1              B=  10000.00        D=         .3
ICOPT=1             IEXPD=0              NOSORS= 3             NUSORS= 3

ALPHA=        .40   GAMMA=         .00   KETA=       1.50     KNU=       1.50     ENU=         .70

     SOURCE I=  1  2  3
ISFUP(I)       10 10  5
ISFLOW(I)       1  2  1
ICOR(I)         0  0  1

INSORS(I) FOR I=1 TO NUSORSA 1, 2, 3,

SOURCE DESCRIPTIONS:
ID     NAME                                                            QU       KBOD   DOSAT     IONESD NPIP  NPPARS(J),NMNTHS(J) J=1 TO NPIP
```

Figure 5.3 -- Continued

05/30/75 12:56:09 WINK 000373053 000373 530 75 DATE 053075

1	JONES MANUFACTURING CO.	100.000	.00	.00	1	1	5, 2	
2	SAFE CHEMICAL CO.	20.700	.00	.00	0	1	2, 3	
3	SEWAGE TREATMENT	525.000	.50	9.00	0	2	1, 7	4, 7

Figure 5.3 -- Continued

```
05/30/75  12:56:09 WINK   000373053    000373         530   75                                DATE 053075

PIPE FLOW AND SELF-MONITORING CONSTITUENT DATA
(SOURCE) (PIPE)
   ID     PIPNO  IQS QSUNIT    MNTHQS,QSMEAN--FOR ALL MONTHS
    1       1     99  3        1,        .25 / 2,        .15 /


   ID     PIPNO   IPARM PRUNIT       SMAX,SMEAN,NSIZE--FOR ALL MONTHS
    1       1       23     6       10.60,         .00, 6/       9.00,         .00, 7/
    1       1       22     6        6.00,         .00, 6/       5.40,         .00, 7/
    1       1       16     2      800.00,      760.00, 6/     510.00,      400.00, 7/
    1       1       25     1         .02,         .01, 6/        .07,         .02, 7/
    1       1       13     1         .02,         .02, 6/        .00,         .00, 0/

EFFLUENT STANDARDS
(SOURCE)  (PIPE)
   ID   PIPNO  EFFLOW      IP,XI,IUNIT,M--FOR ALL CONSTITUENTS OF PIPE
    1     1           .53  23,        9.500,6, 0
                           22,        6.500,6, 0
                           16,         .100,1, 0
                           25,        2.000,1, 1
                           13,         .250,1, 1
```

Figure 5.3 -- Continued

```
05/30/75  12:56:09 MINK   000373053    000373        S30   75                                        DATE 053075

PIPE FLOW AND SELF-MONITORING CONSTITUENT DATA
(SOURCE) (PIPE)
   ID     PIPNO  IQS QSUNIT    MNTHOS,QSMEAN--FOR ALL MONTHS
    2       1      99  3         1,         .04 / 2,         .04 / 3,         .05 /

   ID     PIPNO   IPARM PRUNIT        SMAX,SMEAN,NSIZE--FOR ALL MONTHS
    2       1        23     6        10.00,        9.00,10/        9.90,        9.20,12/        9.20,        9.00,12/
    2       1        22     6         7.00,        9.00,10/        7.40,        9.20,12/        7.60,        9.00,12/

EFFLUENT STANDARDS
(SOURCE)  (PIPE)
   ID    PIPNO   EFFLOW       IP,X1,IUNIT,M--FOR ALL CONSTITUENTS OF PIPE
    2      1           1.43  23,        9.500,6, 0
                             22,        6.700,6, 0
```

Figure 5.3 -- Continued

```
PIPE FLOW AND SELF-MONITORING CONSTITUENT DATA
(SOURCE) (PIPE)
   ID    PIPNO  IQS QSUNIT   MNTHQS,QSMEAN--FOR ALL MONTHS
    3      1     99  8        1,        .43 / 2,       .44 / 3,       .52 / 4,       .00 /
                              5,        .49 / 6,       .48 / 7,       .55 /


   ID    PIPNO   IPARM PRUNIT      SMAX,SMEAN,NSIZE--FOR ALL MONTHS
    3      1        8     1      24.00,     15.50, 2/      8.00,      2.80, 2/     23.60,       7.60, 3/     45.00,      31.40, 5/
                                 56.80,     30.10, 7/     16.80,       .00, 2/     13.20,       6.00, 1/

PIPE FLOW AND SELF-MONITORING CONSTITUENT DATA
(SOURCE) (PIPE)
   ID    PIPNO  IQS QSUNIT   MNTHQS,QSMEAN--FOR ALL MONTHS
    3      2     99  8        1,        .12 / 2,       .13 / 3,       .13 / 4,       .13 /
                              5,        .00 / 6,       .13 / 0,       .00 /


   ID    PIPNO   IPARM PRUNIT      SMAX,SMEAN,NSIZE--FOR ALL MONTHS
    3      2        8     1       8.40,      3.50, 2/     19.20,      5.80, 2/     15.60,       7.10, 3/     20.00,       8.10, 7/
                                 26.00,      6.20, 7/     19.20,      8.90, 7/       .00,        .00, 0/
    3      2       10     7    1080.00,   1010.00, 2/       .00,       .00, 0/   1200.00,        .00, 3/   1210.00,    1050.00,10/
                               1150.00,   1100.00,10/       .00,       .00, 0/       .00,        .00, 0/
    3      2        3     1       7.60,      6.30, 2/     13.00,      5.00, 2/     18.00,      12.00, 3/     11.00,       7.70, 7/
                                   .00,       .00, 0/       .00,       .00, 0/       .00,        .00, 0/
    3      2       30     1       5.70,      5.00, 2/      7.00,      6.70, 2/      8.00,       7.00, 3/      6.70,       6.30, 7/
                                   .00,       .00, 0/      5.40,      5.20, 2/       .00,        .00, 0/

EFFLUENT STANDARDS
(SOURCE)  (PIPE)
   ID   PIPNO  EFFLOW     IP,XI,IUNIT,M--FOR ALL CONSTITUENTS OF PIPE
    3     1         2.00   8,      10.000,1, 1

    3     2          .46   6,      20.000,1, 1
                          10,    1500.000,7, 0
                           3,      15.000,1, 0
                          30,        .000,1, 0


COMPLIANCE MONITORING DATA
(SOURCE)  (PIPE)
   ID         J     IPAR NUM   XI(K),M(K)--FOR K=1 TO NUM CM POINTS
   1          1      23   3
                                           10.000, 1       9.000, 1       9.500, 1
   1          1      22   3
                                            8.000, 1       7.100, 1       6.800, 1
   1          1      14   3
                                             .461, 1        .202, 1        .371, 1
   1          1      25   2
                                             .051, 1        .023, 1
   1          1      13   3
                                             .052, 1        .059, 1        .071, 1
   2          1      23   8
                                            8.500, 1       9.100, 2       8.900, 2       8.300, 3       8.400, 3
                                            8.300, 3       8.700, 3       8.500, 3
```

Figure 5.3   -- Continued

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2	1	22	8					
				7.700, 1	8.000, 2	7.700, 2	7.600, 3	7.600, 3
				7.500, 3	7.400, 3	7.600, 3		

Figure 5.3 -- Continued

```
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                                              INITIAL ALLOCATION

                              SOURCE               TIMES SAMPLED       RESOURCES USED
                              ------------------------------------------------------

                                 1                      1                    560.50
                                 2                      2                   1056.00
                                 3                      1                    593.00

                              ------------------------------------------------------

                                     TOTAL RESOURCES USED    2209.50
                                     COST OF UNDETECTED VIOLATIONS        .32322
```

Figure 5.4   Printout of Initial Resource Allocation

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PRIORITY LIST OF SAMPLES

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	3	.30837067	1.81082	593.00
2	1	.25021163	.40838	1153.50
3	1	.01251636	.33823	1714.00
4	2	.00865593	.29253	2242.00
5	2	.00747338	.25307	2770.00
6	2	.00645239	.21900	3298.00
7	2	.00557088	.18958	3826.00
8	2	.00460981	.16419	4354.00
9	2	.00415270	.14226	4882.00
10	2	.00358537	.12333	5410.00
11	2	.00309555	.10699	5938.00
12	2	.00267265	.09288	6466.00
13	2	.00230752	.08069	6994.00
14	1	.00062511	.07718	7554.50
15	1	.00003132	.07701	8115.00
16	1	.00000157	.07700	8675.50
17	1	.00000008	.07700	9236.00
18	1	.00000000	.07700	9796.50
19	1	.00000000	.07700	10357.00
20	3	.00000000	.07700	10950.00
21	1	.00000000	.07700	11510.50
22	1	.00000000	.07700	12071.00
23	3	.00000000	.07700	12664.00
24	3	.00000000	.07700	13257.00
25	3	.00000000	.07700	13850.00

Figure 5.5 Printout of Sample Priorities

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PRIORITY LIST OF SAMPLES

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	1	.01251636	.25307	2770.00
2	2	.00645239	.21900	3298.00
3	2	.00557088	.18958	3826.00
4	2	.00480981	.16419	4354.00
5	2	.00415270	.14226	4882.00
6	2	.00358537	.12333	5410.00
7	2	.00309555	.10699	5938.00
8	2	.00267265	.09288	6466.00
9	2	.00230752	.08069	6994.00
10	1	.00062611	.07718	7554.50
11	1	.00003132	.07701	8115.00
12	1	.00000157	.07700	8675.50
13	1	.00000008	.07700	9236.00
14	1	.00000000	.07700	9796.50
15	1	.00000000	.07700	10357.00
16	3	.00000000	.07700	10950.00
17	1	.00000000	.07700	11510.50
18	1	.00000000	.07700	12071.00
19	3	.00000000	.07700	12664.00
20	3	.00000000	.07700	13257.00
21	3	.00000000	.07700	13850.00

Figure 5.6 Printout of Sample Priorities Beyond Minimim Allocation

```
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                                  FINAL ALLOCATION

                                  BUDGET  10000.00
```

SOURCE	MIN NO. SAMPLES REQUIRED	MAX NO. SAMPLES ALLOWED	TIMES SAMPLED	RESOURCES USED	COST OF UNDETECTED VIOLATIONS
1	1	10	7	3923.50	.00000
2	2	10	10	5280.00	.07700
3	1	5	1	593.00	.00000

```
TOTAL RESOURCES USED  9796.50
FINAL COST OF UNDETECTED VIOLATIONS     .07700
```

Figure 5.7 Printout of Final Allocation Based on Budget Limit

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FINAL ALLOCATION

MAXIMUM ALLOWED COST OF UNDETECTED VIOLATIONS .25000

SOURCE	MIN NO. SAMPLES REQUIRED	MAX NO. SAMPLES ALLOWED	TIMES SAMPLED	RESOURCES USED	COST OF UNDETECTED VIOLATIONS
1	1	10	2	1121.00	.00369
2	2	10	3	1584.00	.21530
3	1	5	1	593.00	.00000

TOTAL RESOURCES USED 3298.00
FINAL COST OF UNDETECTED VIOLATIONS .21900

Figure 5.8 Printout of Final Allocation Based on Maximum Acceptable "Cost of Undetected Violations"

Output Option 5 : Statistical summary tables for each source (see Figure 5.9).

All of the values under "Resources Used" or "Resources Required" in the output are dollar values. They are derived from the base cost to monitor each effluent source given: (1) its number of pipes (input variable PIPCST), and (2) the cost to analyze each of the constituents of each pipe of an effluent source (input variable CONCST).

The "Cost of Undetected Violations", as listed in the output, refers to the expected value of the damage caused by the pollutants (assuming Resource Criterion #2 is used) for those days when violations go undetected (see Section 2 of this handbook, and Section VI of Reference 1 for a more complete description of the term). The "Marginal Returns" listed are simply the decrease in the cost of undetected violations per unit of resources expended as each sample is taken.

In the statistical summary tables, the means, standard deviations, and standards are in units of Kg/day. For lognormal distributions ('L' under 'DIST'), the mean and standard deviation are of the log values of the loadings.

In some cases, a series of '***' will be printed out in the statistical summary tables. This occurs when a constituent is discharging from more than one pipe; only one value of expected damage and probability of no violation (for the combined loadings) is possible, and so when the constituent is printed more than once '***' replaces the numerical value. Similar output occurs for pH, since pH is always printed out under pH MIN and pH MAX.

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****
SOURCE 1
****

PIPE= 1 MEAN DISCHARGE (ML/DAY)= .7207 UPSTREAM FLOW (ML/DAY)= 100.0000

CONSTITUENT	STANDARD	DIST	EST. MEAN	EST. SIGMA	EXPECTED DAMAGE	PROB. OF NO VIOLATION
PH-MAX	9.5000	N	8.0437	1.6354	********	***********
PH-MIN	6.5000	N	7.6312	1.4335	.5626	.5984
LEAD	.0529	N	.4367	.2788	1.4763	.0843
PHOSPHORUS	1.0580	L	-1.9153	.3106	.0031	1.0000
CYANIDE	.1322	L	-1.5545	.2849	.0687	.9912

****
SOURCE EXPECTED DAMAGE 1.4763
SOURCE PROBABILITY OF NO VIOLATION .0500
****

Figure 5,9 Print of Source Statistical Summaries

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****
SOURCE 2
****

PIPE= 1 MEAN DISCHARGE (ML/DAY)= .1741 UPSTREAM FLOW (ML/DAY)= 20.7000

CONSTITUENT	STANDARD	DIST	EST. MEAN	EST. SIGMA	EXPECTED DAMAGE	PROB. OF NO VIOLATION
PH-MAX	9.5000	N	8.9786	.4401	********	***********
PH-MIN	6.7000	N	8.7976	1.0067	.3345	.8634

****
SOURCE EXPECTED DAMAGE .3345
SOURCE PROBABILITY OF NO VIOLATION .8634
****

Figure 5.9 -- Continued

****
SOURCE 3
****

PIPE= 1 MEAN DISCHARGE (ML/DAY)= .5265 UPSTREAM FLOW (ML/DAY)= 525.0000
MEAN DO CONCENTRATION (MG/L)= 6.1812

CONSTITUENT	STANDARD	DIST	EST. MEAN	EST. SIGMA	EXPECTED DAMAGE	PROB. OF NO VIOLATION
CHLOROFORM EXTRACT	20.0000	L	1.1335	.5282	1.8286	.6245

PIPE= 2 MEAN DISCHARGE (ML/DAY)= .1305 UPSTREAM FLOW (ML/DAY)= 525.0000
MEAN DO CONCENTRATION (MG/L)= 6.1812

CONSTITUENT	STANDARD	DIST	EST. MEAN	EST. SIGMA	EXPECTED DAMAGE	PROB. OF NO VIOLATION
CHLOROFORM EXTRACT	9.3000	L	-.0388	.3944	********	.9947
COLIFORMS--TOTAL	1500.0000	N	1069.0909	80.2886	.0267	1.0000
BOD5	6.9750	N	1.0201	.7307	.0090	1.0000

****
SOURCE EXPECTED DAMAGE 1.8266
SOURCE PROBABILITY OF NO VIOLATION .0000
****

@FIN

Figure 5.9 -- Continued

Error Messages

The program performs a careful check on the input data and should an error be found, a series of 'XXX' followed by an error message will be printed and the program will stop. The error message will include information such as the card number (Column 1 in Table 5.1) or source and pipe number so that the user can locate his mistake; the error message will also include a brief diagnosis of the problem. In most cases, an obvious error such as a transposition of data or a misspecification of an option can be easily found and the reader need only refer to Section 5.2 (Input Description) to correct the error. In certain instances, a sequencing mistake will have been made--a card may have been deleted or identifying numbers rearranged. In this case the error message may not point directly to the source of the error but to some point downstream and the user will need to carefully compare the preceding part of the input deck against Section 5.2 to find the error.

Sometimes an error may not be detected until processing of the data has begun. If sample minimum loadings and mean or maximum loadings have been transposed, for a sample in the input stream, the program will automatically delete the incorrect sample and print out a message specifying the details but processing is continued. However, should the total number of valid samples during the sampling period for any constituent be too small (less than 4) or too large (larger than 40 for pH or 365 for other constituents) an error message will be printed specifying the source and the constituent and the program will stop. Also, should the ratio of the combined maximum to the combined mean, during the sampling period for any constituent too large (greater than 6.0), or too small (less than 1.25), the program will print the details and stop. In the cases mentioned above, a decision will have to be made to correct data that was incorrectly entered or to delete constituents which cannot be tolerated by the program.

SECTION 6
DEMONSTRATION OF PROCEDURES

This section demonstrates results of tests of both hand and computer calculation procedures. The tests were performed using data supplied by the State of Michigan, Department of Natural Resources. The data was obtained on seven effluent sources which are a subset of the data used in the previous SCI demonstration of the computerized procedure [1]. The effluent sources used were those computed to give the highest environmental damage in the first SCI report (see Section 9 of [1]). The constituents used in this demonstration are high and low pH, biological oxygen demand (BOD, total suspended solids (SS), chromium, phosphorus, and oil-grease.

In Section 6.1, data from the year 1972 is used in the hand calculation procedure to determine the initial allocation of monitoring resources. Section 6.2 shows how the more recent 1973 data is used to illustrate the update of statistics procedure. Section 6.3 shows an alternate method of evaluating the magnitude, or severity, of violations in hand calculations. Finally, Section 6.4 gives results of the computer calculation method applied to the same test problem, and compares these with the hand calculation results.

Although there are minor discrepancies between the hand and computer calculation results, due primarily to the different allocation criteria used (described in Section 2), they are in general agreement. In all cases, results were found to be reasonable.

CAVEAT

The objective of this section is the demonstration of the hand calculation approach. The selection of the Grand and Saginaw Rivers to further this objective should not be construed as an expression of opinion concerning the status of these rivers or their tributaries. The results of the demonstration are based on a careful application of the procedure to the data available. The authors have made every attempt to assure that the data used is exhaustive and representative, but they recognize the possibility that relevant information may have been overlooked. To this extent, the results of the demonstration may be considered directly applicable to evaluation of water quality surveillance on the Grand and Saginaw Rivers.

6.1 DEMONSTRATION OF HAND CALCULATION PROCEDURES - INITIAL ALLOCATION

The hand calculation approach was successfully demonstrated using the Section 4, User Manual. Self-monitoring data from seven effluent sources on the Grand and Saginaw Rivers in Michigan were used to determine resource allocations for effluent compliance monitoring. Four sources are automobile and chemical industries, typical of the area, while the other three effluent sources are municipal waste treatment plants located on the same rivers. All are major effluent sources whose discharges historically have been significant. The presentation here follows the order of tasks found in the User Manual (Section 4). The reader is encouraged to use this section as a step-by-step illustration of the hand calculation procedure.

TASKS 1 and 2

The procedures are self-explanatory. Tables 6.1 and 6.2 represent the output from these tasks. All seven sources, their constituents, and relevant standards are shown, although subsequent tasks generally will illustrate the technique only for one source in order to reduce repetitive calculations.

Table 6.1 Statistical Distribution Types by Constituent and Source

Source	Constituent	Distribution	Task 1 Alternate Used 1 or 2
9	pH Max	N	-
	pH Min	N	-
	BOD	N	2
	SS	N	2
	CHR	N	-
10	pH Max	N	-
	pH Min	N	-
	SS	N	2
	phos	N	2
	Oil - Gr	N	2
12	pH Max	N	-
	pH Min	N	-
	BOD	N	2
	SS	N	2
18	BOD	N	2
	SS	N	2
22	BOD	N	2
	SS	N	2
	phos	N	2
25	BOD	N	2
	SS	N	2
27	BOD	N	2
	SS	N	2
	phos	N	2

Table 6.2 Effluent Standards

Source	Constituent		
	Name	Units	Standard Value S
(1)	(2)	(3)	(4)
9	pH Max		9.5
	pH Min		6.5
	BOD	Kg/day	189.27
	SS	Kg/day	473.2
	CHR	Kg/day	5.7
10	pH Max		10.5
	pH Min		6.5
	SS	Kg/day	46.4
	Phos	Kg/day	1.35
	Oil - Gr	Kg/day	19.9
12	pH Max		9.0
	pH Min		6.0
	BOD	Kg/day	41.6
	SS	Kg/day	104.1
18	BOD	Kg/day	3000.0
	SS	Kg/day	4445.2
22	BOD	Kg/day	1360.8
	SS	Kg/day	907.2
	Phos	Kg/day	378.5
25	BOD	Kg/day	4535.9
	SS	Kg/day	3628.7
27	BOD	Kg/day	272.2
	SS	Kg/day	272.2
	Phos	Kg/day	58.3

TASK 3

Table 6.3 presents raw data for source 9 and illustrates the calculation of the mean, m. Data for other sources are similar and are not included in this example.

All constituent data except pH are expressed as concentrations, but must be converted to loading rates (Kg/day) in order to compare data to the standards in Table 6.2. Table 6.4 shows typical conversions.

Finally, all converted data is entered in columns 1-7 of Table 6.5.

TASK 4

Task 4 is concerned with the calculation of self-monitoring statistics. The hand calculation procedure is illustrated below for pH Max.

$\mu = m = 8.39$

$G = 2.735$ (Figure 4.3)

$$\sigma = \frac{\xi - m}{G} = \frac{10.9 - 8.39}{2.735} = 0.9177$$

Distribution is normal (N)

$N = n = 249$

$\nu = 50$ (Figure 4.5)

Although formulas may differ, the procedure for the remaining four constituents of source 9 is virtually identical. The calculated statistics are entered in columns 8-12 of Table 6.5.

Table 6.3 Source Number 9: Raw Data

	pH				BOD (mg/ℓ)			SS (mg/ℓ)			CHR (μg/ℓ)			Effluent Flow
	Avg	Max	Min	n	Avg	Max	n	Avg	Max	n	Avg	Max	n	Avg (mgd)
Jan,72	8.67	9.95	7.52	17	115.6	155.4	15	6.03	15.2	17	3.53	30.	17	1.14
Feb	8.9	10.3	7.8	20	95.5	168.9	20	6.8	16.8	20	0.	0	20	1.21
Mar	9.21	10.43	7.9	20	179.1	279.2	20	5.0	12.2	20	35.5	320.	20	1.27
Apr	9.7	10.9	7.7	20	126.5	295.	20	3.1	9.0	20	2.0	20.	20	1.18
May	8.4	10.4	6.4	22	101.9	234.	22	9.9	44.6	22	.91	10.	22	1.17
Jun	6.2	7.8	4.4	22	92.1	134.	22	10.6	47.	22	4.	20.	22	1.19
Jul	8.4	10.6	6.1	19	60.	84.	19	3.8	16.	19	5.21	70.	19	1.0
Aug	8.5	10.8	7.3	23	46.2	100.4	18	4.7	13.8	23	0.	0.	23	1.1
Sep	9.1	10.2	7.8	21	70.8	198.	17	3.9	8.0	21	0.	0.	21	1.3
Oct	8.2	9.0	7.2	22	94.	358.	22	6.3	12.2	22	59.	400.	22	1.4
Nov	7.8	9.4	7.5	22	80.	150.	22	4.4	8.1	22	0.	0.	21	1.49
Dec,72	7.9	9.0	7.3	21	86.5	208.	19	3.5	6.0	21	0.	0.	21	1.5
$\sum n$	-	-	-	249	-	-	236	-	-	249	-	-	248	-
$\sum nx$	2089	-	-	-	22670	-	-	1423	-	-	2315	-	-	-
$m=\frac{\sum nx}{\sum n}$	8.39	-	-	-	96.06	-	-	5.713	-	0	9.335	-	-	1.25
Min=ω	-	-	4.4	-	-	-	-	-	-	-	-	-	-	-
Max=ξ	-	10.9	-	-	-	358.	-	-	47.	-	-	400.	-	-

Table 6.4 Data and Standards Conversion

	Unconverted Data or Standard	Unconverted Units	Conversion Factor	Converted Units	Converted Data or Standard
BOD	96.06	mg/l	3.783*1.250	kg/day	454.4
	358	mg/l	3.783*1.250	kg/day	1693
SS	5.713	mg/l	3.783*1.250	kg/day	27.02
	47	mg/l	3.783*1.250	kg/day	222.3
Chr	9.335	mg/l	3.783*1.250 *10^{-3}		.04416
	400	mg/l			.1892

Note: This table can be duplicated for use in the hand calculations.

Table 6.5 Effluent Data, Statistics, and Probabilities

γ(Task 6) = 1 Discounting constant, h(Task 7) = 1

TASK 3 Self-monitoring input data (record in source sequence)							TASK 4 Self-monitoring statistics					TASK 6 Self + compliance				TASK 7 New cum. statis.				TASK 8 Probabilities		
Source	Constituent Name	Units	Mean m	Max* ζ	Min** ω	Sample Size n	Est'd Mean μ	Est'd Std. Dev. σ	Distribution L or N	η	ν	$\tilde{\mu}$	$\tilde{\sigma}$	$\tilde{\eta}$	$\tilde{\nu}$	$\hat{\mu}$	$\hat{\sigma}$	$\hat{\eta}$	$\hat{\nu}$	Norm'd Effl't Std. x	Φ(x)	Pr. non-viol'n./const. P_{ij}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
9	pH Max	-	8.39	10.9	-	249	8.39	.9177	N	249	50	SAME AS TASK 4				VALUES SAME AS TASK 6				$\bar{x}$ = 1.2954	.38676	.7892
	pH Min	-	8.39	-	4.4	249	8.39	1.459	N	249	50									$\bar{x}$ = 1.2954	.4024	
	BOD	Kg/day	454.4	1693	-	236	454.4	455.37	N	236	49									-5822	-21978	.2802
	SS	Kg/day	27.02	222.3	-	249	1.2466	.401	L	249	50									3.5622	.4997	.9997
	Chr	Kg/day	.04416	1.892	-	248	-.8227	.68	L	248	50									2.3288	.49007	.99007
10	pH Max	-	8.11	10.1	-	285	8.11	.7176	N	285	53									$\bar{x}$ 4.0220	.4996	.9994
	pH Min	-	8.11	-	7.0	285	8.11	.4003	N	285	53									$\bar{x}$ 3.3905	.4998	
	SS	Kg/day	29.86	91.63	-	285	29.86	22.276	N	285	53									.7425	.27111	.7711
	Phos	Kg/day	1.614	15.71	-	285	-.005	.43	L	285	53									.31473	.12352	.6235
	Oil - Gr	Kg/day	0	0	-	0	0	-	-	0	-									-	-	-
12	pH Max	-	7.64	9.91	-	248	7.64	.8300	N	248	50									$\bar{x}$ 1.639	.4494	.9593
	pH Min	-	7.64	-	6.68	248	7.64	.3510	N	248	50									$\bar{x}$ = 4.632	.4999	
	BOD	Kg/day	64.25	300.1	-	215	64.25	87.742	N	215	47									-.25814	-.1018	.39815
	SS	Kg/day	67.50	617.9	-	247	1.6204	.426	L	247	50									.93204	.32434	.82434
18	BOD	Kg/day	262.98	1673.5	-	21	2.073	.549	L	21	13.8									2.5576	.49473	.9947
	SS	Kg/day	1815.1	6945.5	-	21	1815.01	2681.9	N	21	13.8	SAME AS TASK 6								.9807	.33663	.8366
22	BOD	Kg/day	2140	6105.4	-	349	2140	1396.3	N	349	58									-.5580	-.2115	.2884
	SS	Kg/day	2094	9616.3	-	351	2094	2648.7	N	351	58									-.4481	-.1729	.3271
	Phos	Kg/day	132	453.6	-	347	132	113.24	N	347	58									2.1768	.48525	.9853
25	BOD	Kg/day	5197	11958	-	295	5197	2429.4	N	295	54									-.27212	-.1072	.3928
	SS	Kg/day	5942	17452	-	297	5942	4135.8	N	297	54									-.55934	-.2120	.2880
27	BOD	Kg/day	3639	7838.2	-	142	3639	1643.5	N	142	39									-2.0486	-.4798	.0203
	SS	Kg/day	2849	8291.8	-	149	2849	2117.8	N	149	40									-1.2167	-.3882	.1119
	Phos	Kg/day	295.3	476.28	-	128	295.3	68.87	N	128	43									-3.4413	-.4998	.0003

*Not required for pH min.

**Required only for pH min.

Note: This table can be duplicated for use in the hand calculations.

TASKS 5, 6, and 7

These tasks do not apply in this calculation.

TASK 8

Task 8 is illustrated in Table 6.6, where values for x, $\Phi(x)$, and P_{ij} are calculated for pH of source 9. Results are entered in columns 21, 22, and 23 of Table 6.5.

TASKS 9 and 10

Task 9 is self explanatory. All constituents are statistically independent, and the probability of no violation for each source is easily calculated.

$$P_g = \Pi_j P_{ij} = (.7892)\ (.2802)\ (.9997)\ (.99007) = .2189$$

On the other hand, Task 10 is quite complex. Table 6.7 provides details of the procedure for pH. Method 2 was used to assign violation weighting factors. In this demonstration, k varies with $\frac{1}{\theta}$, where θ is the receiving water concentration standard. Section 6.3 demonstrates the alternative of setting $k \propto \frac{1}{S}$ (S is the prescribed effluent standard).

The expected extent of violation (D) is calculated as shown in Table 6.8 and the violation weighting factor (C_i) for each source is recorded in Table 6.9, column 4.

Table 6.6 Worksheet for Task 8

pH (Max and Min considered simultaneously)

$\hat{\mu} = 8.39$ (Table 4.5)

$\bar{S} = 9.5$ (Table 4.2)

$\underline{S} = 6.5$ (Table 4.2)

$\underline{S} < \hat{\mu} < \bar{S}$, so

$$\underline{x} = \frac{\hat{\mu} - \underline{S}}{\underline{\hat{\sigma}}} = 1.2954$$

$$\bar{x} = \frac{\bar{S} - \hat{\mu}}{\bar{\hat{\sigma}}} = 1.2095$$

$\Phi(\underline{x}) = 0.38676$ (Table 4.7)

$\Phi(\bar{x}) = 0.4024$ (Table 4.7)

$P_{ij} = \Phi(\underline{x}) + \Phi(\bar{x}) = 0.7892$

Table 6.7 Worksheet for Task 10

Method B is chosen for each source

pH (Max and Min considered simultaneously)

$$\bar{k} = \underline{k} = 1$$

$$\hat{\mu} = 8.39$$

$$\bar{S} = 9.5$$

$$\underline{S} = 6.5$$

$$\underline{S} \leq \hat{\mu} \leq \bar{S}, \text{ so}$$

$$D = \bar{k}\,\bar{\hat{\sigma}} \left\{ f(\bar{x}) + \bar{x}[0.5-\Phi(\bar{x})] \right\} + \underline{k}\,\underline{\hat{\sigma}} \left\{ =(\underline{x}) + \underline{x}[0.5-\Phi(\underline{x})] \right\}$$

$$= (1)\ (0.9177) \left\{ 0.192 + 1.2095[0.5-0.38676] \right\}$$

$$+ (1)\ (1.459) \left\{ 0.1725 + 1.2905[0.5-0.4024] \right\} = .7373$$

Table 6.8 Record of Task 10 Options and Calculations - $K = \frac{1}{\theta}$

Violation weighting factor assignment method (1 or 2): 2, i

Source No. i	Constituent Name	Distribution L or N	Type of WFF A/B/C	WFF Coefficient k	Expected Extent of Violation D
(1)	(2)	(3)	(4)	(5)	(6)
9	pH Max	N	C	.1	0.7373
	pH Min	N	C	.1	
	BOD	N	A	.2	68.84
	SS	L	A	.025	0.003
	CHR	L	A	.20	1.1767
10	pH Max	N	C	.1	.0075
	pH Min	N	C	.1	
	SS	N	A	.025	.0740
	Phos	L	A	.10	6.9984
	Oil - Gr	-	A	.10	-
12	pH Max	N	C	.1	.1555
	pH Min	N	C	.1	
	BOD	N	A	.2	9.498
	SS	L	A	.025	.4196
18	BOD	L	A	.2	1.9724
	SS	N	A	.025	5.790
22	BOD	N	A	.2	228.57
	SS	N	A	.025	43.86
	Phos	N	A	.10	6.12
25	BOD	N	A	.2	267.10
	SS	N	A	.025	86.10
27	BOD	N	A	.2	657.78
	SS	N	A	.025	67.29
	Phos	N	A	.10	2370.

Note: This table can be duplicated for use in the hand calculations.

Table 6.9 Ranges of Sampling Rates and Expected Extents of Undetected Violation

Source No. i	Constituent Interdependence SD/SI	TASK 9: Prob. of Non-violation P_i	TASK 10: Violation Weighting Factor c_i	TASK 11: Min. No. Samples Required ℓ_i	TASK 11: Max. No. Samples Allowed L_i	TASK 12: Alternative Expected Extents of Undetected Violations, $C_i(s_i)$, for Various Sampling Rates, s_i: $s_i=1$	2	3	4	5	6	7	8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
9	SI	.2189	68.84	0	3	15.1	3.30	.722	-	-	-	-	-
10	SI	.4805	6.9984	0	3	3.36	1.62	.776	-	-	-	-	-
12	SI	.3149	9.498	0	3	4.99	.942	.300	-	-	-	-	-
18	SI	.8322	5.970	0	3	4.97	4.13	3.44	-	-	-	-	-
22	SI	.1054	228.57	0	3	24.1	2.54	.268	-	-	-	-	-
25	SI	.1131	267.1	0	3	30.2	3.42	.386	-	-	-	-	-
27	SI	.000001	2370.	0	3	.002	0	0	-	-	-	-	-

Note: This table can be duplicated for use in the hand calculations.

TASKS 11 and 12

Limiting sampling rates are established and entered in Table 6.9, columns 5 and 6.

For source 9, the expected extent of undetected violations, C_{ij}, is calculated below.

$$C_9(S_9) = c_9 p_9^{S_9}$$

$$S_9 = C_9(1) = (68.84)(0.2189) = 15.07$$

$$C_9(2) = 3.2986$$

$$C_9(3) = 0.7221$$

TASKS 13 and 14

Component per sample costs were not obtained for this demonstration. As in the computerized procedure, total cost per sample was assumed to be $525 for each source. This figure and the laboratory charges per constituent are entered into Table 6.10.

The marginal return for source 9 and sample 1 is computed using the formula:

$$\mu_9(1) = \frac{c_9 - C_9(1)}{r_9} = \frac{68.84 - 15.07}{560.5} = 0.09593$$

For sample 2 and 3, the following calculations are made:

Table 6.10 Resources Needed to Monitor Each Source Once

Source No. i	Man Hours Per Sample	Cost Per Man Hours	Travel Miles Per Sample	Cost Per Mile	Per Sample Cost of: Man Hours	Travel	Total	Total Per Sample Cost	Laboratory Analysis Charge/Constituent (add constituent names) #1 pH Max	#2 pH Min	#3 BOD	#4 SS	#5 Chr	#6 Phos	Total Cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
9							525		3	0	20	5	750	-	560.5
10							525		3	0	-	5	-	10	543
12							525		3	0	20	5	-	-	553
18							525		-	-	20	5	-	-	550
22							525		-	-	20	5	-	10	560
25							525		-	-	20	5	-	-	550
27							525		-	-	20	5	-	10	560

Note: This table can be duplicated for use in the hand calculations.

$$\mu_9(S_9) = \frac{C_9(S_9-1) - C_9(S_9)}{r_9}$$

$$\mu_9(2) = \frac{15.07 - 3.2986}{560.5} = 0.021$$

$$\mu_9(3) = 0.0046$$

These values are entered in Table 6.11.

TASKS 15, 16, and 17

There are no mandatory samples, so Task 15 does not apply. Tasks 16 and 17 are self explanatory and are illustrated by Tables 6.12 and 6.13.

6.2 UPDATE PROCEDURE

The preceding initial allocation of resources (given in Section 6.1) utilized data from 1972. This section incorporates self-monitoring data from 1973 to illustrate the hand calculation update procedure. Tasks 3 through 7 are illustrated because only these tasks are directly concerned with the update procedure.

The other tasks do not change, although Tasks 8 through 20 are repeated during the update procedure.

Only one source (27) is used to illustrate the update procedure, but all sources are handled similarly.

Table 6.11 Marginal Returns for Each Source

Source No. i	Marginal return, $\mu_i(s_i)$, from one additional sample, number s_i							
	$s_i=1$	2	3	4	5	6	7	8
9	.09593	.02100	.00460	-	-	-	-	-
10	.00670	.00322	.00155	-	-	-	-	-
12	.01177	.00371	.00117	-	-	-	-	-
18	.00182	.00153	.00125	-	-	-	-	-
22	.36514	.03848	.00406	-	-	-	-	-
25	.43071	.04871	.00551	-	-	-	-	-
27	4.2321	.000004	0	-	-	-	-	-

Note: This table can be duplicated for use in the hand calculations.

Table 6.12 Sampling Priority List

Priority Order	Source No. i	Sample No.(s) s_i	Marginal Return $\mu_i(s_i)$	Degree of Undetected Violation: Incremental $\Delta C_i(s_i)$	Degree of Undetected Violation: Cumulative $\Sigma C_i(s_i)$	Monitoring Resources Required: Per Sample(s) r_i	Monitoring Resources Required: Cumulative $R=\Sigma r_i$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				2957.	295.7		0
1	27	1	4.2321	-2370	587	560	560
2	25	1	.43071	-236.9	350.1	550	1110
3	22	1	.36514	-205.5	145.6	560	1670
4	9	1	.09593	-53.8	91.8	560.5	2230.5
5	25	2	.04871	-26.8	65.0	550	2780.5
6	22	2	.03818	-21.6	43.4	560	3340.5
7	9	2	.02100	-11.8	31.6	560.5	3901
8	12	1	.01177	-6.5	25.1	553	4454
9	10	1	.00670	-3.6	21.5	543	4997
10	25	.3	.00551	-3.0	18.5	550	5547
11	9	3	.00460	-2.6	15.9	560.5	6107.5
12	22	3	.00406	-2.3	13.6	560	6667.5
13	12	2	.00371	-2.0	11.6	553	7220.5
14	10	2	.00322	-1.7	9.9	543	7763.5
15	18	1	.00182	-1.0	8.9	550	8313.5
16	10	3	.00155	-8.4	8.06	543	8856.5
17	18	2	.00153	-8.4	7.22	550	9406.5
18	18	3	.00125	-.69	6.53	550	9956.5
19	12	3	.00117	-6.5	5.88	553	10509.5
20	27	2	.000004	-.002	5.878	560	11069.5

Note: This table can be duplicated for use in the hand calculations.

Table 6.13 Sampling Rates

Maximum monitoring resources available, $\bar{R}$ = \$ 5000

Maximum acceptable degree of undetected violations = ______

Source No. i	Min. No. Samples Required ℓ_i	Max. No. Samples Allowed L_i	No. of Times to be Sampled s_i	Monitoring Resources Needed \$	Degree of Undetected Violations $C_i(s_i)$
(1)	(2)	(3)	(4)	(5)	(6)
9	0	3	2	1121	3.2986
10	0	3	1	543	3.3530
12	0	3	1	553	2.9910
18	0	3	0	0	5.9700
22	0	3	2	1120	2.5390
25	0	3	2	1100	3.4170
27	0	3	1	560	.0024
			Totals:	4997	21.5810

TASK 3

New self-monitoring data is entered in columns 1-7 of Table 6.14

TASK 4

The following values for σ are calculated for each constituent

$$\text{BOD}: \quad \sigma = \frac{5892 - 3780}{2.56} = 8.56$$

$$\text{SS}: \quad \sigma = \frac{8868 - 3236}{2.56} = 2200$$

$$\text{Phos}: \quad \sigma = \frac{984 - 318}{2.50} = 230.4$$

TASKS 5, 6, and 7

Tasks 5 and 6 are not applicable to this update, but calculations for Task 7 are shown below

Source 27, BOD

$$\hat{\mu}_1 = \frac{\tilde{\eta}\tilde{\mu} + \hat{\eta}\hat{\mu}}{\tilde{\eta} + \hat{\eta}} = \frac{(144)(3780) + (142)(3639)}{144 + 142} = 3710$$

$$\hat{\sigma}_1 = \sqrt{\frac{\tilde{\nu}\tilde{\sigma}^2 + \tilde{\eta}\tilde{\mu}^2 + \hat{\nu}\hat{\sigma}^2 + \hat{\eta}\hat{\mu}^2 - (\tilde{\eta}+\hat{\eta})\hat{\mu}_1^2}{\tilde{\nu} + \hat{\nu} + 1}}$$

$$= \sqrt{\frac{(39.5)(825)^2+(144)(3780)^2+(39)(1643.5)^2+(142)(3639)^2-(144+142)(3710)^2}{39.5 + 39 + 1}}$$

$$= 1297$$

Table 6.14 Effluent Data, Statistics, and Probabilities

γ(Task 6) = ____________ Discounting constant, h(Task 7) = 2

TASK 3 Self-monitoring input data (record in source sequence)							TASK 4 Self-monitoring statistics					TASK 6 Self + compliance				TASK 7 New cum. statis.				TASK 8 Probabilities		
Source	Constituent Name	Units	Mean m	Max* ζ	Min** ω	Sample Size n	Est'd Mean μ	Est'd Std. Dev. σ	Distribution L or N	η	ν	$\tilde{\mu}$	$\tilde{\sigma}$	$\tilde{\eta}$	$\tilde{\nu}$	$\hat{\mu}$	$\hat{\sigma}$	$\hat{\eta}$	$\hat{\nu}$	Norm'd Effl't Std. x	$\Phi(x)$	Pr. non-viol'n./const. P_{ij}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
27	BOD	kg/day	3780	5892	-	144	3780	825	N	144	395		Same as task 4			3710	1297	286	79			
	SS	kg/day	3236	8868	-	145	3236	2200	N	145	395					3040	2177	290	79			
	Phos	kg/day	318	894	-	120	318	230	N	120	36					306	165	240	72			

*Not required for pH min.

**Required only for pH min.

Note: This table can be duplicated for use in the hand calculations.

$$h = 2$$

$$\hat{\eta}_1 = \min|(\tilde{\eta}+\hat{\eta}),\ h\tilde{\eta}|$$

$$\hat{\eta}_1 = 286$$

$$\hat{\nu}_1 = \min|(\tilde{\nu}+\hat{\nu}+1),\ h\tilde{\nu}| = 79$$

Updated values of the process mean ($\hat{\mu}_1$), standard deviation ($\hat{\sigma}_1$), and confidence constants ($\hat{\eta}_1$ and $\hat{\nu}_1$) for the cumulative estimated mean and standard deviation have been calculated for the constituent BOD for source 27. Calculation for other constituents and other sources are similar. The updated values were entered in columns 17-20 of Table 6.14 (Update of Table 6.5). It can be noted that these updated numbers are somewhat, but not drastically, different from the prior statistics given in columns 8-12 of Table 6.5.

6.3 ALTERNATE DETERMINATION OF VIOLATION WEIGHTING FACTOR

The initial hand calculation calculated a weighting factor function (WFF) with a coefficient k which varied with the reciprocal of the receiving water concentration standard, $\frac{1}{\theta}$. An alternative is to vary k with $\frac{1}{S}$ where S is the constituent effluent standard for a particular source. Task 10 discusses the differences in these representations.

This section illustrates the alternative where $k = \frac{1}{S}$. Tasks 10-17 are completed and the results are summarized in the following tables.

Table 6.15 shows the WFF constant k and the expected extent of violation D for each constituent. These results are utilized in Table 6.16 to calculate c_i and $C_i(s_i)$ for each source. In all instances,

Table 6.15 Record of Task 10 Options and Calculations

Violation weighting factor assignment method (1 or 2): 2 $(k = \frac{1}{S})$

Source No. i	Constituent Name	Distribution L or N	Type of WFF A/B/C	WFF Coefficient k	Expected Extent of Violation D
(1)	(2)	(3)	(4)	(5)	(6)
9	pH Max	N	C		.73733
	pH Min	N	C		
	BOD	N	A	.00528	1.8186
	SS	L	A	.00211	.0002
	Chr	L	A	.1754	.01032
10	pH Max	N	C	.1	.0075
	pH Min	N	C	.1	-
	SS	N	A	.00216	.07974
	Phos	L	A	.7471	.5184
	Oil - Fr.	-	A	-	-
12	pH Max	N	C	1	.1555
	pH Min	N	C	1	-
	BOD	N	A	.0240	1.1415
	SS	L	A	.0961	.16123
18	BOD	N	A	.00033	.00329
	SS	N	A	.00022	.05210
22	BOD	N	A	.00073	.83984
	SS	N	A	.00110	1.9339
	Phos	N	A	.00264	.001617
25	BOD	N	A	.00022	.29443
	SS	N	A	.00028	.94910
27	BOD	N	A	.00367	12.0827
	SS	N	A	.00367	9.8883
	Phos	N	A	.01715	4.0652

Note: This table can be duplicated for use in the hand calculations.

Table 6.16 Ranges of Sampling Rates and Expected Extents of Undetected Violations

Source No. i	Constituent Interdependence SD/SI	TASK 9: Prob. of Non-violation P_i	TASK 10: Violation Weighting Factor c_i	TASK 11: Min. No. Samples Required ℓ_i	TASK 11: Max. No. Samples Allowed L_i	TASK 12: Alternative Expected Extents of Undetected Violations, $C_i(s_i)$, for Various Sampling Rates, s_i: $s_i=1$	2	3	4	5	6	7	8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
9	SI	.2189	1.8186	0	3	.3981	.0871	.0191	-	-	-	-	-
10	SI	.4805	.5184	0	3	.2491	.1197	.0575	-	-	-	-	-
12	SI	.3149	1.1416	0	3	.3595	.1132	.0356	-	-	-	-	-
18	SI	.8322	.0521	0	3	.0434	.0351	.0300	-	-	-	-	-
22	SI	.1054	1.9339	0	3	.2038	.0215	.0023	-	-	-	-	-
25	SI	.1131	.94910	0	3	.1073	.0121	0014	-	-	-	-	-
27	SI	.000001	12.0927	0	3	00001	-	-	-	-	-	-	-

calculations for each constituent are identical to those performed in the initial allocation.

Table 6.17, the same as Table 6.10 in the initial allocation procedure, is used in conjunction with Table 6.16 to calculate the marginal returns $\mu_i(s_i)$ found in Table 6.18. Finally, the sampling priority list (Table 6.19) and the sampling rates (Table 6.20) are formed by allocating resources in the order of diminishing marginal returns.

6.4 COMPARISON OF THE HAND CALCULATION AND COMPUTERIZED RESULTS

The data in the hand calculation procedure was used in the computer allocation program to obtain the results shown in Tables 6.21 and 6.22. In general, the agreement between the two procedures was quite good, however results were not identical. Each assesses potential damage differently, so disagreement - particularly in the realm of marginal returns - is reported. Priorities may be expected to differ, although monitoring frequencies for a fixed budget are remarkably close. Refer to Section 3.2 which discusses the major technical differences between the two approaches.

PRIORITIES

Similarities in the hand calculation and computerized results are observed in Tables 6.19 and 6.21. Both procedures have determined source 27 to be the most injurious to the environment, and consequently both procedures assign top priority to monitoring that source. Furthermore, the probability of uncovering a violation of standards for source 27 was sufficiently high in both procedures so that repeat monitoring was unnecessary.

Sources 9, 22, and 25 were given the next three priorities in both cases, however, their relative positions differed. This is attributed to the different methods of calculating marginal returns.

Table 6.17 Resources Needed to Monitor Each Source Once

Source No. i	Man Hours Per Sample	Cost Per Man Hours	Travel Miles Per Sample	Cost Per Mile	Per Sample Cost of: Man Hours	Per Sample Cost of: Travel	Per Sample Cost of: Total	Total Per Sample Cost	Laboratory Analysis Charge/Constituent (add constituent names) #1	#2	#3	#4	#5	#6	Total Cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
9							525		3	0	20	5	750	–	560.5
10							525		3	0	–	5	–	10	543
12							525		3	0	20	5	–	–	553
18							525		–	–	20	5	–	–	550
22							525		–	–	20	5	–	10	560
25							525		–	–	20	5	–	–	550
27							525		–	–	20	5	–	10	560

Note: This table can be duplicated for use in the hand calculations.

Table 6.18   Marginal Returns for Each Source

Source No. i	Marginal return, $\mu_i(s_i)$, from one additional sample, number s_i							
	$s_i=1$	2	3	4	5	6	7	8
9	.00253	.00055	.00012	-	-	-	-	-
10	.00050	.00024	.00011	-	-	-	-	-
12	.00141	.00045	.00014	-	-	-	-	-
18	.00002	.000011	.00001	-	-	-	-	-
22	.00309	.00033	.00003	-	-	-	-	-
25	.00153	.00017	.00002	-	-	-	-	-
27	.02158	0	0	-	-	-	-	-

Note: This table can be duplicated for use in the hand calculations.

Table 6.19 Sampling Priority List Using Hand Calculating Procedures

Priority Order	Source No. i	Sample No.(s) s_i	Marginal Return $\mu_i(s_i)$	Degree of Undetected Violation: Incremental $\Delta C_i(s_i)$	Degree of Undetected Violation: Cumulative $\Sigma C_i(s_i)$	Monitoring Resources Required: Per Sample(s) r_i	Monitoring Resources Required: Cumulative $R=\Sigma r_i$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				18.4964	18.4964		
1	27	1	.02158	-12.0827	6.4137	560	560
2	22	1	.00309	- 1.7301	4.6836	560	1120
3	9	1	.00253	- 1.4205	3.2631	560.5	1680.5
4	25	1	.00153	- .8418	2.4213	550	2230.5
5	12	1	.00141	- .7821	1.6392	553	2783.5
6	9	2	.00055	- . 311	1.3282	560.5	3344.
7	10	1	.00050	- .2314	1.0968	543	3887.
8	12	2	.00045	- .2463	.8505	553	4440.
9	22	2	.00033	- .1823	.6685	560	5000.
10	10	2	.00024	- .1294	.5388	543	5543.
11	25	2	.00017	- .0952	.4436	550	6093.
12	12	3	.00014	- .0776	.3660	553	6646.
13	9	3	.00012	- . 068	.2980	560.5	7206.5
14	10	3	.00011	- .0622	.2358	543	7749.5
15	22	3	.00003	- .0192	.2166	560	8309.5
16	25	3	.00002	- .0107	.2059	550	8859.5
17	18	1	.00002	- .0087	.1972	550	9409.5
18	18	2	.00001	- .0073	.1899	550	9959.5
19	18	3	.00001	- .0061	.1838	550	10509.5
20	27	2	0	- .00001	.1838	560	11069.5
21	27	3	0	0	.1838	560	11629.5

Note: This table can be duplicated for Use in the hand calculations.

Table 6.20 Sampling Rates Using Hand Calculation Procedures

Maximum monitoring resources available, $\tilde{R}$ = \$ 5000

Maximum acceptable degree of undetected violations = ______

Source No. i	Min. No. Samples Required ℓ_i	Max. No. Samples Allowed L_i	No. of Times to be Sampled s_i	Monitoring Resources Needed \$	Degree of Undetected Violations $C_i(s_i)$
(1)	(2)	(3)	(4)	(5)	(6)
9	0	3	2	1121	.0871
10	0	3	1	543	.2491
12	0	3	2	1106	.1132
18	0	3	0	0	0.
22	0	3	2	1120	.0215
25	0	3	1	550	.1073
27	0	3	1	560	.00001
			Totals:	5000	.57821

Table 6.21 Priority List of Samples Using Computer Calculation Procedure

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	27	1.17790766	20.19641	560.00
2	22	.92823458	14.97045	1125.00
3	9	.64650202	11.34681	1683.50
4	25	.62190388	7.92633	2233.50
5	9	.14467446	7.11543	2794.00
6	22	.11426848	6.47210	3357.00
7	12	.10053506	5.91614	3910.00
8	18	.07626379	5.49669	4460.00
9	18	.06947721	5.11457	5010.00
10	18	.06329455	4.76645	5560.00
11	25	.05015871	4.49057	6110.00
12	10	.03865182	4.28070	6653.00
13	9	.03237530	4.09923	7213.50
14	12	.03157083	3.92465	7766.50
15	22	.01406680	3.84545	8329.50
16	10	.01360758	3.77156	8872.50
17	12	.00941412	3.71674	9425.50
18	10	.00479062	3.69072	9968.50
19	25	.00404547	3.66847	10518.50
20	27	.00000000	3.66847	11078.50
21	27	.00000000	3.66847	11636.50

SAMPLING RATES

Although discrepancies may be found in the priority ordering for each procedure, relatively little disagreement should be found in sampling rates for a sufficiently large budget. Different marginal returns may suggest different priorities, but both procedures should be able to sense in general terms, those sources that require high monitoring priorities. It was seen, for instance, that both procedures recognize the need to monitor source 27 first, but found repeat monitoring unimportant.

Table 6.20 and Table 6.22 present sampling rates for each procedure assuming a fixed budget of $5,000 and the results are close. In both allocations sources 9 and 22 are monitored twice and sources 12 and 27 once. Small differences are found in the number of samples required for sources 18 and 25. The computerized procedure would monitor both sources once, but the hand procedure monitors source 25 twice. Another difference between the two methods can be seen for source 10 which is monitored once by the hand procedure, but is not monitored by the computer method. This difference is largely due to the different sequences in which the budget is spent. Using the hand procedure, it was possible to spend $4,997 to monitor 9 times, but using the computerized procedure it was only possible to monitor 8 times for a cost of $4,460. Had the hand calculation run into similar budetary limits during allocation number 9, source 10 would not have been monitored, and both procedures would agree.

The disagreement in the sampling rates appear quite small. Both procedures tend to monitor the seven sources at about the same frequency but may accomplish these tasks in different sequences. Both procedures recognize the necessity to assign a high monitoring priority to potentially harmful sources and to give lower priority to situations where additional effect would yield relatively little new information.

Table 6.22 Final Allocation Using Computer Calculation Procedure

BUDGET 5000.00

SOURCE	MIN NO. SAMPLES REQUIRED	MAX NO. SAMPLES ALLOWED	TIMES SAMPLED	RESOURCES USED	COST OF UNDETECTED VIOLATIONS
9	0	3	2	1121.00	.23378
10	0	3	0	.00	.32392
12	0	3	1	553.00	.25451
18	0	3	1	550.00	4.29410
22	0	3	2	1126.00	.09031
25	0	3	1	550.00	.30008
27	0	3	1	560.00	.00000

TOTAL RESOURCES USED 4460.00

FINAL COST OF UNDETECTED VIOLATIONS 5.49669

SECTION 7
COMPUTER PROGRAM DOCUMENTATION

7.1 INTRODUCTION

The Effluent Monitoring Program (EFFMON) computes a priority allocation used to schedule future monitoring visits to discharge sources, having been given past information about those sources. For a description of the solution technique and restrictions on the model, the reader should consult Sections 2 and 5. This section will present documentation for EFFMON including general requirements for implementation, descriptions of the main program and subprograms (flow charts included) and, finally, definitions of program variables.

The EFFMON code conforms to ASA Standard FORTRAN V and has been successfully run on a UNIVAC 1108. The average size of the program on the UNIVAC 1108 is about 42K words. Along with the use of logical units 5 and 6 as card reader and line printer, two auxiliary mass storage units are utilized by the program for temporary storage. Logical unit 11 is referenced in the main program only, and is used to sequentially store discharge data for all sources; the data is then read back one source at a time as needed to compute initial statistics, probability of no violation and expected damage for that source. Logical unit 12 is called in the main program to sequentially store certain computed statistics for each source until the time such statistics have been computed for all sources; then, if these statistics are to be written out, subroutine OUTPUT is called, and the statistics are read back andprinted source by source (see Figure 5.7 for an example). Note that if NOUT (the flag variable which controls this putput option) is non-zero, OUTPUT is not called and unit 12 is not used.

One machine-dependent feature of the program which might need to be changed occurs in subroutines PNVCOM and EXPDAM. In those two routines, variables labelled as "WENDTA(7,J,-)" and "WENDTA(6,J,-)" are set equal to extremely large numbers. The reason for doing this is so that an overflow condition will exist when printing out certain terms. The UNIVAC 1108, which the program was run on, prints out the desired asterisks in this case. Adjustments may have to be made on another machine. Note that these asterisks are printed in the (optional) statistical summaries in place of a value for expected damage and probability of no violation when duplication (in multiple pipes) of any constituent at a source occurs.

One other item requiring attention is the function RNORM. Referenced within Function XNORM, RNORM(X) computes a rational function approximation to the standard normal distribution function with argument X:

$$\text{RNORM}(X) = \frac{1}{\sqrt{2\pi}} \int_{\infty}^{X} \exp(-t^2/2)dt$$

RNORM is a library function available through the UNIVAC 1108 STAT-PACK (statistical library). The method for computation as described by STAT-PACK is:

$$\text{RNORM}(X) = \begin{cases} f; \; X \leq 0 \\ 1-f; \; X > 0 \end{cases}$$

where

$$f = \left[\sum_{i=0}^{6} a_i \frac{|X|}{2}^{i} \right]^{-16}$$

and where the a_i's are taken from Hastings' Numerical Approximations for Digital Computers (Princeton, 1955). The user must accommodate EFFMON by supplying a suitable reference for RNORM.

7.2 PROGRAM DESCRIPTION

The EFFMON main program and subprograms are described in the succeeding pages. Figure 7.1 demonstrates the linkages between the main program and subprograms. Simplified flow charts of major individual routines are presented in Figures 7.2 through 7.10. All equations labelled therein are located in Reference [1].

Main Program

The main program reads all input data and echo prints all inputs. The constituent data are converted where the units are inappropriate (standard units for the program are the same as those listed in Table 5.4). The only other calculations done in the main program are those for estimating an average pipe flow for each pipe. The rest of the calculations and output are carried out by subroutines coordinated by the main program. For each source to be considered, the main program calls ISTAT, PNVCOM, and EXPDAM to determine initial statistics, calculate the probability of no violation, and find the expected damage of undetected violations respectively. The priority allocations and corresponding output are then created by calling PRIORT. Additional output of the statistics of the individual sources is obtained by calling OUTPUT.

Subroutine ABEF

Subroutine ABEF computes the coefficients used in calculating the expected damage for pH/pOH.

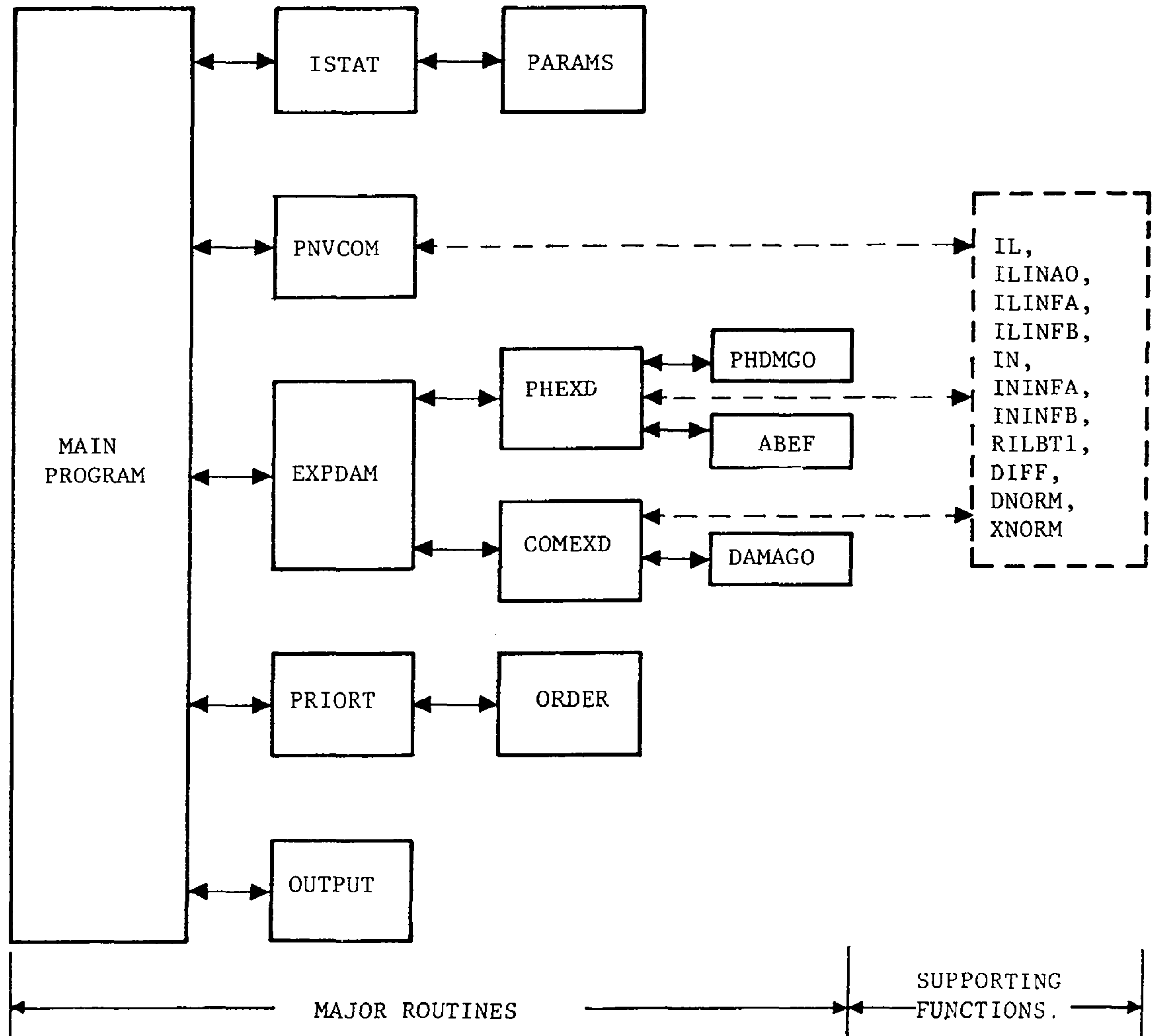


Figure 7.1 General Program Flow Diagram for EFFMON

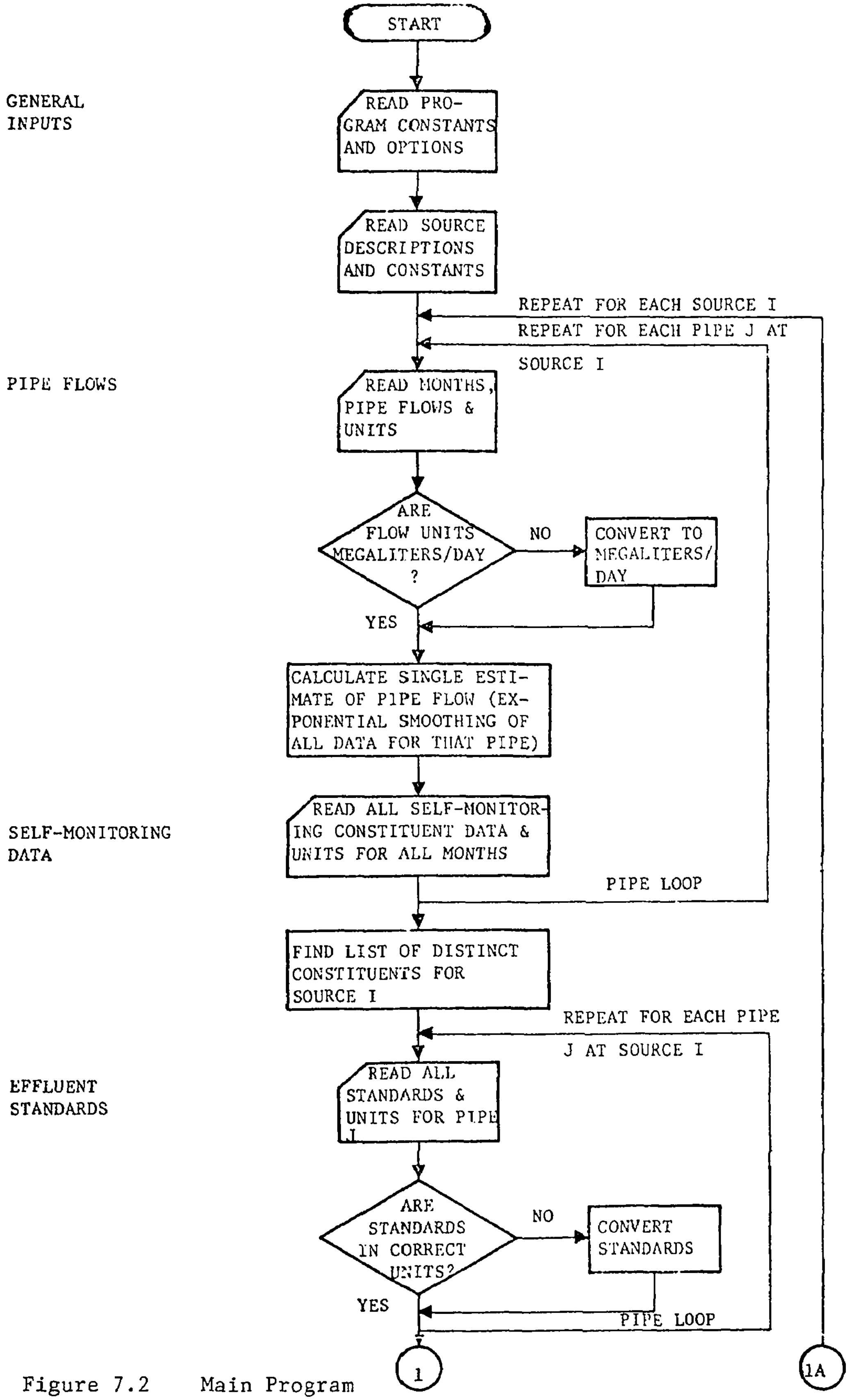


Figure 7.2 Main Program

CONVERSION OF DATA
INTO USABLE UNITS

COMPLIANCE
MONITORING

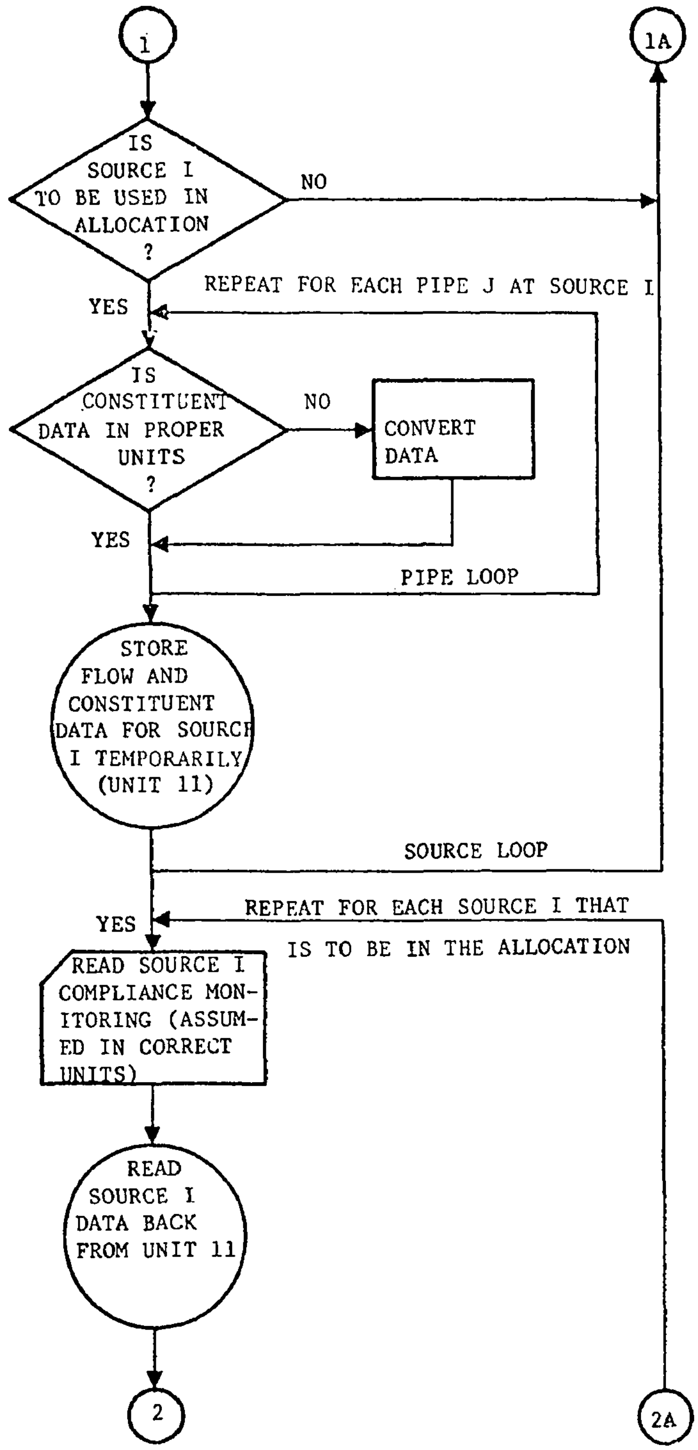


Figure 7.2 -- Continued

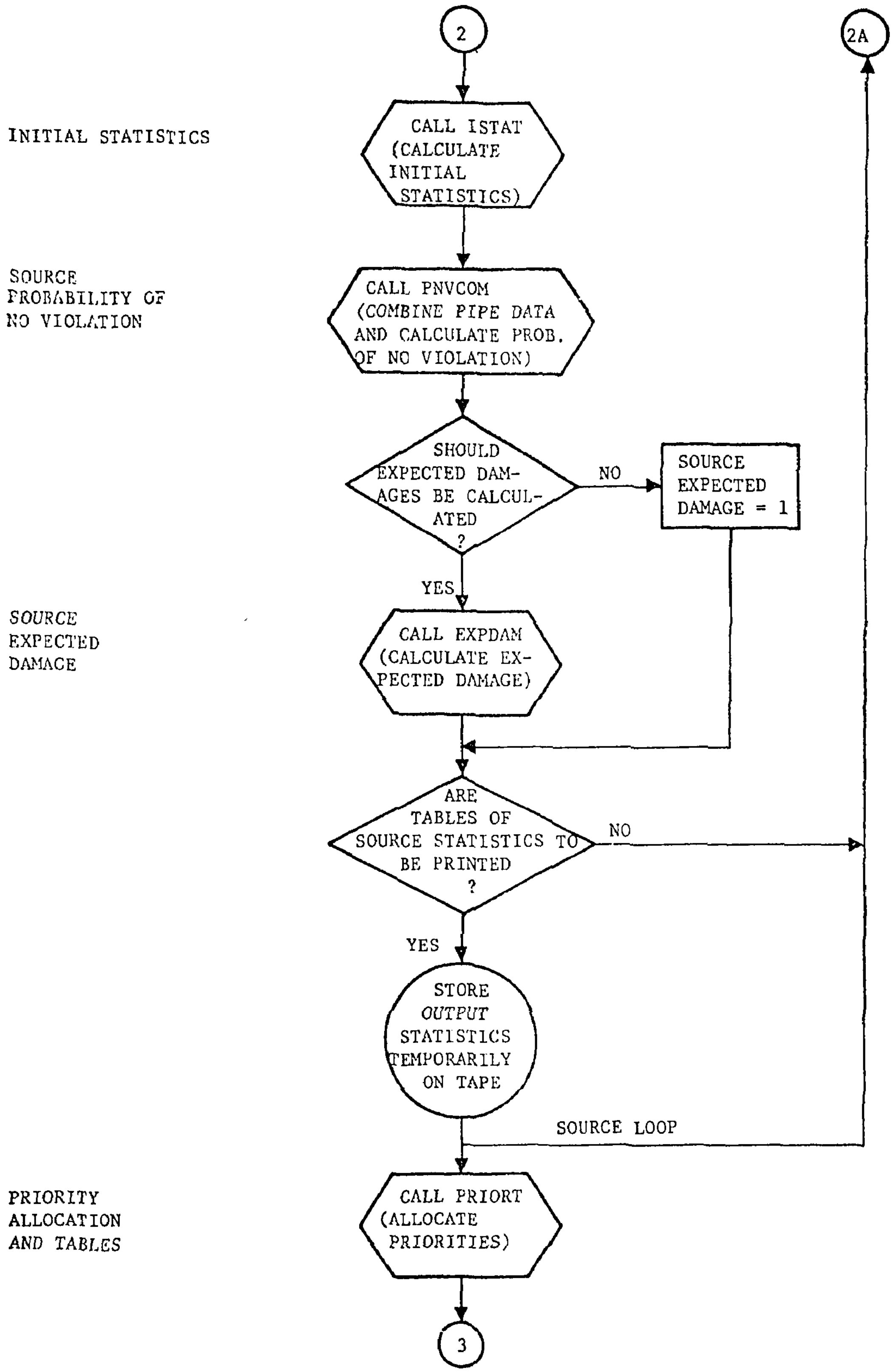


Figure 7.2 -- Continued

SUMMARY TABLES

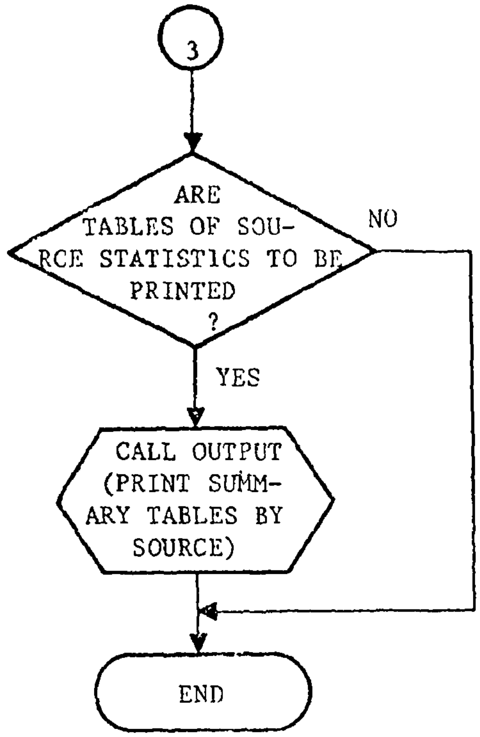


Figure 7.2 -- Continued

CONSTITUENT
EXPECTED
DAMAGE

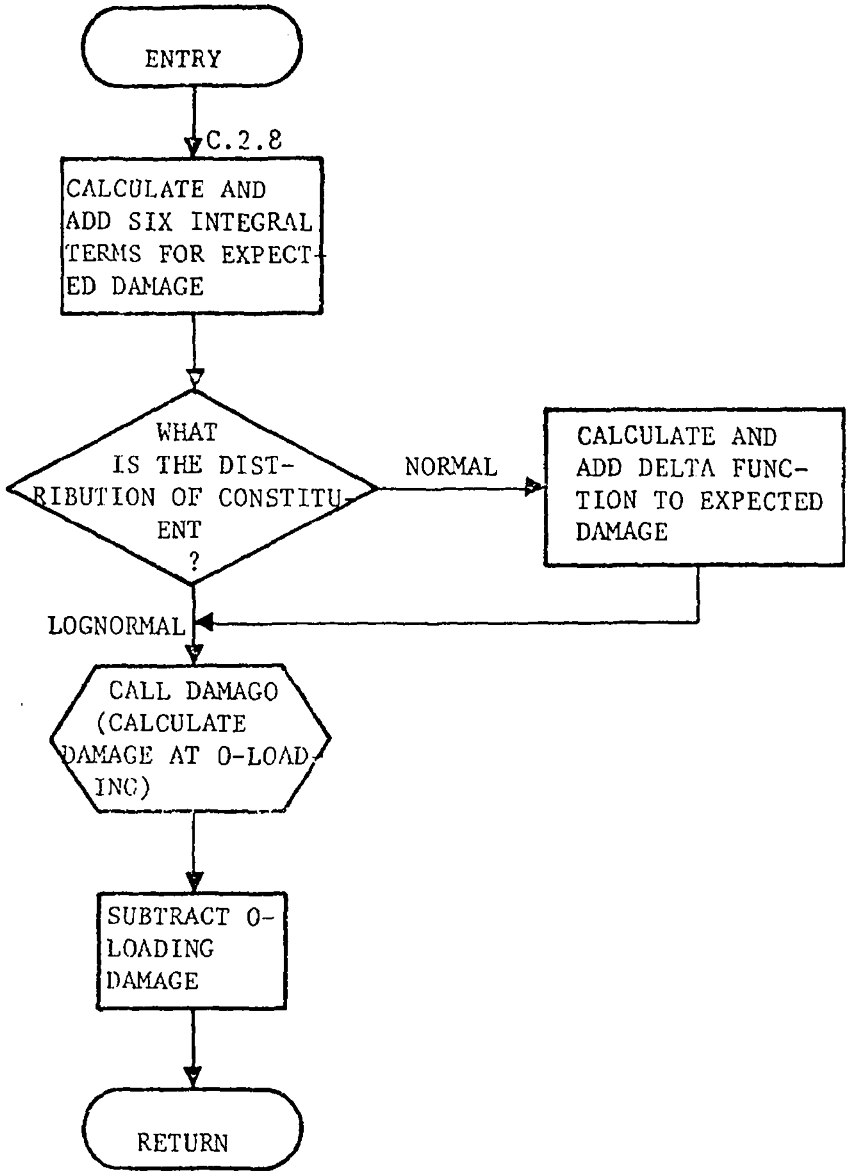


Figure 7.3 Function COMEXD

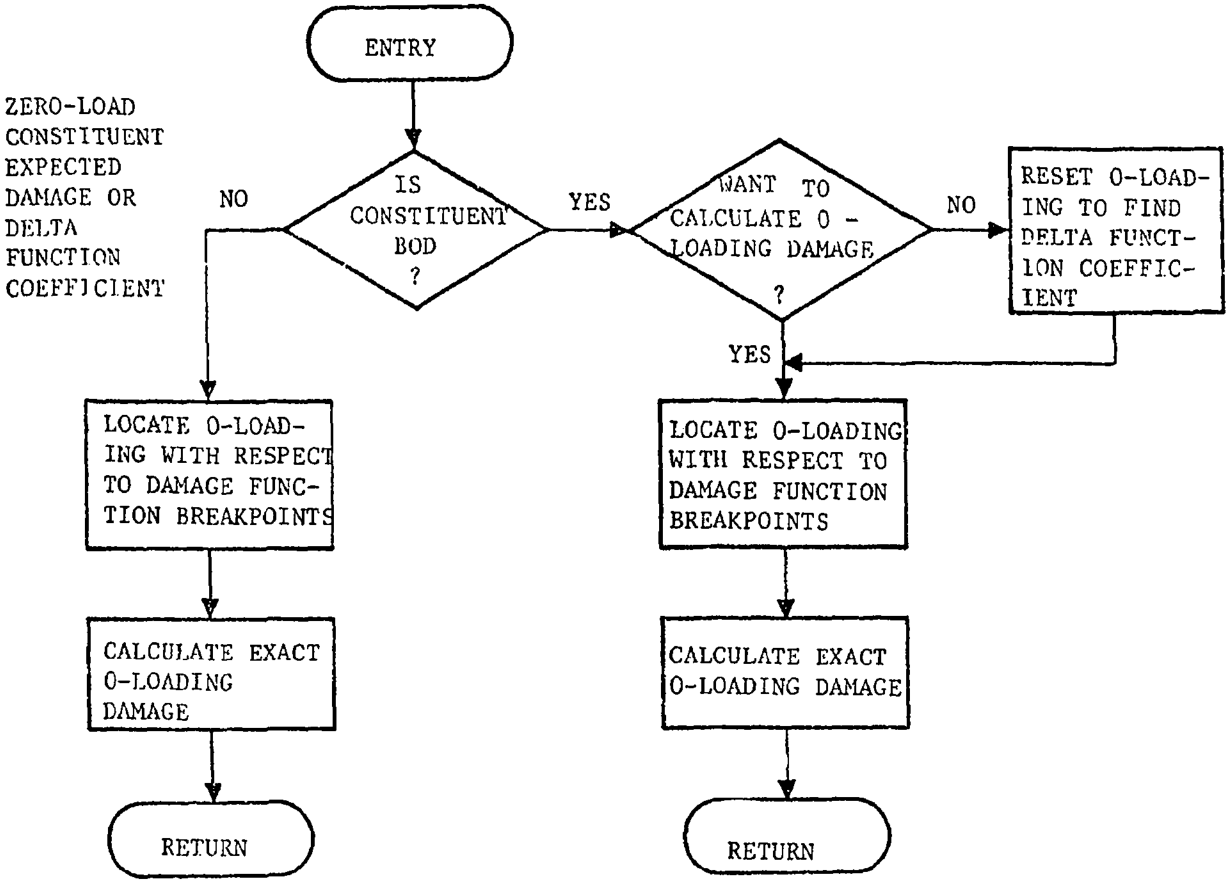


Figure 7.4 Subroutine DAMAGO

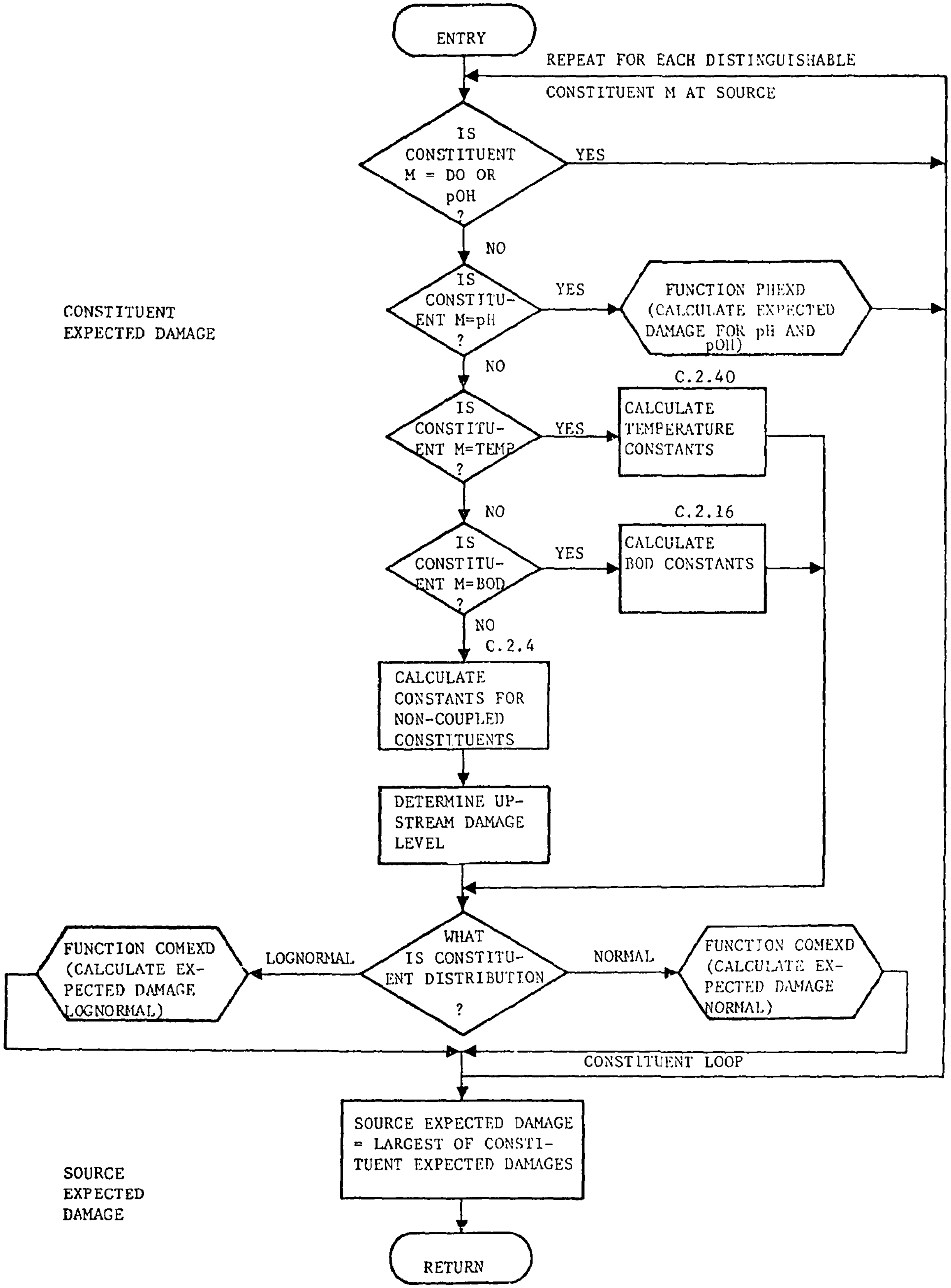


Figure 7.5 Subroutine EXPDAM

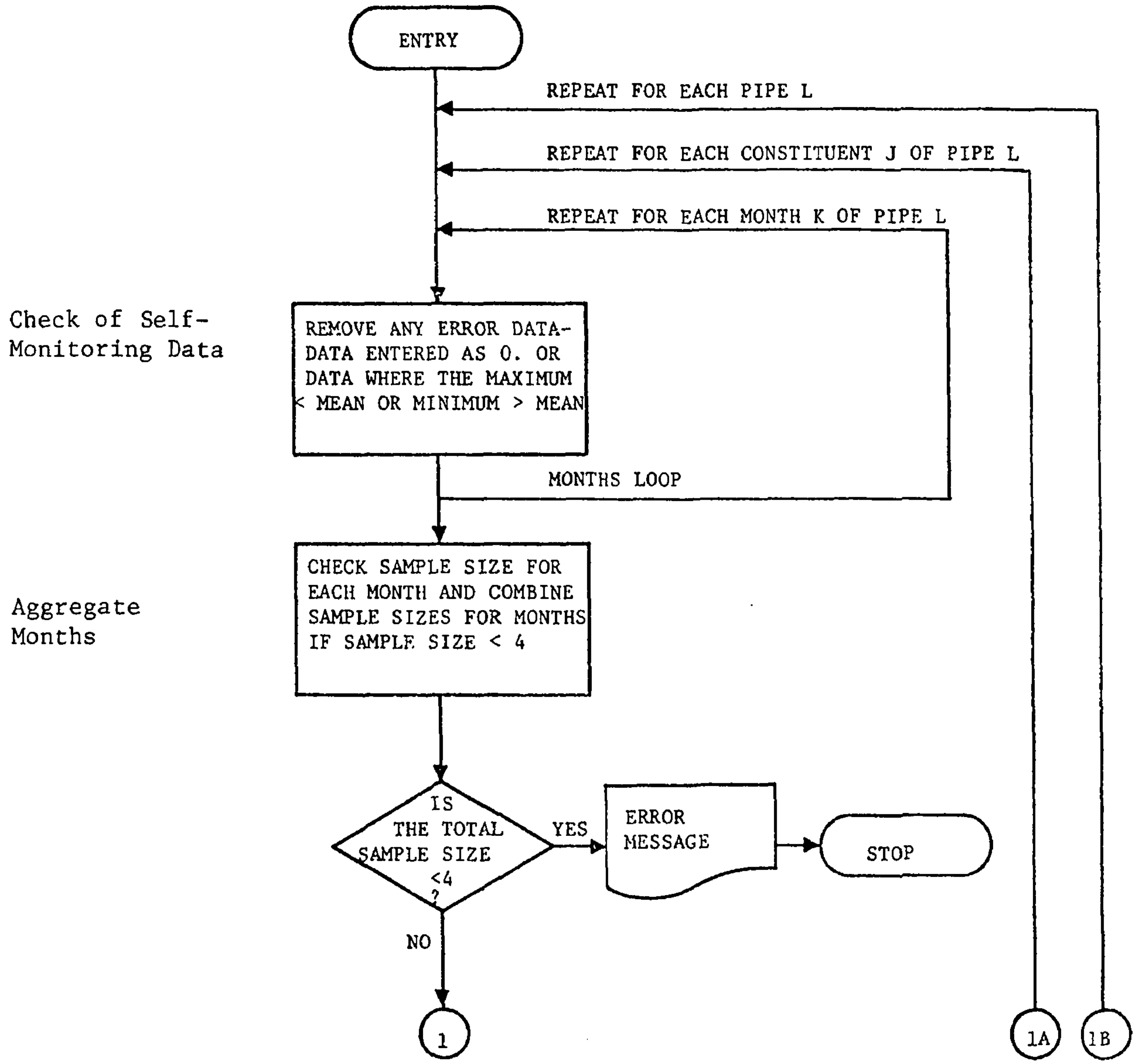


Figure 7.6 Subroutine ISTAT

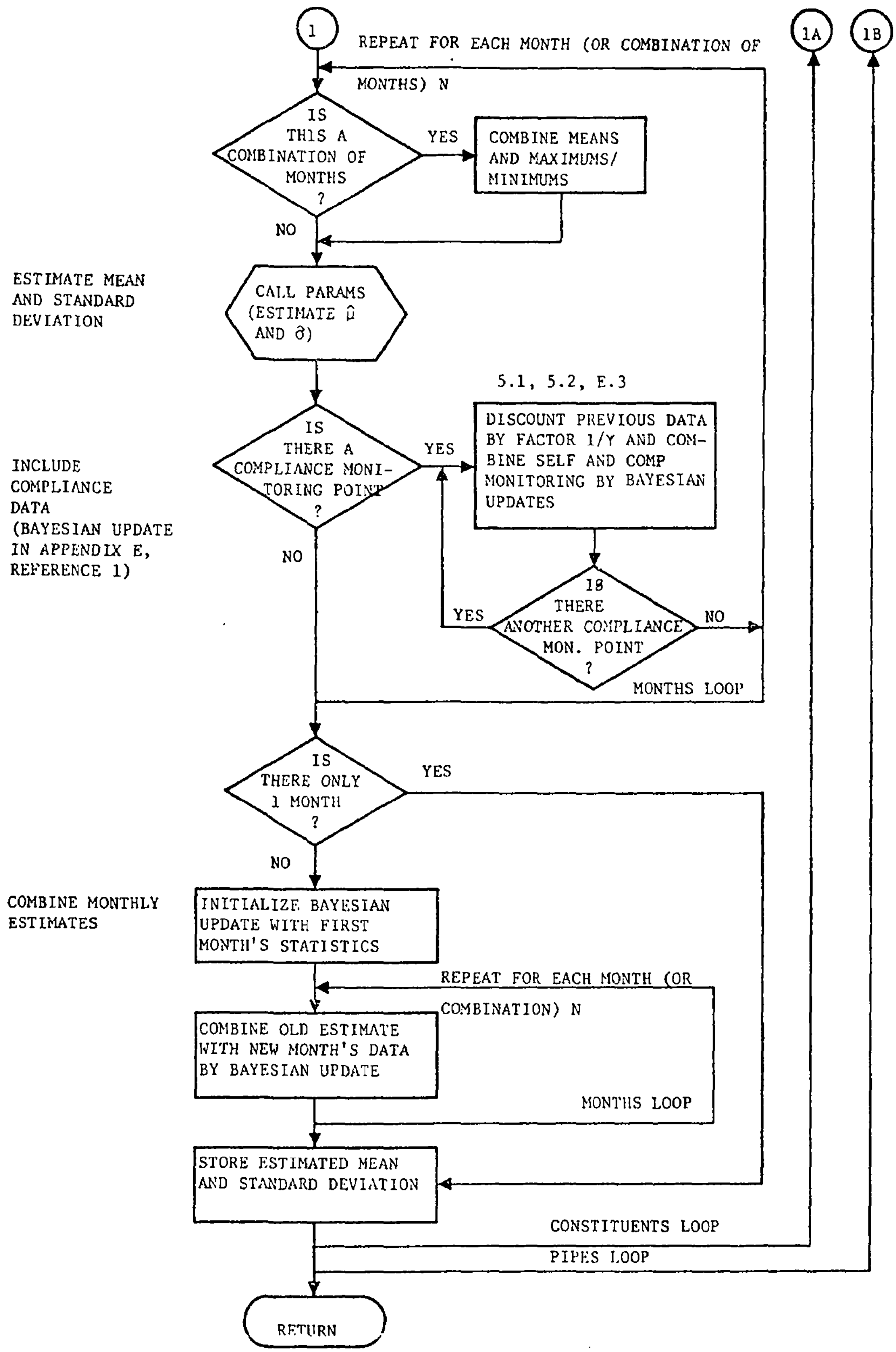
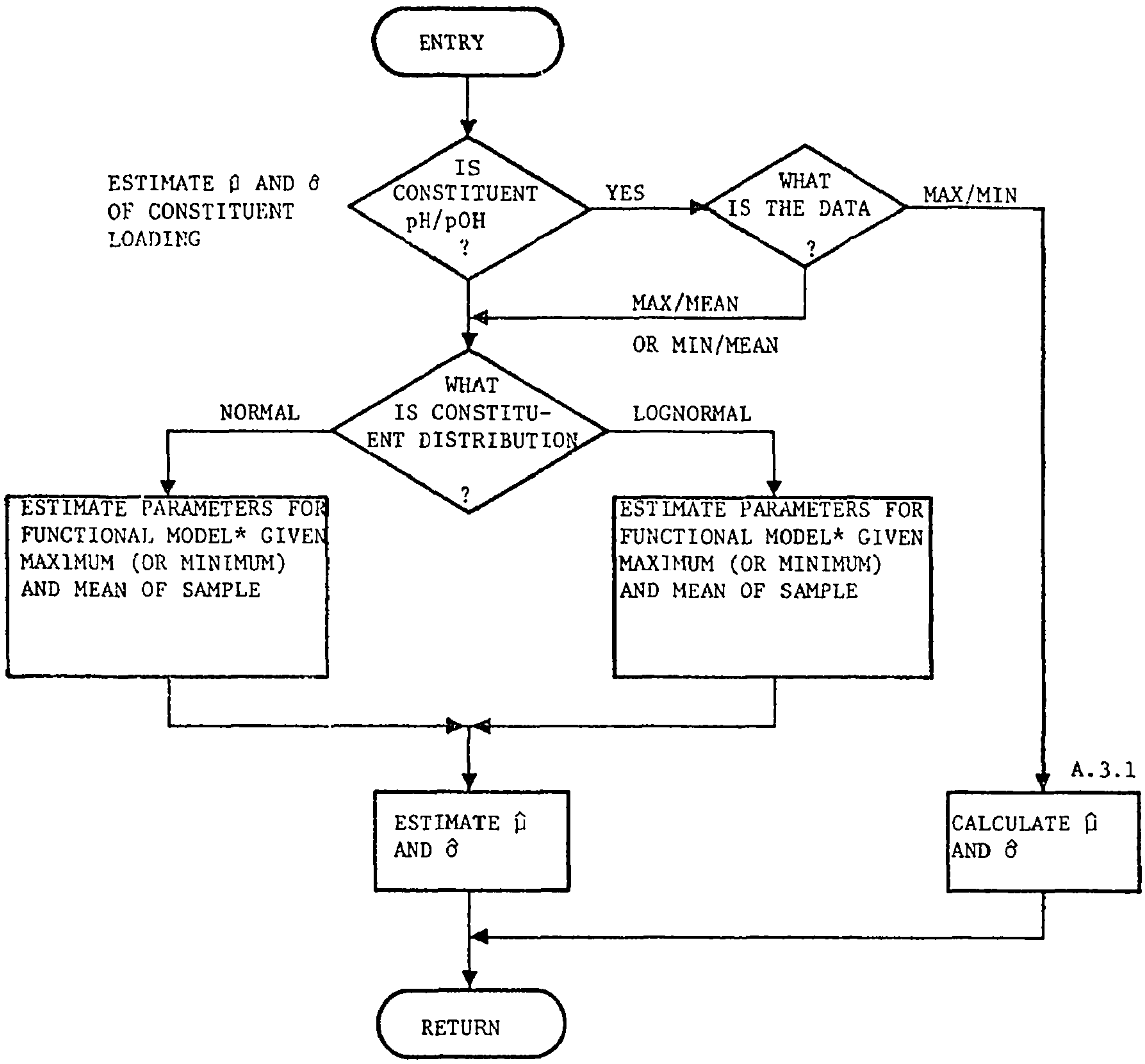


Figure 7.6 -- Continued



*FUNCTIONAL MODELS WERE DEVELOPED AS APPROXIMATIONS TO THE EXACT METHODS FOR FINDING $\hat{\mu}$ AND $\hat{\sigma}$ IN APPENDIX A OF REFERENCE 1.

Figure 7.7 Subroutine PARAMS

EXPECTED DAMAGE FOR
CONSTITUENT pH/pOH

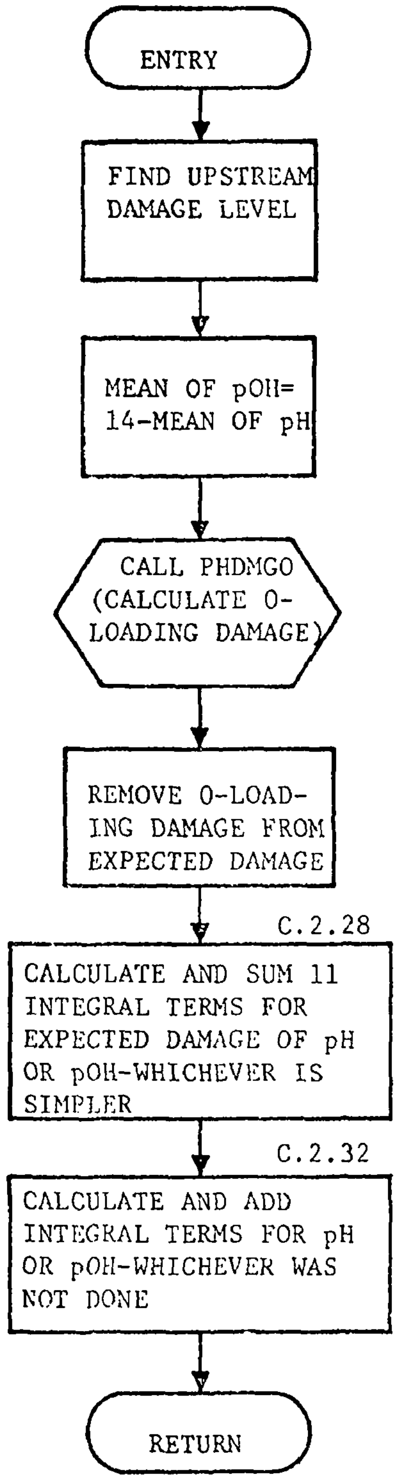


Figure 7.8 Function PHEXD

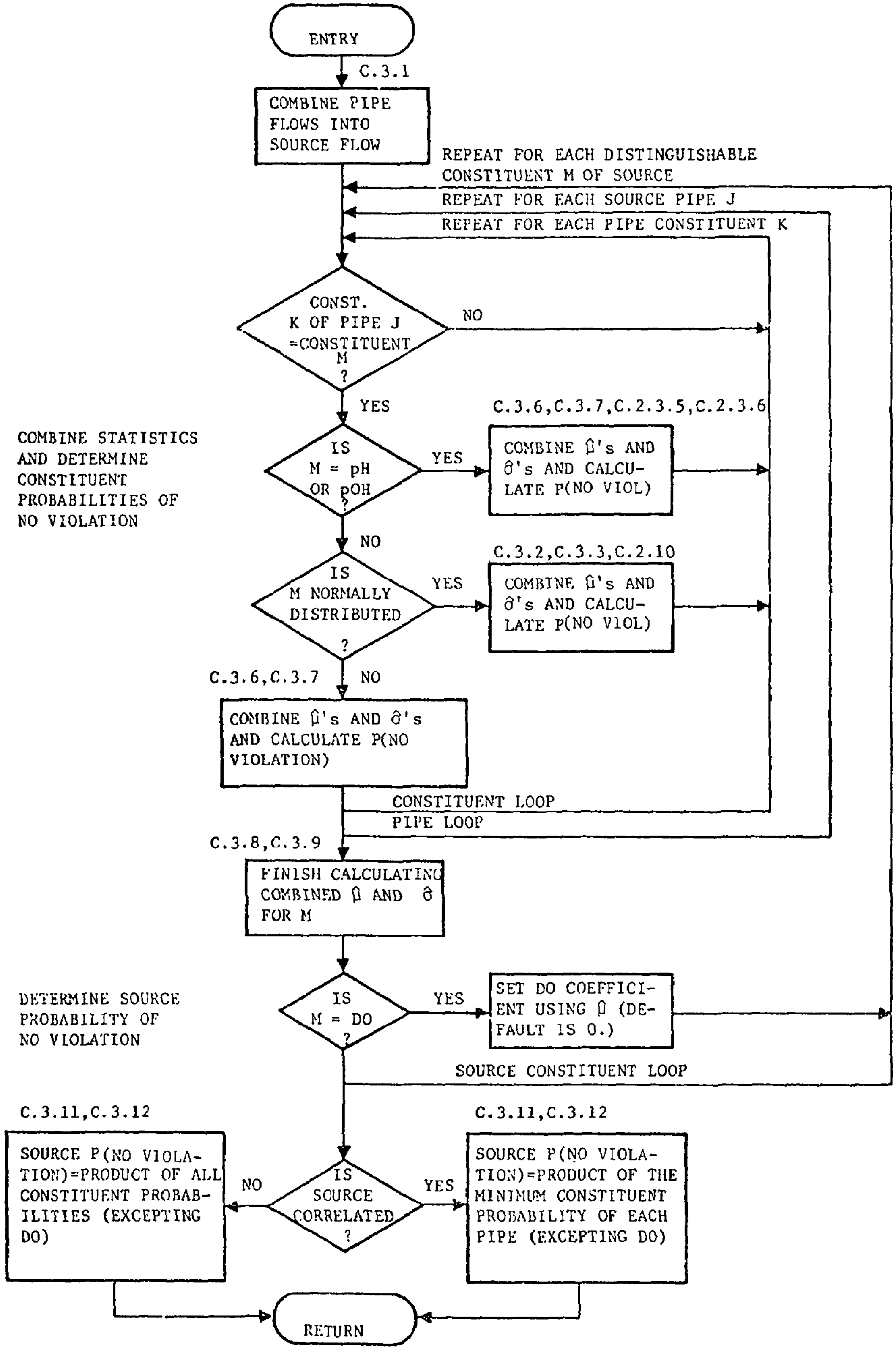


Figure 7.9 Subroutine PNVCOM

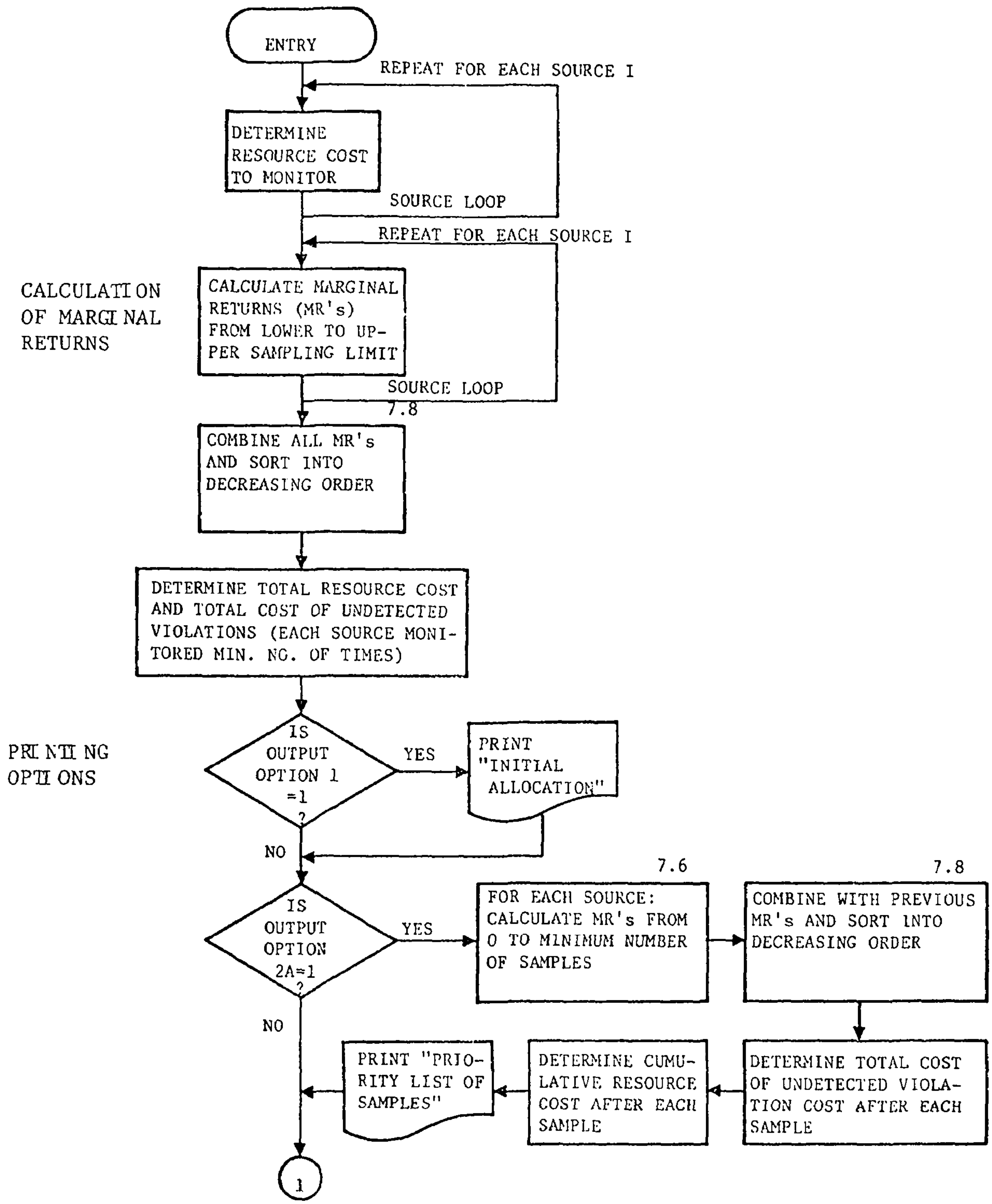


Figure 7.10 Subroutine PRIORT

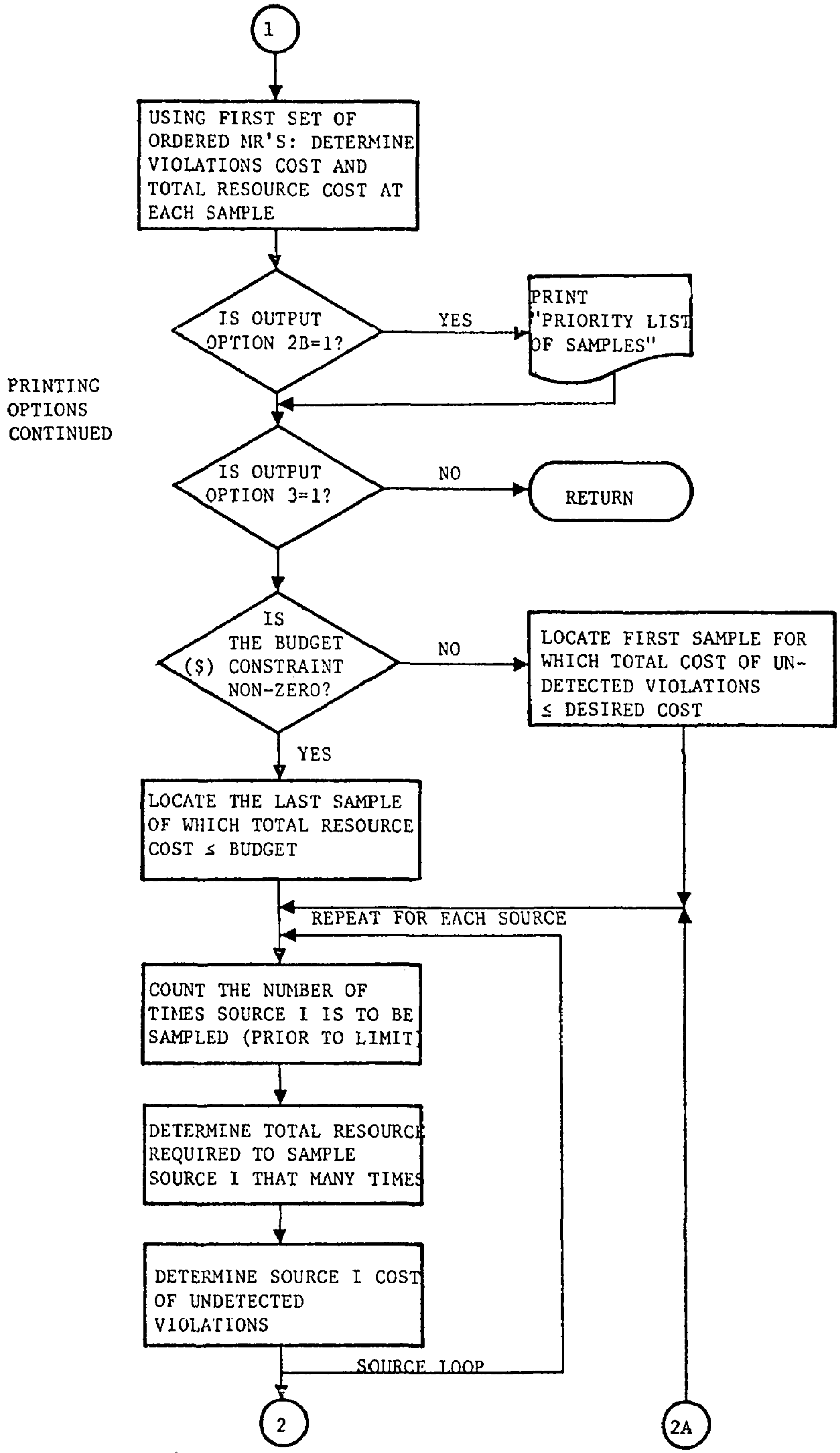


Figure 7.10 -- Continued

PRINTING
OPTIONS
CONTINUED

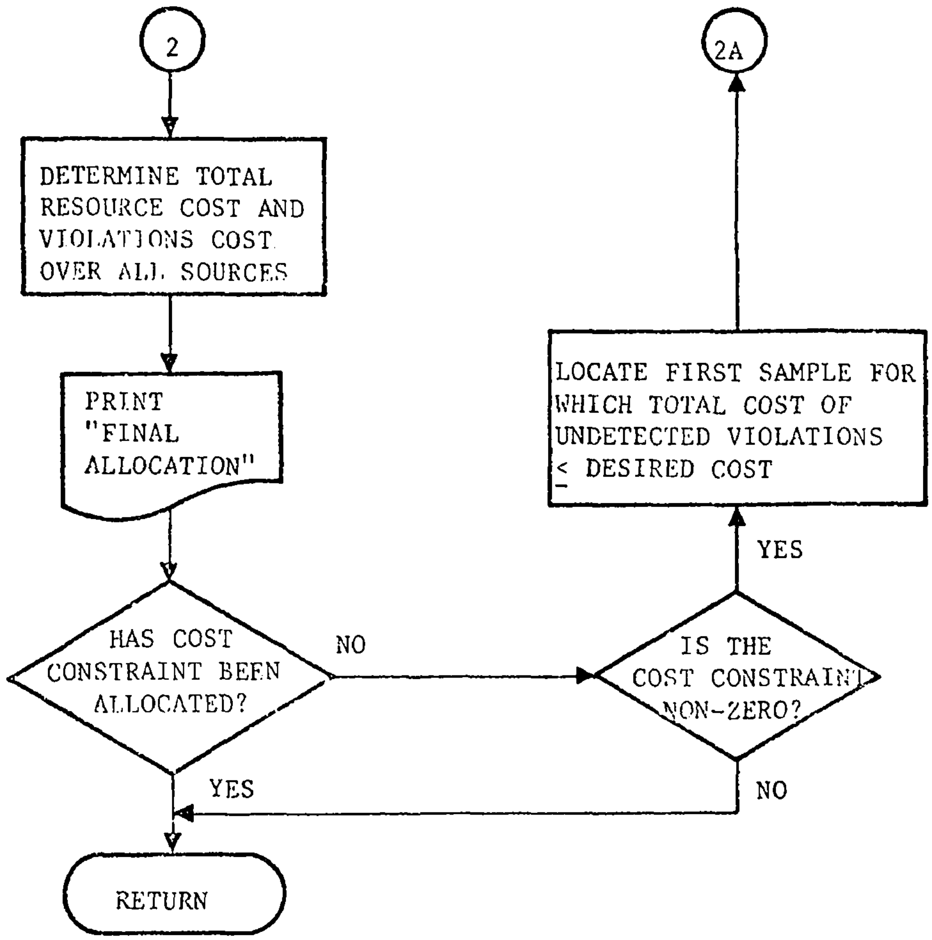


Figure 7.10 -- Continued

Function COMEXD

Function COMEXD calculates the expected damage of any non-pH constituent with the use of IN, IL, ININFB, ILINFB, ILINAO, and XNORM. DAMAGO is used to calculate the damage which would occur under zero load and this damage is subtracted from the expected damage.

Function DAMAGO

DAMAGO calculates the damage for a given constituent that would occur under zero load (damage caused by the upstream concentration of the given constituents). This value is also used as the delta function coefficient.*

Function DIFF

Function DIFF is used in conjunction with function XNORM in order to obtain greater accuracy in taking the difference of two values of the standard normal distribution functions.

Subroutine EXPDAM

Subroutine EXPDAM determines the expected damage for a single source using functions PHEXD (constituent pH/pOH) and COMEXD (non-pH constituents), and sets the source expected damage equal to the maximum of the constituent expected damages.

*The delta function concept is used in the case of normally distributed constituents. The normal distribution curve includes loading values from $-\infty$ to $+\infty$. Since actual loading values cannot be less than 0.0, the delta function accounts for this fact by lumping all negative values together and adding them into the 0.0 loading value when calculating expected damage.

Functions IL, ILINAO, ILINFA, ILINFB, IN, ININFA, ININFB

These functions (along with the entry point RILBT1 in IL) all compute variations of the integral (C.2.9 in Reference [1]).

$$I_\gamma(e,f,\alpha,\beta,\mu,\sigma) = \int_\alpha^\beta (ex + f)\phi_\gamma(x)dx \ ,$$

where ϕ_γ is the normal density function with mean μ and variance σ^2 if γ = normal, and where ϕ_γ is lognormal, with mean and variance of the corresponding normal distribution being μ and σ^2, if γ = lognormal. All of the above functions beginning with the letters "IN" are normal, while those containing "IL" are lognormal.

Subroutine ISTAT

Subroutine ISTAT calculates the initial statistics for a single source. ISTAT combines all given data to find an estimated mean and standard deviation for the loading of each constituent of each discharge pipe. First, these estimates are made for each month (or group of months if any sample size is less than 4) by calling PARAMS, then compliance monitoring data is used to improve the monthly estimates, and finally, the estimates for all the months are combined into a single mean and standard deviation for the constituent.

Subroutine ORDER

ORDER organizes a given array of values into descending order. Called by PRIORT, ORDER is used to rearrange the marginal returns so that a priority allocation can be made.

Subroutine OUTPUT

This subroutine prints one table for each source being considered (see Figure 5.8 for an example). The table summarizes the source statistics for the monitoring period by listing average source flows as well as standards, means, standard deviations, expected damages, and probabilities of no violation for each of the constituents, and also source expected damage and source probability of no violation. OUTPUT is called by the main program only if the user has specified that he desires such tables.

Subroutine PARAMS

PARAMS estimates a mean and standard deviation for the loading of a single constituent given a sample mean, sample maximum, sample size, and distribution specification (normal and lognormal). PARAMS uses two functional models (one for the normal case, the other for the lognormal case), which were developed from the methods of Appendix A of Reference [1]. PARAMS will also yield estimates of mean and standard deviation for the constituent pH/pOH given a mean and maximum, or mean and minimum, or maximum and minimum.

Subroutine PHDMGO

PHDMGO is analogous to DAMAGO in that it calculates the damage caused by zero loading (the upstream damage) or, equivalently, the delta function coefficient. PHDMGO specifically treats pH/pOH, and DAMAGO is called for all other constituents.

Function PHEXD

Function PHEXD calculates the expected damage for a pH constituent.

Calling ABEF to compute coefficients, PHEXD uses IL, RILBT1, and ININFA. PHEXD also calls PHDMGO to calculate zero-loading damage which is subtracted from the total expected damage.

Subroutine PNVCOM

PNVCOM, for a source with multiple discharge pipes, combines constituent loads when the same constituent occurs in more than one pipe of an effluent source. That is, PNVCOM creates a single mean and single standard deviation for each distinguishable constituent of a multi-pipe source. PNVCOM also calculates probabilities of no violation (with the use of IN, ININFA, and ILINFA) for all constituents and combines these into a source probability of no violation. In addition, PNVCOM calculates the total effluent source flow and sets the combined DO concentration if DO data has been provided.

Subroutine PRIORT

PRIORT calculates the total cost to monitor each source. PRIORT also calculates marginal returns for each source and calls ORDER to sort these into descending order. Depending upon which print options are specified by the user, PRIORT uses this sorted list to determine the sampling allocation and prints tables giving the sampling frequencies, monitoring costs, and costs of undetected violations.

Function XNORM

XNORM finds the value F(x) of the standard normal distribution function with argument x. If $|x| \leq 4.0$, XNORM calls RNORM (see Section 5.1, Introduction, for an explanation of RNORM) to find this value.

For $|x| > 4.0$, XNORM uses its own approximation formula (for greater accuracy). XNORM contains entry point DNORM, used when calculating $1-F(x)$.

7.3 DESCRIPTION OF VARIABLES

Variables residing in common blocks within the program will be described in Table 7.1. Then in Table 7.2, local variables are defined according to their respective subprograms. Note that the variable I, defined under COMMON/UPDATE, is used consistently throughout both tables to refer to that effluent source which is currently being worked on by the program.

A complete program listing follows Table 7.2.

Table 7.1 Description of Common Variables

VARIABLE	DEFINITION
COMMON/BIJ/	
--Refer to Equation C.2.22 in Reference 1--	
A1	Mass loading coefficient of downstream concentration for pH or pOH constituent, a_{iJ}
B(1)	Downstream concentration factor for pH, b_{iJ}
B(2)	Downstream concentration factor for pOH, b_{iJ}
COMMON/BODDMG/	
TQS	Total flow for effluent source I
QU	Upstream flow at effluent source I
CS	Mean of DO concentration for source I
IBOD	Internal flag for BOD to indicate the calculation of either zero load damage or delta function coefficient
COMMON/BRKPTS/	
S(J) J=1,...,6	Damage value of the J^{th} point of the non-pH/pOH damage functions
SSPH(J) J=1,...,11	Damage value of the J^{th} point of the pH/pOH damage functions
COMMON/CONST/	
Parms (J,K)	Alphanumeric description (J=1,...,5 alphanumeric words) of constituent identified as K (see Table 5.4)
COMMON/DMG1/	
DAMAGE (J,K) K=1,...,6	The K^{th} breakpoint of the J^{th} function where J is the damage function identification number (see Table 5.3)
COMMON/DMG2/	
DMG (J,K)	
J=1 and K=1,...,11	The K^{th} breakpoint of the pH damage function
J=2 and K=1,...,11	The K^{th} breakpoint of the pOH damage function

Table 7.1 Continued

VARIABLE	DEFINITION
<u>COMMON/EXP/</u>	
NPPARS (J,I)	Number of constituents discharged from pipe J of effluent source I
<u>COMMON/FLAGD/</u>	
ID	Distribution of constituent being examined (0 for normal, 1 for lognormal)
<u>COMMON/IST/</u>	
MNTHQS (J,K) K=1,...,24	Sequentially numbered months (in the range 1-24) for which data was entered for pipe J of source I
NSIZE (J,K,L)	Sample size for data on the K^{th} constituent of pipe J, month L of source I
SMEAN (J,K,L)	Sample mean of the K^{th} constituent of pipe J month L of source I
SMAX (J,K,L)	Sample maximum (or minimum in the case of pH) of the K^{th} constituent of pipe J, month L of source I
NOCPTS (J,K)	Number of compliance monitoring points for K^{th} constituent of pipe J of source I
MNTHSZ (J,K,L)	Numbered month (in the range 1-24) corres-poinding to the L^{th} compliance monitoring point (Z(J,K,L)), K^{th} constitutent of pipe J, source I
Z(J,K,L)	L^{th} compliance monitoring point (maximum 30 points) for the K^{th} constituent of pipe J of source I
DELTA	Not used
GAMMA	Coefficient used in Bayesian update in Subroutine ISTAT
KETA	Coefficient used in Bayesian update in Subroutine ISTAT

Table 7.1 Continued

VARIABLE	DEFINITION
KNU	Coefficient used in Bayesian update in Subroutine ISTAT
ENU	Coefficient used in Bayesian update in Subroutine ISTAT
IPARM (J,K,I)	Constituent identification number of the K^{th} constituent of pipe J of source I (see Table 5.4)
ISTATS (I,J,K,L)	
L=1	Combined mean of the K^{th} constituent of source I, pipe J (for the monitoring period)
L=2	Combined variance of the K^{th} constituent of source I, pipe J (for the monitoring period)
L=3	Combined confidence in the mean of the K^{th} constituent of source I, pipe J (for the monitoring period)
L=4	Combined confidence in the variance of the K^{th} constituent of source I, pipe J (for the monitoring period)
COMMON/ISTPNV/	
MU (J,K)	Combined mean of the K^{th} constituent pipe J, of source I (equal to ISTATS (I,J,K,1)
SIGMA (J,K)	Combined standard deviation of the K^{th} constituent pipe J, for the monitoring period for source I (equal to ISTATS (I,J,K,2))
COMMON/OUT/	
WSRC(1)	Identification number for effluent source I
WSRC(2)	Expected damage for effluent source I
WSRC(3)	Probability of no violation for effluent source I
UPFLW	Upstream flow at effluent source I
DO	Mean of DO concentration for source I
NPTSW	Number of pipes for source I
WEND(1,J)	Mean discharge flow of pipe j, source I

Table 7.1 Continued

VARIABLE	DEFINITION
WEND(2,J)	Number of constituents of pipe J, source I
WENDTA(J,K,L)	For L^{th} constituent of pipe K of source I:
J=1	Constituent identification number (see Table 5.4)
J=2	Constituent effluent standard
J=3	Constituent distribution code
J=4	Estimated constituent loading mean for the monitoring period
J=5	Estimated constituent loading standard deviation for the monitoring period
J=6	Constituent expected damage
J=7	Constituent probability of no violation
COMMON/PCOPT/	
ICOPT	Damage function point (1,2,3,4,5, or 6) whose corresponding damage value is closest to the upstream concentration for a non-coupled constituent (the same point is used for all non-coupled constituents of all sources)
COMMON/PNVEXP/	
--For this common block, constituents present in more than one pipe of an effluent source have been combined and each of the J constituents is distinct--	
DIST(J)	Distribution of the J^{th} constituent of source I specified as 0 or 1 for normal or lognormal
TMU(J)	Mean loading of the J^{th} constituent
TSIG(J)	Standard deviation of loading of the J^{th} constituent
COMMON/PRI/ (as listed in MAIN)	
NOPIPS (I)	Number of pipes at effluent source I
NOPARS (I)	Number of distinct constituents of effluent source I (constituents present in more than one pipe are only counted once)

Table 7.1 Continued

VARIABLE	DEFINITION
INDPAR(J,I)	Index of distinct constituents (J=1,...,10) of effluent source I
ISFUP(I)	Upper sampling limit of effluent source I
ISFLOW(I)	Lower sampling limit of effluent source I
EXPDM(I)	Expected environmental damage due to effluent source I
PNV(I)	Probability of no violation of effluent source I
IOUT1	Output option 1 (a value of "1" signals to print)
IOUT2A	Output option 2A (a value of "1" signals to print)
IOUT2B	Output option 2B (a value of "1" signals to print)
IOUT3	Output option 3 (a value of "1" signals to print)
NAME (I,J)	Source identification for source I (J=1,...,13 alphanumeric words)
B	Budget limit for the monitoring agency during the next monitoring period
D	Desired limit to the undetected violation cost
NUSORS	Number of effluent sources actually included in the allocation procedure(out of all those entered in input)
INSORS(I)	Index of effluent sources actually included in the allocation procedure.
PIPCST(J)	Cost to monitor an effluent source with J pipes
CONCST(J)	Laboratory cost to analyze a sample containing constituent J (see Card Groups 3-6 in Table 5.1)
COMMON/UPDATE/	
I	Effluent source currently being examined
QS(J,I)	Calculated estimate of pipe flow for pipe J of effluent source I

Table 7.2 Description of Local Variables

VARIABLE	DEFINITION
MAIN PROGRAM	
-- See Section 5.2 for a description of input variables --	
Subroutine ABEF	
-- Refer to Equation C.2.27 in Reference 1 --	
D1	$d_J(k)$ where k is KD below
D2	$d_J(K+1)$ where k is KD below
A	a_{iJ} (from C.2.222b)
B	b_{iJ} (from C.2.22c)
KD	k
ALPHA	α_{iJk}
BETA	β_{iJk}
E	e_{iJk}
F	f_{iJk}
L	Internal flag indicating if ALPHA and BETA are both outside of limits (where the limits are $.0000001 \leq ALPHA \leq BETA \leq 1.$) L=1 if ALPHA and BETA are within limits, 2 if not
Function COMEXD	
TMU	Combined mean of the loading of constituent M (defined below) for the entire monitoring period and all pipes of an effluent source where M occurs
TSIG	Combined standard deviation of constituent M for the entire monitoring period and all pipes of an effluent source where M occurs
M	Constituent identification number as defined in Table 5.4
FUNC1	External function -- IN or IL

Table 7.2 Continued

VARIABLE	DEFINITION
Function COMEXD Continued....	
FUNC2	External function -- ININFB or ILINFB
A	a_i (See equation C.2.4b, Reference 1)
B	b_{iJ} (See equation C.2.4c, Reference 1)
E	e_{ijk} (See equation C.2.7d)
F	f_{ijk} (See equation C.2.7e)
ALPHA	α_{ijk} (See equation C.2.7b)
BETA	β_{ijk} (See equation C.2.7c)
DJB	Delta function coefficient or zero-loading damage for constituent M
Subroutine DAMAGO	
DJB	Delta function coefficient or zero-loading damage for constituent M
M	Constituent identification number (as defined in Table 5.4)
B	Coefficient B of COMEXD
BBOD	Coefficient B adjusted (if the constituent is BOD)
Subroutine EXPDAM	
IPARAM (J)	Constituent identification number (as defined in Table 5.4) for J^{th} distinct constituent of source I
KBOD	Coefficient K_{BOD} (C.2.16)
EXPDM	Expected damage due to effluent source I
NOPARS	Number of distinct constituents of effluent source I
IPARM(J,K,I)	Constituent identification number for K^{th} constituent of pipe J of effluent source I
NOPIPS(I)	Number of discharge pipes for effluent source I
I	Effluent source number

Table 7.2 Continued

VARIABLE	DEFINITION
EXPD(J)	Expected damage for each distinct constituent of effluent source I
A	a_i (as in COMEXD)
B	b_{ij} (as in COMEXD)
COPT	Upstream concentration of a non-coupled constituent
<u>Functions IL, ILINAO, ILINFA, ILINFB, IN, ININFA, ININFB</u>	
--Refer to equations for the normal integral (C.4.1) and lognormal integral (page 197) in Reference 1--	
A a	
B b	
ALPHA α	certain of the above functions use constants in place of a, b, α or β in order to calculate commonly used integrals
BETA β	
MU μ	
SIGMA σ	
<u>Subroutine ISTAT</u>	
NOPIPS	Number of discharge pipes for effluent source I
NPPARS(J)	Number of constituents of pipe J
NMNTHS(J)	Number of months of constituent and flow data for pipe J
DIST(J,K)	Distribution of constituent K of pipe J
QU	Streamflow just upstream of effluent source I
EMEAN(L,J,K)	Estimated mean of loading } Pipe L, J^{th} constituent, month K
ESIGMA(L,J,K)	Estimated standard deviation (<u>or</u> at some points, variance) } Pipe L, J^{th} constituent, month K
ETA(L,J,K)	Confidence in the estimated mean } Pipe L, J^{th} constituent, month K
NU(L,J,K)	Confidence in the estimated variance } Pipe L, J^{th} constituent, month K

Table 7.2 Continued

VARIABLE	DEFINITION
Subroutine ORDER	
XMR(M)	Array of M marginal returns to be organized into decreasing order
ISORC(M)	Array of effluent source numbers corresponding to marginal returns in XMR, which is organized exactly as XMR
M	Number of elements in XMR and ISORC as calculated by the program
Subroutine OUTPUT	
NUSORS	Number of effluent sources included in the allocation procedure, (see definition of INSORS in Section 5.2)
Subroutine PARAMS	
SSIZE	Sample size of constituent loadings
SMEAN	Sample mean of constituent loadings
SMAX	Sample maximum (or minimum for pH) of constituent loadings
SMIN	Sample minimum (for pH) of constituent loadings
IONESD	Flag to indicate pH data in maximum/minimum form (no mean)
DIST	Constituent loading distribution
EMEAN	Estimated mean of constituent loading
ESIGMA	Estimated standard deviation of constituent loading
IPRM	Constituent identification number (as in Table 5.4)
Subroutine PHDMGO	
DJB(1)	Expected damage for zero-loading of pH
DJB(2)	Expected damage for zero-loading of pOH
Function PHEXD	
TMU(J)	A monthly mean for constituent j=1=pH, j=2=pOH
TSIG(J)	A monthly standard deviation for J=1=pH, J=2=pOH
TQS	Total flow for effluent source I
QU	Streamflow just upstream of source I

Table 7.2 Continued

VARIABLE	DEFINITION
Function PHEXD continued	
A	a_{iJ} (from C.2.22b, reference 1)
B(J)	b_{iJ}, where J=pH=1 or J=pOH=2 (from C.2.22c, reference 1)
PSI	Delta function coefficient for pH and pOH
Subroutine PNVCOM	
NOPIPS	Number of discharge pipes, effluent source I
NPPARS(J)	Number of constituents discharged from pipe J
NOPARS	Number of distinct constituents, effluent source I
IPARM(J,K)	Constituent identification number for K^{th} constituent of pipe J
INDPAR(M)	Index of constituent identification numbers containing each distinct constituent
DISTYP(J,K)	Distribution of K^{th} constituent of pipe J (0 or 1 for normal or lognormal)
EFST(J,K)	Effluent standard of K^{th} constituent of pipe J
QU	Streamflow just upstream of effluent source I
PNV	Probability of no violation of effluent source I
ICOR	Flag indicating if the constituents of source I are correlated (I=1) or not (I≠1)
TQS	Total effluent source flow
DO	Dissolved oxygen concentration
CS	Dissolved oxygen concentration (CS=DO)
TMU(M)	Mean of M^{th} distinct constituent (all pipes of effluent source I combined)
TSIG(M)	Standard deviation of M^{th} distinct constituent (all pipes of effluent source I combined)
TEMPNV	Probability of no violation for a single constituent
TEMPM	m in equation C.3.4, reference 1
SUMM	m in equation C.3.4, reference 1

Table 7.2 Continued

VARIABLE	DEFINITION
Subroutine PNVCOM continued	
TEMPV	v in Equation C.3.5, Reference 1
SUMV	v in Equation C.3.7, Reference 1
Subroutine PRIORT	
IPARM(J,K,I)	Constituent identification number for the K^{th} constituent of pipe J, effluent source I
NPPARS(J,I)	Number of discharged constituents of pipe J, effleunt source I
RESRCE(I)	Total resource cost to monitor source I
XMR(M)	Marginal returns array where number of elements in array XMR = $\sum_{I=1}^{NUSORS} (ISFUP\ (I) - ISFLOW(I))$ (see COMMON/PRI/ for definition of other variables)
ISORC(M)	Effluent array containing the sources which correspond to the marginal returns in XMR above
TMR(M1)	Marginal returns array containing XMR plus marginal returns for the 1st through minimal number of samples for each source where number of elements in array TMR = $\sum_{I=1}^{NUSORS} ISFUP\ (I)$ (see COMMON/PRI/ for definition of variables)
ISORCT(M1)	Array containing the sources which correspond to the marginal returns in TMR above
NUM(I)	Number of monitoring visits allocated to effluent source I
Function XNORM	
X	Argument of the standard normal distribution function, F(x)

Program Listings

```
      DIMENSION NMNTHS(4,30),DOSAT(30),QSMEAN(4,24),IONESD(30),       00000100
     *   DISTYP(4,10,30),QU(30),QSUNIT(4),PRUNIT(4,24),EFFLOW(4,30),  00000200
     *  EFST(4,10,30),X1(30),M(30),IP(10),IUNIT(10),ICOR(30)          00000300
      REAL KROD(30),KETA,KNU,ISTATS                                   00000400
      INTEGER DISTYP,QSUNIT,PRUNIT,PIPNO                              00000500
      COMMON/IST/MNTHQS(4,24),NSIZE(4,10,24),SMEAN(4,10,24),          00000600
     *   SMAX(4,10,24),NOCPTS(4,10),MNTHSZ(4,10,30),Z(4,10,30),DELTA, 00000700
     *   GAMMA,KETA,KNU,ENU,IPARM(4,10,30),ISTATS(30,4,10,4)          00000800
      COMMON/PRI/NOPIPS(30),NOPARS(30),INDPAR(10,30),ISFUP(30),       00000900
     *   ISFLOW(30),EXPDM(30),PNV(30),IOUT1,IOUT2A,IOUT2B,IOUT3,      00001000
     *   NAME(30,13),B,D,NUSORS,INSORS(30),PIPCST(4),CONCST(30)       00001100
      COMMON/DMG1/DAMAGE(30,6)                                        00001200
      COMMON/DMG2/DMG(2,11)                                           00001300
      COMMON/BRKPTS/S(6),SSPH(11)                                     00001400
      COMMON/PCOPT/ICOPT                                              00001500
      COMMON/EXP/NPPARS(4,30)                                         00001600
      COMMON/UPDATE/I,QS(4,30)                                        00001700
      COMMON/CONST/PARMS(5,30)                                        00001800
      INCLUDE P1,LIST                                                 00001900
      DATA (S(J),J=1,6)/0.,2.,4.,6.,8.,10./                           00002000
      DATA (SSPH(J),J=1,11)/0.,1.,2.,3.,4.,5.,6.,7.,8.,9.,10./        00002100
      DATA (PIPCST(J),J=1,4)/525.,525.,857.,857./                     00002200
      DATA (CONCST(J),J=1,30)/8.5,10.,20.,0.  ,10., 0.,5.,15.,7.5,15.,00002300
     *15.,7.5,15.,8.,7.5,7.5,7.5,15.,7.5,10.,10.,3.,0.,12.5,10.,5.,5.,00002400
     *0.  ,8.5,3./                                                    00002500
      DATA (DAMAGE(1,J),J=1,6)/0.,.01,.05,.10,.50,1./                 00002600
      DATA (DAMAGE(2,J),J=1,6)/0.,.1,.3,.9,2.7,3./                    00002700
      DATA (DAMAGE(3,J),J=1,6)/9.,8.,6.8,4.5,1.8,.9/                  00002800
      DATA (DAMAGE(4,J),J=1,6)/0.,0.,0.,0.,0.,0./                     00002900
      DATA (DAMAGE(5,J),J=1,6)/50.,70.,90.,110.,130.,150./            00003000
      DATA (DAMAGE(6,J),J=1,6)/0.,0.,0.,0.,0.,0./                     00003100
      DATA (DAMAGE(7,J),J=1,6)/0.,25.,175.,200.,240.,250./            00003200
      DATA (DAMAGE(8,J),J=1,6)/0.,.04,.15,.25,.35,.4/                 00003300
      DATA (DAMAGE(9,J),J=1,6)/0.,.02,.05,1.,10.,50./                 00003400
      DATA (DAMAGE(10,J),J=1,6)/0.,100.,2000.,7500.,15000.,150000./   00003500
      DATA (DAMAGE(11,J),J=1,6)/0.,20.,200.,800.,3000.,50000./        00003600
      DATA (DAMAGE(12,J),J=1,6)/0.,.02,.1,1.,5.,10./                  00003700
      DATA (DAMAGE(13,J),J=1,6)/0.,.01,.02,.05,.1,.5/                 00003800
      DATA (DAMAGE(14,J),J=1,6)/.7,.8,.9,1.2,3.,8./                   00003900
      DATA (DAMAGE(15,J),J=1,6)/0.,.1,.3,.9,2.7,3./                   00004000
      DATA(DAMAGE(16,J),J=1,6)/0.,.005,.05,.1,.25,.35/                00004100
      DATA (DAMAGE(17,J),J=1,6)/0.,.05,.17,.5,1.,1.5/                 00004200
      DATA(DAMAGE(18,J),J=1,6)/0.,.001,.005,.01,.02,.05/              00004300
      DATA (DAMAGE(19,J),J=1,6)/0.,.01,1.,3.,9.,20./                  00004400
      DATA (DAMAGE(20,J),J=1,6)/.6,.9,3.,4.5,7.,10./                  00004500
      DATA (DAMAGE(21,J),J=1,6)/0.,.01,.1,5.,30.,50./                 00004600
      DATA (DAMAGE(22,J),J=1,6)/6*0./                                 00004700
      DATA (DAMAGE(23,J),J=1,6)/6*0./                                 00004800
      DATA(DAMAGE(24,J),J=1,6)/0.,.0005,.001,.02,.1,.2/               00004900
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      DATA(DAMAGE(25,J),J=1,6)/0.,.1,.2,.5,1.6,10./                     00005000
      DATA (DAMAGE(26,J),J=1,6)/100.,200.,500.,1000.,1500.,2300./       00005100
      DATA (DAMAGE(27,J),J=1,6)/0.,20.,40.,100.,280.,300./              00005200
      DATA (DAMAGE(28,J),J=1,6)/0.,1.,2.5,3.,4.,10./                    00005300
      DATA (DAMAGE(29,J),J=1,6)/0.,10.,40.,100.,300.,1000./             00005400
      DATA (DAMAGE(30,J),J=1,6)/0.,0.,0.,0.,0.,0./                      00005500
C PH-1                                                                  00005600
      DATA    (DMG(1,J),J=1,11)/.0000001,.000000178,.000000316,.0000005600005700
     *2,.000001,.00000316,.00001,.0000316,.0001,.000112,.000126/        00005800
C POH-2                                                                 00005900
      DATA    (DMG(2,J),J=1,11)/.0000001,.000000316,.000001,.00000158,.000006000
     *0000251,.00000501,.00001,.0000316,.0001,.000112,.000126/          00006100
C ***********************************************************************00006200
C ***********************************************************************00006300
C                                                                       00006400
C READ IN USER-SPECIFIED DAMAGE FUNCTIONS AND MONITORING COSTS          00006500
C (PROGRAM HAS PRESET FUNCTIONS AND COSTS IF NONE ARE READ IN)          00006600
C                                                                       00006700
      READ(5,9000) ICOSTS,IDMG,IDAMAG,ISS                               00006800
 9000 FORMAT(4(I1,1X))                                                  00006900
      WRITE(6,900) ICOSTS,IDMG,IDAMAG,ISS                               00007000
  900 FORMAT('1',10('-'),'THE INPUT CARD DATA FOLLOWS',10('-'),/'0',    00007100
     1       'ICOSTS=',I1,T21,'IDMG=',I1,T41,'IDAMAG=',I1,T61,'ISS=',I1)00007200
      IF(ICOSTS.EQ.0) GO TO 7                                           00007300
      READ(5,9100)(PIPCST(I),I=1,4),(CONCST(I),I=1,30)                  00007400
 9100 FORMAT(4(F10.2,5X),4(/8(F5.2,5X)))                                00007500
    7 IF(IDMG.EQ.0) GO TO 9                                             00007600
      IF(IDMG.NE.1.AND.IDMG.NE.2) GO TO 200                             00007700
      DO 9200 IDUM=1,IDMG                                               00007800
 9200 READ(5,9300) I1,(DMG(I1,J),J=1,11)                                00007900
 9300 FORMAT(I1,4X,6F10.3,/5X,5F10.3)                                   00008000
    9 IF(IDAMAG.EQ.0) GO TO 11                                          00008100
      IF(IDAMAG.LT.1.OR.IDAMAG.GT.30) GO TO 200                         00008200
      DO 9400 IDUM=1,IDAMAG                                             00008300
 9400 READ(5,9500) I1,(DAMAGE(I1,J),J=1,6)                              00008400
 9500 FORMAT(I2,3X,6F10.3)                                              00008500
   11 IF(ISS.EQ.0) GO TO 13                                             00008600
      READ(5,9600) (S(J),J=1,6),(SSPH(J),J=1,11)                        00008700
 9600 FORMAT(6F5.2,/11F5.2)                                             00008800
   13 WRITE(6,910)((I,PIPCST(I),I=1,4),(I,CONCST(I),(PARMS(J,I),J=1,5), 00008900
     1              I=1,30),(J,J=1,11),((DMG(I,J),J=1,11),I=1,2),(J,    00009000
     2              J=1,6),(I,(DAMAGE(I,J),J=1,6),I=1,30))              00009100
  910 FORMAT('0','PIPCST(',I2,')=',F10.2,10X,'**IF PIPCST, CONCST, OR', 00009200
     1       ' DAMAGE FUNCTIONS AND BREAKPOINTS WERE NOT READ IN,',/' ',00009300
     2       6X,'(',I2,')=',F10.2,17X,'VALUES PRINTED ARE THOSE EXIST', 00009400
     3       'ING IN THE PROGRAM',2(/' ',6X,'(',I2,')=',F10.2),/'0',    00009500
     4              'CONCST(',I2,')=',F10.2,10X,5A4,29(/' ',6X,'(',I2,  00009600
     5              ')=',F10.2,10X,5A4),/'1',T18,'J=',10(I2,9X),I2,/' ', 00009700
     6              '--PH',/' ','DMG(1,J)',2X,11F11.7,/' ','--POH',/' ', 00009800
     7              'DMG(2,J)',2X,11F11.7,/'0',T18,'J=',6(2X,I2,9X),/'0',00009900
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     8           'DAMAGE(',I2,',J)',1X,6F13.5,29(/' ',6X,'(',I2,',J)',
     9           1X,6F13.5))
      WRITE(6,920)(S(J),J=1,6),(SSPH(J),J=1,11)
  920 FORMAT('0','S(J)',6X,6(3X,F5.2,3X),/'0','SSPH(J)',3X,11(3X,F5.2,3X
     1))
C
C  READ IN CONSTANTS AND OPTIONS
C
      READ(5,1) NOUT,IOUT1,IOUT2A,IOUT2B,IOUT3,B,D,ICOPT,IEXPD,NOSORS,
     *          NUSORS
    1 FORMAT(5(I1,4X),2F10.2,/2(I1,4X),2(I2,3X))
      WRITE(6,925) NOUT,IOUT1,IOUT2A,IOUT2B,IOUT3,B,D,ICOPT,IEXPD,NOSORS
     1          ,NUSORS
  925 FORMAT('0','NOUT=',I1,T21,'IOUT1=',I1,T41,'IOUT2A=',I1,T61,'IOUT2'
     1         'B=',I1,T81,'IOUT3=',I1,T101,'B=',F10.2,T121,'D=',F10.1,
     2         /' ','ICOPT=',I1,T21,'IEXPD=',I1,T41,'NOSORS=',I2,T61,
     3         'NUSORS=',I2)
      READ(5,2) ALPHA,GAMMA,KETA,KNU,ENU
    2 FORMAT(5F10.2)
      WRITE(6,930) ALPHA,GAMMA,KETA,KNU,ENU
  930 FORMAT('0','ALPHA=',F10.2,T21,'GAMMA=',F10.2,T41,'KETA=',F10.2,T61
     1         ,'KNU=',F10.2,T81,'ENU=',F10.2)
      READ(5,3)(ISFUP(I),I=1,30),(ISFLOW(I),I=1,30),(ICOR(I),I=1,30),
     *          (INSORS(I),I=1,NUSORS)
    3 FORMAT(30I2,/30I2,/30I1,/30I2)
      DO 4 I=1,30
    4 IF(ISFUP(I).LE.ISFLOW(I).AND.(ISFUP(I).NE.0.OR.ISFLOW(I).NE.0)) GO
     1    TO 225
      WRITE(6,940)(I,I=1,NOSORS)
  940 FORMAT('0',5X,'SOURCE I=',30(1X,I2))
      WRITE(6,945)(ISFUP(I),I=1,NOSORS)
  945 FORMAT(' ','ISFUP(I)',6X,30(1X,I2))
      WRITE(6,946)(ISFLOW(I),I=1,NOSORS)
  946 FORMAT(' ','ISFLOW(I)',5X,30(1X,I2))
      WRITE(6,947)(ICOR(I),I=1,NOSORS)
  947 FORMAT(' ','ICOR(I)',7X,30(1X,I2))
      WRITE(6,948)(INSORS(I),I=1,NUSORS)
  948 FORMAT('0','INSORS(I) FOR I=1 TO NUSORS',30(I2,','))
      WRITE(6,949)
  949 FORMAT('0','SOURCE DESCRIPTIONS:',/' ','ID',T9,'NAME',T64,'QU',
     1         T72,'KBOD',T79,'DOSAT',T89,'IONESD NPIP  NPPARS(J),NMNTHS',
     2         '(J) J=1 TO NPIP')
C
C READ SOURCE ID FOR ALL SOURCES
C
      DO 20 I=1,NOSORS
      READ(5,5) ID,(NAME(I,J),J=1,13),QU(I),KBOD(I),DOSAT(I),IONESD(I),
     *     NPIP,(NPPARS(J,I),NMNTHS(J,I),J=1,NPIP)
```

```
    5 FORMAT(I2,1X,13A4,1X,3E6.0,2X,2I2, /4(I2,1X,I2,1X))                00014800
      WRITE(6,950)ID,(NAME(I,J),J=1,13),QU(I),KBOD(I),DOSAT(I),IONESD(I)00014900
     1     ,NPIP,(NPPARS(J,I),NMNTHS(J,I),J=1,NPIP)                      00015000
  950 FORMAT(' ',I2,2X,13A4,1X,F12.3,1X,F6.2,2X,F6.2,6X,I1,5X,I2,5X,
     1      4(I2,',',I2,1X))
      NOPIPS(I)=NPIP                                                     00015300
      IF(ID.NE.I) GO TO 205                                              00015400
   20 CONTINUE                                                           00015500
C                                                                        00015600
C READ FLOW CARD FOR ALL SOURCES AND CONVERT FLOWS IF NECESSARY          00015700
C                                                                        00015800
      DO 75 I=1,NUSORS                                                   00015900
      WRITE(6,951)                                                       00016000
  951 FORMAT('1')                                                        00016100
      J1=NOPIPS(I)                                                       00016200
      DO 45 J=1,J1                                                       00016300
      WRITE(6,955)                                                       00016400
  955 FORMAT('0','PIPE FLOW AND SELF-MONITORING CONSTITUENT DATA',/' ', 00016500
     1      '(SOURCE) (PIPE)',/' ',3X,'ID',4X,'PIPNO  IQS QSUNIT   ',   00016600
     2             'MNTHQS,QSMEAN--FOR ALL MONTHS')                      00016700
      NM=NMNTHS(J,I)                                                     00016800
      READ(5,25) ID,PIPNO,IQS,QSUNIT(J),(MNTHQS(J,K),QSMEAN(J,K),K=1,5) 00016900
   25 FORMAT(I2,2X,3I2,5(4X,I2,2X,E6.0))                                 00017000
      IF(NM.GT.5) READ(5,32)(MNTHQS(J,K),QSMEAN(J,K),K=6,NM)             00017100
   32 FORMAT(10X,4X,I2,2X,E6.0,4X,I2,2X,E6.0,4X,I2,2X,E6.0,4X,I2,2X,E6.000017200
     *      ,4X,I2,2X,E6.0)                                              00017300
      WRITE(6,960)ID,PIPNO,IQS,QSUNIT(J),(MNTHQS(J,K),QSMEAN(J,K),K=1,NM00017400
     1)                                                                  00017500
  960 FORMAT(' ',2I6,4X,2I3,6X,6(T30,4(I2,',',F10.3,1X,'/'),/' '))
      IF(ID.NE.I.OR.PIPNO.NE.J) GO TO 220                                00017700
      IF(IQS.NE.99) GO TO 210                                            00017800
      CNVRT=1.                                                           00017900
      IF(QSUNIT(J).EQ.8) GO TO 381                                       00018000
      IF(QSUNIT(J).NE.3) WRITE(6,380) I,J,QSUNIT(J)                      00018100
  380 FORMAT('0','QS ERROR--SOURCE ',I2,' PIPE ',I2,' UNITS ARE ',I2,'  00018200
     * RATHER THAN 3 (MGD) OR 8 (ML/DAY)--PROGRAM ASSUMES MGD')          00018300
      DO 3800 K=1,NM                                                     00018400
 3800 QSMEAN(J,K)=3.785306*QSMEAN(J,K)                                   00018500
C ESTIMATE A SINGLE MONTHLY FLOW FOR SOURCE/PIPE                         00018600
  381 QS(J,I)=QSMEAN(J,1)                                                00018700
      IF(QS(J,I).LE.0) QS(J,I)=EFFLOW(J,I)                               00018800
      DO 382 K=2,NM                                                      00018900
      IF(QSMEAN(J,K).LE.0.) GO TO 382                                    00019000
      QS(J,I)=(1-ALPHA)*QSMEAN(J,K)+ALPHA*QS(J,I)                        00019100
  382 CONTINUE                                                           00019200
C                                                                        00019300
C READ CONSTITUENT DATA FOR ALL SOURCES                                  00019400
C                                                                        00019500
```

```
          WRITE(6,965)                                                  00019600
      965 FORMAT(' ')                                                   00019700
          K1=NPPARS(J,I)                                                00019800
          WRITE(6,967)                                                  00019900
      967 FORMAT('0','    ID     PIPNO    IPARM PRUNIT        SMAX,SMEAN,NSIZE--'00020000
         1           ,'FOR ALL MONTHS')                                 00020100
          DO 45 K=1,K1                                                  00020200
          READ(5,40)ID,PIPNO,IPARM(J,K,I),PRUNIT(J,K),(SMAX(J,K,L),SMEAN(J,K00020300
         *,L),NSIZE(J,K,L),L=1,5)                                       00020400
          IF(NM.GT.5) READ(5,390)(SMAX(J,K,L),SMEAN(J,K,L),NSIZE(J,K,L),L=6,00020500
         * NM)                                                          00020600
      390 FORMAT(10X,2E6.0,I2,2E6.0,I2,2E6.0,I2,2E6.0,I2,2E6.0,I2)      00020700
       40 FORMAT(I2,2X,3I2,5(2E6.0,I2))                                 00020800
          WRITE(6,970)ID,PIPNO,IPARM(J,K,I),PRUNIT(J,K),(SMAX(J,K,L),   00020900
         1               SMEAN(J,K,L),NSIZE(J,K,L),L=1,NM)              00021000
      970 FORMAT(' ',2I6,5X,I4,4X,I2,3X,6(T30,4(F10.2,',',F10.2,',',I2,'/'),
         1         /' '))
          IF(ID.NE.I.OR.PIPNO.NE.J) GO TO 230                           00021300
       45 CONTINUE                                                      00021400
    C FIND LIST OF DISTINCT CONSTITUENTS FOR SOURCE I                   00021500
          K1=NPPARS(1,I)                                                00021600
          DO 383 K=1,K1                                                 00021700
          INDPAR(K,I)=IPARM(1,K,I)                                      00021800
          IF(INDPAR(K,I).NE.22) GO TO 383                               00021900
          IF(INDPAR(K-1,I).NE.23) GO TO 240                             00022000
          INDPAR(K-1,I)=22                                              00022100
          INDPAR(K,I)=23                                                00022200
      383 CONTINUE                                                      00022300
          NOPARS(I)=K1                                                  00022400
          IF(J1.EQ.1) GO TO 386                                         00022500
          DO 385 J=2,J1                                                 00022600
          K1=NPPARS(J,I)                                                00022700
          DO 385 K=1,K1                                                 00022800
          NO=NOPARS(I)                                                  00022900
          DO 384 L=1,NO                                                 00023000
      384 IF(IPARM(J,K,I).EQ.INDPAR(L,I)) GO TO 385                     00023100
          NO=NO+1                                                       00023200
          NOPARS(I)=NO                                                  00023300
          INDPAR(NO,I)=IPARM(J,K,I)                                     00023400
          IF(INDPAR(NO,I).NE.22) GO TO 385                              00023500
          IF(INDPAR(NO-1,I).NE.23) GO TO 240                            00023600
          INDPAR(NO-1,I)=22                                             00023700
          INDPAR(NO,I)=23                                               00023800
      385 CONTINUE                                                      00023900
    C                                                                   00024000
    C READ  CONSTITUENT EFFLUENT STANDARDS                              00024100
    C                                                                   00024200
      386 WRITE(6,980)
      980 FORMAT('0','EFFLUENT STANDARDS',/' ','(SOURCE)  (PIPE)',/' ',3X,  00024400
         1        'ID',3X,'PIPNO','  EFFLOW',5X,'IP,X1,IUNIT,M--FOR ALL CONS'00024500
```

```
      1       ,'TITUENTS OF PIPE')                                    00024600
       DO 72 J=1,J1
       NP=NPPARS(J,I)                                                 00024800
       READ(5,50) ID,PIPNO,EFFLOW(J,I),(IP(K),X1(K),IUNIT(K),M(K),K=1,5) 00024900
    50 FORMAT(I2,1X,I2,1X,E6.0,5(I2,E6.0,1X,2I1,1X))                   00025000
       IF(NP.GT.5) READ(5,51)(IP(K),X1(K),IUNIT(K),M(K),K=6,NP)        00025100
    51 FORMAT(12X,I2,E6.0,1X,2I1,1X,I2,E6.0,1X,2I1,1X,I2,E6.0,1X,2I1,1X, 00025200
      *       I2,E6.0,1X,2I1,1X,I2,E6.0,1X,2I1)
       WRITE(6,985)ID,PIPNO,EFFLOW(J,I),(IP(K),X1(K),IUNIT(K),M(K),K=1,NP00025400
      1)                                                               00025500
   985 FORMAT(' ',2I6,1X,F12.2,10(T29,I2,',',F12.3,',',I1,',',I2,/' '))
       IF(ID.NE.I.OR.PIPNO.NE.J) GO TO 250                             00025800
C MATCH UP STANDARDS WITH PIPE CONSTITUENTS                            00025900
       INS=0                                                           00026000
       DO 5300 I1=1,NUSORS                                             00026100
       IF(INSORS(I1).NE.I) GO TO 5300                                  00026200
       INS=1                                                           00026300
       GO TO 5301                                                      00026400
  5300 CONTINUE                                                        00026500
       GO TO 72
  5301 DO 70 K=1,NP                                                    00026700
       ICHNG=0                                                         00026800
       DO 55 L=1,NP                                                    00026900
       IF(IP(L).NE.IPARM(J,K,I)) GO TO 55                              00027000
       ICHNG=1                                                         00027100
       CNVRT=1.                                                        00027200
       IF(IP(L).NE.28.AND.IP(L).NE.22.AND.IP(L).NE.23.AND.IP(L).NE.10.AND00027300
      *   .IP(L).NE.11) GO TO 5302                                     00027400
       IF(IP(L).EQ.28.AND.IUNIT(L).NE.5) GO TO 260                     00027500
       IF((IP(L).EQ.22.OR.IP(L).EQ.23).AND.IUNIT(L).NE.6) GO TO 260    00027600
       IF((IP(L).EQ.10.OR.IP(L).EQ.11).AND.IUNIT(L).NE.7) GO TO 260    00027700
       GO TO 54                                                        00027800
  5302 IF(IUNIT(L).EQ.9) GO TO 54                                      00027900
       IF(IUNIT(L).NE.4) GO TO 530                                     00028000
       CNVRT=.453592                                                   00028100
       GO TO 54                                                        00028200
   530 IF(IUNIT(L).NE.2) GO TO 531                                     00028300
       CNVRT=EFFLOW(J,I)*.001                                          00028400
       GO TO 54                                                        00028500
   531 IF(IUNIT(L).NE.1) GO TO 260                                     00028600
       CNVRT=EFFLOW(J,I)                                               00028700
    54 EFST(J,K,I)=X1(L)*CNVRT                                         00028800
       DISTYP(J,K,I)=M(L)                                              00028900
       IF(M(L).NE.0.AND.M(L).NE.1) GO TO 265                           00029000
       IF(IP(L).EQ.22.OR.IP(L).EQ.23) DISTYP(J,K,I)=0                  00029100
       GO TO 70                                                        00029200
    55 CONTINUE                                                        00029300
       IF(ICHNG.EQ.0) GO TO 270                                        00029400
    70 CONTINUE
```

```
         72 CONTINUE                                                    00029500
            INS=0                                                       00029600
            DO 5303 II=1,NUSORS
            IF(INSORS(II).NE.I) GO TO 5303
            INS=1
            GO TO 5304
       5303 CONTINUE
            GO TO 75
       5304 CONTINUE
      C                                                                 00029700
      C CONVERSION OF CONSTITUENT DATA                                  00029800
            DO 7300 J=1,J1                                              00029900
            K1=NPPARS(J,I)                                              00030000
            NM=NMNTHS(J,I)                                              00030100
            DO 7300 K=1,K1                                              00030200
            IPP=IPARM(J,K,I)                                            00030300
            IF(IPR.LT.1.OR.IPR.EQ.4.OR.IPR.EQ.6.OR.IPR.GT.30) GO TO 280 00030400
            IF(IPR.NE.30) GO TO 721                                     00030500
            IF(PRUNIT(J,K).NE.1) GO TO 290                              00030600
            GO TO 7300                                                  00030700
        721 IF(IPR.NE.28.AND.IPR.NE.22.AND.IPR.NE.23.AND.IPR.NE.10.AND.IPR.NE.00030800
           *   11) GO TO 722                                            00030900
            IF(IPR.EQ.28.AND.PRUNIT(J,K).NE.5) GO TO 290                00031000
            IF((IPR.EQ.22.OR.IPR.EQ.23).AND.PRUNIT(J,K).NE.6) GO TO 290 00031100
            IF((IPR.EQ.10.OR.IPR.EQ.11).AND.PRUNIT(J,K).NE.7) GO TO 290 00031200
            GO TO 7300                                                  00031300
        722 IF(PRUNIT(J,K).EQ.9) GO TO 7300                             00031400
        723 IF(PRUNIT(J,K).EQ.4) GO TO 728                              00031500
            IF(PRUNIT(J,K).NE.2) GO TO 724                              00031600
            CNVRT=.001                                                  00031700
            GO TO 726                                                   00031800
        724 IF(PRUNIT(J,K).NE.1) GO TO 290                              00031900
            CNVRT=1.                                                    00032000
        726 DO 727 L=1,NM                                               00032100
            QSM=QSMEAN(J,L)                                             00032200
            IF(QSM.LE.0.) QSM=EFFLOW(J,I)                               00032300
            SMAX(J,K,L)=SMAX(J,K,L)*CNVRT*QSM                           00032400
            SMEAN(J,K,L)=SMEAN(J,K,L)*CNVRT*QSM                         00032500
        727 CONTINUE                                                    00032600
            GO TO 7300                                                  00032700
        728 DO 729 L=1,NM                                               00032800
            SMAX(J,K,L)=SMAX(J,K,L)*.453592                             00032900
            SMEAN(J,K,L)=SMEAN(J,K,L)*.453592                           00033000
        729 CONTINUE                                                    00033100
       7300 CONTINUE                                                    00033200
         74 WRITE(11)((QSMEAN(J,K),MNTHQS(J,K),J=1,J1),K=1,24),(((SMAX(J,K,L),00033300
           *SMEAN(J,K,L),NSIZE(J,K,L),J=1,J1),K=1,10),L=1,24)           00033400
         75 CONTINUE                                                    00033500
            REWIND 11                                                   00033600
      C                                                                 00033700
```

```
      C                                                                 00033800
      C READ IN COMPLIANCE MONITORING DATA                              00033900
      C FOR SOURCES BEING USED (INSORS)                                 00034000
      C                                                                 00034100
            WRITE(6,990)                                                00034200
        990 FORMAT('0','COMPLIANCE MONITORING DATA',/' ','(SOURCE)  (PIPE)  ',00034300
           1       /' ',3X,'ID',8X,'J',4X,'IPAR NUM    X1(K),M(K)--FOR K=1 TO ',00034400
           2       'NUM CM POINTS')                                     00034500
            DO 120 I1=1,NUSORS                                          00034600
            I=INSORS(I1)                                                00034700
            DO 96 NDUM=1,50                                             00034800
            READ(5,79) ID,J,IPAR,NUM,(X1(K),M(K),K=1,7)                 00034900
         79 FORMAT(I2,2X,I1,1X,I2,2X,I2,1X,7(E6.0,I2,1X))               00035000
            IF(ID.NE.I) GO TO 295                                       00035100
            IF(J.EQ.0) GO TO 100                                        00035200
            IF(NUM.GT.7) READ(5,800)(X1(K),M(K),K=8,NUM)                00035300
        800 FORMAT(13X,E6.0,I2,1X,E6.0,I2,1X,E6.0,I2,1X,E6.0,I2,1X,E6.0,I2,1X,00035400
           *E6.0,I2,1X,E6.0,I2,1X)                                      00035500
            WRITE(6,995)ID,J,IPAR,NUM,(X1(K),M(K),K=1,NUM)              00035600
        995 FORMAT(' ',I5,6X,I3,4X,I3,3X,I2,50(/' ',T40,5(F12.3,',',I2)))   00035700
            ICHNG=0                                                     00035800
            K1=NPPARS(J,I)                                              00035900
            DO 90 K=1,K1                                                00036000
            IF(IPAR.NE.IPARM(J,K,I)) GO TO 90                           00036100
            ICHNG=1                                                     00036200
            DO 85 L=1,NUM                                               00036300
            Z(J,K,L)=X1(L)                                              00036400
            MNTHSZ(J,K,L)=M(L)                                          00036500
         85 CONTINUE                                                    00036600
            NOCPTS(J,K)=NUM                                             00036700
            GO TO 96                                                    00036800
         90 CONTINUE                                                    00036900
            IF(ICHNG.EQ.0) GO TO 297                                    00037000
         96 CONTINUE                                                    00037100
        100 J1=NOPIPS(I)                                                00037200
            READ(11)((QSMEAN(J,K),MNTHQS(J,K),J=1,J1),K=1,24),(((SMAX(J,K,L), 00037300
           *   SMEAN(J,K,L),NSIZE(J,K,L),J=1,J1),K=1,10),L=1,24)        00037400
            CALL ISTAT(NOPIPS(I),NPPARS(1,I),NMNTHS(1,I),DISTYP(1,1,I),QU(I), 00037500
           *           IONESD(I))                                       00037600
        115 CALL PNVCOM(NOPIPS(I),NPPARS(1,I),NOPARS(I),IPARM(1,1,I),   00037700
           *  INDPAR(1,I),DISTYP(1,1,I),EFST(1,1,I),QU(I),PNV(I1),ICOR(I))  00037800
        117 IF(IEXPD.EQ.0) GO TO 118                                    00037900
            EXPDM(I1)=1.                                                00038000
            GO TO 1180                                                  00038100
        118 CALL EXPDAM(INDPAR(1,I),KBOD(I),DOSAT(I),EXPDM(I1),NOPARS(I), 00038200
           *            IPARM,NOPIPS,I)                                 00038300
      C                                                                 00038400
      C LOADING FOR SPECIAL OUTPUT                                      00038500
      C                                                                 00038600
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```
1180 IF(NOUT.NE.0) GO TO 120                                            00038700
     IW(1)=I                                                            00038800
     WSRC(2)=EXPDM(I1)                                                  00038900
     WSRC(3)=PNV(I1)                                                    00039000
     UPFLW=QU(I)                                                        00039100
     NPTSW=NOPIPS(I)                                                    00039200
     DO 119 J=1,NPTSW                                                   00039300
     WEND(1,J)=QS(J,I)                                                  00039400
     ITEMP1=NPPARS(J,I)                                                 00039500
     IWEN(2,J)=ITEMP1                                                   00039600
     DO 119 K=1,ITEMP1                                                  00039700
     IWENDT(1,J,K)=IPARM(J,K,I)                                         00039800
     WENDTA(2,J,K)=EFST(J,K,I)                                          00039900
     IWENDT(3,J,K)=DISTYP(J,K,I)                                        00040000
     WENDTA(4,J,K)=ISTATS(I,J,K,1)                                      00040100
     WENDTA(5,J,K)=SQRT(ISTATS(I,J,K,2))                                00040200
 119 CONTINUE                                                           00040300
     WRITE(12) DUMMY                                                    00040400
 120 CONTINUE                                                           00040500
     CALL PRIORT(IPARM,NPPARS)                                          00040600
     IF(NOUT.NE.0) GO TO 150                                            00040700
     REWIND 12                                                          00040800
     CALL OUTPUT(NUSORS)                                                00040900
 150 STOP                                                               00041000
C                                                                       00041100
 200 WRITE(6,201)                                                       00041200
 201 FORMAT('0',10('*'),'PROGRAM STOPPED AT CARD 1--IDAMAG OR IDMG TOO'00041300
    1        ,' LARGE OR SMALL')                                        00041400
     STOP                                                               00041500
 205 WRITE(6,206) ID,I                                                  00041600
 206 FORMAT('0',10('*'),'PROGRAM STOPPED AT SOURCE DESCRIPTION--',/' ',00041700
    1        15X,'SOURCE READ AS',I3,' SHOULD BE',I3)                   00041800
     WRITE(6,2990)                                                      00041900
     STOP                                                               00042000
 210 WRITE(6,211) ID,PIPNO,I,J                                          00042100
 211 FORMAT('0',10('*'),'SEQUENCING OR SPECIFICATIONS ERROR--',/' ',    00042200
    1        15X,'SOURCE READ AS',I3,' PIPE',I3,' WHEN IT SHOULD HAVE'  00042300
    2        ,'BEEN SOURCE',I3,' PIPE',I3)                              00042400
     WRITE(6,2990)                                                      00042500
     STOP                                                               00042600
 220 WRITE(6,221) ID,PIPNO                                              00042700
 221 FORMAT('0',10('*'),'SOURCE',I3,' PIPE',I3,/' ',15X,'FLOW DATA CAR'00042800
    1        ,'D NOT IDENTIFIABLE (IQS IS NOT 99)')                     00042900
     WRITE(6,2990)                                                      00043000
     STOP                                                               00043100
 225 WRITE(6,226) I                                                     00043200
 226 FORMAT('0',10('*'),'MAXIMUM NUMBERS OF SAMPLES LESS THAN OR EQUAL'00043300
    1        ' TO MINIMUM NUMBER OF SAMPLES FOR SOURCE',I3)             00043400
     STOP                                                               00043500
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      230 WRITE(6,231) ID,PIPNO,I,J                                        00043600
      231 FORMAT('0',10('*'),'SEQUENCING OR SPECIFICATIONS ERROR--',/' ',15X00043700
     1          ,'SELF-MONITORING CONSTITUENT DATA CARD READ AS SOURCE',I3,00043800
     2          'PIPE',I3,' WHEN IT SHOULD HAVE BEEN SOURCE',I3,' PIPE',I3)00043900
          WRITE(6,2990)                                                     00044000
          STOP                                                              00044100
      240 WRITE(6,241) I,J                                                  00044200
      241 FORMAT('0',10('*'),'SOURCE',I3,',PIPE',I3,'--PH MUST BE INPUTTED',00044300
     1          'WITH PH MAX (23) PRECEDING PH MIN (22)')                   00044400
          STOP                                                              00044500
      250 WRITE(6,251) ID,PIPNO,I,J                                         00044600
      251 FORMAT('0',10('*'),'SEQUENCING OR SPECIFICATIONS ERROR--',/' ',15X00044700
     1          ,'CONSTITUENT EFFLUENT STANDARDS DATA CARD READ AS SOURCE',00044800
     2           I3,' PIPE',I3,' WHEN IT SHOULD HAVE BEEN SOURCE',I3,'PIPE'00044900
     3          ,I3)                                                        00045000
          WRITE(6,2990)                                                     00045100
          STOP                                                              00045200
      260 WRITE(6,261) I,J,IP(L),IUNIT(L)                                   00045300
      261 FORMAT('0',10('*'),'SOURCE',I3,' PIPE',I3,' CONSTITUENT ID',I3,   00045400
     1          'STANDARD UNITS IDENTIFIED AS',I2,'--RECHECK ALLOWABLE',    00045500
     2          'UNITS')                                                    00045600
          STOP                                                              00045700
      265 WRITE(6,266) I,J,IP(L)                                            00045800
      266 FORMAT('0',10('*'),'SOURCE',I3,' PIPE',I3,' CONSTITUENT',I3,' DIS'00045900
     1          'TRIBUTION ENTERED AS OTHER THAN 3 OR 1')                   00046000
          STOP                                                              00046100
      270 WRITE(6,271) I,J,IPARM(J,K,I)                                     00046200
      271 FORMAT('0'10('*'),'SOURCE',I3,' PIPE',I3,' CONSTITUENT',I3,' STAN'00046300
     1          ,'DARD NOT ENTERED')                                        00046400
          STOP                                                              00046500
      280 WRITE(6,281) I,J,IPR                                              00046600
      281 FORMAT('0',10('*'),'SOURCE',I3,' PIPE',I3,' CONSTITUENT SPECIFIED'00046700
     1          'AS',I3,'--RECHECK LIST OF ALLOWABLE CONSTITUENTS')         00046800
          STOP                                                              00046900
      290 WRITE(6,291) I,J,IPR                                              00047000
      291 FORMAT('0',10('*'),'SOURCE',I3,' PIPE',I3,' CONSTITUENT',I3,' SEL'00047100
     1          'F MONITORING DATA IS NOT IN PROPER UNITS--',/' ',15X,'REC'00047200
     2          'HECK LIST OF ALLOWABLE UNITS')                             00047300
          STOP                                                              00047400
      295 WRITE(6,296) ID,I                                                 00047500
      296 FORMAT('0',10('*'),'SEQUENCING OR SPECIFICATIONS ERROR--SOURCE RE'00047600
     1          'AD AS',I3,' SHOULD BE',I3,' IN COMPLIANCE MONITORING INPUT'00047700
     2          ,/' ','ENTER CM CARDS ONLY FOR SOURCES LISTED AS INSORS')   00047800
          STOP                                                              00047900
      297 WRITE(6,298) I,J,IPAR                                             00048000
      298 FORMAT('0',10('*'),'SOURCE',I3,' PIPE',I3,' COMPLIANCE MONITORING'00048100
     1          'INPUT FOR CONSTITUENT',I3,/' ',15X,'NO SUCH CONSTITUENT ',00048200
     2          'ENTERED UNDER SELF MONITORING DATA')                       00048300
C                                                                           00048400
      299 WRITE(6,2990) I                                                   00048500
```

```
      2990 FORMAT('0','CHECK CARDS TO BE SURE THAT  1)SOURCE AND PIPE NUMBER'00048600
          1       ,'S ARE AS INTENDED',/' ',20X,'2)CARDS ARE IN PROPER SEQUE'00048700
          2       ,'NCE',/' ',20X,'3)NUMBER OF MONTHS OF DATA, NUMBER OF PIP'00048800
          3       ,'ES,ETC. AND OTHER DATA ARE CORRECT',/' ',22X,'FOR SOURCE'00048900
          4       ,I3,' AND PRECEDING SOURCE')                              00049000
           STOP                                                              00049100
           END                                                               00049200
```

A B E F

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           SUBROUTINE ABEF(D1,D2,A,B,KD,ALPHA,BETA,E,F,L)                    00000100
      C                                                                      00000200
      C COMPUTES COEFFICIENTS ALPHA,BETA,E,F FOR PH INTEGRALS                00000300
           COMMON/BRKPTS/S(6),SSPH(11)                                       00000400
           L=1                                                               00000500
           ALPHA=(D1-B)/A                                                    00000600
           BETA=(D2-B)/A                                                     00000700
           DSS=SSPH(KD+1)-SSPH(KD)                                           00000800
           DD=D2-D1                                                          00000900
           E=DSS*A/DD                                                        00001000
           F=DSS*(B-D1)/DD+SSPH(KD)                                          00001100
           X=.0000001                                                        00001200
           IF(ALPHA.LT.X) ALPHA=X                                            00001300
           IF(BETA.LT.X) L=2                                                 00001400
           IF(ALPHA.GT.1.) L=2                                               00001500
           IF(BETA.GT.1.) BETA=1.                                            00001600
           RETURN                                                            00001700
           END                                                               00001800
```

```
          FUNCTION COMEXD(TMU,TSIG,M,FUNC1,FUNC2,A,B)
C
C COMEXD CALCULATES EXPECTED DAMAGE FOR ANY NON-PH CONSTITUENT
          REAL ILINAO
          COMMON/DMG1/DAMAGE(30,6)
C ID CONTAINS DISTRIBUTION SPECIFICATION--0 IS NORMAL AND 1 IS LOGNORMAL
          COMMON/FLAGD/ID
          COMMON/BRKPTS/S(6),SSPH(11)
          COMMON/BODDMG/TOS,QU,CS,IBOD
          COMEXD=0.
          IBOD=0
C
C FIRST FIVE TERMS OF EXPECTED DAMAGE SUMMATION
          DO 10 KD=1,5
          BETA=(DAMAGE(M,KD+1)-B)/A
          ALPHA=(DAMAGE(M,KD)-B)/A
          DD=DAMAGE(M,KD+1)-DAMAGE(M,KD)
          DS=S(KD+1)-S(KD)
          E=DS*A/DD
          F=DS*(B-DAMAGE(M,KD))/DD+S(KD)
          IF(BETA.LE.0.) GO TO 10
          IF(ALPHA.GT.0.) GO TO 7
          ALPHA=0.
          IF(ID.EQ.0) GO TO 7
          COMEXD=COMEXD+ILINAO(E,F,BETA,TMU,TSIG)
          GO TO 10
        7 COMEXD=COMEXD+FUNC1(E,F,ALPHA,BETA,TMU,TSIG)
       10 CONTINUE
C
C SIXTH TERM OF EXPECTED DAMAGE SUMMATION
          ALPHA=BETA
          IF(ALPHA.GT.0.) GO TO 12
          IF(ID.EQ.1) GO TO 15
          ALPHA=0.
       12 COMEXD=COMEXD+FUNC2(ALPHA,TMU,TSIG)
          IF(ID.EQ.1) GO TO 11
C COMPUTE DELTA FUNCTION FOR NORMAL CASE
C
          IF(M.EQ.3) IBOD=1
          CALL DAMAGO(DJB,M,B)
          COMEXD=COMEXD+DJB*XNORM(-TMU/TSIG)
          IF(M.EQ.3) CALL DAMAGO(DJB,M,B)
          COMEXD=COMEXD-DJB
          RETURN
       15 COMEXD=COMEXD+S(6)
       11 CALL DAMAGO(DJB,M,B)
          COMEXD=COMEXD-DJB
          RETURN
          END
```

```
      SUBROUTINE DAMAGO(DJB,M,B)
C
C SUBROUTINE DAMAGE-ZERO DETERMINES DAMAGE FOR LEVEL 0 OF PARAMETER M
C
      COMMON/DMG1/DAMAGE(30,6)
      COMMON/BRKPTS/S(6),SSPH(11)
      COMMON/BODDMG/TQS,QU,CS,IBOD
      IF(M.EQ.3) GO TO 41
      IF(B.GE.DAMAGE(M,1)) GO TO 15
      DJB=0.
      RETURN
   15 DO 20 KD=1,5
      IF(DAMAGE(M,KD).LE.B.AND.B.LT.DAMAGE(M,KD+1)) GO TO 30
   20 CONTINUE
      DJB=S(6)
      GO TO 40
   30 DJB=(S(KD+1)-S(KD))*(B-DAMAGE(M,KD))/(DAMAGE(M,KD+1)-DAMAGE(M,KD))
     *+S(KD)
   40 RETURN
C
C BOD ROUTINE
C
   41 BBOD=B
C
C IBOD=0  FOR 0-LEVEL DAMAGE DETERMINATION
C     =1  FOR DELTA FUNCTION COEFFICIENT DETERMINATION
C
      IF(IBOD.EQ.0) BBOD=B+TQS*(9.-CS)/(QU+TQS)
      IBOD=0
      IF(BBOD.LE.DAMAGE(3,1)) GO TO 42
      DJB=0.
      RETURN
   42 DO 43 KD=1,5
      IF(DAMAGE(3,KD).GE.BBOD.AND.BBOD.GT.DAMAGE(3,KD+1)) GO TO 430
   43 CONTINUE
      DJB=S(6)
      RETURN
  430 DJB=(S(KD+1)-S(KD))*(BBOD-DAMAGE(M,KD))/(DAMAGE(M,KD+1)-DAMAGE(M,
     *KD))+S(KD)
      RETURN
      END
```

```
      FUNCTION DIFF(X,Y)                                                00000100
C                                                                       00000200
C DIFF CALCULATES THE DIFFERENCE OF TWO STANDARD NORMAL DISTRIBUTION FUN00000300
C                                                                       00000400
      IF(X.GT.4..AND.Y.GT.4.) GO TO 10                                  00000500
      GO TO 25                                                          00000600
   10 DIFF=ABS(DNORM(X)-DNORM(Y))                                       00000700
      RETURN                                                            00000800
   25 DIFF=XNORM(X)-XNORM(Y)                                            00000900
      RETURN                                                            00001000
      END                                                               00001100
```

```
      SUBROUTINE EXPDAM(IPARAM,KBOD,DOSAT,EXPDM,NOPARS,IPARM,NOPIPS,I)  00000100
C                                                                       00000200
C EXPDAM DETERMINES EXPECTED DAMAGE FOR A SOURCE                        00000300
C                                                                       00000400
      DIMENSION IPARAM(NOPARS),EXPD(10),IPARM(4,10,30),NOPIPS(30)       00000500
      COMMON/DMG1/DAMAGE(30,6)                                          00000600
      COMMON/DMG2/DMG(2,11)                                             00000700
      COMMON/FLAGD/ID                                                   00000800
      COMMON/BRKPTS/S(6),SSPH(11)                                       00000900
      COMMON/BODDMG/TQS,QU,CS,IBOD                                      00001000
      COMMON/ENVEXP/DIST(10),TMU(10),TSIG(10)                           00001100
      COMMON/PCOPT/ICOPT                                                00001200
      COMMON/EXP/NPPARS(4,30)                                           00001300
      INCLUDE P1.LIST                                                   00001400
      INTEGER DIST                                                      00001500
      REAL KBOD                                                         00001600
      REAL IN,IL,ILINFB,ININFB                                          00001700
      EXTERNAL IN,IL,ILINFB,ININFB                                      00001800
      EXPDM=0.                                                          00001900
      DO 100 M=1,NOPARS                                                 00002000
      ID=DIST(M)                                                        00002100
      IF(IPARAM(M).EQ.30) GO TO 100                                     00002200
      IF(IPARAM(M).EQ.23) GO TO 100                                     00002300
      IF(IPARAM(M).NE.22) GO TO 10                                      00002400
C                                                                       00002500
C EXPECTED DAMAGE FOR PH                                                00002600
C PARAM 22=PH                                                           00002700
C PARAM 23=POH                                                          00002800
      EXPD(M)=PHEXD(TMU(M),TSIG(M),TQS,QU)                              00002900
      GO TO 60                                                          00003000
   10 IF(IPARAM(M).NE.28) GO TO 20                                      00003100
C                                                                       00003200
C TEMPERATURE                                                           00003300
C                                                                       00003400
      A=TQS/(QU+TQS)                                                    00003500
      B=0.                                                              00003600
      IPM=28                                                            00003700
      GO TO 55                                                          00003800
   20 IF(IPARAM(M).NE.3) GO TO 30                                       00003900
C                                                                       00004000
C BOD                                                                   00004100
C                                                                       00004200
      A=-KBOD/(QU+TQS)                                                  00004300
      B=(1./(QU+TQS))*(CS*TQS+DOSAT*QU)                                 00004400
      IPM=3                                                             00004500
      GO TO 55                                                          00004600
C                                                                       00004700
C NON-COUPLED CONSTITUENT                                               00004800
C                                                                       00004900
```

```
   30 A=1./(QU+TQS)                                                  00005000
      IPM=IPARAM(M)                                                  00005100
      IF(IPM.EQ.10.OR.IPM.EQ.11) A=A*TQS                             00005200
      COPT=DAMAGE(IPM,ICOPT)                                         00005300
      IF(ICOPT.EQ.1.AND.COPT.GT.0.) COPT=0.                          00005400
      B=COPT*QU*A                                                    00005500
   55 IF(ID.EQ.1) GO TO 56                                           00005600
      EXPD(M)=COMEXD(TMU(M),TSIG(M),IPM,IN,ININFB,A,B)               00005700
      GO TO 60                                                       00005800
   56 EXPD(M)=COMEXD(TMU(M),TSIG(M),IPM,IL,ILINFB,A,B)               00005900
C SET UP SPECIAL OUTPUT                                               00006000
   60 ICHNG=0                                                        00006100
      NP=NOPIPS(I)                                                   00006200
      DO 65 J=1,NP                                                   00006300
      NPP=NPPARS(J,I)                                                00006400
      DO 65 K1=1,NPP                                                 00006500
      IF(IPARM(J,K1,I).NE.IPARAM(M)) GO TO 65                        00006600
      WENDTA(6,J,K1)=EXPD(M)                                         00006700
      IF(IPARAM(M).EQ.22) WENDTA(6,J,K1-1)=10000000.                 00006800
      ICHNG=ICHNG+1                                                  00006900
      IF(ICHNG.GT.1) WENDTA(6,J,K1)=10000000.                        00007000
   65 CONTINUE                                                       00007100
      IF(EXPD(M).GT.EXPDM) EXPDM=EXPD(M)                             00007200
  100 CONTINUE                                                       00007300
      RETURN                                                         00007400
      END                                                            00007500
```

```
      REAL FUNCTION ILINFB(ALPHA,MU,SIGMA)
C
C COMPUTING IL(0,S(6),ALPHA,INFINITY,MU,SIGMA)
C
      REAL MU
      COMMON/BRKPTS/S(6),SSPH(11)
      ALPHA1=(ALOG10(ALPHA)-MU)/SIGMA
      IF(ALPHA1.GT.4.) GO TO 20
      ILINFB=S(6)*(1.-XNORM(ALPHA1))
      RETURN
   20 ILINFB=S(6)*DNORM(ALPHA1)
      RETURN
      END
```

```
      REAL FUNCTION ILINFA(BETA,MU,SIGMA)                               00000100
C                                                                       00000200
C  CALCULATING IL(0,1,-INFINITY,BETA,MU,SIGMA)                          00000300
      REAL MU                                                           00000400
      ILINFA=XNORM((ALOG10(BETA)-MU)/SIGMA)                             00000500
      RETURN                                                            00000600
      END                                                               00000700
```

```
      REAL FUNCTION ILINA0 (A,B,BETA,MU,SIGMA)                            00000100
C                                                                         00000200
C COMPUTING IL(A,B,0,BETA,MU,SIGMA)                                       00000300
      REAL MU                                                             00000400
      BETA1=(ALOG10(BETA)-MU)/SIGMA                                       00000500
C USING LN(10)=2.3025851                                                  00000600
      BETA2=BETA1-SIGMA*2.3025851                                         00000700
      ILINA0=A*EXP((SIGMA*2.3025851)**2./2.+2.3025851*MU)*XNORM(BETA2)+   00000800
     *B*XNORM(BETA1)                                                      00000900
      RETURN                                                              00001000
      END                                                                 00001100
```

```
      REAL FUNCTION IL(A,B,ALPHA,BETA,MU,SIGMA)                         00000100
C                                                                       00000200
C COMPUTING IL(A,B,ALPHA,BETA,MU,SIGMA                                  00000300
      REAL MU                                                           00000400
      COMMON/BRKPTS/S(6),SSPH(30)                                       00000500
      ALPHA1=(ALOG10(ALPHA)-MU)/SIGMA                                   00000600
      BETA1=(ALOG10(BETA)-MU)/SIGMA                                     00000700
C USING LN(10)=2.3025851                                                00000800
      ALPHA2=ALPHA1-SIGMA*2.3025851                                     00000900
      BETA2=BETA1-SIGMA*2.3025851                                       00001000
      IL=A*EXP((SIGMA*2.3025851)**2./2.+2.3025851*MU)*DIFF(BETA2,ALPHA2)00001100
     *+B*DIFF(BETA1,ALPHA1)                                             00001200
      RETURN                                                            00001300
C                                                                       00001400
C IL(0,S(6),ALPHA,1,MU,SIGMA)                                           00001500
      ENTRY RILBT1(ALPHA,MU,SIGMA)                                      00001600
      ALPHA1=(ALOG10(ALPHA)-MU)/SIGMA                                   00001700
      BETA1=-MU/SIGMA                                                   00001800
      IL=S(6)*DIFF(BETA1,ALPHA1)                                        00001900
      RETURN                                                            00002000
      END                                                               00002100
```

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```
      REAL FUNCTION ININFA(BETA,MU,SIGMA)                                  00000100
C                                                                          00000200
C CALCULATING IN(0,1,-INFINITY,BETA,MU,SIGMA)                              00000300
      REAL MU                                                              00000400
      ININFA=XNORM((BETA-MU)/SIGMA)                                        00000500
      RETURN                                                               00000600
      END                                                                  00000700
```

```
      REAL FUNCTION IN(A,B,ALPHA,BETA,MU,SIGMA)                          00000100
C                                                                        00000200
C COMPUTING IN(A,B,ALPHA,BETA,MU,SIGMA)                                  00000300
      REAL MU                                                            00000400
      ALPHAN=(ALPHA-MU)/SIGMA                                            00000500
      BETAN=(BETA-MU)/SIGMA                                              00000600
      IF(A.EQ.0..AND.B.EQ.1.) GO TO 10                                   00000700
C USING PI=3.1415927                                                     00000800
C  AND 1./SQRT(2*PI) = .3989422                                          00000900
      IN=A*SIGMA*.3989422*(EXP(-(ALPHAN**2.)/2.)-EXP(-(BETAN**2.)/2.))+  00001000
     *(MU*A+B)*DIFF(BETAN,ALPHAN)                                        00001100
      RETURN                                                             00001200
C                                                                        00001300
C IN(0,1,ALPHA,BETA,MU,SIGMA)                                            00001400
   10 IN=DIFF(BETAN,ALPHAN)                                              00001500
      RETURN                                                             00001600
      END                                                                00001700
```

```
      REAL FUNCTION ININFB(ALPHA,MU,SIGMA)                              00000100
C                                                                       00000200
C COMPUTING IN(0,S(6),ALPHA,INFINITY,MU,SIGMA)                          00000300
C                                                                       00000400
      COMMON/BRKPTS/S(6),SSPH(30)                                       00000500
C                                                                       00000600
      REAL MU                                                           00000700
      ALPHAN=(ALPHA-MU)/SIGMA                                           00000800
      IF(ALPHAN.GT.4.) GO TO 20                                         00000900
      ININFB=S(6)*(1.-XNORM(ALPHAN))                                    00001000
      RETURN                                                            00001100
   20 ININFB=S(6)*DNORM(ALPHAN)                                         00001200
      RETURN                                                            00001300
      END                                                               00001400
```

```
      SUBROUTINE ISTAT(NOPIPS,NPPARS,NMNTHS,DIST,QU,IONESD)             00000100
C                                                                       00000200
C SUBROUTINE ISTAT COMPUTES THE INITIAL STATISTICAL DESCRIPTION GIVEN IN00000300
C   DATA FROM A SINGLE SOURCE                                           00000400
C                                                                       00000500
      REAL NU(4,10,24),MU,KETA,KNU,ISTATS                               00000600
      INTEGER DIST,TEMP(24)                                             00000700
      DIMENSION NPPARS(4),DIST(4,10),EMEAN(4,10,24),ESIGMA(4,10,24),    00000800
     $   ETA(4,10,24),NMNTHS(4)                                         00000900
      COMMON/IST/MNTHQS(4,24),NSIZE(4,10,24),SMEAN(4,10,24),            00001000
     *   SMAX(4,10,24),NOCPTS(4,10),MNTHSZ(4,10,30),Z(4,10,30),DELTA,   00001100
     *   GAMMA,KETA,KNU,ENU,IPARM(4,10,30),ISTATS(30,4,10,4)            00001200
      COMMON/ISTPNV/MU(4,10),SIGMA(4,10)                                00001300
      COMMON/UPDATE/I,QS(4,30)                                          00001400
C                                                                       00001500
C FIND INITIAL STATISTICS FOR EACH PARAMETER OF EACH PIPE               00001600
C                                                                       00001700
      DO 50 L=1,NOPIPS                                                  00001800
      NM=NMNTHS(L)                                                      00001900
      NP=NPPARS(L)                                                      00002000
      DO 50 J=1,NP                                                      00002100
      IFLAG=0                                                           00002200
C                                                                       00002300
C FIRST CHECK DATA FOR ZEROS OR MAX/MEAN ERRORS                         00002400
C THEN CHECK TO SEE IF SAMPLE SIZE IS .GT.4 FOR ALL MONTHS, OTHERWISE CO00002500
C                                                                       00002600
C                                                                       00002700
      IF(IONESD.NE.1.OR.(IPARM(L,J,I).NE.22.AND.IPARM(L,J,I).NE.23)) GO 00002800
     1   TO 100                                                         00002900
C CHECK PH DATA WHERE ONLY MAX/MIN ARE GIVEN                            00003000
      IF(IPARM(L,J,I).EQ.22) GO TO 1113                                 00003100
      DO 90 K=1,NM                                                      00003200
      IF(NSIZE(L,J,K).GT.0.AND.SMAX(L,J,K).GT.0.) GO TO 90              00003300
      NSIZE(L,J,K)=0                                                    00003400
      SMAX(L,J,K)=0.                                                    00003500
      NSIZE(L,J+1,K)=0                                                  00003600
      SMAX(L,J+1,K)=0.                                                  00003700
   90 CONTINUE                                                          00003800
      DO 99 K=1,NM                                                      00003900
      NSIZE(L,J+1,K)=NSIZE(L,J,K)                                       00004000
      IF(NSIZE(L,J+1,K).GT.0.AND.SMAX(L,J+1,K).GT.0.) GO TO 98          00004100
      NSIZE(L,J+1,K)=0                                                  00004200
      SMAX(L,J+1,K)=0.                                                  00004300
      NSIZE(L,J,K)=0                                                    00004400
      SMAX(L,J,K)=0.                                                    00004500
   98 IF(SMAX(L,J+1,K).LE.SMAX(L,J,K))GO TO 99                          00004600
      WRITE(6,101) MNTHQS(L,K),L,I                                      00004700
  101 FORMAT('0','MIN-MAX ERROR FOR MONTH',I3,' OF PIPE',I3,' OF SOURCE'00004800
```

```
          1         ,I3,/' ',  'CONSTITUENT 22 MINIMUM IS GREATER THAN CONSTITUE'
          2         ,'NT 23 MAXIMUM--DATA DELETED')
      NSIZE(L,J+1,K)=0
      SMAX(L,J+1,K)=0.
      NSIZE(L,J,K)=0
      SMAX(L,J,K)=0.
   99 CONTINUE
      GO TO 1113
C CHECK FOR REGULAR CONSTITUENTS (INCLUDING PH WITH MEAN)
  100 DO 1112 K=1,NM
      IF(NSIZE(L,J,K).GT.0.AND.SMEAN(L,J,K).GT.0..AND.SMAX(L,J,K).GT.0.)
     *  GO TO 1110
      NSIZE(L,J,K)=0
      SMAX(L,J,K)=0.
      SMEAN(L,J,K)=0.
 1110 IF((IPARM(L,J,I).NE.22.AND.SMAX(L,J,K).GE.SMEAN(L,J,K)).OR.(IPARM(
     *L,J,I).EQ.22.AND.SMAX(L,J,K).LE.SMEAN(L,J,K))) GO TO 1112
      WRITE(6,1111) MNTHOS(L,K),L,I,IPARM(L,J,I)
 1111 FORMAT('0','MAX-MEAN OR MIN-MEAN REVERSED FOR MONTH',I3,' OF PIPE'
     *        ,I3,' OF SOURCE',I3,', CONSTITUENT',I3,'--DATA DELETED')
      NSIZE(L,J,K)=0
      SMAX(L,J,K)=0.
      SMEAN(L,J,K)=0.
 1112 CONTINUE
 1113 K1=0
      IMNTH=0
      DO 15 K=1,NM
      IF(K1.GE.K) GO TO 15
      K1=K
      NS=NSIZE(L,J,K)
   12 IF(NS.GE.4) GO TO 14
      IF(K.EQ.NM.OR.K1.EQ.NM) GO TO 1500
      K1=K1+1
      NS=NS+NSIZE(L,J,K1)
      GO TO 12
   14 IMNTH=IMNTH+1
      TEMP(IMNTH)=K
   15 CONTINUE
C
C TAKE CARE OF EXCEPTIONS--IE,0 OR 1 MONTH TOTAL DATA
C
 1500 IF(IMNTH.EQ.0) GO TO 9999
  151 IF(IMNTH.NE.1) GO TO 16
      IFLAG=1
      GO TO 160
C
C FIND ESTIMATES FOR ALL MONTHS FOR GIVEN PIPE/PARAMETER
C
```

```
      16 IMNTH=IMNTH-1                                                  00009700
     160 DO 30 N=1,IMNTH                                                00009800
         N1=N                                                           00009900
         K=TEMP(N)                                                      00010000
         K2=TEMP(N+1)-1                                                 00010100
         IF(IFLAG.EQ.1) K2=NM                                           00010200
C PH CONSTITUENTS ALWAYS IN ORDER 23,22                                  00010300
      17 IF(IONESD.EQ.1.AND.IPARM(L,J,I).EQ.22) GO TO 220               00010400
         IF(K.EQ.K2) GO TO 200                                          00010500
         SMEAN(L,J,K)=NSIZE(L,J,K)*SMEAN(L,J,K)                         00010600
         KO=K+1                                                         00010700
         DO 19 K1=KO,K2                                                 00010800
         SMEAN(L,J,K)=SMEAN(L,J,K)+NSIZE(L,J,K1)*SMEAN(L,J,K1)          00010900
         NSIZE(L,J,K)=NSIZE(L,J,K)+NSIZE(L,J,K1)                        00011000
         IF(IPARM(L,J,I).NE.22) GO TO 18                                00011100
         IF(NSIZE(L,J,K1).EQ.0) GO TO 19                                00011200
         IF(SMAX(L,J,K).GT.SMAX(L,J,K1)) SMAX(L,J,K)=SMAX(L,J,K1)       00011300
         GO TO 19                                                       00011400
      18 IF(SMAX(L,J,K).GT.SMAX(L,J,K1)) GO TO 19                       00011500
         SMAX(L,J,K)=SMAX(L,J,K1)                                       00011600
      19 CONTINUE                                                       00011700
         SMEAN(L,J,K)=SMEAN(L,J,K)/NSIZE(L,J,K)                         00011800
     200 IF(IONESD.NE.1) GO TO 21                                       00011900
         IF(IPARM(L,J,I).NE.23) GO TO 21                                00012000
         IF(K.EQ.K2) GO TO 202                                          00012100
         DO 201 K1=KO,K2                                                00012200
         IF(NSIZE(L,J+1,K1).EQ.0) GO TO 201                             00012300
         IF(SMAX(L,J+1,K).GT.SMAX(L,J+1,K1)) SMAX(L,J+1,K)=SMAX(L,J+1,K1) 00012400
     201 CONTINUE                                                       00012500
     202 CALL PARAMS(NSIZE(L,J,K),0.,SMAX(L,J,K),DIST(L,J),EMEAN(L,J,K), 00012600
        1            ESIGMA(L,J,K),SMAX(L,J+1,K),IPARM(L,J,I),I,IONESD) 00012700
         ETA(L,J+1,K)=NSIZE(L,J,K)                                      00012800
         NU(L,J+1,K)=(NSIZE(L,J,K)-1)*ENU                               00012900
         EMEAN(L,J+1,K)=EMEAN(L,J,K)                                    00013000
         ESIGMA(L,J+1,K)=ESIGMA(L,J,K)                                  00013100
         GO TO 22                                                       00013200
      21 CALL PARAMS(NSIZE(L,J,K),SMEAN(L,J,K),SMAX(L,J,K),DIST(L,J),   00013300
        1            EMEAN(L,J,K),ESIGMA(L,J,K),0.,IPARM(L,J,I),I,IONESD) 00013400
      22 ETA(L,J,K)=NSIZE(L,J,K)                                        00013500
         NU(L,J,K)=(NSIZE(L,J,K)-1)*ENU                                 00013600
     220 ESIGMA(L,J,K)=ESIGMA(L,J,K)*ESIGMA(L,J,K)                      00013700
         TMPETA=ETA(L,J,K)                                              00013800
         TMPNU=NU(L,J,K)                                                00013900
C                                                                       00014000
C ADD IN ANY COMPLIANCE POINTS FOR MONTH(S) BEING DONE                  00014100
C                                                                       00014200
         NCP=NOCPTS(L,J)                                                00014300
         IF(NCP.EQ.0) GO TO 28                                          00014400
         MLOW=1                                                         00014500
```

```
      DO 26 K1=K,K2                                                     00014600
      MNTH=MNTHQS(L,K1)                                                 00014700
   23 DO 24 M=MLOW,NCP                                                  00014800
      IF(MNTHSZ(L,J,M).EQ.MNTH) GO TO 25                                00014900
   24 CONTINUE                                                          00015000
      GO TO 26                                                          00015100
   25 TMPETA=ETA(L,J,K)/GAMMA                                           00015200
      TMPNU=NU(L,J,K)/GAMMA                                             00015300
      IF(DIST(L,J).EQ.1) Z(L,J,M)=ALOG10(Z(L,J,M))                      00015400
      SAVE=EMEAN(L,J,K)                                                 00015500
      EMEAN(L,J,K)=(TMPETA*SAVE+Z(L,J,M))/(TMPETA+1.)                   00015600
      SAVE=SAVE-Z(L,J,M)                                                00015700
      ESIGMA(L,J,K)=(TMPNU*ESIGMA(L,J,K)+TMPETA*SAVE*SAVE/(TMPETA+1.))  00015800
     */(TMPNU+1.)                                                       00015900
      ETA(L,J,K)=ETA(L,J,K)+1.                                          00016000
      NU(L,J,K)=NU(L,J,K)+1.                                            00016100
      SIG=SQRT(ESIGMA(L,J,K))                                           00016200
      MLOW=M+1                                                          00016300
      IF(MLOW.GT.NCP) GO TO 28                                          00016400
      GO TO 23                                                          00016500
   26 CONTINUE                                                          00016600
C                                                                       00016700
C RESEQUENCE--SET UP FULL ARRAYS BY SEQUENTIAL INDEX OF 'MONTHS' WHICH N00016800
C INCLUDE COMBINATIONS OF MONTHS WHERE DATA WAS INSUFFICIENT            00016900
   28 ETA(L,J,N1)=ETA(L,J,K)                                            00017000
      NU(L,J,N1)=NU(L,J,K)                                              00017100
      ESIGMA(L,J,N1)=ESIGMA(L,J,K)                                      00017200
      EMEAN(L,J,N1)=EMEAN(L,J,K)                                        00017300
C                                                                       00017400
      IF(N.NE.IMNTH)GO TO 30                                            00017500
      IF(IFLAG.EQ.0) GO TO 293                                          00017600
      MU(L,J)=EMEAN(L,J,1)                                              00017700
      SIGMA(L,J)=ESIGMA(L,J,1)                                          00017800
      TMPETA=ETA(L,J,1)                                                 00017900
      TMPNU=NU(L,J,1)                                                   00018000
      GO TO 47                                                          00018100
  293 IMNTH=IMNTH+1                                                     00018200
      K=TEMP(IMNTH)                                                     00018300
      K2=NM                                                             00018400
      N1=N+1                                                            00018500
      GO TO 17                                                          00018600
   30 CONTINUE                                                          00018700
C                                                                       00018800
C COMBINE MONTHLY ESTIMATES                                             00018900
C                                                                       00019000
   32 MU(L,J)=EMEAN(L,J,1)                                              00019100
      SIGMA(L,J)=ESIGMA(L,J,1)                                          00019200
      TMPETA=ETA(L,J,1)                                                 00019300
      TMPNU=NU(L,J,1)                                                   00019400
```

```
      K1=2
      DO 40 K=K1,IMNTH
      IF(TMPNU.GT.KNU*NU(L,J,K)) TMPNU=KNU*NU(L,J,K)
      IF(TMPETA.GT.KETA*ETA(L,J,K )) TMPETA=KETA*ETA(L,J,K)
      SAVE=MU(L,J)
      MU(L,J)=(TMPETA*MU(L,J)+ETA(L,J,K)*EMEAN(L,J,K))/(TMPETA+
     *ETA(L,J,K))
      SIGMA(L,J)=(TMPNU*SIGMA(L,J)+TMPETA*SAVE*SAVE+NU(L,J,K)*ESIGMA(L,J
     *,K)+ETA(L,J,K)*EMEAN(L,J,K)*EMEAN(L,J,K)-(TMPETA+ETA(L,J,K))*MU(L,
     *J)*MU(L,J))/(TMPNU+NU(L,J,K)+1.)
      TMPETA=TMPETA+ETA(L,J,K)
      TMPNU=TMPNU+NU(L,J,K)+1.
      SIG=SQRT(SIGMA(L,J))
   40 CONTINUE
   47 ISTATS(I,L,J,1)=MU(L,J)
      ISTATS(I,L,J,2)=SIGMA(L,J)
      ISTATS(I,L,J,3)=TMPETA
      ISTATS(I,L,J,4)=TMPNU
      SIGMA(L,J)=SIG
   49 NOCPTS(L,J)=0
   50 CONTINUE
      RETURN
C
 9999 WRITE(6,10000) I,IPARM(L,J,I)
10000 FORMAT('0',10('*'),'INSUFFICIENT DATA (COMBINED SAMPLE SIZE LESS'
     1        ,' THAN 4)  FOR SOURCE',I3,' CONSTITUENT',I3)
      STOP
      END
```

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```
      SUBROUTINE ORDER(XMR,ISORC,M)
C
C  BUBBLE SORT ROUTINE
      DIMENSION XMR(M),ISORC(M)
      M1=M-1
      DO 70 I=1,M1
      KFLAG=0
      DO 65 J=1,M1
      IF (XMR(J+1)-XMR(J)) 65,65,64
   64 TEMPMR=XMR(J)
      ITEMPS=ISORC(J)
      XMR(J)=XMR(J+1)
      ISORC(J)=ISORC(J+1)
      XMR(J+1)=TEMPMR
      ISORC(J+1)=ITEMPS
      KFLAG=1
   65 CONTINUE
      IF(KFLAG.EQ.0) RETURN
   70 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUTPUT(NUSORS)                                         00000100
C                                                                       00000200
C OUTPUT PRINTS SOURCE STATISTICS SUMMARY TABLES                         00000300
C                                                                       00000400
      INCLUDE P1,LIST                                                   00000500
      DIMENSION DIST(2)                                                 00000600
      COMMON/CONST/PARMS(5,30)                                          00000700
      DATA DIST(1),DIST(2)/' N  ',' L  '/                               00000800
      DATA (PARMS(L,1),L=1,5)/'ALUM','INUM','    ','    ','    '/       00000900
      DATA (PARMS(L,2),L=1,5)/'AMMO','NIA ','    ','    ','    '/       00001000
      DATA (PARMS(L, 3),L=1,5)/'BOD5','    ','    ','    ','    '/      00001100
      DATA (PARMS(L, 4),L=1,5)/5*'    '/                                00001200
      DATA (PARMS(L, 5),L=1,5)/'CARB','ON  ','    ','    ','    '/      00001300
      DATA (PARMS(L, 6),L=1,5)/5*'    '/                                00001400
      DATA (PARMS(L, 7),L=1,5)/'CHLO','RIDE','    ','    ','    '/      00001500
      DATA (PARMS(L, 8),L=1,5)/'CHLO','ROFO','RM E','XTRA','CT  '/      00001600
      DATA (PARMS(L, 9),L=1,5)/'CHRO','MIUM','    ','    ','    '/      00001700
      DATA (PARMS(L,10),L=1,5)/'COLI','FORM','S--T','OTAL','    '/      00001800
      DATA (PARMS(L,11),L=1,5)/'COLI','FORM','S--F','ECAL','    '/      00001900
      DATA (PARMS(L,12),L=1,5)/'COPP','ER  ','    ','    ','    '/      00002000
      DATA (PARMS(L,13),L=1,5)/'CYAN','IDE ','    ','    ','    '/      00002100
      DATA (PARMS(L,14),L=1,5)/'FLUO','RIDE','    ','    ','    '/      00002200
      DATA (PARMS(L,15),L=1,5)/'IRO ','N   ','    ','    ','    '/      00002300
      DATA (PARMS(L,16),L=1,5)/'LEAD','    ','    ','    ','    '/      00002400
      DATA (PARMS(L,17),L=1,5)/'MANG','ANES','E   ','    ','    '/      00002500
      DATA (PARMS(L,18),L=1,5)/'MERC','URY ','    ','    ','    '/      00002600
      DATA (PARMS(L,19),L=1,5)/'NICK','EL  ','    ','    ','    '/      00002700
      DATA (PARMS(L,20),L=1,5)/'NITR','OGEN','    ','    ','    '/      00002800
      DATA (PARMS(L,21),L=1,5)/'OIL-','GREA','SE  ','    ','    '/      00002900
      DATA (PARMS(L,22),L=1,5)/'PH-M','IN  ','    ','    ','    '/      00003000
      DATA (PARMS(L,23),L=1,5)/'PH-M','AX  ','    ','    ','    '/      00003100
      DATA (PARMS(L,24),L=1,5)/'PHEN','OL  ','    ','    ','    '/      00003200
      DATA (PARMS(L,25),L=1,5)/'PHOS','PHOR','US  ','    ','    '/      00003300
      DATA (PARMS(L,26),L=1,5)/'DISS','OLVE','D SO','LIDS','    '/      00003400
      DATA (PARMS(L,27),L=1,5)/'SUSP','ENDE','D SO','LIDS','    '/      00003500
      DATA (PARMS(L,28),L=1,5)/'TEMP','ERAT','URE ','DIFF','    '/      00003600
      DATA (PARMS(L,29),L=1,5)/'TIN ','    ','    ','    ','    '/      00003700
      DATA (PARMS(L,30),L=1,5)/'DO  ','    ','    ','    ','    '/      00003800
C                                                                       00003900
C OUTPUT ONE TABLE FOR EACH SOURCE                                      00004000
      DO 40 I=1,NUSORS                                                  00004100
      READ(12)DUMMY                                                     00004200
      WRITE(6,5)IW(1)                                                   00004300
    5 FORMAT('1',T60,11('*'),/' ',T61,'SOURCE',I3,/' ',T60,11('*'))     00004400
C HEADING FOR EACH PIPE                                                 00004500
      DO 37 J=1,NPTSW                                                   00004600
      WRITE(6,10) J,WEND(1,J),UPFLW
   10 FORMAT('0',T11,'PIPE=',I2,10X,'MEAN DISCHARGE (ML/DAY)=',F12.4,11X
     *,'UPSTREAM FLOW (ML/DAY)=',F12.4)                                 00004900
```

```
          IF(DO.GT.0)WRITE(6,15)DO                                      00005000
       15 FORMAT(' ',T13,'MEAN DO CONCENTRATION (MG/L)=',F12.4)         00005100
          WRITE(6,20)                                                   00005200
       20 FORMAT('0',T89,'EXPECTED   PROB. OF NO'/' ',T16,'CONSTITUENT',T38,00005300
         *'STANDARD',T52,'DIST',T60,'EST. MEAN',T75,'EST. SIGMA',T90,'DAMAGE00005400
         *',T101,'VIOLATION'/' ',T11,20('-'),T36,13('-'),T52,4('-'),T59,12('00005500
         *-'),T74,12('-'),T89,8('-'),T100,11('-'))                      00005600
          NP=IWEN(2,J)                                                  00005700
    C DATA FOR EACH PARAMETER                                           00005800
          DO 30 K=1,NP                                                  00005900
          IP=IWENDT(1,J,K)                                              00006000
    C DON'T OUTPUT DO AS REGULAR VARIABLE                               00006100
          IF(IP.EQ.30) GO TO 30                                         00006200
          ID=IWENDT(3,J,K)+1                                            00006300
          WRITE(6,25)(PARMS(L,IP),L=1,5),WENDTA(2,J,K),DIST(ID),WENDTA(4,J,K00006400
         *),WENDTA(5,J,K),WENDTA(6,J,K),WENDTA(7,J,K)                   00006500
       25 FORMAT(' ',T11,5A4,T36,F13.4,T52,A4,T59,F12.4,T74,F12.4,T89,F8.4, 00006600
         *T100,F11.4)                                                   00006700
       30 CONTINUE                                                      00006800
          WRITE(6,36)                                                   00006900
       36 FORMAT('0',/'0')                                              00007000
       37 CONTINUE                                                      00007100
          WRITE(6,35)WSRC(2),WSRC(3)                                    00007200
       35 FORMAT('0',T11,50('*'),/' ',T12,'SOURCE EXPECTED DAMAGE',T46,F12.400007300
         *,/' ',T12,'SOURCE PROBABILITY OF NO VIOLATION',T46,F12.4,/' ',T11,00007400
         *50('*'))                                                      00007500
       40 CONTINUE                                                      00007600
          RETURN                                                        00007700
          END                                                           00007800
```

```
      P1      PROC                                                          00000100
             COMMON/OUT  /WSRC(3),UPFLW,DO,NPTSW,WEND(2,4),WENDTA(7,4,10)   00000200
             DIMENSION DUMMY(294),IW(3),IWEN(2,4),IWENDT(7,4,10)            00000300
             EQUIVALENCE (IW,WSRC),(IWEN,WEND),(IWENDT,WENDTA),(WSRC,DUMMY) 00000400
       END                                                                  00000500
```

```
      SUBROUTINE PARAMS(SSIZE,SMEAN,SMAX,DIST,EMEAN,ESIGMA,SMIN,IPRM,I,
     *                   IONESD)
C
C PARAMS CALCULATES ESTIMATES OF MEAN (EMEAN) AND S.D. (ESIGMA)
C      FOR
C          1)NON-PH CONSTITUENT, GIVEN SAMPLE SIZE, MEAN,AND MAX,AND
C            UNDERLYING DISTRIBUTION WHERE 3.LT.SAMPLE SIZE.LT.366,
C            AND 1.25.LE.MAX/MEAN.LE.6.00 FOR LOGNORMAL CASE
C
C          2)PH/POH, GIVEN SAMPLE SIZE, MEAN, AND MAX OR MIN,AND
C            DISTRIBUTION (ALWAYS NORMAL) WHERE 3.LT.SAMPLE SIZE.LT.366
C
C          3)PH/POH, GIVEN SAMPLE SIZE, MAX, AND MIN, AND NORMAL DISTRIBU
C            AND SAMPLE SIZE.LT.40
C
      DIMENSION CN(40)
      DATA (CN(J),J=1,40)/1.,1.128,1.693,2.059,2.326,2.534,2.704,2.847,
     *   2.970,3.078,3.173,3.258,3.336,3.407,3.472,3.532,3.588,
     *   3.640,3.689,3.735,3.778,3.819,3.858,3.895,3.930,3.964,
     *   3.997,4.027,4.057,4.086,4.113,4.139,4.165,4.189,
     *   4.213,4.236,4.259,4.280,4.301,4.322/
      INTEGER DIST, SSIZE
C DATA CHECKS
      IF(SSIZE.GT.365) GO TO 350
      IF(IONESD.EQ.1.AND.(IPRM.EQ.22.OR.IPRM.EQ.23)) GO TO 325
      IF(DIST.EQ.1) GO TO 100
C
C ESTIMATING FOR NORMAL CASE
      C=(ALOG(SSIZE/1.52517)/2.91546)+1.
      ESIGMA=(SMAX-SMEAN)/C
      EMEAN=SMEAN
      RETURN
C
C ESTIMATING FOR LOGNORMAL CASE
  100 RATIO=SMAX/SMEAN
      IF(RATIO.LT.1.25.OR.RATIO.GT.6.00) GO TO 365
      IF(RATIO.GT.2.3) GO TO 200
      ALPHA=1.02
      BETA=ALOG(SSIZE/.18609)/1.21750
      IF(SSIZE.GE.11) GO TO 300
      ALPHA=1.01580+(SSIZE-4.)*(.00249-(SSIZE-6.)*(.00044-(SSIZE-8.)*
     1(.000047)))
      BETA=ALOG(SSIZE/.05610)/1.58888
      GO TO 300
  200 ALPHA=(ALOG(SSIZE/5164.81421)/-24.50367)+1.
      BETA=ALOG(SSIZE/.70636)/1.13932
      IF(SSIZE.LT.30) ALPHA=.96614+(SSIZE-5.)*(.030748 -(SSIZE-10.)*
     1(.001795 -(SSIZE-15.)*(.000065 -(SSIZE-20.)*(.02453/15000+(SSIZE-
     125.)*(.0000000284)))))
```

```
      IF(SSIZE.LT.25)  BETA=2.96342-(SSIZE-5.)*(.02111-(SSIZE-10.)*(     00005000
     1.003224-(SSIZE-15.)*(.00013-(SSIZE-20.)*(.05628/15000))))          00005100
  300 ESIGMA=ALOG(RATIO/ALPHA)/BETA                                      00005200
      EMEAN=ALOG10(SMEAN)-ALOG(10)*ESIGMA**2./2.                         00005300
      RETURN                                                             00005400
C                                                                        00005500
C ESTIMATING FOR PH WITH MAX AND MIN                                     00005600
  325 IF(SSIZE.GT.40) GO TO 375                                          00005700
      EMEAN=(SMIN+SMAX)/2.                                               00005800
      ESIGMA=(SMAX-SMIN)/CN(SSIZE)                                       00005900
      SMIN=-1000.                                                        00006000
      RETURN                                                             00006100
C                                                                        00006200
  350 WRITE(6,351) I,IPRM                                                00006300
  351 FORMAT ('0','***SAMPLE SIZE FOR SOURCE',I3,' CONSTITUENT',I3,' IS'00006400
     *        ' GREATER THAN 365 AND ACCURATE ESTIMATES OF MEAN AND STA'00006500
     *        'NDARD DEVIATION',/' ','ARE NOT POSSIBLE')                 00006600
      STOP                                                               00006700
  365 WRITE(6,366) RATIO,I,IPRM                                          00006800
  366 FORMAT('0','***RATIO OF MAX TO MEAN IS',E12.5,' FOR SOURCE',I3,    00006900
     *       'CONSTITUENT',I3,/' ','MUST BE BETWEEN 1.25 AND 6.00 FOR'   00007000
     *       'ESTIMATION OF MEAN AND STANDARD DEVIATION')                00007100
      STOP                                                               00007200
  375 WRITE(6,376) I                                                     00007300
  376 FORMAT('0','***SAMPLE SIZE IS GREATER THAN 40 FOR SOURCE',I3,      00007400
     *       'CONSTITUENT PH AND ESTIMATES OF MEAN AND STANDARD DEVIATI'00007500
     *       'ON CANNOT BE MADE')                                        00007600
      STOP                                                               00007700
      END                                                                00007800
```

```
      SUBROUTINE PHDMGO(DJB)
C
C SUBROUTINE DAMAGE-ZERO DETERMINES DAMAGE FOR LEVEL 0 OF PARAMETER M
C
      DIMENSION DJB(2)
      COMMON/DMG2/DMG(2,11)
      COMMON/BRKPTS/S(6),SSPH(11)
      COMMON/BIJ/A1,B1,B2
      DO 70 M=1,2
      IF(M.EQ.1 ) B=A1*.0000001+B1
      IF(M.EQ.2 ) B=A1*.0000001+B2
      IF(B.GE.DMG(M,1)) GO TO 45
      DJB(M)=0.
      GO TO 70
   45 DO 50 KD=1,10
      IF(DMG(M,KD).LE.B.AND.B.LT.DMG(M,KD+1)) GO TO 60
   50 CONTINUE
      DJB(M)=SSPH(11)
      GO TO 70
   60 DJB(M)=(SSPH(KD+1)-SSPH(KD))*(B-DMG(M,KD))/(DMG(M,KD+1)-DMG(M,KD))
     *+SSPH(KD)
      KD1=KD+1
   70 CONTINUE
      RETURN
      END
```

```
      FUNCTION PHEXD(TMU,TSIG,TQS,QU)
C
C PHEXD CALCULATES EXPECTED DAMAGE FOR CONSTITUENT PH (AND POH)
C
      DIMENSION TMU(2),TSIG(2),DJB(2)
      REAL IL
      COMMON/DMG2/DAMAGE(2,11)
      COMMON/BIJ/A,B(2)
      COMMON/BPKPTS/S(6),SSPH(11)
      COMMON/PCOPT/ICOPT
      IC=2*ICOPT-1
      COPT1=DAMAGE(1,IC)
      COPT2=DAMAGE(2,IC)
      TMU(2)=14.-TMU(1)
      PHEXD=0.
      A=TQS/(TQS+QU)
      B(1)=COPT1*QU/(TQS+QU)
      B(2)=COPT2*QU/(TQS+QU)
   20 IF(TMU(1).GT.7.) GO TO 24
C
C CASE WHERE MU-H LESS THAN/EQUAL TO 7.
      I=1
      J=2
      GO TO 25
C
C CASE WHERE MU-H GREATER THAN 7.
   24 I=2
      J=1
C CALCULATE DOH OR DH (WHICHEVER HAS SIMPLER TERMS) FIRST
C IFLAG INDICATING TMU=7. OR NOT
   25 IFLAG=0
      PSI=ININFA(7.,TMU(J),TSIG(J))
      CALL PHDMG0(DJB)
      PHEXD=PHEXD-PSI*DJB(J)-(1.-PSI)*DJB(I)
   26 DO 30 KD=1,10
      CALL ASEF(DAMAGE(J,KD),DAMAGE(J,KD+1),A,B(J),KD,ALPHA,BETA,E,F,L)
      IF(L.EQ.2) GO TO 30
      PHEXD=PHEXD+IL(E,F,ALPHA,BETA,-TMU(J),TSIG(J))
   30 CONTINUE
C ALPHA(11)=BETA(10)
      PHEXD=PHEXD+RILBT1(BETA,-TMU(J),TSIG(J))
      IF(IFLAG.EQ.1) RETURN
C CALCULATE OTHER D
C
      T=10.**(-TMU(I))
      LI=0
      IF(T.GE.(DAMAGE(I,1)-B(I))/A) GO TO 39
      J=I
      IFLAG=1
      GO TO 26
```

```
      39 DO 40 KD=1,10                                                   00005100
         CALL ABEF(DAMAGE(I,KD),DAMAGE(I,KD+1),A,B(I),KD,ALPHA,BETA,E,F,L) 00005200
         IF(L.EQ.2) GO TO 40                                             00005300
         IF (ALPHA.LE.T.AND.T.LT.BETA) GO TO 50                          00005400
         PHEXD=PHEXD+IL(E,F,ALPHA,BETA,-TMU(I),TSIG(J))                  00005500
      40 CONTINUE                                                        00005600
C ALPHA(11)=BETA(10)                                                     00005700
C LI=11                                                                  00005800
         PHEXD=PHEXD+IL(0.,SSPH(11),BETA,T,-TMU(I),TSIG(J))+RILBT1(T,-TMU(I00005900
        *),TSIG(I))                                                      00006000
         RETURN                                                          00006100
C                                                                        00006200
C LI=1 TO 9                                                              00006300
      50 PHEXD=PHEXD+IL(E,F,ALPHA,T,-TMU(I),TSIG(J))+IL(E,F,T,BETA,-TMU(I),00006400
        *TSIG(I))                                                        00006500
         LI=KD+1                                                         00006600
         IF(LI.EQ.11) GO TO 60                                           00006700
         DO 55 KD=LI,10                                                  00006800
         CALL ABEF(DAMAGE(I,KD),DAMAGE(I,KD+1),A,B(I),KD,ALPHA,BETA,E,F,L) 00006900
         IF(L.EQ.2) GO TO 55                                             00007000
         PHEXD=PHEXD+IL(E,F,ALPHA,BETA,-TMU(I),TSIG(I))                  00007100
      55 CONTINUE                                                        00007200
C ALPHA(11)=BETA(10)                                                     00007300
      60 PHEXD=PHEXD+RILBT1(BETA,-TMU(I),TSIG(I))                        00007400
         RETURN                                                          00007500
         END                                                             00007600
```

```
      SUBROUTINE PNVCOM(NOPIPS,NPPARS,NOPARS,IPARM,INDPAR,DISTYP,EFST,
     *  QU,PNV,ICUP)
C
C PNVCOM CALCULATES PROBABILITY OF NO VIOLATION FOR A SOURCE, AND COMBIN
C    PARAMETERS (MU,SIGMA,...) WHERE THE SAME CONSTITUENT OCCURS IN MORE
C    ONE PIPE OF A SOURCE
       INTEGER DISTYP(4,10),DIST
      REAL MU,IN,ININFA,ILINFA
      DIMENSION NPPARS(4),IPARM(4,10),INDPAR(10),EFST(4,10)
      DIMENSION X(2)
      DIMENSION SS(2)
      DATA SS/-1.,1./
      COMMON/BODDMG/TQS,TQU,CS,IBOD
      COMMON/ISTPNV/MU(4,10),SIGMA(4,10)
      COMMON/PNVEXP/DIST(10),TMU(10),TSIG(10)
      COMMON/UPDATE/I,QS(4,30)
      INCLUDE P1,LIST
C
C FIND ALL PIPE LOCATIONS OF SAME PARAMETER FOR SOURCE I
C AND COMBINE DATA
C
      DO=0.
      CS=0.
      TQU=QU
      TQS=0.
      DO 10 J=1,NOPIPS
   10 TQS=TQS+QS(J,I)
      PNV=1.
      DO 80 M=1,NOPARS
      SUMM=0.
      SUMV=0.
      TMU(M)=0.
      TSIG(M)=0.
      NSAME=0
      DO 60 J=1,NOPIPS
      NP=NPPARS(J)
      DO 60 K=1,NP
      IF(IPARM(J,K).NE.INDPAR(M)) GO TO 60
      NSAME=NSAME+1
C FOR MULTIPLE OCCURRENCES OF THE SAME PARAMETER, THE FIRST DISTRIBUTION
C SPECIFICATION IS USED
      IF(NSAME.EQ.1) DIST(M)=DISTYP(J,K)
      IF(INDPAR(M).EQ.22.OR.INDPAR(M).EQ.23) GO TO 53
      IF(DIST(M).EQ.1) GO TO 50
C
C--NORMAL CASE,COMBINING
      TMU(M)=TMU(M)+MU(J,K)
      TSIG(M)=TSIG(M)+SIGMA(J,K)*SIGMA(J,K)
      TEMPNV=ININFA(EFST(J,K),MU(J,K),SIGMA(J,K))
```

```
          GO TO 52
    C
    C--LOGNORMAL CASE,COMBINING
    C USING LN(10)=2.3025851,.5*LN(10)=1.1512925
    C
       50 TEMPM=10.**(MU(J,K)+1.1512925*SIGMA(J,K)*SIGMA(J,K))
          SUMM=SUMM+TEMPM
    C ***TEMPV NEEDS TEST TO CHECK FOR LARGE SIGMA TO PREVENT PROGRAM BLOWUP
          IF(SIGMA(J,K).GT.4.) SIGMA(J,K)=4.0
          TEMPV=TEMPM*TEMPM*(10.**(2.3025851*SIGMA(J,K)*SIGMA(J,K))-1.)
          SUMV=SUMV+TEMPV
       51 TEMPNV=ILINFA(EFST(J,K),MU(J,K),SIGMA(J,K))
    C SET VARIABLE FOR OUTPUT OPTION
       52 WENDTA(7,J,K)=TEMPNV
          IF(INDPAR(M).EQ.22) WENDTA(7,J,K-1)=1000000.
          IF(INDPAR(M).EQ.30) GO TO 60
          IF(ICOR.EQ.1) GO TO 60
          PNV=PNV*TEMPNV
          GO TO 60
    C
    C
    C PH/POH
       53 TEMPM=10.**(-MU(J,K)+1.1512925*SIGMA(J,K)*SIGMA(J,K))
          SUMM=SUMM+TEMPM
          TEMPV=TEMPM*TEMPM*(10.**(2.3025851*SIGMA(J,K)*SIGMA(J,K))-1.)
          SUMV=SUMV+TEMPV
          IF (INDPAR(M).EQ.23) GO TO 55
          TEMPNV=1.
          DO 100 KK=1,2
          KPR=K+1-KK
          KKP=KPR+SS(KK)
          X(KK)=SS(KK)*(MU(J,KPR)-EFST(J,KPR))
          IF (X(KK).LE.0.) GO TO 102
          PV=.5+IN(0.,1.,0.,X(KK),0.,SIGMA(J,KKP))
          GO TO 101
      102 PV=ININFA(X(KK),0.,SIGMA(J,KPR))
      101 TEMPNV=TEMPNV-PV
      100 CONTINUE
          GO TO 52
       55 CONTINUE
       60 CONTINUE
          IF(INDPAR(M).EQ.22.OR.INDPAR(M).EQ.23) GO TO 69
          IF(DIST(M).EQ.1) GO TO 65
          TSIG(M)=SQRT(TSIG(M))
          GO TO 70
    C USING 1./LN(10)=.4342944
    C
    C LOGNORMAL CASE
    C
```

```
 65 TSIG(M)=.4342944*ALOG10(SUMV/(SUMM*SUMM)+1.)
    TMU(M)=ALOG10(SUMM)-1.1512925*TSIG(M)
    TSIG(M)=SQRT(TSIG(M))
    GO TO 70
 69 TSIG(M)=.4342944*ALOG10(SUMV/(SUMM*SUMM)+1.)
    TMU(M)=1.1512925*TSIG(M)-ALOG10(SUMM)
    TSIG(M)=SQRT(TSIG(M))
 70 IF(INDPAR(M).NE.30) GO TO 80
    CS=TMU(M)
    DO=CS
 80 CONTINUE
    IF(ICOR.NE.1) GO TO 90
    DO 85 J=1,NOPIPS
    NP=NPPARS(J)
    TEMPNV=1
    DO 85 K=1,NP
    IF(WENDTA(7,J,K).LT.TEMPNV) TEMPNV=WENDTA(7,J,K)
 85 CONTINUE
    PNV=PNV*TEMPNV
 86 CONTINUE
 90 IF(PNV.LT..0000000001) PNV=.0000000001
    RETURN
    END
```

```
      SUBROUTINE PRIORT(IPARM,NPPARS)
C
C PRIORT DETERMINES PRIORITY MONITORING ALLOCATION AND PRINTS TABLES
C
      PARAMETER MRS=900,TRS=900
      DIMENSION RESRCE(30), XMR(MRS),ISORC(MRS),RESCST(MRS),
     * REQRES(TRS),COST(TRS),NUM(MRS),IPARM(4,10,30),NPPARS(4,30)
      DIMENSION TMR(TRS),ISORCT(TRS)
      COMMON/PRI/NOPIPS(30),NOPARS(30),INDPAR(10,30),ISFUP(30),
     *   ISFLOW(30),EXPD(30),PNV(30),IOUT1,IOUT2A,IOUT2B,IOUT3,
     *   NAM(30,13),B,D,NUSORS,ISLIST(30),PIPCST(4),CONCST(30)
C
      DO 55 I=1,NUSORS
      I1=ISLIST(I)
C
C DETERMINE RESOURCE NEED TO MONITOR SOURCE I
      NP=NOPIPS(I1)
      RESRCE(I)=PIPCST(NP)
      DO 55 J=1,NP
      K1=NPPARS(J,I1)
      DO 55 K=1,K1
      IP=IPARM(J,K,I1)
      RESRCE(I)=RESRCE(I)+CONCST(IP)
   55 CONTINUE
C
C CALCULATE MARGINAL RETURNS FOR EACH SOURCE
      M=0
      DO 62 I=1,NUSORS
      ISFL=ISFLOW(I)+1
      K1=ISFUP(I)
      DO 60 K=ISFL,K1
      M=M+1
      XMR(M)=(EXPD(I)*(PNV(I)**(K-1))*(1.-PNV(I)))/RESRCE(I)
      ISORC(M)=I
   60 CONTINUE
   62 CONTINUE
C
C ARRANGE MARGINAL RETURNS IN DESCENDING ORDER
      CALL ORDER(XMR,ISORC,M)
C
C COMPUTE NECESSARY COSTS
C FOR DESIRED OUTPUT OPTIONS AND WRITE OUTPUT
C
C--OPTION 1--
      TOTRES=0.
      TOTCST=0.
      DO 80 I=1,NUSORS
      RESCST(I)=RESRCE(I)*ISFLOW(I)
      TOTRES=TOTRES+RESCST(I)
```

```
      80 TOTCST=TOTCST+EXPD(I)*(PNV(I)**ISFLOW(I))
         IF(IOUT1.NE.1) GO TO 91
         WRITE(6,82)
      82 FORMAT('1',T60,'INITIAL ALLOCATION '/'0',T43,'SOURCE',T62,'TIMES S
     *AMPLED',T81,'RESOURCES USED'/' ',T43,52('-')/'0')
         DO 87 I=1,NUSORS
         I1=ISLIST(I)
      87 WRITE(6,85) I1,ISFLOW(I),RESCST(I)
      85 FORMAT(' ',(T46,I2,T67,I2,T84,F8.2))
         WRITE (6,90) TOTRES,TOTCST
      90 FORMAT('0',T43,52('-'),/'0',T50,'TOTAL RESOURCES USED',F10.2,/' ',
     *T50,'COST OF UNDETECTED VIOLATIONS',F12.5)
C
C--OPTION 2A--
      91 IF(IOUT2A.NE.1) GO TO 104
         WRITE(6,105)
         M1=0
         TOTC=0
         DO 93 I=1,NUSORS
         TOTC=TOTC+EXPD(I)
         IF(ISFLOW(I).EQ.0) GO TO 93
         IS=ISFLOW(I)
         DO 92 K=1,IS
         M1=M1+1
         TMR(M1)=(EXPD(I)*(PNV(I)**(K-1))*(1.-PNV(I)))/RESRCE(I)
         ISORCT(M1)=I
      92 CONTINUE
      93 CONTINUE
         IF(M.EQ.0) GO TO 1000
         DO 94 I=1,M
         TMR(M1+I)=XMR(I)
         ISORCT(M1+I)=ISORC(I)
      94 CONTINUE
    1000 CONTINUE
         M2=M1+M
         CALL ORDER(TMR,ISORCT,M2)
         IS=ISORCT(1)
         REQRES(1)=RESRCE(IS)
         COST(1)=TOTC-(TMR(1)*RESRCE(IS))
         I1=ISLIST(IS)
         TEMPMR=TMR(1)*100.
         WRITE(6,108) I1,TEMPMR,COST(1),REQRES(1)
     108 FORMAT(' ',T45,'1',T55,I3,T60,F13.8,1X,F12.5,2X,F10.2)
         IF(M2.EQ.1) GO TO 1001
         DO 95 I=2,M2
         IS=ISORCT(I)
         COST(I)=COST(I-1)-(TMR(I)*RESRCE(IS))
         REQRES(I)=REQRES(I-1)+RESRCE(IS)
         I1=ISLIST(IS)
```

```
      TEMPMR=TMR(I)*100.
   95 WRITE(6,115) I,I1,TEMPMR,COST(I),REQRES(I)
 1001 CONTINUE
      WRITE(6,118 )
C
C--OPTION 2B--
  104 IS=ISORC(1)
      REQRES(1)=TOTRES+RESRCE(IS)
      COST(1)=TOTCST-(XMR(1)*RESRCE(IS))
      IF(M.EQ.1) GO TO 1002
      DO 110 I=2,M
      IS=ISORC(I)
      COST(I)=COST(I-1)-(XMR(I)*RESRCE(IS))
  110 REQRES(I)=REQRES(I-1)+RESRCE(IS)
 1002 CONTINUE
      IF(IOUT2B.NE.1) GO TO 120
      WRITE (6,105)
  105 FORMAT('1',T56,'PRIORITY LIST OF SAMPLES'/'0',T78,'COST OF'/' ',
     *T54,'SOURCE',T65,'MARGINAL    UNDETECTED  RESOURCES'/' ',T40,'PRIO
     *RITY',T54,'SAMPLED',T64,'RETURN X100  VIOLATIONS   REQUIRED'/' ',
     *T40,58('-')/'0')
      DO 112 I=1,M
      IS=ISORC(I)
      I1=ISLIST(IS)
      TEMPMR=XMR(I)*100.
  112 WRITE(6,115) I,I1,TEMPMR,COST(I),REQRES(I)
  115 FORMAT(' ',(T43,I3,T55,I3,T60,F13.8,1X,F12.5,2X,F10.2))
      WRITE(6,118)
  118 FORMAT('0',T40,58('-'))
C
C--OPTION 3--
  120 IF(IOUT3.NE.1) RETURN
      IF (B)170,170,125
  125 IOUTP=0
      WRITE(6,126) B
  126 FORMAT('1',T60,'FINAL ALLOCATION'/'0',T60,'BUDGET',1X,F9.2)
      DO 135 I=1,M
      IF(B-REQRES(I)) 130,135,135
  130 LIM=I-1
      GO TO 140
  135 CONTINUE
      WRITE(6,137)
  137 FORMAT('0',69('*'),/' ','BUDGET CONSTRAINT CANNOT BE REACHED WITH
     *CURRENT MAXIMUM SAMPLE SIZES IN EFFECT',/' ',69('*'),/'0')
      LIM=M
  140 DO 145 I=1,NUSORS
      NUM(I)=ISFLOW(I)
  145 CONTINUE
      DO 150 I=1,LIM
      IS=ISORC(I)
      NUM(IS)=NUM(IS)+1
```

```
  150 CONTINUE
      WRITE(6,154)
  154 FORMAT('0',T48,'MIN NO.   MAX NO. ',T89,'COST OF'/' ',T48,'SAMPLES
     *',T58,'SAMPLES',T68,'TIMES',4X,'RESOURCES  UNDETECTED',/' ',T40,
     *'SOURCE',T48,'REQUIRED',T58,'ALLOWED',T68,'SAMPLED',5X,'USED',4X,
     *'VIOLATIONS'/' ',T40,58('-')/'0')
      DO 160 I=1,NUSORS
      RRES=RESRCE(I)*NUM(I)
      CST=EXPD(I)*(PNV(I)**(NUM(I)))
      I1=ISLIST(I)
      WRITE(6,155) I1,ISFLOW(I),ISFUP(I),NUM(I),RRES,CST
  155 FORMAT(' ',T42,I2,T54,I2,T61,I2,T71,I2,T77,F9.2,T88,F10.5)
  160 CONTINUE
      WRITE(6,165) REQRES(LIM),COST(LIM)
  165 FORMAT('0',T40,58('-')/'0',T40,'TOTAL RESOURCES USED',F9.2,/' ',T40
     *0,'FINAL COST OF UNDETECTED VIOLATIONS',F10.5)
      IF(IOUTD.EQ.1) RETURN
      IOUTD=1
      IF(D)181,181,170
  170 WRITE (6,175)D
  175 FORMAT('1',T60,'FINAL ALLOCATION'/'0',T40,'MAXIMUM ALLOWED COST OF
     * UNDETECTED VIOLATIONS',1X,F9.5)
      DO 180 I=1,M
      IF(COST(I)-D) 176,176,180
  176 LIM=I
      GO TO 140
  180 CONTINUE
      WRITE(6,1800)
 1800 FORMAT('0',37('*'),/' ','UNDETECTED-VIOLATION-COST CONSTRAINT CANN
     *OT BE REACHED WITH CURRENT MAXIMUM SAMPLE SIZES IN EFFECT',/' ',
     *87('*'),/'0')
      LIM=M
      GO TO 140
  181 RETURN
      END
```

```
      FUNCTION XNORM(X)                                                 00000100
C                                                                       00000200
C XNORM CALCULATES THE STANDARD NORMAL DISTRIBUTION FUNCTION F(X)        00000300
C   FOR X.GT.4 OR X.LT.-4 AND REFERENCES FUNCTION RNORM TO FIND A VALUE 00000400
C DNORM CALCULATES 1-F(X) FOR X+ AND F(X) FOR X-                        00000700
C                                                                       00000800
C USING 1/SQRT(2*PI)=.3989422                                           00000900
      ASSIGN 20 TO OUT                                                  00001000
      IF(ABS(X).LE.4.) GO TO 30                                         00001100
      IF(X.GT.4.) GO TO 10                                              00001200
      X=-X                                                              00001300
      ENTRY DNORM(X)                                                    00001400
      ASSIGN 25 TO OUT                                                  00001500
   10 FX=.3989422*EXP(X*X/-2.)                                          00001600
      X2=1./(X*X)                                                       00001700
      X4=X2*X2                                                          00001800
      X6=X4*X2                                                          00001900
      X8=X4*X4                                                          00002000
      XNORM=(FX/X)*(1.-X2+3.*X4-15.*X6+105.*X8)                         00002100
      GO TO OUT                                                         00002200
   20 XNORM=1.-XNORM                                                    00002300
   25 RETURN                                                            00002400
   30 XNORM=RNORM(X)                                                    00002500
      RETURN                                                            00002600
      END                                                               00002700
```

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LIST OF SYMBOLS (for Section 4)

Symbol	Meaning
A	A constant (in 10)
C_i	Expected extent of undetected violations
c_i	Violation weighting factor per source
D	Expected extent of violation, per constituent
f	The standard normal probability density function
G	Scaling factor
h	Data discounting constant
i	Source number
j	Constituent number
k	Weighting factor function (WFF) constant
L	Lognormal distribution
L_i	Maximum number of examples required at source i
ℓ_i	Minimum number of examples required at source i
M	Constituent mass loading rate (or concentration)
m	Sample mean
N	Normal distribution
n	Sample size
P_i	Probability of non-violation per source
p_{ij}	Probability of non-violation per constituent
R	Total compliance monitoring cost

Symbol	Meaning
r_i	Compliance monitoring cost per source
S	Effleunt standard, for a constituent
$\underline{S}$	Lower effleunt standard for pH
$\bar{S}$	Upper effluent standard for pH
s_i	Sampling rate
W	Weighting factor
x	Normalized effluent standard
y	Any data value (general)
z	Compliance monitoring data point
α	Reliability weighting factor
Δ	An increment of
η	Confidence parameter for μ
θ	Receiving water concentration standard
μ_i	Marginal return
ν	Confidence parameter for σ
ξ	Sample maximum
$\prod$	Product of
ρ	Ratio of sample maximum to sample mean
$\sum$	Sum of
σ	Estimated standard deviation
Φ	The standard normal cumulative distribution function
ω	Sample minimum

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16. ABSTRACT

This report is designed as a handbook specifically oriented to environmental planners and managers. It presents the development and successful demonstration of hand and computerized procedures for the design of effluent compliance monitoring budgetary resources so as to minimize environmental damage. The original technical development of these procedures is given in a companion report, "Quantitative Methods for Effluent Compliance Monitoring Resources Allocation," EPA-600/5-75-015. Both the computerized and hand calculation procedures are demonstrated to function satisfactorily using data supplied by the State of Michigan.

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