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AREAWIDE ASSESSMENT PROCEDURES MANUAL

VOLUME II

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APPENDIX A

MODEL APPLICABILITY SUMMARY

A.1 Introduction

Computer-based mathematical tools form an important and integral part of the arsenal of tools at the disposal of the 208 planner. They are, however, nothing more than tools. Like the calculator or handbook or slide rule, the user must know how they work, what they do, and most importantly what they do not do. Any model is at best only an approximation of reality, and a clear understanding of both the real situation and the approximations made by the model developer is vital to effective model use.

For the first time through the 208 program large-scale integrated wastewater management plans are being developed. It will be difficult to adequately analyze the complex sets of alternatives without having a model available on which to "try-out" these alternatives.

This appendix, then, is a brief summary of some of the models and techniques most likely to be used by the 208 planner. The list is not exhaustive, however the selected models represent a set of tools that others have demonstrated to be of value. They are not new or "research" ideas.

Several factors are worth mentioning:

1. All of these models are in use and undergoing continual change and updating. The descriptions, therefore, may not be up to date.

2. Most of the models have one or more derivatives, which may or may not be of equal utility.

3. This appendix is basically an assemblage of previously published information, edited for inclusion here. Prospective model users should refer to model documentation for complete descriptions.

Two reports (1, 2) have been recently published by the U.S. Environmental Protection Agency which provide much more comprehensive model analyses. They are:

1. "Evaluation of Water Quality Models: A Management Guide for Planners," by Systems Control, Inc. (SCI).

2. "Assessment of Mathematical Models for Storm and Combined Sewer Management," by Battelle Northwest.

These reports are the best of their type available, and should be used as references throughout the 208 planning process. The SCI report contains an excellent chapter on contracting for modeling services which is applicable to any modeling activity. They are available from the U.S. Environmental Protection Agency, Office of Research and Development (RD-682), Washington, D.C. 20460 (Attn: Harry Torno), or from the EPA Water Planning Division.

A.2 Model Selection and Evaluation

The key criterion in the evaluation and selection of models is the problem under study. There are numerous cases on record where a model has been selected first, and then the rest of the study structured around the model. The reason for this is the failure on the part of study personnel to recognize that the model is simply a tool to assist in the conduct of the study. Initially, the following questions should be addressed in model selection:

1. What is the problem to be solved;

2. What temporal resolution is required? Depending on the type of water quality problem and receiving water, seasonal or even annual calculations may be enough;

3. Is a model needed, and if so, what approach (computer, nomogram, hand calculations, etc.) is necessary? In the early stages of, say, a 208 study, one is interested in a gross assessment of relative loads and impacts on water quality of various sources, and a simple model or analytical method may suffice;

4. What input, calibration and verification data are available? The model selected must be calibrated, and adequate input data must be collected. If data is not there, or if adequate funds for data collection are not provided, the use of a complicated model may be ruled out.

If, after preliminary analysis, it seems that a model is needed, several further factors should be considered:

1. Availability of qualified personnel to do water quality studies. Regardless of the method selected, someone skilled in water quality analysis should be available. Any model, simple or complicated, requires a considerable amount of expert judgement in its application, and without this expertise, model application is highly likely to be a failure.

2. Availability of models that have already been calibrated and applied locally. The major costs in applying any computer-based model are in becoming familiar with the model and how it works, in collecting basic data for model application (most of these data remain the same, regardless of how many times the model is used), and in setting the model up on the local computer system. The economics therefore warrant a considerable effort in locating available tools.

A.2.1 Model Selection

When the decision has been made to use models, a careful and systematic examination of the available tools is warranted. The SCI study previously referenced (1) provides an excellent methodology for model evaluation and selection, particularly for water quality models, and should be referred to by any potential model user. The following is a brief summary of questions to be considered in determining if the model is suitable for the problem under study:

1. What water quality constituents are to be modeled (if any) and can the model accomodate them? It may be enough at the outset simply to have a good feel what is going on hydraulically, without giving too much attention to pollutants;

2. Is the problem dynamic or steady-state? There seems little justification given the present state-of-the-art to do completely steady-state modeling of hydrologic phenomena. However, steady-state water quality models may be entirely satisfactory, particularly if design conditions for the plan are for steady-state flow (such as 7-day, 10-year low flow) and effluent loadings;

3. What are the spatial considerations? For streams, a one-dimensional model is adequate if homogeneous mixing across the river cross-section is an adequate assumption. For an estuary, on the other hand, a two- or even three-dimensional model may be required;

4. Has a model under consideration been used and tested, and is good, user-oriented documentation available? This is probably the most critical element to be considered;

5. If a proprietary model is considered, how will continuity in planning be accomodated? The planning process is an on-going one, and models are most economical when used repeatedly;

6. What are the costs of model application? It is important to note here that computer costs are relatively insignificant, and that

the major costs of model use are personnel costs. In general, however, simpler models are cheaper to use than complex ones.

A.2.2 Model Evaluation

At the end of the selection process, the user should have a number of possible models which seem acceptable. A more systematic evaluation process should be undertaken at this point, along the lines of that described in the SCI report (1). While this report is directed primarily at water quality models, the same general methodology could be effectively applied to drainage models as well. The primary emphasis at this stage is in determining the relative resources required, and the data necessary for an effective modeling application. As a minimum, some formal comparative analysis should be conducted, even if only in simple tabular form. The analysis should be as objective as possible, using consistent evaluation criteria and weighting factors for all models.

If modeling work is to be conducted by a consultant, this same evaluation should be conducted, even though the consultant may have a "preferred" model that he normally uses.

A.3 Urban/Non-Urban Drainage Models

Drainage models form a key part of any areawide wastewater management assessment, whether they are simple hand calculations or the more complex computer-based models described here (see Table A-1). This group of models was arbitrarily selected based on the following criteria:

1. Generally available
2. Well documented
3. Tested and applied in several locations

Other models may meet the same criteria, and would be equally valid for the user, particularly if he were experienced in applying some other specific model.

TABLE A-1 URBAN/NON-URBAN DRAINAGE MODELS

MODEL ORIGIN	MODEL ACRONYM	Catchment Hydrology							Sewer Hydraulics								Wastewater Quality									Miscellaneous					
		Multiple Catchment Inflow	Dry-Weather Flow	Input of Several Hyetographs	Snowmelt	Runoff From Impervious Areas	Runoff From Pervious Areas	Water Balance Between Storms	Flow Routing In Sewers	Upstr and Downstr Flow Control	Surcharging and Pressure Flow	Diversions	Pumping Stations	Storage	Prints Stage	Prints Velocities	Dry-Weather Quality	Stormwater Quality	Quality Routing	Sedimentation and Scour	Quality Reactions	Wastewater Treatment	Quality Balance Between Storms	Receiving Water Flow Simulation	Receiving Water Quality Simulation	Continuous Simulation	Can Choose Time Interval	Design Computations	Real Time Control	Applied to Real Problems	Computer Program Available
Corps of Engineers	STORM				●	●	●	●				●		●				●			●		●			●				●	●
Env Protection Agency	SWMM	●	●	●		●	●		●	●	●	●	●	●			●	●	●	●	●	●		●	●		●	●		●	●
Hydrocomp	HSP	●	●	●	●	●	●	●	●	●		●		●	●	●	●	●	●		●		●	●	●	●	●		●	●	
Massachusetts Inst of Technology	MITCAT	●	●	●	●	●	●		●		●	●		●	●	●								●			●			●	
Dorsch Consult	HVM-QQS	●	●	●		●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●	●	●		●			●	
Metcalf & Eddy		●			●	●	●	●						●				●				●	●			●				●	●
Water Resources Engineers	AGRUN	●	●	●		●	●		★	★	★	★	★	★			★	★	★	★	★	★		★	★		●			●	
Ill. State Water Survey	ILLUDAS	●	●	●		●	●		●					●	●												●	●			●

★ AGRUN is an alternative "Runoff" block for use with SWMM, and these features are available in the SWMM

The shortcomings of the rational method or its derivatives are well documented, however it bears mentioning again that given the ease of application of some of the models herein described, particularly to the rainfall-runoff relationships, there appears to be no justification for using the rational method in any areawide management study, except as a part of a very preliminary screening analysis as described in Chapter 2. This is doubly true if storage or retention phenomena are to be examined.

All of the models described have demonstrated the ability to predict runoff quantity with sufficient accuracy, and with relatively little calibration required. This is not true of water quality. The models are very sensitive to pollutant accumulation and washoff functions, and most of the model calibration effort needs to be directed here. Runoff quantity can be roughly calibrated using streamflow data, or more detailed local flow measurements may be made. Runoff quality should be calibrated using current local information. One technique is to use a detailed model (SWMM) on one or more small subcatchments, then to extrapolate these results to the larger study area. It must be pointed out here that models frequently have "default" values for some or all of the calibration parameters. These are values which have been selected by the model developer as representative values. Default values may or may not, however, be appropriate for the local situation in which a model is used, and each calibration parameter should be carefully examined when a model is applied to determine if a default value is appropriate.

A.3.1 Drainage Models

A.3.1.1 STORM (Corps of Engineers)

The Storage, Treatment and Overflow Model (STORM) (3) of the Corps of Engineers Hydrologic Engineering Center is intended primarily for evaluating the stormwater storage and treatment capacity required to reduce untreated overflows below specified values. The model can simulate hourly stormwater runoff and quality for a single catchment for several years.

Five water quality constituents are computed for different land uses: suspended and settleable solids, biochemical oxygen demand, nitrogen, and phosphorus.

The model does not route flows and quality through a sewer network and does not have real-time and design capability. Its main purpose is the assessment of alternatives for treatment and storage of stormwater under varying land use conditions. Dry-weather flows and quality are not simulated; consequently the model is not applicable to combined sewerage systems (The Corps of Engineers is presently modifying STORM to include dry-weather flow). The STORM model includes the following features:

1. Rainfall, snowfall, air temperature, and evaporation at one weather station;

2. Evapotranspiration;

3. Snow accumulation and melt;

4. Stormwater quality for different land uses;

5. Suspended and settleable solids, biochemical oxygen demand, nitrogen, and phosphorus;

6. Stormwater runoff and quality from pervious and impervious areas of a single catchment;

7. Catchment moisture accounting during periods of no precipitation;

8. Capacity of storage facilities;

9. Hydraulic capacity of treatment facilities; and

10. Volume and quality of overflows.

The model does not include the following features:

1. Dry-weather flow and quality;

2. Consideration of nonuniform catchment and precipitation distribution;

3. Stormwater runoff and quality from more than one catchment;

4. Flow and quality routing in gutters, sewers and open channels;

5. Wastewater quality decay, reactions and interactions;

6. Wastewater quality improvement by treatment;

7. Real-time control;

8. Design; and

9. Costs.

Hourly stormwater runoff is defined as the product of a runoff coefficient and hourly rainfall excess. Only one precipitation record can be used. The runoff coefficient is the weighted average of empirical runoff coefficients for the pervious and impervious areas and represents the fraction of rainfall excess lost to infiltration. The rainfall excess is defined as the difference between hourly rainfall and losses to depression storage. The depression storage at the beginning of a rainstorm is defined as the available depression storage at the end of the previous rainstorm plus a linear recovery to account for evaporation during the period of no precipitation. A different evaporation rate can be specified for each month of the year. Snowmelt is computed by the degree-day method which requires mean daily air temperature as input data.

The runoff coefficients, available depression storage, and depression storage recovery factor have to be derived by calibration with observed data. Default values are given in the program but no instructions are provided for estimating adequate values for ungaged catchments. Dry-weather flow is not simulated.

The computations for the stormwater runoff quality are based on formulations first used in the EPA Stormwater Management Model, which simulated only suspended solids, biochemical oxygen demand, and coliform bacteria. The STORM model has been expanded to simulate suspended and settleable solids, biochemical oxygen demand (BOD), nitrogen (N), and phosphorus (P). Empirical equations considering land use, street sweeping practices, and days between rainstorms define the amount of each pollutant on the ground at the beginning of a rainstorm. An exponential function of the runoff rate determines the rate of each pollutant being washed off the catchment during each hour. The rates of runoff of BOD, N, and P are assumed to be dependent on the rate of runoff of suspended and settleable solids.

The runoff quality formulations depend on a large number of empirical coefficients which have been derived from very limited urban stormwater runoff and quality data. The coefficients are internal to the program and do not account for variations in land use and catchment characteristics. Application of the model in different areas may therefore require programming changes to modify the coefficients. Input data which may be difficult to obtain include daily rate of dust and dirt accumulation and the percent of each pollutant contained in the dust and dirt for different land uses (in addition to model documentation, user may refer to Chapter 3 and other EPA guidance (20) for guidance in determining accumulations). Default values are provided by the program. Dry-weather quality is not considered by the model.

Computations of treatment, storage and overflow proceed on an hourly basis by simple runoff volume and pollutant mass balance. If the hourly runoff exceeds the treatment capacity, the excess runoff is put into storage. If the storage capacity is also exceeded, the excess runoff becomes untreated overflow. If the runoff is less than the treatment capacity and water is in storage, then the excess treatment capacity is utilized to diminish the storage volume.

Plug flow is assumed for the routing of pollutants through storage. The water quality is not modified in storage. For treatment, only the hydraulic capacity of treatment facilities is considered. Stormwater quality improvement by treatment is not modeled.

The computer program, written in Fortran IV for the UNIVAC 1108 computer is available from the Hydrologic Engineerinng Center of the Corps of Engineers. The simulations require 1-hour time steps and a minimum of 24 hours of simulation. Several years of data can be simulated in a single run; the maximum duration depends only on computer running costs and the objective of the analysis.

Program output includes hourly precipitation for a single raingage and various summaries of the stormwater runoff and quality analysis for selected storm events. These include the duration and amount of rainfall, the time and amount of treatment, the amount of runoff, the utilization and age of storage, the amount of overflow to receiving waters, and averages for all selected events. Runoff amounts are defined in inches and pollutant quantity in pounds. In addition, tables and line printer plots are available indicating the utilization of storage (see Appendix H for additional cost information).

A.3.1.1.1 STORM Input Data

STORM requires the following input data:

1. Area of drainage basin;

2. Percent of total area in each of 5 land use groups;

3. Average per cent imperviousness of each land use group;

4. Runoff coefficients for pervious and impervious areas;

5. Feet of gutter per acre for each land use group.

6. Depression storage available on impervious areas;

7. Treatment rate;

8. Hourly rainfall;

9. Daily rate of dust and dirt accumulation per 100 feet of gutter for each land use group;

10. Pounds of pollutants per 100 pounds of dust and dirt;

11. Street sweeping frequency and efficiency.

A.3.1.1.2 Evaluation of STORM

The model is suitable for the continuous simulation of stormwater runoff and quality from a single urban catchment. A significant weakness of the model is its inability to simulate dry-weather flow and quality.

Limitations on accuracy of the runoff computations are imposed by the simplified rainfall-runoff formulation, particularly the assumptions of a constant infiltration loss rate during rainstorms, a constant evaporation rate between rainstorms, and immediate runoff of the hourly rainfall excess. The last approximation would reduce model accuracy as the catchment size increases and the time of concentration of the runoff becomes longer than one hour.

The stormwater quality relationships are based on empirical formulations which have been tested on very limited data and whose accuracy has not been sufficiently established. It is therefore not possible to estimate their accuracy for application to areas where no records of concurrent urban stormwater runoff and quality are available for calibration purposes.

The model appears to be useful, however, for analysis of rainfall records to determine critical runoff-producing events and for general planning purposes to estimate the relative magnitudes of required storage and treatment capacities to reduce stormwater overflows below desired levels. The model computes only the quality of the overflows to the receiving waters. Addition of the computation of the quality of the treatment plant effluents would be desirable to obtain the total pollutant load on the receiving water.

A.3.1.2 SWMM (EPA)

The U. S. Environmental Protection Agency's Stormwater Management Model (SWMM) (4, 5) is one of the most comprehensive mathematical models available for the simulation of storm and combined sewerage systems. It computes the combined storm and sanitary runoff from several catchments and routes the flows through a converging branch sewer network. Flow diversion structures can be modeled and storage can be simulated for both inline and overflow retention basins. An additional feature is a receiving water model which includes nonsteady formulations of hydrodynamics and mass transport for two-dimensional (vertically mixed) water bodies receiving sewerage system effluents. Both dry-weather and stormwater quality for suspended and settleable solids, biochemical and chemical oxygen demand, coliform bacteria, phosphorus, nitrogen, and oil and grease are computed for each modeled catchment and routed through the sewerage system. Mathematical formulations which simulate various combinations of overflow treatment processes for one treatment facility are included to evaluate the effectiveness of overflow treatment. The model does not include realtime control features. The model is limited to the simulation of single runoff events and inline treatment cannot be simulated. Cost functions are built into the program to compute the cost of overflow storage and treatment. The SWMM is organized into an executive block (MAIN) and four computational blocks (RUNOFF, TRANSPORT, STORAGE, RECEIVE) which may be used separately or in any combination to simulate the entire urban drainage area.

The Stormwater Management Model includes the following features:

1. Dry-weather flow and quality of several catchments from land use;

2. Several rainfall records;

3. Stormwater runoff and quality for pervious and impervious areas of catchments with several land uses;

4. Eight water quality constituents: suspended and settleable solids, biochemical and chemical oxygen demand, coliform bacteria, phosphorus, nitrogen, oil and grease;

5. Flow routing in gutters;

6. Routing of combined wastewater flow and quality in a converging branch network;

7. Twelve specified closed conduit cross sections, a trapezoidal section, and two arbitrary shapes;

8. Backwater, surcharging and pressure flow;

9. Two types of diversion structures;

10. Pumping stations;

11. One overflow and two inline storage facilities with four types of outlet facilities;

12. Sedimentation and scour of suspended solids;

13. First-order water quality decay of BOD;

14. Removal of coliform dependent on suspended solids removal;

15. One overflow treatment plant with arbitrary combinations of nine unit treatment processes;

16. Costs of storage and treatment;

17. Receiving water flow and quality; and

18. Sizing of circular pipes.

The model does not include the following features:

1. Evapotranspiration;

2. Snow accumluation and melt;

3. Catchment moisture accounting during periods of no precipitation;

4. Sewer flow and quality routing in loops and diverging branches;

5. Downstream flow control and flow reversal;

6. Water quality reactions and interactions in the sewers and in storage; and

7. Real-time control.

Dry-weather flow and quality of eight constituents can either be provided as average values or computed from land use characteristics such as total population, population density, land use, residential income and home valuation of each subcatchment. Adjustment factors can be read in for diurnal (hourly) variations in flow and quality. Weekday adjustment factors can be read in for all but coliform bacteria. Industrial or commercial process flows and quality can be input separately.

Rainfall intensities of several raingages can be provided as input data to compute storm runoff from several catchments. Only one raingage record can be assigned to a particular subcatchment.

Losses are subtracted separately from the rainfall falling on pervious and impervious areas. Runoff occurs only when all depression storage is filled. No other losses are computed for impervious areas. Evaporative losses are not computed.

For pervious areas, the potential infiltration is computed with Horton's equation and the actual infiltration depends on the available overland flow depth. This is a more accurate computation than basing the infiltration losses on the amount of rainfall. Horton's equation, on the other hand, computes the potential infiltration as a function of time only and does not account for the change in potential infiltration with changes in soil moisture. The equation is satisfactory as long as the available moisture is greater than the potential infiltration, but errors are introduced during low intensity and intermittent storms when the available moisture is less than the computed potential infiltration. As a consequence, the infiltration coefficients of the equation have to be adjusted for different storms (theoretically they should be based on catchment soil characteristics only, independent of the storm patterns). This makes it difficult to use one set of coefficients with confidence for prediction purposes.

Overland flow is computed separately for pervious and impervious areas using a kinematic wave formulation with Manning's equation. A similar formulation is used for the gutter flow routing. The model formulation assumes that overland flow length and catchment length are equal. This assumption is satisfactory for small catchments, such as individual lots and possibly city blocks, but errors are introduced if the difference between overland flow and catchment length increases (as occurs when several city blocks are lumped into a single subcatchment). The model assumes that infiltration occurs throughout the time required for the overland flow to run the entire length of the catchment. Actual infiltration, however, may occur only during the time it takes the overland flow to run the length of a single lot. As a consequence, the computed infiltration would be greater than the actual infiltration and the computed runoff hydrograph would be underestimated. Users of the model can compensate for this error by reducing the infiltration coefficients.

Infiltration from the ground into the sewers accounts for dry-weather infiltration, wet-weather infiltration, melting residual ice and snow infiltration, and groundwater infiltration. Average infiltration values for the entire modeled drainage basin have to be provided as input data. The entire catchment infiltration is then apportioned to individual sewers on the basis of the conduit perimeter and number of joints in each conduit. A degree-day method is used to compute the infiltration from snowmelt, but the accumulation of snow and surface runoff from snowmelt is not modeled. The effect of the infiltrating water on the quality of the sewage is considered negligible and not modeled.

Flow routing in the sewers is accomplished using the kinematic wave equation with Manning's equation. The basic formulation neglects downstream flow control, backwater, surcharging, pressure flow and flow reversal. Special formulations are incorporated in the model, however, to approximate backwater, surcharging and pressure flow. General downstream control and flow reversal are not modeled.

An optional transport block has recently been added. The primary differences may be summarized in three categories:

1. Conceptual representation of the transport system. WRE Transport Block uses a node-link idealization totally unlike the original SWMM Transport Block.

2. Basic flow equation. The WRE Transport Block includes the inertial terms of the Navier-Stokes equations in the solution, whereas original SWMM Transport Block is based on a kinematic wave assumption.

3. Special effects and flow control devices. The WRE Transport Block includes the effects of pipe surcharge, looped sewers, weirs, pumps and orifices plus some related features.

Backwater is modeled by formulating a special backwater element with an inline storage element of fixed length and simulating it with a storage routing technique. This requires input data on flow depth versus storage volume which is difficult to compute for special sewer shapes (such as horseshoe shapes, etc.) with a nonzero invert slope. Also, the assumption of a constant backwater length appears to make the formulation highly approximate. Since the program permits only two inline storage elements, backwater can be considered at only two locations in the entire sewerage system. Also definition of a backwater element reduces the number of actual storage facilities that can be modeled.

If surcharging occurs, the model assumes that all water in excess of full pipe flow capacity is stored in the next upstream manhole. The formulation neglects the storage volume of the manhole and the actual propagation of the surcharging farther upstream. The formulation consequently serves only to conserve volume and to warn the user that surcharging conditions exist, without adequately computing the phenomenon. Conduits can be sized by the program to advoid surcharging.

The flow routing scheme is formulated for 12 specified closed conduit cross sections and a trapezoidal section. In addition, two arbitrary conduit shapes can be specified by providing input data relating the dimensions of each shape to flow area, hydraulic radius, and discharge.

Two types of flow diversion structures can be modeled. The first type assumes that all inflow exceeding a maximum value is overflowed. No data are needed to describe the geometry of this type. The second type assumes that no overflow occurs until the inflow exceeds a specified value. In this case, the depth of flow is found from a linear relationship between flow and depth and the overflow computed from this depth with a weir discharge equation. A more accurate formulation would be possible based on the weir and orifice equations.

Pumping stations can also be modeled. The model assumes that the pumps begin to operate at a constant pumping rate when the volume in the wet well reaches a maximum value and continue to pump until the wet well is pumped dry.

The model can simulate the performance of one overflow and up to two inline storage facilities. The model computes depth and volume of storage as a function of the inflow and outflow. The outflow is computed based on the hydraulic performance of the following four options of outflow conditions: gravity with orifice centerline at zero storage tank depth; gravity with fixed weir; gravity with both weir and orifice; and fixed rate pumps. Either regularly or irregularly shaped reservoirs can be specified by different input data. If a reservoir overflows, program execution terminates.

Stormwater quality is computed as a nonlinear function of stormwater runoff rate (which includes an exponential decay with time to account for the higher rates of pollutants being washed off during the beginning of a storm). Coefficients in equations for each of the three modeled pollutants account for different land uses. The equations consider street sweeping practices and days between rainstorms in defining the amount of each pollutant on the ground at the beginning of a rainstorm. The formulations account also for the contribution of accumulated BOD in catch basins. Many of the coefficients in the formulations are internal to the program and have been derived from very limited data of measured stormwater runoff and quality. Programming changes may therefore be required to apply the model to different areas and land use characteristics.

Stormwater and dry-weather qualities are combined at inlet manholes and routed through the sewers according to the flow velocity of the sewage. Dispersion is not modeled directly, but by averaging qualities between successive time steps. The equations consider first-order decay of BOD and sedimentation and scour of suspended solids. Reactions and interactions between the pollutants during the routing are not considered.

Nine overflow treatment processes can be modeled and arranged by the user in any series or combination. The modeled unit processes are: bar racks, fine screens, sedimentation, dissolved air flotation, dissolved air flotation preceded by fine screens, microstrainers, high-rate filters, effluent screens, and chlorination. Mathematical formulations for each process relate hydraulic capacity to removal efficiency. The user does not have the option of varying the process efficiencies without changing coefficients internal to the program. For some processes, however, the amount of chemicals used is read in to account for their effect on treatment performance.

BOD removal and suspended solids removal are considered independently. Coliform removal, however, is defined as a function of suspended solids removal.

Cost functions are built into the model which compute the cost of overflow treatment. Separate functions are defined for each unit treatment process and for storage and pumping if part of the treatment facility. Annual capital costs, land costs, and operation and maintenance costs are related to hydraulic capacity by power functions. The shapes of the cost functions are defined internally by the program. Costs can be adjusted by reading in the Engineering News Record Index for regional adjustments and future expected changes.

The Stormwater Management Model includes also a receiving water flow and quality segment which is based on the original EPA dynamic estuary model. It gives the model the capability not only of modeling flow and quality in sewerage systems, but of assessing the impact of the sewerage system effluents on the receiving water quality.

The flow computations of the receiving water models are based on a simplified explicit finite difference solution of the one-dimensional flow fields represented by an irregular grid of links and nodes. The continuity equation is solved at the nodes (junctions of the links) and the momentum equation is solved along the links (channels between the nodes). The model is very costly to use since very short time steps are required for numerical stability. The formulation becomes unstable if the discarges in adjacent channels and storage volumes of adjacent nodes are not of the same order of magnitude.

The model includes the transport of several conservative and nonconservative water quality constituents, considering first-order decay. Transport is modeled by convection only and chemical and biological interactions between different water quality constituents are not considered.

The computer program, which is available from the U.S. Environmental Protection Agency, is written in FORTRAN IV for an IBM 360/370 computer and is also compatible with UNIVAC and CDC computers. There are five main programs which, depending on computer core storage capacity, can be either loaded together or in sequence depending on the user's needs.

Fairly complete documentation of the model is published by the EPA, including a summary report and user's manual. Unfortunately, no one of these reports presents a complete description of the theoretical bases and mathematical formulations of the model.

The equations for some modeled phenomena are described in the user's manual, and some are not described at all. The reader must compare the two reports to obtain a fair understanding of the capabilities and limitations of the complete model and the meaning of the input data. Also, the user's manual includes much disscussion of model verification and testing which adds to the report's bulkiness and makes it more difficult to find essential information for the preparation of input data.

Program output includes tables and line printer plots of rainfall intensities for each raingage, combined runoff and quality for each subcatchment, and routed discharges and water quality at selected points of the sewerage system. Summaries of treatment effectiveness and costs are also available. Water levels and flow velocities in the sewers are not computed.

A.3.1.2.1 SWMM Input Data

The input data requirements for SWMM are extensive, and include:

1. Rainfall data, antecedent dry days;
2. Subcatchment descriptions including area, overland flow width, slope, roughness coefficients, infiltration rates, percent imperviousness;
3. Land use, population data;
4. Street sweeping frequency and number of passes;
5. Soil erosion data;
6. Pollutant loading and generation factors;
7. Sewer layout, shapes, dimensions, slope, roughness;
8. Specifications of flow control devices;
9. Infiltration data;

10. Dry-weather flows;

11. Catch basin data;

12. Treatment and storage facility data;

13. Tidal variations, water surface elevations and areas, water depths and roughness coefficients for receiving waters; and

14. Receiving water boundary conditions.

A.3.1.2.2 Evaluation of SWMM

The EPA Stormwater Management Model is one of the most complete and widely used mathematical models available for the assessment and planning of storm and combined sewerage systems. Consideration of both wastewater flows and qualities is an important aspect of evaluating needed treatment facilities and the impact of sewage effluents on receiving waters. This is also one of the few models which include cost computations. Although the model does not consider costs in the sizing of sewers, the computation of the costs of overflow storage and treatment should be a valuable aid to the engineer.

Program limitations which may restrict the model's general applicability include the neglect of downstream hydraulic controls (with the exception of very rough approximations of backwater and surcharging conditions) and the absence of formulations for inline treatment and main treatment plants.

The model can be used only for the simulation of individual runoff events since it does not include provisions for either catchment moisture or water quality accounting between rainstorms.

The new version of the program includes an option to suppress the water quality computations and perform the flow simulations alone. This can save considerable computer time if water quality computations are not needed.

The model is very complex and a major effort is required to implement it. The poorly organized documentation makes it difficult for the user to implement the model resulting from misinterpretations of the theoretical bases of the model and the meaning of some input data.

The model has been tested extensively on urban hydrologic data. Numerical testing of the flow computations with data from catchments ranging in size between 5 and 2200 ha (13 and 5400 acres) showed satisfactory accuracy. The accuracy of water quality predictions can be expected to be only of the right order of magnitude. Considerable model improvement, particularly of the formulations relating water quality with land use, are needed before the water quality model can be used with confidence.

Improvements are needed in the output formats. The arrangement of the catchment runoff table makes it difficult to abstract the hydrograph of a particular subcatchment. Complete output of routed flow and quality can be obtained at only twenty selected locations. This is adequate for the evaluation of a few important locations, such as major outfalls. It is a serious limitation, however, for the evaluation of an entire sewerage system since repeated runs of the same data are required to obtain sufficient information on the adequacy, performance, and utilization of all modeled sewer system elements.

Model improvements are in progress at the University of Florida under an EPA contract to add snowmelt, to include more accurate flow and water quality routing schemes, to add new water quality parameters and unit treatment processes, and to simulate inline (main) treatment processes. A new and improved user's manual (5) has been prepared. The model is also being revised to add continuous simulation capability for planning purposes. The model is being used by many consulting firms, and is available for users on several commercial time-sharing computer systems.

A.3.1.3 HSP (Hydrocomp)

The Hydrocomp Simulation Program (6) is one of the most comprehensive mathematical models for the simulation of both rural and urban catchments.

The water flow computations are based on the Stanford Watershed Model which was the first comprehensive mathematical model of catchment hydrology. The Hydrocomp Simulation Program, however, is a considerable improvement over the original Stanford Watershed Model, both with respect to mathematical formulations and data handling capability. Recently, a separate program was developed for the simulation of water quality in river basins which can be interfaced with the hydrologic and flow routing program (see A.4.1.7).

The Hydrocomp Simulation Program is formulated for the continuous simulation of water flow and quality from several catchments and routing in converging branch sewer and open channel networks. Catchment moisture and water quality are accounted for during periods of no precipitation, so the model can be used for continuous simulation of several years. Special features are included for the simulation of impoundments and diversions, including the flow of water over spillways and through hydroelectric turbines. Real-time control and design and cost features are not included.

The Hydrocomp Simulation Program includes the following features:

1. Dry-weather flow and quality of several catchments;

2. Rainfall, snowfall, pan evaporation, air temperature, dew point, solar radiation, and wind velocity of several weather stations;

3. Evapotranspiration;

4. Snow accumulation and melt;

5. Stormwater runoff and quality from pervious and impervious areas of catchments with several land uses;

6. Catchment moisture and water quality accounting during periods of no precipitation;

7. Groundwater infiltration into sewers and open channels;

8. Seventeen water quality constituents with reactions and interactions in natural (receiving) water bodies;

9. Routing of combined wastewater flow and quality in a converging branch network;

10. Circular closed conduits and trapezoidal open channels with trapezoidal flood plains;

11. Upstream and downstream flow control and backwater;

12. Diversion hydrographs;

13. In-line storage reservoirs with rule curve operation; and

14. Water quality decay, reactions, and interactions in natural (receiving) water bodies.

The model does not include the following features:

1. Dry-weather flow and quality from land use;

2. Flow reversal, surcharging and pressure flow;

3. Sedimentation and scour;

4. Water quality decay, reactions and interactions in sewers;

5. Flow and quality routing in loops and diverging branches;

6. Noncircular closed conduits;

7. Sewer flow control and diversion structures;

8. Pumping stations;

9. Wastewater treatment;

10. Real-time control; and

11. Design and costs.

The Hydrocomp Simulation Program includes the most complete formulation of catchment hydrology of all the models listed. The model computes runoff from pervious and impervious areas separately and considers evapotranspiration, snowmelt, and soil moisture accounting.

Precipitation (rain or snow) data is input at constant time intervals for one or more raingages. Other meteorological data needed for the evapotranspiration and snowmelt computations are provided on a daily basis. Not more than one precipitation record can be assigned to a single subcatchment.

Snow accumulation and melt are computed by a method developed by the U.S. Corps of Engineers. The equations require data on precipitation, air temperature, dew point, solar radiation, and wind velocity. Programming defaults are used if some of these data are unavailable. Only precipitation and air temperature are essential.

Dry-weather flow and quality data are input at constant time intervals. Dry-weather quality can also be defined by a power function of dry-weather flow.

The potential infiltration rate is computed from an empirical function of soil moisture. The actual infiltration depends on the rainfall excess after subtracting interception losses rather than on the overland flow depth. The infiltrated moisture is divided into upper zone and lower zone storage. Upper zone storage includes depression storage. Part of the upper zone storage percolates into the lower zone storage and the rest is divided into overland flow and interflow, which become channel (or sewer) inflow. The lower zone storage is divided into a channel inflow contribution and into deep groundwater storage which does not contribute to surface runoff.

Interception, upper zone, lower zone, and groundwater storage are depleted by evaporation or evapotranspiration computed as functions of potential evapotranspiration and available moisture.

Overland flow is routed with a modified kinematic wave formulation using Manning's equation. Several empirical coefficients internal to the program relate surface detention storage to overland flow discharge.

Although the model's representation of infiltration, groundwater percolation and storage, overland flow, groundwater contribution to surface flow, and evaporation from all moisture sources is based on physical concepts, the mathematical formulations are based largely on empirical relationships. They require several empirical coefficients, some of which are defined as soil moisture capacities. The model appears sufficiently complex that its use for prediction purposes without initial calibration with measured data may not be very reliable. Simpler models with fewer empirical coefficients seem adequate to model infiltration and surface flow contributions in urban catchments.

Flow routing in sewers and open channels is also accomplished using the kinematic wave equation with Manning's equation. The solution considers the geometry of circular pipes and of trapezoidal open channels with trapezoidal flood plains. A diffusion term in the kinematic wave equations approximates downstream flow control and backwater conditions. Surcharging and pressure flow in sewers is not modeled but a warning is printed if it occurs. The time step for the routing computations is computed internally to maintain numerical stability.

Reservoirs and channels can be simulated in the channel network. Storage capacity has to be defined as a function of depth and reservoir discharge has to be defined by rule curves relating discharge with time. Diversions are modeled by requiring diversion hydrographs as input data.

The computation of stormwater quality is based on formulations first used by the EPA Stormwater Management Model and then expanded in the Corps of Engineers' STORM Model and Water Resources Engineers' Stormwater Management Model. The concentration of each pollutant washed off a catchment is computed as a nonlinear funtion of runoff. Special empirical functions are built in for water quality balance between runoff events to account for dirt and dust accumulation, natural decay, street cleaning practices, and different land uses. The pollutant accumultion betwen runoff events can vary with the calendar month. Different values can be specified for pervious and impervious areas. The equations and coefficients have not been sufficiently tested for reliable predictions without calibration with measured data.

Pure advection is used to route pollutants through the sewer and open channel network. Dispersion is approximated by a weighted average of concentration values at successive time steps. For receiving water bodies, chemical and biological reactions and interactions among the seventeen modeled water quality constituents are computed. Only one-dimensional flow and water quality routing is formulated. Vertical water quality interchange can be approximated among three horizontal layers in impoundments by providing empirical mixing coefficients. The model documentation does not indicate whether reactions are computed for sewage. The model does not include formulations for wastewater treatment, real-time control, or design and cost computations.

The Hydrocomp Simulation Program is a proprietary model developed by Hydrocomp International, Inc., of Palo Alto, California. Separate user's manuals are available for the flow and water quality computations of the model. These contain sufficient detail covering the mathematical bases of the modeled phenomena and the required input data. The user must contract with Hydrocomp for routine application of the program. The firm conducts periodic workshops to instruct potential users in hydrologic simulation methods and application of the Hydrocomp Simulation Program.

The computer program consists of four main programs and is compatible with IBM 360 and 370 computers with a minimum of 240K bytes of core memory. Information is not published which would allow estimates of computer execution times as a function of problem size.

Computer output includes precipitation; soil moisture status; water stages, velocities, discharges, and water quality concentrations for all channels and storage; and volume of storage. Data input and output can be in metric or British units.

A.3.1.3.1 HSP Input Data

Input requirements are extensive and include:

1. Precipitation data;

2. Potential evapotranspiration;

3. Temperature;

4. Streamflow; and

5. HSP calibration parameters (includes such things as infiltration, depression storage, soil moisture storage, snow parameters, channel characteristics, watershed segments and channel reaches) . Determination of these parameters requires considerable user skill and experience, since not all are measured directly.

HSP has extensive data handling capability, which simplifies the problem of assembling and managing the data required. This is a very attractive feature of this program.

A.3.1.3.2 Evaluation of HSP

The Hydrocomp Simulation Program can be applied for the continuous simulation of both water flow and quality in urban and rural watersheds and channel networks. It was originally developed for the hydrologic simulation of rural catchments, and recently water quality computations for natural rivers and impoundments were added. The Stanford Watershed Model, upon which it is based, is perhaps the most detailed and complete, as well as the most used, rainfall/runoff model.

Modifications for urban applications include the addition of separate run-off computations for pervious and impervious areas and flow and water quality routing in circular closed conduits. Other model additions, however, would make the model more generally applicable to urban sewerage systems: for instance, geometries of different closed conduit cross-sections, hydraulic equations for different flow control and diversion structures, formulations for surcharging and pressure flow, and simulation of treatment processes.

HSP has been tested and applied extensively in many non-urban watersheds in the United States and abroad. Comparisons between measured and computed runoff for selected storm events have produced generally good agreement, with some exceptions attributed to potentially unreliable measured data.

HSP is most suited for runoff modeling of urban and non-urban catchments where detailed continuous simulations are required. It is not suited for systems where treatment processes must be simulated or where pressure flow and surcharging are significant factors. Hydrocomp is developing several versions of the basic HSP program for EPA. One of these, the Agricultural Runoff Model (ARM) has been documented (21) and has received limited testing. It may be obtained from U.S. EPA, Environmental Research Laboratory, Athens, Georgia, 30601.

A.3.1.4 MITCAT (Massachusetts Institute of Technology)

The MIT Catchment Model, MITCAT (7), simulates the time-varying runoff of several catchments and a sewer and open channel network including loops and converging and diverging branches. The model is limited to the simulation of single runoff events. Water quality and real-time control features are not included. The MITCAT may be applied to urban or non-urban areas.

The original model was developed at MIT for the U.S. Office of Water Resources Research, but the model has been modified by Resource Analysis, Inc., for routine application.

The MIT urban watershed model includes the following features:

1. Dry-weather flow of several catchments;
2. Air temperature at one weather station;
3. Several rainfall records;
4. Special statisical analyses to compute design hyetographs (separate program);
5. Evapotranspiration;
6. Snow accumulation and melt;
7. Option to choose one of four different infiltration equations;
8. Stormwater runoff from pervious and impervious areas of several catchments;
9. Catchment moisture accouting during periods of no precipitation;
10. Flow routing in gutters;

11. Routing of combined wastewater flow in a converging network of loops and converging and diverging branches;

12. Various standard closed conduits and open channel cross-sections and arbitrary shapes;

13. Downstream flow control, backwater, surcharging and pressure flow;

14. Flow control and diversion structures;

15. Storage facilities;

16. Hydraulic capacities of treatment facilities; and

17. Least-cost sizes of sewers, overflow storage and treatment plants meeting constraints on surcharging and untreated effluent volume (separate program).

The model does not include the following features:

1. Dry-weather flow from land use characteristics;

2. Catchment moisture accounting during periods of no precipitation;

3. Flow reversal;

4. Water quality; and

5. Real-time control.

Dry-weather flow data for each inlet is input in the form of hydrograph values at constant time intervals. The model does not include provisions to compute dry-weather flow from land use.

Several rainfall intensity records can be provided as input data. Not more than one rainfall record can be used to compute runoff from a subcatchment. Special provisions are built into the model to move a rainstorm across a catchment by specifying its direction and velocity of movement. A separate model is available which computes design hyetographs of specified frequencies from measured rainfall data.

Initial losses to fill depression storage on pervious and impervious areas are subtracted before surface runoff begins. The Resource Analysis version has four options to compute infiltration on the pervious areas: Horton's equation, Holtan's equation, a U.S. Soil Conservation Service method, and a runoff coefficient method. Infiltration is subtracted from rainfall if the last two methods are used, but computed from overland flow depth if Horton's or Holtan's equation is used. A method based on filter theory can be used to estimate the infiltration parameters from measured rainfall and runoff. Snowmelt is computed by the Corps of Engineers degree-day method which requires mean daily air temperature as input data. The Penman equation is programmed to compute evaporation but generally not used for single runoff event simulation.

Flow routing is accomplished with the kinematic wave equation. The equations are solved by a finite difference scheme for overland flow, flow in gutters, and flow in open channels (for various standard cross-sections and arbitrarily shaped closed conduits). Downstream flow control and backwater can be considered if the stage-discharge relationship is known. Surcharging and pressure flow is computed separately for each pipe reach. Flow reversal is not modeled. Weir and orifice flow control and diversion structures can be modeled by their hydraulic equations.

The design model computes the sizes and costs of circular sewers, the volumes of overflow storage facilities, and the hydraulic capacities of treatment plants needed to reduce undesirable flooding and surcharging and to eliminate untreated overflows. Linear programming is used to determine the least-cost combination of these facilities for a selected design storm event. The optimization is based on needed hydraulic capacities alone and does not consider water quality. It requires catchment runoff hydrographs as input data and uses a simplified flow routing scheme.

MITCAT was developed under a series of projects for the U.S. Office of Water Resources Research. Each project covered a different aspect of the overall model development. The computer programs were written for an IBM 360/67 in FORTRAN IV. The design program utilizes the linear programming package of the 1971 IBM Mathematical Programming System Extended (MPSX). The model's core storage requirement is not documented. The potential user has to contract with Resource Analysis, Inc., of Cambridge, Massachusetts, for routine applications of the model.

Computer output of the model includes tables of rainfall intensities and overland, catchment and channel depth, velocity and discharge. Samples of program output are not included in the documentation for the design option but output for this option includes the volume and duration of flooding for each sewer and the required sizes and costs of sewer overflow storage facilities and treatment plants.

A.3.1.4.1 MITCAT Input Data

1. Rainfall data, including velocity and direction of movement;

2. Catchment data, including length, slope, roughness coefficient, infiltration coefficients, detention storage and land use parameters;

3. Stream data, including length, slope, cross-section shape, width/diameter, roughness coefficient, critical conditions;

4. Inflow data;

5. Soil erosion parameters;

6. Storage reservoir data; and

7. Evaporation data.

A.3.1.4.2 Evaluation of MITCAT

The MITCAT is a useful and efficient tool for the simulation of urban and non-urban catchments, including both sewer and natural stream networks where backwater, downstream flow control and surcharging are not important. It is particularly suited where single-event runoff quantity is to be examined. Testing of the model on catchments with drainage areas up to 120 km^2(46 mi^2) shows good agreement between computed and measured runoff. The model is being used extensively for practical engineering assessments. A major weakness is its lack of water quality calculations, though these are likely to be added at some future date.

A.3.1.5 HVM-QQS (Dorsch Consult)

HVM-QQS, the Quantity-Quality Simulation Program (8) is intended for single event or continuous simulation of the time-varying runoff and water quality in combined sewerage systems consisting of several catchments and a closed conduit and open channel network including loops and converging and diverging branches. Runoff from catchment areas is calculated by a unit hydrograph method, considering different land uses including residential, commercial, industrial, and mixed. The flow routing through the sewerage network is based on the dynamic wave equations. Statistical analyses are incorporated to provide monthly and annual flow and pollutant duration curves for any node in the network. Four conservative water quality constituents can be routed.

HVM-QQS includes the following features:

1. Continuous simulation or single event simulation;

2. Dry-weather flow and quality of several catchments;

3. Three rain records;

4. Stormwater runoff (including quality) from pervious and impervious areas of several catchments;

5. Routing of combined wastewater flow and quality in a network of loops and converging and diverging branches;

6. Various closed conduit and open channel cross sections, (with linearized partial filling curves);

7. Backwater, upstream and downstream flow and quality control, surcharging and pressure flow;

8. Weirs and diversion structures considering both upstream and downstream flow conditions;

9. Pumping stations;

10. Retention storage basins;

11. Wastewater quality improvement at treatment plants and overflow treatment facilities; and

12. Statistical analysis of results.

The model does not include the following features:

1. Snow accumulation and melt;

2. flow reversal;

3. Detailed flow and quality routing in gutters;

4. real-time control;

5. Sedimentation and scour in channels;

6. Wastewater quality decay, reactions and interactions in sewers and receiving waters; and

7. Design and costs.

The surface runoff from small catchment areas including the flow in street sewers and laterals is obtained by means of a unit hydrograph method which is modified, however, for water quality calculations. The combined consideration of surface runoff and flow in small sewers and the use of a systemized network, each segment of which can be composed of several sewer elements totaling a length of up to 500 m (547 yds), result in a reduction of network nodes. The assumption of linearity of the runoff process, being sufficiently valid for small catchment areas, is not employed for the flow routing through the system of trunk and interceptor sewers, the flow behaviour of which may be influenced by backwater effects and interaction of branching points, retention facilities and overflow structures. Thus, flow routing is based on the dynamic wave equations, which provides the necessary accuracy and still allows for continuous long-time simulation. The hydrographs and flow velocities obtained by the hydraulic calculations form the basis for the pollutant transport within the network. The model is generally applicable to any urban drainage basin and to any pollutant. Presently areas of up to 40,000 ha (100,000 acres) in size can be studied in one run.

Catchment runoff quality formulations currently include biochemical oxygen demand and settleable solids. Formulations are also planned for carbonaceous oxygen demand, suspended solids, coliform bacteria, chloride, and nutrients. The model does not include real-time control, design and cost computations.

HVM-QQS evaluates the quantitative and qualitative loading of up to two receiving waters arbitrarily connected within an urban area. In one run up to four conservative water quality parameters can be taken into consideration. Three different precipitation records of up to 20 years can enter the calculation, each of which again could be the weighted average of several raingages.

For single event simulation, program output includes both tables and plots of discharges and water quality (mass rates) for any nodal point of the sewerage system and receiving water network. Flow velocities are not printed. For continuous simulation principal output is tables of statistical analysis and graphs of frequency and duration curves.

The computer program consists of a data validation program, a main program and a statistics program which are run sequentially. Model documentation does not describe details of the computer program. This is a proprietary model developed by the engineering consulting firm Dorsch Consult Ingenieurgesellschaft mbH of Munich, Germany (a North American office is maintained in Toronto, Ontario). The model may be released under certain use and distribution restrictions. A user's manual is available upon request.

The complete program package is written in Fortran IV and consists of nearly 30,000 statements. Usable core storage of 400k bytes and a configuration with fast external mass storage are required. The package is presently installed in a Univac 1108 computer. The program, however, can be used on all batch processing systems with Fortran IV compilers.

A.3.1.5.1 HVM-QQS Input Data

Input data requirements for HVM-QQS are extensive, and include:

1. Sewer network data (quite detailed);

2. Precipitation data;

3. Hydrologic data;

4. Dry-weather flow;

5. Input hydrographs;

6. Receiving water geometry and flows;

7. Pollutant accumulation and decay functions; and

8. Storage and treatment facility data.

HVM-QQS has an excellent data validation program which simplifies data management.

A.3.1.5.2 Evaluation of HVM-QQS

HVM-QQS is one of the most complete models for the computation of runoff from urban catchments and the routing of flows in sewer networks. It is potentially the most accurate model for routing flow in sewers, particularly under conditions of surcharge or backwater. Extreme detail with respect to subcatchment discretization is required, however, to calculate accurate overland flow from rainfall. Simplifications are probably possible to allow larger subcatchment areas without significant loss in accuracy.

The implicit solution of the Saint-Venant equations provides an accurate means of computing the flow routing in the sewers coupled with routing through diversion structures and retention basins. The consideration of both upstream and downstream boundary conditions and the computation of backwater is part of the basic equations and does not have to rely on approximate methods such as those included in some kinematic wave or storage routing techniques. The implicit solution of the Saint-Venant equations coupled with diversion equations is complicated, however, and time consuming on the computer as compared to more approximate methods. To simplify the solution somewhat an iterative scheme is used which cannot consider flow reversal (although it is contained in the basic equations).

Although the model formulations are considerably more precise than most tested models, the increased accuracy demands a sacrifice in computer time. The model would be needed primarily where backwater, downstream flow control, diversion structures, retention basins, and surcharging are important features of the sewerage system assessment. If these features are not present or are considered insignificant, simpler models requiring less computer time can be used.

The model has been applied extensively in Germany and Switzerland, and moderately in Canada, the U.S.A. and other countries. Model comparisons with measured runoff data are limited.

HVM-QQS has been verified checking quality against measurements taken in Augsburg, Munich and Stuttgart, Germany, and quantity against the Dorsch Consult HVM-Method and measurements. The model presently is applied to Augsburg, Germany (360,000 inhabitants), and to Rochester, New York. Documentation of the model is not generally available.

A.3.1.6 Metcalf and Eddy Model

The Metcalf and Eddy Model (9) is the simplest of the models evaluated, and is intended as a planning tool to gain some insight into the system under study and to aid in the initial screening of alternatives. It provides a very easy, direct methodology, divided into three subsystems. The first, rainfall characterization, is a sorting and analysis of rainfall data from local records. Operating directly from Weather Bureau tapes or published summaries, long periods of record can be easily analyzed, and the arrayed output allows historical classification of rainfall. The second, storage-treatment balance, uses historical rainfall data, converted to runoff by coefficient which is stored in a special volume which is emptied at a specified rate. When runoff exceeds the combined storage-treatment rates, changes in overflow occurrence and duration can be examined. The third, discharge-receiving water response, applies pollutant concentrations to overflow volumes to determine pollutant mass loadings. Several methods for arriving at pollutant concentrations are suggested. Receiving water response is analyzed separately.

The Metcalf and Eddy Model includes the following features:

1. Analysis of long-term records;

2. Simple, direct calculations;

3. Quality and quantity calculations;

4. Modular, to allow user to select only components he needs; and

5. Allows incorporation of probability in a simple fashions.

The model does not include:

1. Dry-weather flow;

2. Conduit flows; and

3. Costs or design capability.

The computer program, or rather programs, are written in FORTRAN IV, and can be run on virtually any size computer with a FORTRAN IV compiler. Computer program is available from EPA along with the documentation.

A.3.1.6.1 Input Data for Metcalf and Eddy Model

1. Rainfall-program will process Weather Bureau hourly or daily summaries;

2. Sewer system schematic (while not required by the program, essential to understanding system) including overflows and their associated drainage areas and pertinent interceptor capacities;

3. Runoff coefficient;

4. Pollutant concentrations; and

5. Storage capacity and treatment rate.

A.3.1.6.2 Evaluation of Metcalf and Eddy Model

This simple model is an invaluable tool for preliminary analysis. It is particularly useful for rainfall-runoff probability determination, and to get rough first-cut evaluations of storage-treatment alternatives. It is straightforward and inexpensive, and will allow engineers and planners to quickly gain an insight into their local problems, and to determine where more detailed models are required. The model has been applied extensively by Metcalf and Eddy, and is presently being used on an EPA project in Rochester, New York (See Chapter 3 for additional details of this model application in preliminary screening applications).

A.3.1.7 AGRUN (Water Resources Engineers)

AGRUN (10) is a revised version of the RUNOFF block of the Stormwater Management Model (SWMM) which can be used to estimate runoff quantity and quality from agricultural lands. It is included in this list as an example of a model that is useful in rural or semi-rural portions of the 208 area. AGRUN has not been extensively tested, and potential users are cautioned accordingly.

The changes made in the SWMM RUNOFF block to create AGRUN include:

1. The capability to route pollutants through as many as 200 tributary channels. The tributary system must be dendritic. Channel cross sections may be triangular, trapezoidal or rectangular;

2. The capability to model up to 22 quality constituents (only total suspended solids, BOD and fecal coliforms have been verified). The Universal Soil Loss equation is used to compute suspended solids sources loading rates. Source loading rates of other pollutants is assumed directly proportional to the solids loading rate, the proportionality constant being a function of land use type; and

3. The capability to simulate interflow contributions to runoff. Up to five layers of soils are handled on each subarea. Each layer is assumed to be of uniform thickness and parallel to the surface. A planar, impermeable boundary exists at the bottom of the lowest layer.

The computer program is written in FORTRAN V, the program and associated documentation are available from EPA, Office of Water and Hazardous Materials, Washington, D. C. 20460.

A.3.1.7.1 Input Data for AGRUN

In addition to the data required by the normal RUNOFF block, AGRUN requires:

1. Channel specifications;

2. Land use hydrodynamics data;

3. Crop types; and

4. Baseflow data.

A.3.1.7.2 Evaluation of AGRUN

This model, though relatively untested, should prove useful for detailed examination of rural or semi-rural runoff. It may be linked to the SWMM to evaluate such things as storage-treatment options or impacts on receiving water quality. Use of this model should be undertaken by personnel familiar with the basic SWMM.

A.3.1.8 ILLUDAS (Illinois State Water Survey)

The Illinois State Water Survey Urban Drainage Area Simulator (ILLUDAS) (11) was developed by the Illinois State Water Survey for single-event simulation of time-varying runoff in combined sewerage systems consisting of several catchments and a converging sewer and open channel network. The model is based on a computer version of the British Road Research Laboratory Model, but computes also the runoff from pervious areas and includes the option to size either circular sewers or retention basins. The design option is based on hydraulic considerations alone and does not consider costs. Water quality is not modeled.

ILLUDAS will accept a specified storm, or will distribute, according to user specified parameters, a given total rainfall volume. Equal time increments of rainfall are applied to sub-basin of the total urban basin. A computation is made of the travel time required for each increment of runoff to reach the inlets at the downstream end of the sub-basin. In this way a surface hydrograph is provided for each sub-basin. These surface hydrographs from each sub-basin are accumulated in downstream order through the basin. This accumlation of inflow hydrographs is routed through each section of pipe to account for the temporary storage within each pipe section. The result is a computed outflow hydrograph from each section of pipe, and ultimately a hydrograph at the outlet of the total basin.

Infiltration is calculated using Holtan's method and provision is made for satisfying depression storage before infiltration takes place. Detention storage may be handled in two ways. If the user specifies a detention volume at some point in the basin, ILLUDAS will utilize that storage and report the resulting decrease in peak flow. If on the other hand the user wishes to limit the peak flow at some point, ILLUDAS will report the storage volume required to reduce the peak flow to the desired rate.

IILUDAS is available from the Illinois State Water Survey in the form of a Fortran IV deck of some 800 cards. About 150 K bytes of core are required. The program was developed for use on an IBM 360-75 and is available only in that form. The output format is presently best suited to a 130 space line but work is underway to develop a 72 space format for use on remote terminals. ILLUDAS is available commercially on the McDonnell Douglas Automation Company (MCAUTO) system in St. Louis.

A.3.1.8.1 Input Data for ILLUDAS

1. Precipitation data
2. Paved and grassed areas and their slopes
3. Hydrologic soil groups
4. Paved and grassed area abstractions.
5. Sewer length, slope, shape, Manning's "n".
6. Available storage.

A.3.1.8.2 Evaluation of ILLUDAS

ILLUDAS has been extensively tested and used, and the program is well documented. It has some sewer design capability and should be useful in the analysis of runoff-storage analyses. The Illinois State Water Survey provides training courses in application of the model. It is most useful where single rainfall events are to be simulated and water quality is not a consideration.

A.4 Water Quality Models

Water quality models are the most important, and in many ways least understood, link in the chain of models for environmental assessment. The physical, chemical and biological phenomena represented by the models are very complex, and many simplifying assumptions must be made by the user in the course of model development and application. More specialized technical skill is required in the use of water quality models than of any other type. In fact, it is essential that a person skilled in the water quality area be available for input preparation and interpretation of results. The comments regarding default values outlined in section A.3 are equally applicable here.

The models listed in this section (see Table A-2) meet the criteria of being generally available, well-documented and have been tested and applied. They also demonstrate a range of models available to the user. Previously (A.2) it was indicated that a careful investigation should be undertaken to identify models in local use. This is particularly true with water quality models. While the user will have to assure himself that the model has been correctly formulated and properly verified, a water quality model, even a relatively simple one, that is in use in the local area and for which data have been gathered will prove invaluable and may make it the overriding model of choice, particularly where resources are limited.

In general, it is better to examine a limited number of quality constituents in a water quality modeling exercise, even though the model may be formulated to accomodate a broad spectrum. This will simplify the problem of data acquisition, make the model easier and cheaper to use and simplify the analysis of results.

A.4.1 Water Quality Models

A.4.1.1 DOSAG-I (EPA)

DOSAG-I (12), developed originally by a predecessor agency of EPA and modified by the Texas Water Development Board, and now disseminated by EPA, Office of Water and Hazardous Materials, uses the classical Streeter-Phelps DO sag equation, modified to include nitrogenous biochemical oxygen demand to simulate DO and BOD variations. It is a steady-state model, suitable

TABLE A-2 WATER QUALITY MODELS

Model Origin	Acronym	Water Bodies Modeled[1]			Time Variability		Spatial Discretization			Miscellaneous			Constituents Modeled
		Stream	Estuary	Lake	Steady-State	Dynamic	One-Dimensional	Two-Dimensional	Stratified	Documentation Available	Computer Program Available	Applied to Real Problems	
Environmental Prot. Agency	DOSAG-I	●			●		●			●	●	●	DO, BOD (Carbonaceous and nitrogenous)
EPA	QUAL-II	●			● 2		●			●	●	●	BOD, DO, temperature, NH_3, NO_3, NO_2, algae, phosphorus, benthic demand, coliforms, radioactive materials, 3 conservative constituents.
EPA	RECEIV	●	●			●		●		●	●	●	Any six constituents, including DO, BOD, conservative constituents and non-conservative constituents with first order decay.
Raytheon (EPA)	RECEIV-II	●	●			●		●		●	●	●	BOD, DO, coliforms, nutrients, salinity, conservative constituents, non-conservative constituents with first order decay, chlorophyll a.
Systems Control Inc.	SRMSCI	●	●			●		●		●	●	●	BOD, DO, coliforms, excess temperature, NH_3, NO_3, NO_2, OPO_4, Cu, Pb, and two conservatives.
Water Resources Engineers (EPA)	WRECEV	●	●			●		●		●	●		BOD-DO (linked), any four conservative or first order non-conservative.
Hydrocomp, Inc.	HWQM	●		●		●		●	●	●	3	●	BOD, DO, coliforms, temperature, algae, zooplankton, sediment, organic nitrogen, nutrients and conservative constituents.
Office of Water Resources Research	LAKECO			●		●	●		●	●	●	●	Zooplankton, benthic animals, fish, pH, nutrients, conservative constituents, non-conservative constituents with first order decay.

1. Stream models can simulate shallow, well-mixed impoundments.
2. Weather inputs may be dynamic.
3. Available for a fee.

for modeling non-estuarine streams with no reservoirs. The model is constrained in that no more than than 10 headwaters, 20 junctions, 20 stretches (sections between junctions) and 50 reaches may be modeled.

DOSAG-I is capable of calculating flow augmentations needed to maintain DO at a prescribed level, and of determining dissolved oxygen distribution for varying levels of treatment (waste treatment plants) in the simulated river basin. Computations are performed on a reach-by-reach basis. DOSAG-I calculates the time required for a particle of water to travel downstream to the first lateral inflow (tributary, outfall, etc.) to the stream. The changes in the concentration of constituents which would occur during the travel time are computed and the concentrations of constituents adjusted accordingly. These adjusted concentrations represent the stream quality just above the lateral inflow. The inflowing water quantity and wasteload are then added to those of the stream, resulting in a new stream flow and a new value for the concentration of constituents in the stream at the point of inflow. The program then calculates how long it would take a particle of water to travel downstream from that point to the next lateral inflow, and the whole process is repeated. All temperature-dependent parameters are adjusted on a reach-by-reach basis during the computations.

The computational procedure is repeated on each headwater stretch downstream to the first junction, and then proceeds downstream throughout the system until the water quality constituent concentrations are determined for the entire stream system. No diffusion or stratification is modeled and at any point the stream is assumed to be uniformly mixed.

All inflow rates and all constituent concentrations in the inflows are specified by the user. The temperature of each reach is also user specified. Withdrawal of water from the stream system is modeled by specifying a negative inflow at that point.

A.4.1.1.1 DOSAG-I Input Data

Input data required for DOSAG-I is relatively simple and straightforward. It includes:

1. Flow rates for system inputs and withdrawals;

2. Information on reaches, junctions, stretches, headwater reaches;

3. Reaction coefficients;

4. Concentrations of inflows; and

5. Stream temperature.

A.4.1.1.2 Evaluation of DOSAG-I

DOSAG-I is a simple, well-tested, frequently used model which can predict stream DO concentrations with relative accuracy. The model has been modified by others (13), and has good documentation. The computer program is simple enough that repeated program runs may be made at low cost once initial set-up has been done. It is most useful where DO considerations control water quality, and where steady-state conditions apply.

A.4.1.2 QUAL-II (EPA)

QUAL-II (14), developed by Water Resources Engineers as a modification to QUAL-I (15), is a quasi-dynamic stream model. It will simulate both steady-state stream flow and the steady-state and dynamic behavior of the following constituents:

1. Chlorophyll-a;

2. Nitrogen;

Ammonia

Nitrite

Nitrate

3. Phosphorus;

4. Carbonaceous BOD;

5. Benthic oxygen demand;

6. DO;

7. Coliforms; and

8. Conservative substances.

QUAL-II is constrained in that no more than 15 headwaters, 15 junctions, 45 reaches and a total of not more than 45 input/withdrawal elements can be modeled.

QUAL-II numerically integrates, using a wholly implicit numerical scheme, the advection-dispersion mass transport equation for all water quality constituents to be modeled. The equations include the effects of constituent reactions and interactions, and a source term.

QUAL-II is applied by subdividing the stream system into reaches (stretches of stream with uniform hydraulic characteristics). Each reach is then divided into computational elements of equal length, so that all computational elements in all reaches are the same length (Max. of 20 computational elements per reach).

The computer program is written in Fortran IV for the IBM 360/370 series computers. It is structured as one main program supported by 20 subroutines. This allows changes in parameters or modification of parameter relationships with a minimum of model restructuring.

A.4.1.2.1 QUAL-II Input Data

The input data required by QUAL-II include:

1. Identification and description of stream reaches.

2. Initial conditions.

3. Hydraulic coefficients for determining velocity and depth.

4. Reaction coefficients.

5. Junction data.

6. Headwater data.

7. Waste loadings and runoff conditions.

8. If temperature is to be modeled, also requires sky cover, wet bulb/dry bulb air temperature, atmospheric pressure, wind speed, evaporation coefficient, and basin elevation.

A.4.1.2.2 Evaluation of QUAL-II

QUAL-II is a simple model, which has been extensively tested and used. Application of QUAL-II requires less resource expenditure than any of the computer models listed herein except DOSAG-I. QUAL-II is disseminated without cost by EPA, Office of Water and Hazardous Materials, Washington, D.C. The model, given valid input data, will reliably predict water quality with a relatively high degree of accuracy. QUAL-II is most suited to situations where several water quality constituents are to be modeled and where steady-state streamflow calculations are appropriate.

A.4.1.3 RECEIV (EPA)

RECEIV, originally developed as a part of the EPA Stormwater Management Model (SWMM) (4,5), is suitable for modeling estuaries and streams, and may be also used to model lakes if one can assume they are relatively shallow and well-mixed. RECEIV represents the water body with a network of nodal points connected by channels. The nodal points and channels are idealized hydraulic elements which are characterized by parameters such as surface area, cross-sectional area, length and friction coefficient. The equations of motion and continuity are applied to each element and solved simultaneously to produce a true histrory of stage, velocity and flow at the various points of the receiving water system. The model is not suited for modeling highly stratified water bodies. RECEIV has the capability of simulating tidal flats (surface area need not be constant) and will handle tidal boundary conditions at multiple seaward boundary locations. RECEIV will accept transient inputs, such as storm water inflow, and is useful in examining the effects of various upstream treatment schemes with different removal rates in that several water quality simulations may be performed for a given quantity simulation. Water quantity simulations may be performed separately from, or together with, quality simulations. The model will accomodate up to six conservative quality parameters and non-conservative parameters with first-order decay. When BOD is modeled, its influence on DO is calculated and resulting DO levels are determined simultaneously. The model assumes an advective transport mechanism, and does not accomodate diffusion transport. RECEIV computes concentrations of pollutants on incoming tides using a seaward exchange coefficient, and models these concentrations as a constant value during the tidal cycle. RECEIV is programmed in FORTRAN IV.

A.4.1.3.1 RECEIV Input Data

RECEIV requires fairly extensive input data, which includes:

1. Tidal variations

2. Water surface elevations, area and depth

3. Bottom roughness coefficients

4. Meteorological data, including rainfall, evaporation, wind velocity and direction

5. Downstream boundary conditions

6. Junction and channel data

7. Water temperature

8. Initial pollutant concentrations

9. Inflow data

10. Oxygen saturation and reaeration coefficients

A.4.1.3.2 Evaluation of RECEIV

RECEIV is a relatively complex model which is most applicable to estuaries and which has been extensively used. Considerable skill is required to apply it effectively, and the documentation, while adequate, is not as good as documentation for the rest of the SWMM. There are many variants of RECEIV, several of which will be subsequently described. The program and its documentation are available without charge from EPA, Office of Research and Development (RD-682). RECEIV is most applicable when SWMM is being used, and its main strength, as with SWMM lies in the continuing maintenance, improvement and documentation that is taking place.

A.4.1.4 RECEIV-II (RAYTHEON/EPA)

RECEIV-II (16) was developed by Raytheon, under contract to the Water Planning Division, EPA, and is a modification and expansion of the RECEIV model in SWMM. RECEIV-II preserves the compatibility with the original SWMM coding through a new subroutine called SETUP. The other major differences between RECEIV-II and RECEIV are in the water quality constituents modeled and the relationships describing the behavior of those constituents. RECEIV-II simulates eleven (11) water quality constituents, including the nitrogen cycle, phosphororus, chlorophyll-a and salinity, in addition to BOD, DO and coliforms. Included are representations of the biological and chemical linkages between constituents. An important feature is the ability to compute constituent concentrations downstream of a dam, by adjusting DO reaeration due to spillage over the dam. RECEIV-II is programmed in ANSI Standard FORTRAN for both IBM and CDC computers.

A.4.1.4.1 RECEIV-II Input Data

Input data requirements for RECEIV-II are essentially the same as those for RECEIV, except in the SETUP block, which requires more detailed specification of boundary conditions, and in specifying initial pollutant concentrations and reaction coefficients because of the larger number of pollutants modeled.

A.4.1.4.2 Evaluation of RECEIV-II

RECEIV-II has been extensively tested, and has been applied to a number of receiving waters. The documentation is excellent. In fact, it is desirable for a user of RECEIV or any of its variants to have a copy of this documentation, since it gives a much better description of the theory and application than is provided in SWMM documentation. It is only slightly less convenient to use with the SWMM than RECEIV, and will probably give better results, since a number of errors in RECEIV were corrected in the development of RECEIV-II. The program and documentation are available without charge from EPA, Office of Water and Hazardous Materials, or at nominal cost from Raytheon Corporation.

A.4.1.5 SRMSCI (Systems Control Inc.)

SRMSCI, developed by Systems Control, Inc. (13), is another variant of the RECEIV block of SWMM. The principal modification is the addition of the capability to model excess temperature, the nitrogen cycle, phosphorus, lead, and copper. The nutrient-algae cycle and second-order decay of nitrogen or phosphorus are accomodated. In other respects, SRMSCI is the same as RECEIV.

A.4.1.5.1 SRMSCI Input Data

Input data requirirements for SRMSCI are the same as for RECEIV, except that more pollutant data (intial concentrations, decay rates) are required.

A.4.1.5.2 Evaluation of SRMSCI

SRMSCI is well-tested and documented, but has not been as extensively used as RECEIV or RECEIV-II. It should provide results comparable to either model. The program and documentation are available at nominal cost from the Snohomish County Planning Department, Everett, Washington, or Systems Control, Inc.

A.4.1.6 WRECEV (Water RESOURCES Engineers)

WRECEV (17) is yet another modification to the RECEIV block in SWMM, and, like its predecessor has a hydrodynamic module and a quality module. It was developed to increase the applicability of the basic RECEIV to streams.

The following revisions were made in the hydrodynamic module:

1. Modify geometric specifications of channel and junctions;

2. Solve the finite difference form of the equation of motion for flow rate;

3. Allow constant inflows, constant withdrawals and variable flow hydrographs to occur simultaneously at any junction;

4. Use logical variables in the computer code where possible;

5. Reduce core requirements for model execution;

6. Permit execution with no interface units if desired; and

7. Restructure input data requirements.

The following revisions were made in the water quality module:

1. Allow constant inflows, constant withdrawals and variable flow hydrographs to occur simultaneously at any junction.

2. Allow time-variant inflow concentrations of all simulated constituents.

3. Input temperature to allow internal temperature correction for any input reaction rates and internal computation of DO saturation concentration.

4. Include five-day BOD as an optional constituent.

5. Allow spatial variation of any input reaction rates.

6. Compute the reaeration coefficient at each time step.

7. Include the effects of dispersion in the computations.

8. Revise advection computations.

9. Insert warning messages to indicate that the advection ratio criterion has been violated.

10. Restructure input data requirements.

These changes have resulted in making the model easier to use and requiring less computer time for execution. WRECEV has been designed for use either as a stand-alone module or with a direct linkage to SWMM. WRECEV is programmed in FORTRAN IV.

A.4.1.6.1 WRECEV Input Data

Input data requirements for WRECEV are essentially the same as those for RECEIV. The documentation, however, provides a much clearer description of input formats and the data input process.

A.4.1.6.2 Evaluation of WRECEV

WRECEV is relatively new and untried, but is based on considerable experience with RECEIV and should hence perform at least as well. The documentation is excellent, and the reader would, as with RECEIV-II, be well advised to obtain a copy if he plans to use any variant of RECEIV. WRECEV is available without cost from EPA, Office of Water and Hazardous Materials.

A.4.1.7 HWQM (Hydrocomp, Inc.)

The Hydrocomp Water Quality Model (18) is applicable to non-tidal receiving waters. It is a dynamic model simulating a number of water quality indices, including temperature, total dissolved solids (TDS), DO, BOD, coliforms, algae-chlorophyll-a, zooplankton, nitrogen, ortho-phosphate and condensed phosphate, and conservative constituents such as metals and chlorides.

In HWQM a stream system is divided into reaches, assuming complete mixing in each reach. During each time step, the transfer of water into and out of each reach is determined and the chemical and biological processes computed. Impoundments are considered similarly to stream reaches, except that stratification may be analyzed by assuming the impoundment consists of three layers and that mixing occurs between layers. The mixing coefficient (fraction of one layer mixed with another layer) is a function of time of year to approximate various mixing phenomena that occur. Diffusion is not modeled. HWQM is set up for direct linkage to HSP (see A.3.1.3) which will provide surface runoff inputs to the receiving water. HWQM is programmed in PL1.

A.4.1.7.1 HWQM Input Data

The input data requirements for HWQM are extensive, but a Library program module is available (as in HSP) which considerably simplifies the management of this data. Input data includes:

1. Watershed data, including descriptions of reaches and lakes;
2. Reaction coefficients;
3. Initial conditions of flow and pollutant concentrations;
4. Temperature data; and
5. Data on quantity and quality of inflows.

A.4.1.7.2 Evaluation of HWQM

HWQM has not been extensively tested or applied, however it may be expected to give good results. It is a proprietary model, available only from Hydrocomp on several fee bases. Training courses in its application are conducted by Hydrocomp. It is the most complex of the water quality models reviewed here and requires considerable expertise in the water quality area. The documentation is adequate, and available from Hydrocomp for a fee.

A.4.1.8 LAKECO (OWRR)

The Lake Ecologic Model (LAKECO)(19) developed by Water Resources Engineers for the Office of Water Resources Research (OWRR) is a dynamic model for simulating water quality and biological populations in stratified lakes. LAKECO is primarily a tool to aid the user in determing the effects on the water quality and temperature of a lake due to meteorological changes or to changes in the flow rate, temperature, and/or concentrations of the lake inflows or the flow rate and/or positions of the lake outflows. The model may also be used to predict conditions in lakes yet to be formed and to aid designers of impoundments.

It has substantially greater capability than the Deep Reservoir Model from which it was derived. LAKECO carries out most of its hydrodynamic calculations simultaneously with its water quality calculations. LAKECO models TDS, the DO budget, nutrient cycles, coliform and algal life processes, benthal demands and releases, temperature, pH, the detritus cycle, and zooplankton and fish cycles. A total of nineteen non-conservatives and two conservatives may be modeled. The lake being modeled must be represented by less than 100 horizontal layers. A maximum of ten inflows and ten outlets are permitted.

Computations performed by LAKECO include consideration of stratification, dilution, diffusion, advection, settling, mass addition, decay, growth, benthal releases, internal coupling between constituents, reaeration, respiration, mortality, photosynthesis, short wave radiation, wet and dry bulb air temperature and wind.

LAKECO calculates the concentration profiles of the lake being modeled in the following manner: The lake is considered to be divided into a number of horizontal layers. The lake inflow is distributed into the appropriate layers from consideration of temperatures, flow rate, and layer volumes. The lake outflow is withdrawn from the appropriate layers from consideration of outlet location(s), flow rate, and layer volumes. Transports between layers are computed.

The concentration and/or temperature changes in each layer due to factors listed above are then calculated and the concentrations are updated. The temperature and concentrations of the outflows are also calculated for the time step. The procedure is continued until the end of the simulation period is reached, at which time a complete history of the temperature and concentrations in each lake layer and in the lake outflows have been generated. All temperature-dependent parameters are adjusted on a layer by layer basis during the computations. LAKECO is written in FORTRAN IV.

A.4.1.8.1 LAKECO Input Data

Input data requirements for LAKECO are fairly extensive, and include:

1. Meteorologic data, including sky cover, wet/dry-bulb temperature, wind speed and direction, atmospheric pressure;

2. Lake latitude and longitude;

3. Flow rate of lake inflows (steady-state or time varying) during the simulation period;

4. Table defining surface area and volume as functions of depth;

5. Outlet locations;

6. Concentrations (steady-state or time varying) in the lake inflows of all quality constituents (including temperature) being modeled for the simulated time period;

7. All reaction and decay rate constants for each lake layer, including growth rates, mortality rates, respiration rates and settling velocities;

8. Extinction coefficient;

9. Diffusion coefficients;

10. Temperature stability coefficient; and

11. Initial concentrations for the simulation period of all constituents (including temperature) for each layer.

A.4.1.8.2 Evaluation of LAKECO

LAKECO has been extensively tested and applied, and can be expected to give good results, though it is rather complex. Application of LAKECO would provide an adequate picture of an annual lake cycle, but not long-term trends toward eutrophication. The program and documentation are available at nominal cost from OWRR.

A.5 Typical Model Selection Approach

In the application of models in a typical 208 study, the following sequence is suggested.

1. Define the objective - have a clear statement of what the study objectives are. This is, unquestionably, the single most important step in the process, and probably the most difficult. Time spent here, however, will be compensated by the fact that a clear objective will make all subsequent tasks simpler. The objective should be specific, and describe clearly what the study is to accomplish. A study objective such as "develop a 208 plan to satisfy PL 92-500" is vague and subject to a variety of interpretations. If it were refined to read "determine the relative impacts of nonpoint discharges and combined sewer overflows in the 208 area to other point sources in that area with respect to 7-day, 10-year low flow standards, assuming that

upstream loadings will not change," it is much more likely that all parties will have the same understanding. The selection of an appropriate methodology will be much easier, and the study results are more likely to address the real problems.

2. Gather and assess available information - at this stage the requirement is to identify what already exists and where it is located. Data on land use, population, precipitation, streamflow, point discharges, the local sewerage system, etc. should be gathered. The results of any previous studies or on-going work (201 plans, university research projects, 303 (e) plans) should be analyzed to get a feel for the local situation and a better idea of what direction the study should take. Almost every area has had some work done, and time spent locating and evaluating available information can reduce duration and costs of current work. Local expertise familiar with the area under study may be identified, and can become an important part of the study team.

3. Apply some simple model (may or may not be a computer model) to get some idea of how the areawide system you now have behaves, and the relative influence of various pollutant sources - large systems are complex, and intuitive judgements about their behavior may be totally inadequate. By using a simple model, the planner can "play" with his system easily and cheaply and get some feel for the response of the system to various alternatives. This step can also point up shortcomings in the existing data base, and provide valuable insight into more detailed analyses that may be required. Chapters 2 and 3 provide more discussion on this subject.

4. Determine if more detailed modeling is necessary, and if so, where - remember the study objectives, and use only the tools needed to achieve those objectives. The models described herein cover a broad range of capabilities, and in general, the more complex the model, the more resources required for its application. Do not,

however, assume that increased sophistication and resolution necessarily imply increased accuracy or utility. Many 208 planning studies have started with the assumption that a specific model would be applied, and then the rest of the planning was done to fit that assumption. Models are not simple to apply, and the pre-selection of a model without a feel for the problem to be investigated is sure to result in wasted time and effort. The only possible exception is where there is a model already installed and calibrated for an area.

5. Gather data and apply selected models - it is at this point that data for model calibration and verification is collected, if it is not already available. Again, the study objectives must be kept firmly in mind, and only that data gathered which is necessary. Model application should follow procedures outlined in pertinent model documentation. Models applied at this stage will probably be utilized during subsequent studies or in on-going planning, so thorough documentation of the model application should be prepared. If this is not done, continuity is easily lost, and a costly tool will be wasted.

6. Evaluate results and determine future requirements - the results of the modeling should be reviewed to see if study objectives have been met. If further data is required, or if other alternatives are to be analyzed, step 5 may need to be repeated.

A.6 Sources of Assistance:

There are often many sources of assistance available locally to the user. These include:

1. Universities - They may be doing modeling or data-gathering which would be useful, and may even have an operating model which would serve for planning pruposes. Departments of Biology, Ecology,

Water Resources, etc., may be involved as well as engineering departments.

2. Agencies - State and Federal agencies have sponsored a great deal of work, and some of it may be useful in your area. Federal agencies which do environmentally-related modeling or have sponsored such work include:

   a. U.S. Environmental Protection Agency - Office of Research and Development, (RD-682) and the Water Planning Division (WH-554).

   b. U.S. Geological Survey - They also have a data-gathering program.

   c. Soil Conservation Service (USDA).

   d. U.S. Army Corps of Engineers Hydrologic Engineering Center.

   e. Office of Water Resources Research.

3. Consultants - There are a number of consultants specialized in urban drainage and/or water quality modeling. Even though they may not be your primary consultant, they are very useful for review of your program for model application and calibration, or of results obtained.

4. Service Bureaus - Most of the models listed are available on some regional or national service bureau, such as McDonnell Automation, CDC, Service Bureau Corp., University City Science Center, etc. If not, a service bureau will often accept the responsibility for model setup in return for using their system. Some even have personnel familiar with model applications to offer assistance.

5. Training Courses - A number of training courses are offered which are useful to model users. They include:

   a. Short courses in storm water model application offered by U.S. EPA and by the Ontario Ministry of the Environment, Canada.

   b. 208 seminars conducted nation-wide, and sponsored by EPA's Water Planning Division and the Regional offices.

   c. ILLUDAS training course offered by the Illinois State Water Survey.

   d. Urban runoff seminars sponsored by the American Public Works Association (AAWA).

   e. HSP seminars presented by Hydrocomp, Inc.

6. 201 Planning/Design - In many areas wastewater treatment facilities are being or have been analyzed or designed, and much information is available from these studies. Regrettably, there are instances when jurisdictional problems or a lack of communication have resulted in a failure to pool information.

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APPENDIX C

LAND USE DATA COLLECTION AND ANALYSIS

C.1 Introduction

As mentioned in Chapter 2 of this Areawide Assessment Procedures Manual, land use considerations are extremely important in the development of areawide water quality management programs. Land use projections relate directly to the projection of future waste loads generated by both point and nonpoint sources. In this regard, the physical characteristics of the land surface, e.g., soils, slope, vegetative cover, etc., are reflected in the waste loads that may be anticipated to originate from different land use categories such as cropland, forests, etc. Similarly, activities associated with the land surface also are directly related to the potential waste loads generated. Thus a heavily industralized parcel will likely be associated with a different set of water quality problems than a residential area or an area under intensive cultivation.

Although the state-of-the-art in precisely identifying the relationship between land use and water quality is not highly developed, this Appendix is designed to provide a description of a range of land use and demographic data collection, management, and analysis techniques.[1] It is hoped that the "menu" of alternatives summarized herein will be of practical use to 208 planners confronting land use/water quality-related issues in the formulation and evaluation of alternative water quality management plans.

C.1.1 Objectives and Scope

The overall objective of Appendix C is to describe a range of specific techniques and qualitative considerations for land use data collection, management, and analysis in areawide water quality management planning. More specifically, this Appendix is designed to provide 208 planners with a description of:

1. The range of potential land use data needs for 208 planning
2. The available sources of potentially useful land use data (Federal, state, and local)
3. The potentially applicable techniques for land use data collection
4. The alternative approaches to land use data management
5. The potentially applicable techniques for demographic and land use data analysis and projection.

In the discussion of each of the above topics, the objective is to provide the planner with a descriptive survey of alternative approaches to the land use element of the 208 planning process, from relatively simple techniques to complex ones. It should be emphasized that this Appendix is not meant to be prescriptive, but rather an inventory of alternative approaches that will assist the practitioner in selecting appropriate methods to meet his or her specific needs and objectives relative to the land use element of 208.

It should be noted that this Appendix does not address the issue of potentially applicable land use controls that might be considered in the 208 program. Instead, it focuses on the definition of water quality problems relative to land use, and how alternative projected land use configurations and waste loads might be evaluated. In this respect, the land use material discussed here must be utilized in conjunction with the other 208-related areawide assessment procedures outlined in other sections of this *Manual*, particularly the approaches to regional water quality assessment.

C.1.2 Relationship of Appendix C to Other Portions of the *Areawide Assessment Procedures Manual*

As the title of Appendix C suggests, it is designed to provide the 208 planner with information concerning alternative approaches to completing the land use element of the 208 program. In order to be effective, however, the land use element must be prepared in a manner that facilitates its use for point and nonpoint source evaluation and control in both urban and nonurban settings. Thus, the material on land use data collection and analysis contained in Appendix C is a key input to several other portions of the 208 planning process. More specifically, the land use element is related to the following important aspects of areawide water quality management planning:

1. Identification of existing point and nonpoint source loads (including those associated with agriculture, silviculture, construction and mining activities, etc.)
2. Projection and quantification of future pollutant loadings from both point and nonpoint sources.

Thus the land use data collected are an important input to the water quality analysis portion of the 208 planning process, which commonly includes a modeling effort. The alternative land use data collection and analysis techniques outlined in this Appendix must be adapted to the specific procedures chosen for the assessment of pollutant sources and loadings for both urban and non-urban areas. This requires a sensitivity on the part of the practitioner to the need for consistency between the land use information that results from the various analytical approaches, and the input data required to apply to the particular water quality assessment approach chosen. This Appendix presents various land use evaluation techniques that can provide different levels of sophistication in terms of analytical input for the various levels and methods of pollutant loading estimation presented in Chapters 2 through 4 of this Manual.

C.2 Identification of Land Use Data Needs

This section summarizes the types of land use data that 208 planners need to consider as they relate land use issues to water quality management. Since most 208 planning regions have had experience with land use programs of other sorts, the first subsection outlines some data requirements of more traditional land use planning efforts. Next the range of land use data needs for the 208 program is identified. Finally, the more traditional land use planning program data needs are compared and contrasted with those of the 208 program. This comparison is designed to put into perspective the land use element of 208 in terms of more traditional land use programs from which designated 208 agencies will want to extract as much relevant data as possible. Information on the wide range of potentially relevant Federal and EPA programs is found in the information matrices entitled "Selected Federal Programs Related to Regional Planning", and "EPA Programs Related to State, Regional, and Local Planning". These matrices are included in the pocket at the end of this Appendix.

C.2.1 Traditional Land Use Planning Data Needs

Traditional land use planning or comprehensive planning has dealt with a broad range of development issues at the regional level - all of which relate to some extent to the scope of the 208 planning program. The scope of regional comprehensive planning commonly encompasses the following topics:

1. Physical land characteristics, e.g., soils, slope, vegetation, available minerals, etc.
2. Demographic trends translated into demand for housing, employment, and various services, e.g., power, water, sewer, police and fire protection, etc.
3. Future land use configurations in the context of meeting anticipated demands while avoiding nonconforming uses, inefficient development patterns in terms of the provision of needed services, etc.
4. Transportation considerations that influence, and are influenced by, potential land use development trends
5. Recreation demand, and the provision of sufficient facilities, and open space to meet anticipated demands.

Each of the above topics involves the collection and analysis of various types of data in the traditional land use planning program. These data need categories are summarized as follows:

1. Soils information including soil type, development class limitations, bearing capacity, etc.
2. Vegetation classes including cropland, forest associations, barren land, etc.
3. Population growth trends by political subdivisions
4. Baseline data on housing availability by type, employment categories, etc.
5. Identification of existing land uses by land use category,

e.g., single family residential, multi-family residential, industrial (light and heavy), commercial, transportation, etc.

6. Inventory of existing and projected service areas for water and sewer services, etc.
7. Inventory of major existing transportation routes, traffic estimates and bottlenecks, as well as projected transportation projects in the region.
8. Identification of existing and projected recreation facilities and open space
9. Inventory of flood prone land in the region
10. Identification of regional zoning maps, and summary of land use controls employed in the region
11. Location of lands which cannot or should not be developed, e.g., steep slopes, wetlands, critical fish and/or wildlife habitat.

It should be noted that the data categories listed above may or may not be utilized for specific regional land use planning efforts. In addition, the data may be aggregated and displayed in many different formats. Where such data are available, they should be reviewed for use in the 208 program. The land use data needs for areawide water quality management are outlined in the next subsection.

C.2.2 208 Land Use Data Needs

Despite the fact that some data compiled for traditional comprehensive land use planning efforts may be directly useful in 208 planning, there are likely to be certain deficiencies in those data when it comes to applying them in the specific context of water quality management planning. These deficiencies are attributable to the lack of emphasis given to water quality concerns in many traditional comprehensive land use programs. This lack of emphasis will result in the need to seek out other sources of information to fill data gaps in a manner that facilitates the development of alternative 208 plans, and the evaluation of those plans. Subsequent sections of this Appendix provide suggestions for the collection of such data. This subsection identifies a range of land use-related data needs that might be considered by the 208 planner in data collection efforts.

The range of 208 specific land use data needs is summarized in the following list:

1. The size and location of each major drainage area in the planning region in square miles or acres
2. The percentage of various existing land uses in each drainage area, e.g., forest land, cropland, residential land (by density), industrial land, etc.
3. The physical land characteristics of each drainage area including soil types and soil characteristics (drainage, erodibility, etc.), slope, vegetation, and estimated gross percentage of impermeable cover (due to roofs, roads, parking lots, etc.)
4. The geology of the region as it relates to the presence of confined and unconfined aquifers, aquifer recharge areas, depth to groundwater, and known areas of groundwater contamination, e.g., salt water intrusion etc.
5. The location of critical regional environments including key fish and wildlife habitat, wetlands, shorelands, flood prone areas etc.
6. The delineation for each drainage area of water distribution and sewerage systems (including the location of water treatment and wastewater treatment facilities), and the identification of those areas served by wells and septic tanks or package treatment plants
7. The projection of trends in regional development as it might affect changes in land use configuration (and thus runoff characteristics), the need for additional water and sewer service, and the physical character of the land surface
8. The identification and location on maps of major point sources and significant nonpoint sources by drainage area, along with the location of residual waste disposal sites in the planning region

9. Identification of present and projected areas of mining activity, along with major construction sites, e.g., large subdivisions, industrial parks, dam sites etc.

Some of the above data will be extractable from existing local data sources in one form or another. The format and/or the level of aggregation of the data will often require standardization on drainage area maps to optimize the utility of the information for the 208 planner.

C.2.3 Notable Similarities and Differences Between Data Needs for Traditional Land Use Planning Efforts and Those of the 208 Program

Data required for traditional land use planning programs commonly will provide the basic context for the land use element of 208. Portions of the existing land use data base will be applicable to the data needs of the 208 program, and maximum use should be made of existing data and previous land use analyses. This subsection is designed to compare and contrast the data needs of these two kinds of land use planning programs. The intent is to provide the 208 practitioner with some assistance in identifying potentially useful data that may be found in local data bases, as well as in pinpointing where additional data collection efforts may be necessary. The discussion that follows must necessarily be general in nature, since the available land use data bases at the regional level may vary considerably from one designated area to another. Table C-1 summarizes the comparative analysis of land use data needs, and may be consulted to supplement the discussion that follows.

The similarities between data commonly available from traditional land use planning efforts, and the needs of the 208 program are significant. For example, the physical characteristics of the land surface, as outlined previously, are often detailed in traditional land use programs. This information is also commonly displayed on regional maps to facilitate the effective utilization of the data. These maps and their supporting documentation, e.g., aerial photography and land use plan narrative, are likely to be useful inputs to the 208 planning process relative to the identification

TABLE C-1
COMPARISON OF TRADITIONAL AND 208-SPECIFIC LAND USE DATA NEEDS

Data Type	Traditional Land Use Program	208 Land Use Element
1. Physiographic data	Soils, slope, and vegetation data etc. are commonly used to identify physical development constraints and critical regional environments, e.g., important wildlife habitat.	Soils, slope, vegetation, climatological, and geological data are used to estimate anticipated surface runoff characteristics and thus non-point pollution loads.
2. Demographic data	Population projections by various time increments, e.g., by 10-year intervals, are used to estimate the future need or demand for various land uses in the region, e.g., residential, commercial, etc. (Commonly done by political subdivision.)	Population projections in 5-year increments for 20 years to estimate the need or demand for various land uses, as well as the demand for water and sewer services. (Most useful by hydrologic unit or water/sewer service area.)
3. Additional land use data	Using population projections, and information on land use controls, e.g., zoning maps, transportation plans, etc., the future regional land use configuration is estimated within physical and institutional constraints. (Commonly done by political subdivision.)	The same information is used to project one or more future land use configurations, but the projections are taken further to estimate changes in land surface characteristics and activities that would geographically affect water quality, and the demand for water and sewer services. (Best done by drainage area or hydrologic unit.)

of key land surface characteristics, such as slope and soil types, necessary to implement various water quality modeling techniques. Likewise, demographic projections are important inputs to the traditional land use planning process. EPA 208 Guidelines require the use of OBERS Series E (Office of Business and Economic Research Statistics) projections, except where more reliable demographic information is available from other sources at the state and/or regional level. In this case, the designated 208 agency should substantiate the reasoning for their variance before proceeding with the use of projections other than those of OBERS. In either case, the projections will likely be aggregated in different geographic units than would be optimal for the 208 program, e.g., population by traffic zone instead of by drainage area. This will necessitate the interpolation of the existing projections to translate the information to the appropriate unit of analysis, in this case the hydrologic unit.

There are several other similarities in data needs between these two types of land use programs that the 208 planner should be aware of. Traditional land use planning efforts usually recognize the importance of the provision of water and sewer services to regional development, and thus may have the water and sewer service areas mapped, along with projected extensions of these service areas. This information is of direct use to the 208 program. The existing land use maps generated by traditional comprehensive planning programs, and the projected future land use configuration of the planning region for some future base year, e.g., 1985 or 2000, also provide important information to the 208 planner. Here again, the existing and projected land use data will, in all likelihood, have to be reassembled by drainage area to be of use in the water quality evaluation/modeling element of 208. In addition, available land use projections may have to be interpolated to allow the 208 planner to describe changes by 5-year intervals over a 20-year planning horizon for the land use/water quality analyses. Existing zoning maps should be collected and consulted as the above interpolations are made, since those maps will be significant in shaping the future configuration in the urbanizing areas of the region. Any major transportation projects that are likely to significantly modify regional drainage patterns should also be identified from existing comprehensive plans or transportation plans. This information will be of importance to the 208 planner from both a land use and water quality standpoint.

The differences between the data needs of traditional land use planning programs and the needs of the 208 programs may be attributed primarily to a difference in program focus. The 208 program concentrates on developing solutions to water quality problems in a comprehensive fashion dealing with both point and nonpoint sources, as well as with structural and nonstructural control techniques. In contrast, traditional comprehensive planning efforts address water quality considerations in a relatively superficial fashion in most cases. This explains why the land use element of 208 has some data needs that are not likely to be met from data collected in traditional land use planning programs. This also helps explain why the data needs of 208 may require a reaggregation or manipulation of the data available from traditional land use planning programs.

C.3 Identification of Existing Data Sources and Characteristics

Due to the significant constraints of time and budget, 208 planning agencies should utilize existing land use data sources within the 208 region in order to avoid the unnecessary expenditure of resources in land use collection efforts which duplicate already existing data. Identifying, locating, and obtaining existing land use data from primary and secondary sources is the initial basic step in a land use planning effort.

A significant amount of land use information is often required in order to understand and document past development trends, current status, and possible future directions of land use patterns within the 208 region, especially as all this relates to water quality. Although numerous land use data sources normally exist for any region, the information is often scattered throughout the files, libraries, and information systems of many Federal, state, and local public agencies, and even some private sources. Often the land use information from such sources is in a format which is not directly useable by 208 agencies. The 208 program like other emergent Federal and state programs (see below) related to land use, has created demands for specific types of land use information related to air and water quality, and environmental protection not previously collected or routinely available to public agencies.

This section of Appendix C provides a general listing of the types of land use data applicable to 208 planning that are normally available from various Federal, state, regional, and local sources. The objective is to provide the 208 planner with some assistance in locating appropriate land use data sources.

C.3.1 Federal Data Sources

Although many Federal programs (such as those under the Coastal Zone Management Act, the Clean Air Act, the Federal Water Pollution Control Act, and the Flood Insurance Act) have substantial primary and/or secondary impacts on the use of public and private land, no comprehensive catalog or directory of Federal land use data sources exists. While such a compilation has been proposed, efforts to date have stopped short of listing data series items in a "shopping list" format preferred by planners. However, several Federal departments have compiled directories of data and information systems within their agencies. Unfortunately, knowledge of how land is currently being used across the United States is incomplete for major portions of the country. Nonetheless, the paragraphs that follow outline the principal Federal agency repositories of land use data of potential value to the 208 planner and a foldout matrix of Selected Federal Programs Related to Regional Planning is attached at the end of this Appendix.

Six Federal agencies are likely sources of relative land use materials relevant to 208 land use planning. These agencies are as follows:

1. U.S. Department of Agriculture (USDA)
2. U.S. Department of Commerce (DOC)
3. U.S. Department of Housing and Urban Development (HUD)
4. U.S. Department of Interior (DOI)
5. U.S. Army Corps of Engineers (CoE)
6. U.S. Environmental Protection Agency (EPA).

Land use information from these agencies commonly exists in descriptive, inventory, statistical, and/or map formats, and is often available or obtainable through local or regional offices of these agencies. Agency headquarters addresses and telephone numbers are provided in Table C-2 for each of these agencies. Reference to local offices may be subsequently obtained from the respective headquarters operations.

The U.S. Department of Agriculture sponsors several continuing programs which provide data on the acreage and condition of the nation's total natural resources base.[2] The National Cooperative Soil Survey program of the Soil Conservation Service (SCS) has completed detailed maps of soil classifications and interpretations at scales of 1:15,840 to 1:24,000 for about 55 percent of the total U.S. land area. Reconnaissance soil maps at 1:250,000 and smaller scales are available for most parts of the country. Information contained in the detailed county soil survey reports can be used to appraise the effects of alternative land uses on the environment, and on the net productivity of the land resource; and to evaluate soil hazards and suitability for:

1. Farm and rural uses such as selection of kinds and varieties of crops, management practices, and yield predictions
2. Non-farm uses including location, design, and expected performance of local roads, streets, low buildings, septic tanks, sanitary landfills, and reservoirs
3. Forestry, recreation, and wildlife uses
4. Location of mineral deposits etc., e.g., gravel, sand, topsoil, and roadfill, and
5. Miscellaneous uses such as shopping centers, housing subdivisions, and industrial parks.

Watershed surveys, e.g., the P.L. 566 Small Watershed Program of the SCS, and cooperative river basin studies, commonly include map and tabular data of current and projected land uses (up to 50 years in the future) for such land use categories as cropland, pasture, forest, urban, and others.[2] Specialized areas such as flood plains and wetlands are also usually identified in such studies. This type of information can provide important input to the evaluation of alternative land use configurations for meeting present

TABLE C-2
ADDRESSES AND TELEPHONE NUMBERS OF KEY FEDERAL
AGENCIES POSSESSING LAND USE INFORMATION

Federal Agency	Headquarters Address	Telephone Number	Land Use Information Available
U.S. Department of Agriculture	14th St. and Independence Ave., S.W. Washington, D.C. 20250		
Office of Communication	(same)	(202) 447-2791	Information Sources
Rural Development Service	(same)	447-7595	Rural Data
Agricultural Stabilization and Conservation Service (ASCS)	(same)	447-5237	Conservation Programs
Extension Service	(same)	447-6283	Extension Programs
Forest Service	(same)	447-3760	Forestry Programs
Soil Conservation Service	(same)	447-4543	Soils Data and Maps
Economic Research Service	(same)	447-3050	Agricultural Production
U.S. Department of Commerce			
National Oceanic and Atmospheric Administration Office of Coastal Zone Management	6010 Executive Boulevard Rockville, Maryland 20852	(301) 656-4060	Coastal Zone Management Programs
Social and Economic Statistics Administration	Bureau of the Census Washington, D.C. 20230	(301) 763-5557	Population/Economic Data
U.S. Department of Housing and Urban Development	451 Seventh Street, S.W. Washington, D.C. 20410	(202) 655-4000	701 and Block Grant Programs & Flood Plain Programs
U.S. Department of the Interior			
National Park Service	Washington, D.C. 20240	(202) 634-1001	Parks and Recreation
Bureau of Land Management	(same)	343-5717	Public Land Management
Bureau of Outdoor Recreation	(same)	343-4805	Recreation
Bureau of Reclamation	(same)	343-4662	Western Water Resource Development
Bureau of Mines	2401 E Street, N.W. Washington, D.C. 20241	(202) 634-1001	Resource Inventories
Geological Survey	12201 Sunrise Valley Drive Reston, Virginia 22092	(301) 860-7000	Land Use & Resource Maps & Statistics, Aerial Photography
Bureau of Indian Affairs	1951 Constitution Avenue, N.W. Washington, D.C. 20245	(202) 343-7435	Indian Reservation Information
U.S. Army Corps of Engineers Office	Chief of Engineers Department of the Army Washington, D.C. 20314	(202) 693-6456	Public Works, Dredging & Flood Plain Management Information
U.S. Environmental Protection Agency		(202) 755-2933	EPA Land Use Policy
Office of Land Use Coordination	401 M Street, S.W. Washington, D.C. 20460		
Water Planning Division	(same)	(202) 755-2217	EPA 208 Program Activities

and projected land use needs in the 208 program.

The Census of Agriculture and Forest Service Statistical Reporting Service programs provide annual statistical tabulations of land areas in crops, forest, and other agricultural uses on a county basis for most of the U.S.[2] The USDA Soil and Water Conservation Needs Inventory provides a land use inventory of over 19,000 watersheds and indicates those watersheds that are potentially feasible for development under the Watershed Protection and Flood Prevention Act (P.L. 566). County totals of data collected during this inventory are published for each state in tabular format according to a seven-category land capability classification scheme which relates to the capability or suitability of the landscape for agricultural purposes. This information is commonly available at state SCS offices. Aerial photography at scales of 1:24,000 and smaller is used in several USDA agricultural programs. This photography is available for nearly every county in the United States and may include several years of photography that documents historical land use change in the region. Information about available USDA photography may be obtained from county SCS and/or ASCS offices. The photography may be purchased in print and index sheet formats from the USDA Data Center at the following address:

U.S. Department of Agriculture
2505 Parley's Way
Salt Lake City, Utah 84109
(801) 524-5856.

The U.S. Department of Interior, whose responsibilities include the management of over 500 million acres of Federal land, has several programs which generate land use data. The National Cartographic Information Center (NCIC) has been established to provide users with one-stop access for acquiring information about maps, charts, geodetic control, aerial and space imagery, and related cartographic data generated by Federal and ultimately state, local, and private sources. The NCIC usually does not hold the data for which it provides information and access, but it manages a system that provides a link between the user and the data. The center enables customers to find out what cartographic information and materials are available, to place an order, to pay or submit a purchase order, and to receive copies of the information or materials in a reasonable time. The NCIC is both an active information office and the management center of a network of linked data repositories, including those not administratively part of NCIC.[3] The address of the National Cartographic Information Center is:

U.S. Geological Survey, Stop #507
National Center
Reston, Virginia 22092.

The Resource and Land Investigations (RALI) program of the Land Information Analysis Office (LIA) within USGS, and the Divisions of Topography and Geology provide several maps and related land use data bases applicable to 208 planning. Through the Land Use Data and Analysis (LUDA) program begun in 1974, the USGS is undertaking the first comprehensive land use inventory of the United States using the same land use classification system.[4] High altitude National Aeronautics and Space Administration (NASA) photography and other supplementary data are being analyzed with a sophisticated machine-aided analysis system to perform this inventory. The land use classification system is comprised of seven generalized Level I land use categories which are subsequently broken down into more detailed land use classifications. The seven Level I categories are:

1. Urban and Built-up Land
2. Agricultural Land
3. Rangeland
4. Forest Land
5. Water
6. Wetland
7. Barren Land.

The LUDA program was expected to provide 1:250,000 land use and land cover maps for the entire U.S. by 1980. However, this target date may not be reached because of funding problems. The minimum areal unit to be mapped is 10 acres for urban and built-up uses, water areas, confined feeding operations, other agricultural land, and strip mines, quarries, and gravel pits. All other land use/land cover categories, including Federal land holdings, are being delineated with a mimimum unit of 40 acres. For each land use and land cover map being produced, overlays also are being compiled which show Federal land ownership, hydrologic units, counties, and political subdivisions. Computerized graphic displays and statistical data on current land use and land cover will also become available through the program. However, LUDA land use information and products for specific 208 regions may not be completed in time to be useful to 208 programs and the level of detail may not be sufficient to fill specified land use data needs. To determine the status of the LUDA program for a specific region contact:

Dr. James R. Anderson
Chief Geographer
U.S. Geological Survey
12201 Sunrise Valley Drive
Reston, Virginia 22092
(703) 860-6344.

The National Topographic Map Series of the U.S. is complete only at 1:250,000 but topographic maps are most commonly used by local and regional organizations at a scale of 1:24,000 and 1:62,500 for mapping of land use, geological and topographic features, and many other purposes since such maps include relief (by contour lines), water bodies, vegetation, and cultural features. Orthophotoquad maps, which are vertical aerial photographs in quadrangle format and which combine the metric qualities of a line and symbol map with the visual qualities of a photograph, and other planimetric base maps are being prepared by USGS in a 3-year program to provide, by 1977, 1:24,000 base maps for all areas not currently covered at that scale. Also, the National Topographic Map Series is the only nationally available base map series tied to the geodetic control network, and therefore the only one that can provide the positional accuracy needed for computer data handling. An extremely handy reference available from NCIC is a pamphlet entitled, "Types of Maps Published by Government Agencies". The pamphlet gives a listing of types of maps, their publishers, and addresses where more information may be obtained about ordering procedures. Topographic maps are also available from state Geological Surveys.

Geological and mineral resource maps are generally available at small scale (mostly 1:250,000) from the Geological Survey. The Bureau of Mines also collects, compiles, analyzes, and publishes statistical and economic information on all phases of mineral resource development, including the exploration, extraction, processing, and use of mineral resources, and the reclamation of lands disturbed by mineral extraction and processing. Other agencies within the Department of Interior such as the Bureau of Land Management (BLM), Bureau of Outdoor Recreation, Bureau of Reclamation, National Park Service, and the Bureau of Indian Affairs may also have selected land use information on specific areas under their jurisdiction which may be located within or adjacent to the boundaries of a 208 region. BLM and EPA have established a cooperative agreement to share data and planning efforts in regions where BLM administered lands are significantly involved in the 208 program.

The Department of Housing and Urban Development (HUD) maintains some regional land use data, e.g., maps of flood hazard areas. However, the focus of HUD's land use activities is on providing block grants to assist state and local governments in dealing with community development planning efforts. HUD also administers the 701 comprehensive planning program whose regulations now require that each recipient state formulate a land use policy by August, 1977. The land use outputs of the 701 program at the state and regional level will include:[5]

1. Long- and short-term policies, and where appropriate, administrative procedures and legislative proposals, with regard to where growth should and should not take place
2. The type, intensity, and timing of growth
3. Studies, criteria, standards, and implementing procedures necessary for effectively guiding and controlling major decisions as to where growth shall and shall not take place
4. Policies, procedures, and mechanisms necessary for coordinating local, areawide, and state land use policies with functional planning systems (e.g., coastal zone management, air and water quality, transportation, solid

waste etc.) and with capital investment strategies, when available, and improvements in governmental structures, systems and procedures that will facilitate the achievement of land use objectives

5. Consistent land use and housing policies.

The availability of specific land use information, e.g., from 701 programs, can be acquired from regional planning agencies (often the 208 agency also), and from HUD district offices.

An interagency agreement between HUD and EPA has also been established to insure consistency between the 701 land use element and the land use-related provisions of the water quality management plan. The agreement also states that performance criteria will include the land use outputs for both programs.

Within the Department of Commerce, the Bureau of the Census serves as a center for collecting, compiling, analyzing, and publishing a broad range of general purpose statistics dealing with economic, social, and demographic data which may be indicative of land use characteristics in a 208 area. However, rather than being based on standard map series or linked to precise geographically referenced points, the socioeconomic data series is referenced to street addresses, city blocks, or census tracts, or they are aggregated to even larger units such as minor level divisions, cities, urbanized areas, counties, SMSA's, states, or water resource regions. The water resource regions approximate hydrologic units in that they are defined by county within major river basins. It should be noted that data disaggregation will likely be necessary since the designated 208 region will seldom coincide directly with the units used to aggregate land use information for other purposes. Many of these units are also shifting spatial areas in the sense that their boundaries are subject to changes over time which may require interpolation of the data for trend analysis studies. Census data are generally available in published tabular formats at local public libraries. The National Oceanic and Atmospheric Administration (NOAA) also located within the Department of Commerce administers the Coastal Zone Management Program in which 30 participating states are required to prepare land use plans as part of their coastal zone programs. However, NOAA itself is not a source of land use data. The 208 planner should make full use of any land use information available from a Coastal Zone Management agency whose program includes all or part of the 208 study area.

The U.S. Army Corps of Engineers may have specific map and statistical land use information available from the river basin inventories and flood plain studies they commonly undertake. Urban Study and Environmental Reconnaissance Inventory Programs that are currently under way at some of the Corps Districts may generate land use data useful in 208 planning efforts.

The U.S. Environmental Protection Agency maintains a small Office of Land Use Coordination but does not collect or disseminate land use data. However, EPA does maintain computer files of air quality (SAROAD) and water quality (STORET) data which may be of primary value in 208 land use planning programs. EPA also has a Remote Sensing Laboratory in Las Vegas, Nevada, and an Environmental Photographic Interpretation Center (EPIC) in Warrenton, Virginia. In addition, EPA has sponsored considerable land use research of direct relevance to the 208 program. The reports from some of these studies are cited in the annotated bibliography section of Appendix G.

C.3.2 State Data Sources

The availability of state land use data varies considerably from state to state. Few states have undertaken a general indexing of land use data sources, and only nine states have adopted a major state land use program: Colorado, Florida, Hawaii, Maryland, Nevada, North Carolina, Oregon, Vermont, and Wyoming. Less than half of the 50 states have land use maps covering the state at any scale, and less than a dozen have detailed information. The maps that do exist range widely in scale, resolution, classification categories, sources, age, and purpose. Most state maps are overlays of the National Topographic Map Service at scales of 1:500,000 or 1:250,000, which consequently may not provide detailed information required for 208 land use planning programs. Usually, the most current land use information available at the state level has been assembled as part of a specific Federal program such as the HUD 701 Comprehensive Planning Program or the NOAA Coastal Zone Management Program. The major type of state agencies from which land use data can most likely be obtained include the departments/agencies of Agriculture, Natural Resources, Development, Transportation, Geological Survey, and Aerial Engineering.

C.3.3 Regional/Local Data Sources

Probably the land use information most relevant (in terms of useful format and availability) to 208 programs is likely to be available from regional/local sources. As previously mentioned, certain Federal and state offices located in the general area are likely to be good sources of state or Federal land use information for that region. In addition to maintaining local historical information, public libraries are also repositories for many state and Federal documents. Libraries may also have copies of general environmental information, and environmental impact statements which may contain pertinent land use information. Land ownership records (if required) are commonly available at the office of the county recorder. Regional planning agencies (which may be the designated 208 agency) maintain libraries of published and unpublished land use data and maps, as well as topographic base maps, that have been compiled during HUD 701 or EPA 201 planning programs. These agencies also are normally responsible for preparing growth projections and maintaining land use control maps such as zoning maps. County and/or city public service departments and special district organizations, e.g., sanitary districts or drainage districts, maintain transportation base maps, water and sewer service maps, and park and recreation maps. Private utility companies (electricity, gas, and telephone) also normally maintain utility corridor maps and frequently conduct land use inventories and prepare land use projections for business planning purposes. Local Chambers of Commerce may also have relevant land use information, and sometimes compile demographic data for the half interval between national census dates.

C.4 Matching Land Use Data Needs with Available Data Sources

Now that potential land use data needs have been identified and compared with the data needs of more traditional land use planning programs, and the Federal, state, and local data sources have been characterized, this section will briefly discuss the matching of the perceived data needs with the available data sources.

Since data availability is likely to be one of the most significant constraints in selecting techniques for the land use and the water quality analyses, it is often best to do a preliminary data collection survey in order to identify any major data gaps that could preclude the use of certain techniques. This preliminary survey of data availability from Federal, state, the local sources should help give the 208 planner a reasonable indication of the quality of the existing land use data base for the study area. When this information is compared with the data requirements of the various land use analysis techniques available for use, deficiencies in the data base will emerge as well as the presence of extraneous data that are not necessary to accomplish subsequent land use and water quality analyses. The data gaps identified will require the development of plans for primary and/or additional secondary data collection efforts. These plans should include estimates of the costs anticipated for additional data collection, since the constraints of budget may necessitate the use of a less sophisticated land use analysis technique, more fitted to the existing data base, where the costs of acquiring the data necessary to employ a more sophisticated technique are prohibitive.

The objectives of the preliminary data survey may be summarized as follows:

1. To assure that the data requirements of the selected land use and water quality analysis techniques are met by the existing land use data base, or can be met with additional secondary, and if necessary, primary data collection efforts, e.g., new aerial photography, at reasonable cost
2. To eliminate early in the evaluation process those data that are extraneous to the specific needs of subsequent analyses.

Meeting the above objectives will help minimize the time and money spent on subsequent data collection and analysis.

Thus, the selection of land use data management and analysis techniques consistent with the results of a preliminary survey of data availability is a very important step in the land use element of the 208 planning process. If relatively simple, manual land use evaluation techniques will be employed, the data needs will not be as demanding, and the data sources will likely be more easily accessible. The more demanding the data requirements of the selected technique, the more rigorous the search of data sources is likely to have to be in order to meet those requirements.

With respect to filling identified data gaps a more thorough search of data from the same kinds of data sources previously identified is a logical first step. Where additional secondary data cannot be found to fill data gaps, primary data collection efforts may be required. Such efforts might include having the planning area flown to acquire current aerial photography supplemented by selected field surveys, for example.

Section C.7 discusses the data input requirements and product outputs of a range of land use and demographic analysis techniques in more detail. This section should be of some assistance to the 208 planner in matching the data requirements of desired techniques with the quality of the existing land use data base as identified in a preliminary survey of data sources.

The next three sections provide more detailed information on the subjects of land use data collection, data management, and data analysis, respectively. Each section discusses the range of potentially applicable approaches to each topic, from simple to complex.

C.5 Land Use Data Collection Techniques

The land use element of the 208 program must initially describe the existing land uses within the designated study area. The 208 agency can complete this requirement in two ways:

1. Existing secondary land use data commonly available within

the 208 agency and from other relevant sources can be utilized with little to no primary data collection efforts, or

2. Inventory programs can be established for the collection of primary land use data.

Factors which should be considered before initiating a land use data survey include:[6]

1. Costs
2. Availability of trained professional personnel
3. Constraints of the time frame imposed
4. Utility of the data in subsequent analyses
5. Reliability of the data in terms of quality
6. Ease of data base updating
7. Versatility in displaying and extracting information from the data useful in other agency programs.

EPA <u>208 Planning Guidelines</u> state that the process of incorporating land use considerations into the 208 plan should rely primarily on utilizing existing land use plans, projections, and controls. However, in some 208 regions, the necessary land use information available from secondary data sources is inadequate to support the desired level of analysis. Existing regional land use statistics and maps available from secondary sources are often prepared for other purposes. Thus, they may not provide comprehensive coverage of the designated 208 region. Land use map and statistical information acquired from various secondary sources generally vary in format. The age and accuracy of data may also vary.

In general, when any new source and/or method of data acquisition is being considered, it is necessary to assess whether it is more efficient (cost-effective in terms of time, money, and manpower) to collect new data directly or to collect, collate, and possibly reorganize or reformat existing data bases and fill existing data gaps. Governmental programs and/or funds for collecting specific land use data required for a 208 plan generally are limited. Care must be exercised so that the land use data collection activities do not become an enormous "sink" for both manpower and funds, which can easily occur, particularly if the ultimate use of the land use information is not kept in view at all times.

In the following sections, a range of simple to sophisticated alternative land use data collection techniques is described to aid the 208 planner in the collection of new data and in the filling of identified data gaps.

C.5.1 Relatively Simple, Low-Cost Land Use Data Collection Techniques

This subsection will describe some land use data collection techniques that are relatively elementary in design and that do not require expensive or sophisticated equipment, extended allotments of time, and significant formal prior training, but result in reliable land use information for filling land use data requirements. The four specific techniques presented below include extraction of land use information from:

1. Census data and Water Resources Council OBERS (Office of Business and Economic Research Statistics) regional economic activity projections in the United States
2. Existing land use projections and supporting documents such as zoning maps and water/sewer service area maps
3. Aerial photography.

More sophisticated and expensive land use information collection techniques are discussed in subsection C.5.2.

C.5.1.1 Census and OBERS Data

Bureau of the Census data include several series of publications, data files, and special tabulations. Unpublished nonstatistical materials such as maps and computer programs can be made available from the Bureau of the Census (subject to restrictions on disclosure of confidential information), for the cost of reproducing, transcribing, or tabulating the material. Census data generally available in local libraries may include the general statistical compendia and special publications covering the subjects of Agriculture, Construction and Housing, Foreign Trade, Geography, Governments, Manufacturing and Mineral Industries, Population, Retail Trade, Wholesale Trade, and Selected Service Industries, and Transportation. The Census Bureau's County and City Data Book is also a good summary source of census information by county. Additional information is available from the Bureau of the Census (including a description of surveys and computer products), and can be found in two publications:

1. Bureau of the Census Catalog, and
2. Bureau of the Census Guide to Programs and Publications.

The catalog is issued quarterly, while the guide reviews Bureau of the Census programs and publications in the 1960's and 1970's. If these two documents are not already in the library of the designated 208 agency, they are commonly available at public and university libraries, or they can be ordered from the U.S. Government Printing Office, Washington, D.C., 20402. The most important publication from the Bureau of the Census relative to population projections is entitled Population Estimates and Projections. This series of documents is published annually, and includes population estimates by county and by Standard Metropolitan Statistical Area (SMSA). These population estimates are also disaggregated to the township level for the census year, e.g., 1970, and a more current year, e.g., 1973.

OBERS projections are a planning tool prepared in response to a need for basic demographic and economic information by public agencies engaged in comprehensive planning for the use, management, and development of the nation's water and related resources. Various series of the projections have been published which correspond to the series of projected United States population estimates published by the Bureau of Census. OBERS reports include projections of economic activity for the nation; the 173 functional economic areas delineated by the Bureau of Economic Analysis for economic analysis; the 20 water resources regions and the 205 subareas, delineated by the Water Resources Council; the 50 states and the District of Columbia; 253 Standard Metropolitan Statistical Areas (SMSA's); the 173 non-SMSA portions of economic areas; and, the 204 non-SMSA portions of water subareas. Included are projections of population, personal income, employment, and earnings of persons, by industry for various years from 1980 to 2020. Also included are projections of land use by broad categories for the same 50-year period but with fewer intervening years covered. However, the amount of detail included in the OBERS projections varies by type of area, primarily because of the differences in the availability of historical data. The latest Series E OBERS Projections, and those which the EPA 208 Guidelines require for use, are based upon the Series E projected national population (1972). The data are available in seven volumes outlined as follows:

1. Volume I. Concepts, Methodology, and Summary Data
2. Volume II. BEA Economic Areas
3. Volume III. Water Resources Regions and Subareas
4. Volume IV. States
5. Volume V. Standard Metropolitan Statistical Areas
6. Volume VI. Non-SMSA Portions of BEA Economic Areas, and
7. Volume VII. Non-SMSA Portions of Water Resources Subareas.

Census and OBERS data must first be aggregated as accurately as possible for the designated boundaries of the 208 region. If appropriate, the OBERS data can be utilized for baseline and future population projections within the 208 study area. However, care must be exercised in using the OBERS projections, or any projections, in that the assumptions postulated and methods used to derive the projections must be consistent with the anticipated use of the data. Nevertheless, such projections provide an approximate indication of future conditions and may be further used as a benchmark framework for evaluation purposes.

If the existing land use and demographic baseline data and/or projections cannot be utilized or are not available, then available historical data may be used to provide a reasonably accurate indication of future population growth. Several approaches may be employed to produce such projections. However, there is no method which will yield results with 100 percent accuracy. Simple mathematical extrapolations of historical data based on some linear or curvilinear function are the easiest methods to apply. More complex methods include separate analysis of the individual socio-economic components (such as economic base activity) that impact population change, under various assumptions.

In general, population projections are based on techniques which analyze changes in birth, death, and migration components of population change. The three demographic methodologies most frequently used are the component, cohort-survival, and ratio methods.[7] Each of the three methods commonly utilize census data. The component method uses total population data to derive separate projections for births, deaths, and net migration. Those projected components can then be summed algebraically and added to the existing base population to derive the projected population at a future date. The cohort-survival method is the same as the component method except age-specific detail is used to derive all of the component projections. The ratio method is a projection of local area population based on the ratio of the local area population to the population of some larger area for which accepted projections are available.

C.5.1.2 Existing Land Use Data

As discussed in Section C.3., the most comprehensive sources of relevant land use information available to the 208 agency will probably be city/county and regional planning agencies located within the designated 208 region. Additionally, state and Federal offices located within the region may be sources of relevant information. All of the data available at these agencies may not be published, and original data from surveys may exist. Where this is the case, the data might be loaned to the 208 agency for analysis.

Planning documents and maps generally depict existing land use conditions and project future land use based on a set of development assumptions. A community planning document generally contains the following five elements:

1. A historical perspective of regional development
2. Inventories of existing environmental, population, land use, housing and transportation, and social conditions in the community
3. A discussion of the major development issues and community development goals
4. A projection of future conditions within the community and region, and

5. Recommended implementation policies, standards, and controls. Such documents should be carefully reviewed to extract relevant water quality/land use information.

Cursory examination of other various secondary data sources may identify interrelationships among the factors that affect land use within the region. For example, it may be determined from census data that the population of a city has increased by an average of 150,000 residents per decade since 1940. From tax assessment records it might be established that acres of residential land use have increased an average of 50,000 acres per decade over the same time period. Therefore, if a relatively stable relationship between population growth and residential land use expansion exists, the future increase in residential acreage may be estimated. This, of course, assumes that the historical trend will continue into the future.

Various large scale map and supporting statistical data available from sources within the 208 region generally will contain information useful for updating existing land use information and for estimating future land use patterns. Generalized slope maps can be derived from existing topographic maps by measuring the linear distance between contour intervals and determining the ratio of the linear distance to the distance between contour intervals. Street maps, subdivision plat maps, and records of building permits are frequently used to update existing land use map and statistical information. Zoning maps and other land use control documents, and existing and proposed public water and sewer lines can serve as guides in projecting the location of future growth. Sanborn maps, which are prepared by fire insurance underwriters, also provide very detailed land use information for updating maps. Features included on these maps include streets, railroad tracks, building dimensions, and uses of buildings in commercial areas of cities. If available for a given region, these Sanborn maps can be obtained from major insurance companies operating in the study area.

The above land use data collection techniques utilizing existing land use materials are best suited for urbanized areas of the region. Land use information for nonurbanized areas is generally not as abundant. This information generally relates to resource utilization and production rather than to land development. Probably the best sources of land use information for rural areas are compilations of township tax maps and data. Depending upon the jurisdiction, breakdowns of agriculture land use acreages may be provided for various tax rates by lands in cultivation, pasture, forest, built-up areas, and water bodies. Tax records also commonly indicate acreages of commercial, residential, and industrial land on a parcel-by-parcel basis. Location and production volumes of extractive industries are potentially available from state or county offices which issue permits for resource extraction. Agricultural production statistics and soil maps of the area are usually obtainable from the local county office of the Soil Conservation Service (SCS), the local cooperative extension service agent, and other agricultural organizations. Rural zoning legislation (if existing) may also provide an indication of future land use and water quality conditions within the rural area. Regional offices of the U.S. Forest Service may also have useful data on the renewable resources and land use patterns of a given region.

C.5.1.3 Aerial Photographic Data

Conventional aerial photography (panchromatic, color, and color infrared imagery) from low to medium altitudes (5,000 to 30,000 feet) is generally available or readily obtainable at relatively large scales in print or transparency format from local aerial survey companies. Aerial photographs acquired at these altitudes possess sufficient resolution from which a considerable amount of data on existing land use and natural resources can be extracted. The expense of acquiring new aerial photography may not be economically justifiable if the intended use of the data is for supplemental 208 land use information, unless the photography can be acquired as part of another governmental program and/or can be flown by a governmental agency.

A photographic scale of 1:24,000 (1" = 2,000 ft.) is very appropriate for 208 planning purposes since USGS topographic maps and other reference data are often mapped at that scale or multiples thereof (1:12,000 or 1:48,000). Another optimum scale is 1:63,360 (1" = 1 mile). The 9" x 9" black-and-white prints can be duplicated for approximately $2 each.[8] Index sheets and a controlled mosaic of aerial photography in print format at 1:24,000 can be readily used for data analysis purposes and as a communication medium for public participation purposes. These aerial photographic products should be prepared by professionals. Enlargements of high altitude National Aeronautics and Space Administration (NASA) or Department of Interior color or color infrared photography can be similarly used.

A 208 agency staff member with photo-interpretation experience, or an aerial survey company familiar with the landmarks and characteristics of the 208 region, can use a mosaic of aerial photographs, transparent overlay material, and perhaps a stereoscope or a small magnifying glass to identify, delineate, and construct map overlays of the major land use features (such as industrial complexes, water bodies, parking lots, large feed lots, and other features) of direct concern in 208 planning. Different levels of accuracy and resolution may be required for varying levels of pollutant load analysis, depending upon the criticality of a particular area. For example, it may be much more important to highlight cattle feedlots than wheat fields on maps of rural portions of the study area. If multidate photography flown a decade or earlier is available, urban/rural interfaces can be delineated; and, with a hand planimeter the urban areas measured to determine the extent, direction, and rate of urbanization.[9] The costs of obtaining a general land use classification map by purchasing and analyzing recent black and white aerial photography range from $4 to $15 per square mile.[8] While the accuracy of product will depend to a large extent upon the accuracy of the mosaic, the interpretation skills of the photo-interpreter, and the mapping techniques employed, the procedure can inexpensively satisfy certain 208 land use data requirements. However, depending on the detail of the land information required and the size of the 208 designated area, manual interpretation of aerial photographs may be impractical in terms of cost and time. Time constraints are significant because the 208 program is only a two year effort, and the land use inventory is an input required very early in the program. If time is judged to be a critical factor and the 208 agency wishes to maintain the same detail of data analysis, consultant firms possessing more sophisticated data analysis facilities may be used to provide the required analysis on a more timely basis (See Section C.5.2.).

C.5.2 Relatively Sophisticated and Expensive Techniques

This subsection will describe field survey and remote sensing techniques for collecting land use data applicable to 208 planning. These techniques generally are more expensive and often require sophisticated equipment and specially trained personnel to provide reliable land use data compared to those techniques discussed previously in subsection C.5.1.

C.5.2.1 Field Survey Techniques

Field surveys can be made to collect land use data for a variety of reasons including to:

1. Determine the accuracy of existing land use information
2. Fill identified data gaps
3. Update and supplement existing land use data, and
4. Provide land use data for statistical field plots for extrapolation to other areas in the region via remote sensing analysis techniques.

In preparing for a field survey, existing data sources should be reviewed prior to the survey. Routes should be selected which include all areas to be visited as appropriate. Field surveys are usually accomplished by a pair of staff members traveling by auto along existing roads in the region. Two people are required as one serves as navigator and data collector while the other drives the vehicle. Visual inspection of the area can similarly be conducted by aerial reconnaissance flights flown at low altitude over the region. Such flights may provide members of the planning staff with a quick and synoptic overview of existing land use patterns of the region and is a simple way to survey remote areas that are difficult to access by other modes. Clipboards, notebooks, and existing aerial photographs and maps of the area, folded or cut to the appropriate size, on which data voids have been delineated, are required for a field survey. During the survey it may be necessary to question local residents about land uses of hard-to-access areas. Photographs of representative land uses can be taken during the field survey for subsequent inclusion in reports or for slides for use in public presentations. Upon completion of the survey, the data should be transferred from working maps and notes into a more refined format. The costs of obtaining general land use information via windshield survey analysis are approximately $5.00/square mile.[6]

More elaborate and costly field survey methods may be required to obtain land use data on a parcel-by-parcel basis if no other sources of land use information exist. Detailed planning prior to field work is required and training sessions for participating staff are necessary to insure uniformity and to eliminate ambiguity in data classification and data collection techniques. Coding sheets with specific formats and instructions are required as well as large-scale base maps for land use data mapping purposes.[10] However, such detailed surveys will probably not be required to obtain land use data for most 208 land use planning programs. Other data collection techniques, such as interpretation of aerial photography, generally provide comparable levels of land use information quicker and less expensively.

C.5.2.2 Remote Sensing Techniques

Remote sensing (which includes satellite imagery and aerial photography) is an outgrowth of aerial photographic interpretation and involves the collection of data by systems which are not in direct contact with the objects or phenomena under investigation. The technological development of remote sensing systems (sensors and platforms) has generally outstripped corresponding development of interpretation methodologies and techniques, which are needed to convert remotely sensed data into usable information. However, interpretative and analytical procedures have been developed and demonstrated which 208 agencies can purchase from private firms to acquire land use information.

The major advantage that sophisticated remote sensing land use data acquisition and machine-aided or computerized analysis techniques provide is a timely and comprehensive analysis of the entire designated 208 area using the same data base and data evaluation scheme. Requirements for field surveys may also be reduced.

Other advantages of remote sensing techniques include:

1. Land use changes can be monitored and the corresponding map and statistical information updated
2. Interpretation subjectivity of land use classifications is minimized once spectral signatures for land use features have been determined
3. Land use features are displayed during analysis in final or near final form and require little or no additional interpretation
4. Land use features can be displayed individually and at a variety of scales
5. Statistical summary tables of land use features for any area in the region can be quickly generated.

Three major limitations of the current state-of-the-art land use applications of remote sensing techniques are:

1. The acquisition and interpretation of the data requires professional expertise and sophisticated equipment considerably beyond that existing within a typical 208 agency
2. Extensive ground truth measurements and field verification efforts may be required to assure that accuracies of 90 to 95% are achieved for detailed classifications at large scales, and
3. The cost of using remote sensing data acquisition and analysis techniques will generally exceed the cost of extracting land use data from existing data sources, unless it is more efficient to use the new data source than to perform manipulations required to put existing data into useful form.[8]

Table C-3 illustrates the various sources of remote sensing data and general applications of data obtained from the various platforms. Aircraft photography will generally be most appropriate for providing land use data required for 208 planning purposes. Table C-4 provides an indication of the film types, season and scale of aerial photography most appropriate for specific

TABLE C-3

ELEMENTS OF A COORDINATED REMOTE-SENSOR PROGRAM

FOR LAND AND RESOURCE MANAGEMENT

Data Source	Data Output Quality	Applications
LANDSAT Satellite (unmanned)	Low spatial resolution Broadband spectral resolution Small-scale wide-area coverage	Repetitive data base Synoptic update of temporal dynamic changes in Skylab derived regional land use & resource baseline Trend projection
Skylab Satellite (manned)	Moderate to high spatial resolution Narrowband spectral resolution Small-scale wide-area coverage	Static data base Land use baseline Regional land resource evaluation data base Enhance LANDSAT interpretation in defining high-priority areas
High-Altitude Aircraft Photography	High spatial resolution Moderate scale	Specific coverage, as required Detailed analysis of high-priority areas Correlative data base for field activities & decision-making
Low-Altitude Aircraft Photography	Very high spatial resolution Large scale	Specific "pinpoint" area coverage, as required Specific land use & urban area studies Detailed engineering analyses Complete remote-sensor data base
Field Investigations	Specific point investigations Quantitative spectral measurements	Surface or urban sampling Verification of remote-sensor analyses derived from satellite & aircraft data Coordinated data base for decision-making

Source: National Aeronautics and Space Administration, Skylab Earth Resources Data Catalog, Lyndon B. Johnson Space Center, Houston, Texas, 1974, page 52.

TABLE C-4

GUIDELINES FOR AERIAL SURVEYS

Description of Task	Film Type	Season	Scale
Forest mapping; conifers	B & W Pan	Fall, Winter	1:12,000-1:20,000
Forest mapping; mixed stands	Color IR	Late spring, fall	1:10,000-1:12,000
Timber volume estimates	Pan or IR	Spring, fall	1:5,000-1:20,000
Locating property boundaries	B & W Pan	Late fall, winter	1:10,000-1:25,000
Measuring areas	B & W Pan	Late fall, winter	All scales
Topographic mapping; highway surveys	B & W Pan	Late fall, winter	1:5,000-1:10,000
Urban planning	B & W Pan	Late fall, winter	1:4,800-1:9,600
Automobile traffic studies	B & W Pan	All seasons	1:2,400-1:6,000
Surveys of wetlands or tidal regions	B & W IR	All seasons-low tide	1:5,000-1:30,000
Archeological explorations	B & W IR	Fall, winter	1:2,400-1:20,000
Identifying tree species	Color	Spring, summer	1:600-1:4,800
Assessing insect damages	Color IR	Spring, summer	1:600-1:5,000
Assessing plant diseases	Color IR	Spring, summer	1:1,200-1:7,200
Water resources and pollution	Multispectral	All seasons	1:4,800-1:8,000
Agricultural soil surveys	Color	Spring or fall, after plowing	1:4,800-1:8,000
Mapping range vegetation	Color	Summer	1:600-1:2,400
Real estate assessment	Color negative	Late fall, winter	1:4,800-1:12,000
Industrial stockpile inventories	Color negative	All seasons	1:1,200-1:4,800
Recreational surveys	Color negative	Late fall, winter	1:5,000-1:12,000

Source: T. Eugene Every, Photointerpretation for Land Managers, Eastman Kodak Company, Rochester, New York, 1970, page 19.

data analysis tasks. In general, panchromatic black-and-white film with various filter combinations is likely to provide the most useful and inexpensive photographic data base for land use analysis. Color infrared photography is also a very useful data source for determining land use patterns but costs approximately three to five times more than black-and-white photography. Other remote sensing media, such as thermal infrared, radar and laser sensors, will probably not provide land use data that otherwise cannot be obtained by less expensive remote sensing systems. However, thermal infrared data may be very important for determining the location of point sources of thermal pollution. Assistance in the planning of an aerial survey should be sought from local aerial firms, state agencies or remote sensing schools at state universities who, from local experience, can aid in the determination of the optimal photographic film/filter and scale for a land use inventory of a particular region.

Commercial contractors and Federal and state governmental agencies are the primary repositories of existing aerial photography and have the required multispectral camera and scanning systems for acquiring recent remotely sensed data in both photographic and digital formats. In general, commercial contractors acquire aerial photography at low and medium altitudes (5,000 to 30,000 feet), and selected governmental agencies acquire and maintain large volumes of photography taken at medium and high altitudes. Satellite imagery and photography acquired as part of NASA's LANDSAT (formerly ERTS-Earth Resources Technology Satellite) space program are also available for purchase by the general public through the:

U.S. Geological Survey
Earth Resources Observation System
Sioux Falls, South Dakota 57198
(605) 594-6511

Selected aerial survey and mapping firms, specialized architectural and engineering firms, and some research and development firms have the staff and maintain the expensive facilities and equipment for machine-aided and computerized analysis of remotely sensed data. Costs for analyzing remotely sensed data are dependent mainly upon the size of the area and the number of classification parcels per area, and to a lesser degree on the scale of the product and the difficulty of interpretation. Costs for obtaining and analyzing satellite photography to provide generalized land use classifications for a 208 region have ranged from $.50 per square mile for general classifications to $1.50 per square mile for intensive multi-feature classifications.[6]

General characteristics of remotely sensed data which are used to identify, map, and inventory natural and cultural land use/land cover features are the shape, size, tone, location, and texture characteristics of the feature on the imagery. Each land feature absorbs, reflects and emits light in a characteristic way and thus can be identified by its "spectral signature". Various combinations of filters, films and sensors are used to record the differences in spectral reflectance. Ground truth data obtained through field work and low altitude photography of small sample areas are commonly required as identification keys for identifying specific land use/land cover features of a larger area.

A variety of land use data products of direct value to 208 planning can be obtained from remotely sensed data using sophisticated techniques. Color additive viewers employ density analysis techniques to produce thematic maps that show, for example, all cement and blacktopped paved areas (impervious surface), general intensity levels of urbanized development, areas of new construction, and areas of land under cultivation. Density analysis includes the separation of photographic images to display discrete levels of reflectivity, and such viewers generally have built in electronic planimeters which give an instantaneous readout of the land area associated with the specific land use being displayed. Computers can statistically analyze massive quantities of digitized spectral data and determine fine variations between spectral responses which can also be used to identify land use patterns. Computer classified, color-coded, composite land use maps have been produced from LANDSAT imagery which show dominant land use features at an approximate cell or "pixel" size of 1.4 acres. Since LANDSAT data is in digital format, data can be summarized by county, drainage basin or other statistical unit.[11]

Major limitations of land use information obtained by the above sophisticated remote sensing data collection and data analysis techniques are that the weather must be virtually cloud free, and that unrelated land uses may have the same spectral characteristics and thus be incorrectly identified. For example, a plowed field and a construction site may be placed in the same classification, or conversely, an agricultural field crop such as wheat may be misclassified as grassland. Also, not all desired land use classifications e.g. small feedlots may be discernible at reasonable expense, and thus manual photo-interpretation or field surveys may be required to obtain certain land use classifications. In general, the more sophisticated remote sensing techniques are more applicable for obtaining land use information of large rural areas than urban areas. Land use information obtained through remote sensing programs requires field verification to determine levels of accuracy. Nevertheless, remote sensing techniques can be successfully employed to map and inventory large areas at relatively large scales on a timely basis, and produce specific land use data related to water quality programs that may not be otherwise obtainable.

C.6 Identification of Land Use and Demographic Data Management Techniques

Once land use and demographic data have been acquired from secondary sources or produced by the 208 agency, the agency must determine the procedures to be employed for managing the data. This data management function often includes data transfer, data storage, and data manipulation and extraction activities. The two basic data handling options are manual, and computer-aided techniques. Each technique is briefly described in the subsections that follow.

C.6.1 Manual Data Management Techniques

Manual data management techniques are those techniques which are accomplished by human skill, often aided by drafting, photographic, and photogrammetric equipment, but not by a computer. In general, these techniques are still used to carry out most tasks of spatial data handling.

Discussed below are selected manual land use and demographic data management approaches that might be employed by 208 agencies. Included are discussions related to the transfer and storage of data, as well as data manipulation and extraction.

Data transfer is defined as the way in which data in map, graphic, tabular, or report format from a variety of sources are grouped into one comprehensive data base. This process of moving data from various documents to form another data base can be done before the data are stored or at any time thereafter.

The transfer of descriptive data is generally a straightforward task of copying alphanumeric information by various methods such as photocopying, or hand-copying, and the summation of data into graphic or tabular formats. Reproduction facilities should be located in the immediate vicinity of the data center. A copier is a valuable asset for furnishing quick copies to users and can be leased for about $3,000 to $6,000 per year. Since the cost of constructing, equipping, and maintaining a photographic laboratory is generally prohibitive for a 208 agency in terms of anticipated benefits, arrangements should be made with another governmental agency or a commercial firm to provide any photographic services that may be required. The manual transfer of image data (photographs and maps), on the other hand, is a complex operation, particularly when the accuracy and the relationships between the elements must be retained. The transfer of image data may involve two types of data: planimetric or non-planimetric. Planimetric image data are positionally accurate and have a uniform linear scale. Topographic maps and orthophotographs are examples of planimetric image data. Conversely, non-planimetric data, such as aerial photographs, have inherent distortions that affect accuracies of measurement.

For almost all 208 land use planning efforts, it will be sufficient and cost effective for 208 agencies to work with documents in the non-planimetric form rather than incur the expense of producing a planimetric map or photograph.

The transfer of non-planimetric data can simply be completed by using visual guidance aids (such as overlay grids at varying scales) or calculated reference points to transfer the necessary information to a new record base. If great care is exercised, a high degree of accuracy can be achieved. Light tables are useful for transferring transparent or translucent images. A simple and inexpensive light table can be constructed by placing a light bulb in a metal desk drawer and using a heavy frosted plate-glass or opalescent glass as the table surface. Reflecting projectors (overhead projector) are also useful for projecting the image of an illuminated photograph or other source material through a lens and one or more mirrors onto a map overlay or other manuscript. More expensive and accurate photogrammetric instruments that are not frequently found within a planning agency, but are often used by engineering and mapping agencies to transfer planimetric image data, include copy cameras, rectifiers, stereoscopes, and stereoscopic plotters and orthophotoscopes.[8]

The selection and arrangement of facilities for storage of maps, aerial photographs, reports and other land use and demographic planning data are important to assure ease of access and to provide adequate protection from dust, sunlight, dampness and careless handling. Maps are conveniently stored in map files. A typical steel map file case consisting of two five-drawer units with inside drawer dimensions of 50 x 38 x 2 inches costs approximately $650. Aerial photographs are commonly stored in vertical file cabinets but stiff cardboard dividers should be placed between flight lines for each of access and to prevent the photographs from curling. If cut from rolls, aerial photographic transparencies should be placed in plastic protectors to prevent damage from scratching and fingerprints.[8]

Data should be indexed using appropriate library card catalog procedures. Almost all standard map series such as USGS 1:24,000 (7 1/2 minute) maps, and county highway maps have graphic indexes available for map indexing purposes. Also, photo indexes of aerial photographs, which are made by creating a mosaic from exposures of specified areas and adding flight data, geographical references and other information, are very useful for locating specific aerial photographs.

No data base is very useful unless pertinent information can be extracted, manipulated, and used efficiently. Manual data manipulation operations are performed on data to make them more suitable for further processing, e.g. to improve their comparability, or to facilitate their retrievability. Data extraction involves the process of selecting and retrieving data from storage for subsequent analysis.

Manual data manipulation is often required to correct inaccuracies in the data and to overcome compatability constraints arising from the use of the data for analysis. Generally, some summarizing or generalization of the data does not substantially lessen the amount and value of the data, but care must be exercised to avoid the loss of any information. Depending on the type of data manipulation, time required for manipulation, volume of data, and possible use of the data, this operation can take place either when the data are prepared for storage or when they are retrieved from storage for use.

Specific manual data manipulations that may be required include:

1. Synthesis of data from various data sources into graphic or tabular formats
2. Map or photo scale changes and/or adjustments
3. Reclassification of descriptive data, e.g., changing feet to meters
4. Aggregation of data onto another aerial base, e.g., census tracts or transportation corridors to drainage basins
5. Generalization of data records based on similar descriptor codes to the same descriptor coding scheme (for example, deciduous forest and conifer forests into forest land) and
6. Coding of image data by using various grid patterns

Such data manipulations normally are labor-intensive, but labor requirements can be reduced by the use of calculators, grid overlays, and drafting equipment. A pantograph, which is a simple drafting device that mechanically links a drawing device to a cursor with which the original image is traced, is commonly used to copy and change map scales. More expensive optical transfer equipment not normally found in planning agencies, such as zoom transfer scopes, also can be used to superimpose photographs onto maps or transfer map data onto another map.

In data extraction processes, the selection of specific data inputs is based on the requirements of the particular analysis to be made and on the knowledge of the contents of the data center from previous experience or data files. The time, effort, and costs involved in all types of search and identification operations are substantially influenced by how the data elements are organized and indexed. This is why the development of a well-organized data management system is so important in 208 planning efforts, whether that system be manually operated or computer-aided as discussed in the next subsection.

C.6.2 Computer-Assisted Data Management Techniques

More sophisticated than the manual data management techniques just discussed, computer-assisted techniques also may be utilized for land use data transfer, storage, and manipulation by 208 agencies. If the data base to be utilized is very large and/or very complex, or if computer models are to be used for subsequent analyses, the 208 staff should consider the use or computer-assisted data management.

Clearly, access to computer facilities is a prerequisite for the use of such techniques. Since many designated 208 agencies do not have an in-house computer capability, it may be necessary to arrange for computer access from other public agencies or from private consulting firms if computer-assisted data management techniques are selected. Rental fees and use rate expenses (excluding staff charges) for computer services for a 208 agency would likely range from $5,000 to $7,500 per year. It should be noted that an agency-wide data base that includes data relevant to other planning programs, e.g. transportation planning, may be the best approach if an investment is to be made in a computer-assisted data management system. This would also facilitate accounting for these other kinds of planning programs in the 208 planning process. It would also provide a solid data base that could be easily updated and quickly accessed as the agency moves into the continuing planning process after the initial 2 year 208 planning effort.

It is important to recognize that, as with manual data management, special care must be taken to avoid errors in the data placed into the computer-assisted data management system. Any attempt to use other than error-free data files can have disastrous effects on subsequent analyses, since the computer can only deal with conditions that have been explicitly defined, whether correctly or incorrectly.

It is also important for the 208 practitioner to recognize that a total data management system can be conceived of as a logical set of techniques, some performed manually and others with the use of the computer, with the objective being to optimize the performance of the total system. Thus a combination of manual and computer-assisted techniques may provide the designated 208 agency with the optimal approach to data management.

C.6.3 Selecting a Data Management Approach

While it is not possible to deal with the variety of agency-specific data management needs in a manual of this type, this subsection provides some general guidance on selecting an approach to data management, whether that approach uses manual, computer-assisted, or some combination of the two types of techniques.

The assessment of the differences between manual and computer-assisted approaches to data management involves the following considerations:

1. Data complexity
2. Operational flexibility
3. Costs
4. Time requirements
5. Personnel requirements.

The paragraphs that follow briefly discuss each of these considerations.

The complexity of the data base is important to evaluate before the selection of a data management approach is made. If the data base is not very complex, and if the data are already or can be aggregated easily by hand, then manual data management techniques are most appropriate. However, as the complexity of the data base and the volume of the data at hand increase, computer aided techniques generally are more desirable than manual techniques.

With respect to operational flexibility, there are advantages and disadvantages to both manual and computer-assisted techniques. Manual approaches are very flexible as long as there is enough time available to do the data manipulation. On the other hand, computer-assisted approaches generally are more rigidly structured, but in general can be programmed to provide data management flexibility much quicker than manual techniques.

Clearly, cost considerations are extremely important in the selection of an appropriate data management system. It is impossible to provide a meaningful range of costs for manual data management systems here because of the wide range of data management needs in individual 208 agencies. As mentioned previously, rental fees and use rate expenses (excluding staff charges) for computer services range from $5,000 to $7,500 annually. For 208 agencies with in-house computer capability, the economics of computer-assisted data management will be more favorable. In-house expertise and/or consultant services should be utilized to provide the specific cost figures for manual or computer-aided data management systems tailored specifically to the agency's needs.

In terms of time requirements, the 2 year time frame of the 208 program may significantly affect the desirability of going to a computer-assisted data management system. If in-house computer facilities do not exist, it may take too much time to organize the data base, develop or acquire the computer capability, and get the data into the system. If the in-house capability is already present, or can be quickly acquired, computer-assisted techniques become more desirable, especially since they commonly expedite the subsequent data analysis effort. It should also be noted that manual techniques might be used for the initial 2 year planning period while plans are formulated for the use of computer-aided systems in the continuing planning process. In this instance, the manually managed data base should be prepared in a manner that will expedite conversion to a computerized data base at some subsequent date.

Finally, the personnel requirements for manual and computer-assisted approaches are somewhat different. Manual techniques may utilize existing agency staff to a large extent while computer-aided approaches require computer science expertise, e.g. computer programmers, and data management specialists. Even if consultants are utilized, it is recommended that some in-house expertise in computer science be acquired to effectively direct and coordinate the work of the consultants.

Each of the above considerations should be included in the assessment of alternative approaches to data management. How they are used, and the relative importance of these considerations in the decision-making process must be left to the individual 208 agencies.

C.7 Inventory of Land Use and Demographic Data Analysis Techniques

The discussion in this section of the Appendix covers a wide range of land use and demographic data analysis techniques from the simple, traditional approaches to the more complex, sophisticated approaches. The emphasis is on the practical application of such techniques in the context of 208 planning. Each technique will be discussed in terms of the following elements:

1. A brief description of the approach, and the kinds of input data required
2. A description of the output of the technique, and how the output might be used with other tools/techniques, such as water quality models, to formulate and evaluate water quality management alternatives
3. An outline of potentially significant constraints on the use of each technique, along with suggestions on how to avoid potential problem areas
4. A summary of the strengths and weaknesses of the approach relative to the 208 program
5. An estimate of relative costs for each technique.

C.7.1 Relatively Simple, Low-Cost Techniques

This subsection will discuss techniques for demographic and land use analyses at the relatively simple end of the spectrum of potential techniques. These techniques make maximum use of the existing secondary data bases likely to be available to the 208 planner. In terms of cost, they are the least expensive techniques to implement, although they are not as analytically sophisticated as some of the other approaches.

Demographic and economic projections are very important to subsequent land use analyses. The next few paragraphs outline a simple technique for performing the demographic projections for the 208 program which involves the use of data available from the U.S. Bureau of Census, and the Social and Economic Statistics Administration, both in the U.S. Department of Commerce. Data from both these sources, namely census and OBERS data respectively, are possibly already utilized within each designated 208 planning agency for other planning programs. Data collected from the above two sources (see Section C.5) might be utilized by the 208 agency as a baseline from which historical population growth rates can be extrapolated by 5 year increments for the 20 year planning period. The output would be population projections by SMSA, County, and/or township for the 208 region. These data would then serve as inputs to subsequent land use calculations. Using this sort of desk top extrapolation technique assumes that the historical growth rates will hold over the next 20 years. Modifications of the growth rates can be made to generate alternative scenarios for the future.

The use of OBERS Series E population data is also a very attractive, relatively simple option for the 208 agency to use for its demographic projections. Of particular interest to 208 agencies is Volume III, where the data are aggregated by water resources regions and subareas. The units of aggregation in this Volume include twenty major regions defined by hydrologic boundaries that are further divided into tributary and main stem reaches entitled water resources subregions. The subregions cut across county lines to coincide with drainage patterns. However, the water resources subareas are actually county-defined approximations of the actual hydrologic units they represent. In some instances, the 208 agency's planning area may closely approximate the water resource subarea boundaries, in which case the population projections can be utilized directly for the increments given. In other cases, one of the other levels of data aggregation, e.g. by Bureau of Economic Analysis region, may be easier for the 208 agency staff to work with. This determination must be made by comparing the study area boundary with the various data aggregation boundaries, and picking the most appropriate one. Whatever the case, the population data are available by county from 1929 and are projected to 2020. Using these data, the 208 planner need not extrapolate as mentioned previously with the census data since the projections are given in appropriate 5 year intervals. Thus, the OBERS projections are of direct utility to subsequent land use projections. The technique is simple to complete and is likely even less expensive than having the staff extrapolate from census data. One note of caution is in order, however. The assumptions made to arrive at the OBERS projections are explicitly stated in Volume I. (See Section C.5). If these assumptions represent significant violations of the prevailing conditions in the subject 208 region, then extrapolations using different assumptions would be more appropriate.

It should also be noted that many states have their own programs that generate population and economic projections. Likewise, many universities engage in similar projection activities. It is conceivable that projections formulated from such sources would be more appropriate for some 208 programs. For example, if there is one or more 201 planning efforts ongoing in a given 208 region and the 201 program is using state projections, the 208 program should consider the need for consistency in the use of the same state projections.

The simplest approach to the land use element of 208 is to make maximum use of existing land use maps, as well as any maps of projected land use configurations in the study area. Using these maps (if available), the major drainage areas in the 208 region should be superimposed upon the existing and projected land use configurations. Once this is complete, a planimeter can be used to calculate the square mileage and/or acreage of the various land use types in each drainage area. This information will be useful in making water quality projections when associated with precipitation data and estimated runoff characteristics. These land use/drainage area maps can also be used to display the location of major point and nonpoint sources in the 208 region.

Where it becomes necessary to estimate the future land use configuration of a region, (for example the existing land use projections may be for the year 2000 without any indication of what the 1980 and 1990 configurations might be), the population projections can be used along with existing zoning maps, which commonly indicate residential densities, to estimate the extent of urban fringe development that would occur over a given time frame, e.g. over 5 year intervals. The allocation of anticipated population increases using graphic overlays of present zoning restrictions will provide the 208 planner with a picture of how the existing land use pattern might be expected to change incrementally over the 20 year study period. This information can again be utilized as an input to the water quality analyses by using a planimeter to derive acreage figures for each type of land use. It is anticipated that the greatest change over time will take place on the urban fringe. Thus, land uses within some drainage areas may be expected to change very little over the 20 year planning period.

The above techniques for estimating future land use patterns are relatively simple and inexpensive because they depend upon existing data and table-top analyses. They also do not have the sophistication and the analytical flexibility that is characteristic of some of the more complex techniques. The specific costs of the techniques are dependent upon what kinds of existing and projected land use maps are available at the local level, and for what future time periods. In most cases, the land use categories used for these maps will be compatible with the subsequent use of the information in the 208 planning process. This should be checked, however, and appropriate modifications in land use categories made if they are not useful for subsequent analyses.

C.7.2 Intermediately-Complex, Moderate-Cost Techniques

These techniques still involve only manually executed analyses, but include a more careful look at alternative futures in terms of land use/water quality relationships than the simple techniques described previously. Some primary data collection, e.g. aerial photography, will likely be necessary to perform these analyses instead of complete reliance on existing secondary data sources.

The demographic analyses in this category will still utilize, as a baseline, the census and/or OBERS data discussed previously. The principal difference between this approach and the simpler approaches is that a simple extrapolation of past growth rates is only one possibility evaluated. The 208 planner using the intermediately complex approach postulates alternative futures based upon other sets of conceivable assumptions. Thus a range of future growth scenarios is calculated based upon explicit assumptions made using the census or OBERS data as a baseline. A range of population growth scenarios is valuable to consider in the formulation of areawide plans that are sensitive to different alternative futures for the study area.

Again, this technique involves manual calculations using reasonable assumptions upon which to base population projections that differ from those assumptions found in the sources mentioned previously. This approach also allows for the incorporation of region-specific factors that may significantly inhibit or facilitate population growth, e.g., rapidly declining in-migration, that may not be accounted for in other projections.

The land use analysis techniques classified as intermediately complex attempt to incorporate more land use-related variables into the analysis, e.g., land use suitability based upon the physical features of the land surface. The most common example of a technique of intermediate complexity is the overlay approach conceptualized by Ian McHarg in his book <u>Design with Nature</u>.[12] A version of this approach the Land Use Decision-Making System (LUDMS), is described in an EPA publication entitled, "A Land Use Decision Methodology for Environmental Control."[13]

LUDMS utilizes a technique that focuses on the development of environmental analysis component maps. This approach consists of the formulation of a base map of appropriate regional scale and series of clear plastic overlays, each mapping a land use parameter relevant to the land use/water quality relationship. The base map should be relatively uncluttered, but should include major natural and man-made features, e.g. streams, lakes, significant political boundaries etc. The overlays should map the occurrence of key parameters of interest such as:

1. Aquifer recharge areas (based on regional geology)
2. Major point and nonpoint dischargers (from NPDES permits and other available water quality information)
3. Areas unsuitable for septic tank systems (based on soils data, regional geology, and water quality data inputs)
4. Areas with steep slopes (from USGS topographic maps)
5. Critical fish and wildlife habitat (from numerous potential sources, e.g. State Departments of Natural Resources etc.)
6. Existing water and sewer service areas, and projected service areas (from local public utility departments etc.).

These overlay maps can be utilized to illustrate development constraints related to water quantity and quality considerations. These constraints could, in turn, be used as a basis for modifying future land use projections in alternative ways that would be more sensitive to water resource management concerns.

In addition, the overlay technique can be used to identify and evaluate regions where development opportunities exist which will minimize adverse impacts on regional water resources, and the environment in general.

The map overlay from the above analysis can be utilized in conjunction with demographic projections and existing zoning maps to derive alternative future land use configurations for the study area. The procedures for this part of the analysis are similar to those previously described in the section on relatively simple techniques. The final output of the analysis will be one or more land use configurations that represent alternative future scenarios for the region. These future configurations should be more sensitive to water resource management concerns because this technique provides for a more explicit and intensive consideration of water quantity/quality concerns than the traditional land use planning process, upon which the more simplified techniques are more dependent.

The alternative configurations that evolve out of the analysis can then be tabulated in percentages of each land use type present in each drainage area in the planning region. A planimeter can be used to estimate the acreage of each land use type in each drainage area. These figures can then serve as an input to the water quality evaluations. These quantitative values can also be better tempered with qualitative judgement using this moderately complex approach, because of the more focused consideration of water resource-related parameters.

The overlay approach is likely to be more expensive than the simple approach described in the previous subsection due to the additional staff time involved in working with additional variables. The 208 planner needs to decide whether the additional information provided by the overlay approach is worth the additional expenditure. This decision will depend, in part, upon the confidence the planner has in existing land use projections, and in their sensitivity to water quality considerations.

C.7.3 Relatively Sophisticated, High-Cost Techniques

The final category of demographic and land use analysis techniques involves the relatively sophisticated computer
that follow discuss several such approaches, some of which are being employed in ongoing 208 programs.

One example of a computerized demographic projection model is the Demographic and Economic Modeling System (DEMOS) developed by Battelle's Columbus Laboratories. DEMOS is useful for the following applications relevant to 208 planning:

1. Projecting population characteristics by single year, five year or other appropriate intervals, and by political subdivision
2. Analyzing spatial patterns of population distribution
3. Analyzing migration propensities
4. Analyzing demographic structure and labor force potential.

Items 1 and 2 above are particularly relevant to the land use element of the 208 planning process.

DEMOS utilizes many facets of previously developed projection tools such as the cohort survival technique, but combines these concepts with region-specific factors that influence population and employment growth. For example, the model concentrates upon relationships between migration and unemployment, birth rates and unemployment, labor force participation rates and the ratio of employment to population, and labor availability and the demand for labor. Through these relationships, economic and demographic conditions in a given region can be interrelated via demographic, economic, and feedback submodels to provide the practitioner with realistic projections that can be modified to reflect varying assumptions. The model's basic outputs are population by age, employment by industry, and labor force by age, although numerous other variables may also be explored in the model.

It should be noted that one of the attractive aspects of DEMOS and some other similar models such as SEMOS, a model used by the Southeast Michigan Council of Governments (Detroit) in their 208 program, is that it is available in a computer-interactive form. This is to say that the planner can sit at a computer terminal, and with very little previous experience, perform regional projections with varying assumptions. The computer program actually leads the user via a series of questions through the projection process, affording him or her the opportunity to explore the model's assumptions, and the mathematical equations upon which the model is based.

The computerized approach to demographic projections has advantages and disadvantages that should be considered by the 208 planner before an approach is selected. The primary advantages are the flexibility the models afford the user in exploring alternative futures quickly and relatively inexpensively after the "front-end" investment is made, and the increased sophistication and regional sensitivity provided by such an approach. The major disadvantages are that the acquisition of the computer access, the support facilities, and the model are relatively expensive relative to reliance on census or OBERS data. Projections for a 5 county 208 area down to the township level cost in the range of $23,000-27,000 including staff time. This disadvantage might be overcome somewhat by working out a cost-sharing arrangement with other programs and/or agencies, since most planning efforts rely upon good demographic projections. The use of such models also requires staff expertise that may not be present in some 208 programs.

An exhaustive discussion of other demographic projection techniques, including computer models, is found in Demographic Information for Cities: A Manual for Estimating and Projecting Local Population Characteristics written by Peter A. Morrison (see Annotated Bibliography section of Appendix I).

The Toledo, Ohio, 208 program has employed a computer-based information system called the Land Resources Information System (LRIS).[14] LRIS serves as a good example of a relatively sophisticated land use data management and analysis technique. It is designated to measure the co-occurrence of land resource features in a manner that facilitates the measurement of an area's potential for nonpoint source pollution.[14] The technique involves a multivariate analysis on a watershed basis of the impact on water quality of land cover, soils characteristics, and slope variables. The data inputs to LRIS include land cover data derived from an analysis of recent color infrared aerial photography; soils information from available soil surveys; elevation data to the nearest 5 feet derived from USGS 7-1/2 minute quadrangle maps; and location information identifying points by minor watershed, political subdivision, and in metropolitan Toledo, by traffic zone. Special care was taken in the formulation of LRIS to insure the aggregability of data into larger units.

The data are organized according to a 4 hectare rectangular grid system that covers the entire 2006 square mile study area. An unaligned random sampling technique is used to place a single point within each grid cell at which the data for the different variables is recorded to represent the entire cell. The only exception is with the land cover variable for which two decisions are made for each cell, namely the dominant land cover in the entire cell, and the exact cover at the randomly placed point.

By using the data system described above, the Toledo Metropolitan Area Council of Governments is able to identify the co-occurrence of land resource characteristics, e.g. little vegetative cover, and steep slope, that significantly affects regional water quality. To date LRIS has been utilized as a tool for analyzing nonpoint source pollution, as well as for generalized land use planning.

The advantages of such a technique are significant. First of all, the data base is up-to-date for the analyses. The data are well-organized, highly accessible, easy to store, and the computer program facilitates the analytical work. The same system is also very relevant to other ongoing planning programs, e.g., transportation, coastal zone management, and solid waste programs.

The front-end costs of developing such a system are substantial compared to the less sophisticated techniques discussed previously. This kind of approach also requires some in-house staff capabilities in computer science, and data management.

Another land use model of potential interest to 208 planners, is a model developed by A.B. Corbeau and C.F. Meger to evaluate future land uses in the St. Louis SMSA.[15] The model is designed to allocate anticipated population and employment in 10 year increments to parcels of land categorized into four categories:

1. Industrial
2. Residential
3. Commercial, and

4. Public.

Desirability criteria relative to each land use type drive the land allocation process in the model. The data inputs for the model include economic data such as the number of people engaged in a particular land use-related activity; regional population projections; and parameter override factors that permit specific anticipated land use changes as well as controls on population density. The output of this model includes summary reports on the land allocation process by land use type, along with what are called diagnostic reports containing detailed information on each land unit being modelled. This kind of information would be useful in the 208 planning process for anticipating conversion of one land use type into another. This information can then be translated into anticipated water quality impacts using tools discussed elsewhere in this Manual.

The general advantages and disadvantages of the St. Louis model are much the same as those discussed previously relative to the Toledo approach. More specifically, this particular model is quite flexible, and could be applied to most 208 regions. A weakness of the model, however, is that the ranking of the desirability of certain land development is subjective.[15]

One final model of possible applicability to 208 planning is the Dynamic Land Use Allocation Model III (DYLAM III) developed by David Seader and Peter Masseri.[16] This model has been utilized in a water supply study, in a flood plain and stormwater management study, and for numerous long range land use planning efforts.

In essence, DYLAM III simulates land use location decisions allowing for the projection and analysis of probable development.[16] The model also has the capability to simulate the impact of proposed facilities and alternative policies on land use patterns.

In terms of input data requirements, DYLAM III is quite flexible in that it can accomodate any information that can be mapped in a grid cell data format. For example, one study that used the model involved, in part, the following mapped data elements:[16]

1. Moderately sloping land
2. Steeply sloping land
3. Flood plains
4. Swelling soils
5. Water and sanitation districts
6. Industrial parks
7. Lakes and streams.

The model can accommodate up to 60 such elements, and the elements can be tailored specifically to the problem at hand, e.g., characterizing the land use/water quality relationship.

The basic work of the model is to geographically distribute anticipated increments of development. It should be noted, however, that the total estimated acreage of new development must be an input to the model. The model's work involves five basic tasks described briefly as follows:

1. Search for sites, defined as grid cells
2. Determine a grid cell's suitability for development based on input locational requirements
3. Compute a numerical attractiveness of suitability score
4. Rank all developable grid cells from the most to least attractive based upon the numerical scores
5. Allocate the amount of new development specified to the most suitable grid cells.

The conceptual framework of DYLAM III lends itself to a potential 208 application in which the locational requirements for development include relevant water quality and quantity considerations.

The output of the model includes both tabular and mapped information. The maps include present and projected land use configurations at the end of each time period used. The maps highlight where new development occurred. The tabular information indicates the projected order for site development.

The model also has the capability to produce maps illustrating one or more data base elements superimposed on one another. The composite maps produced in this manner can be very useful in highlighting potential water quality problems associated with projected development as discussed in the previous subsection.

The model has the same advantages and disadvantages that the other computer models discussed have had, along with some DYLAM III specific advantages. The model is very flexible in terms of being applicable to a broad range of potential land use-related concerns, including those of the 208 program. The mapping capability is very useful in most applications, including those for 208. The model can also be easily fitted to a broad range of geographic areas, from a single municipality to a large multi-county region.

There are a couple of potentially significant disadvantages of DYLAM III also. Land use development can only be simulated by rectangular grid cells in the model. In addition, only one land use can be assigned to each grid cell at a time, and all the data utilized in the model are nominal data. That is, either the data element is present or absent in a given grid cell. Various degrees of presence cannot be accommodated.

Additional material on potentially relevant land use planning models may be found in the following two documents (See Annotated Bibliography):

1. "Review of Operational Urban Transportation Planning Models", U. S. Department of Transportation
2. "Models and Methods Applicable to Corps of Engineers Urban Studies", U. S. Army Engineer Waterways Experiment System

C.8 Appendix Summary

This Appendix has attempted to provide the practicing 208 planner with some assistance in developing the land use element of the areawide water quality management program. The focus has been on the following topics:

1. Identification of land use data needs
2. Identification of existing data sources and characteristics

3. Matching of data needs with available data sources
4. Collection of land use data
5. Identification of demographic and land use data management techniques
6. Inventory of demographic and land use data analysis techniques.

In each case, the discussion has been structured to provide the practitioner with a range of potential approaches to land use data collection, management, and analysis, from simple to complex. As mentioned at the outset, this Appendix is not designed to be prescriptive in any way, but rather is meant to provide a "shopping list" description of potential approaches along with supporting documentation. The references that follow and the Annotated Bibliography in Appendix F provide the reader with sources of additional information on topics discussed herein that may be of further interest.

C.9 References

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    Timothy G. Mara
    OKI
    426 East 4th Street
    Cincinnati, Ohio 45202
    (513) 621-7060

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APPENDIX D

MONITORING REQUIREMENTS, METHODS, AND COSTS

D.1 Introduction

The nation's waters are as mixed and varied as its population and, just as there is no single measure of human health, there is no single measure of water quality. Furthermore, the nation's waters themselves (ground waters, streams, lakes, estuaries, and coastal waters) vary considerably in size, geological features, flow characteristics, climate and meteorological influences, and the type and extent of human impacts on them, and all these factors have a bearing on water quality.

Most definitions of water quality today are use-related, and each water use is sensitive to different pollution types and levels. For example, sufficient dissolved oxygen is critical to fish and other aquatic life but of little significance to drinking water supplies or swimming. On the other hand, coliform bacteria counts are a classical water pollution measure for human contact or ingestion but have little significance for most industrial uses or aquatic life. Even for the same parameter, the critical concentration for which one use begins to be impaired may be quite different from the level at which another use is affected. Thus, water quality monitoring - the collective activity that allows determination of the suitability of a particular water source for a specific use - is heavily use dependent. It is one thing to evaluate the lower Mississippi River as a drinking water supply and quite another to evaluate Lake Erie for swimming, a small stream in Michigan for trout fishing, or the South Platte River for irrigation. A different monitoring effort would be required for each.

D.1.1 How to Use This Appendix

In view of the foregoing, this Appendix cannot be a cookbook. Its overall objective is to provide the 208 planner with a range of information, considerations, and techniques that will allow him to design and implement a water quality monitoring program that is suited to his particular requirements. As indicated in Chapter 1 of this Manual, special emphasis is placed on equipment and methods suitable for storm-generated discharges.

The organization of this Appendix is indicated in Table D-1. By referring to it, the reader can locate information on the topic of immediate interest, e.g., where to look for available water quality data, how to select test catchments for stormwater model calibration and verification, how to choose an automatic sampler, etc. The topical organization is intended to support the chapters in the main body of this Manual by allowing quick reference to specific information, but it is recommended that this entire Appendix be read and understood thoroughly before implementation.

D.1.2 Purposes and Objectives of 208 Monitoring

The broad objective of a monitoring activity is to provide information upon which decision-makers can act. A more specific statement of objectives is required, however, for design and implementation of a monitoring effort. Examples of more specific monitoring objectives of interest to 208 agencies include:

1. Establishing baseline conditions
2. Determination of assimilative capacities of streams
3. Following the effects of a particular project or activity
4. Pollutant source identification
5. Long-term trend assessment
6. Waste load allocation
7. Projecting future water characteristics

TABLE D-1. ORGANIZATION OF APPENDIX D

TABLE D-1. ORGANIZATION OF APPENDIX D (Cont'd)

These monitoring objectives include both point and nonpoint source considerations involving variable and intermittent as well as continuous flows (see Chapter 1 of this Manual). In particular, Section 208 of PL 92-500 has focused money and attention on stormwater runoff and the need for urban runoff quality planning. The goals of such planning efforts are to define the runoff problem, identify potential solutions and costs, and measure the effectiveness of solution alternatives versus costs. Planning of this nature requires a method of evaluation that can provide comprehensive and areawide analysis, including the prediction of alternative futures. Mathematical models represent a developing tool that can be used by planners to meet these needs (see Appendix A). Such models require field data for their calibration and verification, and monitoring for this objective, along with problem assessment monitoring, will be emphasized in this Appendix.

A detailed listing of some USEPA uses for monitoring information is given in Table D-2. From a review of this table, it is readily apparent that a proper understanding of what is sought is paramount in the design and implementation of any given monitoring activity. Furthermore, the objectives should be reduced to writing, not only to ensure careful consideration of what they actually should be and help prevent misunderstandings by those involved, but also to set the limits, and thus discourage the pursuit of interesting but nonessential bypaths. These objectives will also provide a basis for measuring the extent to which the results of the effort meet the needs that justified the undertaking.

To illustrate the form such objective statements might take, several examples will be given. These were taken from actual 208 program efforts that are being designed and implemented now.

The stated objective for an instream sampling survey is to provide water quality and flow data for calibration and verification of a continuous water quality simulation model which will be used to simulate existing and future

TABLE D-2
SOME USEPA USES OF MONITORING INFORMATION

Develop/revise water quality standards

Develop/revise 303 basin plans

Develop/revise 208 areawide plans

Develop/revise 201 facilities plans

Document progress toward achievement/maintenance of ambient standards and legislative goals

Monitor primitive areas for background levels and significant deterioration

Development of baseline information

Model validation/development

Develop health research/control techniques

Develop/evaluate Environmental Impact Statements

Develop/revise effluent standards

Formulate/revise discharge permits

Determine permit compliance

Develop/revise drinking water standards

Develop/revise pesticides monitoring plan

Develop/revise toxic standards

Develop/revise pretreatment standards

Investigate single pollution incidents (fish kills, oil spills)

Develop/assess/revise point source control strategies

Develop/assess/revise nonpoint source control strategies

Allocate resources

Report indices, trends, etc., to the public

Support enforcement actions

Develop/revise waste load allocations

conditions in selected streams and rivers in northeastern Illinois. Since organic pollutants and nutrients are considered the most general and widespread water quality problems in the region, the sampling and analysis program is designed to provide information necessary to simulate these parameters.

The stated objective for a land use runoff study is to determine nonpoint source pollution loading functions for homogeneous land uses. Transferability of data is required, since these loading functions will then be applied to other areas throughout the region.

The stated objective for a lake study is to determine, in terms of quantity and quality, the pollutional load from nonpoint sources that enters Lake Michigan during storm events. Note that this objective does not suggest that a complete survey of Lake Michigan be undertaken (a task of great magnitude) but, rather, seeks to determine what is going into the lake.

The three foregoing statements of objective were selected to illustrate that being specific and concise can go together (and should). As a final example, the following eight objectives are stated for an urban nonpoint source monitoring network:

- Collect basin rainfall and runoff data for 14 Philadelphia area drainage basins.

- Calibrate the USGS Dawdy parametric rainfall-runoff model using 3 to 5 years of data.

- Using long-term Weather Service rainfall records as input to the calibrated model, develop flood frequency duration curves for 14 urban drainage basins.

- Measure physical basin characteristics of the 14 urban drainage basins.

- Relate physical basin characteristics to optimized model parameters.

- Using developed regression relationships between model and basin characteristics, develop flood-frequency duration curves for ungaged basins.

- Verify results with collected data on selected test basins.

- Collect average stream quality data for development of quality trends as related to type of development.

Once the objective statement has been clearly formulated, the survey design can begin, but not before.

D.1.3 Types of Monitoring Activities

There exist a number of types of monitoring activities that can be employed in meeting overall monitoring requirements. Their suitability and applicability will depend upon the purposes and objectives of the particular effort involved. Included are (1) reconnaissance surveys, (2) point source characterizations, (3) intensive surveys, (4) fixed station network monitoring networks, (5) ground water monitoring, and (6) biological monitoring. The last two types of monitoring activities are broken out separately only because they require skills, equipment, and techniques that are markedly different from those used in the first four. None of these should be considered as completely separate activities in actual practice. Comprehensive data interpretation will require that all monitoring data be considered together.

A brief description of these monitoring activities follows, with emphasis placed on typical objectives of each. By comparing them, the reader can see how they differ and how they may be combined to meet overall 208 monitoring objectives.

D.1.3.1 Reconnaissance Survey

A reconnaissance survey is a general or overall examination of a particular area. It is a visual or superficial qualitative (and sometimes quantitative) survey. Typical objectives of a reconnaissance survey include:

1. Getting the "lay of the land" in preparation for an intensive survey.
2. Identification of all waste sources in a particular catchment.
3. Identification of water uses in terms of types, locations, quantities, and frequencies.
4. Determination of general stream characteristics.
5. Obtaining information necessary for establishing the overall design of a fixed-station network.
6. Investigation of reported pollution incidents or spills.

D.1.3.2 Point Source Characterization

A point source characterization (or effluent monitoring) study is one conducted to determine the characteristics of an identifiable, discrete discharge (either continuous or intermittent) into a receiving body of water. Although several point sources are usually involved in a complete survey, the mechanics of execution are basically similar, and the same general considerations apply. It is also possible that more than one measurement site (i.e., sampling and flow determination) might be involved as, for example, in a treatment plant efficiency study. Mass loading discharges rather than simple parameter concentrations are usually sought. Some objectives are:

1. Determination of frequency, quantity, and strength of combined sewer overflows.
2. Characterization of storm sewer discharges.
3. Determination of treatment plant efficiency.
4. Verification of a permit application.
5. Infiltration/inflow determination at a given site.

6. Verification of self-monitoring data with regard to permit compliance.
7. Determination of pretreatment requirements or verification of compliance with pretreatment standards.
8. Verification of toxic substances sources.
9. Case preparation (as part of an enforcement action).

D.1.3.3 Intensive Survey

Intensive surveys are major elements in a monitoring program. The intensive survey: (1) bridges the gap between the data bases generated by effluent monitoring and fixed-station monitoring; (2) provides a definitive basis for understanding and describing receiving water quality and the mechanisms and processes that affect water quality; (3) provides the documentation required to explain the trends observed at fixed network stations; and (4) is a tool for determining the ultimate fate of pollutants in the water environment.

Some generalizations concerning the overall nature of intensive surveys and their planning and execution follow.

1. Repetitive measurements of water quality are made at each station (sources and receiving water). The stations will typically comprise a short, very dense, sampling network throughout the duration of the field effort.

2. The duration of an intensive survey is dictated by the objectives of the survey, with 3 to 14 days being typical for freshwater streams, lakes, and reservoirs. Surveys in tidal bodies are typically more complex and longer in duration as are nonpoint source surveys (e.g., for calibrating a stormwater management model).

3. The measurements taken during an intensive study vary. A study may be oriented towards one particular type of data (chemical, biological, sediment, etc.) or it may involve the collection of many types of data.

4. Continuous and intermittent point and nonpoint sources within the survey area are usually monitored during the study.

Some major objectives of intensive surveys are:

1. Determining quantitative cause-and-effect relationships of water quality for making load allocations, assessing the effectiveness of pollution control programs, or for developing alternative solutions to pollution problems.

2. Setting priorities for establishing or improving pollution controls.

3. Supporting and setting priorities for enforcement actions.

4. Identifying and quantifying nonpoint sources of pollution and assessing their impact on water quality.

5. Assessing the biological, chemical, physical, and trophic status of publicly-owned lakes and reservoirs.

6. Providing data for the classification or reclassification of stream segments as being either effluent limited or water quality limited.

7. Evaluating the locations and distribution of fixed monitoring stations.

8. Calibrating and verifying stormwater management models.

Such objectives should be considered mutually compatible. The incremental cost of expanding a single-purpose survey into a multipurpose survey should always be evaluated prior to conducting the survey.

D.1.3.4 Fixed Station Monitoring Networks

The fixed monitoring network is a system of fixed stations that are sampled in such a way that well-defined histories of the physical, chemical, and biological conditions of the water and sediments can be established. In general, other monitoring data will be needed to explain, in detail, the trends observed at the fixed stations. Thus, a high level of coordination between the fixed-station monitoring network and other monitoring activities is essential for developing a useful data base. The basic objectives of fixed monitoring networks are to provide data and information that, when taken in combination with other data, will:

1. Characterize and define trends in the physical, chemical, and biological condition of surface waters, including significant publicly-owned lakes and impounded waters.

2. Establish baselines of water quality.

3. Provide for a continuing assessment of water pollution control programs.

4. Identify and quantify new or existing water quality problems or problem areas.

5. Aid in the identification of stream segments as either effluent limited or water quality limited.

6. Act as a triggering mechanism for intensive surveys, enforcement proceedings, or other actions.

D.1.3.5 Ground Water Monitoring

Because of the increasing threat to the quality of ground water posed by some waste management practices and a general lack of comprehensive information on the origins, scope, and nature of existing ground water pollution problems, it is important that programs be established and maintained to monitor ground water quality. Some objectives of ground water monitoring are:

1. Obtaining data for the purpose of determining baseline conditions in ground water quality and quantity.

2. Providing data for the early detection of ground water pollution or contamination, particularly in areas of ground water use.

3. Identifying existing and potential ground water pollution sources and maintaining surveillance of these sources, in terms of their impact on ground water quality.

4. Providing a data base upon which management and policy decisions can be made concerning the surface and subsurface disposal of wastes and the management of ground water resources.

Ground water monitoring has been extensively treated in a recent series of USEPA reports (1-5) and will not be discussed further in this Appendix. It is only mentioned here to point up its importance to the 208 planning process.

D.1.3.6 Biological Monitoring

Aquatic organisms and communities act as natural pollution monitors. Some organisms tend to accumulate or magnify toxic substances, pesticides, radionuclides, and a variety of other pollutants. Organisms also can reflect the synergistic and antagonistic interactions of point and nonpoint source pollutants within the receiving water system. Some objectives of a biological monitoring program are to gather biological data in such a manner as to:

1. Determine suitability of the aquatic environment for supporting abundant, useful, and diverse communities of aquatic organisms.

2. Provide information adequate to detect, evaluate, and characterize changes in water quality through the study of biological productivity, diversity, and stability of aquatic systems.

3. Detect the presence and buildup of toxic and potentially hazardous substances in aquatic biota.

4. Provide information adequate to periodically update the eutrophic condition classification of freshwater lakes.

D.1.4 Coordination With Other Monitoring Programs

An attempt to put 208 monitoring somewhat in perspective is presented in Figure D-1, taken from the National Water Monitoring Panel (6). It is obvious that if each functional purpose is to be productive, the proper information must be provided by the monitoring program. It also should be clear that persons responsible for monitoring must maintain a frequent and substantive contact with those programs requiring information. Finally, there is abundant need for coordination among all aspects of a monitoring program.

The importance of this last statement regarding coordination among monitoring activities can be emphasized by considering the following. At the federal level, legislative authority for monitoring is contained in at least six Acts:

- The Federal Water Pollution Control Act
- The Safe Drinking Water Act
- The Refuse Act
- The Marine Protection, Research and Sanctuaries Act
- The Federal Insecticide, Fungicide, and Rodenticide Act
- The Solid Waste Disposal Act

When combined with State and local legislation, the legislative mandates form an almost staggering dimension. The activities responsible for monitoring implementation form an equally large dimension. At the federal level alone,

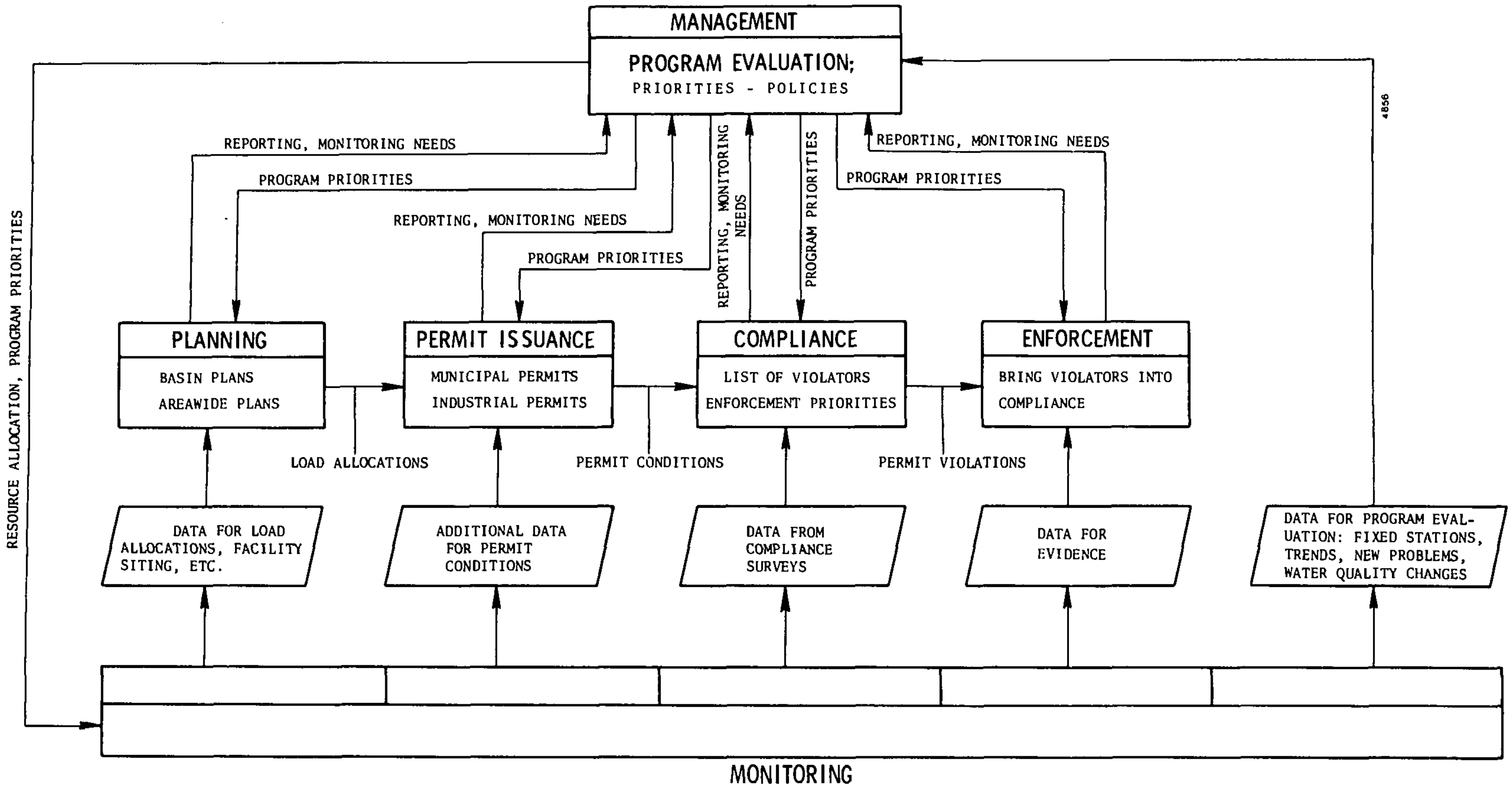


FIGURE D-1
MONITORING IN PERSPECTIVE

they include the U.S. Environmental Protection Agency; the U.S. Geological Survey; the U.S. Department of Agriculture; the Bureau of Reclamation; the Department of Defense, including the Army Corps of Engineers and the Naval Facilities Engineering Command; the Bureau of Mines; the National Aeronautics and Space Administration; the Occupational Safety and Health Administration; the Food and Drug Administration; the Energy Research and Development Administration; and others, not to mention special purpose monitoring efforts conducted by federal activities such as the National Science Foundation, the Council on Environmental Quality, the Office of Manpower and Budget, the Office of Technology Assessment, and so on. These efforts must be combined with those of the states, designated agencies, and all pollutant dischargers operating under effluent permits. Typically, monitoring efforts are far from centralized. For example, in the USEPA alone, monitoring responsibilities - encompassing both the collection and use of information - are found in 16 Headquarters offices under 5 assistant administrators. Similarly, USEPA field responsibilities are dispersed among the 10 regional offices and 13 research laboratories.

D.1.5 Available Data Sources

The prudent use of resources dictates that the maximum use practicable be made of existing data. For 208 planning, these can be grouped into three categories: meteorological, geographical, and water quality. Available data sources for each category will be discussed in turn. One caveat more or less applicable to each must be mentioned, however. All prior data may not be of acceptable quality (i.e., truthfulness, suitability, accuracy). Where at all possible, attempt to determine the original source and some indication of the "goodness" of the data. For example, USGS stream gage records are annotated with a somewhat subjective indication of the quality of the record, e.g., poor, fair, good, etc. Unfortunately, this is the exception rather than the rule. Be especially chary of water quality records; attempt to determine how the samples were taken, whether or not they were handled properly, and how the analyses were run.

D.1.5.1 Meteorological Data

The best source of long-term rainfall data in the United States is the National Weather Service (NWS). Data can be obtained from the NWS either on tape files or through published daily and hourly summaries. Tapes can be obtained by contacting:

U.S. Department of Commerce
National Climatic Center
NOAA Environmental Data Service
Federal Building
Ashville, N.C. 28801

Telephone (704) 258-2850

Data are available on two record files: Deck 448-USWB HOURLY PRECIPITATION and Deck 345-WBAN SUMMARY OF DAY. Most first-order stations are covered. The period of record is usually from August 1949 to the current data with some gaps. Long-term 5-minute data are also available from the NWS for over 50 major U.S. cities, and can be generated for most cities having a NWS city or airport office.

One word of caution; be sure to determine if there is a high aerial variability of rainfall for the region in question. For example, the total rainfall measured at the NWS station at Philadelphia International Airport was 44.47 inches for 1975. The totals for individual gaged catchments within the city for the same period ranged from 40 to over 60 inches, with a city-wide average of 51.37 inches.

Other meteorological data available from NOAA include snowfall, temperature, wind, sunshine and sky cover, evaporation, and humidity. Local data sources and the possible existence of data from previous studies should also be investigated.

D.1.5.2 Geographical Data

In this context, the term geographical is used in its broadest meaning. Chief among this category are land use data, but other physical, cultural, and demographic data will also be desired (e.g., catchment slopes and terrain, soil types, sewer maps, population distributions, etc.). Sources of such data are described in detail in Appendix C of this Manual, but generally include:

- U.S. Census Bureau
- Metropolitan Sanitary Districts
- State and local planning agencies
- Office of the County Surveyor (or equivalent)
- U.S. Coast and Geodetic Survey
- U.S. Department of Housing and Urban Development
- USDA Soil Conservation Service
- Standard Metropolitan Statistical Area Data
- Previous basin (303e) or facilities (201) plans

D.1.5.3 Water Quality Data

The STORET system of the USEPA is the largest source of water quality data in the nation. The system is operated as a utility serving states, areawide agencies, and other organizations. Data are stored in the system by the data collecting organization for their own purposes as well as for sharing with others. The STORET system should be queried for existing data during the initial design phase of the 208 areawide monitoring effort. USEPA headquarters and regional offices may be contacted for assistance in the use of STORET.

Other existing water quality data are widespread, but the recent establishment of the National Water Data Exchange (NAWDEX) should considerably assist users in locating and acquiring needed data. Unlike STORET, NAWDEX is not a large depository of water data. Rather, its objective is to provide the user with sufficient information to define what data are available, where these data may be obtained, in what form the data are available, and some of the major characteristics of the data.

The U.S. Geological Survey has the lead-role responsibility for NAWDEX. In this capacity, it has established the NAWDEX Program Office at its National Center in Reston, Virginia. This office became active in November 1975 and provides the central management for NAWDEX. It also has the responsibility for coordinating all operational activities within the program. This includes serving as liaison between NAWDEX members and users of the system.

The service capabilities of NAWDEX will be supported by a nationwide network of Local Assistance Centers established in the offices of NAWDEX members to provide local and convenient access to NAWDEX and its services. This network will initially be established in late 1976 in the 46 district offices of the U.S. Geological Survey. These offices are located in 45 states and Puerto Rico. Most are equipped with computer terminals, thereby providing an extensive telecommunication network for access to the computerized directory and indexes being developed for the NAWDEX program. As the NAWDEX membership increases, additional centers will be added in large population areas and areas of high user interest to provide improved access to NAWDEX and its services.

The NAWDEX Program Office is currently developing a Water Data Sources Directory. This directory will identify organizations that collect water data, locations within these organizations from which water data may be obtained, the geographic areas in which water data are collected by these organizations, the types of water data collected, alternate sources for acquiring the organization's data, and the media in which the data are available. This directory is scheduled for release in 1977.

A computerized Master Water Data Index is also being prepared which is scheduled for nationwide use in November 1976. This index will identify individual sites for which water data are available, the locations of these sites, the organizations collecting the data, the hydrologic disciplines represented by the data, the periods of record, water data parameters, the frequency of measurement of the parameters, and the media in which the data are available. More than 350,000 water data sites are currently being indexed from information contributed by 19 federal agencies and more than 300 non-Federal agencies.

Through its Water Data Sources Directory, Master Water Data Index, and indexes and other reference sources made available by its participating members, NAWDEX assists its users in locating data of special interest. These data include water data in computerized and in both published and unpublished forms. The user is then referred to the organization(s) having the needed data. NAWDEX thus serves as a central point of contact for locating water data that may be held by several different organizations. Data search assistance may be obtained from the NAWDEX Program Office or from any of the Local Assistance Centers.

To expedite locating existing data, NAWDEX and STORET should be queried at the same time. In addition to referring the user to STORET, NAWDEX will provide information on other data sources for the area under consideration in many instances.

Requests for services or additional information related to NAWDEX and STORET may be directed to:

National Water Data Exchange
U.S. Geological Survey
421 National Center
Reston, VA 22092

Telephone (703) 860-6031

STORET (WH-553)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Telephone (202) 426-7792

Local points of contact for the USEPA STORET system and state Water quality agencies are given in Chapter 2 of this Manual (Tables 2-4 and 2-7). Selected federal sources for water quality information are given in Table D-3. A call to the Federal Information Center, (202) 755-8660, with its staff of trained information specialists, will assist the user in finding the appropriate contact within any of these federal agencies.

TABLE D-3
SELECTED FEDERAL SOURCES FOR WATER QUALITY INFORMATION

Department of Agriculture

- Forest Service
- Soil Conservation Service

Department of Commerce

- National Oceanic and Atmospheric Administration
- National Bureau of Standards

Department of Defense

- Army Corps of Engineers
- Army Civil Engineering Research Laboratory
- Navy Facilities Engineering Command
- Air Force Civil Engineering Research Center

Department of Health, Education, and Welfare

- Public Health Service

Department of Interior

- Bureau of Reclamation
- Bureau of Land Management
- Bureau of Indian Affairs
- Bureau of Mines
- Bureau of Sport Fisheries and Wildlife
- Bureau of Outdoor Recreation
- Geological Survey
- Office of Saline Water
- Fish and Wildlife Service
- Office of Water Resources Research

Department of Transportation

- Coast Guard

Energy Research and Development Administration

Environmental Protection Agency

National Aeronautics and Space Administration

Nuclear Regulatory Commission

Water Resources Council

Council on Environmental Quality

D.2 Measurement Site, Parameter, and Frequency Selection

D.2.1 Site Selection

The location of measurement sites is critical to obtaining good quality data and properly interpreting them. The following discussion covers overall site location guidance, site selection for waste load allocation surveys, catchment selection for stormwater model calibration and verification, and specific local site selection criteria.

D.2.1.1 Overall Site Location Guidance

For overall background and problem assessment the following locations are recommended for the chemical and physical sampling of the water column. Biological and sediment stations should also be established at these locations, as appropriate.

1. At critical locations in water quality limited areas. Stations should be located within areas that are known or suspected to be in violation of water quality standards, ideally at the site of the most pronounced water quality degradation. The data from these stations should gage the effectiveness of pollution control measures being required in these areas.

2. At the major outlets from and at the major or significant inputs to lakes, impoundments, estuaries, or coastal areas that are known to exhibit eutrophic characteristics. These stations should be located in such a way as to measure the inputs and outputs of nutrients and other pertinent substances into and from these water bodies. The information from these stations will be useful in determining cause/effect relationships and in indicating appropriate corrective measures.

3. At critical locations within eutrophic or potentially eutrophic lakes, impoundments, estuaries, or coastal areas. These

stations should be located in those areas displaying the most pronounced eutrophication or considered to have the highest potential for eutrophication. The information from these stations, when taken in combination with the pollution source data, can be used to establish cause/effect relationships and to identify problem areas.

4. At locations upstream and downstream of major population and/or industrial centers which have significant waste discharges into flowing surface waters. These stations should be located in such a way that the impact on water quality and the amounts of pollutants contributed can be measured. The information collected from these stations should gage the relative effectiveness of pollution control activities.

5. Upstream and downstream of representative land use areas and morphologic zones within the area. These stations should be located and sampled in such a manner as to compare the relative effects of different land use areas (e.g., cropland, mining area) and morphologic zones (e.g., piedmont, mountain) on water quality. A particular concern for these stations is the evaluation of nonpoint sources of pollution and the establishment of baselines of water quality in sparsely populated areas.

6. At the mouths of major or significant tributaries to mainstem streams, estuaries, or coastal areas. The data from these stations, taken in concert with permit monitoring data and intensive survey data, will determine the major sources of pollutants to the area's mainstem water bodies and coastal areas. By comparison with other tributary data, the relative magnitude of pollution sources can be evaluated and problem areas can be identified.

7. At representative sites in mainstem rivers, estuaries, coastal areas, lakes, and impoundments. These stations will provide data for the general characterization of the area's surface

waters and will provide baselines of water quality against which progress can be measured. The purpose of these stations is not to measure the most pronounced areas of pollution, but rather to determine the overall quality of the water. Biological monitoring will be a basic tool for assessing the overall water quality of an area.

8. In major water use areas, such as public water supply intakes, commercial fishing areas, and recreational areas. These stations serve a dual purpose: the first is public health protection and the second is for the overall characterization of water quality in the area. Determining the presence and accumulation of toxic substances and pathogenic bacteria and their sources are primary objectives of these stations.

Sediment sampling sites should be located in sink areas as determined by intensive surveys, reconnaissance surveys, and historical data. A major concern of sediment monitoring will be to assess the accumulation of toxic substances, and locations for sediment sampling should be chosen with this in mind. Sediment mechanics and the hydrological characteristics of the water body must be considered. Refer also to Chapter 4 of this Manual.

In general, biological monitoring stations should be established as follows:

1. At key locations in water bodies that are of critical value for sensitive uses such as domestic water supply, recreation, and propagation and maintenance of fish and wildlife.

2. In major impoundments near the mouths of major tributaries.

3. Near the mouths of major rivers where they enter an estuary.

4. At locations in major water bodies potentially subject to inputs of contaminants from areas of concentrated urban, industrial, or agricultural use.

5. At key locations in water bodies largely unaffected by man's activities.

For purposes of biological monitoring, a station will normally encompass areas, rather than points, within a reach of river or area of lake, reservoir, or estuary adequate to represent a variety of habitats typically present in the body of water being monitored. Unless there is a specific need to evaluate the effects of a physical structure, it is advisable to avoid areas that have been altered by a bridge, weir, within a discharge plume, etc. Thus, biological sampling stations may not always exactly coincide with water column or sediment stations.

To the extent possible, all monitoring stations should be located in such a manner as to aid cause/effect analyses. Some station requirements may be such that, with careful station siting, one particular station could meet the criteria of a number of types of stations. Caution should be exercised, however, to avoid compromising the worth of a station for the sake of false economy. In general, the quality of a monitoring program is not judged solely by the number of stations. A few critically located stations may be extremely valuable, while a large number of randomly selected stations may yield meaningless data. Resource constraints will limit the total number of stations. Figure D-2, taken from (6), shows some examples of station locations.

The stations shown on Figure D-2 are described as follows:

1. At a water supply intake; upstream station of a pair bracketing a municipal and industrial center.

2. At a critical location in a water quality limited segment; downstream station of a pair bracketing a municipal and industrial center; mouth of a significant input to a reservoir known to exhibit eutrophic characteristics.

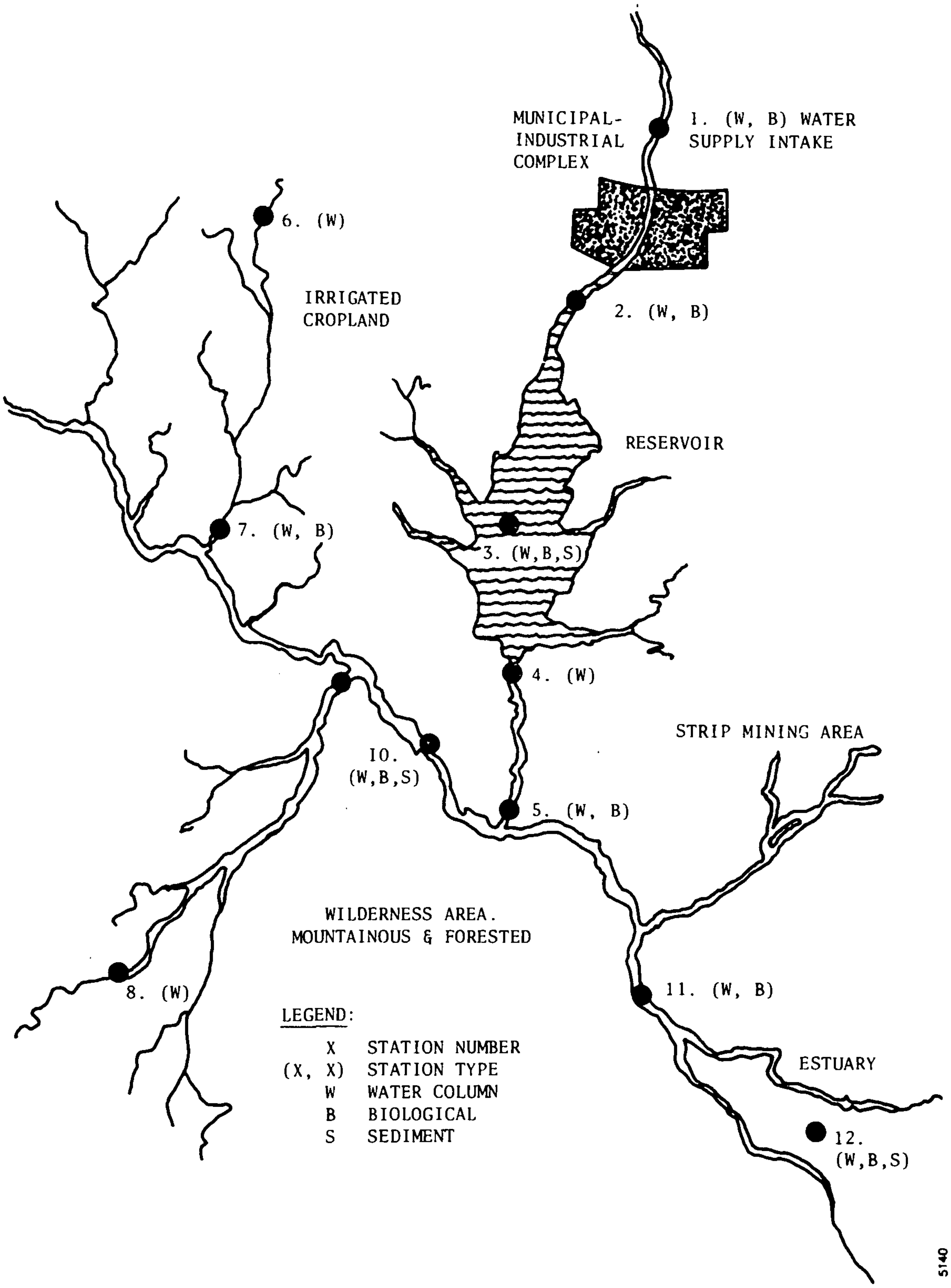


FIGURE D-2
STATION LOCATIONS

3. At a critical location in a reservoir known to exhibit eutrophic characteristics; in an area of recreation.

4. Upstream of a major land use area (strip mining); major outlet from a eutrophic reservoir.

5. Downstream of a land use area (strip mining); mouth of a significant tributary to mainstem river.

6. Upstream of a major land use area (irrigated cropland).

7. Downstream of a land use area (irrigated cropland); mouth of a significant tributary; representative site for other streams passing through same land use.

8. Upstream of a major land type area (wilderness).

9. Downstream of a major land type area (wilderness); mouth of significant tributary to mainstem river.

10. Representative site in mainstem river.

11. Representative site in mainstem river, mouth of major input to a potentially eutrophic estuary.

12. Representative site in estuary, recreational area, shellfish harvesting area.

D.2.1.2 Site Selection for Waste Load Allocation Surveys

Intensive surveys for waste load allocation will form an important part of a 208 agency's monitoring program. Since water quality problems don't manifest themselves on demand and we can't afford to wait around for the 10-year dry spell, the use of mathematical models for problem assessment will be required. These models will require monitoring data from intensive surveys for calibration and verification. By and large, at least two intensive surveys will be required for each waste load allocation study. The first, or preliminary, survey should be performed during slightly higher flow conditions than the second, or primary, survey which should be conducted when flow conditions are as low as possible.

For the case where only one outfall impacts upon the water quality of a stream, measurement sites should be located as follows:

A - directly upstream of the outfall.

B - effluent from the outfall.

C - mix point (i.e., where effluent is thoroughly mixed with stream flow).

D_i - intermediate points between the mix point and the DO sag point or a tributary, if one enters the stream ahead of the sag point. Spacing of 0.1 mile or less is usually warranted.

E - directly upstream of any tributaries.

F - tributary.

G_i - intermediate points between tributaries (if more than one) or between tributary and sag point.

H - sag point.

I_i - points downstream from the sag point. Measure at least every 0.1 mile until there is a definite recovery in the DO profile.

Where more than one outfall discharges into the stream, these sources must also be measured, and the above site locations altered accordingly.

The problem of determining the mix point deserves special mention. The common practice of locating the mix point either by visual inspection of the stream or by simply assuming that the stream is well mixed a certain distance downstream is simply inadequate. A more rigorous method must be used. One technique that has successfully been employed is to follow the concentration of chlorides downstream. The steps in this procedure are:

1. Measure chloride concentration upstream of the outfall.

2. Measure chloride concentration in the effluent.

3. Perform a mass balance calculation to determine the mixed chloride concentration.

4. Measure chloride concentrations at increasing distances downstream from the outfall.

5. Locate the mix point where the measured chloride concentration is equal to the calculated value.

D.2.1.3 Catchment Selection for Stormwater Model Calibration and Verification

Field data will be required for calibration and verification of stormwater models, with details dependent upon the actual model selected (see Appendix A). However, it must be emphasized at the outset that instrumentation of a large, multiuse drainage basin can only generate data for verification of urban planning models. Calibration of these models requires data from small catchments of uniform land use to provide information for adjusting model parameters for each individual land use. Since it will not be practicable to instrument all catchments within a planning area, the effectiveness of the planning models will depend to a large degree on the ability to estimate parameters for catchments that have no calibration data. This implies the selection of catchments that have a high potential for data transferability as "benchmark" stations and instrumenting them accordingly. Each instrumented catchment must therefore be viewed as a "sample" of the planning area's catchments. Selection of representative and (to the extent possible) uniform "samples" is necessary in order to arrive at a set of transferable model parameters that cover the variations among catchments for the entire planning area.

Catchment selection begins with an inventory of catchments in the planning area. Minimum characterization includes size; present and projected land use; drainage type (non-sewered, degrees of partial sewer service, fully sewered, and sewer types); physical catchment characteristics; and relationship to major streams, lakes, or estuaries within the area of interest. Catchments in urban areas are small and numerous, emphasizing the need for selecting a small, representative subset. The size will affect the relative importance of runoff flow and water quality constituent routing. Very small (e.g., less than 0.1 square mile) catchments should be avoided as their (typically) extremely rapid response times may make runoff characterization impossible. It is unlikely that the requirement for uniformity of land use will allow utilization of large (e.g., over 5 square miles) catchments in urban areas.

The extent of sewering will have a significant impact on catchment runoff, affecting routing, length of overland flow, and the relative importance of infiltration. In urban areas, the ratio of sewer length to drainage area typically falls between 8 and 18. The corresponding ratio for natural river and stream channels would be less than 2. The physical catchment characteristics such as percent imperviousness, ground slope, soil characteristics, and infiltration potential will obviously affect runoff and must be considered in selecting representative catchments for instrumentation.

The recommended procedure is to prepare a matrix inventory characterizing each catchment within the area of interest. These should then be categorized using land use as the factor, since parameters in currently available models are largely functions of land use. One should not feel constrained to use only the conventional single-family residential, multi-family residential, commercial, industrial, and open-space land use types. Use types reflecting the local conditions are more meaningful. For example, it may be desirable to distinguish between single-family residential areas near the center of a city and those in the suburbs; review of the catchment inventory may indicate a number of small suburban shopping centers and the desirability of a mixed residential/commercial category. Other locally important factors for determining land use types might be traffic volume, population density, age of development, family income, percent of streets with curb and gutter, type of industry, and so on. Although local conditions will determine the exact number of land use categories to be employed, fewer than five will probably not allow satisfactory data transfer and more than ten will increase field data collection costs beyond reason. See Appendix C of this Manual for further guidance.

The problem of site selection from among those catchments in each land use category now remains. Budgetary constraints will mandate selection of only one catchment for instrumentation in each land use category for the most part and, therefore, the "best" must be selected. Although random selection may be expedient, a more rigorous and comprehensive approach is usually desirable. On the other hand, a sophisticated multiple regression analysis with serial and/or factor differentiation of catchment variables is probably not warranted. The technique of weighted suitability ratings often employed in land use planning will be adequate in most instances. It has the advantage that the selection criteria can easily be illustrated on a single chart for relative catchment comparison. Although the procedure is necessarily subjective in the selection of factors, suitability values, and weights, so was the basic selection of land use types.

D.2.1.4 Specific Site Selection Criteria

Given an identified catchment, stream reach, or other general location where measurements are desired, there are some general criteria that can aid in selecting the specific measurement site. They include:

1. Maximum accessibility and safety. Manholes on busy streets should be avoided if possible; shallow depths with manhole steps in good condition are desirable. Sites with a history of surcharging or submergence by surface water, or both, should be avoided if possible.

2. Be sure that the site provides the information desired. Familiarity with the sewer system is necessary. Knowledge of the existence of inflow or outflow between the measurement point and point of data use is essential.

3. Make certain the site is far enough downstream from tributary inflow to ensure mixing of the tributary with the main stream.

4. Locate in a straight length of channel, at least six widths below bends.

5. Locate at a point of maximum turbulence, as found in sections of greater roughness and of probable higher velocities. Locate just downstream from a drop or hydraulic jump, if possible.

6. In all cases, consider the cost of installation, balancing cost against effectiveness in providing the data needed.

The success or failure of selected equipment or methods, with respect to accuracy and completeness of data collected as well as reasonableness of cost, depends very much on the care and effort exercised in selecting the site. A requirement with regard to flow measurement that appears to be obvious, but which is frequently not sufficiently considered, is that the site selected be located to give the desired flow measurement. Does flow at the site provide information actually needed to fulfill given needs? Sometimes influent flows, diversions, or storage upstream or downstream from the selected site would bias the data in a manner not understood without a thorough study of the proposed site. Such study would include reference to surface maps and to sewer maps and plans. Sometimes groundwater infiltration or unrecorded connections may exist. For these reasons, a thorough field investigation should be made before establishing a flow measurement site.

A basic consideration in site selection is the possible availability of measurements or records collected by others. At times, data being collected by the USGS, by the state, or by other public agencies can be used. There are locations where useful data, although not currently being collected, may have been collected in prior years. Additional data to supplement those earlier records may be more useful than new data collected at a different site.

Requirements that apply to all measurement sites are accessibility, personnel and equipment safety, and freedom from vandalism. If a car or other vehicle can be driven directly to the site at all times, the cost in time required for installation, operation, and maintenance of the equipment will be less, and it is possible that less expensive equipment can be selected. Consideration should be given to access during periods of adverse weather conditions and during periods of flood stage. Sites on bridges or at manholes where heavy traffic occurs should be avoided unless suitable protection for men and equipment is provided. If entry to sewers is required, the more shallow locations should be selected where possible. Manhole steps and other facilities for sewer access must be carefully inspected, and any needed repairs made. Possible danger from harmful gases, chemicals, or explosion should be investigated. With respect to sites at or near streams, historical flood marks should be determined and used for placement of access facilities and measurement equipment above flood level where this is possible. Areas of known frequent vandalism should be avoided.

In this last regard, the problem of vandalism can be serious and costly, both in terms of equipment damage and data loss. The selection of sites in open, rather than secluded, areas may help reduce vandalism as may illumination at night. Attempts to hide or camouflage equipment have been generally unsuccessful. Instrumentation should be sheltered to the extent possible, trading off the cost of protective facilities, the latitude afforded by the site, and the need for easy access. Occasionally, solid masonry or steel shelters surrounded by heavy fencing may be required for measurement sites, and these additional costs must be included in such instances. Finally, warning signs are generally unsuccessful; they may only encourage vandalism regardless of the type of threat -- high voltage, radiation hazard, fine, or imprisonment.

D.2.2 Parameter Selection

A review of the Parameter Handbook points out that the list of possible water quality parameters that might be of interest to the 208 planner is almost endless. Parameter selection must be based on the specific objectives of the study and a knowledge of general pollution source characteristics. For example, nonmunicipal effluent limitations guidelines for existing point sources, standards of performance for new sources, and pretreatment standards for new and existing sources discharging to publicly-owned waste treatment facilities have been published for 28 point source categories (40 CFR 405-432). Effluent limitations establish the mass of specific pollutants that may be discharged per unit of production or raw material input. Limitations are established for a maximum production day and for the 30-day average. Table D-4 summarizes the effluent parameters included in each of the published effluent guidelines.

For publicly-owned treatment works in existence on July 1, 1977, or approved for a Federal construction grant prior to June 30, 1974, effluent limitations

TABLE D-4
EFFLUENT PARAMETERS BY INDUSTRIAL CATEGORIES

INDUSTRY CATEGORY	BOD_5	TSS	pH	COLOR	COD	PHENOLS	OIL AND GREASE	SURFACTANTS	TOC	NH_3	SULFIDE	Cr TOTAL	Cr 6	ZINC	K. NITROGEN	FECAL COLIFORM	NO_3-N	ORGANIC N	T. PHOSPHORUS	FLUORIDE	HEAT	COPPER	ALUMINUM	CYANIDE	MANGANESE	NICKEL	ARSENIC	CHLORINE	IRON	LEAD	MERCURY	T. DISSOLVED SOLIDS
1. PULP, PAPER AND 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 AND FISHING	X	X	X				X				X	X			X	X																
9. CANNED AND PRESERVED FRUITS AND VEGETABLES	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																									
TOTALS:	18	27	27	2	11	8	12	1	2	5	2	7	4	3	1	6	2	1	3	5	4	3	2	3	1	2	1	1	2	1	2	2

are based upon an effluent standard of secondary treatment. Secondary treatment is defined in 40 CFR 133.102 and consists of:

Parameter	7-day Average	30-day Average
BOD_5	45 mg/ℓ	30 mg/ℓ
Suspended Solids	45 mg/ℓ	30 mg/ℓ
Fecal Coliform Bacteria (geometric mean)	400/100 mℓ	200/100 mℓ
Removal Efficiency		85 percent
pH	6.0 - 9.0	

The recommended procedure is to examine the sources and processes involved in the study area and, on the basis of need-to-know and reasonable expectation, select measurement parameters accordingly. Flow should always be included. Parameters should not be limited to those that are known to be a problem, but should also include those that can reasonably be expected to become a problem. The 208 monitoring program should identify new problems as well as track existing ones. The results of early analyses should be used to assess parameter coverage and assist in determining whether an increase or decrease is warranted. Resist the temptation to "look at the whole world." Analyses cost money, and wise resource management dictates that only parameters, the knowledge of which directly supports specific study objectives, should be included. Put in writing a justification for each parameter selected. Use the Parameter Handbook for guidance.

D.2.2.1 Parameters for Storm-Generated Discharges

Parameter selection will be facilitated by initially considering water quality characteristics in gross categories rather than as specific compounds or elements. As an example, the following treats the quality characteristics considered important for storm-generated discharges. See Wullschleger et al. (7) for elaboration.

D.2.2.1.1 Oxygen Demand

One of the most important quality characteristics in a receiving body of water is the dissolved oxygen concentration. The dissolved oxygen concentration has a direct bearing on the quality and natural balance of much of the aquatic biota. Dissolved oxygen concentration can also have an effect on the recreational and aesthetic uses of a body of water. Storm-generated discharges that contain organic and inorganic compounds that exert a demand for the oxygen dissolved in water can be considered pollutional discharges in the same sense as dry-weather municipal wastewaters.

Oxygen demand is exerted by (1) organic compounds that undergo biochemical oxidation as a result of microbial activity and (2) by the immediate demand exerted by the chemical oxidation of inorganic reduced compounds. However, storm-generated discharges have certain characteristics different from municipal sewage that affect not only the DO level in the receiving waters, but also the conventional tests used to measure oxygen demand. Since combined sewer overflows have a variety of sources other than just municipal sewage, the discharges may contain materials that cause special problems. During dry weather, when flow through a combined sewer system is low, solids settle out. At the start of a storm, the first flush of water through the system may have a high concentration of solids that affects the demand characteristics of the waste. It has been found that the fraction of BOD in the particulate form can range from 69 to 87 percent, which is considerably higher than the 30 to 50 percent present in most municipal wastewaters. Also, combined sewer overflows from industrial areas and urban runoff may contain oils, toxic materials and chemicals which are foreign to the natural environment and interfere with traditional oxygen demand tests. Finally, storm-generated discharges contain a large amount of natural materials such as silt, vegetation, wood; and other materials such as plastic that may not exert an immediate demand but will eventually use the oxygen required for decomposition. These characteristics cause these discharges to be different from that waste normally encountered in sanitary analyses.

There are numerous tests available for use as potential oxygen demand indicators, including BOD_5, BOD_{20}, BOD_X, ΔCOD, COD, TOC, and TOD. The desired test should have a well established, standardized test procedure and provide a measurement of the total oxygen demand on the environment. No single analytical test can meet both of these criteria. Therefore, two parameters are recommended to indicate oxygen demand for storm-generated discharges, TOD and BOD_5. TOD reflects the long-term demand, allowing correct determination of discharge effects, and lacks the serious interference problems of other tests, notably COD. BOD_5 is recommended, despite its numerous disadvantages, because of its widespread and historical use. Also, because of toxicity effects on the BOD_5 test, comparison of BOD_5 and TOD results can yield information about the degree of toxicity and its possible effect on the natural environment.

D.2.2.1.2 Particulate Concentration

The solid matter present in storm-generated discharges can be divided into two major categories; namely, particulate solids and dissolved solids. Particulate solids are important in combined sewer overflows and storm runoff applications because they usually represent a large fraction of the total solids. Also, these solids are generally removed from the flow by physical treatment processes such as sedimentation, screening, flotation, and filtration--the type of processes most commonly used for storm-generated discharges. It is, in fact, the relatively high concentration of particulate solids in these flows which makes such processes attractive.

The recommended parameter for indicating particulate concentration in storm-generated discharges is nonfilterable residue (suspended solids). The analysis is routine and not as time consuming and cumbersome as some of the other particulate tests and, with a few additional steps, both the volatile and fixed portions can be determined, yielding another useful piece of information in most instances. Where settleable residue is desired, the gravimetric method is recommended, not the Imhoff cone. Turbidity measurements provide little comparable data about particulate matter or concentration and are not recommended for this purpose.

D.2.2.1.3 Pathogenic Microorganism Potential

Any discharge that includes waters which have come into contact with excrement from warm-blooded animals of any type should be considered as having the potential for conveying pathogenic bacteria, viruses, protozoa, and other contagions. It is extremely difficult, if not logistically impossible, to monitor these discharges for the many pathogens themselves. This problem was recognized in the water supply field many years ago and has led to the almost universal usage of the coliform group of bacteria as the indicator or measure of the sanitary quality of water. The coliforms themselves are not necessarily pathogenic, but their presence should infer the possible presence of pathogens. However, for a number of reasons the coliform group is not necessarily the most sensitive indicator as far as storm-generated discharges are concerned.

The recommended indicator parameters are fecal coliform and fecal streptococcus. Furthermore, it is recommended that the membrane filter (MF) technique be used rather than the multiple tube fermentation procedure where results are expressed as the most probable number (MPN) statistic.

D.2.2.1.4 Eutrophic Potential

In addition to sunlight and carbon dioxide, aquatic plants require nutrients and trace salts. The principal nutrients are compounds which contain the elements phosphorus, nitrogen, and potassium. The proliferation of aquatic plants in most water bodies is undesirable. The term "eutrophic" refers to a condition in a water body where copious plant growth has resulted in an undesirable or unsightly situation of accelerated lake deterioration. Although eutrophication is a natural process, it can be accelerated by man's activities.

Nitrogen and phosphorus are measures of the eutrophic potential of storm-generated discharges. It is recommended that two nitrogen analyses be conducted, nitrate plus nitrite (run by reducing nitrate to nitrite and measuring the latter) and Kjeldahl. Of the 14 different phosphorus fractions, total phosphorus is the recommended parameter.

D.2.2.1.5 Toxic and Related Substances

A large number of compounds of varying toxicity and concentration are likely to be found in combined sewer overflows and storm runoff. However, the toxicants of major concern can be divided into the general categories of heavy metals, pesticides, and herbicides.

When studying the quality of storm flows, it is recommended that a composite sample of the flow be analyzed for lead, zinc, copper, chromium, mercury, cadmium, arsenic, nickel, and tin four times a year (seasonally). Based upon the results of these tests, a decision can be made as to how often certain heavy metals will have to be analyzed thereafter. It is expected that lead, zinc, copper, and chromium may be measured routinely. In certain combined sewer areas serving known industries, or in certain storm sewer discharges from areas of heavy vehicular traffic, it may be necessary to do more frequent analysis.

Because of the wide variability of pesticides in use, the periodic nature of their application depending upon season and nature of the drainage area, and the complexity of the laboratory analyses, no pesticides or associated compounds are recommended for routine analysis. However, it is recommended that, when evaluating the quality of a storm-generated discharge, a study of the drainage area should be made to determine the likelihood of pesticide application (and the type) and if it is probable that the storm flow may contain pesticides. At least one discharge should be analyzed to see if that pesticide is present. Depending upon this result, a decision can be made as to whether more analyses are needed.

D.2.2.1.6 Other Parameters

There are a host of other parameters that can be used to characterize storm-generated discharges. In the absence of site specific concerns, however, only pH is recommended for routine measurement.

D.2.2.2 Parameters for a National Water Quality Monitoring Program

As a further aid in parameter selection, the proposed minimum parameter list for a national water quality monitoring program will be discussed. Temperature, pH, and dissolved oxygen are included because they are the primary constituents in most chemical reactions that occur within the waterbody. They are also the essential factors that govern whether the ecosystem will maintain aquatic life. A conductivity measurement is included to determine the degree to which dissolved solids contribute to the water quality. This is a most reliable measurement and can be done on site. Salinity is measured in estuaries and bays.

Fecal coliform is included because it is, at present, the most reliable test for indicating the possible presence of pathogenic microorganisms in the system. Trace metals were limited to those that are of high priority and are toxic. Since the concern of the program is to measure the total load, total metals instead of dissolved forms are measured.

In order to determine the extent of total nutrient contribution, total phosphorus, total Kjeldahl nitrogen, and nitrite and nitrate are measured. Since the basic concern of the program is the total nutrient load, total phosphorus is measured instead of the other various forms of phosphorus.

This is also more economically sound. In determining the contribution of nitrogen to the system, the concern of the program is also to arrive at some understanding of the stage of nitrification within the system. Therefore, total Kjeldahl nitrogen is included as a measurement of organic nitrogen and ammonia, and nitrate and nitrite are included to determine the extent of oxidized nitrogen.

A total suspended solids measurement is included to measure the contribution of solid material to the system and to give some indication of water clarity and the probability of chemical adsorption.

A chemical oxygen demand (COD) measurement is included to get an indication of the oxygen demand placed on the system. Chemical oxygen demand was chosen over biochemical oxygen demand (BOD) and total organic carbon (TOC) because it is more reliable than BOD, does not involve problems with holding time and sample transport as do BOD samples, and does not require the sophisticated equipment required of a TOC measurement. COD is not measured in lakes and impoundments because it is usually found only in such low concentrations that it renders the measurement meaningless. TOC is measured in estuaries because the COD measurement does not yield satisfactory results in salt water due to chloride interference.

The trace organics included in the program were chosen because they appear most frequently on several USEPA priority lists relating to toxic substances; for example, measurements required for the permit program, measurements required for the drinking water program, the Section 307(a) list, and several listings proposed by the Office of Toxic Substances.

The effects of contaminants on aquatic organisms are complex. Synergistic chemical/physical reactions, biomagnification, and other natural events cannot be easily quantified. For these reasons and for the purposes of the program, the best approach to determine the presence and potential health threat of toxic substances in the ecosystem appears to be the chemical analysis of fish and shellfish tissue. This has, therefore, been included in the monitoring program.

D.2.2.3 Parameters for Waste Load Allocations

As an example of possible parameter coverage for waste load allocation surveys, Tables D-5 and D-6 indicate minimum parameters for the preliminary and primary intensive surveys discussed in Section D.2.1.2. The measurement locations indicated in the tables are those described in Section D.2.1.2. In addition to the indicated parameters, it will usually be desirable to perform a metals and pesticide scan on at least one sample from the preliminary survey and, based on the results, consider additional parameters for the primary low flow survey.

D.2.3 Measurement Frequency Selection

Monitoring frequencies are established by the variations of the system (sources and receiving water) and the nature of the pollutants (conservative and nonconservative). Frequencies selected should be adequate to account for variations in the flows and quality of pollution sources, the variations in stream flow, and tidal action. This establishes a spectrum ranging from a periodic grab sample (suitable for the rare steady-state condition) to continuous collection over a suitable time period.

D.2.3.1 Frequency for Background and Trend Data

Background and trend data must be representative of the variations in water quality and changes in pollution occurring over the course of a year, and the measurement frequency must be less than the shortest anticipated frequency of pollutant variation. To aid in such sampling frequency determination, Tables D-7, D-8, and D-9 present the proposed sampling frequencies for the national water quality monitoring program for rivers and streams, lakes and impoundments, and estuaries and bays.

The sampling frequencies given in the foregoing represent the bare minimum and, depending upon the anticipated variability, considerations should be given to utilizing more frequent intervals. If at all possible, new stations should be sampled on a weekly or biweekly basis for the first 6 months to

TABLE D-5
PARAMETERS FOR PRELIMINARY SURVEY

Location	DO	Temp	Distance Downstream	Travel Time	Flow Measurement	BOD_{20}	BOD_{20} Inh	Nitrogen Compounds
A	x	x			x		x	x
B	x	x			x	x	x	x
C	x	x	x	x	x			
D_i	x	x	x	x*				
E	x	x	x		x			
F	x	x	x		x			
G_i	x	x	x	x*				
H	x	x	x	x				
I_i	x	x	x	x*	x*			

* Measurements need be taken at only one of the multiple locations designated by each of D_i, G_i, or I_i.

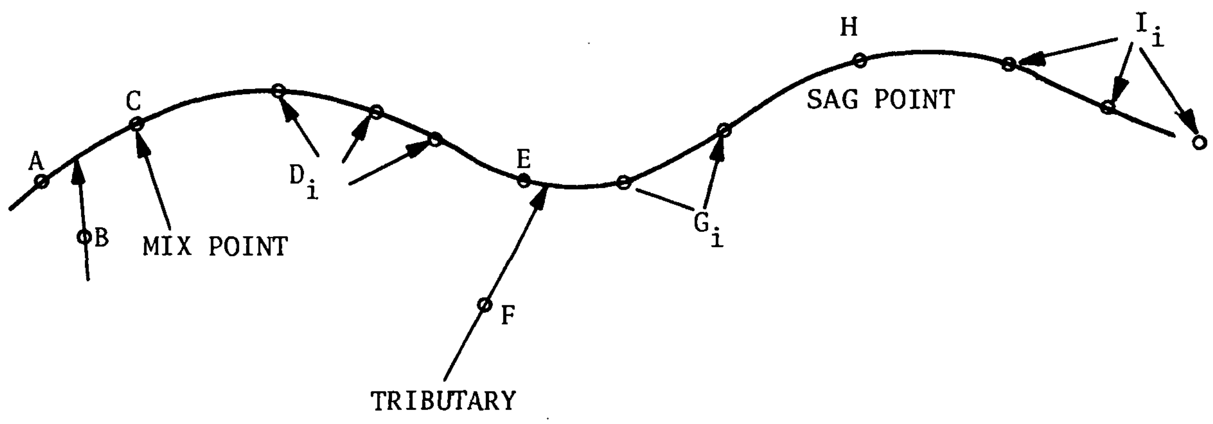


TABLE 6
PARAMETERS FOR PRIMARY SURVEY

Location	DO	pH	Temp	Distance Downstream	Travel Time	Flow Measurement	Continuous DO	Nitrogen Compounds	BOD_5	BOD_5 Inh	BOD_{20} Inh
A	x	x	x			x		x			x
B	x	x	x			x		x	x	x	x
C	x	x	x	x	x	x	x	x			x
D_i	x	x	x	x	x			x		x	
E	x	x	x	x	x	x				x	
F	x	x	x	x		x		x			x
G_i	x	x	x	x	x			x		x	
H	x	x	x	x	x		x	x			x
I_i	x	x	x	x	x	x*		x		x	

* Measurements need be taken at only one of the multiple locations designated by I_i.

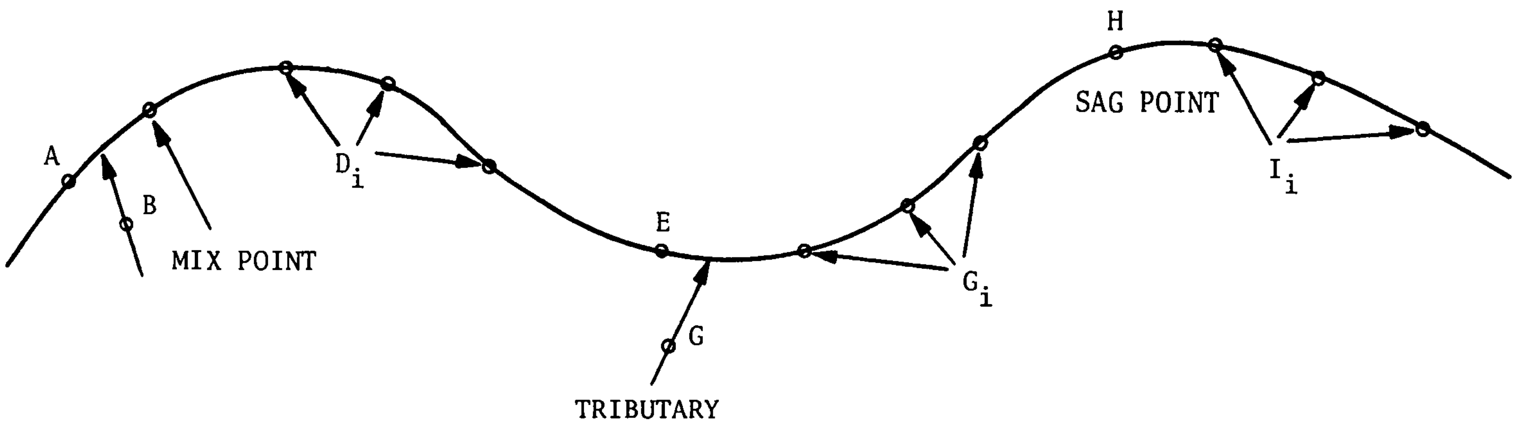


TABLE D-7
PARAMETER LIST AND SAMPLING FREQUENCY
FOR THE NATIONAL MONITORING PROGRAM

Rivers and Streams	
Parameter (Units) (STORET Parameter Code)	Sampling Frequency
Temperature (C°) (00010)	Monthly
Dissolved oxygen (mg/ℓ) (00300)	Monthly
pH (Standard Units) (00400)	Monthly
Conductivity (UMHOS/cm @ 25°C) (00095)	Monthly
Fecal Coliform (No./100mℓ) (31616)	Monthly
Total Kjeldahl nitrogen (mg/ℓ) (00625)	Monthly
Nitrate + nitrite (mg/ℓ) (00630)	Monthly
Total phosphorus (mg/ℓ) (00665)	Monthly
Chemical oxygen demand (mg/ℓ) (00335)	Monthly
Total suspended solids (mg/ℓ) (00530)	Monthly
Representative fish/shellfish tissue analysis (see Table D-9)	Annually
Flow (CFS) (00060)	Monthly

TABLE D-7
PARAMETER LIST AND SAMPLING FREQUENCY
FOR THE NATIONAL MONITORING
PROGRAM (Cont'd)

Lakes and Impoundments, Including the Great Lakes	
Parameter (Units) (STORET Parameter Code)	Sampling Frequency
pH (Standard Units) (00400)	Seasonally
Temperature (°C) (00010)	Seasonally
Dissolved oxygen (mg/ℓ) (00300)	Seasonally
Conductivity (UMHOS/cm @ 25°C) (00095)	Seasonally
Fecal Coliform (No./100mℓ) (31616)	Seasonally
Total phosphorus (mg/ℓ) (00665)	Seasonally
Total Kjeldahl nitrogen (mg/ℓ) (00625)	Seasonally
Nitrate + nitrite (mg/ℓ) (00630)	Seasonally
Total suspended solids (mg/ℓ) (00530)	Seasonally
Representative fish/shellfish tissue analysis (see Table D-9)	Annually
Transparency Secchi Disk (Meters) (00078)	Monthly

TABLE D-7
PARAMETER LIST AND SAMPLING FREQUENCY
FOR THE NATIONAL MONITORING
PROGRAM (Cont'd)

Estuaries and Bays	
Parameter (Units) (STORET Parameter Code)	Sampling Frequency
Temperature (°C) (00010)	Monthly
Dissolved oxygen (mg/ℓ) (00300)	Monthly
Total organic carbon (mg/ℓ) (00680)	Monthly
pH (Standard Units) (00400)	Monthly
Salinity (°/oo) (00480)	Monthly
Fecal Coliform (No./100mℓ) (31616)	Monthly
Transparency Secchi Disk (Meters) (00078)	Monthly
Total Kjeldahl nitrogen (mg/ℓ) (00625)	Monthly
Total phosphorus (mg/ℓ) (60665)	Monthly
Nitrate + nitrite (mg/ℓ) (00630)	Monthly
Total suspended solids (mg/ℓ) (00530)	Monthly
Representative shellfish tissue analysis (see Table D-9)	Annually

TABLE D-8
TRACE ORGANICS AND METALS ANALYSES FOR WATER COLUMN[1]

Parameter (STORET), (μg/1)	
PCBs (39516)	Endrin (39390)
Aldrin (39330)	Methoxychlor (39480)
Dieldrin (39380)	Hexachlorobenzene (39700)
o,p-DDE (39327)	Pentachlorophenol (39032)
p,p'-DDE (39320)	Hexachlorocyclohexane
o,p-DDD (39315)	α-BHC (39334)
p,p'-DDD (39310)	γ-BHC (39810)
o,p-DDT (39305)	Arsenic (01002)
p,p'-DDT (39300)	Cadmium (01027)
Chlordane	Chromium (01042)
cis isomer (39062)	Copper (01034)
trans isomer (39065)	Mercury (71900)
cis nonachlor (39068)	Lead (01051)
trans nonachlor (39071)	

(1) For water column analysis when applicable (24).

TABLE D-9
TRACE ORGANICS AND METALS ANALYSES FOR FISH/SHELLFISH TISSUE AND SEDIMENT

Parameter (STORET:tissue, STORET:sediment), (μg/g tissue, μg/kg sediment)	
PCBs (39520,39519)	Endrin (39397, 39393)
Aldrin (39334, 39333)	Methoxychlor (39482, 39481)
Dieldrin (39387, 39383)	Hexachlorobenzene (39703, 39701)
o,p-DDE (39329, 39328)	Pentachlorophenol (39060, 39061)
p,p'-DDE (39322, 39321)	Hexachlorocyclohexane
o,p-DDD (39325, 39316)	α-BHC (39074, 39076)
p,p'-DDD (39312, 39311)	γ-BHC (39075, 39811)
o,p-DDT (39318, 39306)	Arsenic (01004, 01003)
p,p'-DDT (39302, 39301)	Cadmium (71940, 01028)
Chlordane	Chromium (71939, 01029)
cis isomer (39063, 39064)	Copper (71937, 01039)
trans isomer (39066, 39067)	Mercury (71930, 71921)
cis nonachlor (39069, 39070)	Lead (71936, 01052)
trans nonachlor (39072, 39073)	

1 year of operation or until the data indicate that less frequent sampling is warranted.

Fish samples should be collected annually in the fall, since contaminant concentrations are at their maximum at this time of year. Only fish samples that will be most representative of the water quality in the area of interest should be collected for tissue analysis. Migratory species should be discounted. Two replicate whole fish composite samples of a representative bottom feeder and one whole fish composite sample of a predator species should be collected at each station. Commercially or recreationally important species should be collected wherever possible. Each composite should include at least five fish, each of approximately the same size. Because of their sedentary existence and great water-filtering capabilities, shellfish are excellent concentrators of contaminants. Therefore, wherever possible, shellfish samples should be collected and analyzed, especially in estuarine environments.

Where incidents of fish kill occur, the appropriate information should be recorded. This should include the date of occurrence (or period if it persists), the location or affected area, the species affected, estimates of the magnitude of the kill (i.e., number of fish), and any other information that would be useful. The frequency and magnitude of such events should decrease as a result of implementing the areawide plans, and this can be a dramatic way of indicating progress.

D.2.3.2 Frequency for Waste Load Allocation Surveys

Samples could be taken at any convenient time if stream conditions did not vary. The necessary number of samples would be only that dictated by the desired degree of precision of the results, taking into account the precision of the laboratory analytical methods. In theory, the times of collection and numbers of samples are dictated by the need to ensure both an acceptable measure of the variations in stream conditions and an acceptable precision of laboratory analysis. In practice, these considerations are tempered by inescapable limitations of budget, personnel, and facilities, and frequently by the amount of time available.

There is no fixed number of samples that will yield results within selected limits of precision in all situations. The number of samples needed for any point on a stream varies with the variability in water quality at that point. A preliminary estimate of the variability can be calculated after a limited number of analytical results has been obtained. A preliminary prediction of the number of samples needed to ensure final results within selected confidence limits can be based on the preliminary estimate of variability. The prediction can be refined as the number of analytical results is increased until the point is reached at which a firm prediction of the number of samples required becomes possible. Data from a previous study under comparable conditions may be used to determine variability and predict the number of samples required.

In the absence of better information, daily grab samples should be taken from each stream measurement site over at least a 14-day period. Furthermore, the time of sampling at each site should be varied as much as possible to indicate any diurnal variations. Try to collect at least one set of samples at night to indicate photosynthetic effects. Review the analytical results from the early samples, and adjust the frequency accordingly.

For continuous point source discharges, the sampling frequency will also be dependent upon anticipated pollutant variability. If knowledge about the time-varying characteristics of the discharge is required, collect a sequential discrete sample series. Hourly time steps will be adequate for most continuous discharges, but in some instances either shorter time periods or flowmeter pacing will be required. If only average daily loadings are required, twenty-four-hour, flow proportional composite samples represent the best approach. These should be taken over a minimum of five consecutive days, and longer if variability indicates.

D.2.3.3 Frequency for Storm Generated Discharges

For intermittent storm related discharges, measurement frequencies must be quite short, especially for model calibration and verification where knowledge of temporal variations is very important. The measurement interval required is related to catchment size, shape, slope, and percent imperviousness. During sampling of the first few storms in a catchment, it is prudent to estimate sampling intervals on the short side. They can be increased later if the data warrant. Model input frequency requirements must also be considered. Suggested minimum measurement intervals are given in Table D-10. The first sample should be collected as close to the beginning of the storm-generated runoff as possible. This can be accomplished by triggering an automatic sampler at a predetermined indication of stage or rate of rise. Subsequent samples can be paced by timer settings or a flowmeter with flow increments selected so that the rising limb is well characterized. It may not be necessary to analyze all samples on the falling limb. Early data analysis will indicate if some can be eliminated or composited and still allow adequate discharge characterization.

D.3 Flow Measurement Considerations, Equipment, and Procedures

Although flow can be thought of as simply another parameter, it is so often neglected that it should properly be considered as an essential component of a monitoring program. Flow measurements are absolutely necessary for mass discharge calculations, stream and runoff studies, and model calibration and verification.

D.3.1 General Considerations

Concentrations of natural constituents, such as alkalinity, hardness, and minerals, generally vary inversely with stream flows. Total loads, or quantities, of natural constituents carried by a stream, on the other hand, increase as flow increases. The increasing water carried by the stream more than balances the decreasing concentration to yield a greater load in terms of a unit of total quantity, such as pounds per day. Other factors come into play with unstable constituents. Time-of-water travel increases as flow decreases, and this serves to accomplish natural purification in shorter distances. Higher densities of bacteria, for example, occur just below the

TABLE D-10
MAXIMUM MEASUREMENT INTERVALS

		Desirable Maximum Measurement Interval (min)	
Catchment Size	Variable	Highly Impervious Catchment	Highly Pervious Catchment
50 acres	Rainfall	2	3
	Flow	2	3
	Water Quality	3	4
100 acres	Rainfall	3	5
	Flow	3	5
	Water Quality	4	7
600 acres	Rainfall	5	12
	Flow	5	12
	Water Quality	7	20
3000 acres	Rainfall	12	20
	Flow	12	20
	Water Quality	15	30

point of discharge at lower flows, but they die off in shorter distances because of the longer time of travel. Likewise, BODs are higher near the point of discharge but stabilize in shorter distances at low discharges.

The natural flow of uncontrolled streams usually varies over a wide range. Stream flows follow precipitation patterns except in the colder areas of the country, where precipitation falls as snow in winter and much of the surface water is frozen. There can be wide differences in stream flow throughout the year and in the annual flow cycle from year to year. Flow in most areas tends to be high in late winter and to taper off to minimum quantities in the fall. High flows usually occur in colder areas when relatively warm spring rains melt the winter accumulation of ice and snow. However, the natural cycle may be altered to a considerable extent in streams controlled by impoundments. Thus, stream flows must be considered in selecting periods for stream study because of the considerable variations in water quality that accompany changes in flow. The objectives of the study are important in this selection, as they are in other decisions.

In manmade conduits, the effects of flow variation are probably greatest in storm sewers. Although storm sewers are basically designed to carry storm runoff, during periods of no rainfall they often carry a small but significant flow (dry weather flow). This may be flow from ground water, or "base flow," which gains access to the sewer from unpaved stream courses. Much of the dry weather flow in storm sewers is composed of domestic sewage or industrial wastes or both. Where ordinances concerning connections to sewers are lax or are not rigidly enforced, unauthorized connections to storm sewers will appear. In some cases, the runoff from septic tanks is carried to them. Connections for the discharge of swimming pools foundation drains, sump pumps, cooling water, and pretreated industrial process water to storm sewers are permitted in many municipalities and contribute to flow during periods of no rainfall. In some areas, sewers classed as storm sewers are, in fact, sanitary or industrial waste sewers due to the unauthorized or inappropriate connections made to them. This may become so aggrevated that a continuous flow of sanitary or industrial wastes, or both, discharges into the receiving stream. Furthermore, this "dry-weather" portion of storm sewer flow may vary significantly with time.

Storm runoff is the excess rainfall which runs off the ground surface after losses resulting from infiltration to ground water, evaporation, transpiration by vegetation, and ponding occur. In general, storm runoff is intermittent in accordance with the rainfall pattern for the area. It is also highly variable from storm to storm and during a particular storm. The time-discharge relationship, or hydrograph, of a typical storm, with its synchronous time-precipitation relationship, or hyetograph, is illustrated in Figure D-3. The meanings of various parameters given in the figure are:

R_p - Rainfall retained on the permeable portion of the drainage basin, and not available for runoff.

P_e - Precipitation in excess of that infiltrated into the ground, plus that retained on the surface. (Equals the volume of flood runoff.)

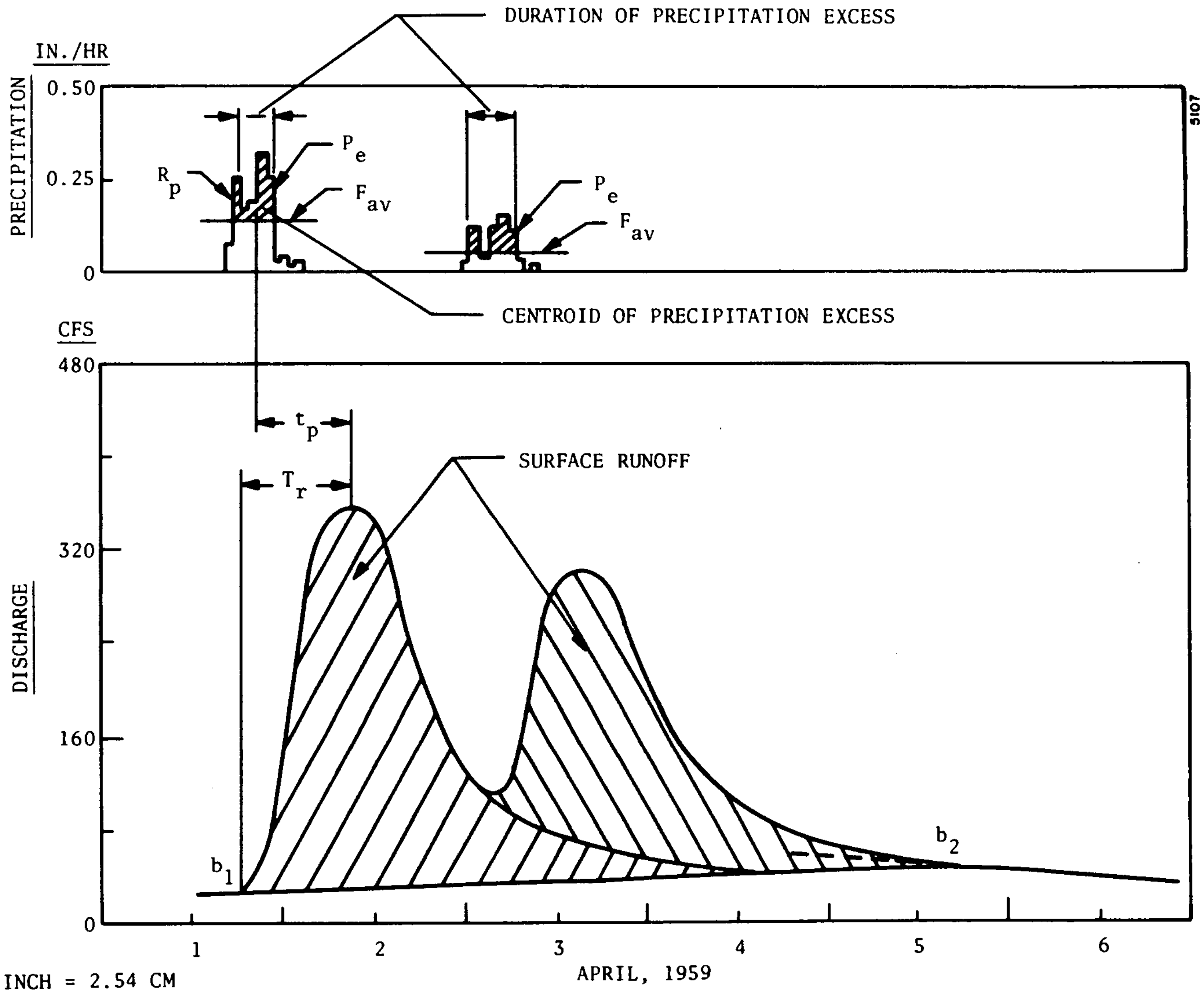
F_{av} - Average infiltration of the ground during the storm.

T_r - Period of rise from the beginning of storm runoff to peak of the hydrograph.

T_p - Time from center of gravity of rainfall excess to the hydrograph peak (lag time).

b_1, b_2 - Baseline separating groundwater discharge from surface runoff.

The total volume of runoff for a particular storm is represented by the areas between the baseline and the hydrograph.



NOTE: 1 INCH = 2.54 CM
1 CUBIC FOOT = 28.3 LITERS

FIGURE D-3
TYPICAL STORM HYETOGRAPH AND HYDROGRAPH

To illustrate some of the problems in measuring storm runoff in small basins, peak flows exceeding 85 cubic meters per second per 260 hectares (3000 cfs per square mile) have been observed. Lag times (t_p) of 15 minutes to a hydrograph peak of about 28 cubic meters per second (1000 cfs) from a 600-hectare (2.3 sq mi) area are not uncommon. With such rapid changes in the flow, only highly responsive flow measurement methods can be used. The high rates of flow, with accompanying high velocities, further limit the usable flow measuring methods.

All flow data must be synchronized with time, at least on a watch time basis, to have any useful meaning. A particular need for attention to the time element occurs in the measurement of flows from small urban storm sewers in order to define the hydrograph and to provide data for the development and verification of rainfall-runoff-quality models. Peak flows, storm runoff volumes, daily flows, or other flow parameters are often correlated with similar flows at other points on a storm sewer or stream, or with flows of other storm sewers or streams, to provide a means for flow estimation. Correlations with temperature, soil moisture, or antecedent precipitation may be made at times. In most cases, it is essential that the correlated variables be synchronous, so accurate timing of the data is often required. It is mandatory if time-series analysis is contemplated.

Timing of measured flows and collection of quality samples can be useful in determining sources of pollution. For example, they can be related to time of release of pollutants from industrial plants, or to the time of accidental spills of pollutants. The time of travel of pollutants along a stream or storm sewer can be estimated from the time of travel of small rises or other flow changes in the channel.

D.3.2 Flow Measurement Equipment

This brief discussion is intended to provide an overview to aid the 208 planner in the selection of equipment for the quantitative measurement of flows. For further reading, see Shelley and Kirkpatrick (8), ASME (9), Replogle (10), McMahon (11), USDI Bureau of Reclamation (12), Leupold and Stevens (13), and any of the many standard texts on hydraulics and fluid mechanics.

Any flow measurement system consists of two distinct parts, each having a separate function to perform. The first, or primary element, is that part of the system which is in contact with the fluid, resulting in some type of interaction. The secondary element is that part of the system which translates this interaction into the desired readout or recording. While there is almost an endless variety of secondary elements, primary elements are related to a more limited number of physical principles, being dependent upon some property of the fluid other than, or in addition to, its volume or mass such as kinetic energy, inertia, specific heat, or the like. These primary element physical principles form a natural classification system for flow-measuring devices as presented in Table D-11.

D.3.2.1 Desirable Equipment Characteristics

Not all types of flow meters are suitable for measuring wastewater flows. The severe conditions and vagaries of many of these flows place a number of very stringent design requirements on flow measurement equipment if it is to function satisfactorily. No single design can be considered ideal for all flow measurement activities in all flows of interest. Despite this, one can set forth some equipment "requirements" in the form of primary design considerations and some desirable equipment features in the form of secondary design considerations.

The following are primary design considerations for equipment that is to be used to measure more difficult wastewaters such as storm and combined sewer flows:

1. Range. Since flow velocities may range from 0.03 to 9 m/s (0.1 to 30 fps), it is desirable that the unit have either a very wide range of operation; be able to automatically shift scales; or otherwise cover at least a 100 to 1 range.

TABLE D-11
FLOW METER CATEGORIZATION

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Division	Classification	Type	Subtype
Quantity	Gravimetric	Weigher	
Quantity	Gravimetric	Tilting Trap	
Quantity	Gravimetric	Weight Dump	
Quantity	Volumetric	Metering Tank	
Quantity	Volumetric	Reciprocating Piston	
Quantity	Volumetric	Oscillating or Ring Piston	
Quantity	Volumetric	Nutating Disc	
Quantity	Volumetric	Sliding Vane	
Quantity	Volumetric	Rotating Vane	
Quantity	Volumetric	Gear or Lobed Impeller	
Quantity	Volumetric	Dethridge Wheel	
Rate	Differential Pressure	Venturi	
Rate	Differential Pressure	Dall Tube	
Rate	Differential Pressure	Flow Nozzle	
Rate	Differential Pressure	Rounded Edge Orifice	
Rate	Differential Pressure	Square Edge Orifice	Concentric
Rate	Differential Pressure	Square Edge Orifice	Eccentric
Rate	Differential Pressure	Square Edge Orifice	Segmented
Rate	Differential Pressure	Square Edge Orifice	Gate or Variable Area
Rate	Differential Pressure	Centrifugal	Elbow or Long Radius Bend
Rate	Differential Pressure	Centrifugal	Turbine Scroll Case
Rate	Differential Pressure	Centrifugal	Guide Vane Speed Ring
Rate	Differential Pressure	Impact Tube	Pitot-Static
Rate	Differential Pressure	Impact Tube	Pitot Venturi
Rate	Differential Pressure	Linear Resistance	Pipe Section
Rate	Differential Pressure	Linear Resistance	Capillary Tube
Rate	Differential Pressure	Linear Resistance	Porous Plug
Rate	Variable Area	Gate	
Rate	Variable Area	Cone and Float	
Rate	Variable Area	Slotted Cylinder and Piston	
Rate	Head-Area	Weir	Sharp Crested
Rate	Head-Area	Weir	Broad Crested
Rate	Head-Area	Flume	Venturi
Rate	Head-Area	Flume	Parshall
Rate	Head-Area	Flume	Palmer-Bowlus
Rate	Head-Area	Flume	Diskin Device
Rate	Head-Area	Flume	Cutthroat
Rate	Head-Area	Flume	San Dimas
Rate	Head-Area	Flume	Trapezoidal
Rate	Head-Area	Flume	Type HS, H, and HL
Rate	Head-Area	Open Flow Nozzle	
Rate	Flow Velocity	Float	Simple
Rate	Flow Velocity	Float	Integrating
Rate	Flow Velocity	Tracer	
Rate	Flow Velocity	Vortex	Vortex-Velocity
Rate	Flow Velocity	Vortex	Eddy-Shedding
Rate	Flow Velocity	Turbine	
Rate	Flow Velocity	Rotating Element	Horizontal Axis
Rate	Flow Velocity	Rotating Element	Vertical Axis
Rate	Force-Displacement	Vane	
Rate	Force-Displacement	Hydrometric Pendulum	
Rate	Force-Displacement	Target	
Rate	Force-Displacement	Jet Deflection	
Rate	Force-Displacement	Ball and Tube	
Rate	Force-Momentum	Axial Flow Mass	
Rate	Force-Momentum	Radial Mass	
Rate	Force-Momentum	Gyroscopic	
Rate	Force-Momentum	Mangus Effect	
Rate	Thermal	Hot Tip	
Rate	Thermal	Cold Tip	
Rate	Thermal	Boundary Layer	
Rate	Other	Electromagnetic	
Rate	Other	Acoustic	
Rate	Other	Doppler	
Rate	Other	Optical	
Rate	Other	Dilution	
Rate	Other	Electrostatic	
Rate	Other	Nuclear Resonance	

2. Accuracy. For most purposes, an accuracy of ±10 percent of the reading at the readout point is necessary, and there will be applications where an accuracy of ±5 percent is highly desirable. Repeatability of better than ±2 percent is desired in almost all instances.

3. Flow Effects on Accuracy. The unit should be capable of maintaining its accuracy when exposed to rapid changes in flow; e.g., depth and velocity changes in an open channel flow situation. There are instances where the flows of interest may accelerate from minimum to maximum in as short a time period as 5 minutes.

4. Gravity and Pressurized Flow Operation. Because of the conditions that exist at many measuring sites, it is sometimes desirable that the unit have the capability (within a closed conduit) of measuring over the full range of open channel flow as well as the conduit flowing full and under pressure.

5. Sensitivity to Submergence or Backwater Effects. Because of the possibility of changes in flow resistance downstream of the measuring site due to blockages, rising river stages including possible reverse flow, etc., it is highly advantageous that the unit be able to continue to function under such conditions or, at a minimum, be able to sense the existence of such conditions which would lead to erroneous readings.

6. Effects of Solids Movement. The unit should not be seriously affected by the movement of solids such as sand, gravel, debris, etc., within the fluid flow.

7. Flow Obstruction. The unit should be as nonintrusive as possible to avoid obstruction or other interference with the flow, which could lead to flow blockage or physical damage to some portion of the device.

8. Head Loss. To be usable at a maximum number of measurement sites, the unit should induce as little head loss as possible.

9. Manhole Operation. To allow maximum flexibility in utilization, the unit should have the capability of being installed in confined and moisture-laden spaces such as sewer manholes.

10. Power Requirements. The unit should require minimum power at the measuring site to operate; the ability to operate on batteries is a definite asset for many installations.

The following secondary design considerations are desirable features for flow measuring equipment.

Site Requirements. Unit design should be such as to minimize site requirements, such as the need for a fresh water supply, a vertical drop, excessive physical space, etc.

Installation Restrictions or Limitations. The unit should impose a minimum of restrictions or limitations on its installation and be capable of use on or within sewers of varying size.

Simplicity and Reliability. To maximize reliability of results and operation, the design of the unit should be as simple as possible, with a minimum of moving parts, etc.

Unattended Operation. For the majority of applications, it is highly desirable that the equipment be capable of unattended operation.

Maintenance Requirements. The design of the equipment should be such that routine maintenance is minimal and troubleshooting and repair can be effected with relative ease, even in the field.

Adverse Ambient Effects. The unit should be unaffected by adverse ambient conditions such as high humidity, freezing temperatures, hydrogen sulphide or corrosive gases, etc.

Submersion Proof. The unit should be capable of withstanding total immersion without significant damage.

Ruggedness. The unit should be of rugged construction and as vandal and theft proof as possible.

Self Contained. The unit should be self contained insofar as possible in view of the physical principles involved.

Precalibration. In order to maximize the flexibility of using the equipment in different settings, it is desirable that it be capable of precalibration; i.e., it should not be necessary to calibrate the system at each location and for each application.

Ease of Calibration. Calibration of the unit should be a simple, straightforward process requiring a minimum amount of time and ancillary equipment.

Maintenance of Calibration. The unit should operate accurately for extended periods of time without requiring recalibration.

Adaptability. The system should be capable of: indicating and recording instantaneous flow rates and totalized flows; providing flow signals to associated equipment (e.g., an automatic sampler); implementation of remote sensing techniques or incorporation into a computerized urban data system, including a multisensor single readout capability.

Cost. The unit should be affordable both in terms of acquisition and installation costs as well as operating costs, including repair and maintenance.

It is not necessary that all of these primary and secondary design considerations be achieved for all applications. For example, flow measurement devices used to calibrate others need not necessarily be self-contained, nor would unattended operations be required. Furthermore, meeting all of the listed design considerations for all installations and settings would be difficult, if not impossible, to achieve in a single design. Nonetheless, the primary and secondary design considerations can be used to formulate a set of evaluation parameters against which a given design or piece of equipment can be judged. Since application details may make certain parameters more or less important in one instance or another, no attempt has been made to apply weighting factors or assign numerical rank. The evaluation factors should prove useful, as a check list among other things, for the 208 planner who has a flow measurement requirement and who may require assistance in the selection of his equipment. The evaluation parameters together with qualitative scales, are presented in the form of a flow measurement equipment checklist in Table D-12.

D.3.2.2 Evaluations of Some Promising Devices

A slightly modified form of the flow measurement equipment checklist given in Table D-12 has been used to evaluate the various flow-measuring devices and techniques of Table D-11, and a matrix summary is given as Table D-13. It must be emphasized that these evaluations are made with a highly variable wastewater application such as storm or combined sewer flow measurement in mind and will not necessarily be applicable for other types of flows.

Only a few of the evaluation parameters normally have numbers associated with them. To assist the reader in interpreting the ratings, the following general guidelines were used. If the normal range of a particular device was considered to be less than about 10 to 1, it was termed poor; if it was considered to be greater than around 100 to 1, it was termed good. The intermediate ranges were termed fair. The accuracy that might reasonably be anticipated in measuring storm or combined sewer flows was considered rather than the best accuracy achievable by a particular device. For example, although a sharp-crested weir may be capable of achieving accuracies of ±1.5 percent or better in clear irrigation water flows, accuracies of much better than ±4 to 7 percent should not necessarily be anticipated for a sharp-crested weir measuring stormwater or combined sewer discharges. If the accuracy of a particular flow-measuring device or method was considered to be better than around ±1 to 2 percent, it was termed good; if it was considered

TABLE D-12
FLOW MEASUREMENT EQUIPMENT CHECKLIST

Designation: ____

	Evaluation Parameter	Scale			Weight and Score
1	Range	☐ Poor	☐ Fair	☐ Good	
2	Accuracy	☐ Poor	☐ Fair	☐ Good	
3	Flow Effects on Accuracy	☐ High	☐ Moderate	☐ Slight	
4	Gravity & Pressurized Flow Operation	☐ No		☐ Yes	
5	Submergence or Backwater Effects	☐ High	☐ Moderate	☐ Low	
6	Effect of Solids Movement	☐ High	☐ Moderate	☐ Slight	
7	Flow Obstruction	☐ High	☐ Moderate	☐ Slight	
8	Head Loss	☐ High	☐ Medium	☐ Low	
9	Manhole Operation	☐ Poor	☐ Fair	☐ Good	
10	Power Requirements	☐ High	☐ Medium	☐ Low	
11	Site Requirements	☐ High	☐ Moderate	☐ Slight	
12	Installation Restrictions or Limitations	☐ High	☐ Moderate	☐ Slight	
13	Simplicity and Reliability	☐ Poor	☐ Fair	☐ Good	
14	Unattended Operation	☐ No	☐	☐ Yes	
15	Maintenance Requirements	☐ High	☐ Medium	☐ Low	
16	Adverse Ambient Effects	☐ High	☐ Moderate	☐ Slight	
17	Submersion Proof	☐ No		☐ Yes	
18	Ruggedness	☐ Poor	☐ Fair	☐ Good	
19	Self Contained	☐ No		☐ Yes	
20	Precalibration	☐ No		☐ Yes	
21	Ease of Calibration	☐ Poor	☐ Fair	☐ Good	
22	Maintenance of Calibration	☐ Poor	☐ Fair	☐ Good	
23	Adaptability	☐ Poor	☐ Fair	☐ Good	
24	Cost	☐ High	☐ Medium	☐ Low	
25	Portability	☐ No		☐ Yes	

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Comments:

to be worse than around ±10 percent, it was termed poor. The intermediate accuracies were termed fair.

The flow-measuring devices and techniques were not rated on two evaluation parameters, submersion proof and adaptability, because these factors are so dependent upon the design details of the secondary element selected by the user.

In comparison with Table D-13, Table D-14 offers a different (and even more subjective) comparison of the most promising primary devices or techniques. Each method is numerically evaluated in terms of its percent of achievement of several desirable characteristics. Dilution techniques as a class appear to be most promising of all. In view of the current state-of-the-art, however, their usefulness is probably greatest as a tool for in-place calibration of other primary devices. They have also been extremely useful for general survey purposes and have found some application as an adjunct to other primary devices during periods of extreme flow such as pressurized flow in a conduit that is normally open channel.

Acoustic open channel devices are also quite promising; but, because of their dependency upon the velocity profile and the frequently resulting requirement for several sets of transducers, they are presently only justifiable for very large flows in view of the expense involved. The usefulness of the Parshall flume is evidenced by its extreme popularity. The requirement for a drop in the floor is a disadvantage, and submerged operation may present problems at some sites. Known uncertainties in the head-discharge relations (possibly up to 5 percent) together with possible geometric deviations make calibration in place a vital necessity if high accuracy is required. Palmer-Bowlus type flumes are very popular overall. They can be used as portable as well as fixed devices in many instances, are relatively inexpensive, and can handle solids in the flow without great difficulty.

All point velocity measuring devices have been lumped together in the current meter category. In the hands of a highly experienced operator, good results can be obtained (the converse is also true, unfortunately), and they are

TABLE D-13
FLOWMETER EVALUATION SUMMARY

	Range	Accuracy	Flow Effects on Accuracy	Gravity & Pressurized Flow Operations	Submergence or Backwater Effects	Effect of Solids Movement	Flow Obstruction	Head Loss	Manhole Operation	Power Requirements	Site Requirements	Installation Restrictions or Limitations	Simplicity and Reliability	Unattended Operation	Maintenance Requirements	Adverse Ambient Effects	Submersion Proof	Ruggedness	Self Contained	Precalibration	Ease of Calibration	Maintenance of Calibration	Adaptability	Cost	Portability
Gravimetric-all types	G	G	H	Y	L	H	H	H	P	M	H	H	P	Y	H	M	-	F	Y	Y	G	F	-	H	N
Volumetric-all types	P	G	H	Y	L	H	H	M	P	L	H	H	F	Y	H	M	-	F	Y	Y	G	F	-	H	N
Verturi Tube	P	G	S	N	L	S	S	L	P	L	H	H	G	Y	M	M	-	G	Y	Y	G	G	-	H	N
Dall Tube	P	G	S	N	L	M	S	L	P	L	H	M	G	Y	M	M	-	G	Y	Y	G	F	-	H	N
Flow Nozzle	P	G	S	N	L	S	S	M	P	L	H	M	G	Y	L	M	-	G	Y	Y	G	G	-	M	N
Orifice Plate	P	F	S	N	L	H	H	H	P	L	H	S	G	Y	H	M	-	F	Y	Y	G	P	-	L	Y
Elbow Meter	P	F	S	N	L	S	S	L	P	L	H	S	G	Y	L	M	-	G	Y	N	F	G	-	L	N
Slope Area	F	P	H	N	H	S	S	L	G	L	M	S	G	Y	L	M	-	G	Y	N	F	G	-	H	N
Sharp-Crested Weir	F	F	M	N	M	H	H	H	F	L	M	M	G	Y	H	M	-	G	Y	Y	G	P	-	L	Y
Broad-Crested Weir	F	F	S	N	H	H	M	M	G	L	M	M	G	Y	L	M	-	G	Y	N	F	F	-	L	N
Subcritical Flume	F	F	S	N	L	S	S	L	F	L	M	S	G	Y	L	M	-	G	Y	Y	G	G	-	M	N
Parshall Flume	G	F	S	N	M	S	S	L	F	L	M	M	G	Y	L	M	-	G	Y	Y	G	G	-	M	Y
Palmer-Bowlus Flume	F	F	S	N	M	S	S	L	G	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	Y
Diskin Device	F	F	S	N	M	M	H	L	G	L	S	S	G	N	H	H	-	F	Y	Y	F	F	-	L	Y
Cutthroat Flume	G	F	S	N	L	S	S	L	P	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	N
San Dimas Flume	G	F	D	N	L	S	S	L	F	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	N
Trapezoidal Flume	G	F	S	N	L	S	S	L	F	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	N
Type HS, H & HL Flume	G	F	S	N	H	M	S	H	G	L	M	M	G	Y	M	M	-	G	Y	Y	G	F	-	L	Y
Open Flow Nozzle	G	F	S	N	H	M	S	H	G	L	M	M	G	Y	M	M	-	G	Y	Y	G	F	-	L	Y
Float Velocity	G	P	H	N	L	S	S	L	G	L	S	S	G	N	L	H	-	G	N	-	-	-	-	L	Y
Tracer Velocity	F	F	M	Y	L	S	S	L	G	M	S	S	F	Y	M	S	-	F	N	N	G	G	-	H	Y
Vortex Velocity	P	F	S	N	L	H	H	L	P	L	H	H	F	Y	H	S	-	F	Y	Y	F	F	-	H	N
Eddy-Shedding	F	F	S	Y	L	M	M	L	G	L	S	S	F	Y	M	S	-	F	Y	Y	G	F	-	M	Y
Turbine Meter	P	F	S	N	L	H	H	M	P	L	H	M	F	Y	H	S	-	F	Y	Y	G	F	-	H	N
Rotating-Element Meter	F	F	S	Y	L	H	M	L	F	L	S	S	G	N	H	N	-	G	N	Y	G	G	-	L	Y
Vane Meter	P	F	S	N	L	M	H	L	F	L	S	M	G	Y	M	M	-	G	Y	Y	F	F	-	L	N
Hydrometric Pendulum	P	P	S	N	L	M	M	L	G	L	S	S	G	N	L	H	-	G	N	Y	F	F	-	L	Y
Target Meter	P	F	S	N	L	M	H	M	P	M	S	M	F	Y	H	S	-	P	Y	Y	G	F	-	H	N
Force-Momentum	P	G	S	N	L	M	M	L	P	H	H	H	P	Y	H	S	-	P	Y	Y	G	G	-	H	N
Hot-Tip Meter	F	P	S	Y	L	H	M	L	F	M	M	M	F	Y	H	M	-	F	Y	Y	G	F	-	H	N
Boundary Layer Meter	G	G	S	Y	L	S	S	L	P	M	M	M	F	Y	M	S	-	G	Y	Y	G	G	-	H	N
Electromagnetic Meter	F	G	S	Y	L	S	S	L	P	H	M	M	F	Y	M	S	-	F	Y	Y	G	G	-	H	N
Acoustic Meter	G	G	S	Y	L	M	S	L	F	M	M	M	F	Y	M	S	-	F	Y	Y	G	G	-	H	N
Doppler Meter	P	G	S	Y	L	H	S	L	F	M	M	M	F	Y	M	S	-	F	Y	Y	G	G	-	H	N
Optical Meter	F	P	S	N	L	S	S	L	F	L	S	S	G	N	L	H	-	G	N	Y	G	G	-	L	Y
Dilution	G	G	M	Y	L	S	S	L	G	M	S	S	F	Y	M	S	-	F	N	N	G	G	-	H	Y

Legend:

F - Fair
G - Goal
H - High
L - Low
M - Medium or Moderate
N - No
P - Poor
S - Slight
Y - Yes

TABLE D-14
COMPARISON OF MOST POPULAR PRIMARY DEVICES OR TECHNIQUES

Primary Device or Technique	Desirable Characteristic (% of Achievement)								Comments
	Range	Uncalib. Accuracy	Head Loss	Free From Upstream Effects	Free From Downstream Effects	Solids Bearing Liquids	Portability	Unattended Operation	
Dilution	100	100	100	100	100	100	100	80	Especially useful as a calibration tool.
Acoustic (Open Channel)	100	100	100	60	90	95	80	100	Good in large flows but expensive.
Parshall Flume	90	95	80	90	80	90	70	100	Requires drop in floor.
Palmer Bowlus Flume	80	90	85	90	85	90	90	100	Good overall.
Current Meter	90	95	100	100	100	90	100	0	Results are very operator dependent.
Electromagnetic	50	100	100	100	100	100	0	100	Generally requires pressure flow.
Acoustic (Pressure Flow)	100	100	100	60	90	95	0	100	Wetted transducers recommended.
Open Flow Nozzle	60	95	70	80	75	80	80	95	Good if head drop is available.
Sharp-Crested Weir	60	95	70	80	80	50	80	90	Will require frequent cleaning.
Flow Tube	50	100	95	40	100	95	0	100	Pressurized flow only.
Venturi Tube	20	100	90	70	100	90	0	100	Pressurized flow only.
Trajectory Coordinate	80	70	50	100	70	100	100	0	Requires free discharge.
Slope Area	80	50	100	20	100	100	100	0	Use as last resort.

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often used to calibrate primary devices in place or for general survey work. They are generally not suited for unattended operation, however.

Electromagnetic flowmeters show considerable promise where pressurized flow is ensured, as do closed pipe acoustic devices. Neither can be considered portable if one requires that the acoustic sensors be wetted, a recommended practice for most wastewater applications.

Open flow nozzles and sharp-crested weirs are often used where the required head drop is available. Weirs will require frequent cleaning and are best used as temporary installations for calibration purposes. Flow tubes and venturis are only suitable for pressurized flow sites such as might be encountered, for example, at the entrance to a treatment plant.

Trajectory coordinate techniques, such as the California pipe or Purdue methods, require a pipe discharging freely into the atmosphere with sufficient drop to allow a reasonably accurate vertical measurement to be made, a situation not often encountered in sewers. Slope area methods (e.g., Manning, formula) must generally be considered as producing estimates only, and consequently should be considered as the choice of last resort (despite their apparent popularity).

D.3.2.3 Review of Commercially Available Equipment and Costs

The number of commercial firms that offer liquid flow-measuring equipment in the marketplace today is astoundingly large, probably well in excess of 200. Many manufacturers offer more than one type of primary device (and these typically in numerous models) and, when combined with secondary device choices, the number is virtually overwhelming. Thus, no attempt to cover all available equipment can be made here. We simply note that two or more firms offer all devices that were described except for sharp-crested weirs, which are usually fabricated directly by (or for) the user in accordance with specifications for the particular measuring site.

The firms offering flow-measuring equipment as at least a part of their product line range from very large, well-known manufacturers that have offered a wide range of flow-measuring equipment for over a century to relatively small organizations with a limited product line that has only recently been introduced. This latter category should not be excluded from consideration solely because of their seemingly novitiate status. The principals involved frequently have many years of experience, and their designs often reflect the most up-to-date expressions of the state-of-the-art.

The revolution in the electronics industry, especially as regards solid-state designs and integrated circuitry, has not gone unnoticed by most flowmeter manufacturers; as a result, many new, sophisticated secondary devices have recently appeared, and older equipment is frequently being upgraded in design to reflect the more modern technologies. Furthermore, many of these new secondary devices are of digital (rather than analog) design and are frequently computer compatible as supplied, offering tremendous possibilities for system structure.

A listing, by no means complete, of some manufacturers who offer flow-measuring equipment in the categories listed in Table D-14 is presented in Table D-15. Under the heading "Company," the name, address, and telephone number have been provided. Under the heading "Products" only those products bearing on the flow measurement categories of Table D-14 have been listed, even though the particular company may have a much more extensive flow measurement product line. The product emphasis was placed on primary devices, with secondary devices (in the form of level gages) indicated only where they are offered as "flowmeters." It can be generally assumed that each manufacturer offers a complete line of secondary elements for use with his primary devices.

Table D-15 can be used to obtain direct, up-to-date information on all of the types of equipment discussed from at least two suppliers. Reference can be made to Shelley and Kirkpatrick (8) for descriptions of the offerings of these and a number of other manufacturers.

TABLE D-15
SOME FLOW MEASUREMENT EQUIPMENT MANUFACTURERS

Company	Products
American Chain and Cable Company, Inc. ACCO Bristol Division Waterbury, Connecticut 06720 Telephone (203) 756-4451	Combination depth and velocity measuring device in a single unit
Badger Meter, Inc. Instrument Division 4545 West Brown Deer Road Milwaukee, Wisconsin 53223 Telephone (414) 355-0400	Flow tubes, open flow nozzles, Parshall flumes
Badger Meter, Inc. Precision Products Division 6116 East 15th Street Tulsa, Oklahoma 74115 Telephone (918) 836-4631	Acoustic (open channel)
BIP - A Unit of General Signal 1600 Division Road West Warwick, R.I. 02893 Telephone (401) 885-1000	Flow tubes, open flow nozzles, Parshall flumes, "universal" venturi tubes
Brooks Instrument Division Emerson Electric Company 407 West Vine Street Hatfield, Pennsylvania 19440 Telephone (215) 247-2366	Electromagnetic
Controlotron Corporation 176 Control Avenue Farmingdale, L.I., New York 11735 Telephone (516) 249-4400	Acoustic (pressure flow)
Cushing Engineering Inc. 3364 Commercial Avenue Northbrook, Illinois 60062 Telephone (312) 564-0500	Electromagnetic
C.W. Stevens, Inc. P. O. Box 619 Kennett Square, Pennsylvania 19348 Telephone (215) 444-0616	Acoustic level gage
Drexelbrook Engineering Company 205 Keith Valley Road Horsham, Pennsylvania 19044 Telephone (215) 674-1234	Electronic level gage
Environmental Measurement Systems A Division of Wesmar 905 Dexter Avenue North Seattle, Washington 98109 Telephone (206) 285-1621	Acoustic (open channel)
Epic Inc. 150 Nassau Street Suite 1430 New York, New York 10038 Telephone (212) 349-2470	Current meters, level gages
Fischer & Porter Co. Warminster, Pennsylvania 18974 Telephone (215) 675-6000	Electromagnetic, flow tubes, open flow nozzles, Parshall flumes, level gages
Carl Fisher and Company Division of Formulabs, Inc. 529 West Fourth Avenue P. O. Box 1056 Escondido, California 92025 Telephone (714) 745-6423	Fluorescent dyes
Flumet Co. P. O. Box 575 Westfield, New Jersey N. Y. Office: Telephone (212) 227-6668	Palmer-Bowlus flumes
The Foxboro Company Foxboro, Massachusetts 02035 Telephone (617) 543-8750	Electromagnetic, level gages
Hinde Engineering Company of California P. O. Box 56 Saratoga, California 95070 Telephone (408) 378-4112	Palmer-Bowlus flumes
Interocean Systems, Inc. 3510 Kurtz Street San Diego, California 92110 Telephone (714) 299-4500	Current meters, level gages
Kahl Scientific Instrument Corporation P. O. Box 1166 El Cajon, California Telephone (714) 444-2158	Current meters, fluorescent dyes
F. B. Leopold Company Division of Sybron Corporation 227 S. Division St. Zelienople, Pennsylvania 16063 Telephone (412) 452-6300	Open flow nozzles, Palmer-Bowlus flumes, Parshall flumes
Leupold & Stevens, Inc. P. O. Box 588 600 N. W. Meadow Drive Beaverton, Oregon 97005 Telephone (503) 646-9171	Float level gages
Manning Environmental Corp. 120 Du Bois Street P. O. Box 1356 Santa Cruz, California 95061 Telephone (408) 427-0230	Acoustic and "dipper" level gages
Martig Bub-L-Air 2116 Lakemoor Drive Olympia, Washington 98502 Telephone (206) 943-2390	Bubbler level gage
Metritape, Inc. 77 Commonwealth Avenue West Concord, Massachusetts 01742 Telephone (617) 369-7500	Electronic level gage
NB Products, Inc. 35 Beulah Road New Britain, Pennsylvania 18901 Telephone (215) 345-1879	Portable V-notch weirs, level gages

TABLE D-15
SOME FLOW MEASUREMENT EQUIPMENT MANUFACTURERS (Cont'd)

Company	Products	Company	Products
N-Con Systems Company 308 Main Street New Rochelle, New York 10801 Telephone (914) 235-1020	Float and "dipper" level gages	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Telephone (716) 735-3616	Bubbler level gage
Nusonics, Inc. 9 Keystone Place Paramus, New Jersey 07652 Telephone (201) 265-2400	Acoustic (pressure flow)	Singer-American Meter Division 13500 Philmont Avenue Philadelphia, Pennsylvania 19116 Telephone (215) 637-2100	Palmer-Bowlus flumes, Parshall flumes, level gages
Ocean Research Equipment, Inc. Falmouth, Massachusetts 02541 Telephone (617) 548-5800	Acoustic (open channel)	Sirco Controls Company 8815 Selkirk Street Vancouver 14, British Columbia, Canada Telephone (604) 261-9321	Acoustic level gage
The Permutit Company Division of Sybron Corporation E49 Midland Avenue Paramus, New Jersey Telephone (201) 262-8900	Flow tubes, open flow nozzles, Parshall flumes, venturi tubes	Taylor Sybron Corporation Taylor Instrument Process Control Division Telephone (716) 235-5000	Electromagnetic
Plasti-Fab, Inc. 11650 S. W. Ridgeview Terrace Beaverton, Oregon 97005 Telephone (502) 644-1428	Palmer-Bowlus flumes, Parshall flumes, V-notch weir boxes	Tri-Aid Sciences, Inc. 161 Norris Drive Rochester, New York 14610 Telephone (716) 461-1660	Acoustic level gage
Plocon, Inc. An Affiliate of Carl F. Buettner & Associates, Inc. 5106 Hampton Avenue St. Louis, Missouri 63109 Telephone (314) 353-5993	Open channel flow tube	Universal Engineered Systems, Inc. 7071 Commerce Circle Pleasanton, California 94566 Telephone (415) 462-1543	Palmer-Bowlus flumes
PORTAC Min-Ell Company, Inc. 1689 Blue Jay Lane Cherry Hill, New Jersey 08003 Telephone (609) 429-0421	Current meter flow tube	Vickery-Simms, Inc. P. O. Box 459 Arlington, Texas 76010 Telephone (817) 261-4446	Parshall flumes, venturi
Robertshaw Controls Company P. O. Box 3523 Knoxville, Tennessee 37917 Telephone (615) 546-0524	Parshall flumes, level gages	Wallace-Murray Corporation Carolina Fiberglass Plant P. O. Box 580 510 East Jones Street Wilson, North Carolina 27893 Telephone (919) 237-5371	Parshall flumes
Saratoga Systems, Inc. 10601 South Saratoga-Sunnyvale Road Cupertino, California 95014 Telephone (408) 247-7120	Acoustic (pressure flow)	Wesmar Industrial Systems Division 905 Dexter Avenue North Seattle, Washington 98109 Telephone (206) 285-2420	Acoustic level gages
Scarpa Laboratories, Inc. 46 Liberty Street, Brainy Boro Station Metuchin, New Jersey 08840 Telephone (201) 549-4260	Acoustic (pressure flow)	Westinghouse Electric Corporation Oceanic Division P. O. Box 1488, Mail Stop 9R30 Annapolis, Maryland 21404 Telephone (301) 765-5658	Acoustic (open channel)

In these days of inflation, little can be said about equipment costs except in a very cursory fashion. For example, one manufacturer is anticipating a 30-percent increase in the cost of basic flow tube forgings, catalog pricing is giving way to individual quotes for larger systems, and some manufacturers are quoting tentative estimates subject to adjustment at delivery. Desired features such as remote readouts, digital outputs, recorder types, battery parts, etc., add another diversion to total system costs. The following discussion is more indicative them precise, and all costs must be increased if many accessories are desired.

Dilution flow measurement systems can be put together for under $3K. The chemicals (salt, dye, etc.) are inexpensive. Acoustic open channel devices start at around $5K, and larger systems are quoted on an installation basis only, with $15-40K being a typical charge for a four-path system and some large, complex installations approaching $100K in cost. Parshall flumes run from $300 to over $2K in portable versions, depending upon size, and from $500 to $5K for fixed installations, not counting secondary devices. Palmer-Bowlus flumes without a level gage will cost between $300 and $3K depending upon size. Construction materials also affect flume prices.

Simple current meters start at around $300 for basic Price or Ott types and may run as high as $1,500. Electromagnetic current meters cost from $2K to $3K. Electromagnetic pipe meters start at around $2K for small (2 in.) sizes and run to over $30K in the largest practicable sizes. Acoustic pipe meters run from $2K to $20K depending upon size. These prices are for complete systems including secondary devices.

Open flow nozzles, flow tubes, and Venturi tubes are comparably priced with forging costs and machining accounting for the major portion. In small sizes (3 in.) they run under $1K, and range up to $15-20K in large sizes (48 in.). These prices do not include secondary devices.

The liquid level gage market is intensely competitive at the present time, and prices are similar regardless of technique (e.g., electronic, bubble, acoustic, dipper, etc.). They run from just under $1K for a basic device with visual read-out to over $2K with flow converters, recorders, transmitters, etc., as accessories.

As a closing note, construction, installation, and (importantly) projected maintenance and repair costs must be considered in addition to the equipment acquisition costs given above to arrive at true cost of ownership, which is the only real basis for comparison.

D.3.2.4 Review of Recent Field Experience

A brief review of flow measurement experiences, with emphasis on recent projects in the storm and combined sewer area, will be given to allow a better appreciation of the application of some of the flow-measuring devices and techniques in an actual field setting. The various experiences are presented by primary device or technique as listed in Table D-14. It should be pointed out that, although the following discussion focuses more on the negative experiences, instances of good results were encountered with all types of flow measurement.

Dilution methods were successfully used to calibrate primary devices in several instances. In one installation, this technique was used to measure flows in a sewer under surcharged conditions. A Palmer-Bowlus flume was employed for normal flow conditions. When the secondary device indicated that the sewer line was nearly filled, a signal was given to begin chemical injection. An automatic sampler was used to obtain samples for concentration analysis at a site downstream from the injection equipment. Some other attempts to use dilution methods were less successful, and it was abandoned by several projects. Erroneous effects due to exposed sludge banks, insufficient turbulence to ensure mixing, and poor equipment operation (especially samplers) were among difficulties cited.

Open channel acoustic devices had rather little use in the projects examined because of their recent origin. Although successful installations exist, their use has been abandoned at other locations. The primary difficulties have to do with particles, notably air bubbles, in the flow causing improper readings, the complex velocity patterns requiring a number of transverse sensors, and simple shakedown difficulties typical of early designs of many complex electronic devices. Acoustic level gages were plagued by wind (in an open application), foam, standing ripples on the water surface, and false echoes from manhole structures or other confined areas. More recent indications are that such problems are being overcome, and satisfaction with these devices appears to be increasing.

Parshall flumes were used in many projects, and they performed well when dimensions were faithfully followed, standard approach conditions were present, and (especially) when calibrated in place. Unfortunately, far too many Parshall flume installations are nonstandard, reflecting difficulties in making precise structures from poured concrete, the improper use of a lightweight plastic flume liner as a form, etc.

Palmer-Bowlus type flumes were successfully used in a number of instances, including portable versions intended for short-time application at any given site. Other than their loss of accuracy as the pipe fills and surcharges, no general negative comments about the devices themselves were encountered. There were numerous complaints concerning secondary devices used in conjunction with Palmer-Bowlus flumes, however, especially bubblers. Instances of their collecting debris and otherwise requiring frequent cleaning and maintenance abound. In one project, their use was abandoned altogether, and they were replaced with another type of level sensor.

Current meters were almost exclusively used to spot check flows and verify or rate existing structures. There were flows where they could not be used at all, however, because they immediately became fouled by rags, plastic sheets, and other debris.

Electromagnetic devices were not encountered, except where they had already been installed for other purposes. They appeared to work well, but the need for periodic inspection and verification of any fixed flow-measuring device was illustrated at one installation. As a part of a general flowmeter inspection in one district an apparently well performing electromagnetic flowmeter was found to be in error by over 50 percent. The cause was a piece of utility pole resting in the meter proper.

No projects examined used pressure flow acoustic meters, but their use in industrial plant applications has apparently been successful in many instances. Open flow nozzles performed rather well where sites allowed their use. Frequent inspection and cleaning were required at several installations, however, to ensure proper readings.

Sharp-crested weirs were among the most commonly used (and misused) primary devices encountered. Problems ranged from failure to properly account for approach velocity, improper sizing, backwater elevations causing surcharging and flooding, to almost continual cleaning being required in very trashy flows.

Flow tubes and venturi tubes were seldom encountered, except where they had existed for other purposes. They generally seemed to produce complete and accurate records.

Trajectory coordinate estimates were uncommon, owing to the lack of suitable sites.

Slope-area methods (Manning in particular) were far and away the most frequently encountered. They ranged from proper applications yielding reasonable discharge estimates to totally unsuitable applications, as in one case where the combined sewer discharge was found to considerably exceed the measured precipitation event. Difficulties ranged from accurately measuring slopes to estimating the proper friction coefficient (n) to use, in the best instances, to unknowledgeable attempts and improper applications in the worst. Apparently, far too many persons think that all that has to be done is to measure stage and plug into a handy formula to obtain flow. It is long past time that that situation be corrected.

D.3.3 Flow Measurement Field Procedures

For flow measurement in natural streams and channels, it is recommended that USGS assistance be obtained. They will establish gaging stations (temporary or permanent) at reasonable cost upon request and provide ratings to convert stage to discharge. Often a culvert or some other control structure for which a theoretical rating can be developed will be used. In some instances, weirs or flumes will have to be used. It is prudent to spot check the ratings of new gaging stations periodically. Be alert to changes in channel characteristics that would affect the established rating, e.g., sedimentation, erosion, deposition of large stones or boulders, etc.

Follow the manufacturer's recommendations for the installation, calibration, and operation of the liquid level gages used to record stage. Where stilling wells are employed, the connecting pipe should be checked for obstruction on each visit, as should the float and cable operation. Note any instances that could affect readings in the field log and the corrective action taken. It is also prudent to verify chart time at each visit if record length exceeds visit frequency (e.g., weekly flow charts but daily sampling). If a manual sample is taken, a mark made on the flow chart can assist in subsequent data analysis.

For manually gaging natural streams at the time of sampling, follow the guidance given by the Bureau of Reclamation (12). Do not take a stream gaging until all required samples for the site have been collected. Try to minimize or avoid walking in the stream until sampling is completed. Stirring up the bottom may result in nonrepresentative samples. A complete flow record is more desirable, however, and flow determinations made manually at the time of sampling should be considered as a last choice.

For flow measurement in man-made channels and conduits, the use of an appropriate primary device (refer to discussion in section D.3.2) is recommended. These should be properly installed, following manufacturer's recommendations in the case of commercial devices. The Bureau of Reclamation

Manual (12) provides much helpful information. An independent verification of the installation (i.e., by someone not on the installation team) will be prudent in most instances. This is especially true where existing flow-metering stations are to be used. Checklists for each type of primary device should be prepared to facilitate field inspection. As an example, a check-list for a contracted rectangular weir is presented in Table D-16.

Comments made above for secondary devices apply here as well. In closed conduits that are subject to occasional surcharging, try to install the level gage so that it will indicate when this condition occurs. Although the degree of surcharging cannot be indicated by most designs, knowledge of the period of time over which the surcharge condition exists may be helpful in subsequent data analysis. Such sites are best avoided wherever possible, however.

On each visit, the flow-measuring equipment should be inspected to ensure proper functioning. Visual verification of stage readings with a staff gage is recommended at each visit, and results should be noted in the field log, along with any anomalies discovered (e.g., a rag caught in the notch of a weir, a stuck float, a clogged stilling well connection tube, etc.) and any corrective actions taken. The possible buildup of sediment behind a weir should be checked (the staff gage can be used) and any accumulation removed. An occasional in-place calibration check is recommended to ensure that subtle changes that could affect the record have not occurred.

One word of caution as regards the use of sewer maps is in order. Typically, such maps (elevations especially) reflect intentions rather than installations. Even so-called as-built drawings may only indicate average invert slopes from manhole to manhole and tell little about variations in true slope. It is generally a prudent practice to verify pipe slopes entering and leaving manholes where flow measurements are to be made.

Flow measurement at outfall sites can present some unique difficulties. Where there is a drop from the discharge pipe invert to the upper level of the receiving stream, the site will probably be acceptable, and a temporary

TABLE D-16

CHECKLIST FOR CONTRACTED RECTANGULAR WEIR

1.	What is the maximum measurable head?	____
2.	Is upstream face of bulkhead smooth?	☐
3.	Is upstream face of bulkhead vertical? (check for plumb with level)	☐
4.	Is upstream face of weir plate smooth, straight, and flush with upstream face of bulkhead?	☐
5.	Is weir axis perpendicular to channel axis? (check with line and carpenter's square)	☐
6.	Is entire crest level?	☐
7.	What is thickness of crest in flow direction? (should be between 0.03 and 0.08 inch)	____
8.	Is upstream corner of crest sharp and at right angles to upstream face?	☐
9.	Are both side edges truly vertical and of same thickness as crest?	☐
10.	Are downstream edges of notch chamfered? (angle should be 45° or more to crest surface)	☐
11.	What is distance of crest from bottom of approach channel? (should be at least twice the depth above the crest and never under one foot)	____
12.	What is distance from sides of weir to sides of approach channel? (should be at least twice the depth above the crest and never under one foot)	____
13.	Does nappe touch only the upstream edges of the crest and sides? Is nappe free? Is there free fall?	☐
14.	Does zero head reading match with crest elevation?	☐
15.	Is head reading taken upstream a distance of at least 3 times the maximum head on the crest?	☐
16.	Is the cross-sectional area of the approach channel at least 8 times that of the nappe?	☐
17.	Does this condition extend upstream at least 15 times the depth above the crest?	☐
18.	If weir pool is smaller than defined above, measure velocity of approach with current meter.	____
19.	If appreciable velocity of approach is measured are head readings being corrected?	☐

weir box can be installed and used satisfactorily. Where the receiving stream level is above the invert but below the crown, a pipe extension and Palmer-Bowlus flume (or a Parshall flume in some instances) can possibly be used. The real problem occurs where the outfall is completely submerged, and the expense of a permanent device such as an electromagnetic flow meter (otherwise, an excellent choice for such a site since it can measure flow in either direction) cannot be tolerated. The best advice is to find another site. If that cannot be done, the only recourse is to use a current meter to obtain a velocity, adjust this to an average value, and multiply by the pipe area to obtain flow. Where there is insufficient debris in the flow to cause problems in operation, an oceanographic type recording current meter or some other recording point velocity sensor can be used. For very trashy flows, the only solution may be to measure velocities manually, cleaning up the current meter between observations. This approach may be acceptable for some intermittent discharges if a man can get to the site on time, but continuous records are impracticable.

D.4 Sampling Considerations, Equipment, and Procedures

The objective of any sampling effort is to remove, from a defined universe, a small portion that is in some way representative of the whole. Ideally, a representative sample will accurately reflect the physical and chemical characteristics of the bulk source in every respect as they were during the sampling period. In water quality, such representativeness is seldom if ever achieved and, fortunately, seldom required. As used herein, a representative sample is one that, when examined for a particular parameter, will yield a value from which that bulk source characteristic can be determined. The proper sampling methodology, i.e., that which will produce a representative sample, is dependent upon the type of bulk source to be sampled, e.g., surface water in natural channels (rivers, streams, lakes), municipal wastewater, ground water, urban runoff, industrial wastewater, treatment lagoon, and so on. Nonetheless, there are some more or less universal sampling considerations, and they will now be addressed.

D.4.1 Sample Types

The selection of the type of sample to be collected depends on a number of factors, such as the rates of change of flow and the character of the water or wastewater, the accuracy required, and the availability of funds for conducting the sampling program. All samples collected, either manually or with automatic equipment, are included in the following types, which terminology has been recommended for standard usage by Shelley and Kirkpatrick (14).

Discrete Sample

A discrete sample (sometimes called a grab sample) is one that is collected at a selected point in time and retained separately for analysis. A sequential discrete sample is a series of such samples, usually taken at constant time intervals (e.g., one each hour over a 24-hour period), but sometimes at constant discharge increments (e.g., one for each 100,000 gallons of flow) when paced by a flow totalizer.

Simple Composite Sample

A simple composite sample is one that is made up of a series of aliquots (smaller samples) of constant volume (Vc) collected at regular time intervals (Tc) and combined in a single container. Such a sample could be denoted by TcVc, meaning time interval between successive aliquots constant and volume of each aliquot constant.

Flow Proportional Composite Sample

A flow proportional composite sample is one collected in relation to the flow volume during the period of compositing, thus indicating the "average" condition during the period. One of the two ways of accomplishing this is to collect aliquots of equal volume (Vc), but at variable time intervals (Tv), that are inversely proportional to the volume of the flow. That is, the time interval between aliquots is reduced as the volume of flow increases. Alternatively, flow proportioning can be achieved by increasing the volume of each aliquot in proportion to the flow (Vv), but keeping the time interval between aliquots constant (Tc).

Sequential Composite Sample

A sequential composite sample is composed of a series of short-period composites, each of which is held in an individual container. For example, each of several samples collected during a 1-hour period may be composited for the hour. The 24-hour sequential composite is made up from the individual 1-hour composites.

Continuous Sample

A continuous sample is one collected by extracting a small, continuously flowing stream from the bulk source and directing it into the sample container. The sample flow rate may be constant (Qc), in which case the sample is analogous to the simple composite, or it may be varied in proportion to the bulk source flow rate (Qv), in which case the sample is analogous to the flow proportional composite.

For initial characterization of wastewater flows, sequential discrete sampling is generally desired. It is mandatory for accurate stormwater characterization, since it allows characterization of the wastewater over a time history and provides information about its variations with time. If the samples are sufficiently large, manual compositing can also be performed, based on flow records or some other suitable weighting scheme, and a preferred composite type determined. Some form of automatic compositing will usually be desired for continued wastewater discharge characterization.

A brief look at the different types of composite samples is in order. Any scheme for collecting a composite sample is, in effect, a method for mechanically integrating to obtain average flow characteristics. The simple composite is the crudest attempt at such averaging and will be representative of the waste flow during the period only if the flow properties are relatively constant.

For variable flows, some type of proportioning must be used. This is equivalent to saying that the simple composite is a very poor scheme for numerical integration, and a higher order method is desirable. There are two fundamental approaches to obtaining better numerical integration, given a fixed number of steps. One is to increase the order of the integration scheme to be used, as in going from the trapezoidal rule to Simpson's rule. The other is to vary the step size in such a way as to lengthen the steps when slopes are changing very slowly and shorten them when slopes change rapidly. Typical of the first approach are the constant time interval, variable volume (TcVv) proportional composites. There are two straightforward ways of accomplishing this. One is to let the aliquot volume be proportional to the instantaneous flow rate, and the other is to make the aliquot volume proportional to the quantity of flow that has passed since extraction of the last aliquot. Typical of the second approach is the variable time interval, constant volume (TvVc) proportional composite. Here a fixed volume aliquot is taken each time an arbitrary quantity of flow has passed.

It is instructive to compare these four composite sample schemes. For the purposes of this example, four flow functions and five concentration functions are examined. The selections are completely arbitrary (except for simplicity in exact integration) and, in practice, site specific data should be used. For each flow/concentration combination, the exact average concentration of the flow was computed (as though the entire flow stream were diverted into a large tank for the duration of the event and then its concentration measured). The ratio of the composite sample concentration to the actual concentration so computed is presented in matrix form in Figure D-4 (taken from Shelly and Kirkpatrick, 15). The four rows in each cell represent the four types of composite samples discussed as indicated in the legend. The best overall composite for the cases examined is the TcVv, with the volume proportional to the instantaneous flow rate q. The TcVv where the volume is proportional to the flow since the last sample, and the TvVc gave very similar results with a slight edge to the former. However, the differences are not large for any case. This brief look at compositing merely scratches the surface. Flow records and a knowledge of the temporal

q FLOW \ CONC k	$1-t$	$1-\frac{t}{2}$	$\cos\frac{\pi t}{2}$	e^{-t}	$\sin \pi t$
C	0.90 0.90 0.90 0.90	0.97 0.97 0.97 0.97	0.92 0.92 0.92 0.92	0.95 0.95 0.95 0.95	0.99 0.99 0.99 0.99
t	1.35 0.90 0.86 0.87	1.09 0.97 0.96 0.96	1.26 0.90 0.87 0.89	1.14 0.97 0.95 0.95	0.99 0.90 0.89 0.97
1-t	0.68 0.95 0.92 0.92	0.87 0.98 0.97 0.97	0.72 0.98 0.95 0.93	0.82 0.96 0.95 0.95	0.99 1.12 1.09 0.97
$\sin \pi t$	0.90 1.01 0.90 0.90	0.97 1.00 0.97 0.97	0.88 1.00 0.92 0.92	0.97 1.00 0.95 0.95	0.80 1.01 0.98 0.97

The rows within each flow/concentration cell refer to the following sample types:

Row 1. TcVc - Simple composite
Row 2. TcVv - Volume proportional to flow rate (q)
Row 3. TcVv - Volume proportional to flow (Q) since last sample
Row 4. TvVc - Time varied to give constant ΔQ

FIGURE D-4
RATIO OF COMPOSITE SAMPLE CONCENTRATION TO ACTUAL CONCENTRATION

fluctuation of pollutants, as can be obtained from discrete samples, are required in order to choose a "best" compositing scheme for a given installation.

Continuous samples are also composite in nature but do not fit in the foregoing discussion since the discrete step integration analogy is not applicable. Had we included the Qv continuous sample in the foregoing example, its ratio would have been unity for all combinations in Figure D-4. Other considerations severely limit the instances where a continuous sample is the composite of choice. For wastewater sampling, it is generally agreed that the minimum line inside diameter is 0.6 cm (1/4 in.) and that the sample flow velocity should be at least 0.76 m/s (2.5 fps). A simple calculation shows that the minimum volume of a 24-hour continuous sample would be 2085 liters (551 gal), hardly a practicable size. For this reason, continuous samples are useful only for very pristine flows (e.g., drinking water), where the very low flow rates necessary to keep sample volumes reasonable may still allow a representative sample to be obtained.

D.4.2 Automatic Sampling Equipment

In the following, a systems breakdown of automatic sampling equipment is given in generic terms to allow the reader to better appreciate their functional purposes and requirements. A survey of commercially available automatic sampling equipment and costs is given, and a review of field experience with these devices is provided.

D.4.2.1 Elements of an Automatic Sampler System

In a system breakdown by functional attributes, an automatic liquid sampler may be divided into five basic elements or subsytems. Each of these will be discussed in turn.

D.4.2.1.1 Sample Intake Subsystem

The operational function of the sample intake is to reliably allow the gathering of a representative sample from the flow stream in question. Its reliability is measured in terms of freedom from plugging or clogging, to the degree that sampler operation is affected, and invulnerability to physical damage due to large objects in the flow. It is also desirable, from the viewpoint of sewer operation, that the sample intake offer a minimum obstruction to the flow in order to reduce the possibility of blockage of the entire pipe by lodged debris, etc.

The sample intake of many commercially available automatic liquid samplers is often only the end of a plastic suction tube, and the user is left to his own ingenuity and devices if he desires to do anything other than simply dangle the tube in the stream to be sampled. Some manufacturers provide a weighted, perforated plastic cylinder that screens the hose inlet from the unwanted material that might cause choking or blockage elsewhere within the sampler. Typical hole sizes are around 1/3 cm (1/8 in.) in diameter and, if there are sufficient holes to ensure free flow, results have been satisfactory in some applications. Samplers that employ pneumatic ejection have their own intake chambers that must be used in order for the equipment to function properly.

D.4.2.1.2 Sample-Gathering Subsystem

Three basic sample-gathering methods or categories can be identified: mechanical, forced flow, and suction lift. The sample lift requirements of the particular site often play a determining role in the gathering method to be employed.

Mechanical Methods. There are many examples of mechanical gathering methods used in both commercially available and one-of-a-kind samplers. One of the more common designs is the cup on a chain driven by a sprocket drive arrangement. In another design, a cup is lowered within a guide pipe, via a small automatic winch and cable. Other examples include a self-closing pipe-like device that extracts a vertical "core" from the flow stream, a specially contoured box assembly with end closures that extracts a short length (plug) of the entire flow cross section, and a revolving or oscillating scoop that traverses the entire flow depth.

Some of the latter units employ scoops that are characterized for use with a particular primary flow measurement device, such as a weir or Parshall flume, and extract an aliquot volume that is proportional to the flow rate. Another design for mechanically gathering flow-proportional samples involves the use of a sort of Dethridge wheel with a sample cup mounted on its periphery. Since the wheel rotation is proportional to flow, the effect is that a fixed volume aliquot is taken each time a certain discharge quantity has passed, and total discharge can be estimated from the size of the resultant composite sample.

The foregoing designs have primarily arisen from one of two basic considerations: (1) site conditions that require very high lifts, or (2) the desire to gather samples that are integrated across the flow depth. One of the penalties that must be traded off in selecting a mechanical gathering unit is the necessity for some obstruction to the flow, at least while the sample is being taken. The tendency for exposed mechanisms to foul, together with the added vulnerability of many moving parts, means that successful operation will require periodic inspection, cleaning, and maintenance.

Forced Flow Methods. All forced flow gathering methods require some obstruction to the flow, but usually it is less than with mechanical gathering methods. It may be only a small inlet chamber with a check valve assembly of some sort, or it may be an entire submersible pump. The main advantage of submersible pumps is that their high discharge pressures allow sampling at greater depths, thereby increasing the flexibility of the unit somewhat, insofar as site depth is concerned. Pump malfunction and clogging, especially in the pump sizes often used for samplers, is always a distinct possibility; because of the pump's location in the flow stream itself, maintenance is much more difficult and costly to perform than on above-ground or more easily accessible units. Submersible pumps also necessarily present an obstruction to the flow and are thus in a vulnerable position as regards damage by debris.

Pneumatic ejection is a forced flow gathering method used by a number of commercial samplers. The gas source required by these units varies from bottled refrigerant to motor-driven air compressors. The units that use bottled refrigerant must be of a fairly small scale to avoid an enormous appetite for the gas and, hence, a relatively short operating life before the gas supply is exhausted. Furthermore, concern has recently been expressed about the quantities of freon that are being discharged into the atmosphere. The ability of such units to backflush or purge themselves is also limited. The advantages of few moving parts, inherent explosion-proof construction, and high lift capabilities must be weighed against low or variable line velocities, low or variable sample intake velocities, and relatively small sample capacities in some designs. Another disadvantage of many pneumatic ejection units is that the sample chamber fills immediately upon discharge of the previous sample. Thus, it may not be representative of flow conditions at the time of the next triggering and, if paced by a flow meter, correlation of results may be quite difficult.

Suction Lift Methods. Suction lift units must be designed to operate in the environment near the flow to be sampled or else their use is limited to a little over 9m (30 ft) due to atmospheric pressure. Several samplers that take their suction lift directly from an evacuated sample bottle are available today. Vacuum leaks, the variability of sample size with lift, the requirement for heavy glass sample bottles to withstand the vacuum, the difficulty of cleaning due to the requirement for a separate line for each sample bottle, the necessity of placing the sample bottles near the flow stream (and hence in a vulnerable position), and the varying velocities as the sample is being withdrawn, are among the many disadvantages of this technique.

Other units are available that use a vacuum pump and some sort of metering chamber to measure the quantity of sample being extracted. These units, in some designs, offer the advantages of fairly high sample intake and transport velocities. The fluid itself never comes in contact with the pump, and the pump output can easily be reversed to purge the sampling line and intake to help prevent cross-contamination and clogging.

A variety of positive displacement pumps have been used in the design of suction lift samplers, including flexible impeller, progressive cavity rotary screw, roller or vane, and peristaltic types. Generally these pumps are self-priming (as opposed to many centrifugal pumps), but some designs should not be operated dry because of internal wearing of rubbing parts. The desirability of a low-cost pump that is relatively free from clogging has led many designers to use peristaltic pumps. A number of types have been employed including finger, nutating, and two- and three-roller designs using either molded inserts or regular tubing. Most of these operate at such low flow rates, however, that the representativeness of suspended solids is questionable. Newer high-capacity peristaltic pumps are now available and are finding application in larger automatic samplers. The ability of some of these pumps to operate equally well in either direction affords the capability to blow down lines and help remove blockages. Also, they offer no obstruction to the flow since the transport tubing need not be interrupted by the pump, and strings, rags, cigarette filters, and the like are passed with ease.

All in all, the suction-lift gathering method appears to offer more advantages and flexibility than either of the others for many applications. The limitation on sample lift can be overcome by designing the pumping portion of the unit so that it can be separated from the rest of the sampler and thus positioned within 6m (20 ft) or so of the flow to be sampled. For many sites, however, even this will not be necessary.

D.4.2.1.3 Sample Transport Subsystem

The majority of the commercially available automatic samplers have fairly small line sizes in the sample train. Such tubes, especially at 1/3 cm (1/8 in.) inside diameter and smaller, are very vulnerable to plugging, clogging due to the buildup of fats, etc. For many applications, a better minimum line size would be 1 to 1.3 cm (3/8 to 1/2 in.) inside diameter.

For flows that are high in suspended solids, it is imperative that adequate sample flow rate be maintained throughout the sampling train in order to effectively transport them. In horizontal runs, the velocity must exceed the scour velocity while, in vertical runs, the settling or fall velocity must be exceeded several times to ensure adequate transport of solids in the flow. Sharp bends and twists or kinks in the sampling lines should be avoided if there is a possibility of trash or debris in the lines that could become lodged and restrict or choke the flow. The same is true of some valve designs. In summary, the sampling train must be sized so that the smallest opening is large enough to give assurance that plugging or clogging is unlikely in view of the material being sampled. However, it is not sufficient to simply make all lines large, which also reduces friction losses, without paying careful attention to the velocity of flow. For many applications, minimum velocities of 0.6 to 1 m/s (2 to 3 fps) would appear warranted, and even higher velocities are required for some applications.

D.4.2.1.4 Sample Storage Subsystem

The sample container itself should either be easy to clean or disposable. Although some of today's better plastics are much lighter than glass and can be autoclaved, they are not so easy to clean or inspect for cleanliness. Also, the plastics will tend to scratch more easily than glass and, consequently, cleaning a well-used container can become quite a chore.

The requirements for sample preservation are discussed elsewhere, but it should be noted here that refrigeration is stated as the best single preservation method and will, in all likelihood, be required unless the sampling cycle is brief and samples are retrieved shortly after being taken. Light can also affect samples, and either a dark storage area or opaque containers would seem desirable. If opaque containers are used, however, they should be disposable, since it would be difficult to inspect an opaque container for cleanliness.

D.4.2.1.5 Controls and Power Subsystem

The control aspects of some commercial automatic samplers have come under particular criticism. It is no simple matter, to provide great flexibility in operation of a unit while at the same time avoiding all complexities in its control system. The problem is not only one of component selection but of packaging as well. For instance, even though the possibility of immersion may be extremely remote in a particular installation, the corrosive, highly humid atmosphere, which will, in all likelihood, be present, makes sealing of control elements and electronics desirable in most instances.

The controls determine the flexibility of operation of the sampler, e.g., its ability to be paced by various types of flow-measuring devices. Built-in timers should be repeatable, and time periods should not be affected by voltage variations. The ability to repeatedly gather the required aliquot volume independent of flow depth or lift is very important if composite samples are to be collected. Provisions for manual operation and testing are desirable, as is a clearly laid out control panel. Some means of determining the time when discrete samples were taken is necessary if synchronization with flow records is contemplated. An event marker is desirable for a sampler that is to be paced by an external flow recorder. Reliability of the control system can dominate the total system reliability. At the same time, this element will, in all likelihood, be the most difficult to repair and calibrate. Furthermore, environmental effects will be the most pronounced in the control system.

The required tasks can be best executed, in the light of the current electronics state-of-the-art, by a solid-state controller element. Such designs offer higher inherent reliability and are becoming more and more common in commercially available samplers. In addition, the unit should be of modular construction for ease of modification, performance monitoring, fault location, and replacement/repair. Such an approach also lends itself to encapsulation, which will minimize environmental effects. Solid-state switching eliminates the possibility of burned or welded contacts, either of which will cause complete sampler breakdown.

Some automatic samplers available today require a 110V AC power supply, but many battery-operated units are also available. The latter are, of necessity, smaller in size and sample transport velocity but still have a wide range of application. Other portable units utilize compressed gas or spring motors as the only required power source.

D.4.2.2 Considerations in Automatic Sampler Selection

Presently available automatic liquid samplers have a great variety of characteristics with respect to size of sample collected, lift capability, type of sample collected (discrete or composite), materials of construction, and numerous other both good and poor features. A number of considerations in selection of a sampler are:

- Rate of change of wastewater conditions
- Frequency of change of wastewater conditions
- Range of wastewater conditions
- Periodicity or randomness of change
- Availability of recorded flow data
- Need for determining instantaneous conditions, average conditions, or both
- Volume of sample required
- Need for preservation of sample
- Estimated size of suspended matter
- Need for automatic controls for starting and stopping
- Need for mobility or for a permanent installation
- Operating head requirements

In addition to the foregoing attributes of automatic sampling equipment, there are also certain desirable features that will enhance the utility and value of the equipment. For example, the design should be such that maintenance and troubleshooting are relatively simple tasks. Spare parts should be readily available and reasonably priced. The equipment design should be such that the unit has maximum inherent reliability. As a general rule, complexity in design should be avoided even at the sacrifice of a certain degree of flexibility of operation. A reliable unit that gathers a reasonably representative sample most of the time is much more desirable than an extremely sophisticated, complex unit that gathers a very representative sample 10 percent of the time, the other 90 percent of the time being spent undergoing some form of repair due to a malfunction associated with its complexity.

It is also desirable that the cost of the equipment be as low as practical both in terms of acquisition as well as operational and maintenance costs. For example, a piece of equipment that requires 100 man-hours to clean after every 24 hours of operation is very undesirable. It is also desirable that the unit be capable of unattended operation and remaining in a standby condition for extended periods of time.

The sampler should be of sturdy construction with a minimum of parts exposed to the sewage or to the highly humid, corrosive atmosphere associated directly with the sewer. It should not be subject to corrosion or the possibility of sample contamination due to its materials of construction. The sample containers should be capable of being easily removed and cleaned; preferably they should be disposable.

For portable automatic wastewater samplers, the list of desirable features is even longer. Harris and Keffer (16) give a number of features of an "ideal" portable sampler, which are based upon sampler comparison studies and over 90,000 hours of field experience.

D.4.2.3 Survey of Commercially Available Equipment

Some types of automatic liquid sampling equipment have been available commercially for quite a while. In the last few years, however, there has been a proliferation of commercial sampling equipment designed for various applications. New companies are being formed and existing companies are adding automatic sampling equipment to their product lines. In addition to their standard product lines, most manufacturers of automatic sampling equipment provide special adaptations of their equipment or custom designs to meet unique requirements of certain customers. Some designs that began in this way have become standard products, and this can be expected to continue.

The products themselves are also rapidly changing. Not only are improvements being made as field experience is gathered with new designs, but attention is also being paid to certain areas that have heretofore been largely ignored. For example, one company is introducing sampling probes that allow the gathering of oil or various other liquids from the flow surface; solid-state electronics are being used more and more in sampler control subsystems; new types of batteries are offering extended life between charges and less weight; and so on. Table D-17 lists the names and addresses of some 38 manufacturers who are known to offer standard lines of automatic wastewater sampling equipment.

An overall matrix, which summarizes the equipment characteristics to facilitate comparisons, is presented in Table D-18. There are several column headings for each sampler model (or class of models). "Gathering Method" identifies the actual method used (mechanical, forced flow, suction lift) and type (peristaltic, vacuum, centrifugal pump, etc.). Depending upon the gathering method employed, the sample flow rate may vary while a sample is being taken, vary with parameters such as lift, etc. Therefore, the "Flow Rate" column typically lists the upper end of the range for a particular piece of equipment, and values significantly lower may be encountered in a field application. "Lift" indicates the maximum vertical distance that is allowed between the sampler intake and the remainder of the unit (or at least its pump, in the case of suction lift devices).

"Line Size" indicates the minimum line diameter of the sampling train. "Sample Type" indicates which type or types of sample the unit (or series) is capable of gathering. Not all types can necessarily be taken by all units in a given model class; e.g., an optional controller may be required to enable taking a TvVc type sample, etc. The "Installation" column is used to indicate if the manufacturer considers the unit to be portable or if it is primarily intended for a fixed installation. "Cost Range" indicates either the approximate cost for a typical unit or the lowest price for a basic model and a higher price reflecting the addition of options (solid-state controller, battery, refrigerator, etc.) that might enhance the utility of the

TABLE D-17
AUTOMATIC WASTEWATER SAMPLER MANUFACTURERS

A & H Enterprises
1711 South 133 Avenue
Omaha, Nebraska 68144

Advanced Instrumentation, Inc.
Box 2216
Santa Cruz, California 95063

T. A. Baldwin Company, Inc.
16760 Schoenborn Street
Sepulveda, California 91343

Bestel-Dean Limited
92 Worsley Road North,
Worsley
Manchester, England M28 5QW

BIF Sanitrol
P.O. Box 4
Largo, Florida 33546

Brailsford and Company, Inc.
Milton Road
Rye, New York 10580

Brandywine Valley Sales Co.
20 East Main Street
Honey Brook, Pennsylvania 19344

Chandler Development Company
1031 East Duane Avenue
Sunnyville, California 94086

Chicago Pump Division
FMC Corporation
1800 FMC Drive
Itasca, Illinois 60143

Collins Products Co.
P.O. Box 382
Livingston, Texas 77351

Environmental Marketing
Associates
3331 Northwest Elmwood Dr.
Corvallis, Oregon 97330

ETS Products
12161 Lackland Road
St. Louis, Missouri 63141

Fluid Kinetics, Inc.
3120 Production Drive
Fairfield, Ohio 45014

Horizon Ecology Company
7435 North Oak Park Drive
Chicago, Illinois 60648

Hydro-Numatic Sales Co.
65 Hudson Street
Hackensack, New Jersey 07602

Hydraguard Automatic Samplers
850 Kees Street
Lebanon, Oregon 97355

Instrumentation Specialties Co.
Environmental Division
P.O. Box 5347
Lincoln, Nebraska 68505

Kent Cambridge Instrument Co.
73 Spring Street
Ossining, New York 10562

Lakeside Equipment Corp.
1022 East Devon Avenue
Bartlett, Illinois 60103

Manning Environmental Corp.
120 DuBois Street
P.O. Box 1356
Santa Cruz, California 98061

Markland Specialty Eng. Ltd.
Box 145
Etobicoke, Ontario (Canada)

Nalco Chemical Company
180 N. Michigan Avenue
Chicago, Illinois 60601

Nappe Corporation
Croton Falls Industrial Complex
Route 22
Croton Falls, New York 10519

N-Con Systems Company
308 Main Street
New Rochelle, New York 10801

Paul Noascono Company
805 Illinois Avenue
Collinsville, Illinois 62234

NP Industries, Inc.
P.O. Box 746
Niagara Falls, New York 14302

Peri Pump Company, Ltd.
180 Clark Drive
Kenmore, New York 14223

Phipps and Bird, Inc.
303 South 6th Street
Richmond, Virginia 23205

Protech, Inc.
Roberts Lane
Malvern, Pennsylvania 19355

Quality Control Equipment Co.
P.O. Box 2706
Des Moines, Iowa 50315

Sigmamotor, Inc.
14 Elizabeth Street
Middleport, New York 14105

Sirco Controls Company
8815 Selkirk Street
Vancouver, B.C.

Sonford Products Corporation
400 East Broadway, Box B
St. Paul Park, Minnesota 55071

Testing Machines, Inc.
400 Bayview Avenue
Amityville, New York 11701

Tetradyne Corporation
1681 South Broadway
Carrollton, Texas 75006

Tri-Aid Sciences, Inc.
161 Norris Drive
Rochester, New York 14610

Williams Instrument Co., Inc.
P.O. Box 4365, North Annex
San Fernando, California 91342

Universal Engineered Systems, Inc.
7071 Commerce Circle
Pleasanton, California 94566

TABLE D-18
SAMPLER CHARACTERISTIC SUMMARY MATRIX

Sampler	Gathering Method	Flow Rate (ml/min)	Lift (m)	Line Size (mm)	Sample Type	Installation	Cost Range ($)	Power
Bestel-Dean Mk II	S-Watson-Marlow	690	6.1	6.4	D, TcVc, TvVc	Portable	Unk	AC/DC
Bestel-Dean Crude	S-screw type	Unk	6.1	19.1	D, TcVc, TvVc	Portable	Unk	AC
BIF 41	M-cup on chain	NA	4.9	25.4	TcVc, TvVc	Fixed	~1,000	AC
Brailsford DC-F & EP	S-piston type	10	<2	4.8	Continuous	Portable	296-373	DC
Brailsford EVS	S-vacuum pump	5	3.7	4.8	TcVc, TvVc	Portable	520-672	AC/DC
Brailsford DV-2	S-piston type	10	<2	4.8	TcVc, TvVc	Portable	373	DC
BVS PP-100	F-pneumatic	*	85	3.2	TcVc, TvVc	Portable	853-1,525	AC/DC
BVS PE-400	F-submersible pump	7,600	9.8	12.7	TcVc, TvVc	Portable	1,500-2,510	AC/DC
BVS SE-800	F-submersible pump	7,600	9.8	12.7	D, TcVc, TvVc	Fixed	5,650	AC
BVS PPE-400	F-pneumatic	*	85	3.2	TcVc, TvVc	P or F	1,450-3,350	AC/DC
Chicago Pump	user supplied	~133,000	NA	25.4	TcVc, TvVc	Fixed	2,600-3,200	AC
Collins 42	user supplied	>3,785	NA	2.4	TcVc, TvVc	P or F	985-2,478	AC
Collins 40	user supplied	~5,000	NA	2.4	TcVc, TvVc	P or F	835-2,328	AC
EMA 200	F-piston type	Unk	<1	9.5	TcVc, TvVc	Portable	199-456	AC/DC
ETS FS-4	S-peristaltic	~20	8.8	6.4	Continuous	Portable	1,095-up	AC
Horizon S7570	S-peristaltic	100	9.1	0.8	Grab	Portable	~410	AC/DC
Horizon S7576	S-peristaltic	100	9.1	0.8	TcVc	Portable	~220	AC
Horizon S7578	S-peristaltic	100	9.1	0.8	Continuous, TcVc	Portable	595	DC
Hydraguard HP	F-pneumatic	*	>9	6.4	TcVc	Portable	246-541	Air
Hydraguard A	F-pneumatic	*	>9	6.4	TcVc	Portable	285-668	Air & AC
Hydra-Numatic	S-centrifugal	5,700	4.6	6.4	TcVc, TvVc	Portable	1,800	AC
ISCO 1392	S-peristaltic	1,500	7.9	6.4	D, TcVc, TvVc, S	Portable	1,095-1,498	AC/DC
ISCO 1480	S-peristaltic	NA	7.9	6.4	TcVc, TvVc	Portable	645-1,020	AC/DC
ISCO 1580	S-peristaltic	1,400	7.9	6.4	TcVc, TvVc	Portable	750-1,130	AC/DC
Kent SSA	S-peristaltic	150	4.9	6.4	Discrete	Portable	1,240	AC/DC
Kent SSB	S-peristaltic	200	4.0	6.4	D, TcVc, TvVc, S	Fixed	2,354	AC
Kent SSC	S-screw type	33,000	5.0	25.4	D, TcVc, TvVc, S	Fixed	2,354	AC
Lakeside T-2	M-scoop	NA	0	12.7	TcVv	Fixed	~700-up	AC
Manning S-4000	S-vacuum pump	3,800	6.7	9.5	D, S	Portable	1,290	DC
Markland 1301	F-pneumatic	*	18.3	6.4	TcVc, TvVc	Portable	1,095-1,350	Air & DC
Markland 101 & 102	F-pneumatic	*	18.3	6.4	D, TcVc	Fixed	594-2,189	Air & DC
Markland 104T	F-pneumatic	*	18.3	6.4	D, TcVc, TvVc	Fixed	1,094-2,644	Air & AC
Midlab ML 1000 & 2000	S-peristaltic	1,680	9.1	6.4	TcVc, TvVc	Portable	1,500-2,500	AC
Midlab ML 3000	S-peristaltic	1,680	9.1	6.4	TcVc, TcVv	Portable	3,000-3,500	AC
Nalco S-100	F-submersible pump	28,400	7.6	12.7	TcVc, TvVc	Portable	Unk	AC
Nappe Porta-Positer	S-flexible impeller	11,400	1.8	6.4	TcVc	Portable	225-285	AC/DC
Nappe Series 46	S-flexible impeller	13,200	4.6	9.5	TcVc, TvVc	Fixed	1,100-1,800	AC
Noascono Shift	S-peristaltic	8	9.1	4.8	Continuous	Portable	Unk	AC
N-Con Surveyor II	S-flexible impeller	20,000	1.8	6.4	TcVc, TvVc	Portable	290-590	AC
N-Con Scout II	S-peristaltic	150	5.5	6.4	TcVc, TvVc	Portable	575-935	AC/DC
N-Con Sentry 500	S-peristaltic	150	5.5	6.4	Sequential	Portable	1,125-1,205	AC/DC

TABLE D-18
SAMPLER CHARACTERISTIC SUMMARY MATRIX (Continued)

Sampler	Gathering Method	Flow Rate (ml/min)	Lift (m)	Line Size (mn)	Sample Type	Installation	Cost Range ($)	Power
N-Con Trebler	M-scoop	NA	0	12.7	TcVv	Fixed	1,050-1,350	AC
N-Con Sentinel	user supplied	63,000	NA	25.4	TcVc, TvVc	Fixed	~2,600	AC
Peri 704	S-peristaltic	160	7.6	6.4	TcVc	Portable	Unk	DC
Phipps and Bird	M-cup on chain	NA	18.3	NA	TcVc, TvVc	Fixed	1,000-up	AC
ProTech CG-110	F-pneumatic	1,000	9.1	3.2	TcVc	Portable	485	- -
ProTech CG-125	F-pneumatic	1,000	9.1	3.2	TcVc	Portable	695-1,205	-/AC
ProTech CG-125FP	F-pneumatic	1,000	9.1	3.2	TcVc, TvVc	Portable	925-1,610	AC/DC
ProTech CEG-200	F-pneumatic	1,000	16.8	3.2	TcVc, TvVc	P or F	1,354-2,445	Air/AC
ProTech CEL-300	F-submersible pump	6,000	9.1	12.7	TcVc, TvVc	P or F	1,495-2,750	AC
ProTech DEL-4005	F-submersible pump	6,000	9.1	12.7	Discrete	Fixed	3,995-4,765	AC
QCEC CVE	S-vacuum pump	3,000	6.1	6.4	TcVc, TvVc	Portable	570-1,030	AC/DC
QCEC CVE II	S-vacuum pump	3,000	6.1	6.4	TcVc, TvVc	Portable	~1,000-up	AC/DC
QCEC E	M-cup on chain	NA	18.3	NA	TcVc, TvVc	Fixed	~1,000-up	AC
Rice Barton	S-vacuum pump	Unk	3.7	25.4	TcVc	Fixed	Unk	AC
SERCO NW-3	S-evacuated jars	Varies	~3	6.4	Discrete	Portable	~1,000	-
SERCO TC-2	user supplied	42,000	NA	~19	TcVc, TvVc	Fixed	~2,500	Air & AC
Sigmamotor WA-1	S-peristaltic	60	6.7	3.2	TcVc	Portable	430-730	AC/DC
Sigmamotor WAP-2	S-peristaltic	60	6.7	3.2	TcVc, TvVc	Portable	650-870	AC/DC
Sigmamotor WM-3-24	S-peristaltic	60	6.7	3.2	Discrete	Portable	975-1,525	AC/DC
Sigmamotor WA-5	S-peristaltic	80	5.5	6.4	TcVc	Portable	750-990	AC/DC
Sigmamotor WAP-5	S-peristaltic	80	5.5	6.4	TcVc, TvVc	Portable	850-1,215	AC/DC
Sigmamotor WM-5-24	S-peristaltic	80	5.5	6.4	Discrete	Portable	1,225-1,775	AC/DC
Sirco B/ST-VS	S-vacuum pump	12,000	6.7	9.5	TcVc, TvVc	P or F	1,900-3,000	AC/DC
Sirco B/IE-VS	M-cup on cable	NA	61	9.5	TcVc, TvVc	Fixed	1,500-3,000	AC
Sirco B/DP-VS	user supplied		NA	9.5	TcVc, TvVc	P or F	1,600-3,000	AC/DC
Sirco MK-VS	S-vacuum pump	6,000	6.7	9.5	D, TcVc, TvVc, S	Portable	~1,300-up	AC/DC
Sonford HG-4	M-dipper	NA	0.5	19.0	TcVc, TvVc	Portable	325-495	AC/DC
Streamgard DA-2451	user supplied	NA	NA	6.4	Discrete	Portable	775	-
TMI Fluid Stream	F-pneumatic	*	7.6	12.7	TcVc	Fixed	~800	Air & AC
TMI Mk 38 (Hants)	S-evacuated jars	Varies	~3	3.2	Discrete	Portable	~700-up	-
Tri-Aid	S-peristaltic	500	7.5	9.5	TcVc, TvVc	P or F	650-985	AC
Williams Oscillamatic	S-diaphragm type	60	3.6	6.4	TcVc	P or F	438	-

Legend:
M - Mechanical
F - Forced Flow
S - Suction Lift
* - Depends on pressure and lift
NA - Not Applicable
Unk - Unknown at time of writing

device. Finally, the "Power" column is used to indicate whether line current (AC), battery (DC), or other forms of power (e.g., air pressure) are required for the unit to operate.

D.4.2.4 Review of Recent Field Experience

In order to assess the efficacy of both commercially available samplers and custom engineered units in actual field usage, a survey of recent USEPA projects, many of which were in the storm and combined sewer pollution control area, was conducted. None of these projects was undertaken solely to compare or evaluate samplers, but all required determination of water quality. In the following paragraphs, difficulties encountered with various elements of the liquid samplers are described.

The small diameter, low intake velocity probes found in several commercial units were felt to be unable to gather as representative a sample of the flow as could be obtained manually. There were many instances of inlet tube openings being blocked by rags, paper, disposable diapers, and other such debris. Although less a fault of the equipment than an installation practice, there were several instances of intake tubes being flushed over emergency overflow weirs, up onto manhole steps, etc., during periods of high flow and left high and dry and unable to gather any samples when the flow subsided.

There were numerous instances of pre-evacuated bottle samplers losing their vacuum in 24 to 48 hours, resulting in little or no data. Furthermore, personnel find these units with their 24 individual intake tubes virtually impossible to clean in the field. The low suction lifts on many commercial units render some sites inacessible. In one project, three sites required manual sampling because none of the samplers on hand could meet the 5- to 6-meter lifts required at these sites. There were several instances of sample quantity varying with sewage level as well as with the lift required at the particular site. On at least two occasions, submersible pumps were damaged or completely swept away by heavy debris in the flow.

Within the sampling train itself, line freezing during winter operation was a problem in several projects with instances of up to 60-percent data loss reported. In one project, the intake line was too large, which allowed solids to settle out in it until it ultimately became clogged. There were numerous instances of smaller suction tubes becoming plugged with stringy and large-sized material. A very frequent complaint, applied especially to discrete samplers, was that they gathered inadequate sample volumes for the laboratory analyses required.

On one project, although not directly the fault of the sampling equipment itself, data were lost for 14 storms due to improper sterilization of non-disposable sample bottles.

The control subsystems of commercial units probably came in for more criticism than any other. Comments on automatic starters ranged from poor to unreliable to absolutely inadequate. There were instances where dampness deteriorated electrical contacts and solenoids causing failure of apparently well-insulated parts. The complexity of some electrical systems made them difficult to maintain and repair by field personnel. Inadequate fuses and failures of microswitches, relays, and reed switches were commonly encountered. The minimum time between collection of samples for some commercial units was too long to adequately characterize some rapidly changing flows.

Collected USEPA experience in one region reported by Harris and Keffer (16) involved over 90,000 hours use of some 50 commercial automatic liquid samplers of 15 makes and models. They found that the mean sampler failure rate was approximately 16 percent with a range of 4 to 40 percent among types. They also found that the ability of an experienced team to gather a complete 24-hour composite sample is approximately 80 percent. When one factors in the possibility of mistakes in installation, variations in personnel expertise, excessive changes in lift, surcharging, and winter operation, it is small wonder that projects on which more than 50 to 60 percent of the desired data were successfully gathered using automatic samplers were, until recently, in the minority.

In fairness to present day equipment, it must be pointed out that some of the above cited complaints stem from equipment designs of up to 10 years ago, and many commercial manufacturers, properly benefitting from field experience, have modified or otherwise improved their products' performance. The would-be purchaser of commercial automatic samplers today, however, should keep in mind the design deficiencies that led to the foregoing complaints when selecting a particular unit for his application.

D.4.3 Manual Versus Automatic Sampling

The decision whether to sample manually or use automatic samplers is far from straightforward, and involves many considerations in addition to equipment costs. Experience has indicated that operator training is necessary if manual sampling is to produce reproducible results. Instances have been noted wherein two different operators were asked to obtain a sample at a particular site with no other guidance given. Analyses of samples taken at almost the same instants in time have shown differences exceeding 50 percent. Other work conducted solely to compare manual sampling methods has indicated such discrepancies in results that suspicion must be cast upon manual methods that involve dipping of samples out of raw waste sources and has raised questions regarding the suitability of such manual grab sampling as a yardstick against which to measure other techniques.

The decision to use automatic sampling equipment does not represent the universal answer to water and wastewater characterization, however. For initial characterization studies, proper manual sampling may represent the most economical method of gathering the desired data. It is also prudent from time to time to verify the results of an automatic sampler with manual samples.

In general, manual sampling is indicated when infrequent samples are required from a site, when biological or sediment samples or both are also required from a site, when investigating special incidents (e.g., fish kills, hazardous material spills), where sites simply will not allow the use of automatic devices, for most bacteriological sampling, etc. Manual sampling will often be the method of choice in conducting stream surveys, especially those of relatively short duration where only a single daily grab sample is required from each site. For large rivers, lakes, and estuaries, manual sampling will almost always be required.

Automatic samplers are indicated where frequent sampling is required at a given site, where long-term compositing is desired, where simultaneous sampling at many sites is necessary, etc. Automatic sampling will often be the method of choice for storm-generated discharge studies, for longer period outfall monitoring, for treatment plant efficiency studies, where 24-hour composite samples are required, and so on.

Typically, the wide spectrum of 208 agency monitoring activities will require a capability for both manual and automatic sampling, and so the question is not which capability to obtain but when to use each. The answer should be determined in the design of each survey, using the above information as guidance.

D.4.4 Sampling Field Procedures

D.4.4.1 Manual Sampling Procedures

The preferred method of gathering manual samples from a raw waste stream is to use a pump to actually extract the fluid and tubing of appropriate size to transport it to the sample container. Pump and tubing sizes should be such that effective collection and transport of all suspended solids of interest is ensured. Both small, flexible impeller centrifugal pumps and progressive cavity screw pumps have been successfully used with good repeatability of results. It should be noted, however, that the collection of flow proportional or sequential composite samples can become quite tedious if performed manually at the sampling site. Locate the intake at approximately the three-quarters depth point (i.e., one-fourth of the way up from the bottom) and point it upstream into the flow. Adjust the pump speed until intake velocity approximately equals the mean flow velocity (obtained from a flow-measuring device or current meter) and, after about 60 seconds, direct the stream into the sample container. Avoid using an intake screen unless absolutely necessary.

When manually sampling natural streams, use a depth-integrating sampler at the center of the stream if the flow is laterally homogeneous. Check the site for this by occasionally taking samples from the quarter points and comparing results. If significant differences are found, either choose another site or take a number (5 to 20 depending upon stream width) of depth integrated samples along a transect perpendicular to the flow. Based on the results, choose the minimum number of transverse stations that will yield acceptable results.

Depth integrating samplers for use in more swiftly running streams are relatively heavy, and so some type of hoist or winch is normally used to facilitate handling. These can be mounted on boats for river and estuary cruises, on trucks or trollies for bridge sampling, etc. Contact the nearest USGS field office for more information on availability and use of different depth integrating samplers.

Samples may be manually gathered at a given depth in the water column by using a Juday bottle or one of its modifications (e.g., Kemmerer, Van Dorn). This type is essentially a cylinder with stoppers that leave the ends open while the sampler is being lowered to allow free passage of water through the cylinder. When the desired depth is reached (as determined by markings on the line, for instance) a messenger is sent down the line and causes the stoppers to close the cylinder, which is then raised and the sample transferred to its container. These devices can be used to approximate depth integration through the water column, to investigate stratification in lakes, or wherever a sample from a particular depth is desired. When using such devices from bridges, take precautions so that the messenger, when dropped from the height of the bridge, does not batter and ruin the triggers that release the stoppers. One simple way to avoid this is to support the messenger a few feet above the sampler with a string and release it when the desired depth is reached.

If vertical concentration gradients are not severe, a single grab sample will suffice. It is recommended that a container smaller in volume than the desired total sample volume be used, and that the required sample volume be obtained by repeated dippings at one minute intervals. Rinse the container two or three times in the water to be sampled prior to taking the first aliquot. Comparison of the results between depth integrated and simple grab samples will indicate when the latter technique will suffice.

For reproducibility of manual sampling results, operator training is absolutely essential; 208 agencies can ill afford to entrust this task to well-intentioned but untrained staff or volunteers. Also, it is time that we forget about using a beer can nailed to a stick as a sample gathering device. All in all, the manual pumping sampler described earlier in this section will produce the most reproducible results, and its use is recommended whenever feasible. One subject that should also be touched on briefly is manual compositing according to flow records. Given a series of discrete samples of equal volume taken at regular time intervals and a flow record, the question is what size aliquot should be taken from each discrete sample container to form the flow proportional composite sample? Recall from Section D.4.1 that this can be done in one of two ways: either extract an aliquot volume that is proportional to the instantaneous flow rate at the time the discrete sample was taken, or extract an aliquot volume that is proportional to the total discharge that has occurred since the last discrete sample was taken. The formula used for this can be written as:

$$a_i = f_i V_c / \Sigma f_i$$

where: a_i = aliquot volume to be extracted from the i-th discrete sample, i.e., the one taken at time t_i

i = index indicating the order in which the discrete samples were taken, $1 \leq i \leq n$

f_i = flow variable; either the flow rate when the i-th discrete sample was taken (q_i) or the total discharge that has occurred since the (i-1)-th sample was taken ($\Delta Q_i = Q_i - Q_{i-1}$)

V_c = composite sample volume desired

n = number of discrete samples taken

The desired composite sample volume is determined based on the requirements for the analyses to be conducted. The subtle problem is that one does not have complete freedom in selecting V_c because of the fixed discrete sample volume (V_d), and the entire sequential discrete series may be wasted if this is not recognized, because there might not be enough sample in one bottle to fulfill its aliquot requirements. This is best illustrated by an example (see Table D-19). Note that if steps 3 and 4 had not been carried out, when the operator came to bottle number 5 he would not have been able to continue, since he would be 250 mℓ short. This has happened. Also, it is incorrect to use leftover liquid from the adjacent discrete samples to make up the deficit (which has also occurred).

In actuality, one can compute the maximum composite sample volume that can be formed from a series of discrete samples. The formula is

$$(V_c)_{max} = V_d \, \Sigma f_i/(f_i)_{max}$$

If this quantity is greater than the amount desired, the formula given earlier for determining aliquot volume can be used. If not, the aliquot size should be computed from

$$a_i = f_i \, V_d/(f_i)_{max}$$

This will be illustrated by a second example, shown in Table D-20. Since the available composite sample is nearly half a liter less than was desired, a new decision on how to allocate the available volume must be made.

Example III (Table D-21) is included to indicate how to manually prepare a time-constant, volume-proportional-to-discharge-since-last-sample-was-taken composite when a record of flow rate rather than discharge is available. The results of Examples II and III agree because the same flow function (q=5,000 sin $\pi t/8$) was used in each case and the trapezoidal integration scheme worked well.

The details for manually preparing a time-constant, volume-proportional-to-instantaneous-flow-rate composite sample using the flow rate record given in Example III will not be presented (a_i=191, 354, 462, 500, 462, 354, 191, 0; Σa_i=2,514 mℓ), but it is of interest to contrast the measured concentration of a constituent of interest obtained by this method as opposed to the method of Example II. For this purpose, assume that the constituent behavior is a

TABLE D-19
MANUAL COMPOSITE SAMPLE EXAMPLE I

Example: Manually preparing a time-constant, volume-proportional-to-instantaneous-flow-rate composite sample.

Given: A 500 mℓ discrete sample was taken at the end of each hour over an 8-hour shift. A 2-liter composite is desired. A recording of flow rate is available.

Sample No. (i)	q_i	a_i	a_ix500/750
1	300	47	31
2	600	94	63
3	1,200	188	125
4	2,400	375	250
5	4,800	750	500
6	2,000	312	208
7	1,000	156	104
8	500	78	52
Σq_i =	12,800	2,000	1,333

Steps:

1. Enter q_i from record and sum.
2. Calculate $a_i = q_i V_c / \Sigma q_i = 2000 q_i / 12{,}800$.
3. Check to see if maximum a_i exceeds discrete sample volume.
4. Compute new aliquot volume = a_ix500/750.

TABLE D-20
MANUAL COMPOSITE SAMPLE EXAMPLE II

Example: Manually preparing a time-constant, volume-proportional-to-discharge-since-last-sample-was-taken composite.

Given: A 500-mℓ discrete sample was taken at the end of each hour over an 8-hour shift. A 3-liter composite is desired. A recording of totalized flow is available.

Sample No. (i)	Q_i	ΔQ_i	a_i
0	0	-	-
1	969	969	99
2	3,729	2,760	284
3	7,860	4,130	424
4	12,732	4,873	500
5	17,605	4,873	500
6	21,736	4,130	424
7	24,496	2,760	284
8	25,465	969	99
	$\Sigma\Delta Q_i$ =	25,464	2,614

Steps:

1. Enter Q_i from record and calculate $\Delta Q_i = Q_i - Q_{i-1}$.
2. Calculate $(V_c)_{max}$ = (500) (25,464)/4,873 = 2,614 mℓ.
3. Since $(V_c)_{max}$ is less than desired, calculate aliquot size from $a_i = 500\ \Delta Q_i/4,873$.

TABLE D-21
MANUAL COMPOSITE SAMPLE EXAMPLE III

Example: Manually preparing a time-constant, volume-proportional-to-discharge-since-last-sample-was-taken composite.

Given: A 500-mℓ discrete sample was taken at the end of each hour over an 8-hour shift. A 3-liter composite is desired. A recording of flow rate is available.

Sample No. (i)	q_i	ΔQ_i	a_i
0	0	-	-
1	1,913	957	99
2	3,536	2,725	283
3	4,619	4,078	424
4	5,000	4,810	500
5	4,619	4,810	500
6	3,536	4,078	424
7	1,913	2,725	283
8	0	957	99
	$\Sigma\Delta Q_i$ =	25,140	2,612

Steps:

1. Enter q_i from record and use trapezoidal rule to calculate $\Delta Q_i = (q_i + q_{i-1})/2$ (another integration scheme could be used if warranted).
2. Calculate $(V_c)_{max}$ = (500) (25,140)/4,810 = 2,613
3. Calculate $a_i = 500\ \Delta Q_i/4{,}810$

simple linear decay (i.e., conc.=9-t). The true concentration in the flow rate proportional sample would be 5.0 (assuming the discrete samples from which the composite was formed were 100 percent representative). The corresponding true concentration of the discharge proportional composite (Example II) would be 4.5, a difference of around 10 percent due solely to the method of compositing.

The possible importance of sediment oxygen demand (SOD) measurements to 208 agency plans is well illustrated by Butts (17) who noted, as a result of an extensive SOD study, that "... it is doubtful that the aquatic ecology of the (Illinois) waterway can be measurably enhanced solely by achieving current water quality standards." The subject of SOD measurement remains somewhat controversial, but it is recommended that determinations be made in situ rather than in the laboratory. Ascertaining the relationship between SOD rates and DO content of the overlying waters is better accomplished by performing in situ measurements. This can be done, for example, by setting a bell-shaped shallow cover over the spot on the bottom where the measurement is to be made, circulating the water within this "sampler" with a small pump, and measuring the change in DO with time.

The design of an in-situ SOD measuring device developed by the Illinois State Water Survey is described by Butts (17), who also reports favorably on its use. The cover was made from a 14-inch-diameter by 24-inch-long steel pipe split longitudinally in half. End plates were welded on, and angle iron was welded around the lower edge to act as cutting edges and seating flanges. Fittings for raising and lowering the device, two hose attachments to allow connection of a pump for water circulation, and a split collar to hold the DO/temperature probe were also welded in place. The "sampler" covered a flat bottom area of about 0.2 square meter (336 sq in.), and the total volume of water within the system was around 31 liters. The device is handled with a USGS bridge winch adapted for use on a boat.

D.4.4.2 Automatic Sampling Procedures

When using automatic samplers, the greatest problem comes in mounting the intake. Screened intakes should be used in waters containing large solids, trash, or debris to prevent clogging. Screen openings should be slightly smaller than the smallest opening in the sampling train. More and more commercial devices are now provided with intake screens by their manufacturers. When using these, the end of the intake hose should be approximately at the center of the screen. If intake screens are not provided with the samples, they can be fabricated quite simply by drilling a large number of appropriately sized holes in a piece of plastic pipe, cementing on end covers, and drilling out one end to accept the sample tube and fastening it with a hose clamp and fitting. Clear plastic is recommended to facilitate inspection. A typical size for an intake screen to accommodate a 3/8 inch ID tube is approximately 1.5 to 2 inches in diameter by 6 to 10 inches long. Hole diameters could be 1/4 inch if the rest of the sampling train is larger.

The flexible plastic intake tubing commonly used in most commercial automatic samplers will require some protection in many installations, or wear from particles in the flow and damage from debris will necessitate frequent replacement. Flexible electrical conduit and reinforced garden hose have been successfully used in this regard. Even with such protection, it is recommended that sample intake lines be trenched in where they run over earthen surfaces.

One of the most challenging sample intake mounting problems is in a natural, wet weather stream. If the intake is allowed to rest on the bottom where it could obtain samples at very low flows and, hence, more readily determine first flush effects, there is a possibility that flow fields around the intake may induce scour and cause artificially high solids readings. Mounting the intake well above the bottom obviates this problem but prevents acquiring samples of very low flow. The best compromise seems to be to mount the intake horizontally, at right angles to the flow, in the middle of the stream and with its lowest surface around 2 inches above the bottom (higher if significant bedload depths are anticipated). The stream bottom at this point should be reasonably flat and free of stones or other flow-altering obstructions upstream of the intake. For cobble-strewn bottoms, follow the above procedure but measure from a sheet of plywood resting on the stones.

To anchor the sample intake to the bottom, use screw augers or metal rods driven well into the soil. Simple hose clamps can be used to affix the intake screen to these supports.

For continuously flowing natural streams, similar considerations pertain. The main difference will be in the vertical location of the intake. In the absence of other factors, mount the intake near the low flow mid-depth. If stream depth allows, the intake should be mounted with its center line vertical, and suction taken from the bottom. In this configuration, a single mounting rod can be used. It should be located to one side of the intake (never in front of it).

The foregoing has been written with smaller streams, typical of those that would be encountered in an urban runoff study, in mind. As indicated earlier in this section, it is not expected that automatic samplers will find wide use in river monitoring.

In man-made channels and conduits, there is no longer a concern for bottom scour. For those carrying intermittent flows, the intake screen can be allowed to rest on the bottom unless significant bedload depths are anticipated. Where large debris is likely to be encountered, a spring-loaded intake screen mounting should be considered to help prevent destruction. It is a fairly common practice to simply let the intake screen trail downstream by its tubing. In very low or no-flow periods it will rest on the invert and, during higher flows, hydrodynamic forces will tend to lift it up. The chief objection to this practice is that probes facing downstream do not gather representative solids due to momentum effects. Data on the degree of under-representation caused by this practice are virtually nonexistent, however. Use this practice as a last resort.

Where the flow is continuous (but variable), position the intake screen near the low flow mid-depth. As opposed to natural streams, however, in many man-made conduits it will be more convenient to dangle the intake from above with the suction tube pointing down. Although the vertically up orientation is preferable, this practice is also acceptable. The chief disadvantage of "dangling" approaches to intake mounting is that you never really know where the intake is. Be certain that there is no possibility of full flow positioning the intake where it could be left "high and dry" as the flow recedes. Manhole benches, steps, weirs, and the like have taken their toll in careless intake installations.

For the (rare) case where relatively steady flow is anticipated in either natural or man-made channels, position the intake at about the three-quarter depth point. If two automatic sampling devices are used for redundancy at a critical site, position one intake at the eight-tenths depth point and one at the four-tenths depth point. Shelley (18) discusses the rationale for sample intake location in some detail and presents designs for maintaining intakes at a constant percentage of depth in variable flows, noninvasive intakes, etc.

All of the foregoing has been written primarily with suction lift intakes in mind, but similar considerations apply if forced-flow devices are used. For samplers employing mechanical gathering methods, follow the manufacturer's directions.

Mounting the main body of the automatic sampler is rather straightforward; follow the manufacturer's directions. Keep the lift as short as possible commensurate with the likelihood of submergence. If excess sample tubing exists, cut it off. Do not simply coil it out of the way, thinking that the extra length might be useful at the next installation.

After setting up the controls and power subsystem according to the operator's manual for the particular sampler being used, manually cycle it a few times and measure the quantity of sample actually being taken. This is especially important where fixed aliquot volume composite samples are to be collected. Verify sample volume gathered on each site visit. Partial plugging, intake blockage, or other occurrences that might not be immediately obvious can affect the sample quantity in most designs. Also, use a stopwatch to record the time that it takes to gather the sample and verify this on subsequent visits. For battery-operated units, frequent voltage checks are in order until service life can be established for the installation. Manufacturers are not noted to be conservative in estimating battery life, and it will be affected by a number of factors such as sample lift, temperature, etc. Always inspect the sample intake at each visit.

For operation in very cold weather, a heated enclosure for the sampler body will be required. Sample lines should be wrapped with heater tape and insulated -- large plastic trash bags work well for this. Check for possible ice buildup at each visit. Should frozen (or partially frozen) samples be encountered, do not discard them, but immediately enter the facts in the field log and also report the condition to the analytical laboratory when the samples are delivered.

Maintenance and troubleshooting of automatic samplers are so design-dependent that little general guidance can be given other than to follow manufacturer's instructions and recognize the importance of these activities in contributing to project success. However, one word of caution pertaining to suction lift samplers using peristaltic pumps must be made. Some of these pump designs require that the tubing be lubricated. This must be done or tube life will be considerably shortened; failures after less than 2 hours of operation have been reported for some designs when inadequate lubrication was applied. With care and consideration, most automatic samplers can be made to work reasonably well; with carelessness and disregard, almost none will.

D.4.5 Sample Quantity, Preservation, and Handling

Since the required sample volume is dependent upon the type and number of parameters to be analyzed for and the instrumentation and methods to be employed in the analysis at the laboratory, the laboratory analyst is the best person to specify the quantity needed. A preliminary estimate of sample volume can be obtained as follows. Determine the parameters to be analyzed for and, from the Parameter Handbook, obtain the sample volume required for each analysis. Sum these to obtain the minimum volume, and increase this amount as necessary to allow for spillage, mistakes, sample splitting, and for analytical laboratory quality control purposes. In the absence of better information, doubling the minimum volume should be adequate.

Having collected a representative sample of the fluid mixture in question, there remains the problem of sample preservation and analysis. It is a practical impossibility either to perform instant analyses of the sample on the spot or to completely and unequivocally preserve it for subsequent examination. Preservation methods are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce volatility of constituents. They are generally limited to pH control, chemical addition, refrigeration, and freezing. The USEPA (19) has compiled a list of recommendations for preservation of samples according to the measurement analysis to be performed. In order to provide an overview for some common parameters, this list has been reproduced here as Table D-22. For other parameters and program design, reference should be made to the Parameter Handbook.

Proper sample handling is also essential to obtaining successful results from any monitoring program. A few general guidelines are given below.

1. Each sample container must have a designation, normally a number, that uniquely distinguishes it from all other samples in the survey.

TABLE D-22
RECOMMENDATIONS FOR PRESERVATION OF SAMPLES ACCORDING TO MEASUREMENT[1]

Measurement	Vol Req (mℓ)	Container	Preservative	Holding Time[6]
Acidity	100	P,G[2]	Cool, 4°C	24 Hrs
Alkalinity	100	P,G	Cool, 4°C	24 Hrs
Arsenic	100	P,G	HNO_3 to pH <2	6 Mos
BOD	1000	P,G	Cool, 4 C	6 Hrs[3]
Bromide	100	P,G	Cool, 4 C	24 Hrs
COD	50	P,G	H_2SO_4 to pH <2	7 Days
Chloride	50	P,G	None Req	7 Days
Chlorine Req	50	P,G	Cool, 4°C	24 Hrs
Color	50	P,G	Cool, 4°C	24 Hrs
Cyanides	500	P,G	Cool, 4°C NaOH to pH 12	24 Hrs
Dissolved Oxygen				
Probe	300	G only	Det on site	No Holding
Winkler	300	G only	Fix on site	No Holding
Fluoride	300	P,G	Cool, 4°C	7 Days
Hardness	100	P,G	Cool, 4°C	7 Days
Iodide	100	P,G	Cool, 4°C	24 Hrs
MBAS	250	P,G	Cool, 4°C	24 Hrs
Metals				
Dissolved	200	P,G	Filter on site HNO_3 to pH <2	6 Mos
Suspended			Filter on site	6 Mos
Total	100		HNO_3 to pH <2	6 Mos
Mercury				
Dissolved	100	P,G	Filter HNO_3 to pH <2	38 Days (Glass) 13 Days (Hard Plastic)
Nitrogen				
Ammonia	400	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Kjeldahl	500	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Nitrate	100	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Nitrate	50	P,G	Cool, 4°C	24 Hrs[4]

Measurement	Vol Req (mℓ)	Container	Preservative	Holding Time[6]
NTA	50	P,G	Cool, 4°C	24 Hrs
Oil and Grease	1000	G only	Cool, 4°C H_2SO_4 to pH <2	24 Hrs
Organic Carbon	25	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs
pH	25	P,G	Cool, 4°C Det on site	6 Hrs[3]
Phenolics	500	G only	Cool, 4°C H_3PO_4 to pH <4 1.0g $CuSO_4$/l	24 Hrs
Phosphorous				
Orthophosphate, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs[4]
Hydrolyzable	50	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Total	50	P,G	Cool, 4°C	24 Hrs[4]
Total, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs[4]
Residue				
Filterable	100	P,G	Cool, 4°C	7 Days
Nonfilterable	100	P,G	Cool, 4°C	7 Days
Total	100	P,G	Cool, 4°C	7 Days
Volatile	100	P,G	Cool, 4°C	7 Days
Settleable Matter	1000	P,G	None Req	24 Hrs
Selenium	50	P,G	HNO_3 to pH <2	6 Mos
Silica	50	P only	Cool, 4°C	7 Days
Specific Conductance	100	P,G	Cool, 4°C	24 Hrs[5]
Sulfate	50	P,G	Cool, 4°C	7 Days
Sulfide	50	P,G	2 mℓ zinc acetate	24 Hrs
Sulfite	50	P,G	Cool, 4°C	24 Hrs
Temperature	1000	P,G	Det on site	No Holding
Threshold Odor	200	G only	Cool, 4°C	24 Hrs
Turbidity	100	P,G	Cool, 4°C	7 Days

NOTES:

1. Taken from (9).
2. Plastic or Glass.
3. If samples cannot be returned to the laboratory in less than 6 hours and holding time exceeds this limit, the final reported data should indicate the actual holding time.
4. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/ℓ, especially if a longer holding time is required. However, the use of mercuric chloride is discouraged whenever possible.
5. If the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.
6. It has been shown that samples properly preserved may be held for extended periods beyond the recommended holding time.

2. When frequent sampling over a long time period is involved, consideration should be given to incorporating a temporal indication as a part of the sample identification number; e.g., the number of the week in a year, the last two digits of the year, etc. The temptation to code too much information about the sample into its identification number must be resisted, however, or else the risk of mixups due to unauthorized abbreviations becomes too great.

3. Consideration should be given to the use of preprinted, sticky-back labels in many instances. Be certain, however, that they are waterproof. Rubberband and tie-on tags have also been used successfully.

4. The use of color-coded labels has been successful where sample splitting or different preservation techniques are employed. In the latter case, for example, a green label could indicate that nitric acid had been added and that, therefore, an analyst could obtain aliquots from this sample for metal analyses, etc.

5. Where possible, the type of sample, date, and any preservatives added should be written on the sample label prior to collecting the sample in the field. The time of day should be added when the sample is collected. Additional information should be noted in the field notebook and on supplemental forms where used.

6. The foregoing should be observed in addition to any chain-of-custody procedures that are involved. See (20) for USEPA recommendations for a chain-of-custody program.

The proper cleaning of all equipment used in the sampling of wastewater is essential to ensuring valid results from laboratory analyses. Cleaning protocols should be developed for all sampling equipment early in the design of the monitoring program. Here, also, the laboratory analyst should be consulted, both to ensure that the procedures and techniques are adequate as well as to avoid including practices that are not warranted in view of the analyses to be performed. The possibility of the container affecting the sample analyses should be checked periodically. Distilled or demineralized water should be placed in a typical container for a period of time similar to that of a normal sample. Then the particular constituent of interest should be measured in the water from this blank. Also, checks for sample adsorption on the container should be made by placing a known amount of a particular constituent in a typical container. After a specified holding time, analyses should be made to determine if any of the material was adsorbed into the container or changed in any other manner. These checks should be done after sample bottles have been used for a series of samples. In this way the cleaning techniques used can be tested for thoroughness.

The use of blanks and spikes just mentioned brings up the subject of quality control in general. Although outside the scope of this Appendix, each 208 agency must have a viable quality assurance program. The USEPA (21, 22) has published minimal requirements for a water quality assurance program and a handbook for analytical quality control in the laboratory. The recommendations in these two references should be followed by all 208 agencies.

D.4.6 Sampling Accumulated Roadway Material

Accumulated roadway material may represent a significant source of pollution during storm-generated discharges in urban areas. In order to quantify this source, provide inputs for models, determine if better urban housekeeping practices would produce commensurate water quality improvements, etc., sampling of accumulated roadway material will be required. The following discussion is abstracted from Wullschleger et al. (7).

Samples of materials deposited on roadways are collected using a combination of sweeping, vacuuming, and water flushing techniques. Each sample will consist of three fractions: litter, dust and dirt, and water flush. The particulate materials collected by sweeping and vacuuming are separated on the basis of particle size into a litter fraction and dust and dirt fraction. The litter fraction consists of that portion of the particulates retained by a U.S.A. No. 6 sieve (i.e., greater than 3.35 mm in diameter). This fraction is usually composed of stones, gravels, wood fragments, and other larger sized materials in addition to bottles, cans, paper production, etc., which are normally thought of as litter. The dust and dirt fraction will contain particulates smaller than 3.35 mm in diameter. The water flush fraction contains those components of the dust and dirt fraction which were not picked up at high efficiencies by the sweeping and vacuuming techniques. The flush plus the dust and dirt constitute a total dust and dirt fraction which is the major source of water pollutants found in runoff from urban roadways.

If a physical and chemical description of the street surface contaminants is needed, the sample should be collected by hand sweeping, followed by flushing. All of the dry solid material collected from the test area should be placed in clean containers and shipped back to the laboratory. There it should be air dried thoroughly and sealed for storage until analyzed. All of the flushed material should be measured for volume, but only a portion of it need be retained for analysis. The liquid sample should be stored in clean containers (glass, if pesticide analyses are to be made) and cooled to <4°C if possible. The analyses of the liquid fraction should be made as soon as possible after collection. To reduce the number of chemical analyses required, the dry and liquid samples can be combined on an equal sample area basis before the analyses are performed.

If only physical loading information (such as kg (lb) of solids per curb km (mile)) is needed, hand sweeping is probably sufficient. In most cases, the additional quantity of material that can be obtained by subsequent vacuuming and/or flushing is insignificant. If information regarding particle size distribution is required, then the sample should be collected using a combination of hand sweeping and dry vacuuming. The vacuum is more efficient in removing the fine particles which are needed for size distribution analyses. If size distribution of the solids in the wet phase is needed, then flushing will also be required.

The basic procedures for the collection of samples are:

Hand sweeping - Hand sweeping for dry solids collection should utilize a standard stiff-bristled push broom. The sweeping pattern should be from the center of street or from one edge of the test area towards the gutter or opposite side of the test area. After concentrating the material along this edge, the sample should be collected, using a whisk broom and dustpan.

Vacuuming - Vacuuming the test area usually removes more smaller-sized particles than is possible by only using sweeping techniques. The vacuuming pattern should approximate the pattern described for hand sweeping. An industrial wet/dry "shop" vacuum cleaner with a 5-7.6 cm (2 in. to 3 in.) diameter hose is recommended. Other types of units, ranging from small household vacuums to large motorized vacuum sweepers, may also be satisfactory, depending on the size of the test area.

Flushing - The test area can be flushed with water after hand sweeping to remove soluble films and other nonsweepable material. The materials removed with this method more closely resemble those which are removed by a runoff event. The test area is first slightly wetted to soften and facilitate removal of soluble materials. It is then flushed with a stream of water from a garden hose and spray nozzle connected to a fire hydrant or other water supply. Begin at the road crown and flush toward the edge. The downslope gutter is dammed with sandbags to create a collection area. A small vacuum collector is used before an industrial wet/dry vacuum cleaner to remove the sample water from the collection area. All water and contaminants are collected using this vacuum-operated collector trap. This is an air-tight box or drum with a capacity of several gallons to several hundreds of gallons (depending upon specific test procedures), outfitted to function as a "trap" in a vacuum line. The inlet hose of the collector trap has a pickup nozzle on the open end. The outlet hose of the collector trap is connected to an industrial shop vacuum.

The vacuum cleaner used for collection of roadway particulates consists of a pick-up head attached to a 38ℓ (10 gal) canister on the top of which is mounted an exhaust motor. Exhaust ports from the canister leading to the motor are covered by a filter bag to retain solids picked up during the vacuuming operations. Since the finer particles found on roadways are relatively more heavily laden with water pollutants, experiments have been performed to determine the retention of smaller-sized particles by the filter bag. Recoveries of 99, 93, and 94 percent were obtained using a new filter bag with each sampling run. These tests indicate satisfactory retention of fine particulates by the filter bags as well as quantitative removal and recovery of vacuumed particles from the canister walls and bags.

The water flush procedure has also been tested in the field. It was found that a roadway area of 92 sq m (1000 sq ft) could be thoroughly flushed with about 95ℓ (25 gal) of water. In most cases, over 50 percent of the applied flush was recovered by vacuuming of the impounded water along the curb.

A specific stepwise sampling procedure for the collection of street surface contaminants is given below.

1. Select a roadway sampling site 30.48 continuous curb meters (100 ft) or more. The street surface and curbing should be in relatively good condition. Mark the limits of the sampling length selected.

2. Rake and/or brush along the curb for 3.0 or 4.6m (10 or 15 ft) from the limit markings away from the section to be sampled.

3. Knock the brush clean. Rake and/or brush from the higher elevation limit. Shovel bulk litter plus swept dust and dirt into a clean galvanized garbage can.

4. Vacuum along the entire curb length of the roadway sampling site out to a distance of four to five feet from the curb. Three vacuumings of the site should be carried out to collect the dust and dirt sample fractions. Two vacuum cleaners are

used simultaneously to speed up the operation with particular attention at the litter pickup point.

5. Position several sand bags at the curb of the lower limit of the sampling area to impound the flush water.

6. Place the nozzle of a dual motor shop vacuum at a low point in front of the sand bags so as to suck water into a 208ℓ (55-gal) drum.

7. Place the intake hose from a rotary screw pump into a 208ℓ (55-gal) drum filled with water and begin flushing the roadway using the garden hose.

8. Flush the entire roadway surface area toward the curb and finish by flushing the gutter toward the sand bags.

9. Approximately 57 to 95ℓ (15 to 25 gal) of water are required to flush 56-93 sq m (600-1000 sq ft) of roadway. Generally greater than 50 percent of the flush water applied is recovered by the vacuum.

10. Take out the filter bags and shake well into garbage can with bulk material. Save the bags.

11. Empty vacuum canisters into garbage can. Brush canisters well.

12. Take combined litter and dust and dirt in garbage can and the flush fraction to the laboratory. Other equipment may proceed to next sampling site.

Sampling sites should be chosen to represent the range of conditions that occur in the area. Important variables may include land use, average daily traffic, type of adjacent landscaping, and street surface material. It is recommended that at least a single complete analysis be made for each land use area, with total solids analyses being made on samples representing other identified variables. If several sampling sites are established in each land use area, a portion of each sample could be combined for complete composite chemical analysis representing that land use.

For one 12-month field study, seven area roadways were chosen based primarily upon the range of average daily traffic levels and road use categories encompassed. Other factors considered in the roadway selections were speed limit and roadway surface material. Satisfactory condition of the street surface and a sufficient length of curb against which the sample could be deposited and collected were important factors in selection of the specific sampling sites on the area roadways chosen.

In general, the following information should be collected for a sampling site: sampling location; date; local land use; parking restrictions; traffic characteristics; composition, type and condition of the street, gutter, and curb; the size of the test area; and a description of the adjoining area. Photographs of the area are often valuable. Data concerning the cleaning frequency, the date of the last recorded cleaning, and the recent rainfall history should also be obtained for each test area.

If the selected study area is subject to vehicular traffic, it will be necessary to establish some type of traffic control for the protection of the field workers. Flagmen and traffic cones are probably a minimum precaution which should be used in all areas.

The type of study area (street surface, parking lots, or other large surfaces) and sampling objectives will determine the size of sampling area. A typical secondary street can usually be sampled using a single test area of about 93 sq m, 7.6m x 12.2m (1000 sq ft, 25 x 40 ft). Large paved surfaces may be better sampled using several smaller test areas (0.9 sq m (10 sq ft)) and averaging the results. Experimental design procedures should be incorporated to determine the necessary types of study areas to sample to satisfy specific study objectives.

As with the selection of the study area, the frequency of sampling will depend on the objectives of the sampling program. For one 12-month field study, a schedule was set up early in the program such that the roadways were sampled during several seasons of the year in order that seasonal effects on pollutant deposition rates might be studied. However, during the winter season, freezing conditions prevented the collection of some of the flush fractions.

Sampling periods were scheduled to begin on a Monday and end one week later on the following Monday. Sample collections were planned to be carried out in the following manner:

1. An initial sample was obtained by cleaning the roadway surface and quantitative collection of materials initially found on the site. No measurements of traffic were taken to correspond with the initial sample; however, records of precipitation and dates of the most recent antecedent cleaning of the roadway surfaces were maintained throughout the 12-month field study.

2. The site was sampled a second time after an accumulation period of approximately 24 hours during which time a measured volume of traffic passed the roadway site. As many as four samples having a one-day accumulation period were taken during the remainder of the week. Traffic counts were taken with each one-day sample.

3. The final sample of the period was gathered following the weekend. Ideally then, a sampling period consisted of an initial sample, four one-day samples, and a weekend sample with traffic data for all samples except the initial one.

4. Precipitation frequently interrupted the planned pattern of the sampling periods. Samples were gathered after rainstorms in a few cases; however, it was felt that such samples would be atypical; and, therefore, collections after runoff events were

abandoned early in the program. The roadway site was cleaned as soon as convenient after precipitation had ceased and a new sample accumulation period begun. Sampling periods were extended in some instances in order to make up for loss of samples due to precipitation.

Experimental design procedures should be incorporated to determine the required sampling frequency and sample numbers to satisfy specific study objectives. The published results of previous sampling programs may be useful in this design process.

D.5 Cost Estimation

It is difficult to provide precise program cost information, since costs are dependent upon so many program and locality related factors, e.g., institutional setting and accounting procedures, area complexities and program size, opportunity free labor, etc. This section presents a methodology for cost estimation for any given program, some "ball park" rules of thumb for preliminary rough cut costing, and some specific examples. The costing methodology is divided into six steps:

1. Estimate Instrumentation Costs
2. Estimate Related Equipment Costs
3. Estimate Manpower Costs
4. Estimate Field Operations Costs
5. Estimate Laboratory Analysis Costs
6. Estimate Data Analysis and Reporting Costs

These will be discussed in turn. Note that modeling costs are not included.

D.5.1 Instrumentation Costs

Instrumentation costs were discussed in Section D.3 and will only be summarized here. These costs represent capital acquisition costs for the most part, and amortization schedules will be a matter of local accounting procedures and discretion. Resist the temptation to lower apparent program costs by using long amortization periods, especially for equipment used in storm-generated discharge studies. Such hostile flows take a great instrumentation toll, and one or two years life is much more typical than ten or twenty.

For flow measurement, the types and numbers of primary and secondary devices must be determined. These are multiplied by the cost of each to arrive at the total dollars required. Make an allowance for spare parts for secondary devices (say 10% in the absence of more specific information). Consider the purchase of at least one complete extra unit to allow for quick field fixes. Instrument breakdown is most likely to occur during important data collection periods, and record interruptions should be as brief as possible.

Langbein and Harbeck (23) reported that a sample of four USGS districts yielded the following costs (in 1972 dollars) for flow-gaging stations: $5K to $10K for installation of an indefinite-term full-record station; $2.5K to $4K for installation of a short-term full-record station; station operating costs of $0.8K to $1.3K per year; office costs for processing the record of $0.5K to $1.3K per year. For partial-record stations, costs as a percentage of full-record stations were stated as: 5 percent for low flow only; 15 to 20 percent for crest stage record; and up to 50 percent for a flood hydrogram. They also noted that there could be extremely large variations outside of these nominal ranges.

In the absence of better information, it is suggested that $10K be budgeted for each urban flow measurement site for the acquisition and installation of a primary flow measurement device. Allow $2K each for the secondary device. The former number takes into account that some sites will allow relatively inexpensive portable devices to be used, while others may require considerable modification, e.g., installation of a below ground metering vault. The desirability of using existing USGS gaging sites where feasible is obvious.

Where possible, try to use existing meteorological instrumentation operated by others. One notable exception will be raingages. They typically cost less than $400 each; recorders may add another $500-$1,000 each. Give serious consideration to the use of leased telephone lines to provide rainfall indication back to a central location. The cost is nominal, and the information is invaluable in crew dispatching and operations. At least one raingage per catchment will be required.

For automatic samplers, the number and types must be determined. For storm-generated discharge sampling, the bulk of the commercially available devices will not be suitable without some modification. Most manufacturers will do this, but it adds cost. Between $2K and $4K should be allowed for each unit. Allow 10 percent for spares and purchase at least one complete extra unit. Also give consideration to installing two separate automatic samplers at critical sites for redundancy. If both function flawlessly, the extra sample quantity won't hurt, and the likelihood of missing a critical storm event is considerably diminished. Manual sampling equipment must be provided to each field crew. Allow two sets for each crew and plan on $100 for each set.

D.5.2 Related Equipment Costs

Shelters will be required for monitoring instrumentation at most sites. Costs can range from under $300 for a metal garden shed to well over $2K if concrete slabs and heavy fencing are required. Consideration should be given to ease of moving instrumentation from site to site; transportable (i.e., trailer) shelters have been used successfully in this regard. For some installations, e.g., one with a large mechanically refrigerated sampler, AC power will be required, and the expense of running electrical lines should be included as part of the overall station cost. Such costs may not be insignificant; $6.4K was spent just to get power to one 208 stormwater monitoring site in Illinois. Site preparation costs should not be capitalized.

Other related equipment that will be required includes small tools, personnel safety and protective gear (e.g., waders, hard hats, respirators, harnesses, etc.), and miscellaneous field hardware. These may or may not be already available. As a very rough estimate, allow 2 percent to 5 percent of the total instrumentation acquisition cost for this purpose. Do not capitalize them.

Other related equipment includes vehicles (automobiles, vans, trucks, etc.), boats, motors, generators, pumps, and the like. These are capital equipment items but, because of their multiplicity of uses, they should probably not be fully charged to a 208 program alone. In the event that the local 208 agency does not have such equipment at its disposal, consideration should be given to leasing rather than purchase. Lease rates vary with locality, but for longer term rentals, i.e., months, not days, rates can be quite reasonable. For mobility of field crews, consideration should be given to leasing extra vehicles during periods of intense activity. Of course all leasing costs should be directly charged to the monitoring program.

D.5.3 Manpower Costs

The manpower costs associated with a 208 monitoring program will vary tremendously from agency to agency, depending upon the size of the program (and hence the number and skill mix of personnel required) as well as local wage scales (including fringe benefits) and accounting practices (application rates for overhead and general and administrative expenses). Therefore, skill levels here will be indicated by estimating equivalent federal government service ratings. Salaries can be adjusted up or down to suit local conditions, and burdens can be applied according to local accounting practices. Table D-23 indicates the types of talent that a 208 program may require.

As an example of the use of Table D-23 to estimate manpower requirements, consider the following. It is desired to conduct one intensive survey per month for a one-year period. The objective of these intensive surveys is to provide information for waste load allocation studies. The basic unit manpower for the estimates made here consist of a field party chief, three qualified technicians, a chemist, a microbiologist, and a biologist. It is assumed that the minimum sampling period would be 5 consecutive days. The

TABLE D-23
TALENT REQUIREMENTS

Skill Area	Federal GS Rating	Annual Pay Rate
Environmental Engineer (1)	GS 13-14	$23K to $35K
Sanitary Engineer	GS 11-12	$16K to $25K
Hydrologist	GS 9-11	$13K to $21K
Chemical Engineer	GS 9-11	$13K to $21K
Chemist	GS 11-13	$16K to $30K
Oceanographer (2)	GS 11-12	$16K to $25K
Biologist	GS 9-12	$13K to $25K
Limnologist (3)	GS 9-11	$13K to $21K
Field Technicians	GS 3-6	$7K to $13K
Lab Technicians	GS 5-7	$9K to $14K
Clerical	GS 2-4	$6K to $10K

NOTES:

1. Assumed to be responsible for overall monitoring program.
2. Required for estuarine or near coastal studies.
3. Required for lake surveys.

basic intensive survey unit manpower estimates are shown in Table D-24. Using the salary figures from Table D-23 as a guide, the direct labor costs for one intensive survey are as follows: Field Party Chief, $26K x 3.75 MW = $1.9K; Chemist, $18K x 16 MW = $5.5K; Biologist, $16K x 5 MW = $1.5K; Field Technicians, $9K x 5 MW = $0.9K; Lab Technicians, $11K x 3.25 MW = $0.7K; Typist $7K x 1 MW = $0.1K. Thus, the total salary requirements for one intensive survey would be approximately $10.6K.

Of course it must be kept in mind that not all personnel time can be utilized at 100 percent efficiency due to a number of reasons (e.g., in runoff studies the field crews have to be paid whether it rains or not), and so a better procedure for budget estimation is to calculate annual salary costs for all required personnel rather than on a work unit basis. One last comment on manpower costs deals with the actual hours worked while in the field. Twelve hour (or longer) days are the rule rather than the exception, and extra compensation for this overtime must be allowed for in arriving at total manpower costs. Non-professional (i.e., non-exempt) personnel must be paid in accordance with applicable wage/hour laws (e.g., time and one-half for over 8 hours per day or sixth straight day in a week, etc.). Professional (exempt) personnel will be paid straight time for hours worked, given compensatory time off, or some such consideration depending upon local policy, but this also represents cost to the program and must be accounted for.

D.5.4 Field Operations Costs

This is a miscellaneous category that covers costs incurred incidental to field operations and that do not logically fit in any of the foregoing discussions. Included are such items as personnel travel costs and per diem as appropriate, miscellaneous supplies (as opposed to equipment, e.g., ice for samples if required, chemical preservatives, sample containers, gasoline, etc.), performance bonds for site restoration if required, charges for utilities (electricity, telephone lines, etc.), and so on.

TABLE D-24
ESTIMATED MANPOWER REQUIREMENTS FOR INTENSIVE SURVEYS

Activity	Personnel	Time (man-weeks)	Remarks
Initial planning	Field party chief* and lab personnel	2 MW	Assemble maps and post data
Reconnaissance (if needed)	Field party chief* and biologist	1 MW	Select sampling sites and synoptic biological screening
Mobilize field equipment and crew	Field party chief* technicians and lab crew	1 MW	Get all equipment together and ensure it is in working order
Field sampling	Field party chief* 2 laboratory crew 3 technicians 1 biologist	1 MW 3 MW 4 MW 1 MW	Field sample collection and field lab analyses
Fixed lab analyses chemistry and biology	Chemist Biologist	15 MW 3 MW	Assume 20 samples per day for 15 parameters, chemistry and plankton, and invertebrate identification and enumeration
Data analyses and report preparation	Field party chief* chemist and microbiologist, typist	3 MW	Analyze data, write and type report

* In the case of estuarine or near coastal studies this would be an oceanographer.

Taken individually, these items do not represent major sums of money but, collectively, they form a sum that may not be insignificant for many 208 monitoring programs and, therefore, must be considered in total cost estimation. They are so project and locality specific that no specific guidance can be given for cost estimation. Lacking anything else, add 2 to 5 percent of the total survey cost to cover this category and adjust as appropriate during detailed survey design.

D.5.5 Laboratory Analysis Costs

Use costs for analyses of the selected parameters quoted by the chosen laboratory where possible. Use costs given in the Parameter Handbook for preliminary estimating if local cost data are not available. Add 10 percent to 20 percent to the total for quality control costs.

As an example, Table D-25 contains average analysis costs for the minimum recommended parameter list for characterizing urban runoff. Summing the costs for the individual analyses results in a total estimated analysis cost of $163 per sample. If a sequential discrete sample series of 24 bottles was collected to characterize a storm event, the total lab fee would be $163 x 24 = $3,912. Adding 15 percent for quality control, the final estimated laboratory analysis cost would be approximately $4.5K per storm event. Thus, laboratory analysis costs are one of the major operating costs and may amount to 30 percent to 50 percent of the total cost for this portion of the program budget.

D.5.6 Data Analysis and Reporting

Costs in this category will depend upon the complexity of the survey, the degree of data interpretation required, computer charges for statistical analyses where necessary, and the type of report being generated, e.g., event summary, annual project, etc. Ball park estimates of 20 percent to 50 percent of the estimated professional manpower costs for field work will be adequate in most instances. Use more refined, project specific cost information as it becomes available.

TABLE D-25
AVERAGE ANALYSIS COSTS FOR URBAN RUNOFF PARAMETERS

Parameter	Cost
BOD_5	$ 10
TOD	30
Suspended Solids (NFS)	8
Volatile Suspended Solids	7
Fecal Coliform (MF)	10
Fecal Streptococcus (MF)	10
Nitrate-Nitrite Nitrogen	15
Kjeldahl Nitrogen	15
Total Phosphorous	15
Lead	10
Zinc	10
Copper	10
Chromium	10
pH	3

D.5.7 Example USEPA Costs

Harris and Keffer (16) have provided some information on the costs of a USEPA Surveillance and Analysis Field Investigations Section engaged in effluent monitoring for compliance verification purposes and technical assistance to 208 agencies, e.g., stream monitoring. Major field equipment with approximate initial costs is listed in Table D-26. The Field Investigations Section professional staff includes two sanitary engineers (GS-13 and 11), one chemical engineer (GS-11), and one hydrologist (GS-9). The subprofessional staff consists of four engineering technicians in grades ranging from GS-3 to 6. The regional laboratory, with a staff of eight professional chemists (GS-7 to 13) and three microbiologists (GS-7, 9, and 12), is responsible for operating the mobile laboratories of the section during field surveys.

TABLE D-26
MAJOR FIELD EQUIPMENT AVAILABLE TO USEPA REGION VII
SAD FIELD INVESTIGATIONS SECTION

Quantity	Equipment	Approximate Initial Cost
1	Mobile Laboratory	$15,000
1	Mobile Laboratory (on loan)	-
7	GSA Vehicles	-
5	Boats and Motors	5,000
50	Automatic Samplers	28,000
-	Flow-Measuring Devices	6,600
-	Field Analysis Devices	6,100
-	Portable Detector	1,200
1	Metal Detector	300

In areas outside the range in which analytical support can be provided by the regional laboratory, field sampling teams normally operate within a 161-km (100-mile) radius of a mobile laboratory, which is generally set up at a wastewater treatment facility in a community within the area of interest. Because of logistics problems in some of the more sparsely populated areas of the region, it is frequently necessary to work field teams outside of this 161-km (100-mile) radius. Ten to twenty-five percent of the total field activity may be conducted at distances up to 322 km (200 miles) from the laboratory base. Operating at these greater distances reduces capability by an estimated 50 percent and greatly increases the unit cost of sample collection.

Prior to mounting a survey, every effort is made to ascertain and consolidate the various data needs of the Agency and of the State in order to avoid duplication of effort and to minimize the number of laboratory setups. It requires a minimum of 1 week to 10 days to prepare and stock a mobile laboratory; get it on site; have electricity, water, and phone installed; and then torn down and returned to the base station following completion of a survey. If possible, field activities in areas requiring mobile laboratory support are restricted to surveys of 30 days duration or longer.

Under favorable conditions, a mobile laboratory field operation works best with a crew of seven people including: two engineers, two engineering technicians, one chemist, one microbiologist, and one laboratory technician. Working entirely within a 161-km (100-mile) radius of the mobile laboratory, this staff (which is rotated at 2-week intervals) would be able to install samplers and collect approximately 100 samples per week for field and laboratory analyses. Total time and costs for a 30-day field survey are estimated as follows:

Engineers

- 1 man-month office preparation
- 2 man-months field work
- 2 man-months data analyses and report writing

Engineering Technicians

- 2 man-months mobile laboratory and equipment repair and preparation
- 4 man-months field work

Laboratory Personnel

- 6 man-months mobile laboratory work
- 6 man-months regional laboratory analytical work

Clerical

- 2 man-months planning and report preparation

Costs

Salaries	$23,500
Per Diem	7,300
Travel of Personnel	400
Government Bill of Ladings	400
Vehicles	1,000
Miscellaneous Equipment	1,500
(Ice, batteries, containers, utilities, chemicals, etc.)	
	$34,100

When reviewing the foregoing costs, it should be kept in mind that they do not reflect any burdens (e.g., office space, heating, employee fringe benefits), that equipment costs have increased considerably, and that this team is proficient, well trained, and one of the most efficient in the country.

D.6 Waste Load Allocation Study Procedures

This section contains procedures for conducting a waste load allocation study and some recommendations and guidelines for implementation of the field surveys that will be necessary to carry it out. Most waste load allocation studies will require, as a minimum, one reconnaissance survey and two intensive surveys, one to gather model calibration data and the other to gather verification data. The procedural steps to be followed in conducting a waste load allocation study are outlined in Table D-27.

The first step is to obtain all relevant existing data. This will include all available water quality and flow data for surface water and known sources of wastes. Locations of water use (and a list of legitimate uses) should be determined. Obtain maps and either mark or prepare overlays showing land uses, outfall locations; existing stream gaging and monitoring site locations; stream slopes, cross sections, and flows; locations of rapids, dams, pools, etc.

Analyze the existing data; estimate stream velocities, relative loads from each point source and nonpoint source area, water quality coming into and leaving the planning area, travel times downstream from discharge locations, etc. Use the results to determine first approximations of station locations and parameters to be covered. Plan the reconnaissance survey accordingly. It is recommended that the reconnaissance survey include a toxics scan of all major discharges and others of concern to the 208 agency in order to identify toxic parameters that should be included in the intensive survey.

The next step is the conduct of the reconnaissance survey. The information gathered at this time will form the basis for the intensive survey implementation plan. In conducting the reconnaissance survey, the field survey

TABLE D-27
PROCEDURAL STEPS FOR CONDUCTING A WASTE LOAD ALLOCATION STUDY

(1) Obtain all relevant existing data.

(2) Analyze existing data and perform preliminary calculations.

(3) Based on (1) and (2), plan reconnaissance survey.

(4) Conduct reconnaissance survey.

(5) Analyze results of reconnaissance survey and make preliminary model runs.

(6) Based on (3) and (5), plan calibration survey.

(7) Conduct intensive survey for model calibration.

(8) Reduce data from calibration survey and analyze results.

(9) Fit model using results from (8) and run.

(10) Review results of model runs.

(11) Based on (8) and (10), plan verification survey.

(12) Conduct intensive survey for model verification.

(13) Compare results of verification survey with model predictions.

(14) If results of (13) are favorable, use the model for planning. If not, make adjustments to the model as warranted in view of (13), using the verification data gathered in (12) as additional calibration data. New verification data will now be required, so repeat steps (11) through (13).

manager should be accompanied by persons who supplement his own skills, e.g., if he is a sanitary engineer, he may have with him a biologist and a chemist. The biologist is an especially important member of the reconnaissance team. An experienced aquatic biologist in a very short time can collect and examine bottom organisms that will reveal both the severity of pollution in a general way, and the length of stream affected. His findings can, for example, reveal whether the effects of the wastes have extended farther downstream in the past then they do at the time of the reconnaissance and will have an important influence on the final planning of the study, especially with regard to the number and locations of biological sampling sites.

A quick tour of the area and the streams at readily accessible points may be taken to get the general "lay of the land" and the relationships among water uses, waste sources, and the stream. After this, the individuals of the team may go about their separate duties. The field survey manager needs to cover much of the ground that each of the others does, though in less detail. He must have the entire situation in mind to develop the final study plan, supervise the subsequent field operation, and prepare the report.

The field survey manager should become thoroughly familiar with characteristics of the streams. A trip throughout each reach by boat, if the stream is deep enough, provides the best opportunity for observation. Access to the stream may be limited to bridges and roads that parallel the stream if a boat cannot be used. An overall view of the stream may be obtained from a plane or helicopter, but observation of detail from the height involved is limited. Walking often is difficult because of undergrowth or rough terrain, and can be extremely time consuming unless the stream reach is very short.

Detailed notes of observations should be made promptly; don't depend on memory. Notes should include general impressions of depths, currents, velocities, bends, widths, types of bottom, water uses, waste discharges and mixing of wastes, availability of access, and sensory evidences of pollution, such as excessive plankton or attached growth, floating materials, oil, color, suspended matter, sludge deposits, gas bubbles, and odor. Special attention should be paid to tentative sampling stations selected in the preliminary planning. Accessibility of stations, as well as suitability for sampling, must be considered. Stations should be marked or otherwise identified to ensure sample collection at the proper points. For example, the stream miles may be painted on bridges, with arrows indicating the sampling points.

A dry run of the sampling route or routes should be made and timed. This information will be needed in estimating the final number of sample collectors that will be necessary and the maximum time samples will be held. The routes should be marked on a map, and notes made of any check points that will assist in following the routes. Stream samples for preliminary analysis should be collected at this time to assist in parameter selection for the intensive survey and to familiarize the laboratory personnel with what to anticipate when the study starts, e.g., determination of coliform and BOD will assist in selection of proper dilutions, possible interferences can be identified, etc. Simple field determinations, such as those of temperature, DO, and pH, may be made at the same time.

Potential locations for a mobile laboratory, if one is to be used, should be investigated. Frequently the site is a local water or sewage treatment plant. Accessibility and suitability of an area where the unit may be parked must be considered. Availability of necessary water and electrical connections must be checked. Arrangements for metering water or electricity should be made, if necessary. An area, sewer, or drain to which wastes can be discharged from the laboratory without nuisance is needed. Arrangements for access at any time, day or night, must be made if the area is fenced or otherwise protected. A nearby storage room or space for supplies and materials that are not in immediate use in the laboratory is useful. Convenient telephone service is a must, especially if the laboratory is to serve as headquarters for the field crew.

Facilities may be established in a local laboratory of a water or sewage treatment plant, high school, university, or industrial plant as a substitute for a mobile laboratory. The chemist in the reconnaissance survey crew should review such local facilities to determine their adequacy and what additional equipment and supplies will be needed.

If stormwater runoff is a survey concern, try to include a rainy-day visit as part of the reconnaissance effort. Much valuable information can be obtained, as well as a better appreciation of the conditions the field crew will be working under. For urban areas, sewer maps should be verified as to discharge locations, and the possibility of unrecorded outfalls investigated. Obtain information on traffic density by driving during rush hours and use these travel times for urban field crew logistics planning.

After completion of the reconnaissance survey, analyze the results and make preliminary model runs using the reconnaissance data to get the model segmented properly and to better locate stations. With the results of the reconnaissance survey and model runs as a guide, a workable intensive survey plan may be generated. Start by a careful review of the objectives; can they all be accomplished? Now is the time for any additions or deletions, not halfway through the field activity. Put the detailed plan down in writing and have it reviewed by all involved prior to finalizing. Don't discount helpful comments and suggestions from the field technicians. Include samples of all field data sheets, equipment checklists, etc.

Pay especial attention to all logistics aspects during preparation of the intensive survey plan. For example, if ice is used to cool samples and the survey calls for round-the-clock activity, locate sources where ice can be obtained at odd hours, e.g., automatic machines at service stations, all-night convenience stores, etc., and write them down so all will know. The 25-cent do-it-yourself car wash facilities at some service stations represent sources of high-pressure hot water (and soap, if detergent analyses are not performed) that can be used for cleaning automatic sampling and other field equipment, and their locations should be indicated.

The parameters to be measured must be listed, taking into account the problem assessment of parameters determined from the toxics scan, along with any special handling precautions to be observed, preservatives to be used, sample volumes required, etc. Lists of special supplies and equipment and personnel requirements should be prepared at this time. The funds allocated for the survey and the anticipated cost of the field operations should be reviewed here also.

For around-the-clock survey efforts (with two crews working 12-hour shifts, for example), allow for communication of significant information at shift change by having each shift leader report at least 30 minutes early. If such surveys are for extended periods of time, plan on changing crews every 2 weeks to avoid excessive fatigue. In any event, a system of communication that allows any crew member to be contacted within a reasonable period of time (say 3 hours) is highly recommended. Radios on vehicles are also useful communication aids.

Prepare complete equipment inventories that show locations, status, and maintenance and calibration schedules. Be certain that maintenance responsibilities are clearly defined. In addition to the more obvious equipment, instrumentation, and spares discussed earlier in this Appendix, there are a number of other miscellaneous items that will prove useful in the field, and a few examples will be mentioned. A fairly strong magnet on a line is useful for retrieving metal objects dropped in water. A metal detector is also a handy device at times. A set of basic surveying gear (transit, distance tape or chain, stadia poles, optical rangefinder, etc.) will be useful in some instances. A pick, shovel, ax, and saw will find several applications, such as improving rural stream access for sampling. Some of the basic carpenter's tools on hand will be needed at times. A Danaides (orifice) bucket is useful for estimating moderate pipe discharges into open air. A number of uses will arise for rope, string, wire, and reinforced sticky tape. A walkie-talkie set greatly facilitates communications in the field.

Obviously, not every contingency can be allowed for, and experience in conducting field surveys will facilitate future planning. However, the field survey manager should feel very uncomfortable in reviewing the intensive survey implementation plan if he:

- Does not clearly understand the survey objectives,
- Has strong preconceived notions about the results,
- Has not personally visited each measurement site,
- Has not consulted with laboratory personnel,
- Has not clearly assigned responsibilities,
- Has trusted to luck or favorable opportunities.

Conduct the intensive survey in accordance with the implementation plan insofar as practicable. Be certain that there are compelling reasons for any changes or deviations and document them. The importance of recording all information that might aid in the interpretation and analysis of other data that are being collected has been stressed throughout this Appendix. Even seemingly insignificant bits of information may be very useful in fitting the entire puzzle together. However, if they are not recorded in a clear and intelligible way, they are likely to be lost completely. Never trust to memory.

Field logbooks should be provided to each leader of a survey team and others as appropriate. Standard procedures for field data taking should be observed, e.g., logbooks should be bound with pages numbered serially, entries should be made with ballpoint pen, erasures should never be permitted (use strike-outs), all entries should be signed and dated, etc. Field logbooks should be clearly titled on the cover (to prevent the aquatic biologist from accidentally picking up the equipment crew's log, for example) and should have an assigned location when not in use. The field survey managers should frequently review all field logbooks and initial and date them when this is done.

The field logbooks are the main source of data annotation information. Be sure to record information so that it will be useful to future surveys as well as the present one. For example, entries may range from snake sightings to traffic jams that delayed getting samples to the laboratory. Knowledge of the former can reduce possible future danger to personnel, while information about the latter may suggest the desirability of route alteration. It would be improper to assume the snake would never pose a problem (even if it were killed, others may be around) or that anyone could tell that there had been a delay in getting the samples to the laboratory by comparing the time they were removed from the sampler with the time they were logged in at the laboratory.

The importance of time synchronization of data has been stressed earlier. This is equally important with data annotations. Write down the time of day (use watch time) whenever an entry is made in a field logbook. This will assist in subsequent interpretation. Finally, make full use of field logs and other annotation records in report preparation. The perfect survey has yet to be performed, and mistakes and errors will happen. Sweeping these under the table is much more censorable than admitting that they occurred, especially where a significant impact on data quality or interpretation is likely to result. The worst sin is data fudging (or outright falsification) in an attempt to cover up mistakes. This abhorrent practice should be subject to the most severe reprimand possible. Do not confuse this with data adjustment based on the best available information and professional judgment, e.g., adjustment to a flow record time base to account for a uniformly slow-running clock drive, accounting for a zero offset, etc. Data adjustment is an acceptable practice if it is clearly annotated and explained.

After completing the intensive survey for model calibration, reduce and analyze the data and prepare it for model input. Fit the model using the calibration data and make several runs. After reviewing the results of the calibration survey and the model runs, plan the intensive survey to collect verification data. Unless confidence in the model results is very high, it will be prudent to plan and conduct the verification survey with the same degree of coverage as the calibration survey. Conduct the intensive survey for verification data following the above guidance for the calibration survey and taking advantage of lessons learned from it.

Finally, compare the results of model runs with the data gathered during the verification survey. If the comparison is favorable, the model may be considered verified and can be used for waste load allocation planning. If differences are significant, make adjustments to the model as warranted from a review of the discrepancies between the model predictions and the results of the verification survey, using the verification data now as additional calibration data. Once this latter step is done, there is no longer any information about the verification of the model. The importance of this point must not be overlooked. To verify the model it will be necessary to plan and conduct another intensive survey solely for this purpose. In many instances, however, it will not need to be as extensive as the earlier intensive surveys, since the level of confidence in model results should be considerably higher than before.

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APPENDIX D, PART II

PARAMETER HANDBOOK

This Parameter Handbook has been written as a part of the Areawide Assessment Procedures Manual to aid 208 planning agencies in the establishment and conduct of water quality monitoring programs. The material presented summarizes existing work rather than representing new research results. The intent is to present, on one sheet of paper, enough salient information about a particular water quality parameter to allow decisions to be made as to the likelihood of the constituent's presence in a particular stream or discharge, its effects upon water quality or use, and factors pertaining to sampling and analysis of the constituent that should be considered in determining the ramifications of including the parameter in a water quality monitoring program. The information presented on analytical methodology, including sample quantity and preservation and handling considerations, was largely taken from one of three widely available sources:

- *Methods for Chemical Analysis of Water and Wastes, 1974* (commonly called "EPA Methods Manual"). Available from USEPA Environmental Research Information Center, Cincinnati, OH 45268.

- *Standard Methods for the Examination of Water and Waste Water*, 14th Edition, 1976 (commonly called "Standard Methods"). Available from the American Public Health Association, 1015 18th Street, N.W., Washington, D.C. 20036.

- *Annual Book of Standards, Part 31, Water, 1975* (commonly called "ASTM Methods"). Available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

The information presented herein was taken in the order indicated above, i.e., if the parameter is covered in the EPA Methods Manual, that reference was used as the primary source; if the parameter is not in the EPA Methods Manual but is covered by Standard Methods, the latter was used as the primary source; and so on. For parameters not treated by any of the above sources, other publications, especially those of the U.S. Geological Survey, were used.

It must be emphasized that this Parameter Handbook is not a specification; the information presented herein is illustrative, not exhaustive, and carries no legal authority. In this latter regard, the USEPA has published, pursuant to section 304(g) of the Water Pollution Control Act Amendments (PL 92-500), "Guidelines Establishing Test Procedures for the Analysis of Pollutants" in the Wednesday, December 1, 1976 issue of the Federal Register (40 CFR 136), a copy of which is attached at the end of this Parameter Handbook. Some minor corrections to these Guidelines were published in the Federal Register on Tuesday, January 18, 1977.

The synoptic presentations in this Parameter Handbook are written for a reader without extensive training or experience in water and wastewater analysis. A common format, depicted in Figure 1, has been used for each parameter. The entries will be discussed in turn.

Parameter Name: This is the most common name by which the parameter is most frequently known, not necessarily its proper chemical name. Where other names are commonly used or the chemical formula might be helpful, they are indicated in the general discussion.

A number of parameters are part of the USEPA water quality data storage and retrieval system (STORET) at the present time, and more will be added in the future. Where a parameter is a part of the STORET System as of March 1977, the following two entries are filled in; otherwise they are left blank.

Parameter Group: Each parameter is assigned to a designated group (e.g., metals, general organic, pesticides) in the STORET System, and this entry indicates the group to which the parameter belongs.

STORET Units: The units that must be used for entry of the concentration of the parameter into the STORET System are given here; e.g., micrograms per liter (μg/ℓ).

General: This is a brief summary of salient parameter characteristics. Typically covered are such things as what the parameter is; any common alternate name or chemical formula where possibly helpful; natural sources; uses of the substance and possible sources related thereto; indications of the persistence of the parameter in water, including its solubility where appropriate; effects of the parameter on water use, including toxicity data where appropriate; and, since many of these parameters are actually toxic substances or surrogate measures for toxic substances, the level of regulation that has been imposed upon them (such as the two technologically feasible control oriented standards of "best practicable control technology currently available" (BPT) or "best available control technology economically achievable" (BAT) or "toxicity effluent limitations") has been noted in accordance with the regulation (40 CFR 136), BAT parameters under the Consent Decree, or toxicity guidelines under the Consent Decree or other regulatory mandates.

PARAMETER NAME

Parameter Group:

STORET Units:

General:

Criterion:

Preservation Method:

Maximum Holding Time:

Container Type:

Sample Volume Required:

Measurement:

Precision and Accuracy:

Cost of Analysis:

Figure 1. Format for Parameter Information

Criteria: If the USEPA has issued water quality criteria for the parameter, they are given here along with the beneficial use to be protected by the criterion established.

Preservation Method: Physical and chemical preservatives to be used to help maintain sample integrity are indicated here along with any special sample handling considerations, e.g., keep sealed until analyzed.

Maximum Holding Time: The maximum holding time between gathering and preserving the sample and its analysis in the laboratory is given here. It is a function not only of the physical and chemical characteristics of the substance involved but also of the other constituents in the sample. The holding times given are conservative in some instances and, if data indicate that longer holding times do not significantly affect analytical results, they may be used.

Container Type: Acceptable sample container materials are indicated here. Although not addressed here, sample equipment cleaning is very important, and special cleaning protocols will be required for some parameters, e.g., pesticides, as will other special considerations such as the use of TFE fluorocarbon cap liners, etc.

Sample Volume Required: An estimate of the quantity of sample necessary to allow analysis for the parameter is given here. No allowance for replication, sample splitting, spillage, etc., is made. The exact sample quantity required will depend upon the strength of the constituent, the need for concentration or dilution, removal of interferences, etc., and is best established after preliminary laboratory work, but the given volumes can be used as a first cut.

Measurement: Descriptions of common methods for making the determination are given here, primarily to indicate any special laboratory equipment that might be required (e.g., AA, GC). Applicable concentration ranges are given, and possible interferences and precautions are indicated in many cases. Where a measurement is mandated by regulation, the regulation is cited.

Precision and Accuracy: Method sensitivity and detection limits are provided where generally agreed to. Precision and accuracy data are given where known.

Cost of Analysis: The information provided here is intended to give an appreciation of the relative magnitude of cost for performing the analysis. The data are typically presented as a range that represents differences in cost among laboratories and (sometimes) methods for a given parameter. Cost information was obtained from various laboratories across the United States and representative values were selected for the range. Extremely low or high costs for a particular parameter from a given laboratory were discarded as atypical. Costs are also influenced by sample preparation procedures necessary to remove interferences. This is especially true for pesticide analyses and is represented by large ranges in many instances, with the lower end of the range being more typical in most cases. Finally, although not indicated in the cost data presented herein, many laboratories offer quantity discounts that may be quite substantial, and local laboratories should be consulted if firm budget numbers are desired.

There are many water quality parameters that might be of interest to some 208 agencies. Those that were selected for inclusion in this first edition of the Parameter Handbook are the ones that were considered to have the broadest appeal. They represent a compilation of those found in the newly issued EPA Water Quality Criteria, the EPA Methods Manual, and the majority of the substances listed in the Consent Decree. It is contemplated that the parameter coverage will be increased in future editions of this handbook. For many parameters, preferred analytical methods, preservation techniques, maximum holding times, etc., have not been established or are tentative. Considerable advancement is expected in the near term time frame, and future editions will be updated to disseminate this information.

To assist the reader in locating parameters of interest, a number of tables are provided. In Table 1, all the parameters in the handbook are listed in alphabetical order. The parameters are alphabetically listed within each STORET parameter group in Table 2. Those parameters for which the USEPA has issued water quality criteria are alphabetically listed in Table 3. Finally, those parameters designated by the Consent Decree are listed alphabetically in Table 4. The parameter sheets in the handbook are in alphabetical order. A copy of the 1 December 1976 Federal Register is attached at the end.

TABLE 1. ALPHABETICAL LISTING OF PARAMETERS

Acidity
Acrolein
Acrylonitrile
Aldrin
Alkalinity
Aluminum
Antimony
Arsenic
Asbestos
Atrazine

Barium
Benzene
Benzene Hexachloride (BHC)
Benzidine
Beryllium
Biochemical Oxygen Demand (BOD)
Boron
Bromide

Cadmium
Calcium
Captan
Carbaryl
Carbon Tetrachloride
Chemical Oxygen Demand
Chlordane
Chloride
Chlorinated Benzenes
Chlorinated Ethanes
Chlorinated Naphthalene
Chlorinated Phenols (Other)
Chlorine Demand
Chlorine Dioxide
Chlorine, Residual
Chloroalkyl Ethers
Chloroform
2-Chlorophenol
Chromium
Cobalt
Color
Copper
Cyanide

2, 4-D
DD
DDE
DDT
Demeton
Diazinon
Dichlorobenzenes
Dichlorobenzidine
Dichloroethylenes
2, 4-Dichlorophenol
Dichloropropane
Dichloropropene
Dieldrin
2, 4-Dimethylphenol
Dissolved Oxygen
Disyston
Diuron

Endosulfan
Endrin
Ethylbenzene

Fecal Coliform
Fecal Streptococci
Fluoride

Guthion

Haloethers
Halomethanes
Hardness, Total
Heptachlor

Iodine
Iron

Lead
Lindane
Lithium

Magnesium
Malathion
Manganese

TABLE 1. ALPHABETICAL LISTING OF PARAMETERS (Cont'd)

Mercury
Methane
Methoxychlor
Methyl Parathion
Methylene Blue Active Substances (MBAS)
Mirex
Molybdenum

Naphthalene
Nickel
Nitrilotriacetic Acid (NTA)
Nitrobenzene
Nitrogen-Ammonia
Nitrogen, Kjeldahl
Nitrogen, Nitrate
Nitrogen, Nitrate-Nitrite
Nitrogen, Nitrite
Nitrophenols

Oil and Grease
Organic Carbon

Parathion
PCNB
Pentachlorophenol
pH
Phenolics
Phosphorous (all forms)
Phthalate Esters
Polychlorinated Biphenyls
Polynuclear Aromatic Hydrocarbons
Potassium

Radioactivity (alpha and beta)
Radium
Residue, Settleable
Residue, Total
Residue, Total Filterable
Residue, Total Nonfilterable
Residue, Volatile

Selenium
Silica
Silicon
Silver
Silvex (2, 4, 5-TP)
Sodium
Specific Conductance
Strontium
Sulfate
Sulfide
Sulfite

2, 4, 5-T
Temperature
Thallium
Threshold Odor
Tin
Titanium
Toluene
Total Coliform
Toxaphene
Trichloroethylene
Turbidity

Uranium

Vandaium
Vinyl Chloride

Xylene

Zinc

TABLE 2. LISTING OF PARAMETERS ACCORDING TO STORET GROUP

Bacteriologic

Fecal Coliform
Fecal Streptococci
Total Coliform

Dissolved Oxygen

Dissolved Oxygen

General Organic

Benzene
Methylene Blue Active Substances (MBAS)
Nitrilotriacetic Acid (NTA)
Oil and Grease
Organic Carbon
Phenolics
Phthalate Esters
Polychlorinated Biphenyls
Toluene
Xylene

General Inorganic

Acidity
Alkalinity
Asbestos
Bromide
Chloride
Chlorine Demand
Cyanide
Fluoride
Hardness, Total
Iodide
Sulfate
Sulfide
Sulfite

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Tin
Titanium
Uranium
Vanadium
Zinc

Miscellaneous

Chlorine, Residual

TABLE 2. LISTING OF PARAMETERS ACCORDING TO STORET GROUP (Cont'd)

Nitrogen

Nitrogen-Ammonia
Nitrogen, Kjeldahl
Nitrogen, Nitrate
Nitrogen, Nitrate-Nitrite
Nitrogen, Nitrite

Oxygen Demand

Biochemical Oxygen Demand (BOD)
Chemical Oxygen Demand

Pesticides

Aldrin
Atrazine
Benzene Hexachloride (BHC)
Benzidine
Captan
Carbaryl
Carbon Tetrachloride
Chlordane
Chloroform
2, 4-D
DDD
DDE
DDT
Demeton
Diazinon
Dieldrin
Disyston
Diuron
Endosulfan
Endrin
Guthion
Heptachlor
Lindane
Malathion
Methoxychlor
Methyl Parathion
Mirex
Parathion
Pentachlorophenol
Silvex (2, 4, 5-TP)
2, 4, 5-T
Toxaphene

Phosphorous

Phosphorus (all forms)

Physical

Color
PH
Specific Conductance
Threshold Odor
Turbidity

Radiological

Radioactivity (alpha and beta)
Strontium

Solids

Residue, Settleable
Residue, Total
Residue, Total Filterable
Residue, Total Nonfilterable
Residue, Volatile
Silica
Silicon

Temperature

Temperature

TABLE 3. PARAMETERS FOR WHICH THE USEPA HAS ISSUED WATER QUALITY CRITERIA

Aldrin	Lead
Alkalinity	Lindane
Arsenic	Malathion
Barium	Manganese
Beryllium	Mercury
Boron	Methoxychlor
Cadmium	Mirex
Chlordane	Nickel
Chlorine, Residual	Oil and Grease
Chromium	Parathion
Color	pH
Copper	Phenolics
Cyanide	Phosphorus (all forms)
2,4-D	Phthalate Esters
DDT	Polychlorinated Biphenyls
Demeton	Residue, Total Filterable
Dieldrin	Residue, Total Nonfilterable
Dissolved Oxygen	Selenium
Endosulfan	Silver
Endrin	Silvex
Guthion	Temperature
Heptachlor	Toxaphene
Iron	Zinc

TABLE 4. CHEMICAL CLASSES AND COMPOUNDS DESIGNATED AS PRIORITY POLLUTANTS IN THE TOXICS SETTLEMENT AGREEMENT

Acenaphthene
Acrolein
Acrylonitrile
Aldrin
Antimony (total)
Arsenic (total)
Asbestos
Benzene
Benzidine
Beryllium (total)
Cadmium (total)
Carbon Tetrachloride (tetrachloromethane)
Chlordane (technical mixture and metabolites)
Chlorinated Benzenes (other than dichlorobenzenes)
Chlorinated Ethanes (including 1, 2-trichloroethane and hexachloroethane)
Chlorinated Naphthalene
Chlorinated Phenols, (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
Chloroalkyl Ethers (chloromethyl, chloroethyl, and mixed ethers)
Chloroform (trichloromethane)
2-Chlorophenol
Chromium (total)
Copper (total)
Cyanide (total)
DDT and Metabolites
Dichlorobenzenes
Dichlorobenzidine
Dichloroethylenes (1, 1-dichloroethylene and 1, 2-dichloroethylene)
2, 4-Dichlorophenol
Dichloropropane and Dichloropropene
2, 4-Dimethylphenol
2, 4-Dinitrophenol
Dinitrotoluene
1, 2-Diphenlhydrazine
Endosulfan and Metabolites
Endrin and Metabolites
Ethylbenzene
Fluroanthene
Haloethers (other than those listed elsewhere)
Halomethanes (other than those listed elsewhere)
Heptachlor and Metabolites
Hexachlorobutadiene
Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentadiene
Isophorone
Lead (total)
Mercury
Naphthalene
Nickel (total)
Nitrobenzene
Nitrophenols (including 2, 4-dinitrophenol and dinitrocresol)
Nitrosamines
Pentachlorophenol
Phenol
Phthalate Esters
Polychlorinated Biphenyls (PCB's)
Polynuclear Aromatic Hydrocarbons
Selenium (total)
Silver (total)
2, 3, 7, 8-Tetrachlorodibenzo-P-Dioxin (TCDD)
Tetrachloroethylene
Thallium (total)
Toluene
Toxaphene
Trichloroethylene
Vinyl Chloride (chloroethylene)
Zinc (total)

ACIDITY

Parameter Group: General Inorganic

STORET Units: mg/ℓ as $CaCO_3$

General: Acidity is a measure of a gross property of water, its quantitative ability to neutralize a strong base to a designated pH. It can be interpreted in terms of specific substances only when the chemical composition of the sample is known. Acids contribute to corrosiveness and influence certain chemical and biological processes; therefore, the acidity of water is important. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as practicable. Fill sample bottles completely and cap tightly. The sample should not be agitated or exposed to air for a prolonged period of time. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The pH of the sample is determined and a measured amount of standard acid is added, as needed, to lower the pH to 4 or less. Hydrogen peroxide is added, the solution boiled for several minutes, cooled, and titrated electrometrically with standard alkali to pH 8.2. Suspended matter present in the sample, or precipitates formed during the titration may cause a sluggish electrode response. This may be offset by allowing a 15-20 second pause between additions of titrant or by slow dropping addition of titrant as the endpoint pH is approached. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: On a round robin conducted by ASTM on 4 acid mine waters, including concentrations up to 2,000 mg/ℓ, the precision was found to be ±10 mg/ℓ.

Cost of Analysis: \$4 - \$5

ACROLEIN

Parameter Group: STORET Units:

General: Acrolein (also known as acrylic aldehyde or 2-propenol) is a clear, colorless liquid at ordinary temperatures with a pungent irritating odor. It is extremely irritating to the skin and mucous membranes and is readily soluble in water. Its main use is as an aquatic weed killer. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: No standard procedures for acrolein have been developed. It may require special treatment to extract from water prior to gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: Expensive; must be quoted based on sample composition.

ACRYLONITRILE

Parameter Group: STORET Units:

General: Acrylonitrile is a flammable liquid used in the manufacture of synthetic rubber and plastics and as a pesticide fumigant for stored grain. It is moderately soluble in water and does not disassociate markedly. Upon disassociation it can form HCN, the toxic cyanide principle. Concentrations of 20 mg/ℓ are deleterious for many fish. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: No preferred method has been established. Acrylonitrile has been determined in wastewater by azeotropic distillation with methanol followed by measurement of NH_3 liberated by alkali saponification, but the method may not be practicable for many wastewaters. Detection limits are around 2,000 μg/ℓ. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: Expensive; must be quoted based on sample composition.

ALDRIN

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Aldrin, the common name of an organochlorine insecticide, is metabolically converted to dieldrin by aquatic organisms. Because of this metabolic conversion and because of evidence that dieldrin is as toxic or slightly more toxic than aldrin to aquatic organisms, an acceptable water concentration is based on the presence of either aldrin or dieldrin or the sum of both. Aldrin is used agriculturally at rates varying from 2 oz to 6 lb per acre, usually as a dust or emulsifiable concentrate; it is virtually insoluble in water. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria

- 003 μg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of aldrin cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for aldrin. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.015 and 0.110 μg/ℓ concentrations, recoveries were around 69% and 72% and precisions were 47% and 41%, respectively.

Cost of Analysis: $30 - $150, depending upon preparation required.

ALKALINITY

Parameter Group: General Inorganic STORET Units: mg/ℓ as $CaCO_3$

General: Alkalinity is a measure of a gross property of water, its quantitative ability to neutralize a strong acid to a designated pH. It can be interpreted in terms of specific substances only when the chemical composition of the sample is known. Alkalinity, therefore, is a measure of the buffering capacity of the water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 20 mg/ℓ or more as $CaCO_3$ for freshwater aquatic life except where natural concentrations are less.

Preservation Method: Analyze as soon as practicable. Fill sample bottles completely and cap tightly. The sample should not be agitated or exposed to air for a prolonged period of time. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: An unaltered sample is titrated to an electrometrically determined end point of pH 4.5. The sample must not be filtered, diluted, concentrated, or otherwise altered in any way. Substances such as salts of weak organic and inorganic acids present in large amounts may cause interference in the electrometric pH measurements. Oil and grease may interfere by coating the electrode, thereby causing sluggish response. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: No general statement can be made about precision due to the great variation in sample characteristics. Forty analysts in seventeen laboratories analyzed synthetic water samples containing increments of bicarbonate equivalent to around 9 and 116 mg/ℓ $CaCO_3$. The bias was approximately +16% and -8% and relative standard deviation was approximately 14% and 5%, respectively.

Cost of Analysis: \$4 - \$5

ALUMINUM

Parameter Group: Metals STORET Units: $\mu g/\ell$ as Al

General: Aluminum, being the third most abundant element in the earth's crust, occurs in minerals, rocks, and clays. Aluminum is found as a soluble salt, a colloid, or an insoluble compound in natural waters. Aluminum in wastewaters occurs from primary aluminum production and from secondary aluminum processes such as ingot cooling and shot quenching, scrubbing of furnance fumes during demagging, and wet milling of residues. Washwater from water treatment plants is another likely source, as are discharges from dyeing and cloth printing operation, paper mills, disinfectant operation, tanneries, viscose rayon plants, and many other industrial operations. Very little ingested aluminum is absorbed in the alimentary canal, so its presence does not normally pose a public health problem. Conflicting literature abounds on crop effects. An average daily dose of 2 mg aluminum has not harmed rats. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 $m\ell$

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 309.2 nm. Aluminum is partially ionized in the nitrous oxide-acetylene flame. This problem may be controlled by the addition of an alkali metal (potassium, 1,000 $\mu g/m\ell$) to both sample and standard solutions. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 1,000 $\mu g/\ell$; its detection limit is 100 $\mu g/\ell$. The optimum concentration range is 5,000-100,000 $\mu g/\ell$. At a concentration of 300 $\mu g/\ell$, the relative standard deviation is 22.2%, and the relative error is 0.7%. Precision and accuracy decrease markedly for decreasing concentrations. For example, in an interlaboratory study on trace metals analysis, at true values of 35 and 15 $\mu g/\ell$, the relative standard deviations were 309% and 1,120%, respectively, while the relative errors were 175% and 627%, respectively.

Cost of Analysis: \$10 - \$20

ANTIMONY

Parameter Group: Metals STORET Units: μg/ℓ as Sb

General: Natural antimony occurs chiefly as the sulfide or in oxide forms. Antimony is used in various industrial operations, especially in alloying as, for example, with lead for storage battery plates, with lead and tin in type metals, and with tin and copper as a bearing or antifriction material, and may be introduced into wastewaters from such sources, as well as the rubber, textile, explosives, paint, ceramic, and glass industries. Antimony has been reported to cause dermatitus and gastrointestinal disturbances in humans (it has long been used as an emetic) and has been found to shorten the life span of rats. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 217.6 nm. In the presence of lead (1,000 mg/ℓ), a spectral interference may occur at the 217.6 nm resonance line. In this case, the 231.1 nm antimony line should be used. Increasing acid concentrations decrease antimony absorption. To avoid this effect, the acid concentration in the samples and in the standards should be matched. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 500 μg/ℓ; its detection limit is 200 μg/ℓ. The optimum concentration range is 1,000-40,000 μg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 5,000 μg and 15,000 μg Sb/ℓ, the relative standard deviations were 1.6% and .66%, respectively. Recoveries at these levels were 96% and 97%, respectively.

Cost of Analysis: $10 - $20

ARSENIC

Parameter Group: Metals STORET Units: μg/ℓ as As

General: Mineral dissolution, industrial discharges, or the application of pesticides may lead to the occurrence of arsenic in water. Though most forms of arsenic are toxic to humans, arsenicals have been used in the medical treatment of spirochaetal infections, blood dyscrasias and dermatitis. Arsenic and arsenicals have many diversified industrial uses such as hardening of copper and lead alloys, tannery operations, pigmentation in paints and fireworks, and the manufacture of glass and ceramics, cloth, electrical semiconductors, and petroleum products. Arsenicals are used in the formulation of herbicides for forest management and agriculture. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 μg/ℓ for domestic water supplies (health)
- 100 μg/ℓ for irrigation of crops

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric gaseous hydride method is recommended for determining total arsenic, using a wavelength of 193.7 nm. The method is applicable to most fresh and saline waters in the absence of high concentrations of chromium, copper, cobalt, mercury, molybdenum, nickel, and silver. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is approximately 2.5 μg/ℓ; its detection limit is 2.0 μg/ℓ. The working range of the method is 2.0-20 μg/ℓ. At a concentration of 10 μg/ℓ, the relative standard deviation is 6% and the relative error is 1%. Ten replicate solutions of o-arsenilic acid at the 5, 10, and 20 μg/ℓ level were analyzed by a single laboratory. Relative standard deviations were 6%, 9%, and 5.5% with recoveries of 94, 93, and 85%, respectively.

Cost of Analysis: $15 - $20

ASBESTOS

Parameter Group: General Inorganic

STORET Units: Count/liter with length/width >1

General: Asbestos is primarily an air pollutant which has been shown to produce asbestosis, lung cancer, and mesothelioma in asbestos workers. However, the problems of asbestos in water have been recognized. It was discovered in 1973 that the drinking water of Duluth, Minnesota, and other cities on Lake Superior was heavily contaminated with asbestos. Sources of asbestos contamination include: asbestos mining, pulpmills, asbestos products, installation of asbestos construction material, spray-on steel fireproofing, and insulating cement application. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible

Maximum Holding Time: Unknown

Container Type: Glass or plastic

Sample Volume Required: Approximately 1,000 mℓ

Measurement: The present procedure is the microscopic counting of fibers in water. Asbestos probably cannot be routinely determined in effluents in the absence of gross contamination. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: No standard pricing due to impracticability of analysis.

ATRAZINE

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Atrazine, 2-chloro-4-ethylamino-6-isopropylamino-S-triazine, is a triazine pesticide. It is used as a selective herbicide. It has an oral LD_{50} in rats of 3.08 g/kg. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000 mℓ

Measurement: The recommended method covers the determination of various symmetrical triazine pesticides. It involves an efficient sample extraction procedure and provides, through use of column chromatography, a method for the elimination of non-pesticide interferences and the pre-separation of pesticide mixtures. Identification is made by selective gas chromatographic separation, and measurement is accomplished by the use of an electrolytic conductivity detector (CCD). Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. The interferences in industrial effluents are high and varied. Nitrogen containing compounds other than the triazines may interfere. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Atrazine can be determined by this method with a sensitivity of 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 to $150, depending upon preparation required.

BARIUM

Parameter Group: Metals   STORET Units: µg/ℓ as Ba

General: Barium compounds are used in a variety of industrial applications including the metallurgical, paint and dye, glass, ceramic, and electronics industries, as well as for medicinal purposes, the vulcanizing of rubber, and explosives manufacturing. Barium naturally occurs only in trace amounts in water. Therefore, appreciable amounts of barium indicates undesirable industrial discharges. A barium dose of 550,000 to 600,000 µg is considered fatal to human beings. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 1 mg/ℓ for domestic water supply (health)

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 553.6 nm. The use of a nitrous oxide-acetylene flame virtually eliminates chemical interference; however, barium is easily ionized in this flame and potassium must be added (1,000,000 µg/ℓ) to standards and samples alike to control this effect. If the nitrous oxide flame is not available and acetylene-air is used, phosphate, silicon and aluminum will severely depress the barium absorbance. This may be overcome by the addition of 2,000,000 µg/ℓ lanthanum. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 400 µg/ℓ; its detection limit is 30 µg/ℓ. The optimum concentration range is 1000-20,000 µg/ℓ. At a concentration of 500 µg/ℓ, the relative standard deviation is 10%, and the relative error is 8.6%. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 400 and 2,000 µg Ba/ℓ, the relative standard deviations were 10.8% and 6.5%, respectively. Recoveries at these levels were 94% and 113%, respectively.

Cost of Analysis: $10 - $15

BENZENE

Parameter Group: General Organic

STORET Units: μg/ℓ

General: Benzene (C_6H_6) is the simplest of the aromatic compounds and is used extensively as a commercial solvent and for the synthesis of other organic substances. At normal temperatures it is a volatile, flammable, colorless liquid with an ethereal odor. It is moderately soluble in water, 820 mg/ℓ at 22°C. It occurs in wastes from chemical plants, dyeing and other textile operations, and many other industrial processes. The oral LD_{50} for rats is around 5,600 mg/kg of body weight. The toxicity of benzene toward fish has been reported from 5,000 μg/ℓ up to 395,000 μg/ℓ depending upon age and species. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by a gas chromatographic and mass spectrometric analysis is often used. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits should be around 2-10 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

BENZENE HEXACHLORIDE (BHC)

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Benzene hexachloride (BHC), the common name of hexachlorocyclohexane, is an organochlorine pesticide. It has five known stereoisomers, the gamma isomer (lindane) being the most powerful insecticidal principle. BHC has a residual life in soil approaching that of DDT. Elevated concentrations of BHC reduce treatment plant efficiency, cause stream organisms to disappear, and produce disagreeable odors. It can impart a musty odor and taste to crops. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for BHC. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

BENZIDINE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Benzidine (4, 4'-diaminobiphenyl, $C_{12}H_{12}N_2$) is a polynuclear organic pesticide. A crystalline substance, it is only slightly soluble in water. It possesses carcinogenic properties and must be handled with great care. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 1 week

Container Type: Borosilicate glass

Sample Volume Required: 1,000-4,000 mℓ, depending on concentration and instrument used.

Measurement: Benzidines are separated and concentrated by multiple extractions and then oxidized by chloramine T. The oxidation product is extracted and measured spectrophotometrically. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is approximately 0.2 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $20 - $40; because of its carcinogenic properties, special facilities may be required at greatly increased cost.

BERYLLIUM

Parameter Group: Metals   STORET Units: μg/ℓ as Be

General: Beryllium is not likely to occur at significantly toxic levels in ambient natural waters. Beryllium could enter waters in effluents from certain metallurgical plants and discharges from industries dealing with atomic reactors, X-ray diffraction tubes, neon signs, aircraft and rockets, and missile fuel. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 11 μg/ℓ for the protection of aquatic life in soft fresh water
- 1,100 μg/ℓ for the protection of aquatic life in hard fresh water
- 100 μg/ℓ for continuous irrigation on all soils; except
- 500 μg/ℓ for irrigation on neutral to alkaline fine-textured soils

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric or aluminum colorimetric methods are suitable. The latter requires either a spectrophotometer for use at 515 nm or a filter photometer equipped with a green filter having maximum transmittance near 515 nm; either must provide a light path of 5 cm. Sodium and silicon at concentrations in excess of 1,000,000 μg/ℓ have been found to severely depress the beryllium absorbance. Bicarbonate ion is reported to interfere; however, its effect is eliminated when samples are acidified to a pH of 1.5. Aluminum at concentrations of >500 μg/ℓ is reported to depress the sensitivity of beryllium. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 25 μg/ℓ; its detection limit is 5 μg/ℓ. The optimum concentration range is 50-2,000 μg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 10, 50, and 250 μg/ℓ, the relative standard deviations were 10%, 2%, and 1%, respectively. Recoveries at these levels were 100%, 98%, and 97%, respectively. In 32 laboratories using a known sample containing 250 μg/ℓ, the beryllium was determined colorimetrically with a relative standard deviation of 7% and a relative error of 12%.

Cost of Analysis: $10 - $20

BIOCHEMICAL OXYGEN DEMAND (BOD)

Parameter Group: Oxygen Demand   STORET Units: mg/ℓ

General: The biochemical oxygen demand (BOD) determination is an empirical test used to obtain a measure of the relative oxygen demand of water, especially treatment plant loadings and removal efficiencies. It is important to realize that BOD results cannot be compared unless the results have been obtained under identical test conditions and that the test is of limited value in determining the actual oxygen demand of surface waters. Complete stabilization of a given sample may require a period of incubation too long for practicable purposes, so the 5-day test is most commonly reported. As an indicator parameter, BOD is not a pollutant and exercises no direct harm. Its indirect effect is to depress dissolved oxygen levels. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 6 hours

Container Type: Plastic or glass

Sample Volume Required: 1000 mℓ

Measurement: The recommended method is an empirical bioassay type procedure which measures the dissolved oxygen consumed by microbial life while assimilating and oxidizing the organic matter present. The standard test conditions include dark incubation at 20°C for 5 days. The determination of dissolved oxygen may be made by use of either the modified Winkler or the electrode method. Many samples will require seeding due to low microbal populations. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Eighty-six analysts in fifty-eight laboratories analyzed natural water samples plus an exact increment of biodegradable organic compounds. At mean values of 2.1 and 175 mg/ℓ BOD, the standard deviations were ±0.7 and ±26 mg/ℓ, respectively. There is no acceptable procedure for determining the accuracy of the BOD test.

Cost of Analysis: $10 - $17

BORON

Parameter Group: Metals   STORET Units: µg/ℓ as B

General: Boron is usually found in nature as a sodium or calcium borate salt. A major source of boron in domestic wastewater is sodium perborate, used as a bleach in household washing powders. Fluoroborate solutions are used for plating of cadmium, copper, lead, nickel, tin, and zinc. Boron salts are used in fire retardants, the production of glass, leather tanning and finishing industries, cosmetics, photographic materials, metallurgy, and for high energy rocket fuels. The ingestion of excessive doses of borates may cause nausea, cramps, convulsions, coma, or other symptoms of distress. It appears to pose a greater hazard to plants than humans, however. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 750 µg/ℓ for long-term irrigation on sensitive crops

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Polyethylene bottles or alkali-resistant, boron-free glassware.

Sample Volume Required: 50-200 mℓ

Measurement: The curcumin method using colorimetric equipment is recommended for concentrations in the 100 to 1,000 µg/ℓ range. When a sample of water containing boron is acidified and evaporated in the presence of curcumin, a red-colored product called rosocyanine is formed. The rosocyanine is taken up in a suitable solvent, and the red color is compared with standards either visually or photometrically. One of the following equipments will be required: (a) spectrophotometer for use at 540 nm with a light path of 1 cm, or (b) a filter photometer equipped with a green filter having a maximum transmittance near 540 nm with a minimum light path of 1 cm. Nitrate nitrogen concentrations above 20,000 µg/ℓ interfere. Significantly high results are possible when the total of calcium and magnesium hardness exceeds 100,000 µg/ℓ as $CaCO_3$. Passing the sample through a cation exchange resin eliminates this problem. Close control of such variables as volumes and concentrations of reagents, as well as time and temperature of drying, must be exercised for maximum accuracy. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The minimum detectable quantity is 0.2 μg/ℓ B. A synthetic sample, containing 240 μg/ℓ B, 40 μg/ℓ As, 250 μg/ℓ Be, 20 μg/ℓ Se, and 6 μg/ℓ V in distilled water, was analyzed by the curcumin method in 30 laboratories with a relative standard deviation of 22.8% and a relative error of 0%.

Cost of Analysis: $5 - $20

BROMIDE

Parameter Group: General Inorganic   STORET Units: mg/ℓ as Br

General: Naturally occurring bromide in water is negligible, outside of coastal areas, the major sources being chemical industry and saltworks effluents. It is used for medicinal compounds, dyestuffs, gasoline additives, and swimming pool water sterilization. Like other halogens it is antiseptic and disinfectant and, hence, may possibly interfere with bacterial and other natural purification processes. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The titrimetric method is recommended. The concentration range for this method is 2-20 mg bromide/ℓ. After pretreatment to remove interferences, the sample is divided into two aliquots. One aliquot is analyzed for iodide. The other aliquot is analyzed for iodide plus bromide. Bromide is then calculated by difference. Iron manganese and organic matter can interfere; however, the calcium oxide pretreatment removes or reduces these to insignificant concentrations. Color interferes with the observation of indicator and bromine - water color changes. This interference is eliminated by the use of a pH meter instead of a pH indicator and the use of standardized amounts of oxidant and oxidant quencher. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a single laboratory, using a mixed domestic and industrial waste effluent, at concentrations of 0.3, 2.8, 5.3, 10.3, and 20.3 mg/ℓ of bromide, the relative standard deviations were 43%, 13%, 7.2%, 4.3%, and 2.1%, respectively. At concentrations of 2.8, 5.3, 10.3, and 20.3 mg/ℓ of bromide, recoveries were 96%, 83%, 97%, and 99%, respectively.

Cost of Analysis: $15 - $20

CADMIUM

Parameter Group: Metals   STORET Units: μg/ℓ as Cd

General: Cadmium occurs in nature chiefly as a sulfide salt, frequently in association with zinc and lead ores. The salts of the metal also may occur in wastes from electroplating plants, pigment works, textile and chemical industries. Cadmium is also used in everyday items such as paint, some pottery pigments, plastics, and automobile tires. Cadmium is present as an impurity in the more common galvanized coatings. Biologically, cadmium is a nonessential, nonbeneficial element recognized to be of high toxic potential. The concentration and not the absolute amount determines the acute toxicity of cadmium. Cadmium and cadmium compounds produce acute or chronic symptoms varying in intensity from irritations to extensive disturbances resulting in death. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 10 μg/ℓ for domestic water supply (health)
- Aquatic Life:

Fresh Water

Soft Water	Hard Water	
0.4 μg/ℓ	1.2 μg/ℓ	for cladocerans and salmonid fishes
4.0 μg/ℓ	12.0 μg/ℓ	for other, less sensitive, aquatic life

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 228.8 nm. For levels of cadmium below 20 μg/ℓ, the extraction procedure is recommended. The dithizone procedure may also be used. It requires either a spectrophotometer for use at 518 nm or a filter photometer equipped with a green filter having a maximum light transmittance near 518 nm; either must provide a light path of at least 1 cm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 250 μg/ℓ; its detection limit is 2 μg/ℓ. The optimum concentration range is 50-2,000 μg/ℓ. At a concentration of 50 μg/ℓ, for the AA method the relative standard deviation is 21.6% and the relative error is 8.2%, while for the dithizone method they are 24.6% and 6.0%, respectively.

Cost of Analysis: $10 - $15

CALCIUM

Parameter Group: Metals   STORET Units: mg/ℓ as Ca

General: Calcium enters water supplies through passage over deposits of limestone, dalomite, gypsum, and gypsiferous shale. Calcium salts and ions are among the most commonly encountered substances in water. Calcium salts breakdown on heating to form scale in boilers, pipes, and cooking utensils. Calcium adds to the total hardness of water. Calcium salts used on unpaved roadways and in innumerable industrial discharges represent other sources. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 422.7 nm. Phosphate, sulfate and aluminum interfere but are masked by the addition of lanthanum. The nitrous oxide-acetylene flame will provide two to five times greater sensitivity and freedom from chemical interferences. Ionization interferences should be controlled by adding a large amount of alkali to the sample and standards. For general use, the EDTA titrimetric method is the method of choice due to its simplicity and rapidity. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.08 mg/ℓ; its detection limit is 0.003 mg/ℓ. The optimum concentration range is 0.2-20 mg/ℓ. In a single laboratory, using distilled water at concentrations of 9.0 and 36 mg/ℓ, the relative standard deviations were 3.3% and 1.6%, respectively. Recoveries at both these levels were 99%. In a 44-laboratory test, synthetic unknown samples containing 108 mg/ℓ Ca (with other metals) were analyzed with a relative standard deviation of 9.2% and a relative error of 1.9%.

Cost of Analysis: $5 - $15

CAPTAN

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Captan is an approved name for the organochlorine fungicide $C_9H_8Cl_3NO_2S$. It is the active ingredient in the proprietary product Captan 50-W and was also known as SR-406, Vancide 89, and Orthocide. It is insoluble in water but partially soluble in some organic solvents. Captan has a very low toxicity to mammals (e.g., the LD_{50} for rats is over 9 g/kg of body weight) and is readily hydrolyzed, the effective residual life being on the order of two weeks. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for captan. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

CARBARYL

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Carbaryl, commonly known as Sevin, is an O-ARYL carbamate insecticide. It is commonly used on lawns as well as for other purposes. It is slightly soluble in water, sparingly soluble in most organic solvents, but freely soluble in amides. It has low mammalian toxicity, the acute oral LD_{50} to rats being reported from 500,000 to 2,190,000 μg/kg of body weight. Although persistent, its toxicity to aquatic life appears to be low also. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000 mℓ

Measurement: In the recommended method, a measured volume of water is extracted with methylene chloride, and the concentrated extract is cleaned up with a Florisil column. Appropriate fractions from the column are concentrated and portions are separated by thin-layer chromatography. The carbamates are hydrolyzed on the layer and the hydrolysis products are reacted to yield specific colored products. Quantitative measurement is achieved by visually comparing the responses of sample extracts to the responses of standards on the same thin layer. Identifications are confirmed by changing the pH of the layer and observing color changes of the reaction products. Phenols interfere directly, and indirect interferences may be encountered from naturally colored materials whose presence masks the carbamate reaction. The method is recommended for use only by an experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Carbaryl can be determined with a sensitivity of 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $60

CARBON TETRACHLORIDE

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Carbon tetrachloride, CCl_4, is used in industry as an organic solvent, fire extinguisher, and for dry cleaning of clothing. In human and veterinary medicine, it is used as an anti-helminthic. Carbon tetrachloride is colorless nonflammable liquid with a strong odor. Death has occurred from ingestion of 5 mℓ, about 8 grams. Repeated skin contact will result in dermatitis. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect the sample from phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: The recommended method for carbon tetrachloride is a direct aqueous-injection procedure for the determination of gas chromatographable chlorinated hydrocarbons. A 3-10 μℓ aliquot of the sample is injected into the gas chromatograph equipped with a halogen specific detector. Compounds containing bromine or iodine will interfere with the determination. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60.

CHEMICAL OXYGEN DEMAND

Parameter Group: Oxygen Demand   STORET Units: mg/ℓ

General: The chemical oxygen demand (COD) test determines the quantity of oxygen required to oxidize a portion of organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. It is an important parameter for stream and industrial waste studies and control of waste treatment plants and can be rapidly determined. Exactly the same technique must be used each time, since the results depend upon the chemical oxidant used, the structure of the organic compounds, and the manipulative procedures. Although empirical correlations with other oxygen demand indicators may be made for a given waste stream, there is no uniform theoretical basis for association. COD is not a pollutant in and of itself and exercises no direct harm. Its indirect effect is to depress dissolved oxygen levels. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add H_2SO_4 to pH <2.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The dichromate reflux method is recommended. The method is applicable to domestic and industrial waste samples having an organic carbon concentration greater than 15 mg/ℓ. For lower concentrations of carbon such as in surface water samples, the low level modification should be used. When the chloride concentration of the sample exceeds 2,000 mg/ℓ, the modification for saline waters is required. To reduce loss of volatile organics, the flask should be cooled during addition of the sulfuric acid solution. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Eighty-six analysts in fifty-eight laboratories analyzed a distilled water solution containing oxidizable organic material equivalent to 270 mg/ℓ COD. The relative standard deviation was 6.6% and relative error was 4.7%. A set of synthetic unknowns analyzed by 74 laboratories resulted in a relative standard deviation of 6.5% at the 200 mg/ℓ COD level. At 160 mg/ℓ COD and 100 mg/ℓ chloride, the relative standard deviation was 10.8%.

Cost of Analysis: $10 - $17

CHLORDANE

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Chlordane, the common name of an organochlorine insecticide, is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food. Technical grade chlordane is a mixture of toxic compounds that have not been separated in manufacture. There is an extremely wide range for the acute toxicity of chlordane to various species of freshwater fishes. Fishes can concentrate chlordane directly from water by a factor of 1,000 to 3,000 times, and invertebrates may concentrate to twice this magnitude. Chlordane is stable in the soil and is fungicidal. It could be contained in irrigation return flows. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 0.01 μg/ℓ for freshwater aquatic life
- 0.004 μg/ℓ for marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of chlordane cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for chlordane under favorable conditions. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

CHLORIDE

Parameter Group: General Inorganic   STORET Units: mg/ℓ as Cl

General: Chloride is one of the major inorganic anions in water arising from natural mineral origin, seawater intrusion, salts used for agricultural purposes, sewage, industrial effluents (including paperworks, galvanizing plants, water softening plants, oil wells, and petroleum refineries), roadway deicing, and other sources. Chlorides in drinking water are not normally harmful at palatable concentrations. It is generally the cation associated with the chloride that produces a harmful effect. Chloride ions exert a significant effect on the corrosion rate of metals (e.g., steel and aluminum) and are considered to be among the most troublesome anions in irrigation water. Injury to livestock seldom occurs below the 4,000 mg/ℓ level, but injury to fish has been reported at 400 mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: None required

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The mercuric nitrate method is recommended wherein a dilute mercuric nitrate solution is added to an acidified sample in the presence of mixed diphenylcarbazone-bromophenol blue indicator. The method is suitable for all concentration ranges, but to avoid large titration volumes, the sample aliquot should not contain more than 10 to 20 mg Cl per 50 mℓ. Sulfites interfere and, if their presence is suspected, oxidize by treating 50 mℓ of sample with 0.5 to 1.0 mℓ if H_2O_2. Bromide and iodide are titrated in the same manner as chloride. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A synthetic unknown sample containing 241 mg/ℓ Cl was analyzed in 10 laboratories with a relative standard deviation of 3.3% and a relative error of 2.9%.

Cost of Analysis: $3 - $4

CHLORINATED BENZENES

Parameter Group: STORET Units:

General: Chlorinated benzenes (other than dichlorobenzenes) include chlorobenzene, 1, 2, 4-trichlorobenzene, and hexachlorobenzene. They are heavy liquids and settle to the bottom in quiescent water unless emulsified. Their chief use is as aquatic herbicides to control weeds in lakes and ditches. They have pungent odors and therefore are unlikely to cause serious harm to humans through direct ingestion. Mild symptoms of poisoning of sheep and cattle have been reported at concentrations in excess of 2,700 mg/ℓ. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 0.1 to 10 μg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $25 - $40

CHLORINATED ETHANES

Parameter Group: STORET Units:

General: Chlorinated ethanes are volatile halocompounds including: 1, 2-trichloroethane; hexachloroethane; 1, 2-dichloroethane; 1, 1, 1-trichloroethane; hexachloroethane; 1, 1-dichloroethane; 1, 1, 2-trichloroethane; 1, 1, 2, 2-tetrachloroethane; and chloroethane. Widely used in various industries and processes, their characteristics vary from compound to compound. For example, 1, 2-dichloroethane (also called ethylene dichloride, $C_2H_4Cl_2$) is a heavy liquid with a pleasant odor and sweet taste and is highly soluble in water. It is used as an industrial solvent and in the manufacture of tobacco extract. Its oral LD_{50} for rats is 770 mg/kg of body weight. By contrast, 1, 1, 1-trichloroethane (also called methyl chloroform) is insoluble in water. It is used as a solvent for fats, waxes, resins, and alkaloids, and for cleaning metal and plastic molds. Its toxicity towards the marine pinperch is twice that of 1, 1, 2-trichloroethane (i.e., 75-100 mg/ℓ versus 150-175 mg/ℓ). This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

CHLORINATED NAPHTHALENE

Parameter Group: STORET Units:

General: 2-chloronaphthalene ($C_{10}H_7Cl$) is a solid (at normal temperatures) polynuclear organic compound. It is insoluble in water, but moderately soluble in other media such as alcohol, benzene, and ether. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly. Cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ

Measurement: The general procedure involves extraction and measurement with a gas chromatograph. Various cleanup techniques to remove interferences may be required depending upon other constituents in the sample. A skilled chemist or specialist will be required. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits in the 1-10 µg/ℓ range should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

CHLORINATED PHENOLS (OTHER)

Parameter Group: STORET Units:

General: Other chlorinated phenols ($C_6H_3Cl_3O$) include the trichlorophenols and chlorinated cresols (C_7H_7ClO). Although their specific properties vary from compound to compound, they are generally only slightly soluble in water but fairly soluble in other media such as alcohol, benzene, and ethers. Their main aesthetic problem stems from their organoleptic properties in water and fish. For example, the threshold odor level in water for 2, 4, 6-trichlorophenol is 3 µg/ℓ. They tend to be persistent in water and are capable of being transported long distances. They are not efficiently removed by conventional water treatment processes and can cause odor problems in distribution systems. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

CHLORINE DEMAND

Parameter Group: General Inorganic STORET Units: mg/ℓ

General: The chlorine demand of water is caused by inorganic reductants and others and varies with the amount of chlorine applied, contact time, pH, and temperature. It is the difference between the amount of chlorine applied at the amount of free, combined, or total available chlorine remaining at the end of the contact period. The usual purpose of a chlorine demand test is to determine the amount of chlorine that must be applied to produce a specific residual after a selected period of contact, rather than as an indicator of pollution. It should not be confused with chlorine requirement.

Criterion: Not designated

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 200-500 mℓ; 5,000 mℓ may be required to develop a breakpoint curve.

Measurement: A laboratory method is recommended which involves the addition of chlorine to the sample until the "breakpoint" is reached. At the end of the contact period the free and/or combined available residual chlorine is determined by a suitable technique, e.g., the amperometric titration method.

Precision and Accuracy: Precision and accuracy will depend upon the method chosen to measure free and/or combined available residual chlorine.

Cost of Analysis: $50 - $80 with breakpoint curve

CHLORINE DIOXIDE

Parameter Group: STORET Units:

General: Chlorine dioxide is added to water supplies to combat tastes and odors due to phenolic-type wastes, actinomycetes, and algae as well as to oxidize soluble iron and manganese to a more easily removable form. Chlorine dioxide acts as a disinfectant. See also the residual chlorine discussion.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Avoid exposing the sample to sunlight or agitation that aerates the sample excessively.

Maximum Holding Time: No holding. Analyze on site if possible.

Container Type: Plastic or glass

Sample Volume Required: 200 mℓ

Measurement: The amperometric titration method is recommended. It is an extension of the method for residual chlorine.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $30 - $40

CHLORINE, RESIDUAL

Parameter Group: Miscellaneous   STORET Units: mg/ℓ

General: The toxicity of chlorine to aquatic life will depend upon the concentration of total residual chlorine, which is the amount of free chlorine plus chloramines. The persistence of chloramines is dependent on the availability of material with a lower oxidation-reduction potential. Free available chlorine (HOCl and OCl^-) and combined available chlorine (mono- and di-chloramines) appear transiently in surface or ground waters as a result of disinfection of domestic sewage or from industrial processes that use chlorine for bleaching operations or to control organisms that grow in cooling water systems. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria: Total residual chlorine:

- 2.0 μg/ℓ for salmonid fish
- 10.0 μg/ℓ for other freshwater and marine organisms

Preservation Method: Analyze as soon as possible. Cool to 4°C. Chlorine determinations should be started immediately after sampling, avoiding excessive light and agitation.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The amperometric titration method is recommended. It is applicable to all types of waters and wastes that do not contain a substantial amount of organic matter. This method cannot be used for samples containing above 5 mg/ℓ total residual chlorine. Samples containing significant amounts of organic matter interfere with the amperometric titration and the iodometric method must be used. The amperometric titration is not subject to interference from color, turbidity, iron, manganese, or nitrite nitrogen. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A sample containing a concentration of .8 mg/ℓ was analyzed by 23 laboratories using the amperometric method. The relative standard deviation was 42.3% with a relative error of 25.0%.

Cost of Analysis: $30 - $40

CHLOROALKYL ETHERS

Parameter Group: STORET Units:

General: Chloroalkyl ethers are volatile halocompounds including bis (chloromethyl) ether, bis (2-chloroethyl) ether, and 2-chloroethyl vinyl ether (mixed). This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: No standard procedure has been established. Methodology may require extraction, concentration, gas chromatography, and mass spectrometry. Detection limits of 60 μg/ℓ or less should be achievable if procedure is optimized for sample composition. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: \$20 - \$30 each

CHLOROFORM

Parameter Group: Pesticides   STORET Units: µg/ℓ

General: Chloroform is used as an anesthetic, counterirritant, solvent, cleansing agent, and antiseptic. It is a colorless and volatile liquid with an ethereal odor and sweetish taste. Stickleback will avoid solutions of 100,000 to 200,000 µg/ℓ of chloroform in tap water. At 500,000 µg/ℓ, they become anesthetized. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect the sample from phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: The recommended method for chloroform is a direct aqueous-injection procedure for the determination of gas chromatographable chlorinated hydrocarbons. A 3-10 µℓ aliquot of the sample is injected into the gas chromatograph equipped with a halogen specific detector. Compounds containing bromine or iodine will interfere with the determination. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60.

2-CHLOROPHENOL

Parameter Group: STORET Units:

General: 2-chlorophenol (C_6H_5ClO) is a liquid only slightly soluble in water but fairly soluble in other media such as alcohol. Its major aesthetic problem stems from its organoleptic properties in water and fish. Threshold odor levels for 2-chlorophenol are around 2 µg/ℓ. It is a persistent substance, capable of being transported long distances in water and is not removed efficiently by conventional water treatment. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

CHROMIUM

Parameter Group: Metals   STORET Units: μg/ℓ as Cr

General: The primary source of chromium is industrial discharges. Chromium compounds are used in cooling water to inhibit corrosion and are employed in the manufacture of paint pigments, in chrome tanning, aluminum anodizing, and other metal cleaning, plating, and electroplating operations. Chromium in industrial wastes occurs predominately as the hexavalent form, but the trivalent form is also present, either as a result of partial wastewater treatment or from its direct use. Industries that use trivalent chromium directly in manufacturing processes include glass, ceramics, photography, and textile dyeing. It is not clear if chromium is an essential element to man. Hexavalent chromium has been considered a toxic metal for years. Trivalent chromium is less toxic, no reports of oral toxicity are known. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 μg/ℓ for domestic water supply (health)
- 100 μg/ℓ for freshwater aquatic life

Preservation Method: Acidify all samples at the time of collection to keep the metal in solution and prevent plating out on the container wall; therefore, analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended for the determination of total chromium in water and wastewater samples. The colorimetric method may be used for the determination of hexavalent chromium in potable water. Use a wavelength of 357.9 nm with the AA spectrophotometric method. The absorption of chromium is suppressed by iron and nickel. If the analysis is performed in a lean flame the interference can be lessened but the sensitivity will also be reduced. The interference does not exist in nitrous oxide-acetylene flame. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 100 μg/ℓ; its detection limit is 20 μg/ℓ. The optimum concentration range is 200-10,000 μg/ℓ. At a concentration of 50 μg/ℓ, the relative standard deviation is 26.4%, and the relative error is 2.3%. These decrease with concentration; at 15.0 μg/ℓ they are 60% and 6.8% respectively, while at 7.4 μg/ℓ they are 105% and 38%, respectively.

Cost of Analysis: $10 - $15

COBALT

Parameter Group: Metals STORET Units: μg/ℓ as Co

General: Cobalt naturally occurs primarily as arsenide and sulfide, generally associated with iron, nickel, copper, and silver minerals. Cobalt is used in alloys for magnets, high hardness steels, cutting tools, heat resistant jet engine parts, etc., and may appear in discharges from these and other industrial sources, including nuclear technology, china and glass, ink, galvanoplating, and as a feed supplement in salt licks. Ingestion of cobalt salts may cause nausea or vomiting due to irritation, but it has a relatively low toxicity to man. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 240.7 nm. For levels of cobalt below 50 mg/ℓ, the extraction procedure is recommended. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 200 μg/ℓ; its detection limit is 30 μg/ℓ. The optimum concentration range is 500-10,000 μg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 200, 1,000 and 5,000 μg Co/ℓ, the relative standard deviations were 6.5%, 1.0%, and 1.0%, respectively. Recoveries at these levels were 98%, 98%, and 97%, respectively.

Cost of Analysis: $10 - $15

COLOR

Parameter Group: Physical

STORET Units: Platinum-Cobalt Units

General: The most common causes of color in natural water are minerals and complex organic compounds originating from the decomposition of naturally-occurring organic matter. Sources of organic material include humic materials from the soil such as tannins, humic acid and humates; decaying plankton; and other decaying aquatic plants. Virtually all industrial discharges and irrigation return flows also contain color to varying extents. The effects of color on public water supplies are aesthetic. The effects of color in water on aquatic life are to reduce light penetration, and thereby generally reduce photosynthesis by phytoplankton and to restrict the zone for aquatic vascular plant growth. Color is undesirable in waters for a number of industrial uses also. Color values are extremely pH dependent. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- Waters shall be virtually free from substances producing objectionable color for aesthetic purposes;
- The source of supply should not exceed 75 color units on the platinum-cobalt scale for domestic water supplies;
- Increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The platinum-cobalt visual comparison method is acceptable for measuring the color of potable water. The method is not applicable to color measurement on waters containing highly colored industrial wastes, in which case the spectrophotometric or tristimulus methods are useful. In the platinum-cobalt method, color is measured by visual comparison of the sample with platinum-cobalt standards. One unit of color is that produced by

1 mg/ℓ platinum in the form of the chloroplatinate ion. Slight amounts of turbidity interfere with the determination; therefore, samples showing visible turibidity should be clarified by centrifugation. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $5 for visual
$10 - $15 for tristimulus
$30 - $40 for spectrophotometric (10 ordinates)
$70 - $80 for spectrophotometric (30 ordinates)

COPPER

Parameter Group: Metals STORET Units: µg/ℓ as Cu

General: Oxides and sulfates of copper are used for pesticides, algicides, and fungicides. Copper is frequently incorporated into paints and wood preservatives to inhibit growth of algae and invertebrate organisms. Copper salts are used in water supply systems for controlling biological growths and for catalyzing the oxidation of manganese. Primary sources of copper in industrial wastewater are metal process pickling and plating baths; other sources involve mine drainage, pulp and paper mills, fertilizer manufacturing, petroleum refining, and certain rayon processes. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 1.0 mg/ℓ for domestic water supplies (welfare).
- For freshwater and marine aquatic life, 0.1 times a 96-hour LC_{50} as determined through nonaerated bioassay using a sensitive aquatic resident species.

Preservation Method: Copper ion tends to be adsorbed on the surface of the sample container; therefore, analyze as soon as possible. If storage is necessary, use 0.5 mℓ 1 + 1 HCl per 100 mℓ of sample to prevent plating out. Alternatively, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 50 to 200 mℓ

Measurement: The AA spectrophotometric and neocupreine methods are recommended because of their high degree of freedom from interferences. The latter requires either a spectrophotometer for use at 457 nm or a filter photometer equipped with a narrow-band violet filter having maximum transmittance in the 450- to 460-nm range; either must provide a light path of at least 1 cm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 100 μg/ℓ; its detection limit is 100 μg/ℓ. Precision and accuracy decrease with concentration. At 1,000 μg/ℓ, the relative standard deviation is around 11% and the relative error, 3%. At 300 μg/ℓ, the relative standard deviation has increased to nearly 18%, at 70 μg/ℓ it is over 30%, and approaching 10 μg/ℓ it exceeds 80%. Relative error has increased to nearly 16% at the last concentration.

Cost of Analysis: $5 - $10

CYANIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as CN

General: All of the CN groups in cyanide compounds that can be determined as the cyanide ion, CN^-, whether in simple, e.g., A(CN)x, or complex, AyM(CN)x, form. In the first expression, A may be an alkali or a metal; in the second, A is an alkali and M a heavy metal. In such latter alkali-metallic cyanides, the anion is not the CN group but the radical M(CN)x. Sources of cyanide in waste streams include ore mining and extracting, photographic processing, coke furnaces, synthetic manufacturing, case hardening and pickling of steel, electroplating, and industrial gas scrubbing. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 5.0 µg/ℓ for freshwater and marine aquatic life and wildlife.

Preservation Method: Most cyanides are very reactive and unstable. Analyze as soon as possible. If oxidizing agents are present, reduce with ascorbic acid. Add NaOH to raise sample pH to 12 or above and cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 500 mℓ

Measurement: For total cyanides, both dissociable and nondissociable forms of cyanide are being measured. Cyanides amenable to chlorination represent only the former. Standard methods for determination of total cyanide make use of a reflux-distillation procedure for concentrating and removing cyanides. The liberated hydrogen cyanide is collected in sodium hydroxide, and its concentration determined by using a titration method (above 1 mg/ℓ), a colorimetric method (below 1 mg/ℓ), or an ion selective electrode method (0.05 to 10 mg/ℓ). Although the distillation procedure eliminates or reduces many interferences, sulfides will distill over and adversely affect the colorimetric and titrimetric procedures, fatty acids will distill and form soaps under the alkaline titration procedures obscuring the end point, thiocyanates may interfere when distillation is carried out with the cuprous chloride reagent, and aldehydes will convert cyanide to nitrile under the distillation conditions. Special precautions are required when any of these are present. The colorimetric method requires either a spectrophotometer for use at 578 nm or a filter photometer equipped with a red filter having maximum transmittance in the 570 to 580 nm range; either must provide a light path of 1 cm. The ion selective electrode method requires a suitable meter, a cyanide-ion selective electrode, and a double junction reference electrode. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The titrimetric method yields a relative standard deviation of 2% for samples containing more than 1 mg/ℓ CN without significant interferences, increasing with decreasing concentration down to the limit of sensitivity, which is around 0.1 mg/ℓ, e.g., at 0.4 mg/ℓ the relative standard deviation is 8%. The colorimetric method is sensitive to about 0.02 mg/ℓ. Within its designated range, its overall precision is given as 0.115X + 0.031, where X is the CN concentration in mg/ℓ. Using mixed domestic and industrial waste samples at concentrations of 0.28 and 0.62 mg/ℓ CN, relative standard deviations of 11% and 15% and recoveries of 85% and 102%, respectively, were observed in a single laboratory. The overall precision of the ion selective electrode method is given as 0.113X + 0.024, where X is the concentration in mg/ℓ CN.

Cost of Analysis: $10 - $30

CAUTION! Exercise care in the manipulation of cyanide samples because of their toxicity. Avoid contact, inhalation, or ingestion.

2, 4-D

Parameter Group: Pesticides   STORET Units: μg/ℓ

General: 2, 4-D (2, 4-dichlorophenoxyacetic acid) is the widely used chlorophenoxy herbicide $C_8H_6Cl_2O_3$. This compound is formulated in a variety of salts and esters that may have a marked difference in herbicidal properties, but all are hydrolyzed rapidly to the corresponding acid in the body. 2, 4-D herbicide is used for weed control on land, and as an aquatic herbicide in lakes, streams, and irrigation canals. It is a plant hormone that stimulates excessive growth, causing the plant to destroy itself. 2, 4-D is of low toxicity to mammals, the acute oral LD_{50} for rats being 500,000 μg/kg of body weight, but may give water an unpleasant taste. Fish toxicity levels are in the hundreds of mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 100 μg/ℓ for domestic water supply (health).

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ, depending upon measurement method used.

Measurement: In the recommended method, chlorinated phenoxy acids and their esters are extracted from the acidified water sample with ethyl ether. The esters are hydrolyzed to acids and extraneous organic material is removed by a solvent wash. The acids are converted to methyl esters which are extracted from the aqueous phase. The extract is cleaned up by passing it through a micro-adsorption column. Detection and measurement are accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography. Interferences may be high and varied and often pose great difficulty in obtaining accurate and precise measurement of chlorinated phenoxy acid herbicides. Organic acids, especially chlorinated acids, cause the most direct interference with the determination. Phenols including chlorophenols will also interfere with this procedure. The method is recommended for use only by an experienced pesticide analyst (or under the close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is 1 μg/ℓ. Detection limits of 0.05 μg/ℓ or so may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: \$45 - \$150, depending upon preparation required.

DDD

Parameter Group: Pesticides STORET Units: µg/ℓ

General: DDD, a metabolite of DDT, is an organochlorine insecticide. It is the same as TDE and is also known as Rhothane. DDD has much the same properties and is used similarly to DDT. Its insecticidal activity approaches that of DDT, but its mammolian toxicity is only about 20% of that of DDT. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for DDD. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

DDE

Parameter Group: Pesticides STORET Units: μg/ℓ

General: DDE, a metabolite of DDT, is an organochlorine insecticide. It is the same as DDX. DDE has much the same properties and is used similarly to DDT. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for DDE. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

DDT

Parameter Group: Pesticides STORET Units: μg/ℓ

General: DDT (1, 1, 1-trichloro -2, 2-bis (p-chlorophenyl) ethane) is an organochlorine insecticide. Acute toxicity to mammals generally is low. DDT is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food and also is considered a potential human carcinogen. DDT will accumulate in the food chain. A residue accumulation of up to two million times for fish can occur. Application of DDT in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. Practically insoluble in water, dilute acids, and alkalies, it is readily soluble in many organic solvents. The vehicle is very important in determining the toxicity of DDT. It has been found in river waters at concentrations to 20 μg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion:

- 0.001 μg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of DDT cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for DDT. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.040 and 0.200 μg/ℓ concentrations, recoveries were around 101% and 77% and precisions were 40% and 19%, respectively.

Cost of Analysis: $30 - $150, depending upon preparation required.

DEMETON

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Demeton (also known as Systox) is the organophosphorus insecticide $C_8H_{19}O_3PS_2$. Commercial demeton is a mixture of isomers of varying toxicities. It is insoluble in water but soluble in alcohol. The estimated fatal dose to a 70-kg man is 0.1 gram. The acute oral LD_{50} for stock and wildlife is reported between 2,500 to 40,000 μg/kg of body weight. Toxicity to aquatic life varies widely with age and species. Demeton is unique in that the persistence of its ACHE enzyme inhibiting ability is greater than that of ten other common organophosphates, even though its acute toxicity is apparently less. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.1 μg/ℓ for freshwater and marine acquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for demeton. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors but is usually 0.010 μg/ℓ or higher. Sensitivity is typically 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: \$30 - \$150, depending upon preparation required.

DIAZINON

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Diazinon is the registered trade name of an organophosphorus insecticide. It is a liquid with a faint ester-like odor and is miscible with a number of hydrocarbon solvents. Diazinon has very high insecticidal and acaricidal properties. The estimated fatal dose for a 70-kg man is 25 grams. The oral LD_{50} to rats ranges from 100,000 to 435,000 μg/kg of body weight. Toxicity data for aquatic life are limited. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for diazinon. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 μg/ℓ or higher. Sensitivity is typically 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

DICHLOROBENZENES

Parameter Group: STORET Units:

General: Dichlorobenzenes ($C_6H_4Cl_2$) include 1, 2-dichlorobenzene, 1, 3-dichlorobenzene, and 1, 4-dichlorobenzene. Metadichlorobenzene is a colorless liquid, insoluble in water, and seldom used commercially. Othodichlorobenzene is also a liquid and insoluble in water and is used as a solvent for waxes, for preserving plants, and for destroying insects such as termites. Paradichlorobenzene is a white crystallic solid with a characteristic odor used chiefly for killing moths, their larvae, and other insects. It is slightly soluble in water, 70 mg/ℓ at 25°C. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 0.1 to 10 μg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $25 - $40

DICHLOROBENZIDINE

Parameter Group: STORET Units:

General: Dichlorobenzidine (3, 3'-dichlorobenzidine) is a polynuclear organic compound. Due to its suspected carcinogenic properties, it must be handled with great care. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 1 week

Container Type: Borosilicate glass

Sample Volume Required: 1,000-4,000 mℓ depending on concentration and instrument used.

Measurement: Dichlorobenzidine is separated and concentrated by multiple extractions and then oxidized by chloramine T. The oxidation product is extracted and measured spectrophotometrically. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is approximately 0.2 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $20 - $40; because of its carcinogenic properties, special facilities may be required at greatly increased cost.

DICHLOROETHYLENES

Parameter Group: STORET Units:

General: Dichloroethylenes are volatile halocompounds including 1, 1-dichloroethylene and 1, 2-dichloroethylene. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine and iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

2, 4-DICHLOROPHENOL

Parameter Group: STORET Units:

General: 2, 4-dichlorophenol ($C_6H_4Cl_2O$) is a colorless, crystalline substance only slightly soluble in water but fairly soluble in other media such as alcohol. It is used in the manufacture of the herbicide 2, 4-D as well as for other purposes. It is persistent and, since it is not efficiently removed by conventional water treatment processes, can cause odor problems in distribution systems. Fish flesh tainting concentrations range from 1 to 5 µg/ℓ, levels that do not appear to adversely affect the fish. The threshold odor level in water is as low as 1 µg/ℓ. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

DICHLOROPROPANE

Parameter Group: STORET Units:

General: 1, 2-dichloropropane (also called propylene chloride, $C_3H_6Cl_2$) is a heavy liquid that is slightly soluble in water. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. Confirmation should be made for dichloropropane. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

DICHLOROPROPENE

Parameter Group: STORET Units:

General: 1, 3-dichloropropene ($C_3H_4Cl_2$) is a heavy liquid, insoluble in water, and with a chloroform-like odor. It is used as a soil fumigant for the control of nematodes. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. Confirmation should be made for dichloropropene. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

DIELDRIN

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Dieldrin, the common name for an organochlorine insecticide, is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food and is also considered a potential human carcinogen. The USEPA has suspended the production and use of dieldrin. This should result in a gradual decrease in concentration in the environment. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria:

- .003 μg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogencity of dieldrin cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for dieldrin. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.02 and 0.125 μg/ℓ concentration, recoveries were around 108% and 85% and precisions were 91% and 24%, respectively.

Cost of Analysis: $30 - $150 depending upon preparation required.

2, 4-DIMETHYLPHENOL

Parameter Group: STORET Units:

General: 2, 4-dimethylphenol (2, 4-dimethyl-1-hydroxybenzene) is only slightly soluble in water but highly soluble in other media such as alcohol. It has a higher odor threshold concentration than many other phenolic compounds, up to 75 μg/ℓ. It is a persistent substance, capable of being transported long distances in water and is not removed efficiently by conventional water treatment processes. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

DISSOLVED OXYGEN

Parameter Group: Dissolved Oxygen STORET Units: mg/ℓ

General: Dissolved oxygen (DO) levels in water, an important gage of its overall quality, depend upon its physical, chemical, and biological activities. Although excessive DO may be detrimental to certain uses (e.g., it increases metallic corrosion), the main concern is with DO deficiencies. Insufficient DO in the water column may be detrimental to aquatic fauna, causes anaerobic decomposition of any organic materials present, and generally degrades the aesthetic quality of the water body. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- Aesthetics: Water should contain sufficient dissolved oxygen to maintain aerobic conditions in the water column and, except as affected by natural phenomena, at the sediment-water interface.

- Freshwater aquatic life: A minimum concentration of dissolved oxygen to maintain good fish populations is 5.0 mg/ℓ. The criterion for salmonid spawning beds is a minimum of 5.0 mg/ℓ in the interstitial water of the gravel.

Preservation Method: Electrode: determine on site; Winkler: fix on site.

Maximum Holding Time: No holding

Container Type: Glass only

Sample Volume Required: 300 mℓ

Measurement: The electrode method is recommended for a variety of reasons, including freedom from interferences and, when used in situ, from sampling effects that are otherwise difficult to account for. Modified Winkler methods may be used, but great care in sampling and accounting for interferences must be exercised. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: With most commercially available membrane electrode systems an accuracy of ±0.1 mg/ℓ and a precision of ±0.05 mg/ℓ should be obtainable. No meaningful precision and accuracy data are available for the modified Winkler method.

Cost of Analysis: $3 - $6

DISYSTON

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Disyston, an organophosphorus insecticide, is a clear, oily liquid that is slightly soluble in water and quite soluble in most organic solvents. Its acute oral LD_{50} to rats has been reported from 2,600 to 12,500 μg/kg of body weight. Toxicity data for aquatic life are sparse but indicate a wide variability with age and species. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for disyston. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 μg/ℓ or higher. Sensitivity is typically 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

DIURON

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Diuron is the urea pesticide $C_9H_{10}Cl_2N_2O$. It is a crystalline compound only slightly soluble in water and oils. Its acute oral LD_{50} to rats is 3,400 μg/ℓ of body weight. Its toxicity to fish varies widely with age and species, but lethal doses are measured in mg/ℓ concentrations. Apparently, aeration slightly reduces the toxicity of diuron to aquatic life. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000 mℓ

Measurement: The recommended method involves an extraction process with methylene chloride and the concentrated extract is cleaned up with a Florisil column. A thin-layer chromatography process is then used. The layer is sprayed with 1-naphthol and the products appear as colored spots. The measurement is achieved visually. Direct interferences may be encountered from aromatic amines that may be present in the sample. Indirect interferences may be encountered from naturally colored materials whose presence masks the chromogenic reaction. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The determination can be made with a sensitivity of 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $60

ENDOSULFAN

Parameter Group: Pesticides   STORET Units: µg/ℓ

General: The acute toxicity of endosulfan, an organochlorine insecticide, to different fish species varies widely. No data are available on the levels to which endosulfan could be expected to accumulate in tissues of aquatic organisms at various water concentrations. Residues in fish are not anticipated to pose a hazard to fish-eating predators because of endosulfan's low oral toxicity to birds and mammals. Application of endosulfan in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 0.003 µg/ℓ for freshwater aquatic life
- 0.001 µg/ℓ for marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for endosulfan. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

ENDRIN

Parameter Group: Pesticides   STORET Units: μg/ℓ

General: Application of endrin, an organochlorine insecticide, in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. It is possible that some fish would accumulate endrin to 30,000 times water concentration. Although it has strong residual toxicity as does its closely related compound dieldrin, endrin has been found to be eliminated quickly after termination of exposure and to disappear relatively quickly. Thus, it does not appear to cause an accumulation problem. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria:

- 0.2 μg/ℓ for domestic water supply (health)
- 0.004 μg/ℓ for freshwater and marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for endrin. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

ETHYLBENZENE

Parameter Group: STORET Units:

General: Ethylbenzene (C_8H_{10}) is a volatile, flammable liquid with an ethereal odor. It is insoluble in water at normal temperatures. It is used commercially as a solvent and in the synthesis of other organic compounds. Its toxicity to fish varies with water temperature, age, and species. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by gas chromatographic and mass spectrometric analysis is often used. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits should be around 2-10 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: \$15 - \$30

FECAL COLIFORM

Parameter Group: Bacteriologic   STORET Units: MPN

General: Pollution of aquatic systems by the excreta of warm-blooded animals creates public health problems for man and animals and potential disease problems for aquatic life. It is known that enteric microbial pathogens may inhabit the gut of most warmblooded animals and are shed in feces. The presence of bacterial, viral, protozoan, and possibly fungal species is indicated by the presence of the fecal coliform group of bacteria. The number of fecal coliforms present is indicative of the degree of health risk associated with using the water for drinking, swimming, or shellfish harvesting. The fecal coliform bacteria, which comprise a portion of the total coliform group, are able to grow at 44.5°C and ferment lactose, producing acid and gas. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

Bathing Waters

Based on a minimum of not less than five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log mean of 200 per 100 mℓ, nor should more than 10 percent of the total samples taken during any 30 day period exceed 400 per 100 mℓ.

Shellfish Harvesting Waters

Not to exceed a median fecal coliform bacterial concentration of 14 MPN per 100 mℓ with not more than 10 percent of samples exceeding 43 MPN per 100 mℓ for the taking of shellfish.

Preservation Method: Cool to 4°C. Add a dechlorinating agent (e.g., sodium thiosulfate) if residual chlorine is present. Samples high in heavy metals should have a chelating agent (e.g., EDTA) added to reduce metal toxicity.

Maximum Holding Time: 6 hours (30 hours absolute maximum for potable water samples).

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The multiple tube fermentation technique may be used if a determination of the total coliform group is also being made. Otherwise, the simpler membrane filter technique is recommended. Results of the former are expressed statistically as the Most Probable Number (MPN), while the latter are expressed as number of colonies per 100 mℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The accuracy of the membrane filter technique for differentiating between coliforms from warm-blooded animals and coliforms from other sources is approximately 93%.

Cost of Analysis: $10 - $12 MFT
$15 - $20 MPN

FECAL STREPTOCOCCI

Parameter Group: Bacteriologic   STORET Units: Unspecified

General: The normal habitat of the fecal streptococcus group of bacteria is the intestines of man and other warm-blooded animals and, thus, these organisms are indicators of fecal pollution. Because of their survival characteristics, it is not recommended that fecal streptococci be used as the sole fecal indicator. Since certain fecal streptococci are host-specific, they may provide valuable additional information about the source of pollution; e.g., a predominance of S. bovis and S. equinus would indicate excrement from nonhuman, warm-blooded animals as, for example, from feedlot and farmland runoff, dairy wastes, and meat processing plants. S. faecalis var liquefaciens is not restricted to the intestines of warm-blooded animals, being also associated with vegetation, insects, and certain types of soils. Biochemical characterization is required to eliminate the possibility of a preponderance of this latter type, thus avoiding misinterpretation of results. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C. Add a dechlorinating agent (e.g., sodium thiosulfate) if residual chlorine is present. Samples high in heavy metals should have a chelating agent (e.g., EDTA) added to reduce metal toxicity.

Maximum Holding Time: 6 hours (30 hours absolute maximum for potable water samples).

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The multiple tube fermentation technique and the simpler membrane filter technique are both recommended, especially for nondrinking water tests. Results of the former are expressed statistically as the Most Probable Number (MPN), while the latter are expressed as number of colonies per 100 mℓ. The fecal streptococcal plate count method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Not applicable

Cost of Analysis: $10 - $12 MFT
$15 - $20 MPN

FLUORIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as F

General: The most reactive nonmetal, flourine is never found free in nature, but it is a constitute of a number of minerals. Fluorides in high concentrations are not common in natural surface waters. They are used as insecticides, as disinfectants, as a flux in steelmaking, for preserving wood and mucilages, for the manufacture of glass and enamels, in chemical industries, toothpaste manufacture, for water treatment, and a host of minor applications. They are not normally found in industrial wastes (other than traces) except as a result of spillage. In sufficient quantities (over 200 mg), fluorides can be toxic to humans. Up to 5 mg/ℓ the only bad effect seems to be tooth discoloration. Under 100 mg/ℓ produces little adverse effects on plants. Toxic effects on aquatic life are observed starting at concentrations above 2 mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 300 mℓ

Measurement: The SPADNS method with Bellack distillation is recommended. A spectrophotometer for use at 570 nm or a filter photometer equipped with a greenish yellow filter having maximum transmittance at 550-580 nm is required; either must have a light path of at least 1 cm. The method covers the range from 0.1 to about 2.5 mg/ℓ F. Following distillation to remove interferences, the sample is treated with the SPADNS reagent. The loss of color resulting from the reaction of fluoride with the zirconyl-SPADNS dye is a function of the fluoride concentration. The SPADNS reagent is more tolerant of interfering materials than other accepted fluoride reagents. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: On a sample containing 0.83 mg/ℓ F with no interferences, the results of 53 analysts using the SPADNS method had a relative standard deviation of 8% and a relative error of 1.2%. After direct distillation, the relative standard deviation was 11.0% and the relative error 2.4%. On a sample containing 0.57 mg/ℓ F (with 200 mg/ℓ SO_4 and 10 mg/ℓ Al as interferences) results from the 53 analysts had relative standard deviations and errors of 16.2% and 7.0% without distillation and 17.2 and 5.3 with distillation.

Cost of Analysis: $3 - $5 without distillation
$15 - $20 with distillation

GUTHION

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Guthion is the organophosphorus insecticide $C_{10}H_{12}N_3O_3PS_2$. It is a brown waxy solid that is insoluble in water but soluble in most organic solvents. The half-life of guthion spray and dust on cotton leaves has been reported as 2-4 days and 1-2 days for pondwater. An investigation of the persistence of guthion in fish revealed that 50% of the chemical was lost in less than one week. The estimated fatal dose for a 70-kg man is 0.2 grams. The acute oral LD_{50} to rats ranges from 11,000 to 80,000 μg/kg of body weight. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.01 μg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for guthion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 μg/ℓ or higher. Sensitivity is typically 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

HALOETHERS

Parameter Group: STORET Units:

General: Haloethers as used here comprise 4-chlorophenyl phenyl ether; 4-bromophenyl phenyl ether, bis (2-chloroisopropyl) ether; and bis (2-chloroethoxy) methane. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 1 to 10 μg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

HALOMETHANES

Parameter Group: STORET Units:

General: The halomethanes include dichloromethane (methylene chloride), chloromethane (methyl chloride), bromomethane (methyl bromide), tribromomethane (bromoform), dichlorobromomethane, trichlorofluoromethane (Freon 11), dichlorodifluoromethane (Freon 12), and chlorodibromomethane. These volatile halocompounds are mostly gaseous at surface water temperatures and atmospheric pressure. They range from soluble to insoluble in water; e.g., methyl chloride is soluble to about 4,000 mg/ℓ at 20°C. Chief uses are as refrigerants, aerosol propellents, and certain industrial operations. Taste of water containing halomethanes in appreciable concentrations is sharp, sickening, and sweetish when first taken into the mouth, followed by a burning sensation. It is unlikely that humans would voluntarily drink such water. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

HARDNESS, TOTAL

Parameter Group: General Inorganic

STORET Units: mg/ℓ as $CaCO_3$

General: Water hardness is caused by the polyvalent metallic ions dissolved in water. Principally, these are calcium and magnesium. Other metals such as iron, strontium, and manganese contribute to the extent that appreciable concentrations are present. Natural sources of hardness are soil and geological formations (e.g., limestone) with which the water may have come in contact. Industrial sources include the inorganic chemical industry and discharges from operating and abandoned mines. Irrigation return flows also increase hardness. The detrimental effects of hardness include excessive soap consumption, the formation of scums and curds in laundries and textile mills, the toughening of vegetables cooked in hard water, and the formation of scabs in boilers, hot water heaters, pipes, and utensils. Hence, they are principally economic in nature. The hardness of "good" water should not exceed 250 mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The EDTA method, recommended when a complete mineral analysis is not performed, is applicable to drinking, surface, and saline waters, domestic and industrial wastes. Calcium and magnesium ions in the sample are sequestered upon the addition of disodium ethylenediamine tetraacetate (Na_2EDTA). The end point of the reaction is detected by means of Calmagite Indicator, which has a red color in the presence of calcium and magnesium and a blue color when the cations are sequestered. Excessive amounts of heavy metals can interfere. This is usually overcome by complexing the metals with cyanide. Routine addition of sodium cyanide solution to prevent potential metallic interference is recommended. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A synthetic unknown containing 610 mg/ℓ total hardness as $CaCO_3$ was analyzed in 56 laboratories with a relative standard deviation of 2.9% and a relative error of 0.8%.

Cost of Analysis: $5 - $15

HEPTACHLOR

Parameter Group: Pesticides STORET Units: µg/ℓ

General: The acute toxicity of heptachlor, a refined ingredient of the well-known organochlorine insecticide chlordane, is generally low to mammals; however, aquatic organisms exhibit sensitivity to this pesticide at microgram-per-liter levels. Heptachlor will accumulate in the food chain. Heptachlor is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food and also is considered a potential human carcinogen. In July 1975, the USEPA suspended the production and use of heptachlor. This should result in a gradual decrease in concentrations in the environment. Any addition of heptachlor to water should be considered potentially hazardous to humans. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion:

- 001 µg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of heptachlor cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for heptachlor. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

IODIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as I

General: Only trace concentrations of iodides are found in natural fresh water; seawater is somewhat higher. Higher concentrations may also be found in natural brines, waters treated with iodine as the disinfectant, and a limited number of industrial wastes. It is used sparingly in industry, e.g., for medicines, germicides, analytical chemistry, and as a table salt additive. All waterborne pathogens are destroyed by 8 mg/ℓ of iodine; no adverse effects were reported when water containing over twice this concentration was consumed in the tropics. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The titrimetric method is recommended. After pretreatment to remove interferences, the sample is analyzed for iodide by converting the iodide to iodate with bromine water and titrating with phenylarsine oxide (PAU) or sodium thiosulfate. Iron, manganese and organic matter can interfere; however, the calcium oxide pretreatment removes or reduces these to insignificant concentrations. Color interferes with the observation of indicator and bromine-water color changes. This interference can be eliminated by the use of a pH meter instead of a pH indicator and the use of standardized amounts of bromine water and sodium formate solution instead of observing the light yellow color changes. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a single laboratory, using a mixed domestic and industrial waste effluent, at concentrations of 1.6, 4.1, 6.6, 11.6, and 21.6 mg/ℓ of iodide, the relative standard deviations were 14.4%, 4.1%, 1.4%, .5%, and 2.3%, respectively. At concentrations of 4.1, 6.6, 11.6 and 21.6 mg/ℓ of iodide, recoveries were 80%, 97%, 97%, and 92%, respectively.

Cost of Analysis: $15 - $20

IRON

Parameter Group: Metals   STORET Units: μg/ℓ as Fe

General: Iron is an essential trace element required by both plants and animals. The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) irons, are the primary forms of concern in the aquatic environment. The ferrous (Fe^{++}) form can persist in waters void of dissolved oxygen and originates from groundwaters or mines when these are pumped or drained. The ferric (Fe^{++}) form is insoluble. Potential sources of dissolved iron species include discharges from mining operations, ore milling, chemical industries (organic, inorganic, petrochemical), dye industries, metal processing industries, textile mills, food canneries, tanneries, titanium dioxide production, petroleum refining, and fertilizers. Limitations in drinking water arise primarily from taste consideration. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 0.3 mg/ℓ for domestic water supplies (welfare)
- 1.0 mg/ℓ for freshwater aguatic life

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2. For precise determinations of total iron, use a separate container for sample collection and treat with acid immediately to place the iron in solution and prevent adsorption or desposition on the container walls.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 248.3 nm. The orthophenanthroline method may be used for natural and treated waters. It requires either a spectrophotometer for use at 510 nm or a filter photometer equipped with a green filter having maximum transmittance near 510 nm; either must have a light path of at least 1 cm. In the presence of excessive amounts of organic constituents, the sample should first be digested to ensure complete dissolution of the iron. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 120 μg/ℓ; its detection limit is 20 μg/ℓ. The optimum concentration range is 300-10,000 μg/ℓ. At a concentration of 300 μg/ℓ, the relative standard deviation is 16.5%, and the relative error is 0.6%. For the colorimetric method at 300 μg/ℓ Fe, the values were 25.5% and 13.3%, respectively, from a 44-laboratory test. Serious divergences have been found in reports of different laboratories because of variations in methods of collecting and treating samples.

Cost of Analysis: $3 - $15

LEAD

Parameter Group: Metals STORET Units: μg/ℓ as Pb

General: Natural lead concentrations in surface waters may range up to 40 μg/ℓ. Lead and its compounds may also enter water at any stage during mining, smelting, and processing. Lead is used in the manufacture of storage batteries, television tubes, printing, pigments, fuels, photographic materials, pesticides, and explosives. The dissolution of lead plumbing is another source. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 μg/ℓ for domestic water supply (health)
- 0.01 times the 96-hour LC_{50} value, using the receiving or comparable water as the diluent and soluble lead measurements (nonfilterable lead using a 0.45 micron filter), for sensitive freshwater resident species.

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time. 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 283.3 nm. The analysis of this metal is exceptionally sensitive to turbulence and absorption bands in the flame. Therefore, care should be taken to position the light beam in the most stable, center portion of the flame. The dithizone colorimetric method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 500 μg/ℓ; its detection limit is 50 μg/ℓ. The optimum concentration range is 1,000-20,000 μg/ℓ. At a concentration of 50 μg/ℓ, the relative standard deviation is 23.5%, and the relative error is 19.0%. At 25 μg/ℓ, the relative error was 25.7% in a 60-laboratory test.

Cost of Analysis: $10 - $15

LINDANE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Lindane, the common name of the gamma isomer of benzene hexachloride (BHC), is an organochlorine insecticide. Application of lindane in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. The highest level of lindane found to have minimal or no long-term effects in the most sensitive mammal tested, the dog, is 15.0 mg/kg in the diet or 0.3 mg/kg of body weight/day. An increased resistance to lindane toxicity among fish and invertebrates experiencing previous exposure to the chemical has been observed. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 4.0 µg/ℓ for domestic water supply (health)
- 0.01 µg/ℓ for freshwater aquatic life
- 0.004 µg/ℓ for marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for lindane. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.010 and 0.100 μg/ℓ concentrations, recoveries were around 97% and 73% and precisions were 53% and 26%, respectively.

Cost of Analysis: $30 - $150, depending upon preparation required.

LITHIUM

Parameter Group: Metals STORET Units: μg/ℓ as Li

General: Lithium is present in fresh waters in concentrations below 10,000 μg/ℓ; brines and thermal waters may be higher. Lithium and its salts are used in dehumidifying units, as a deoxidizer and degasser for nonferrous castings, to form a protective atmosphere in furnaces, in medicinal waters, in metallurgical processes, in the manufacture of some types of glass and storage batteries, and as the hydride for many controlled organic reductions. In addition to these sources, lithium hypochlorite is used as a source of chlorine in some swimming pools. Lithium may have a toxic effect on plants and some forms of aquatic life, but little data exist documenting toxicity to man.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Pyrex bottle

Sample Volume Required: 100-200 mℓ

Measurement: The flame photometric method is often used, using a wavelength of 671 nm. Interferences in the photometric determination include barium, strontium, and calcium. These can be removed by the addition of a sodium sulfate-sodium carbonate solution. Digestion will be necessary if considerable organic matter is present.

Precision and Accuracy: The minimum detectable lithium concentration is approximately 100 μg/ℓ. In a lithium range of 700 to 1,200 μg/ℓ, an accuracy of ±0.1 to 200 μg/ℓ can be obtained in the determination of the lithium concentration.

Cost of Analysis: $12 - $18

MAGNESIUM

Parameter Group: Metals STORET Units: mg/ℓ as Mg

General: Magnesium salts are important contributors of hardness to water. Sources of magnesium include mining and ore processing, oxide production, metallurgy, refractories, iron and steel production, and its use in flash and incendiary products, signal flares, as a deoxidizer in the casting of metals, as a reagent in organic chemistry, and a host of other applications. Magnesium is an essential element to humans, the daily requirement being about 700 mg. Taste considerations, rather than toxicity, are paramount for magnesium in drinking water. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 285.2 nm. The interference caused by aluminum at concentrations greater than 2 mg/ℓ is masked by the addition of lanthanum. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.007 mg/ℓ; its detection limit is 0.0005 mg/ℓ. The optimum concentration range is 0.02-2 mg/ℓ. At a concentration of .2 mg/ℓ, the relative standard deviation is 10.5%, and the relative error is 6.3%. In a single laboratory, using a distilled water sample at concentrations of 2.1 and 8.2 mg/ℓ, the relative standard deviations were 4.7% and 2.4%, respectively. Recoveries at both of these levels were 100%.

Cost of Analysis: $10

MALATHION

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Malathion, the organophosphorus pesticide $C_{10}H_{19}O_6PS_2$, enters the aquatic environment primarily as a result of its application as an insecticide. Because it degrades quite rapidly in most waters, depending on pH, its occurrence is sporadic rather than continuous. It is soluble in water to 145,000 µg/ℓ. The freshwater fish most sensitive to malathion appear to be the salmonids and centrarchids. Many aquatic invertebrates appear to be more sensitive than fish to malathion. It appears to be about 100 times less toxic to warm-blooded animals than parathion, but only 2 to 4 times less toxic to insects. The estimated fatal dose for a 70-kg man is 60 grams. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.1 µg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for malathion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

MANGANESE

Parameter Group: Metals   STORET Units: μg/ℓ as Mn

General: Manganese and its salts are used in manufacturing steel alloys, dry cell batteries, glass and ceramics, paint and varnish, ink and dye, and matches and fireworks. Manganese is normally ingested as a trace nutrient in food. Very large doses of ingested manganese can cause some diseases and liver damage. Inadequate quantities of manganese in domestic animal food results in reduced reproductive capabilities and deformed or poorly maturing young. Manganese imparts objectionable and stubborn stains to laundry and plumbing fixtures. Low limits on domestic water supplies stem from these, rather than toxicological, considerations. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 50 μg/ℓ for domestic water supplies (welfare)
- 100 μg/ℓ for protection of consumers of marine mollusks

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 279.5 nm. For levels of manganese below 25 μg/ℓ, the extraction procedure is recommended. Analytical sensitivity is dependent on lamp current. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 50 μg/ℓ; its detection limit is 10 μg/ℓ. The optimum concentration range is 100-10,000 μg/ℓ. At a concentration of 50 μg/ℓ, the relative standard deviation is 13.5%, and the relative error is 6.0%. These increase at decreasing concentrations. In a 55-laboratory test, at concentrations of 17 and 11 μg/ℓ the relative standard deviations were 118% and 245%, respectively, and the relative errors were 22% and 93%, respectively.

Cost of Analysis: $10

MERCURY

Parameter Group: Metals STORET Units: μg/ℓ as Hg

General: Mercury is widely distributed in the environment, and biologically is a nonessential or nonbeneficial element. Discharged mercury does not remain localized. Mercury can enter the environment by seeping up through layers of earth to the surface, outgassing of mercury from rock and soil, and transport by natural cycles. Most industrial mercury is eventually lost as waste into streams or the atmosphere. Uses of mercury include the electrical industry, chlor-alkali industry, industrial control equipment, paints, agriculture, dental preparations, pulp and paper industry, catalysts in chemical manufacturing processes, and general laboratory uses. The toxicity of mercury is attributed to its high affinity for sulfur-containing compounds. Toxic effects vary with the form of mercury and its mode of entry into the organism. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 2.0 μg/ℓ for domestic water supply (health)
- 0.05 μg/ℓ for freshwater aquatic life and wildlife
- 0.10 μg/ℓ for marine aquatic life

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 38 days (glass), 13 days (hard plastic)

Container Type: Glass or hard plastic

Sample Volume Required: 100 mℓ

Measurement: The flameless AA spectrophotometric method is recommended. It is a physical method based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance is measured as a function of mercury concentrations. Possible interference from sulfide is eliminated by the addition of potassium permanganate. Copper has also been reported to interfere. Interference from certain volatile organic materials which will absorb at this wavelength is also possible. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: At a concentration of 0.4 μg/ℓ, the relative standard deviation is 21.2%, and the relative error is 2.4%. In a single laboratory, using an Ohio River composite sample with a background mercury concentration of 0.35 μg/ℓ, spiked with concentrations of 1, 3, and 4 μg/ℓ, the standard deviations were ±0.14, ±0.10, and ±0.08, respectively. Standard deviation at the 0.35 level was ±0.16. Percent recoveries at the three levels were 89%, 87%, and 87%, respectively.

Cost of Analysis: $15 - $25

METHANE

Parameter Group: STORET Units:

General: Methane is a gaseous saturated (paraffin) hydrocarbon. It is colorless, odorless, tasteless, and flammable. Methane sources include the anaerobic decomposition of organic matter (e.g., some marshes, mines, treatment plants, etc.) and natural gas and petroleum plants. Concern about methane arises from its explosion hazard rather than its negligible toxicity. For example, an explosive limit of methane in air could be reached in a poorly ventilated space sprayed with hot (68°C) water having a methane concentration of only 0.7 mg/ℓ.

Criterion: Not established

Preservation Method: Analyze as soon as possible. When collecting the sample, ensure that the sample is under sufficient pressure to ensure that no gas escapes from the water.

Maximum Holding Time: Unknown, but short

Container Type: Glass

Sample Volume Required: 3,000 mℓ

Measurement: The combustible-gas indicator method is often used. The procedure is based on the catalytic oxidation of a combustible gas or a heated platinum filament that is made a part of a wheatstone bridge. Small amounts of ethane, hydrogen gas, and hydrogen sulfide may interfere. For greater accuracy, a gas chromatograph should be used.

Precision and Accuracy: The sensitivity of the method is approximately 0.2 mg/ℓ. The accuracy of the determination is limited by the accuracy of the instrument employed; errors of around 10% may be expected.

Cost of Analysis: $15 - $20

METHOXYCHLOR

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Application of methoxychlor, an organochlorine insecticide, in agriculture and forest areas contributes to the presence of this material in surface and ground waters. It is slightly soluble in water but very soluble in alcohol. Sodium and dimethylamine salts are freely soluble in water. The concentration of methoxychlor has been found to be degraded in a few weeks or less in natural waters. The highest level of methoxychlor found to have minimal or no long-term effects in man is 2.0 mg/kg of body weight/day. Few data are available on acute and chronic effects of methoxychlor on freshwater fish. Methoxychlor appears to be considerably less bioaccumulative in aquatic organisms than some of the other organochlorine pesticides. Methoxychlor has a very low accumulation rate in birds and mammals. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 100 μg/ℓ for domestic water supply (health)
- 0.03 μg/ℓ for freshwater and marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for methoxychlor. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

METHYL PARATHION

Parameter Group: Pesticides   STORET Units: µg/ℓ

General: Methyl parathion is an organophosphorus insecticide similar in action to parathion, Phosdrin, and TEPP. Its toxicity is also similar. The half-life of methyl parathion on cotton leaves is less than one hour. The estimated fatal dose for a 70-kg man is 0.15 gram. The acute oral LD_{50} for rats ranges from 9,000 to 25,000 µg/kg of body weight. Toxicity data for aquatic life are sparse but appear to range widely with age and species. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for methyl parathion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

METHYLENE BLUE ACTIVE SUBSTANCES (MBAS)

Parameter Group: General Organic

STORET Units: mg/ℓ

General: Certain solutes, even at low concentrations, have the property of lowering the surface tension or other interfacial properties of their solvents. Such solutes are known as surfactants or surface-active agents. They are found in soaps, detergents, emulsifiers, wetting agents, and penetrants, with the most common use, by far, being in synthetic detergents where they may account for 20% - 40% of the product in active form alone. The specific surfactant most widely used until recently is the group of alkyl benzene sulfonates (ABS), which persist in sewage and streams in biologically active solution without appreciable decomposition from either treatment processes or natural purification, being largely immune to biological degradation. Today, the more biodegradable linear alkyl sulfonate (LAS) has essentially replaced ABS on the surfactant market so that measurable surface-active agents will probably be LAS type materials. In addition to foaming problems, anionic surfactants may enhance slime growth, inhibit the growth of nitrifying bacteria, delay gas exchange with the atmosphere, and interfere with the uptake of oxygen. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 250 mℓ

Measurement: Anionic-type surfactants react with methylene blue dye in aqueous solution to form a blue colored salt which is extractable with chloroform, its color intensity being proportional to the concentration of MBAS. The more complicated, time consuming, and expensive tests for specific substances (e.g., LAS) are not usually warranted. The method is recommended for determination in drinking waters, surface waters, domestic and industrial wastes. It is not applicable to measurement of surfactant-type materials in saline waters. Chlorides at concentration of about 1,000 mg/ℓ show a positive interference, but the degree of interference has not been quantified. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A sample of filtered river water, spiked with 2.94 mg LAS/ℓ was analyzed in 110 laboratories with a relative standard deviation of 9.1% and a relative error of 1.4%. In similar analyses with a sample of tap water spiked with 0.48 mg LAS/ℓ, relative standard deviations and errors of 9.9% and 1.3% were obtained, and for a sample of distilled water spiked with 0.27 mg LAS/ℓ, the respective values were 14.8% and 10.6%.

Cost of Analysis: $10 - $15

MIREX

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Mirex, an organochlorine insecticide, is largely used to control the imported fire ant in the southeastern United States. Crayfish and channel catfish survival is affected by mirex in the water or by ingestion of the bait particles. Bioaccumulation is well established for a wide variety of organisms but the effect of this bioaccumulation on the aquatic ecosystem is unknown. There is evidence that mirex is very persistent in bird tissue. Considering the extreme toxicity and potential for bioaccumulation, every effort should be made to keep mirex bait particles out of water containing aquatic organisms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.001 μg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50 to 100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for mirex. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

MOLYBDENUM

Parameter Group: Metals STORET Unit: µg/ℓ as Mo

General: Molybdenum occurs naturally as molybdenum sulfide and lead molybdate. Its chief use is in the production of alloy steels (especially corrosion-resistant stainless steels) where advantage is made of its marked passivity. Other possible sources include mining and ore processing operations, chemical production, some fertilizers, and metallurgical operations. Molybdenum has a relatively low order of toxicity. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 313.3 nm. With the nitrous oxide-acetylene flame, interferences of calcium and other ions may be controlled by adding 1,000,000 µg/ℓ of a refractory metal such as aluminum. This should be done to both the samples and standards. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 300 µg/ℓ; its detection limit is 100 µg/ℓ. The optimum concentration range is 500-20,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 300, 1,500, and 7,500 µg Mo/ℓ, the relative standard deviations were 2.3%, 1.3%, and .93%, respectively. Recoveries at these levels were 100%, 96%, and 95%, respectively.

Cost of Analysis: $10 - $15

NAPHTHALENE

Parameter Group: STORET Units:

General: Naphthalene ($C_{10}H_8$) is the most abundant single constituent of coal tar. It is a white solid with the odor of moth balls. It is soluble in water at 20°C to the extent of about 30 mg/ℓ. The use of naphthalene in organic syntheses and dye manufacture is extensive, and hence it may occur in wastes from refineries, coal-tar plants, textile mills, and chemical industries. Lethal concentrations to fish are around 5-20 mg/ℓ. Fish tainting can occur at 1 mg/ℓ. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly. Cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ

Measurement: The general procedure involves extraction and measurement with a gas chromatograph. Various cleanup techniques to remove interferences may be required depending upon other constituents in the sample. A skilled chemist or specialist will be required. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits in the 1-10 μg/ℓ range should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

NICKEL

Parameter Group: Metals STORET Units: μg/ℓ as Ni

General: Nickel principally occurs in nature as sulfide. Its main industrial use is in electroplating, alloying, coin making, and in alkaline storage batteries. Other potential sources include silver refineries, basic steel works and foundaries, motor vehicle and aircraft industries, and printing operations. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permit program. It is one of the Consent Decree pollutants.

Criterion: 0.01 of the 96-hour LC_{50} for freshwater and marine aquatic life.

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 232.0 nm. The 352.4 nm wavelength is less susceptible to nonatomic absorbance and may also be used. The calibration curve is more linear at this wavelength; however, there is some loss of sensitivity. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 150 μg/ℓ; its detection limit is 20 μg/ℓ. The optimum concentration range is 300-10,000 μg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 200, 1,000, and 5,000 μg Ni/ℓ, the standard deviations were ±0.011, ±0.02, and ±0.04, respectively. Recoveries at these levels were 100%, 97%, and 93%, respectively.

Cost of Analysis: $10 - $15

NITRILOTRIACETIC ACID (NTA)

Parameter Group: General Organic

STORET Units: mg/ℓ

General: Nitrilotriacetic acid (NTA) is insoluble in water, but its tribasic salt is quite soluble. NTA has a strong affinity for iron, calcium, magnesium, and zinc, but its relative affinity for toxic metals such as cadmium and mercury is not known, nor have its chelating properties in complex ionic solutions been characterized. It has a potential large-scale use as a substitute for phosphates in detergents. No cases of acute human poisoning by NTA have been reported. It is biodegraded in the natural environment within 4 to 5 days; degradation is accelerated by biological waste treatment.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The zinc-zircon method is often used. In this method, NTA refers to the tri-sodium salt of nitrilotriacetic acid. It is applicable to surface waters in the range of 0.5-10.0 mg/ℓ NTA. Cations, such as calcium, magnesium, zinc, copper, iron, and manganese, complex with NTA and give a negative interference. These ions are removed by batch treating samples with ion-exchange resin. At concentrations higher than expected in typical river waters, only zinc, copper, and iron were not completely removed with ion-exchange treatment.

Precision and Accuracy: In a single laboratory, using spiked surface water samples at concentrations of 0.5, 2, 6, and 10 mg/ℓ NTA, relative standard deviations were 3.4%, 7%, 1.7%, and 1.6%, respectively. In a single laboratory, using spiked surface water samples at concentrations of 1.0 and 7.5 mg/ℓ NTA, recoveries were 120% and 103%, respectively.

Cost of Analysis: $10 - $12

NITROBENZENE

Parameter Group: STORET Units:

General: Nitrobenzene ($C_6H_5NO_2$) is moderately soluble in water. It is used in the manufacture of analine, soaps, and shoe polishes. Nitrobenzene is an oily liquid and has an almond odor. A concentration of 0.03 mg/ℓ in water will produce a faint odor. The oral LD_{50} for rabbits is 700 mg/kg of body weight. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 1 to 10 μg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

NITROGEN-AMMONIA

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Ammonia, one of the chemically interconvertible components of the nitrogen cycle, is naturally present in surface and ground water in concentrations from less than 0.01 to around 0.2 mg/ℓ as N in the absence of pollution. It is produced largely by the deamination of nitrogenous organic matter and the hydrolysis of urea. It may also result from the reduction of nitrate under anaerobic conditions. Other sources include the discharge of industrial wastes from chemical and gas plants, from ice plants, and where it is used in scouring and cleaning operations. There appears little physiological risk in palatable concentrations, the odor threshold being 0.037 mg/ℓ. Because it changes rapidly to nitrites and nitrates, ammonia is actually a fertilizer for most crops; ammonium salts constitute a major source of nitrogen fertilization. The toxicity of ammonia to fish is highly pH dependent. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ of concentrated H_2SO_4 or 40 mg $HgCl_2$/ℓ and store at 4°C. The use of mercuric chloride is discouraged whenever possible, however.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 400 mℓ

Measurement: The distillation procedure is recommended for the determination of ammonia-nitrogen. The method covers the range from about 0.05 to 1.0 mg/ℓ NH_3-N/ℓ for the colorimetric procedures, from 1.0 to 25 mg/ℓ for the titrimetric procedure, and from 0.05 to 1,400 mg/ℓ for the electrode method. A number of aromatic and aliphatic amines will cause turbidity upon the addition of Nessler reagent. Cyanate will hydrolyze to some extent. Volatile alkaline compounds may cause an off-color upon Nesslerization. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy are highly dependent upon concentration, other constituents present, and the finish method. Relative standard deviations may range from around 4% to 40% and relative errors from under 1% to over 15%.

Cost of Analysis: $10 - $12

NITROGEN, KJELDAHL

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Kjeldahl nitrogen is defined as the sum of free-ammonia and organic nitrogen compounds which are converted to ammonium sulfate $(NH_4)_2SO_4$ under conditions of digestion. Organic nitrogen includes natural materials such as proteins and peptides, nucleic acids and urea, and numerous synthetic organic substances. The organic nitrogen concentrations of water and wastewater may vary from less than 0.01 mg/ℓ for the former to over 10 mg/ℓ for the latter. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ of concentrated H_2SO_4 to pH <2 or 40 mg $HgCl_2$/ℓ and store at 4°C. The use of mercuric chloride is discouraged whenever possible, however.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 500 mℓ

Measurement: In the Kjeldahl nitrogen determination the sample is heated in the presence of concentrated sulfuric acid, K_2SO_4, and $HgSO_4$ and evaporated until SO_3 fumes are obtained and the solution becomes colorless or pale yellow. The residue is cooled, diluted, and is treated and made alkaline with a hydroxide-thiosulfate solution. The ammonia is distilled and determined by either the titrimetric method, the Nesslerization method, or the potentiometric method. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Thirty-one analysts in twenty laboratories analyzed natural water samples containing exact increments of organic nitrogen. At the 0.2-0.3 mg/ℓ as N concentration level the relative standard deviation and error were around 90% and 10%, respectively. At around 4 mg/ℓ as N they were about 25% and 1%, respectively.

Cost of Analysis: $15 - $20

NITROGEN, NITRATE

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Nitrate, one of the chemically interconvertible compounds of the nitrogen cycle, occurs in trace quantities in surface water and in small amounts in fresh domestic wastewater. It is seldom abundant, since it serves as an essential nutrient for all types of plants. Some ground water may contain high levels of nitrate (as a result of leachings from cesspools or excess applications of fertilizers, etc.) due to the lack of photosynthetic action. There has been no reporting of physiological harm at concentrations of less than 10 mg/ℓ as N. Nitrates are injurious for certain industrial uses (e.g., fabric dyeing, fermentative processes). High nitrate concentrations stimulate the growth of plankton and aquatic weeds and accelerate eutrophication. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ concentrated H_2SO_4/ℓ to ph <2 or 40 mg $HgCl_2$/ℓ and store at 4°C. The use of mercuric chloride is discouraged whenever possible, however.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The brucine method is recommended in the range from 0.1 to 2 mg NO_3-N/ℓ for determination in drinking, surface, and saline waters, domestic and industrial wastes. Dissolved organic matter will cause an off color. The effect of salinity is eliminated by the addition of sodium chloride to the blanks, standards, and samples. All strong oxidizing or reducing agents interfere. Residual chlorine interference is eliminated by the addition of sodium arsenite. Ferrous and ferric iron and quadrivalent manganese give slight positive interferences. Uneven heating of the samples and standards during the reaction time will result in erratic values. The cadmium reduction method may also be used; see discussion under Nitrogen, Nitrate-Nitrite. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Five synthetic samples containing nitrate and other constituents were analyzed in 50 laboratories at concentrations of 0.05, 0.5, and 5 mg/ℓ as N; relative standard deviations were 66.7%, 14.4%, and 15.4% and relative errors were 7.6%, 0.6%, and 4.5%, respectively.

Cost of Analysis: \$10 - \$12

NITROGEN, NITRATE-NITRITE

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: See discussions under nitrate and nitrite. The combined test is less expensive than making individual determinations and provides a determination of total oxidized nitrogen. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Store at 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The cadmium reduction method is recommended for the determination of nitrite and nitrate combined in drinking, surface, and saline waters, domestic and industrial wastes. Buildup of suspended matter in the reduction column will restrict sample flow. Low results might be obtained for samples that contain high concentrations of iron, copper, or other metals. EDTA is added to the samples to eliminate this interference. Samples that contain large concentrations of oil and grease will coat the surface of the cadmium. This interference is eliminated by pre-extracting the sample with an organic solvent. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The applicable range of this method is 0.01 to 1.0 mg/ℓ nitrate-nitrite nitrogen. In a single laboratory, using sewage samples at concentrations of 0.04, 0.24, 0.55, and 1.04 mg NO_3 + NO_2-N/ℓ, the relative standard deviations were 12.5%, 1.6%, .9%, and .9%, respectively, while recoveries were 100%, 102%, and 100%, respectively.

Cost of Analysis: $10 - $15

NITROGEN, NITRITE

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Nitrite, one of the chemically interconvertible compounds of the nitrogen cycle, occurs in the oxidation of ammonia to nitrate and in the reduction of nitrate. This oxidation and reduction may occur in wastewater treatment plants, water distribution systems, and natural waters. In conjunction with ammonia and nitrate, nitrites are often indicative of water pollution. They exhibit the same deleterious effects as nitrates except at lower concentrations, e.g., no physiological harm under 2 mg/ℓ as N. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Store at 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The diazotization method is recommended for the determination of nitrite nitrogen in the range from 0.01 to 1.0 mg NO_2-N/ℓ. The diazonium compound formed by diazotation of sulfanilamide by nitrite in water under acid conditions is coupled with N-(1-naphthyl)-ethylenediamine to produce a reddish-purple color which is read in a spectrophotometer at 540 nm. The presence of strong oxidants or reductants to the samples will affect the nitrite concentrations. High alkalinity (>600 mg/ℓ) will give low results due to a shift in pH. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $5 - $12

NITROPHENOLS

Parameter Group: STORET Units:

General: Nitrophenols include 2, 4-dinitrophenol; dinitrocresol, 2-nitrophenol, 4-nitrophenol, and 4, 6-dinitro-o-cresol. Metanitrophenol is highly soluble in cold water, p-nitrophenol moderately so, and o-nitrophenol only sparingly soluble. The ortho isomer is used in chemical manufacturing. Minimum lethal doses to fish vary with isomer, species, and other water constituents (e.g., hard water concentrations may be 10 times greater than those of distilled water). This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 1 to 10 μg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: \$40 - \$60

OIL AND GREASE

Parameter Group: General Organic

STORET Units: mg/ℓ

General: Oils and grease are not definitive chemical categories but include thousands of organic compounds with varying physical, chemical, and toxicological properties. Grease and oil include hydrocarbons, fatty acids, soaps, fats, waxes, and oils. The three major industrial sources of oily waste are the petroleum industry, metals manufacture and machining, and food processors. Field and laboratory evidence have demonstrated both acute lethal toxicity and long-term sublethal toxicity of oils to aquatic organisms. Bioaccumulation of petroleum products presents two especially important public health problems: (1) the tainting of edible, aquatic species, and (2) the possibility of edible marine organisms incorporating the high boiling, carcinogenic polycyclic aromatics in their tissues. The direct effects of aquatic oil pollution on man are minimal. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria: For domestic water supply: Virtually free from oil and grease, particularly from the tastes and odors that emanate from petroleum products.

For aquatic life:

- 0.01 of the lowest continuous flow 96-hour LC_{50} to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals.
- Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed.
- Surface waters shall be virtually free from floating non-petroleum oils of vegetable or animal origin, as well as petroleum-derived oils.

Preservation Method: Analyze as soon as possible. If storage is required, cool to 4°C, add H_2SO_4 to pH <2.

Maximum Holding Time: 24 hours

Container Type: Glass

Sample Volume Required: 1,000 mℓ

Measurement: The Soxhlet extraction method is recommended when relatively polar, heavy petroleum fractions are present. The method is applicable to the determination of relatively non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, and greases. The separatory funnel extraction method can also be used. The infrared method is applicable for measurement of most light petroleum fuels. The Soxhlet extraction and separatory funnel extraction methods are not applicable to the light hydrocarbons that volatize at temperatures below 70°C. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The three oil and grease methods were tested by a single laboratory on a sewage. The Soxhlet extraction method determined the oil and grease level in the sewage to be 14.8 mg/ℓ. When 1-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 88% with a standard deviation of 1.1 mg. The separatory funnel extraction method determined the oil and grease level in the sewage to be 12.6 mg/ℓ. When 1-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 93% with a standard deviation of 0.9 mg. The infrared method determined the oil and grease level in the sewage to be 17.5 mg/ℓ. When 1-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 99% with a standard deviation of 1.4 mg.

Cost of Analysis: $15 - $30

ORGANIC CARBON

Parameter Group: General Organic STORET Units: mg/ℓ as C

General: Organic carbon is the carbon oxidized by dichromate or other strong oxidizing agents, the most common measurement being total organic carbon (TOC). As in the case of BOD, TOC is a measure of a significant aspect of the strength of a discharge but is not a pollutant per se. The value of TOC usually falls below the true concentration of organic contaminants because other constituent elements are excluded. TOC is a more direct expression of the organic chemical content of water than either the BOD or COD tests and is faster and more convenient. It is often used, after an empirical relationship has been established, to estimate BOD or COD. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C. Add H_2SO_4 to pH <2.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass (brown glass preferred)

Sample Volume Required: 25 mℓ

Measurement: The combustion-infrared method is recommended. The method is applicable to measurement of organic carbon above 1 mg/ℓ. Carbonate and bicarbonate carbon represent an interference under the terms of this test and must be removed or accounted for in the final calculation. Instrument manufacturer's directions must be followed. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The difficulty of sampling particulates limits the precision to approximately 5 to 10% or higher. On clear or filtered samples, the precision may approach 1 to 2%. A distilled water solution containing 107 mg/ℓ of oxidizable organic compounds was analyzed by 28 analysts in 21 laboratories with a relative standard deviation of 7.6% and a relative error of 1.01%.

Cost of Analysis: $12 - $15

PARATHION

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Parathion is the organophosphorus insecticide $C_{10}H_{14}O_5NPS$. It is a yellow liquid that is insoluble in water or kerosene but freely soluble in alcohols and aromatic hydrocarbons. It is most commonly applied to row and orchard crops. Few chronic exposure data are available for aquatic organisms. At high concentrations of parathion, deformities, tremors, convulsions, hypersensitivity, hemorrhages were evident in bullheads. Inhibition of cholinesterase enzymes is the established mode of physiological action of parathion. Parathion has been found acutely toxic to aquatic invertebrates. The half-life of parathion in river water (pH 7.3-8.0) is one week. The estimated fatal dose for a 70-kg man is 0.1 gram. The acute oral LC_{50} for rats ranges from 3,000 to 15,000 µg/kg of body weight. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.04 µg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for parathion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

PCNB

Parameter Group: STORET Units:

General: Pentachloronitrobenzene (PCNB) is an organochlorine insecticide. It is used as an agricultural fungicide. It is soluble in carbon disulfide, benzene, and chloroform. It is practically insoluble in water and cold alcohol.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for PCNB. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person).

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: \$30 - \$150, depending upon preparation required

PENTACHLOROPHENOL

Paramater Group: Pesticides   STORET Units: μg/ℓ

General: Pentachlorophenol (C_6HCl_5O) is a crystalline material only slightly soluble in water but freely soluble in alcohol, ether, and benzene. However, its sodium salt is highly soluble in water. Pentachlorophenol possesses bactericidal, herbicidal, insecticidal, fungicidal, and molluscicidal properties. In concentrated doses, it causes lung, liver, and kidney damage to humans. In sea water, a concentration of 1.0 mg/ℓ of soidum pentachlorophenol prevents the attachment of marine fouling organisms in pipe and conduit. Its toxicity is highly dependent upon the vehicle in which it is administered. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

pH

Parameter Group: Physical STORET Units: Standard Units

General: The pH of a solution is expressed as the logarithm of the reciprocal of the hydrogen ion activity in moles per liter at a given temperature. The practical scale extends from 0 (very acidic) to 14 (very alkaline) with 7 corresponding to exact neutrality at 25°C. Whereas alkalinity and acidity are measures of the total resistance to pH change or buffering capacity of a sample, pH represents the free hydrogen ion activity not bound by carbonate or other bases. The pH of most natural waters falls in the range of 4 to 9 with the majority being slightly basic. Changes in the normal pH for a given water may indicate the discharge of alkaline or acidic wastes. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 5-9, domestic water supplies (welfare).
- 6.5 - 9.0, freshwater aquatic life.
- 6.5 - 8.5, marine aquatic life (within this range, pH should not be more than 0.2 unit outside the normally occurring range).

Preservation Methods: Analyze on site if at all possible. Otherwise, seal the sample container and cool to 4°C. Sample bottle should not be opened before analysis.

Maximum Holding Time: Any holding time beyond 6 hours should be reported with the measurement.

Container Type: Plastic or glass

Sample Volume Required: 25 to 100 mℓ

Measurement: Although pH can be measured colorimetrically, the method suffers from numerous interferences, deterioration of indicators and color standards, and limited indicator range. The glass electrode method is the standard technique, employing either a glass electrode in conjunction with a separate reference (constant potential) electrode, e.g., calomel, silver-silver chloride, or a combination electrode (glass and reference). The measurement is temperature-dependent. Oil and grease may coat the pH electrode and cause a sluggish response. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The precision and accuracy attainable will depend upon the type and condition of the water and the care used in standardization and operation. Precisions of ±0.02 pH and accuracies of ±0.05 pH are achievable, but ±0.1 pH represents the accuracy limit under normal conditions. Typical standard deviations are from 0.1 to 0.2 pH.

Cost of Analysis: $3

PHENOLICS

Parameter Group: General Organic STORET Units: μg/ℓ

General: Phenols are hydroxy derivatives of benzene and its condensed nuclei. Phenolic compounds include a wide variety of organic chemicals and may arise from the distillation of coal and wood; from oil refineries; chemical plants; livestock dips; human and other organic wastes; hydrolysis, chemical oxidation, and microbial degradation of pesticides; and from naturally occurring sources and substances. Despite the fact that it is used as a bactericide, weak phenol solutions are decomposed by bacteria and biological action, rates typically exceeding 2,000 μg/ℓ per day in natural streams. Chlorination of water containing phenolic compounds produces odoriferous and objectionable tasting chlorophenols. The ingestion of concentrated solutions of phenol will result in severe pain, renal irritation, shock, and possibly death. A 1.5-gram dose may be fatal. Many of the phenolic compounds are more toxic than pure phenol, especially to lower life forms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 1 μg/ℓ for domestic water supply (welfare), and to protect against fish flesh tainting.

Preservation Method: Analyze as soon as possible. Cool to 4°C. Add H_3PO_4 to pH <4 and 1.0g $CuSO_4$/ℓ.

Maximum Holding Time: 24 hours

Container Type: Glass only

Sample Volume Required: 500 mℓ

Measurement: The 4-aminoantipyrine (4-AAP) method with distillation is recommended and is applicable to the analysis of drinking, surface, and saline waters, domestic and industrial wastes. Phenolic materials react with 4-aminoantipyrine in the presence of potassium ferricyanide at a pH of 10 to form a stable reddish-brown colored antipyrine dye. The amount of color produced is a function of the concentration of the phenolic material. For most samples, a preliminary distillation is required to remove interfering materials. Gas chromatograph tests can be used to isolate specific compounds. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Using the extraction procedure for concentration of color, six laboratories analyzed samples at concentrations of 9.6, 48.3, and 93.5 μg/ℓ. Relative standard deviations were 10.3%, 6.4%, and 4.5%, respectively. The method must be regarded as an approximation representing the minimum amount of phenols present because the phenolic value varies with the types of phenols within a given sample. It is therefore impossible to express the accuracy of the method.

Cost of Analysis: \$15 - \$25

PHOSPHORUS (ALL FORMS)

Parameter Group: Phosphorus STORET Units: mg/ℓ P

General: Phosphorus in its elemental form (yellow phosphorus) does not occur free in nature and is particularly toxic to animal life, being subject to bioaccumulation in much the same way as mercury. Phosphorus as phosphate is abundant in nature and also from the activities of man. Phosphates occur as a result of leaching from minerals and ores in natural processes of degradation, from agricultural drainage as one of the stabilized products of decomposition of organic matter, as a result of innumerable industrial discharges, from some treated cooling waters, and as a major element of municipal sewage. It is an essential nutrient for plant and animal growth. Major uses include fertilizers, detergents, and industrial chemicals. Organic phosphates are used extensively in pesticides. The chief deleterious effect of high concentrations is accelerated eutrophication. They also interfere with coagulation and removal of turbidity. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. Definitions of the various phosphorus forms are given below.

Total Phosphorus - all of the phosphorus present in the sample, regardless of form, as measured by the persulfate digestion procedure.

Total Orthophosphate - inorganic phosphorus in the sample as measured by the direct colorimetric analysis procedure.

Total Hydrolyzable Phosphorus - phosphorus in the sample as measured by the sulfuric acid hydrolysis procedure, and minus pre-determined orthophosphates. This hydrolyzable phosphorus includes polyphosphorus plus some organic phosphorus.

Total Organic Phosphorus - phosphorus (inorganic + oxidizable organic) in the sample measured by the persulfate digestion procedure, and minus hydrolyzable phosphorus and orthophosphate.

Dissolved Phosphorus - all of the phosphorus present in the filtrate of a sample filtered through a phosphorus-free filter of 0.45 micron pore size and measured by the persulfate digestion procedure.

Dissolved Orthophosphate - as measured by the direct colorimetric analysis procedure.

Dissolved Hydrolyzable Phosphorus - as measured by the sulfuric acid hydrolysis procedure and minus pre-determined dissolved orthophosphates.

Dissolved Organic Phosphorus - as measured by the persulfate digestion procedure, and minus dissolved hydrolyzable phosphorus and orthophosphate.

When sufficient amounts of phosphorus are present in the sample to warrant such consideration, the insoluble forms may be calculated as the total minus the dissolved fraction and reported as Insoluble Phosphorus, Insoluble Orthophosphate, Insoluble Hydrolyzable Phosphorus, or Insoluble Organic Phosphorus.

Criterion: 0.10 μg/ℓ yellow (elemental) phosphorus for marine or estuarine waters.

Preservation Method: Filter on site if dissolved determination is desired. Cool to 4°C. Analyze as soon as possible. Add 40 mg/ℓ mercuric chloride as a preservative if absolutely necessary, but its use is discouraged whenever possible.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The persulfate digestion method is recommended. After digestion, determine the total orthophosphate in the sample by the direct colorimetric analysis procedure. High iron concentrations can cause precipitation of and subsequent loss of phosphorus. Mercury chloride interferes when the chloride level of the sample is low, <50 mg Cl/ℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Natural water samples with an exact increment of organic phosphate were analyzed by 33 analysts in 19 laboratories. At around 0.1 and 0.8 mg/ℓ P, relative standard deviations were around 35% and 15%, respectively, and relative error ranges were 3-12% and 1-3%, respectively. Natural water samples with an exact increment of orthophosphate were analyzed by 26 analysts in 16 laboratories. At around 0.01 and 0.02 mg/ℓ P, relative standard deviations were around 28% and 6% respectively, and relative errors were around 5.5% and 2.3%, respectively.

Cost of Analysis: $10 - $15

PHTHALATE ESTERS

Parameter Group: General Organic　　STORET Units: μg/ℓ

General: Phthalate esters include bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, diethyl phthalate, and dimethyl phthalate and are organic compounds used as plasticizers, particularly in polyvinyl chloride plastics. The di-2-ethylhexyl and di-n-butyl phthalates are used as an orchard acaricide and insect repellent. Phthalate esters can be detrimental to aquatic organisms at low water concentrations. Ability to concentrate high levels from water and reproductive impairment in certain species are suggestive of potential environmental damage. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: 3 μg/ℓ for freshwater aquatic life.

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 0.1 to 10 μg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $25 - $40

POLYCHLORINATED BIPHENYLS

Parameter Group: General Organic   STORET Units: μg/ℓ

General: Polychlorinated biphenyls (PCB's) are a class of compounds produced by the chlorination of biphenyls and are registered in the United States under the trade name Aroclor(R). PCB compounds are slightly soluble in water (25 to 200 μg/ℓ), soluble in lipids, oils, and organic solvents, and resistant to both heat and biological degradation. PCB's are relatively nonflammable, have useful exchange and dielectric properties, and were used principally in the electrical industry in capacitors and transformers. The acute and chronic effects of PCB's have been determined on a number of aquatic organisms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion:

- .001 μg/ℓ for freshwater and marine aquatic life and for consumers thereof
- Every reasonable effort should be made to minimize human exposure.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ

Measurement: The recommended gas chromatograph method covers the following PCB mixtures: Aroclors 1221, 1232, 1242, 1248, 1254, 1260, and 1016. It is an extension of the method for organochlorine pesticides - both the PCB's and the organochlorine pesticides may be determined on the same sample. They are co-extracted by liquid-liquid extraction and separated from one another prior to gas chromatographic determination. A combination of the standard Florisil column cleanup procedure and a silica gel microcolumn separation procedure are employed. Identification is made from gas chromatographic patterns obtained through the use of two or more unlike columns. Detection and measurement is accomplished using an electron capture, microcoulometric, or electrolytic conductivity detector. Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. All of these materials must be demonstrated to be free from interferences under the conditions of the analysis. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Analysis: The detection limit is approximately 1 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 to $50 for a scan and one compound
$95 to $100 for total PCB's

POLYNUCLEAR AROMATIC HYDROCARBONS

Parameter Group: STORET Units:

General: Polynuclear aromatic hydrocarbons include 1, 2-benzanthracene, 3, 4-benzopyrene, 3, 4-benzofluoranthene, 11, 12-benzofluoranthene, chrysene, acenapthylene, anthracene, 1, 12-benzoperylene, fluoroethane, phenanthrene, 1, 2:5, 6-dibenanthracene, indeno (1, 2, 3-C, D) pyrene, and pyrene. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly. Cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000-4,000 mℓ

Measurement: Procedures for determination of polynuclear aromatic hydrocarbons involve extraction, thin layer chromatography, and fluorescence or UV absorption spectra. They require confirmation on wastewater. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits range from around 0.2 to 20 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $300 - $600

POTASSIUM

Parameter Group: Metals   STORET Units: mg/ℓ as K

General: Potassium occurs in nature as chloride or sulfate in certain salt deposits, in common rocks (average of the solid earth shell is 2.6%) and minerals (e.g., feldspar, greensand, alunite, leucite), and is present in vegetation. It is one of the most active metals and, hence, is only found in the ionized or molecular form. Its salts are indispensable for fertilizers, some varieties of glass, and certain other purposes. All are highly soluble and uses include baking powders, effervescent antiacids, as a flux for silver solders, treating coal to prevent slag formation, tanning, soap manufacturing, in matches and explosives, pesticides, in wood industries, dyeing and bleaching cotton, paint and varnish removers, electroplating, photoengraving, lithography, photographic emulsions, table salt, disinfectants, and a host of other uses. Potassium is an essential nutritional element, but in excessive doses it acts as a cathartic. Its level of toxicity to fish and other aquatic life depends upon its form and the age and species involved. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or Pyrex

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 766.5 nm. Sodium may interfere if present at much higher levels than the potassium. This effect can be compensated by approximately matching the sodium content of the potassium standards with that of the sample. The flame photometric method is rapid, sensitive, and accurate but requires a special instrument and much preliminary work before samples can be run routinely. The colorimetric method is usually inadvisable for potassium levels below 10 mg/ℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.04 mg/ℓ; its detection limit is 0.005 mg/ℓ. The optimum concentration range is 0.1-2 mg/ℓ. In a single laboratory, using distilled water samples at concentrations of 1.6 and 6.3 mg/ℓ, the relative standard deviations were 13% and 8%, respectively. Recoveries at these levels were 103% and 102%. In a 33-laboratory test using a synthetic unknown at 3.1 mg/ℓ K, results from the flame photometric method yielded a relative standard deviation of 15.5% and a relative error of 2.3%.

Cost of Analysis: $5 - $10

RADIOACTIVITY (ALPHA AND BETA)

Parameter Group: Radiological STORET Units: Unspecified

General: Naturally occurring radioactivity in water is due to contact with mineral deposits; many springs and deep wells have high levels of radioactivity. Uranium, thorium, and radium and their long series of daughter products are the chief naturally occurring emitters of alpha and beta radiation. With the advent of nuclear science, man has produced a long series of radioactive products, including almost all of the elements in the periodic table. In addition to mining and separation operations, other manmade sources include the manufacture of nuclear weapons, nuclear reactors, the production of isotopes, and their use in medical therapy, research, and industrial processes and instrumentation. Radioactivity may be considered as an indestructable property from the viewpoint of man's inability to cancel or neutralize it by chemical or physical means. Gross alpha and beta activity measurements represent the best overall indicator of the presence of radioactive contamination in waters and the need for more specific determinations of the more hazardous radionuclides. The radioactivity of natural waters is usually in the 1 to 1,000 pCi/ℓ range but may reach 100,000 pCi/ℓ, and the radon (short-lived) content of some mineral springs has been found to be as high as 750,000 pCi/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Preservatives may alter the distribution of radioactivity in a sample and should not be used until the sample is separated into suspended and dissolved fractions.

Maximum Holding Time: Unstated. Adsorption onto container surfaces represents the greatest problem.

Container Type: Plastic or glass

Sample Volume Required: 1,000 mℓ

Measurement: The internal proportional counter is the recommended instrument for counting gross beta radioactivity. With a Geiger counter, the alpha activity cannot be determined separately. Alpha counting efficiency in end-window counters may be very low. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a study of two sets of paired water samples containing known additions of radionuclides, 15 laboratories determined the gross alpha activity and 16 analyzed the gross beta activity. The average recoveries of added gross alpha activity were 86%, 87%, 84%, and 82%. The average recoveries of added gross beta activity were 99%, 100%, 100%, and 100%.

Cost of Analysis: \$9 - \$15

RADIUM

Parameter Group: STORET Units:

General: There are four naturally occurring radium isotopes: radium 223, radium 224, radium 226, and radium 228. Radium 226 has a half life of 1600 years. Ra-228 is a beta emitter; the others are alpha emitters. Although alpha particles cannot penetrate the skin, they are particularly dangerous when ingested and deposited within the body. The determination of radium by precipitation is a screening technique applicable in particular to drinking water. It includes all alpha emitting isotopes, and as long as concentrations are within standards for Ra-226, the need for examination by a more specific method is minimal. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: None

Maximum Holding Time: Unknown, but prompt analysis is recommended.

Container Type: Plastic or glass

Sample Volume Required: 1,000 mℓ

Measurement: The recommended method is the determination of radium by precipitation. It involves the alpha counting of a borium-radium sulfate precipitate that has been isolated from the sample and purified. The method is also applicable to sewage and industrial wastes, provided that steps are taken to destroy organic matter and eliminate other interfering ions. A counting instrument is required. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a 20-laboratory study involving the analysis of four samples for total radium, all four results from two laboratories and two results from a third had to be rejected as outliers. Of the remainder, recoveries averaged higher than 95%. At the 95% confidence level, the precision was around 30%.

Cost of Analysis: $40 - $50

RESIDUE, SETTLEABLE

Parameter Group: Solids   STORET Units: mℓ/ℓ

General: Settleable residue (solids) which blankets the bottom of water bodies damage the invertebrate populations, block gravel spawning beds, and if organic, remove dissolved oxygen from overlying waters. They can interfere with recreation, navigation, fish and shellfish production, and destroy aesthetic values of water. They may decompose to produce putrefactive odors and may exude products of decomposition to overlying waters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 1000 mℓ

Measurement: Settleable matter is measured volumetrically with an Imhoff cone. The practical lower limit of the determination is about 1 mℓ/ℓ/hr. For some samples, a separation of settleable and floating materials will occur. In such cases, the floating materials are not measured. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $5

RESIDUE, TOTAL

Parameter Group: Solids STORET Units: mg/ℓ

General: Total residue (total solids) refers to all the solid matter (suspended and dissolved) in water or wastewater and is the material left in a vessel after evaporation of a sample and its subsequent drying in an oven. Thus it is the sum of filterable and nonfilterable residue. Waters with high residue are generally of inferior palatability and may induce adverse reaction to transient consumers. Also see discussions of filterable and nonfilterable residue. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: A well mixed aliquot of the test sample is quantitatively transferred to a pre-weighed evaporating dish and evaporated to dryness at 103-105°C. The practical range of the determination is from 10 mg/ℓ to 20,000 mg/ℓ. Large, floating particles or submerged agglomerates (non-homogeneous materials) should be excluded from the test sample. Floating oil and grease, if present, should be included in the sample and dispersed by a blender device before aliquoting. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The practical upper limit for this determination is 20,000 mg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $15

RESIDUE, TOTAL FILTERABLE

Parameter Group: Solids STORET Units: mg/ℓ

General: Total filterable residue (total dissolved solids) consists of inorganic salts, small amounts of organic matter, and dissolved materials. The principal inorganic anions dissolved in water include the carbonates, chlorides, sulfates and nitrates (principally in ground waters); the principal cations are sodium, potassium, calcium, and magnesium. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs because of corrosion or the necessity for additional treatment. Some communities use water containing up to 4,000 mg/ℓ for drinking purposes. There is no proof of beneficial or therapeutic value to mineral waters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 250 mg/ℓ for chlorides and sulfates in domestic water supplies (welfare).

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method is applicable to drinking, surface, and saline waters, doméstic and industrial wastes. A well mixed sample is filtered through a standard glass fiber filter. The filtrate is evaporated and dried to constant weight at 180°C. Highly mineralized waters containing significant concentrations of calcium, magnesium, chloride and/or sulfate may be hygroscopic and will require prolonged drying, desiccation and rapid weighing. Samples containing high concentrations of bicarbonate will require careful and prolonged drying at 180°C to insure that all the bicarbonate is converted to carbonate. Too much residue in the evaporating dish will crust over and entrap water that will not be driven off during drying. Total residue should be limited to about 200 mg. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The practical range of the determination is 10 mg/ℓ to 20,000 mg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: \$3 - \$15

RESIDUE, TOTAL NONFILTERABLE

Parameter Group: Solids STORET Units: mg/ℓ

General: Total nonfilterable residue (suspended solids) is the material retained on a standard glass fiber filter disk after filtration of a well mixed sample. In natural waters it consists of erosion silt, organic detritus, and plankton. The discharge of wastewater presents virtually unlimited possibilities. Total nonfilterable residue includes all settleable solids. It has varying effects upon water uses (apart from individual effects of the substances constituting the suspended solids). It is the most difficult parameter in terms of obtaining a representative sample from the bulk source and is used as a measure of treatment plant efficiency. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the established norm - for aquatic life.

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method involves filtering a well mixed sample through a standard glass fiber filter, and the residue retained on the filter is dried to constant weight at 103-105°C. Too much residue on the filter will entrap water and may require prolonged drying. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The practical range of the determination is 10 mg/ℓ to 20,000 mg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $15

RESIDUE, VOLATILE

Parameter Group: Solids STORET Units: mg/ℓ

General: The volatile components in the residue represent a rough indication of the amount of organic matter present. Since the result may reflect loss of water of crystallization, loss of volatile organic matter before combustion, incomplete oxidation of certain complex organics, and decomposition of mineral salts during combustion, it may not yield an accurate measure of organic carbon. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method determines the weight of solid material combustible at 550°C. The residue obtained from the determination of total, filterable, or nonfilterable residue is ignited at 550°C in a muffle furnace. The loss of weight on ignition is reported as mg/ℓ volatile residue. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A collaborative study involving three laboratories examining four samples by means of ten replicates showed a standard deviation of ±11 mg/ℓ at 170 mg/ℓ volatile residue concentration.

Cost of Analysis: $10 - $15

SELENIUM

Parameter Group: Metals   STORET Units: μg/ℓ as Se

General: Selenium appears in the soil as basic ferric selenite, calcium selenate, and as elemental selenium. Selenium salts are used in many industries, including paint, pigment and dye producers, electronics, glass manufacture, insecticide sprays, electrical apparatus (rectifiers, semiconductors, photoelectric cells, etc.), rubber, and alloying. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 10 μg/ℓ for domestic water supply (health)
- For marine and freshwater aquatic life; 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The AA spectrophotometric gaseous hydride method is recommended using a wavelength of 196.0 nm. The method is applicable to most fresh and saline waters, in the absence of high concentrations of chromium, cobalt, copper, mercury, molybdenum, nickel and silver. The diaminobenzidine colorimetric method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is approximately 2.5 μg/ℓ; its detection limit is 2 μg/ℓ. The working range of the method is 2-20 μg/ℓ. At a concentration of 10 μg/ℓ, the relative standard deviation is 11% and the relative error is 0.0%. Ten replicate solutions of selenium oxide at the 5, 10 and 15 μg/ℓ level were analyzed by a single laboratory. Relative standard deviations were 12%, 11%, and 19% with recoveries of 100%, 100%, and 101%.

Cost of Analysis: $15 - $40

SILICA

Parameter Group: Solids STORET Units: mg/ℓ as SiO_2

General: Silica is abundant in the earth's crust. It appears as an oxide in many rocks. The degradation of the rocks results in the presence of silica in natural waters. Silica is also widely used in industry and in water treatment. Silica in water forms silica and silicate scales in various equipments, particularly on high pressure steam turbine blades. In normally occurring concentrations it does not appear to cause adverse physiological effects. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or hard rubber

Sample Volume Required: 50-1000 mℓ

Measurement: Total silica is determined by a gravimetric method wherein silica acids are formed and precipitated, ignited, and the final determination made as the loss on volatilization. The recommended method for dissolved silica involves filtering a well-mixed sample through a 0.45μ membrane filter. The filtrate, upon the addition of molybdate ion in acidic solution, forms a greenish-yellow color complex proportional to the dissolved silica in the sample. The color complex is then measured spectrophotometrically. Excessive color and/or turbidity interfere. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision of the gravimetric method is approximately ±0.2 mg SiO_2. Photometric evaluations by the amino-naphthal-sulfuric acid procedure have an estimated precision of ±0.10 mg/ℓ in the range from 0 to 2 mg/ℓ. Photometric evaluations of the silica-molybdate color in the range from 2 to 50 mg/ℓ have an estimated precision of approximately 4% of the quantity of silica measured.

Cost of Analysis: \$5 - \$15

SILICON

Parameter Group: Solids   STORET Units: μg/ℓ as Si

General: Silicon, the second most abundant element making up 26% of the earth's crust, is not found free in nature but occurs chiefly as the oxide (silica) in sand, quartz, agate, opal, etc., and as silicates in granite, feldspar, kaolinite, and other minerals. Silicon is one of man's most useful elements, with applications ranging from metallurgy to solid state electronics and the production of silicones, polymeric products ranging from liquids to hard glass-like solids with many beneficial properties. Silicon is also important in plant and animal life.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is often used, with a wavelength of 251.6 nm. Avoid any prolonged contact with glass.

Precision and Accuracy: The AA method sensitivity is 2,000 μg/ℓ; its detection limit is 300 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $10 - $20

SILVER

Parameter Group: Metals STORET Units: µg/ℓ as Ag

General: Silver ions cannot be expected to occur in significant concentrations in natural waters. As a solid metal, silver is used in the jewelry, silverware, metal alloy, and food processing industries. The solid metal produces very little soluble waste. Silver nitrate, which is soluble, is used in the porcelain, photographic, electroplating and ink manufacturing industries, and as an antiseptic. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 µg/ℓ for domestic water supply (health)
- For marine and freshwater aquatic life, 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 328.1 nm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 60 µg/ℓ; its detection limit is 10 µg/ℓ. The optimum concentration range is 100-4,000 µg/ℓ. At a concentration of 550 µg/ℓ, the relative standard deviation is 17.5%, and the relative error is 10.6%.

Cost of Analysis: $10 - $15

SILVEX (2, 4, 5-TP)

Parameter Group: Pesticides STORET Units: μg/ℓ

General: Silvex, 2 (2, 4, 5-trichlorophenoxy) propionic acid, is a chlorinated phenoxy acid herbicide. It is used for weed control on land, and its esters and salts have been used as an aquatic herbicide in lakes, streams, and irrigation canals. It is slightly soluble in water and freely soluble in acetone and methyl alcohol. Silvex is reported to be slightly less toxic than 2, 4-D and 2, 4, 5-T type materials. Its acute oral LD_{50} to rats is 650,000 mg/kg of body weight. At a level of 2,000 μg/ℓ it has temporarily (e.g., 2 weeks) reduced the number of plankton in lakes, but fish are unaffected. Apparently the threshold of toxicity for fish is around 5,000 μg/ℓ. In some instances, however, fish have acquired an unpleasant, oily taste following exposure to Silvex. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 10 μg/ℓ for domestic water supply (health).

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 - 1,000 mℓ, depending on measurement method used.

Measurement: In the recommended method, chlorinated phenoxy acids and their esters are extracted from the acidified water sample with ethyl ether. The esters are hydrolyzed to acids, and extraneous organic material is removed by a solvent wash. The acids are converted to methyl esters which are extracted from the aqueous phase. The extract is cleaned up by passing it through a micro-adsorption column. Detection and measurement are accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography. Interferences may be high and varied and often pose great difficulty in obtaining accurate and precise measurement of chlorinated phenoxy acid herbicides. Organic acids, especially chlorinated acids, cause the most direct interference with the determination. Phenols including chlorophenols will also interfere with this procedure. The method is recommended for use only by an experienced pesticide analyst (or under the close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is 1 μg/ℓ. Detection limits of 0.01 μg/ℓ or so may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 - $150, depending upon preparation required.

SODIUM

Parameter Group: Metals STORET Units: mg/ℓ as Na

General: Sodium is present in most natural waters and, as the cation of many salts used in industry, is one of the most common ions in industrial waters. A high sodium ratio has harmed soil permeability. Humans with certain diseases (cardiac, renal, and circulatory) require water with a low sodium concentration. Otherwise, taste considerations prevail as far as human ingestion is concerned. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add HNO_3 to pH of 2.

Maximum Holding Time: 6 months

Container Type: Polyethylene bottles

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 589.6 nm. Low-temperature flames increase sensitivity by reducing the extent of ionization of this easily ionized metal. Ionization may also be controlled by adding potassium (1,000 mg/ℓ) to both standards and samples. The flame photometric method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.015 mg/ℓ; its detection limit is 0.002 mg/ℓ. The optimum concentration range is 0.03-1.0 mg/ℓ. In a single laboratory, using distilled water samples at levels of 8.2 and 52 mg/ℓ, the relative standard deviations were 1.2% and 1.5%, respectively. Recoveries at these levels were 102% and 100%. In a 35-laboratory test using the flame photometric method on a synthetic unknown at 19.9 mg/ℓ Na, a relative standard deviation of 17.3% and a relative error of 4.0% were reported.

Cost of Analysis: $5 - $10

SPECIFIC CONDUCTANCE

Parameter Group: Physical STORET Units: μmhos/cm @ 25°C

General: The determination of conductivity (specific electrical conductance) is a quick method for determining the ion concentration of water. The mobility of each of the various ions, their valences, and their actual and relative concentrations affect conductivity. The specific conductance of potable waters generally ranges from 50 to 1,500 μmhos/cm; for wastewaters it is highly variable and may be well in excess of 10,000 μmhos/cm. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The specific conductance of a sample is measured by use of a self-contained conductivity meter, Wheatstone bridge-type or equivalent. Samples are preferably analyzed at 25°C. If not, temperature corrections are made and results reported at 25°C. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Typically, relative standard deviations of around 7 to 9% and relative errors from 2 to 5% are experienced.

Cost of Analysis: $3 - $5

STRONTIUM

Parameter Group: Radiological   STORET Units: Unspecified

General: The radioactive nuclides of strontium produced in nuclear fission are Sr-89 and Sr-90. Strontium 90 is one of the most hazardous of all fission products. It has a half-life of 28 years. Strontium is concentrated in the bones if it is ingested. Ten percent of the occupational maximum concentration for Sr-90 in water is 100 pCi/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established.

Preservation Method: None

Maximum Holding Time: Unknown, but prompt analysis is recommended.

Container Type: Plastic or glass

Sample Volume Required: Not determined

Measurement: The recommended method involves the use of a "carrier" which is inactive strontium ions in the form of strontium nitrate. Precipitation is used to obtain strontium carbonate from the strontium carrier and the radionuclide of strontium. It is dried to determine recovery of the carrier and then measured for radioactivity. Radioactive barium interferes in the determination of radioactive strontium. A counting instrument is required. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a study of two sets of paired water samples containing known additions of radionuclides, 12 laboratories determined the total radiostrontium and 10 laboratories determined Sr-90. The average recoveries of total radiostrontium from the four samples were 99%, 99%, 96%, and 93%. The average recoveries of added Sr-90 from the four samples were 90%, 96%, 80%, and 94%.

Cost of Analysis: $40 - $50

SULFATE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as SO_4

General: Sulfates occur naturally in waters as a result of leachings from gypsum and other common minerals or as the final oxidized stage of sulfides, sulfites, and thiosulfates having both mineral and organic origins. They may also be found in the wastes from numerous industries, including tanneries, sulfate pulp mills, textile mills, and other plants using sulfates or sulfuric acid. Excessive sulfates may exert a laxative action toward new users and cause taste problems, but such effects are not observed below 500 mg/ℓ. Limits for industrial users (especially sugar making) are much lower. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The turbidimetric method using a nephelometer is normally acceptable. The method is suitable for all concentration ranges of sulfate; however, in order to obtain reliable readings, use a sample aliquot containing not more than 40 mg/ℓ SO_4. Suspended matter and color interfere. Correct by running blanks from which the barium chloride has been omitted. The gravimetric method is recommended when results of the greatest accuracy are required. It is most accurate for sulfate concentrations above 10 mg/ℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A synthetic unknown sample containing 259 mg/ℓ sulfate, 108 mg/ℓ Ca, 82 mg/ℓ Mg, 3.1 mg/ℓ K, 19.9 mg/ℓ Na, 241 mg/ℓ chloride, 250 μg/ℓ nitrite N, 1.1 mg/ℓ nitrate N and 42.5 mg/ℓ total alkalinity (contributed by $NaHCO_3$) was analyzed by the gravimetric method, with a relative standard deviation of 4.7% and a relative error of 1.9% in 32 laboratories. Using the turbidimetric method in 19 laboratories, the relative standard deviation was 9.1% and the relative error, 1.2%.

Cost of Analysis: \$4 - \$12

SULFIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as S

General: Sulfide is often present in groundwater and is common in some natural waters and sewage, coming in part from the anaerobic decomposition of organic matter. Sulfides are constituents of many industrial wastes, e.g., tanneries, paper mills, chemical plants, and gas works. It also occurs due to bacterial reduction of sulfates. The highly unpleasant taste and odor that results when sulfides occur in water make it unlikely that humans or animals will consume a harmful dose. Small traces of sulfide may be detrimental to some industrial uses. Sulfides are of little importance in irrigation waters. The sulfide ion readily reacts with free hydrogen ions in water to form hydrogen sulfide, which is very toxic, attacks metals directly, and indirectly causes serious corrosion to concrete sewers. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ zinc acetate, fill bottle completely, and stopper.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The titrimetric iodine method is recommended. It is applicable to the measurement of total and dissolved sulfides. Acid insoluble sulfides are not measured by this test. Reduced sulfur compounds, such as sulfite, thiosulfate and hydrosulfite, which decompose in acid may yield erratic results. Volatile iodine consuming substances will give high results. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data have not been determined.

Cost of Analysis: $5 - $12

SULFITE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as SO_3

General: Sulfite may occur in certain industrial wastes but is most commonly found in boilers and boiler feedwater to which sodium sulfite has been added to reduce dissolved oxygen to a minimum and prevent corrosion. It is thought that a high concentration of sulfite in water may cause exema. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The recommended method has a minimum detectable limit of 2-3 mg/ℓ SO_3. An acidified sample containing an indicator is titrated with a standard potassium iodide-iodate titrant to a faint permanent blue end point. The temperature of the sample must be below 50°C. Oxidizable substances, such as organic compounds, ferrous, iron and sulfide are positive interferences. Nitrite gives a negative interference by oxidizing sulfite when the sample is acidified. Copper and possibly other metals catalyze the oxidation of sulfite. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $5 - $12

2, 4, 5-T

Parameter Group: Pesticides STORET Units: μg/ℓ

General: 2, 4, 5-T (2, 4, 5-trichlorophenoxyacetic acid) is the chlorinated phenoxy acid herbicide $C_8H_5Cl_3O_3$. It is a crystalline substance, almost insoluble in water, but soluble in alcohol. It is a plant hormone. The estimated lethal dose for a 90-kg man is 54 grams. The acute oral LD_{50} to rats is 300,000 mg/kg of body weight. 2, 4, 5-T forms phenol as a breakdown product. Toxicity data for aquatic life are sparse. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ, depending on measurement method used.

Measurement: In the recommended method, chlorinated phenoxy acids and their esters are extracted from the acidified water sample with ethyl ether. The esters are hydrolyzed to acids and extraneous organic material is removed by a solvent wash. The acids are converted to methyl esters which are extracted from the aqueous phase. The extract is cleaned up by passing it through a micro-adsorption column. Detection and measurement are accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography. Interferences may be high and varied and often pose great difficulty in obtaining accurate and precise measurement of chlorinated phenoxy acid herbicides. Organic acids, especially chlorinated acids, cause the most direct interference with the determination. Phenols including chlorophenols will also interfere with this procedure. The method is recommended for use only by an experienced pesticide analyst (or under the close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is 1 μg/ℓ. Detection limits of 0.002 μg/ℓ or so may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 - $150, depending upon preparation required.

TEMPERATURE

Parameter Group: Temperature   STORET Units: °C

General: Temperature changes in waters are due to natural climatic phenomena or the discharge of irrigation return flows and wastes, such as distilling effluents and cooling waters. The elevation of stream temperatures may contribute to decreased oxygen capacity, increased oxygen demand, anaerobic zones, and putrefaction of sludge deposits. Temperature is a significant factor for water treatment and many industrial uses, e.g., pulp and paper. Temperature also affects the value of numerous other water quality parameters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

Freshwater Aquatic Life

For any time of year, there are two upper limiting temperatures for a location (based on the important sensitive species found there at that time):

1. One limit consists of a maximum temperature for short exposures that is time dependent and is given by the species-specific equation:

$$\text{Temperature}_{(C^{o})} = (1/b)\left(\log_{10}\left[\text{time}_{(min)}\right] - a\right) - 2°C$$

where: $\log_{10}$ = logarithm to base 10 (common logarithm)

a = intercept on the "y" or logarithmic axis of the line fitted to experimental data and which is available from Appendix II-C, NAS, 1974 for some species.

b = slope of the line fitted to experimental data and available from Appendix II-C, NAS, 1974 for some species.

and

2. The second value is a limit on the weekly average temperature that:

a. In the cooler months (mid-October to mid-April in the north and December to February in the south) will protect against mortality of important species if the elevated plume temperature is suddenly dropped to the ambient temperature, with the limit being the acclimation temperature minus 2°C when the lower lethal threshold temperature equals the ambient water temperature (in some regions this limitation may also be applicable in summer).

or

b. In the warmer months (April through October in the north and March through November in the south) is determined by adding to the physiological optimum temperature (usually for growth) a factor calculated as one-third of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most sensitive important species (and appropriate life state) that normally is found at that location and time.

or

c. During reproductive seasons (generally April through June and September through October in the north and March through May and October through November in the south) the limit is that temperature that meets site-specific requirements for successful migration, spawning, egg incubation, fry rearing, and other reproductive functions of important species. These local requirements should supersede all other requirements when they are applicable.

or

d. There is a site-specific limit that is found necessary to preserve normal species diversity or prevent appearance of nuisance organisms.

Marine Aquatic Life

In order to ensure protection of the characteristic indigenous marine community of a water body segment from adverse thermal effects:

a. The maximum acceptable increase in the weekly average temperature due to artificial sources is 1°C (1.8°F) during all seasons of the year, providing the summer maxima are not exceeded; and

b. Daily temperature cycles characteristic of the water body segment should not be altered in either amplitude or frequency.

Summer thermal maxima, which define the upper thermal limits for the communities of the discharge area, should be established on a site-specific basis. Existing studies suggest the following regional limits:

	Short-term Maximum	Maximum True Daily Mean*
Sub-tropical Regions (south of Cape Canaveral and Tampa Bay, Florida, and Hawaii	32.2°C (90°F)	29.4°C (85°F)
Cape Hatteras, N.C., to Cape Canaveral, Florida	32.2°C (90°F)	29.4°C (85°F)
Long Island (south shore) to Cape Hatterras, N.C.	30.6°C (87°F)	27.8°C (82°F)

* (True Daily Mean = average of 24 hourly temperature readings.)

Baseline thermal conditions should be measured at a site where there is no unnatural thermal addition from any source, which is in reasonable proximity to the thermal discharge (within 5 miles) and which has similar hydrography to that of the receiving waters at the discharge.

Preservation Method: Determination on site

Maximum Holding Time: No holding

Container Type: Plastic or glass

Sample Volume Required: 1000 mℓ

Measurement: Temperature measurements may be made with any good grade of mercury-filled or dial type Celsius thermometer, or a thermistor. The measurement device should be checked against a precision thermometer certified by the National Bureau of Standards. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy will depend upon instrument used.

Cost of Analysis: Not immediately determinable.

THALLIUM

Parameter Group: Metals STORET Units: μg/ℓ as Tl

General: Thallium salts are used as rodenticides and ant bait, dyes and pigments in fireworks, in optical glass, and as a dipilatory. They are highly soluble in water and discharges are not likely to form precipitates. It is a cumulative poison, four times as toxic as arsenious oxide and affects the nervous system, causes muscular pain, endocrine disorders, and loss of hair. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 276.8 nm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 500 μg/ℓ; its detection limit is 100 μg/ℓ. The optimum concentration range is 1,000-20,000 μg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 600, 3,000, and 15,000 μg/ℓ Tl, the relative standard deviations were 3%, 1.7%, and 1.3%, respectively. Recoveries at these levels were 100%, 98%, and 98%, respectively.

Cost of Analysis: $15 - $20

THRESHOLD ODOR

Parameter Group: Physical   STORET Units: Threshold Number

General: Odor is a quality factor that affects water in several ways including the acceptability of drinking water, tainting of fish, and the aesthetics of recreational waters. Odor can originate from industrial and municipal waste discharges and from natural sources such as decomposition of vegetable matter and living microscopic organisms. Odorous substances in water must be vaporizable in order to be smelled.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Glass

Sample Volume Required: 200 to 500 mℓ

Measurement: The consistent series method, in which the sample is divided to the point of the least definitely perceptible odor to each tester, is often used. Highly odorous samples are reduced in concentration proportionately before being tested. The method is applicable to samples ranging from nearly odorless natural waters to industrial wastes with threshold odor numbers in the thousands. Most tap waters and some waste waters are chlorinated. Dechlorination is achieved using sodium thiosulfate in exact stoichiometric quantity.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: $5 - $10

TIN

Parameter Group: Metals STORET Units: µg/ℓ as Sn

General: Tin does not occur in natural waters. It is used in dyeing of fabrics, decorating porcelain, glassworks, fingernail polishes, some lacquers and varnishes, fungicides, insecticides, antihelminthics, antifoulant marine coatings and, of course, the tinning of vessels, especially foodstuff containers. Other sources include iron and steel production and power plant and industrial boilers. Tin is not believed to be toxic to man or other life forms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 286.3 nm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 4 mg/ℓ; its detection limit is 800 µg/ℓ. The optimum concentration range is 16,000-200,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 4,000, 20,000, and 60,000 µg/ℓ Sn, the relative standard deviations were 6.2%, 2.5%, and .8%, respectively. Recoveries at these levels were 96%, 101%, and 101%, respectively.

Cost of Analysis: $15 - $20

TITANIUM

Parameter Group: Metals STORET Units: μg/ℓ as Ti

General: Titanium ores and salts are abundantly distributed in the earth's crust, constituting from 0.5% to 10% of soils. The metal is used chiefly in alloying, and its salts are used in paint, paper, and dyeing industries, in the manufacture of electronic components, and in glass and ceramic production. There is little evidence of harm to life forms from titanium. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 365.3 nm. A number of elements increase the sensitivity of titanium. To control this problem, potassium (1,000 mg/ℓ) must be added to the standards and samples. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 2,000 μg/ℓ; its detection limit is 300 μg/ℓ. The optimum concentration range is 5,000-100,000 μg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 2,000, 10,000, and 50,000 μg/ℓ Ti, the relative standard deviations were 3.5%, 1.0%, and .8%, respectively. Recoveries at these levels were 97%, 91%, and 88%, respectively.

Cost of Analysis: $10 - $20

TOLUENE

Parameter Group: General Organic

STORET Units: μg/ℓ

General: Toluene ($C_6H_5CH_3$), a flammable liquid with an odor of benzene, is a constituent of coal tar. It is used in the manufacture of organic substances and as a solvent in the extraction of various principles from plants. Toluene is modestly soluble in water at normal temperatures. Its LD_{50} for rats is 7,000 mg/kg of body weight. Lethal concentrations to fish in clean water range from 10,000 to over 90,000 μg/ℓ depending upon temperature and species. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by gas chromatographic and mass spectrometric analysis is often used. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits should be around 2-10 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

TOTAL COLIFORM

Parameter Group: Bacteriologic   STORET Units: See below

General: The coliform bacteria group as defined by the tests described herein includes organisms of diverse origins, including intermediate and Aerobactor aerogenes strains, which are usually of soil, vegetable, or other non-fecal origin; E. coli, which is usually but not always of fecal origin; and fecal coliform, which is a positive indication of the excrement of warm-blooded animals. The direct examination for the presence of a specific pathogen in water is not usually practicable for control purposes, and total coliform has been widely used as a microbiological indicator organism. The more specific fecal coliform indicator is gaining in popularity, however. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C. Add a dechlorinating agent (e.g., sodium thiosulfate) if residual chlorine is present. Samples high in heavy metals should have a chelating agent (e.g., EDTA) added to reduce metal toxicity.

Maximum Holding Time: 6 hours (30 hours absolute maximum for potable water sample).

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The multiple tube fermentation technique, which defines the coliform group as all aerobic and facultative anaerobic, gram negative, rod-shaped, nonspore-forming bacteria that ferment lactose with gas formations within 48 hours at 35°C, is recommended. The simpler membrane filter technique, which defines the coliform group as the above bacteria that produce a dark colony with a metallic sheen within 24 hours on an Endo-type medium containing lactose, is also recommended, especially for nondrinking water tests. Results of the former are expressed statistically as the Most Probable Number (MPN), while the latter are expressed as number of colonies per 100 mℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Not applicable

Cost of Analysis: $10 - $12 MFT
$15 - $20 MPN

TOXAPHENE

Parameter Group: Pesticides   STORET Units: μg/ℓ

General: Toxaphene is a chlorinated camphene insecticide. It is insoluble in water but highly soluble in organic solvents and oils. It has been reported that lakes treated with toxaphene concentrations ranging from 40 to 150 μg/ℓ remained toxic to fish for periods of a few months to five years. Bioconcentration accumulations of toxaphene of 5,000 to 21,000 times water concentrations have been observed in brook trout exposed only through water. Accumulation factors of 3,400 to 17,000 from aqueous solution have been reported for bacteria, algae, and fungi. Owing to the turpentine odor, it is not likely that toxic concentrations will be consumed by man or animals. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria:

- 5 μg/ℓ for domestic supply (health)
- 0.005 μg/ℓ for freshwater and marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for toxaphene under favorable conditions. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

TRICHLOROETHYLENE

Parameter Group: STORET Units:

General: Trichloroethylene, a nonflammable liquid with a chloroform-like odor, is practically insoluble in water. It is used as a solvent and in solvent extraction by several industries, in degreasing, in the manufacture of chemicals and pharmaceuticals, and in dry cleaning. The oral LD_{50} for dogs is 5.86 g/kg of body weight. Concentrations of 55 mg/ℓ will stupify fish within 10 minutes. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

TURBIDITY

Parameter Group: Physical

STORET Units: Formazin Turbidity Units

General: Turbidity is an optical property of water, reflecting its propensity for scattering light. From chlorination considerations, finished drinking waters typically have a maximum limit of 1 turbidity unit where the water enters the distribution system. Turbid water interferes with recreational use and aesthetic enjoyment of water. The less turbid the water, the more desirable it becomes for swimming and other water contact sports. See discussion for suspended solids. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method is applicable to drinking, surface, and saline waters in the range of turbidity from 0 to 40 nephelometric turbidity units (NTU). The method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. The presence of floating debris and course sediments which settle out rapidly will give low readings. Finely divided air bubbles will affect the results in a positive manner. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a single laboratory, using surface water samples at levels of 26, 41, 75 and 180 NTU, the relative standard deviations were 2.3%, 2.3%, 1.6%, and 2.6%, respectively.

Cost of Analysis: $3 - $5

URANIUM

Parameter Group: Metals STORET Units: mg/ℓ

General: In addition to atomic energy applications, uranium is used in photography, glazing and painting porcelain, and in chemical processes. Many uranium salts are soluble in water. It has been reported that uranium and many of its salts are toxic; however, limited studies indicate that natural uranium, absorbed by people through the water and foodstuffs grown on land, may be a limiting factor in the incidence of leukemia. There is generally greater concern about the radiological hazards of uranium than about its chemical effects, however.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add HNO_3 to $pH \approx 2$ and cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The direct fluorometric method is often used. The concentration range is from 0.005 to 2.0 mg/ℓ. For higher concentrations, the extraction method may be used. The method involves the measurement of the fluorescence of a fused disk of sodium fluoride, lithium fluoride, and uranium compound exposed to ultraviolet light. The intensity of the fluorescence is proportional to the uranium concentration. Small quantities of cadmium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, lead, platinum, silicon, thorium, and zinc interfere by quenching the uranium fluorescence and a purification or spiking method must be used. The AA method may also be used.

Precision and Accuracy: The single operator precision (S) at a uranium concentration of X mg/ℓ may be estimated from

$$\log (S-0.0016) = \log 0.129 + 120 \log X.$$

Cost of Analysis: $30 - $40

VANADIUM

Parameter Group: Metals STORET Units: µg/ℓ as V

General: Minerals containing vanadium are widespread in nature. In addition to its metallurgical uses, principally in steel alloying, its salts are used in the manufacture of glass, ceramics, ink, in photography, and in the dyeing and printing of fabrics. It is not considered toxic and, in fact, may play a beneficial role in reducing cholesterol, preventing heart disease and dental caries, and lowering the phospholipid content of the liver. Small quantities of vanadium may stimulate plant growth. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 318.4 nm. High concentrations of aluminum and titanium increase the sensitivity of vanadium. This interference can be controlled by adding excess aluminum (1,000 mg/ℓ) to both samples and standards. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 800 µg/ℓ; its detection limit is 200 µg/ℓ. The optimum concentration range is 1,000-100,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 2,000, 10,000, and 50,000 µg/ℓ V, the relative standard deviations were 5%, 1%, and .4%, respectively. Recoveries at these levels were 100%, 95%, and 97%, respectively.

Cost of Analysis: $10 - $20

VINYL CHLORIDE

Parameter Group: STORET Units:

General: Vinyl chloride (chloroethene, CH_2:CHCl), a flammable gas with an ethereal odor, is only slightly soluble in water. It is prepared by catalytic addition of hydrogen chloride to acetylene or by pyrolysis of ethylene dichloride and is used chiefly for making vinyl resins. U.S. production exceeds 3 billion pounds annually. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 μg/ℓ. Detection limits of 0.2-3 μg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

XYLENE

Parameter Group: General Organic   STORET Units: μg/ℓ

General: Xylene ($C_6H_4(CH_3)_2$), a flammable liquid, is a constituent of coal tar. It is used in the manufacture of dyes and organic substances, as a solvent, and as a cleaning agent. Xylene is insoluble in water. Its LD_{50} for white rats is 4.3g/kg of body weight. Lethal concentrations to fish range from 10,000 to 90,000 μg/ℓ depending upon temperature and species.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by gas chromatographic and mass spectrometric analysis is often used.

Precision and Accuracy: Detection limits should be around 2-10 μg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

ZINC

Parameter Group: Metals STORET Units: µg/ℓ as Zn

General: Zinc is usually found in nature as the sulfide. Zinc is used in galvanizing and in the preparation of alloys for dye casting. Zinc is also used in brass and bronze alloys, slush castings, photoengraving, printing plates, silver and stainless steel tableware, viscose rayon yarn, wood pulp, and newsprint paper. Other sources include mining areas, paint pigments, cosmetics, pharmaceutics, insecticides, and many more. Zinc is an essential and beneficial element in human metabolism. Excessive amounts of zinc affect growth rates and decrease both the weight and fat content of the liver. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.
Zinc is a

Criteria:

- 5,000 µg/ℓ for domestic water supplies (welfare).
- For freshwater aquatic life, 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 213.9 nm. The air-acetylene flame absorbs about 25% of the energy at the 213.9-nm line. The sensitivity may be increased by the use of low-temperature flames. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BPT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 20 µg/ℓ; its detection limit is 5 µg/ℓ. The optimum concentration range is 50-2,000 µg/ℓ. At a concentration of 500 µg/ℓ, the relative standard deviation is 8.2%, and the relative error is 0.4%.

Cost of Analysis: $10 - $15

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PART II

ENVIRONMENTAL PROTECTION AGENCY

■

WATER PROGRAMS

Guidelines Establishing Test Procedures for Analysis of Pollutants

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Notice was pubished in the FEDERAL REGISTER issue of June 29, 1973 (38 FR 17318) at 40 CFR 130, that the Environmental Protection Agency (EPA) was giving consideration to the testing procedures required pursuant to section 304(g) of the Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816, et seq., Pub. L. 92-500 (1972)) hereinafter referred to as the Act. These considerations were given in the form of proposed guidelines establishing test procedures.

Section 304(g) of the Act requires that the Administrator shall promulgate guidelines establishing test procedures for the analysis of pollutants that shall include factors which must be provided in: 1, any certification pursuant to section 401 of the Act, or 2, any permit application pursuant to section 402 of the Act. Such test procedures are to be used by permit applicants to demonstrate that effluent discharges meet applicable pollutant discharge limitations, and by the States and other enforcement activities in routine or random monitoring of effluents to verify effectiveness of pollution control measures.

These guidelines require that discharge measurements, including but not limited to the pollutants and parameters listed in Table I, be performed by the test procedures indicated; or under certain circumstances by other test procedures for analysis that may be more advantageous to use, when such other test procedures have the approval of the Regional Administrator of the Region where such discharge will occur, and when the Director of an approved State National Pollutant Discharge Elimination System (NPDES) Program (hereinafter referred to as the Director) for the State in which such discharge will occur has no objection to such approval.

The list of test procedures in Table I is published herein as final rulemaking and represents major departures from the list of proposed test procedures which was published in 38 FR 17318, dated June 29, 1973. These revisions were made after carefully considering all written comments which were received pertaining to the proposed test procedures. All written comments are on file and available for public review with the Quality Assurance Division, Office of Research and Development, EPA, Washington, D.C.

The principal revisions to the proposed test procedures are as follows:

1. Where several reliable test procedures for analysis are available from the given references for a given pollutant or parameter, each such test procedure has been approved for use for making the measurements required by sections 401 and 402 and related sections of the Act. Approved test procedures have been selected to assure an acceptable level of intercomparability of pollutants discharge data. For several pollutants and parameters it has still been necessary to approve only a single test procedure to assure this level of acceptability. This is a major departure from the proposed test procedures which would have required the use of a single reference method for each pollutant or parameter.

2. Under certain circumstances a test procedure not shown on the approved list may be considered by an applicant to be more advantageous to use. Under guidelines in §§ 136.4 and 136.5 it may be approved by the Regional Administrator of the Region where the discharge will occur, providing the Director has no objections. Inasmuch as there is no longer a single approved reference method against which a comparison can be made, the procedures for establishing such comparisons that were required by the proposed test procedures in § 130.4(b) have been deleted from this final guideline for test procedures for the analysis of pollutants.

3. A mechanism is also provided to assure national uniformity of such approvals of alternate test procedures for the analysis of pollutants. This is achieved through a centralized, internal review within the EPA of all applications for the use of alternate testing procedures. These will be reviewed and approved or disapproved on the basis of submitted information and other available information and laboratory tests which may be required by the Regional Administrator.

As deemed necessary, the Administrator will expand or revise these guidelines to provide the most responsive and appropriate list of test procedures to meet the requirements of sections 304(g), 401 and 402 of the Act, as amended.

These final guidelines establishing test procedures for the analysis of pollutants supersede the interim list of test procedures published in the FEDERAL REGISTER on April 19, 1973 (38 FR 9740) at 40 CFR Part 126 and subsequent procedures published on July 24, 1973 (38 FR 19894) at 40 CFR Part 124. Those regulations established interim test procedures for the submittal of applications under section 402 of the Act. Because of the importance of these guidelines for test procedures for the analysis of pollutants to the National Pollution Discharge Elimination System (NPDES), the Administrator finds good cause to declare that these guidelines shall be effective October 16, 1973.

JOHN QUARLES,
Acting Administrator.

OCTOBER 3, 1973.

PART 136—TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Sec.

AUTHORITY: Sec. 304(g) of Federal Water Pollution Control Act Amendments of 1972 86 Stat. 816, et seq., Pub. L. 92-500).

§ 136.1 Applicability.

The procedures prescribed herein shall, except as noted in § 136.5, be used to perform the measurements indicated whenever the waste constituent specified is required to be measured for:

(a) An application submitted to the Administrator, or to a State having an approved NPDES program, for a permit under section 402 of the Federal Water Pollution Control Act as amended (FWPCA), and,

(b) Reports required to be submitted by dischargers under the NPDES established by Parts 124 and 125 of this chapter, and,

(c) Certifications issued by States pursuant to section 401 of the FWPCA, as amended.

§ 136.2 Definitions.

As used in this part, the term:

(a) "Act" means the Federal Water Pollution Control Act, as amended, 33 U.S.C. 1314, et seq.

(b) "Administrator" means the Administrator of the U.S. Environmental Protection Agency.

(c) "Regional Administrator" means one of the EPA Regional Administrators.

(d) "Director" means the Director of the State Agency authorized to carry out an approved National Pollutant Discharge Elimination System Program under section 402 of the Act.

(e) "National Pollutant Discharge Elimination System (NPDES)" means the national system for the issuance of permits under section 402 of the Act and includes any State or interstate program which has been approved by the Administrator, in whole or in part, pursuant to section 402 of the Act.

(f) "Standard Methods" means *Standard Methods for the Examination of Water and Waste Water*, 13th Edition, 1971. This publication is available from the American Public Health Association, 1015 18th St. NW., Washington, D.C. 20036.

(g) "ASTM" means *Annual Book of Standards, Part 23, Water, Atmospheric Analysis, 1972*. This publication is available from the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pennsylvania 19103.

(h) "EPA Methods" means *Methods for Chemical Analysis of Water and Wastes*, 1971, Environmental Protection Agency, Analytical Quality Control Laboratory, Cincinnati, Ohio. This publication is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock Number 5501-0067).

§ 136.3 Identification of test procedures.

Every parameter or pollutant for which an effluent limitation is now specified pursuant to sections 401 and 402 of the Act is named together with test descriptions and references in Table I. The discharge parameter values for which reports are required must be determined by one of the standard analytical methods cited and described in Table I, or under certain circumstances by other methods that may be more advantageous to use when such other methods have been previously approved by the Regional Administrator of the Region in which the discharge will occur, and providing that the Director of the State in which such discharge will occur does not object to the use of such alternate test procedures.

Under certain circumstances the Regional Administrator or the Director in the Region or State where the discharge will occur may determine for a particular discharge that additional parameters or pollutants must be reported. Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator or Director upon the recommendation of the Director of the Methods Development and Quality Assurance Research Laboratory.

TABLE I—LIST OF APPROVED TEST PROCEDURES

Parameter and units	Method	References		
		Standard methods	ASTM	EPA methods
General analytical methods:				
1. Alkalinity as $CaCO_3$ mg $CaCO_3$/liter.	Titration: electrometric, manual or automated method—methyl orange.	p. 370	p. 143	p. 6. p. 8.
2. B.O.D. five day mg/liter.	Modified winkler or probe method	p. 489		
3. Chemical oxygen demand (C.O.D.) mg/liter.	Dichromate reflux	p. 495	p. 219	p. 17.
4. Total solids mg/liter	Gravimetric 103-105° C	p. 535		p. 280.
5. Total dissolved (filterable) solids mg/liter.	Glass fiber filtration 180° C			p. 275.
6. Total suspended (nonfilterable) solids mg/liter.	Glass fiber filtration 103-105° C	p. 537		p. 278.
7. Total volatile solids mg/liter.	Gravimetric 550° C	p. 536		p. 282.
8. Ammonia (as N) mg/liter.	Distillation—nesslerization or titration automated phenolate.			p. 134. p. 141.
9. Kjeldahl nitrogen (as N) mg/liter.	Digestion + distillation—nesslerization or titration utomated digestion phenolate.	p. 469		p. 149. p. 157.
10. Nitrate (as N) mg/liter.	Cadmium reduction; brucine sulfate; automated cadmium or hydrazine reduction.	p. 458 p. 461	p. 124	p. 170. p. 175. p. 185.
11. Total phosphorus (as P) mg/liter.	Persulfate digestion and single reagent (ascorbic acid), or manual digestion, and automated single reagent or stannous chloride.	p. 526 p. 532	p. 42	p. 235. p. 246. p. 259.
12. Acidity mg $CaCO_3$/liter	Electrometric end point or phenolphthalein end point.		p. 148	
13. Total organic carbon (TOC) mg/liter.	Combustion—infrared method [1]	p. 257	p. 702	p. 221.
14. Hardness—total mg $CaCO_3$/liter.	EDTA titration; automated colorimetric atomic absorption.	p. 179	p. 170	p. 76. p. 78.
15. Nitrite (as N) mg/liter.	Manual or automated colorimetric diazotization.			p. 185. p. 195.
Analytical methods for trace metals:				
16. Aluminum—total [3] mg/liter.	Atomic absorption	p. 210		p. 98.
17. Antimony—total [3] mg/liter.	Atomic absorption [4]			
18. Arsenic—total mg/liter.	Digestion plus silver diethyldithiocarbamate; atomic absorption.[3]	p. 65 p. 62		p. 13.
19. Barium—total [3] mg/liter.	Atomic absorption [4]	p. 210		
20. Beryllium—total [3] mg/liter.	Aluminon; atomic absorption	p. 67 p. 210		
21. Boron—total mg/liter	Curcumin	p. 69		
22. Cadmium—total [3] mg/liter.	Atomic absorption; colorimetric	p. 210 p. 422	p. 692	p. 101.
23. Calcium—total [3] mg/liter.	EDTA titration; atomic absorption	p. 84	p. 692	p. 102.
24. Chromium VI mg/liter.	Extraction and atomic absorption; colorimetric.	p. 429		p. 94.
25. Chromium—total [3] mg/liter.	Atomic absorption; colorimetric	p. 210 p. 426	p. 692 p. 403	p. 104.
26. Cobalt—total [3] mg/liter.	Atomic absorption [4]		p. 692	
27. Copper—total [3] mg/liter.	Atomic absorption; colorimetric	p. 210 p. 430	p. 692 p. 410	p. 106.
28. Iron—total [3] mg/liter	do	p. 210 p. 433	p. 692 p. 152	p. 108.
29. Lead—total [3] mg/liter	do	p. 210 p. 436	p. 692	p. 110.
30. Magnesium—total [3] mg/liter.	Atomic absorption; Gravimetric	p. 210 p. 416 p. 201	p. 692	p. 112.
31. Manganese—total [3] mg/liter.	Atomic absorption	p. 210	p. 692	p. 114.
32. Mercury—total mg/liter.	Flameless atomic absorption [5]			
33. Molybdenum—total [3] mg/liter.	Atomic absorption [4]			
34. Nickel—total [3] mg/liter.	Atomic absorption; colorimetric [4]	p. 443	p. 692	
35. Potassium—total [3] mg/liter.	Atomic absorption; colorimetric; flame photometric.	p. 283 p. 285	p. 326	p. 115.
36. Selenium—total mg/liter.	Atomic absorption [3]			
37. Silver—total [3]	Atomic absorption [4]	p. 210		
38. Sodium—total [3] mg/liter.	Flame photometric; atomic absorption	p. 317	p. 326	p. 118.
39. Thallium—total [3] mg/liter.	Atomic absorption [4]			
40. Tin—total [3] mg/liter	do			
41. Titanium—total mg/liter.	do			
42. Vanadium—total [3] mg/liter.	Atomic Absorption; [4] Colorimetric	p. 157		
43. Zinc—total [3] mg/liter	Atomic Absorption; Colorimetric	p. 210 p. 444	p. 692	p. 120.
Analytical methods for nutrients, anions, and organics:				
44. Organic nitrogen (as N) mg/liter.	Kjeldahl nitrogen minus ammonia nitrogen.	p. 468		p. 149.
45. Ortho-phosphate (as P) mg/liter.	Direct single reagent; automated single reagent or stannous chloride.	p. 532	p. 42	p. 235. p. 246. p. 259.
46. Sulfate (as SO_4) mg/liter.	Gravimetric; turbidimetric; automated colorimetric—barium chloranilate.	p. 331 p. 334	p. 51 p. 52	p. 286. p. 288.
47. Sulfide (as S) mg/liter	Titrimetric—iodine	p. 551		p. 294.
48. Sulfite (as SO_3) mg/liter.	Titrimetric; iodide-iodate	p. 337	p. 261	
49. Bromide mg/liter	do		p. 216	
50. Chloride mg/liter	Silver nitrate; mercuric nitrate; automated colorimetric-ferricyanide.	p. 96 p. 97	p. 23 p. 21	p. 29. p. 31.
51. Cyanide—total mg/liter.	Distillation—silver nitrate titration or pyridine pyrazolone colorimetric.	p. 397	p. 556	p. 41.
52. Fluoride mg/liter	Distillation—SPADNS	p. 171 p. 174	p. 191	p. 64.
53. Chlorine—total residual mg/liter.	Colorimetric; amperometric titration	p. 382	p. 223	
54. Oil and grease mg/liter	Liquid-Liquid extraction with trichloro-trifluoroethane.	p. 254		
55. Phenols mg/liter	Colorimetric, 4 AAP	p. 502	p. 445	p. 232.
56. Surfactants mg/liter	Methylene blue colorimetric	p. 339	p. 619	p. 131.
57. Algicides mg/liter	Gas chromatography [6]			
58. Benzidine mg/liter	Diazotization—colorimetric [7]			
59. Chlorinated organic compounds (except pesticides) mg/liter.	Gas chromatography [6]			
60. Pesticides mg/liter	Gas chromatography [6]			
Analytical methods for physical and biological parameters:				
61. Color platinum-cobalt units or dominant wave-length, hue, luminance, purity.	Colorimetric; spectrophotometric	p. 160 p. 392		p. 38.
62. Specific conductance mho/cm at 25° C.	Wheatstone bridge	p. 323	p. 163	p. 284.
63. Turbidity Jackson units.	Turbidimeter	p. 350	p. 467	p. 308.

See Note at end of Table I

Parameter and units	Method	References		
		Standard methods	ASTM	EPA methods
64. Fecal streptococci bacteria number/100 ml.	MPN; membrane filter; plate count	p. 689 p. 690 p. 691		
65. Coliform bacteria (fecal) number/100 ml.	MPN: Membrane filter	p. 669 p. 684		
66. Coliform bacteria (total) number/100 ml.	do	p. 664 p. 679		
Radiological parameters:				
67. Alpha—total pCi/liter	Proportional counter; scintillation counter	p. 598	p. 509	
68. Alpha—counting error pCi/liter.	do	p. 598	p. 512	
69. Beta—total pCi/liter	Proportional counter†	p. 598	p. 478	
70. Beta—counting error pCi/liter.	do	p. 598	p. 478	
71. Radium—total pCi/liter.	Proportional counter; scintillation counter	p. 611 p. 617	p. 674	

[1] A number of such systems manufactured by various companies are considered to be comparable in their performance. In addition, another technique, based on Combustion-Methane Detection, is also acceptable.

[2] For the determination of total metals the sample is not filtered before processing. Choose a volume of sample appropriate for the expected level of metals. If much suspended material is present, as little as 50–100 ml of well-mixed sample will most probably be sufficient. (The sample volume required may also vary proportionally with the number of metals to be determined.)

Transfer a representative aliquot of the well-mixed sample to a Griffin beaker and add 3 ml of concentrated distilled HNO_3. Place the beaker on a hotplate and evaporate to dryness making certain that the sample does not boil. Cool the beaker and add another 3 ml portion of distilled concentrated HNO_3. Cover the beaker with a watch glass and return to the hotplate. Increase the temperature of the hotplate so that a gentle reflux action occurs. Continue heating, adding additional acid as necessary until the digestion is complete, generally indicated by a light colored residue. Add (1:1 with distilled water) distilled concentrated HCl in an amount sufficient to dissolve the residue upon warming. Wash down the beaker walls and the watch glass with distilled water and filter the sample to remove silicates and other insoluble material that could clog the atomizer. Adjust the volume to some predetermined value based on the expected metal concentrations. The sample is now ready for analysis. Concentrations so determined shall be reported as "total".

[3] See D. C. Manning, "Technical Notes", Atomic Absorption Newsletter, Vol. 10, No. 6 p. 123, 1971. Available from Perkin-Elmer Corporation, Main Avenue, Norwalk, Connecticut 06852.

[4] Atomic absorption method available from Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, USEPA, Cincinnati, Ohio 45268.

[5] For updated method, see: Journal of the American Water Works Association 64, No. 1, pp. 20–25 (Jan. 1972) or ASTM Method D 3223–73, American Society for Testing and Materials Headquarters, 1916 Race St., Philadelphia, Pa. 19103.

[6] Interim procedures for algicides, chlorinated organic compounds, and pesticides can be obtained from the Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, USEPA, Cincinnati, Ohio 45268.

[7] Benzidine may be estimated by the method of M.A. El-Dib, "Colorimetric Determination of Aniline Derivatives in Natural Waters", El-Dib, M.A., Journal of the Association of Official Analytical Chemists, Vol. 64, No. 6, Nov., 1971, pp. 1383–1387.

†As a prescreening measurement.

§ 136.4 Application for alternate test procedures.

(a) Any person may apply to the Regional Administrator in the Region where the discharge occurs for approval of an alternative test procedure.

(b) When the discharge for which an alternative test procedure is proposed occurs within a State having a permit program approved pursuant to section 402 of the Act, the applicant shall submit his application to the Regional Administrator through the Director of the State agency having responsibility for issuance of NPDES permits within such State.

(c) Unless and until printed application forms are made available, an application for an alternate test procedure may be made by letter in triplicate. Any application for an alternate test procedure under this subchapter shall:

(1) Provide the name and address of the responsible person or firm making the discharge (if not the applicant) and the applicable ID number of the existing or pending permit, issuing agency, and type of permit for which the alternate test procedure is requested, and the discharge serial number.

(2) Identify the pollutant or parameter for which approval of an alternate testing procedure is being requested.

(3) Provide justification for using testing procedures other than those specified in Table I.

(4) Provide a detailed description of the proposed alternate test procedure, together with references to published studies of the applicability of the alternate test procedure to the effluents in question.

§ 136.5 Approval of alternate test procedures.

(a) The Regional Administrator of the region in which the discharge will occur has final responsibility for approval of any alternate test procedure.

(b) Within thirty days of receipt of an application, the Director will forward such application, together with his recommendations, to the Regional Administrator. Where the Director recommends rejection of the application for scientific and technical reasons which he provides, the Regional Administrator shall deny the application, and shall forward a copy of the rejected application and his decision to the Director of the State Permit Program and to the Director of the Methods Development and Quality Assurance Research Laboratory.

(c) Before approving any application for an alternate test procedure, the Regional Administrator shall forward a copy of the application to the Director of the Methods Development and Quality Assurance Laboratory for review and recommendation.

(d) Within ninety days of receipt by the Regional Administrator of an application for an alternate test procedure, the Regional Administrator shall notify the applicant and the appropriate State agency of approval or rejection, or shall specify the additional information which is required to determine whether to approve the proposed test procedure. Prior to the expiration of such ninety day period, a recommendation providing the scientific and other technical basis for acceptance or rejection will be forwarded to the Regional Administrator by the Director of the Methods Development and Quality Assurance Research Laboratory. A copy of all approval and rejection notifications will be forwarded to the Director, Methods Development and Quality Assurance Research Laboratory, for the purposes of national coordination.

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federal register

WEDNESDAY, DECEMBER 1, 1976

PART II:

ENVIRONMENTAL PROTECTION AGENCY

■

WATER PROGRAMS

Guidelines Establishing Test Procedures for the Analysis of Pollutants

Amendments

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

[FRL 630-4]

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Amendment of Regulations

On June 9, 1975, proposed amendments to the Guidelines Establishing Test Procedures for the Analysis of Pollutants (40 CFR 136) were published in the FEDERAL REGISTER (40 FR 24535) as required by section 304(g) of the Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816, et seq., Pub. L. 92-500, 1972) hereinafter referred to as the Act.

Section 304(g) of the Act requires that the Administrator shall promulgate guidelines establishing test procedures for the analysis of pollutants that shall include factors which must be provided in: (1) any certification pursuant to section 401 of the Act, or (2) any permit application pursuant to section 402 of the Act. Such test procedures are to be used by permit applicants to demonstrate that effluent discharges meet applicable pollutant discharge limitations and by the States and other enforcement activities in routine or random monitoring of effluents to verify compliance with pollution control measures.

Interested persons were requested to submit written comments, suggestions, or objections to the proposed amendments by September 7, 1975. One hundred and thirty-five letters were received from commenters. The following categories of organizations were represented by the commenters: Federal agencies accounted for twenty-four responses; State agencies accounted for twenty-six responses; local agencies accounted for seventeen responses; regulated major dischargers accounted for forty-seven responses; trade and professional organizations accounted for eight responses; analytical instrument manufacturers and vendors accounted for seven responses; and analytical service laboratories accounted for six responses.

All comments were carefully evaluated by a technical review committee. Based upon the review of comments, the following principal changes to the proposed amendments were made:

(A) *Definitions*. Section 136.2 has been amended to update references: Twenty commenters, representing the entire spectrum of responding groups pointed out that the references cited in §§ 136.2 (f), 136.2(g), and 136.2(h) were out-of-date; §§ 136.2(f), 136.2(g), and 136.2(h), respectively, have been amended to show the following editions of the standard references: "14th Edition of Standard Methods for the Examination of Water and Waste Water;" "1974 EPA Manual of Methods for the Analysis of Water and Waste;" and "Part 31, 1975 Annual Book of ASTM Standards."

(B) *Identification of Test Procedures*. Both the content and format of § 136.3, "Table I, List of Approved Test Procedures" have been revised in response to twenty-one comments received from State and local governments, major regulated dischargers, professional and trade associations, and analytical laboratories.

Table I has been revised by:

(1) The addition of a fourth column of references which includes procedures of the United States Geological Survey which are equivalent to previously approved methods.

(2) The addition of a fifth column of miscellaneous references to procedures which are equivalent to previously approved methods.

(3) Listing generically related parameters alphabetically within four subcategories: bacteria, metals, radiological and residue, and by listing these subcategory headings in alphabetic sequence relative to the remaining parameters.

(4) Deleting the parameter "Algicides" and by entering the single relevant algicide, "Pentachlorophenol" by its chemical name.

(C) *Clarification of Test Parameters*. The conditions for analysis of several parameters have been more specifically defined as a result of comments received by the Agency:

(1) In response to five commenters representing State or local governments, major dischargers, or analytical instrument manufacturers, the end-point for the alkalinity determination is specifically designated as pH 4.5.

(2) Manual digestion and distillation are still required as necessary preliminary steps for the Kjeldahl nitrogen procedure. Analysis after such distillation may be by Nessler color comparison, titration, electrode, or automated phenolate procedures.

(3) In response to eight commenters representative of Federal and State governments, major dischargers, and analytical instrument manufacturers, manual distillation at pH 9.5 is now specified for ammonia measurement.

(D) *New Parameters and Analytical Procedures*. Forty-four new parameters have been added to Table I. In addition to the designation of analytical procedures for these new parameters, the following modifications have been made in analytical procedures designated in response to comments.

(1) The ortho-tolidine procedure was not approved for the measurement of residual chlorine because of its poor accuracy and precision. Its approval had been requested by seven commenters representing major dischargers, State, or local governments, and analytical instrument manufacturers. Instead, the N,N-diethyl-p-phenylenediamine (DPD) method is approved as an interim procedure pending more intensive laboratory testing. It has many of the advantages of the ortho-tolidine procedure such as low cost, ease of operation, and also is of acceptable precision and accuracy.

(2) The Environmental Protection Agency concurred with the American Dye Manufacturers' request to approve its procedure for measurement of color, and copies of the procedure are now available at the Environmental Monitoring and Support Laboratory, Cincinnati (EMSL-CI).

(3) In response to three requests from Federal, State governments, and dischargers, "hardness," may be measured as the sum of calcium and magnesium analyzed by atomic absorption and expressed as their carbonates.

(4) The proposal to limit measurement of fecal coliform bacteria in the presence of chlorine to only the "Most Probable Number" (MPN) procedure has been withdrawn in response to requests from forty-five commenters including State pollution control agencies, permit holders, analysts, treatment plant operators, and a manufacturer of analytical supplies. The membrane filter (MF) procedure will continue to be an approved technique for the routine measurement of fecal coliform in the presence of chlorine. However, the MPN procedure must be used to resolve controversial situations. The technique selected by the analyst must be reported with the data.

(5) A total of fifteen objections, representing the entire spectrum of commenters, addressed the drying temperatures used for measurement of residues. The use of different temperatures in drying of total residue, dissolved residue and suspended residue was cited as not allowing direct intercomparability between these measurements. Because the intent of designating the three separate residue parameters is to measure separate waste characteristics (low drying temperatures to measure volatile substances, high drying temperatures to measure anhydrous inorganic substances), the difference in drying temperatures for these residue parameters must be preserved.

(E) *Deletion of Measurement Techniques*. Some measurement techniques that had been proposed have been deleted in response to objections raised during the public comment period.

(1) The proposed infrared spectrophotometric analysis for oil and grease has been withdrawn. Eleven commenters representing Federal or State agencies and major dischargers claimed that this parameter is defined by the measurement procedure. Any alteration in the procedure would change the definition of the parameter. The Environmental Protection Agency agreed.

(2) The proposed separate parameter for sulfide at concentrations below 1 mg/l, has been withdrawn. Methylene blue spectrophotometry is now included in Table I as an approved procedure for sulfide analysis. The titrimetric iodine procedure for sulfide analysis may only be used for analysis of sulfide at concentrations in excess of one milligram per liter.

(F) *Sample Preservation and Holding Times*. Criteria for sample preservation and sample holding times were requested by several commenters. The reference for sample preservation and holding time criteria applicable to the Table I parameters is given in footnote (1) of Table I.

(G) *Alternate Test Procedures*. Comments pertaining to § 136.4, Application for Alternate Test Procedures, included objections to various obstacles within these procedures for expeditious approval of alternate test procedures. Four analytical instrument manufacturers commented that by limiting of application for review and/or approval of alternate test procedures to NPDES permit holders, § 136.4 became an impediment to the commercial development of new or improved measurement devices based on new measurement principles. Applications for such review and/or approval will now be accepted from any person. The intent of the alternate test procedure is to allow the use of measurement systems which are known to be equivalent to the approved test procedures in waste water discharges.

Applications for approval of alternate test procedures applicable to specific discharges will continue to be made only by NPDES permit holders, and approval of such applications will be made on a case-by-case basis by the Regional Administrator in whose Region the discharge is made.

Applications for approval of alternate test procedures which are intended for nationwide use can now be submitted by any person directly to the Director of the Environmental Monitoring and Support Laboratory in Cincinnati. Such applications should include a complete methods write-up, any literature references, comparability data between the proposed alternate test procedure and those already approved by the Administrator. The application should include precision and accuracy data of the proposed alternate test procedure and data confirming the general applicability of the test procedure to the industrial categories of waste water for which it is intended. The Director of the Environmental Monitoring and Support Laboratory, after review of submitted information, will recommend approval or rejection of the application to the Administrator, or he will return the application to the applicant for more information. Approval or rejection of applications for test procedures intended for nationwide use will be made by the Administrator, after considering the recommendation made by the Director of the Environmental Monitoring and Support Laboratory, Cincinnati. Since the Agency considers these procedures for approval of alternate test procedures for nationwide use to be interim procedures, we will welcome suggestions for criteria for approval of alternate test procedures for nationwide use. Interested persons should submit their written comments in triplicate on or before June 1, 1977 to: Dr. Robert B. Medz, Environmental Protection Technologist, Monitoring Quality Assurance Standardization, Office of Monitoring and Technical Support (RD-680), Environmental Protection Agency, Washington, D.C. 20460.

(H) *Freedom of Information.* A copy of all public comments, an analysis by parameter of those comments, and documents providing further information on the rationale for the changes made in the final regulation are available for inspection and copying at the Environmental Protection Agency Public Information Reference Unit, Room 2922, Waterside Mall, 401 M Street, SW., Washington, D.C. 20460, during normal business hours. The EPA information regulation 40 CFR 2 provides that a reasonable fee may be charged for copying such documents.

Effective date: These amendments become effective on April 1, 1977.

Dated: November 19, 1976.

JOHN QUARLES,
Acting Administrator,
Environmental Protection Agency.

Chapter I, Subchapter D, of Title 40, Code of Federal Regulations is amended as follows:

1. In § 136.2, paragraphs (f), (g), and (h) are amended to read as follows:

§ 136.2 Definitions.

* * * * *

(f) "Standard Methods" means *Standard Methods for the Examination of Water and Waste Water,* 14th Edition, 1976. This publication is available from the American Public Health Association, 1015 18th Street, N.W., Washington, D.C. 20036.

(g) "ASTM" means *Annual Book of Standards, Part 31, Water, 1975.* This publication is available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

(h) "EPA Methods" means *Methods for Chemical Analysis of Water and Waste, 1974.* Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, Cincinnati, Ohio 45268; U.S. Environmental Protection Agency, Office of Technology Transfer, Industrial Environmental Research Laboratory, Cincinnati, Ohio 45268. This publication is available from the Office of Technology Transfer.

2. In § 136.3, the second sentence of paragraph (b) is amended, and a new paragraph (c) is added to read as follows:

§ 136.3 Identification of test procedures.

* * * * *

(b) * * * Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator or the Director upon the recommendation of the Director of the Environmental Monitoring and Support Laboratory, Cincinnati.

(c) Under certain circumstances, the Administrator may approve, upon recommendation by the Director, Environmental Monitoring and Support Laboratory, Cincinnati, additional alternate test procedures for nationwide use.

3. Table I of § 136.3 is revised by listing the parameters alphabetically; by adding 44 new parameters; by adding a fourth column under references listing equivalent United States Geological Survey methods; by adding a fifth column under references listing miscellaneous equivalent methods; by deleting footnotes 1 through 7 and adding 24 new footnotes, to read as follows:

* * * * *

TABLE I.—*List of approved test procedures*[1]

Parameter and units	Method	References (page nos.): 1974 EPA methods	14th ed. standard methods	Pt. 31 1975 ASTM	USGS methods[2]	Other approved methods
1. Acidity, as $CaCO_3$, milligrams per liter.	Electrometric end point (pH of 8.2) or phenolphthalein end point.	1	273(4d)	116	40	[3](607)
2. Alkalinity, as $CaCO_3$, milligrams per liter.	Electrometric titration (only to pH 4.5) manual or automated, or equivalent automated methods.	3 5	278	111	41	[3](607)
3. Ammonia (as N), milligrams per liter.	Manual distillation[4] (at pH 9.5) followed by nesslerization, titration, electrode, Automated phenolate.	 159 165 168	410 412 616	 237	 116	 [3](614)
BACTERIA						
4. Coliform (fecal)[5], number per 100 ml.	MPN;[6] membrane filter		922 937		 [7](45)	
5. Coliform (fecal)[5] in presence of chlorine, number per 100 ml.	do.[6 8]		922 926, 937			
6. Coliform (total),[5] number per 100 ml.	do.[6]		916 928		 [7](35)	
7. Coliform (total)[5] in presence of chlorine, number per 100 ml.	MPN;[6] membrane filter with enrichment.		916 933			
8. Fecal streptococci,[5] number per 100 ml.	MPN;[6] membrane filter; plate count.		943 944 947		 [7](50)	
9. Benzidine, milligrams per liter.	Oxidation—colorimetric[9]					
10. Biochemical oxygen demand, 5-d (BOD_5), milligrams per liter.	Winkler (Azide modification) or electrode method.		543		[7](50)	 [10](17)
11. Bromide, milligrams per liter.	Titrimetric, iodine-iodate	14		323	58	
12. Chemical oxygen demand (COD), milligrams per liter.	Dichromate reflux	20	550	472	124	[8](610) [10](17)
13. Chloride, milligrams per liter.	Silver nitrate; mercuric nitrate; or automated colorimetric-ferricyanide.	 29 31	303 304 613	267 265	 [11](46)	 [8](615)

See footnotes at end of table.

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.) Pt. 31 1975 ASTM	USGS methods [9]	Other approved methods
14. Chlorinated organic compounds (except pesticides), milligrams per liter.	Gas chromatography [12]					
15. Chlorine—total residual, milligrams per liter.	Iodometric titration, amperometric or starch-iodine end-point; DPD colorimetric or Titrimetric methods (these last 2 are interim methods pending laboratory testing).	35	318 322 332 329	278		
16. Color, platinum cobalt units or dominant wave length, hue, luminance, purity.	Colorimetric; spectrophotometric; or ADMI procedure.[13]	36 39	64 66		82	
17. Cyanide, total,[14] milligrams per liter.	Distillation followed by silver nitrate titration or pyridine pyrazolone (or barbituric acid) colorimetric.	40	361	503	85	[10](22)
18. Cyanide amenable to chlorination, milligrams per liter.	do	49	376	505		
19. Dissolved oxygen, milligrams per liter.	Winkler (Azide modification) or electrode method.	51 56	443 450	368	126	[3](609)
20. Fluoride, milligrams per liter.	Distillation [4] followed by ion electrode; SPADNS; or automated complexone.	65 59 61	389 391 393 614	307 305	93	
21. Hardness—Total, as $CaCO_3$, milligrams per liter.	EDTA titration; automated colorimetric; or atomic absorption (sum of Ca and Mg as their respective carbonates).	68 70	202	161	94	[3](617)
22. Hydrogen ion (pH), pH units.	Electrometric measurement.	239	460	178	129	[3](606)
23. Kjeldahl nitrogen (as N), milligrams per liter.	Digestion and distillation followed by nesslerization, titration, or electrode; automated digestion automated phenolate.	175 165 182	437		122	[3](612)
METALS						
24. Aluminum—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Eriochrome Cyanine R).	92	152 171		[11] (19)	
25. Aluminum—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced methods for total aluminum.					
26. Antimony—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	94				
27. Antimony—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total antimony.					
28. Arsenic—Total, milligrams per liter.	Digestion followed by silver diethyldithiocarbamate; or atomic absorption.[16] [18]	9 95	285 283 159		[11] (31) [11] (37)	
29. Arsenic—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total arsenic.					
30. Barium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	97	152		52	
31. Barium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total barium.					
32. Beryllium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Aluminon).	99	152 177		53	
33. Beryllium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total beryllium.					
34. Boron—Total, milligrams per liter.	Colorimetric (Curcumin)	13	287			
35. Boron—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total boron.					
36. Cadmium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	101	148 182	345	62	[3] (619) [10] (37)
37. Cadmium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total cadmium.					
38. Calcium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption; or EDTA titration.	103	148 189	345	66	
39. Calcium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total calcium.					
40. Chromium VI, milligrams per liter.	Extraction and atomic absorption; colorimetric (Diphenylcarbazide).	89, 105	192		76 75	
41. Chromium VI—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for chromium VI.					
42. Chromium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Diphenylcarbazide).	105	148 192	345 286	78 77	[3] (619)
43. Chromium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total chromium.					

See footnotes at end of table.

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.) Pt. 31 1975 ASTM	References (page nos.) USGS methods [2]	Other approved methods
44. Cobalt—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	107	148	345	80	[10] (37)
45. Cobalt—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total cobalt.					
46. Copper—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Neocuproine).	108	148 196	345 293	83	[3] (619) [16] (37)
47. Copper—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total copper.					
48. Gold—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
49. Iridium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
50. Iron—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Phenanthroline).	110	148 208	345 326	102	[3] (619)
51. Iron—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total iron.					
52. Lead—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	112	148 215	345	105	[3] (619)
53. Lead—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total lead.					
54. Magnesium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption; or gravimetric.	114	148 221	345	109	[3] (619)
55. Magnesium—Dissolved milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total magnesium.					
56. Manganese—Total milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Persulfate or periodate).	116	148 225, 227	345	111	[3] (619)
57. Manganese—Dissolved milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total manganese.					
58. Mercury—Total, milligrams per liter.	Flameless atomic absorption.	118	156	338	[11] (51)	
59. Mercury—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total mercury.					
60. Molybdenum—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	139		350		
61. Molybdenum—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total molybdenum.					
62. Nickel—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Heptoxime).	141	148	345	115	
63. Nickel—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total nickel.					
64. Osmium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
65. Palladium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
66. Platinum—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
67. Potassium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption, colorimetric (Cobaltinitrite), or by flame photometric.	143	235 234	403	134	[3] (620)
68. Potassium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total potassium.					
69. Rhodium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
70. Ruthenium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[19]					
71. Selenium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[18] [19]	145	159			
72. Selenium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total selenium.					
73. Silica—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by colorimetric (Molybdosilicate).	274	487	398	139	
74. Silver—Total,[20] milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	146	148 243		142	[3](619) [10](37)
75. Silver—Dissolved,[20] milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total silver.					
76. Sodium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption or by flame photometric.	147	250	403	148	[3] (621)
77. Sodium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total sodium.					

See footnotes at end of table.

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.) Pt. 31 1975 ASTM	USGS methods [2]	Other approved methods
78. Thallium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	149				
79. Thallium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total thallium.					
80. Tin—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	150			[11] (65)	
81. Tin—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total tin.					
82. Titanium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	151				
83. Titanium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total titanium.					
84. Vanadium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Gallic acid).	153	152 260	 441	 [11] (67)	
85. Vanadium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total vanadium.					
86. Zinc—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	155	148 265	345	159	[3](619) [10](37)
87. Zinc—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total zinc.					
88. Nitrate (as N), milligrams per liter.	Cadmium reduction; brucine sulfate; automated cadmium or hydrazine reduction.[21]	201 197 207	423 427 620	 358	 119	 [3](614) [10](28)
89. Nitrate (as N), milligrams per liter.	Manual or automated colorimetric (Diazotization).	215	434		121	
90. Oil and grease, milligrams per liter.	Liquid-liquid extraction with trichloro-trifluoroethane-gravimetric.	229	515			
91. Organic carbon; total (TOC), milligrams per liter.	Combustion—Infrared method.[22]	236	532	467	[22] (4)	
92. Organic nitrogen (as N), milligrams per liter.	Kjeldahl nitrogen minus ammonia nitrogen.	175, 159	437		122	[3] (612, 614)
93. Orthophosphate (as P), milligrams per liter.	Manual or automated ascorbic acid reduction.	249 256	481 624	384	131	[3] (621)
94. Pentachlorophenol, milligrams per liter.	Gas chromatography [12]					
95. Pesticides, milligrams per liter.	do.[12]		555	529	[23] (24)	
96. Phenols, milligrams per liter	Colorimetric, (4AAP)	241	582	545		
97. Phosphorus (elemental), milligrams per liter.	Gas chromatography [24]					
98. Phosphorus; total (as P), milligrams per liter.	Persulfate digestion followed by manual or automated ascorbic acid reduction.	249 256	476, 481 624	384	133	[3] (621)
RADIOLOGICAL						
99. Alpha—Total, pCi per liter	Proportional or scintillation counter.		648	591	[11,25](75+78)	
100. Alpha—Counting error, pCi per liter.	do.		648	594	[11] (79)	
101. Beta—Total, pCi per liter	Proportional counter		648	601	[11,22](75+78)	
102. Beta—Counting error, pCi per liter.	do.		648	606	[11] (79)	
103. (a) Radium—Total, pCi per liter.	do.		661	661		
(b) [226] Ra, pCi per liter	Scintillation counter		667		[11] (81)	
RESIDUE						
104. Total, milligrams per liter	Gravimetric, 103 to 105° C	270	91			
105. Total dissolved (filterable), milligrams per liter.	Glass fiber filtration, 180° C.	266	92			
106. Total suspended (nonfilterable), milligrams per liter.	Glass fiber filtration, 103 to 105° C.	268	94			
107. Settleable, milliliters per liter or milligrams per liter.	Volumetric or gravimetric		95			
108. Total volatile, milligrams per liter.	Gravimetric, 550° C	272	95			
109. Specific conductance, micromhos per centimeter at 25° C.	Wheatstone bridge conductimetry.	275	71	120	148	[3] (606)
110. Sulfate (as SO_4), milligrams per liter.	Gravimetric; turbidimetric; or automated colorimetric (barium chloranilate).	 277 279	493 496	424 425		[3] (624) [3] (623)
111. Sulfide (as S), milligrams per liter.	Titrimetric—Iodine for levels greater than 1 mg per liter; Methylene blue photometric.	284	505 503		154	
112. Sulfite (as SO_3), milligrams per liter.	Titrimetric, iodine-iodate	285	508	435		
113. Surfactants, milligrams per liter.	Colorimetric (Methylene blue).	157	600	494	[23] (11)	
114. Temperature, degrees C	Calibrated glass or electrometric thermometer.	286	125		[24] (31)	
115. Turbidity, NTU	Nephelometric	295	132	223	156	

[1] Recommendations for sampling and preservation of samples according to parameter measured may be found in "Methods for Chemical Analysis of Water and Wastes, 1974" U.S. Environmental Protection Agency, table 2, pp. viii xii.

[2] All page references for USGS methods, unless otherwise noted, are to Brown, E., Skougstad, M. W., and Fishman, M. J., "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," U.S. Geological Survey Techniques of Water-Resources Inv., book 5, ch. A1, (1970).

[3] EPA comparable method may be found on indicated page of "Official Methods of Analysis of the Association of Official Analytical Chemists" methods manual, 12th ed. (1975).

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

[5] The method used must be specified.

[6] The 5 tube MPN is used.

[7] Slack, K. V. and others, "Methods for Collection and Analysis of Aquatic Biological and Mircobiological Samples: U.S. Geological Survey Techniques of Water-Resources Inv. book 5, ch. A4 (1973)."

[8] Since the membrane filter technique usually yields low and variable recovery from chlorinated wastewaters, the MPN method will be required to resolve any controversies.

[9] Adequately tested methods for benzidine are not available. Until approved methods are available, the following interim method can be used for the estimation of benzidine: (1) "Method for Benzidine and Its Salts in Wastewaters," available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

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

[11] Fishman, M. J. and Brown, Eugene, "Selected Methods of the U.S. Geological Survey for Analysis of Wastewaters," (1976) open-file report 76-177.

[12] Procedures for pentachlorophenol, chlorinated organic compounds ,and pesticides can be obtained from the Environmental Monitoring and Support Lbaoratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[13] Color method (ADMI procedure) available from Environmental Monitoring and Support Lbaoratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[14] For samples suspected of having thiocyanate interference, magnesium chloride is used as the digestion catalyst. In the approved test procedure for cyanides, the recommended catalysts are replaced with 20 ml of a solution of 510 g/l magnesium chloride ($MgCl_2 \cdot 6H_2O$). This substitution will eliminate thiocyanate interference for both total cyanide and cyanide amendable to chlorination measurements.

[15] For the determination of total metals the sample is not filtered before processing. Because vigorous digestion procedures may result in a loss of certain metals through preciptation, a less vigorous treatment is recommended as given on p. 83 (4.1.4) of "Methods for Chemical Analysis of Water and Wastes" (1974). In those instances where a more vigorous digestion is desired the procedure on p. 82 (4.1.3) should be followed. For the measurement of the noble metal series (gold, iridium, osmium, palladium, platimum, rhodium and ruthenium), an aqua regia digestion is to be substituted as follows: Transfer a representitive aliquot of the well-mixed sample to a Griffin beaker and add 3 ml of concentrated redistilled HNO_3. Place the beaker on a steam bath and evaporate to dryness. Cool the beaker and cautiously add a 5 ml portion of aqua regia. (Aqua regia is prepared immediately before use by carefully adding 3 volumes of concentrated HCl to one volume of concentrated HNO_3.) Cover the beaker with a watch glass and return to the steam bath. Continue heating the covered beaker for 50 min. Remove cover and evaporate to dryness. Cool and take up the residue in a small quantity of 1:1 HCl. Wash down the beaker walls and watch glass with distilled water and filter the sample to remove silicates and other insoluble material that could clog the atomizer. Adjust the volm e to some predetermined value based on the expected metal concentration. The sample is now ready for analysis.

[16] As the various furnace devices (flameless AA) are essentially atomic absorption techniques, they are considered to be approved test methods. Methods of standard addition are to be followed as noted in p. 78 of "Methods for Chemical Analysis of Water and Wastes," 1974.

[17] Dissolved metals are defined as those constitutents which will pass though a 0.45 μm membrane filter. A prefiltration is permissible to free the sample from larger suspended solids. Filter the sample as soon as practical after collection using the first 50 to 100 ml to rinse the filter flask. (Glass or plastic filtering apparatus are recommended to avoid possible contamination.) Discard the portion used to rinse the flask and collect the required volume of filtrate. Acidify the filtrate with 1:1 redistilled HNO_3 to a pH of 2. Normally, 3 ml of (1:1) acid per liter should be sufficient to preserve the samples.

[18] See "Atomic Absorption Newsletter," vol. 13, 75 (1974). Available from Perkin-Elmer Corp., Main Ave., Norwalk, Conn. 06852.

[19] Method available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

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

[21] An automated hydrazine reduction method is available from the Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[22] A number of such systems manufactured by various companies are considered to be comparable in their performance. In addition, another technique, based on combustion-methane detection is also acceptable.

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

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

[25] The method found on p. 75 measures only the dissolved portion while the method on p. 78 measures only suspended. Therefore, the 2 results must be added together to obtain "total."

[26] Stevens, H. H., Ficke, J. F., and Smoot, G. F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation: U.S. Geological Survey Techniques of Water Resources Inv., book 1 (1975)."

4. In § 136.4, the second sentence of paragraph (c) is amended by deleting the word "subchapter" immediately following the phrase "procedure under this" and immediately preceding the word "shall" and replaced with the phrase "paragraph c;" and § 136.4 is amended by adding a new paragraph (d) to read as follows:

§ 136.4 Application for alternate test procedures.

* * * * *

(c) * * * Any application for an alternate test procedure under this paragraph (c) shall: * * *

(d) An application for approval of an alternate test procedure for nationwide use may be made by letter in triplicate to the Director, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. Any application for an alternate test procedure under this paragraph (d) shall:

(1) Provide the name and address of the responsible person or firm making the application.

(2) Identify the pollutant(s) or parameter(s) for which nationwide approval of an alternate testing procedure is being requested.

(3) Provide a detailed description of the proposed alternate procedure, together with references to published or other studies confirming the general applicability of the alternate test procedure to the pollutant(s) or parameter(s) in waste water discharges from representative and specified industrial or other categories.

(4) Provide comparability data for the performance of the proposed alternate test procedure compared to the performance of the approved test procedures.

§ 136.5 [Amended]

5. In § 136.5, paragraph (a) is amended by inserting the phrase "proposed by the responsible person or firm making the discharge" immediately after the words "test procedure" and before the period that ends the paragraph.

6. In § 136.5, paragraph (b) is amended by inserting in the first sentence the phrase "proposed by the responsible person or firm making the discharge" immediately after the words "such application" and immediately before the comma. The second sentence of paragraph (b) is amended by deleting the phrase "Methods Development and Quality Assurance Research Laboratory" immediately after the phrase "State Permit Program and to the Director of the" at the end of the sentence, and inserting in its place the phrase "Environmental Monitoring and Support Laboratory, Cincinnati."

7. In § 136.5, paragraph (c) is amended by inserting the phrase "proposed by the responsible person or firm making the discharge" immediately after the phrase "application for an alternate test procedure" and immediately before the comma; and by deleting the phrase "Methods Development and Quality Assurance Laboratory" immediately after the phrase "application to the Director of the" and immediately before the phrase "for review and recommendation" and inserting in its place the phrase "Environmental Monitoring and Support Laboratory, Cincinnati."

8. In § 136.5, the first sentence of paragraph (d) is amended by inserting the phrase, "proposed by the responsible person or firm making the discharge," immediately after the phrase, "application for an alternate test procedure," and immediately before the comma.

The second sentence of paragraph (d) is amended by deleting the phrase, "Methods Development and Quality Assurance Research Laboratory," immediately after the phrase, "to the Regional Administrator by the Director of the," and immediately preceding the period ending the sentence and inserting in its place the phrase, "Environmental Monitoring and Support Laboratory, Cincinnati."

The third sentence of paragraph (d) is amended by deleting the phrase, "Methods Development and Quality Assurance Research Laboratory," immediately after the phrase, "forwarded to the Director," and immediately before the second comma and by inserting in its place the phrase, "Environmental Monitoring and Support Laboratory, Cincinnati."

9. Section 136.5 is amended by the addition of a new paragraph (e) to read as follows:

§ 136.5 Approval of alternate test procedures.

* * * * *

(e) Within ninety days of the receipt by the Director of the Environmental Monitoring and Support Laboratory, Cincinnati of an application for an alternate test procedure for nationwide use, the Director of the Environmental Monitoring and Support Laboratory, Cincinnati shall notify the applicant of his recommendation to the Administrator to approve or reject the application, or shall specify additional information which is required to determine whether to approve the proposed test procedure. After such notification, an alternate method determined by the Administrator to satisfy the applicable requirements of this part shall be approved for nationwide use to satisfy the requirements of this subchapter; alternate test procedures determined by the Administrator not to meet the applicable requirements of this part shall be rejected. Notice of these determinations shall be submitted for publication in the FEDERAL REGISTER not later than 15 days after such notification and determination is made.

[FR Doc.76-35032 Filed 11-30-76;8:45 am]

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Amendment of Regulations; Corrections

In FR Doc. 76-35032 appearing at pages 52780 to 52786 in the FEDERAL REGISTER of Wednesday, December 1, 1976, the following changes should be made:

§ 136.3 [Amended]

1. On Page 52783, for parameter number 62, Nickel—Total, add "232" to the page references in the column under the 14th edition of Standard Methods opposite the colorimetric method designation.

2. On page 52784, for parameter number 89, change the parameter designation from "Nitrate" to "Nitrite."

3. On page 52784, for parameter number 96, Phenols, delete the present method designation, "Colorimetric, (4AAP)," and replace it with the method designation, "Distillation followed by colorimetric, (4AAP)"; delete the page reference in the column under the 14th edition of Standard Methods, "582," and replace it with page number "574".

Dated. January 10, 1977.

WILSON K. TALLEY,
Assistant Administrator for Research and Development.

[FR Doc.77-1453 Filed 1-17-77;8:45 am]

APPENDIX E

DOCUMENTATION FOR SYNOPTIC RAINFALL DATA ANALYSIS PROGRAM - SYNOP

E.1 Introduction

An integral part of the assessment of storm loads on water quality, is the statistical evaluation of rainfall records. Hourly rainfall records of many years duration are cumbersome and difficult to analyze. Tools to summarize the variables of interest (volume, duration, intensity, and time between storms) are needed to determine seasonal trends which are of importance in assessing impacts and selecting control alternatives for storm related loads. The purpose of the SYNOP rainfall data analysis program is to provide the user with a tool for summarizing and statistically characterizing a rainfall record of interest. Copies of the Synoptic Rainfall Data Analysis Program (SYNOP) with sample rainfall tapes and documentation can be obtained at a modest cost from:

National Technical Information Service
Office of Computer Products
5285 Port Royal Road
Springfield, Virginia 22161

E.2 Description

Hourly rainfall data is obtained for a minimum of five years of record to provide sufficient confidence in the rainfall characterization. Longer term records covering many years are preferable and are usually available from U.S. Weather Bureau Stations.

The hourly data are then summarized by storm events, each with an associated unit volume (V, inches), duration (D, hours), average intensity (I = V/D, inches/hour), and time since the previous storm (Δ, hours) measured from the midpoint of the successive storms. A storm definition must be established to determine when, in the hourly record, a storm begins and ends. Program SYNOP delineates storm events as rainfall periods separated by a minimum number of consecutive hours without rainfall. The recommended number of hours without rainfall is 3 hours.

The statistics of relevant storm parameters are then computed. The mean and the coefficient of variation of each parameter are determined: the mean is the arithmetic average; the coefficient of variation is defined as the standard deviation divided by the mean. The parameters of interest are storm intensity, duration, unit volume and time between storms. At the end of each year, a histogram is produced showing the amount of rainfall for each hour of the year.

After the complete period of record has been read, the following operations are performed on duration, D, intensity, I, volume, V, and delta, Δ:

1. Statistics by month
2. Plot of average and standard deviation by month
3. Statistics by year
4. Plot of average and standard deviation by year
5. Percent of occurrences less than or equal to the given value (and associated plot)
6. Return period in years and associated plot.

E.3 Input Structure

The usual method for transmitting rainfall data is via magnetic tape. SYNOP has been written assuming that the data is aligned on a U.S. Weather Bureau tape in chronological order within each station. There is no logical separation between stations and a tape marker appears at the end of a file. Sometimes, depending on the retrieval system used to generate the tapes, stations are divided by time periods among several tape files. The various possibilities have been accounted for by the several fields that appear on the control card. For each station, at least one control card is needed for each tape file. The user concludes his input deck with a card containing a /* in columns 1 and 2.

E.3.1 Control Card Description

6	8	10	15	20	25	30	35	41	(Ending Col. Nos.)
ISTA	IRQYR	IRWD	STMDF	ISKIP	IPAUS	IDISM	ICNST	TAPEN	

FORMAT (A6, A2, I2, 5I5, 3A2)

ISTA = desired station number (station number is defined by the U.S. Weather Bureau)

IRQYR = last 2 digits of year number where execution is to begin. If left blank, then the execution will begin at the first hourly rainfall record.

IRWD = 0, begin search immediately (used for initial search)
1, rewind tape before beginning search (used as required in subsequent searches)

STMDF = storm definition, number of consecutive hours without rainfall which indicates the end of a storm (3 hours is recommended)

ISKIP = 0, print hourly rainfall data
1, skip printing hourly rainfall data

IPAUS = 0, indicates that data for the requested station will end after the present tape file has been read.
1, indicates that more data for the requested station is expected after the present tape file has been read. The program will pause to allow the operator to change tapes if necessary.

IDISM = 0, no rewind after the present tape file has been read.
1, rewind and dismount tape after file has been read.
IDISM = 1 for last analysis on a tape.

ICNST = 0, data for the requested station begins with the current tape.
1, data for the requested station is being continued from a previous tape file.

TAPEN = next tape number to be mounted (is printed on the console typewriter as an operator instruction).

In the example shown in Table E-1, 2 stations are requested, Station 410016 appears on 4 tape files (thus requiring 4 control cards) and Station 052220 appears on only one tape file. A brief explanation of this data input follows.

Card Number	Explanation
1	Station 410016; rewind tape before beginning search; 3 consecutive dry hours define end of storm; print hourly data; pause after reading tape file because more data is expected; rewind after tape file has been read; data for 410016 begins with this tape file; next tape is W1036.
2	Station 410016; starting in 1962; rewind tape before search begins; 3 consecutive dry hours end storm; print hourly data; pause after reading tape file because more data is expected; rewind after tape file has been read; this is a continuation of Station 410016; next tape is W3375.
3	Same as 2, but do not rewind after station has been read and start at first hourly rainfall record. Note that the next tape to be mounted is W3375 (the same as the present tape). No rewinding is done since the next set of data is on the next file on the same tape.
4	Begin in 1974; do not rewind tape before search begins; 3 consecutive dry hours end each storm; print hourly data; end of station will be recognized after this tape file has been read; rewind tape after tape file has been read; this is a continuation of Station 410016.
5	Station 052220; rewind tape before beginning search; 3 consecutive dry hours define the end of storm; print hourly data; end of station after this tape file has been read.
6	End of input data deck.

TABLE E-1

INPUT STRUCTURE FOR PROGRAM SYNOP

Card No.	ISTA (Columns 1–6)	IRQYR (Columns 7–8)	IRWD (Column 10)	STMDF (Columns 11–15)	ISKIP (Column 20)	IPAUS (Column 25)	IDISM (Column 30)	ICNST (Column 35)	TAPEN (Columns 36–41)
1	410016		1	3	0	1	1	0	W1036
2	410016	62	1	3	0	1	1	1	W3375
3	410016		1	3	0	1	0	1	W3375
4	410016	74	0	3	0	0	1		
5	052220		1	3	0	0	0		
6	/*								

E.4 Source Listing of Program SYNOP

Program SYNOP is written in FORTRAN IV, Level G for IBM 1130 compatible computer systems. Minor changes in the coding of input-output functions will facilitate its use on other computer systems. The program nominally uses a high speed printer, a disk drive, a magnetic tape drive, and a card reader.

This section presents a flow chart of the SYNOP program and a complete listing of the FORTRAN source code. Section E.5 presents an example execution of program SYNOP.

E.4.1 Flow Chart For Program SYNOP

A flow chart for program SYNOP is presented on the following two pages.

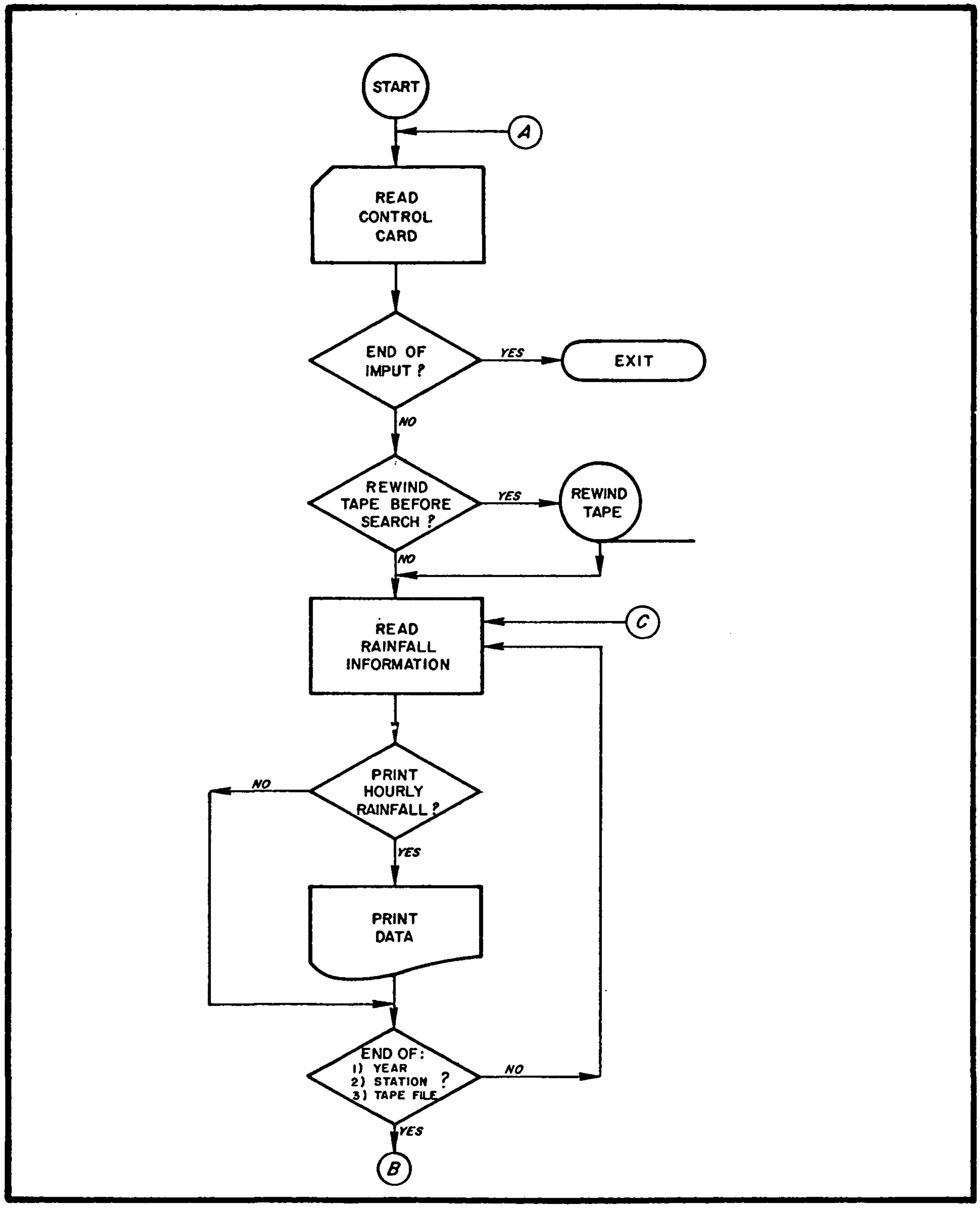


FIGURE E-1

FLOW CHART FOR PROGRAM 'SYNOP'

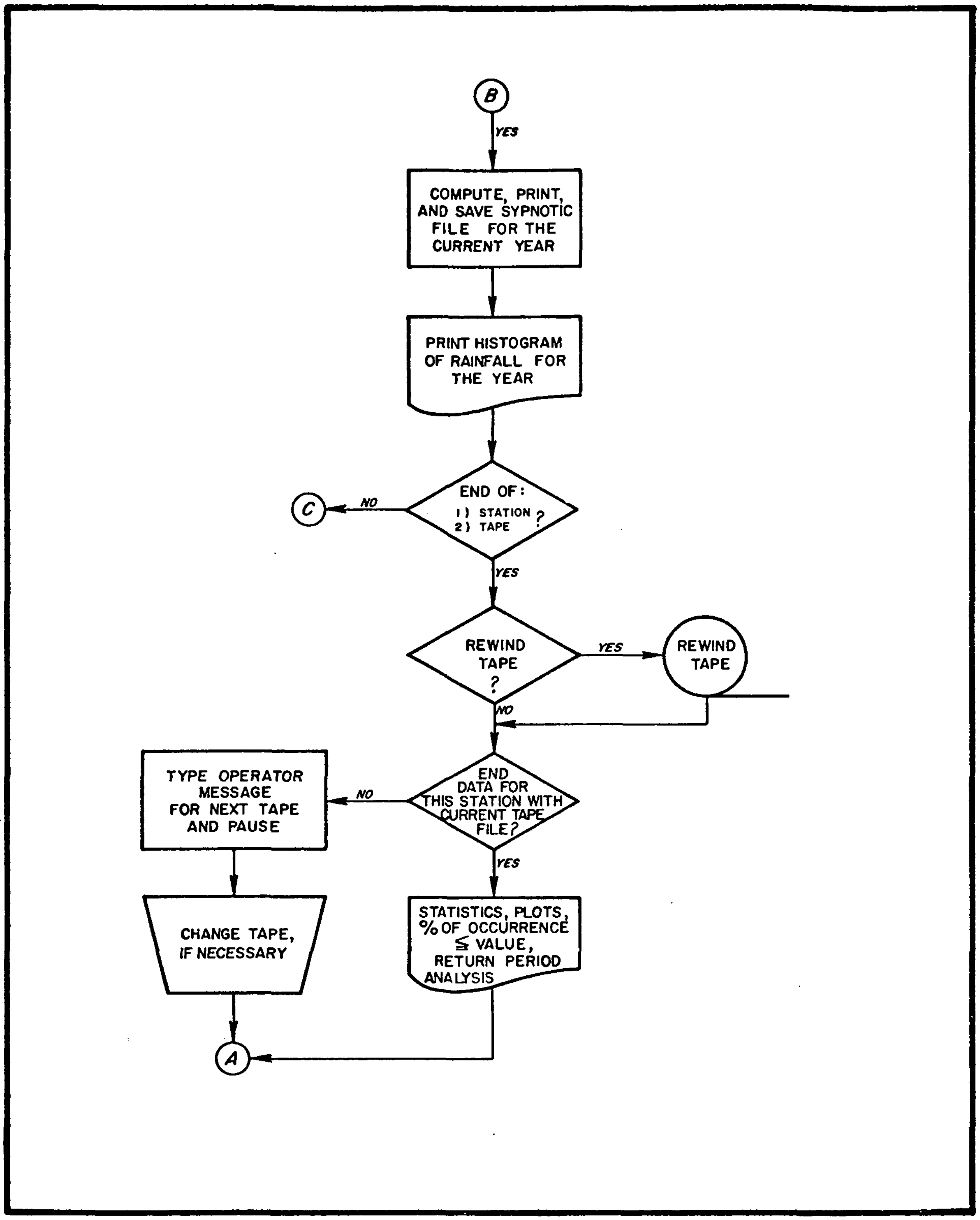


FIGURE E-1 (CONT'D.)

FLOW CHART FOR PROGRAM 'SYNOP'

E.4.2 Source Listing for Program SYNOP

```
C              ***** SUBROUTINE COAD2 *****
C
      SUBROUTINE COAD2 (X,Y,XMAX,XMIN,YMAX,YMIN,NTOT,NPLT,NLINE,NXSPA,
     1ICODE,INOSK,ISIDE,ISYM)
C
C     THIS SUBROUTINE WILL PLOT UP TO 10 SIMULTANEOUS PLOTS ON THE SAME
C     GRAPH
C     IT WILL ALSO PLOT 2 GRAPHS SIDE BY SIDE IF ISIDE IS SET EQUAL TO 1
C
C     X=ARRAY OF X'S (1-DIMENSIONAL ARRAY, FIRST NTOT REPRESENT X1, SECOND
C     NTOT REPRESENT X2, ETC.)
C     Y=ARRAY OF Y'S (1-DIMENSIONAL ARRAY, FIRST NTOT REPRESENT Y1, SECOND
C     NTOT REPRESENT Y2, ETC.)
C     WHEN USING THE OPTION TO PLOT 2 GRAPHS SIDE BY SIDE, THEN INPUT
C     THE X'S AND Y'S AS FOLLOWS...
C     THE FIRST NTOT(1)*NPLT(1) ARE FOR THE LEFT GRAPH AND THE NEXT NTOT(2)
C     *NPLT(2) ARE FOR THE RIGHT GRAPH
C     XMAX=MAXIMUM VALUE IN X-DIRECTION
C     XMIN=MINIMUM VALUE IN X DIRECTION
C     YMAX=MAXIMUM VALUE IN Y-DIRECTION
C     YMIN=MINIMUM VALUE IN Y-DIRECTION
C     NTOT=NUMBER OF POINTS PER PLOT
C     NPLT=NUMBER OF PLOTS
C     THERE IS A XMAX, XMIN, YMAX, YMIN,NTOT, NPLT FOR EACH GRAPH IF 2 ARE
C     BEING USED
C     NLINE=NUMBER OF LINES IN Y-DIRECTION
C     NXSPA=NUMBER OF SPACES IN THE X-DIRECTION FOR EACH GRAPH
C     ICODE=0 IF ONLY ONE SET OF X'S ARE TO BE PLOTTED
C     ICODE=1 IF MORE THAN ONE SET OF X'S ARE TO PLOTTED
C     NOTE--EXCEPT WHEN ICODE IS 0, DIMENSION X AND Y BY NTOT*NPLT IN THE
C     MAINLINE.
C     WHEN ICODE=0, DIMENSION Y BY NTOT*NPLT, AND X BY NTOT IN THE MAINLINE.
C     INOSK=OPTION NOT TO SKIP TO A NEW PAGE EACH TIME COIPL IS CALLED.
C                    INOSK=0--SKIP TO A NEW PAGE
C                    INOSK=1--DO NOT SKIP TO A NEW PAGE
C     ISIDE DETERMINES WHETHER 1 OR 2 GRAPHS WILL BE PLACED SIDE BY SIDE
C         ISIDE=0..1 PLOT ON PAGE
C         ISIDE=1..2 ADJACENT GRAPHS WILL BE PLOTTED
C
C     ISYM=VECTOR OF SUBSCRIPTS CORRESPONDING TO SYMBOLS TO BE PLOTTED
C     FOR EACH OBSERVATION
C     TABLE OF CORRESPONDING SYMBOLS--
C
C     NUM SYMB       NUM SYMB       NUM SYMB       NUM SYMB       NUM SYMB       NUM SYMB
C       1   1          9   9         17   G         25   O         33   W         41   $
C       2   2         10   0         18   H         26   P         34   X         42   )
C       3   3         11   A         19   I         27   Q         35   Y         43   (
C       4   4         12   B         20   J         28   R         36   Z         44
C       5   5         13   C         21   K         29   S         37   .         45   '
C       6   6         14   D         22   L         30   T         38   *         46   +
C       7   7         15   E         23   M         31   U         39   ,         47   -
C       8   8         16   F         24   N         32   V         40   /
      DIMENSION X(1),Y(1),IY(51)
      DIMENSION XMAX(2),XMIN(2),YMAX(2),YMIN(2),XSCAL(2),YSCAL(2),E(2)
      DIMENSION  YVAL(2),IC(10,2),NTOT(2),NPLT(2),ICODE(2)
      DIMENSION ABC(20),       IX(102),FSCAL(11),IA(48),ISYM(1)
      DATA IB/' '/,JX/20*'J'/,ABC/20*'....'/
```

```
      DATA IA/'1','2','3','4','5','6','7','8','9','0','A','B','C','D','E
     1','F','G','H','I','J','K','L','M','N','O','P','Q','R','S','T','U',
     2'V','W','X','Y','Z','.','*',',','/','$',')','(',20544,32064,'+',
     3'-',' '/
      IO=5
C             SET ARRAY  IC  DIMENSIONED 10 X 2 EQUAL TO 1
      CALL SETIA(IC,10,2,1)
      DO 16 I=1,2
C             CALCULATE INTERVAL BETWEEN PRINT POSITIONS ON X-AXIS AND
C             BETWEEN LINES ON Y-AXIS
      XSCAL(I)=(XMAX(I)-XMIN(I))/FLOAT(NXSPA)
      YSCAL(I)=(YMAX(I)-YMIN(I))/FLOAT(NLINE)
C             E=HALF THE INTERVAL IN THE Y-DIRECTION (EPSILON)
   16 E(I)=YSCAL(I)/2.
C             NGRTO=NUMBER OF POINTS X NUMBER OF PLOTS.  GRAND TOTAL
C             OF THE NUMBER OF POINTS ON THE LEFT SIDE GRAPH.
      NGRTO=NTOT(1)*NPLT(1)
C             CHECK IF NEW PAGE IS DESIRED
      IF (INOSK .NE. 1) WRITE (IO,202)
  202 FORMAT (1H1)
C             LXSPA=NUMBER OF 5-SPACES ON X-AXIS
    1 LXSPA=NXSPA/5
C             PRINT OUT TOP BOARDER
      WRITE(IO,203) (ABC(I),IX(I),I=1,LXSPA)
  203 FORMAT (13X,'I',20(A4,A1))
C             CHECK IF TWO GRAPHS SIDE BY SIDE ARE DESIRED
      IF (ISIDE-1) 84,15,84
C             IF THEY ARE, PRINT TOP BOARDER FOR RIGHT GRAPH.
   15 WRITE(IO,205)(ABC(I),IX(I),I=1,LXSPA)
  205 FORMAT (1H+,67X,'I',10(A4,A1))
   84 IXSPA=NXSPA+1
      KXSPA=NXSPA+2
      NLIN=NLINE+1
C             M2=NUMBER OF SIDE BY SIDE GRAPHS
      M2=1+ISIDE
      DO 13 K=1,NLIN
C             SET OUTPUT LINE TO BLANKS
      CALL SETIA(IX,102,1,IB)
C             SET RIGHT SIDE OF LINE TO BLANKS
      CALL SETIA(IY,51,1,IB)
C             SET LAST ELEMENT OF LINE TO AN  'I'
      IX(KXSPA)=-14016
      IF (ISIDE-1) 88,87,88
C             IF SIDE BY SIDE IS CHOSEN, SET LAST ELEMENT OF RIGHT SIDE
C             TO AN  'I'
   87 IY(KXSPA)=-14016
   88 DO 18 M=1,M2
C             YVAL=VALUE OF CURRENT POSITION ALONG Y-AXIS.  (BEGINNING
C             AT TOP OF THE GRAPH WITH A VALUE OF  YMAX  AND DECREASING
C             BY A VALUE OF  YSCAL  FOR EACH LINE)
      YVAL(M)=YMAX(M)-(K-1)*YSCAL(M)
C             NP=NUMBER OF PLOTS ON THIS SIDE
      NP=NPLT(M)
C             NT=NUMBER OF POINTS ON THIS SIDE
      NT=NTOT(M)
C             4 LOOP IS FOR EACH PLOT
      DO 4 I=1,NP
```

```
C             11 LOOP IS FOR EACH POINT
      DO 11 KQ=1,NT
C             CHECK IF COUNTER FOR THIS PLOT EXCEEDS NUMBER OF POINTS
C             FOR THIS PLOT
      IF(IC(I,M)-NT)  20,20,4
C             IF NOT, SET  J  EQUAL TO CURRENT COUNTER VALUE
   20 J=IC(I,M)
C             I1=SUBSCRIPT OF CURRENT POINT
      I1=J+(I-1)*NTOT(M)+NGRTO*(M-1)
C             TEST=DIFFERENCE BETWEEN Y VALUE OF CURRENT POINT AND CUR-
C             RENT Y POSITION
      TEST   =ABS(Y(I1)-YVAL(M))
C             IF TEST IS LESS THAN OR EQUAL TO EPSILON, THIS POINT IS TO
C             BE PLOTTED ON CURRENT LINE
      IF(TEST-E(M)-1.E-6) 12,12,3
C             IF TEST IS GREATER THAN EPSILON, SEE IF Y-VALUE OF CURRENT
C             POINT IS GREATER THAN CURRENT Y POSITION
    3 IF( Y(I1)-YVAL(M))  4,4,5
C             IT IS GREATER, THEREFORE INCREASE COUNTER AND GO TO NEXT
C             POINT
    5 IC(I,M) = IC(I,M)+1
      GO TO 11
C             TEST INDICATES THE POINT IS TO BE PLOTTED ON THIS LINE
C             I2=CORRESPONDING SUBSCRIPT IN X-DIRECTION
   12 I2=J+(I-1)*NTOT(M)*ICODE(M)+NGRTO*(M-1)
C             UPDATE COUNTER
      IC(I,M) = IC(I,M)+1
C             IPOS=POSITION ALONG X-AXIS
      IPOS=(X(I2)-XMIN(M))/XSCAL(M)+1.5
C             IF  IPOS  IS LESS THAN 0 OR GREATER THAN THE NUMBER OF
C             POSITIONS IN THE X-DIRECTION, THEN DON'T PLOT IT
      IF( IPOS.GT.IXSPA.OR.IPOS.LE.0 )   GO TO 11
      IF (M-1) 33,33,32
   33 IF (INOSK .NE. 2) IAI=ISYM(I1)
      IF (INOSK .EQ. 2) IAI=38
      IX(IPOS)=IA(IAI)
      GO TO 11
   32 IAI=ISYM(I1)
      IY(IPOS)=IA(IAI)
   11 CONTINUE
    4 CONTINUE
   18 CONTINUE
      IF (ISIDE-1) 34,35,34
   34 WRITE(IO,200)YVAL(1),(IX(J),J=1,KXSPA)
  200 FORMAT (1X,F10.3,' I',102A1)
      GO TO 13
   35 WRITE(IO,206)YVAL(1),(IX(J),J=1,KXSPA)
  206 FORMAT (1X,F10.3,' I',43A1)
      WRITE(IO,207)YVAL(2),(IY(J),J=1,KXSPA)
  207 FORMAT (1H+,55X,F10.3,' I',42A1)
   13 CONTINUE
      DO 10 I=1,20
   10 IX(I)=-14016
      WRITE(IO,203)(ABC(I),IX(I),I=1,LXSPA)
      IF (ISIDE-1) 38,39,38
   39 WRITE(IO,205)(ABC(I),IX(I),I=1,LXSPA)
   38 KXSPA=NXSPA/10+1
```

```
      DO 17 M=1,M2
      I2=KXSPA*M
      I1=I2-KXSPA+1
      DO 17 I=I1,I2
   17 FSCAL(I)=XMIN(M)+(I-1-(M-1)*KXSPA)*XSCAL(M)*10.
      WRITE(IO,204) (FSCAL(J),J=1,KXSPA)
  204 FORMAT (6X,11F10.2)
      IF (ISIDE-1) 60,43,60
   43 WRITE(IO,210)(FSCAL(J),J=I1,I2)
  210 FORMAT (1H+,60X,5F10.2)
   60 RETURN
      END
C
C
C              ***** SUBROUTINE DAIDA *****
C
      SUBROUTINE DAIDA(IDAYN,MONTH,DAY,YEAR)
      INTEGER MOS(12),MONTH,DAY,YEAR
      DATA MOS/31,0,31,30,31,30,31,31,30,31,30,31/
      IDATE=0
      DO 10 YEAR=1,99
      NDAYY=365
      IF (YEAR/4*4 .EQ. YEAR) NDAYY=366
      IDATE=IDATE+NDAYY
      IF (IDATE .GE. IDAYN) GO TO 20
   10 CONTINUE
   20 IDATE=IDATE-NDAYY
      MOS(2)=28
      IF (YEAR/4*4 .EQ. YEAR) MOS(2)=29
      DO 30 MONTH=1,12
      IDATE=IDATE+MOS(MONTH)
      IF (IDATE .GE. IDAYN) GO TO 40
   30 CONTINUE
   40 NDAYM=MOS(MONTH)
      IDATE=IDATE-NDAYM
      DO 50 DAY=1,NDAYM
      IDATE=IDATE+1
      IF (IDATE .GE. IDAYN) RETURN
   50 CONTINUE
      RETURN
      END
C
C
C              ***** SUBROUTINE SHELL *****
C
C     SHELL SORT
C     REFERENCES..
C         D.A.SHELL, CACM, VOL 2 (1959), PP 30..32
C         T.N. HIBBERD, SDC RPEORT SP-982
C         J.ROOTHROYD, CACM, ALGORITHM 201
C     THIS IS A FORTRAN VERSION OF ALGORITHM 201.
      SUBROUTINE SHELL (IA,N,NROW,NCOL,JK,ID)
C     IA=INPUT ARRAY TO BE ARRANGED
C     N=NUMBER OF ELEMENTS (FILLED ROWS) IN IA
C     NROW=NUMBER OF ROWS IN IA
C     NCOL=NUMBER OF COLUMNS IN IA
C     JK=ARRAY CONTAINING HIERARCHY OF COLUMNS TO DETERMINE
```

```
C              FINAL ARRANGEMENT OF IA (JK(LAST+1)=0)
C     ID=ARRAY IN 1 OT 1 CORRESPONDANCE WITH JK TO DETERMINE DIRECTION OF
C              SORT.  ID=1...ASCENDING
C                     ID=2...DESCENDING
      DIMENSION IA(1),ID(1),JK(1)
      INTEGER ITES1*4,ITES2*4
C     FIND M=ONE LESS THAN LEAST POWER OF 2.GT.N
      M=0
   10 M=M+M+1
      IF (M-N) 10,20,20
C  20 OUTER LOOP, .HALVE M.
   20 M=M/2
C     TEST FOR END OF OUTER LOOP.
      IF (M) 70,70,30
C  30 FIND LIMIT FOR MIDDLE LOOP
   30 K=N-M
C     BEGIN MIDDLE LOOP
      DO 60 J=1,K
C     SETUP FOR INNER LOOP
      I=J
C  40 MIDDLE AND INNER LOOP . . COMPARE.
   40 L=I+M
      LJ=1
   23 IAD=NROW*(JK(LJ)-1)
      L1=L+IAD
      I1=I+IAD
      IDEC=ID(LJ)
      ITES2=IA(L1)
      ITES1=IA(I1)
      GO TO (21,22),IDEC
   21 IF (ITES1-ITES2) 60,61,50
   22 IF (ITES1-ITES2) 50,61,60
   61 LJ=LJ+1
      IF (JK(LJ)) 60,60,23
C  50 NOT IN SEQUENCE, SO SWAP
   50 DO 80 IP=1,NCOL
      NROCO=NROW*(IP-1)
      NI=NROCO+I
      NL=NROCO+L
      ITEMP=IA(NI)
      IA(NI)=IA(NL)
   80 IA(NL)=ITEMP
C     GO DOWN INNER LOOP . . ONLY IF SWAP
      I=I-M
C     TEST FOR END OF INNER LOOP
      IF (I) 60,60,40
C  60 END OF INNER AND MIDDLE LOOP.
   60 CONTINUE
      GO TO 20
C  70 SORT COMPLETE
   70 RETURN
      END
C
C
C              ***** SUBROUTINE SHELR *****
C
C     SHELL SORT
```

```
C      REFERENCES..
C          D.A.SHELL, CACM, VOL 2 (1959), PP 30..32
C          T.N. HIBBERD, SDC RPEORT SP-982
C          J.ROOTHROYD, CACM, ALGORITHM 201
C      THIS IS A FORTRAN VERSION OF ALGORITHM 201.
       SUBROUTINE SHELR ( A,N,NROW,NCOL,JK,ID)
C       A=INPUT ARRAY TO BE ARRANGED
C      N=NUMBER OF ELEMENTS (FILLED ROWS) IN  A
C      NROW=NUMBER OF ROWS IN  A
C      NCOL=NUMBER OF COLUMNS IN  A
C      JK=ARRAY CONTAINING HIERARCHY OF COLUMNS TO DETERMINE
C               FINAL ARRANGEMENT OF  A (JK(LAST+1)=0)
C      ID=ARRAY IN 1 OT 1 CORRESPONDANCE WITH JK TO DETERMINE DIRECTION OF
C              SORT.  ID=1...ASCENDING
C                     ID=2...DESCENDING
       DIMENSION  A(1),ID(1),JK(1)
C      FIND M=ONE LESS THAN LEAST POWER OF 2.GT.N
       M=0
   10  M=M+M+1
       IF (M-N) 10,20,20
C  20  OUTER LOOP. .HALVE M.
   20  M=M/2
C      TEST FOR END OF OUTER LOOP.
       IF (M) 70,70,30
C  30  FIND LIMIT FOR MIDDLE LOOP
   30  K=N-M
C      BEGIN MIDDLE LOOP
       DO 60 J=1,K
C      SETUP FOR INNER LOOP
       I=J
C  40  MIDDLE AND INNER LOOP . . COMPARE.
   40  L=I+M
       LJ=1
   23  IAD=NROW*(JK(LJ)-1)
       L1=L+IAD
       I1=I+IAD
       IDEC=ID(LJ)
       GO TO (21,22),IDEC
   21  IF ( A(I1)- A(L1)) 60,61,50
   22  IF ( A(I1)- A(L1)) 50,61,60
   61  LJ=LJ+1
       IF (JK(LJ)) 60,60,23
C  50  NOT IN SEQUENCE, SO SWAP
   50  DO 80 IP=1,NCOL
       NROCO=NROW*(IP-1)
       NI=NROCO+I
       NL=NROCO+L
        TEMP= A(NI)
        A(NI)= A(NL)
   80   A(NL)= TEMP
C      GO DOWN INNER LOOP . . ONLY IF SWAP
       I=I-M
C      TEST FOR END OF INNER LOOP
       IF (I) 60,60,40
C  60  END OF INNER AND MIDDLE LOOP.
   60  CONTINUE
       GO TO 20
```

```
C   70 SORT COMPLETE
    70 RETURN
       END
C
C
C               ***** FUNCTION IDATE *****
C
       FUNCTION IDATE(IDAY,MONTH,IYEAR)
       IDATE=IDAY
       JYEAR=IYEAR-1
       DO 300 I=1901,JYEAR
       IF((I/4)*4-I)100,200,100
  100  IDATE=IDATE+365
       GO TO 300
  200  IDATE=IDATE+366
  300  CONTINUE
       IF((IYEAR/4)*4-IYEAR)400,500,400
  400  IFEB=28
       GO TO 600
  500  IFEB=29
  600  GO TO (1,2,3,4,5,6,7,8,9,10,11,12),MONTH
  12   IDATE=IDATE+30
  11   IDATE=IDATE+31
  10   IDATE=IDATE+30
   9   IDATE=IDATE+31
   8   IDATE=IDATE+31
   7   IDATE=IDATE+30
   6   IDATE=IDATE+31
   5   IDATE=IDATE+30
   4   IDATE=IDATE+31
   3   IDATE=IDATE+IFEB
   2   IDATE=IDATE+31
   1   RETURN
       END
C
C
C               ***** SUBROUTINE SETIA *****
C
       SUBROUTINE SETIA (IARAY,NROW,NCOL,IVALU)
C               SET INTEGER ARRAY DIMENSIONED  NROW X NCOL  TO  IVALU
       INTEGER IARAY(1)
       NELEM=NROW*NCOL
       DO 10 I=1,NELEM
       IARAY(I)=IVALU
    10 CONTINUE
       RETURN
       END
C
C
C               ***** PROGRAM SYNOP *****
C
C
C
C               NOTE THAT ALL SOURCE CARDS DENOTED BY A '*' IN COLUMN 73
C                    ARE NEEDED TO ACCESS THE DSC/META 4 TAPE DRIVE AND
C                    SHOULD EITHER BE REPLACED OR ELIMINATED.  SUGGESTED
C                    REPLACEMENT STATEMENTS ASSUME THAT  99  IS SPECIFIED
```

```
C                    AS THE TAPE DEVICE CODE.
C
C
C
C
      INTEGER JK4(2)
      INTEGER JK3(2)
      INTEGER NSPAC(2),BLANK
      INTEGER ISTA(3),KEY(3800,3),JK1(3),JK2(3)
      INTEGER TITLE(5,4),NABRK(3,2)
      INTEGER ICOUN(13,22)
      INTEGER ICAR1(49)
      INTEGER YEAR,MONTH,DAY,CARD,RAIN(12),STA(6),PREST(6)
      INTEGER INPHR(366,27),DRY,WET,PRCON,STORM,MSTRM,DSTRM,YSTRM,HSTRM
      INTEGER DURAT,STMDF,DURLS,COND
      INTEGER IBUF(400)
      INTEGER ISAVE(9)
      INTEGER ISYM(100),TAPEN(3)
      INTEGER ANDGT
      REAL PLOT(60,3)
      REAL XVALU(3500,2)
      REAL Y2MAX(4)
      REAL X(30),Y(30,8),XMAX(2),XMIN(2),YMAX(4)
      REAL INTEN
      REAL RESVD(4),STAT(4,8)
      EQUIVALENCE (KEY(1,1),INPHR(1,1))
      EQUIVALENCE (XVALU(1,1),KEY(2,1))
      DATA JK1/1,3,0/,JK2/1,1,0/
      DATA JK3/2,0/
      DATA JK4/1,0/
      DATA DRY/2/,WET/1/
      DATA IAST/'**'/
      DATA XMIN/0.,40./,XMAX/12.,80./,NSPAC/60,80/,BLANK/'    '/
      DATA NABRK/' MONTH  YEAR'/
      DATA TITLE/'DURATION  INTENSITY VOLUME    DELTA      '/
      DATA ANDGT/Z506E/
      DEFINE FILE 89(10,40,U,LOC89)
      DEFINE FILE 98(12000,80,E,LOC98)
      DEFINE FILE 99(10,80,E,LOC99)
      IN=8
      IO=5
      ITYP=1
C
C             START TAPE AT SPECIFIED STATION
C
C     *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *
      LOC99=11                                              *
C     *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *
C
C
C             READ CONTROL CARD
C     ISTA=STATION NUMBER
C     IRQYR=LAST 2 DIGITS OF YEAR TO BEGIN ANALYSIS.  IF OMITTED, THEN
C           BEGIN AT FIRST HOURL RAINFALL RECORD
C     IRWD=CODE TO REWIND TAPE BEFORE SEARCH...0=DON'T REWIND, 1=REWIND
C     STMDF=NUMBER OF CONSECTIVE DRY HOURS THAT DEFINE THE END OF THE
C           STORM
C     ISKIP=CODE TO SKIP PRINTING OF HOURLY RAINFALL DATA.  0=PRINT,
```

```
C               1=DON'T PRINT
C         IPAUS=CODE TO PAUSE AFTER THIS STATION OR TAPE HAS BEEN READ.
C               0=END OF STATION AFTER THIS READ OF TAPE, 1=PAUSE-CONTINUE
C               STATION ON NEXT FILE OR NEXT TAPE.
C         IDISM=CODE TO REWIND (DISMOUNT) TAPE AFTER STATION OR TAPE HAS
C               BEEN READ.  0=DON'T REWIND, 1=REWIND
C         ICNST=CODE THAT INDICATES THAT STATION IS BEING CONTINUED FROM A
C               PREVIOUS TAPE OR FILE.  0=NEW STATION-START HERE, 1=CONTINUE
C         TAPEN=NUMBER OF NEXT TAPE TO BE MOUNTED.
      1 READ (IN,1020,END=999)ISTA,IRQYR,IRWD,STMDF,ISKIP,IPAUS,IDISM,
       .                         ICNST,TAPEN
C
C         *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *   * *
          CALL ENDGO                                                                     *
          GO TO 1
C         *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *   * *
C
C                 CHECK FOR REWINDING TAPE
C
C         *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *   * *
  9998    IF (IRWD .EQ. 1) CALL MAGTA(3,0)                                               *
          IRC01=1                                                                        *
          IF (IRWD .EQ. 1  .OR.  LOC99 .GT. 10) GO TO 2                                  *
          READ (89'1) IBUF                                                               *
          IRC01=LOC99                                                                    *
          GO TO 510                                                                      *
C                 READ A BLOCK OF TAPE                                                   *
      2   CALL MAGTA (0,0,400,IBUF(2))                                                   *
C                 CONVERT TO IBM 1130                                                    *
          CALL EXELM (400,IBUF)                                                          *
    510   DO 4 I=IRC01,10                                                                *
          K=40*(I-1)                                                                     *
C         *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *   * *
C                 REPLACE BY
C         IF (IRWD .EQ. 1) REWIND 99
C     2   READ (99,1030,END=1) (IBUF(J),J=1,4)
C1030     FORMAT (4A2)
C         K=0
C
          CALL DATSW(0,ISWO)
          IF (ISWO .EQ. 1) GO TO 210
C                 CHECK FIRST 6 CHARACTERS OF EACH RECORD FOR DESIRED
C                 STATION
             DO 3 J=1,3
             K=K+1
             IF(IBUF(K) .NE. ISTA(J)) GO TO 4
      3      CONTINUE
C                 IF REQUESTED YEAR EXISTS, CHECK THAT IT MATCHES
          IF (IRQYR .NE. BLANK  .AND.  IRQYR .NE. IBUF(4)) GO TO 4
C                 DESIRED STATION FOUND
C
C         *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *   * *
          WRITE (89'1) IBUF                                                              *
          CALL DEOF                                                                      *
          LOC99=I                                                                        *
C         *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *   * *
C                 REPLACE BY
```

```
C     BACKSPACE 99
C
      GO TO 5
    4 CONTINUE
      IRC01=1
      GO TO 2
    5 CONTINUE
C
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
C             SET UP FOR END-OF-TAPE MARKER                               *
      CALL ENDGO                                                          *
      GO TO 200                                                           *
 9999 CONTINUE                                                            *
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
C
C             RESET INITIAL CONDITIONS FOR NEW STATION
      IF (ICNST .EQ. 1) GO TO 8
      LOC98=1
      DURLS=0
      COND=DRY
      NDRY=0
      NDRHR=0
      VOLUM=0
      DURAT=0
      STORM=0
      NOYRS=0
    8 CONTINUE
      ILSTC=2
C             READ STATION NUMBER AND YEAR FROM NEXT RECORD
C
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
      READ (99'LOC99,1000) STA,NEWYR                                      *
      LOC99=LOC99-1                                                       *
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
C             REPLACE BY
C     READ(99,1000,END=200)STA,NEWYR
C     BACKSPACE 99
C
      NEWYR=NEWYR+1900
      DO 6 I=1,6
      PREST(I)=STA(I)
    6 CONTINUE
C             CLEAR THIS YEAR'S MATRIX
    7 CONTINUE
      CALL SETIA(INPHR,366,27,0)
C             COMPUTE STARTING DAY NUMBER FOR THIS YEAR
      IDAST=IDATE(0,1,NEWYR)
      WRITE (IO,2040)
      IPRN=0
   10 CONTINUE
C
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
C             CHECK IF NEXT BLOCK OF TAPE IS TO BE READ                   *
      IF (LOC99 .LE. 10) GO TO 11                                         *
C             READ A BLOCK OF TAPE                                        *
      CALL MAGTA (0,0,400,IBUF(2))                                        *
C             CONVERT TO IBM 1130 ARRAY CONVENTION                        *
```

```
      CALL EXELM (400,IBUF)                                                  *
      WRITE (89'1) IBUF                                                      *
      CALL DEOF                                                              *
      LOC99=1                                                                *
C             EACH BLOCK OF TAPE CONTAINS 10 RECORDS                         *
   11 CONTINUE                                                               *
      READ (99'LOC99,1000,END=200,ERR=30)STA,YEAR,MONTH,DAY,CARD,RAIN,       *
     .                                  IYRA2,IMOA2,IDYA2                    *
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C             REPLACE ABOVE BY
C     READ (99,1000,END=200,ERR=30)STA,YEAR,MONTH,DAY,CARD,RAIN,
C    .                                  IYRA2,IMOA2,IDYA2
C
      REREAD 1010,ICAR1
C
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C             SWITCH 0 UP WILL CAUSE PROGRAM TO BRANCH TO END OF STATION*
C                   ROUTINE                                              *
      CALL DATSW(0,ISW0)                                                     *
      IF (ISW0 .EQ. 1) GO TO 210                                             *
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C
      IF (CARD .NE. 1  .AND.  CARD .NE. 2) GO TO 30
C             CHECK FOR 2 CONSECTIVE CARD 1'S OR 2'S
      IF (CARD .NE. ILSTC) GO TO 14
C             PRINT LAST RECORD IF TWO CONSECUTIVE CARD 1
      IF (CARD .EQ. 1) WRITE (IO,2000) ISAVE,(INPHR(IDAY,I),I=1,24),IAST
C             PRINT AN ASTERISK IF 2 CONSECUTIVE CARD 2'S
      IF (CARD .EQ. 2) WRITE (IO,2200) IAST
C         CHECK FOR SAME STATION
   14 DO 16 I=1,6
      IF (STA(I) .NE. PREST(I)) GO TO 17
   16 CONTINUE
C             SAME STATION
      GO TO 19
C             NEW STATION-COMPUTE THE SYNOPTIC DATA FILE FOR THE YEAR
C                   JUST CONCLUDED
   17 IALT=1
      GO TO 40
C             CHECK FOR SAME YEAR
   19 YEAR=YEAR+1900
      IF (YEAR .LT. NEWYR) GO TO 30
C             A NEW YEAR SIGNALS ALTERNATIVE 2
C
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
      IF (YEAR .NE. NEWYR) LOC99=LOC99-1                                     *
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C             REPLACE ABOVE BY
C     IF (YEAR .NE. NEWYR) BACKSPACE 99
C
      IF (YEAR .NE. NEWYR) IALT=2
      IF (YEAR .NE. NEWYR) GO TO 40
      ILSTC=CARD
C     ADD TO THIS YEAR'S MATRIX.  FIND DAY NUMBER
      IDAY=IDATE(DAY,MONTH,YEAR)-IDAST
      YEAR=YEAR-1900
      IHR=(CARD-1)*12
```

```
      DO 20 I=1,12
      IHR=IHR+1
      INPHR(IDAY,IHR)=RAIN(I)
   20 CONTINUE
      INPHR(IDAY,25)=IMOA2
      INPHR(IDAY,26)=IDYA2
      INPHR(IDAY,27)=IYRA2
      IPRN=1
      ISAVE(7)=MONTH
      ISAVE(8)=DAY
      ISAVE(9)=YEAR
      DO 25 I=1,6
      ISAVE(I)=STA(I)
   25 CONTINUE
C             ONLY PRINT WHEN SECOND CARD IS READ
      IF (CARD .EQ. 1) GO TO 10
      IF (ISKIP .EQ. 0)
     .         WRITE (IO,2000) STA,MONTH,DAY,YEAR,(INPHR(IDAY,I),I=1,24)
      IPRN=0
      GO TO 10
   30 WRITE (IO,2060) ICAR1
C             FORMAT ERROR OR ILLEGAL CARD CODE-JUST PRINT CARD
      GO TO 10
C
C             END OF YEAR OR END OF FILE-COMPUTE SYNOPTIC DATA
C
   40 WRITE (IO,2030)
C             SAVE LAST STORM NUMBER AND PRESENT FILE NUMBER
      NOLDS=STORM
      LOLD9=LOC98
      NDRSA=NDRY
C             FIND NUMBER OF DAYS IN THIS YEAR
      NDAYR=IDATE(1,1,NEWYR+1)-IDATE(1,1,NEWYR)
      CALL SETIA (ICOUN,13,22,0)
      NOYRS=NOYRS+1
      DO 100 J=1,NDAYR
      IDAYN=IDATE(1,1,NEWYR)+J-1
      CALL DAIDA (IDAYN,IROW,IDY1,IY1)
      IROW=IROW
      DO 90 K=1,24
      IF (INPHR(J,K) .EQ. 0) NCATG=1
      IF (INPHR(J,K) .NE. 0) NCATG=(INPHR(J,K)-1)/1+2
      IF (NCATG .GT. 20) NCATG=21
      ICOUN(IROW,NCATG)=ICOUN(IROW,NCATG)+1
C             PRESENT CONDITION IS DETERMINED IF ANY PRECIPITATION IS
C             RECORDED FOR THIS HOUR
      PRCON=2
      IF (INPHR(J,K) .GT. 0) PRCON=1
C             PREVIOUS CONDITION AND PRESENT CONDITION DETERMINE CURRENT
C             STATUS
      NEXT=(COND-1)*2+PRCON
C             PRCON  AND  COND  CAN BE EITHER 1 OR 2.  THUS  NEXT
C             WHICH DEFINES THE CURRENT STATUS CAN BE EITHER 1,2,3, OR 4
C             AS INDICATED IN THE FOLLOWING TABLE
C
C                             PREVIOUS CONDITION
C                                WET       DRY
```

```
C                          (COND=1)   (COND=2)
C     PRESENT         WET
C     CONDITION   (PRCON=1)      1          3
C
C                     DRY        2          4
C                 (PRCON=2)
C
      GO TO (50,60,70,80),NEXT
C              CONTINUE STORM (NEXT=1)
   50 DURAT=DURAT+1+NDRHR
      NDRHR=0
      VOLUM=VOLUM+INPHR(J,K)*0.01
      GO TO 90
C              DRY PERIOD (NEXT=2)-CHECK IF NOL OF CONSECUTIVE DRY HOURS
C              IS SUFFICIENT TO BE CONSIDERED AS END OF STORM
   60 NDRHR=NDRHR+1
      IF (NDRHR .LT. STMDF) GO TO 90
C              END OF STORM
      STORM=STORM+1
C              FOR FIRST STORM ON FILE ASSUME DURATION OF LAST STORM TO
C              BE THE SAME AS THE FIRST STORM
      IF (STORM .EQ. 1) DURLS=DURAT
      DELTA=0.5*(DURAT+DURLS)+FLOAT(NDRY)
      IF (STORM .EQ. 1) DELTA=0.
      VOLUM=VOLUM+0.000005
      INTEN=VOLUM/FLOAT(DURAT)
      WRITE (98'LOC98,2010) PREST,MSTRM,DSTRM,YSTRM,HSTRM,DURAT,INTEN,
     .                       VOLUM,DELTA
      WRITE (IO,2020) PREST,STORM,MSTRM,DSTRM,YSTRM,HSTRM,DURAT,INTEN,
     .                       VOLUM,DELTA
      NDRY=NDRHR
      NDRHR=0
      COND=DRY
      DURLS=DURAT
      GO TO 90
C              BEGINNING OF STORM  (NEXT=3)
   70 MSTRM=INPHR(J,25)
      DSTRM=INPHR(J,26)
      YSTRM=INPHR(J,27)
      HSTRM=K
      DURAT=1
      VOLUM=INPHR(J,K)*.01
      NDRHR=0
      COND=WET
      GO TO 90
C              CONTINUATION OF DRY WEATHER (NEXT=4)
   80 NDRY=NDRY+1
   90 CONTINUE
  100 CONTINUE
      WRITE (IO,2210) (I,I=1,20),ANDGT
      ISUM=0
      DO 9134 I=1,12
      DO 9134 J=1,21
      ICOUN(13,J)=ICOUN(13,J)+ICOUN(I,J)
      ICOUN(I,22)=ICOUN(I,22)+ICOUN(I,J)
      ISUM=ISUM+ICOUN(I,J)
 9134 CONTINUE
```

```
      DO 9135 I=1,12
      WRITE (IO,2220)(ICOUN(I,J),J=1,22),I
 9135 CONTINUE
      WRITE (IO,2220)(ICOUN(13,J),J=1,21)
      WRITE (IO,2135) ISUM
C               UPDATE FOR NEXT YEAR
      NEWYR=NEWYR+1
C               REVERT TO SAVED STORM AND RECORD NUMBER IF LESS THAN 2
C                     STORMS
      IF (STORM-NOLDS .GE. 2) GO TO 105
      NDRY=NDRSA
      STORM=NOLDS
      LOC98=LOLD9
C               SUBTRACT NUMBER OF YEARS FOR RETURN PERIOD
      NOYRS=NOYRS-1
  105 CONTINUE
C               CHECK WHICH ALTERNATIVE HAS BEEN SELECTED
C               ALTERNATE 1=END OF STATION OR END OF TAPE MARKER
C               ALTERNATE 2=END OF YEAR ONLY
      GO TO (110,7),IALT
C               CHECK FOR DISMOUNTING PRESENT TAPE
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
  110 IF (IDISM .EQ. 1) CALL MAGTA(6,0)                                                       *
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C               REPLACE ABOVE BY
C 110 IF (IDISM .EQ. 1) REWIND 99
C
C
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C               SWITCH 0 UP WILL CAUSE PROGRAM TO BRANCH TO END OF STATION*
C                     ROUTINE                                                                 *
      CALL DATSW(0,ISW0)                                                                      *
      IF (ISW0 .EQ. 1) GO TO 210                                                              *
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C
C               CHECK FOR PAUSING FOR NEXT TAPE
      IF (IPAUS .EQ. 0) GO TO 210
      WRITE (ITYP,2190) TAPEN
      PAUSE 1111
      GO TO 1
C               REWIND TAPE AND GO TO SUMMARY
C
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
  200 CALL MAGTA (6,0)                                                                        *
C     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * *
C               REPLACE ABOVE BY
C 200 REWIND 99
C
      IALT=1
      GO TO 40
C               READ SYNOPTIC FILE KEY FIELDS (MONTH AND YEAR)
C               WRITE EOF ON DISK
  210 WRITE (98'LOC98,2050)
      LOC98=1
      I=1
  220 READ (98'LOC98,1040,END=230)(KEY(I,J),J=1,2)
      KEY(I,3)=I
```

```
      I=I+1
      GO TO 220
  230 NREC=I-1
C               FOR EACH KEY, OBTAIN STATISTICS
      DO 400 ICOL=1,2
      JK1(1)=ICOL
      CALL SHELL (KEY,NREC,3800,3,JK1,JK2)
      WRITE (IO,2070)((NABRK(J,ICOL),J=1,3),I=1,2)
      KEYV=KEY(1,ICOL)
      NREC1=NREC+1
      IC=0
      DO 235 J=1,4
      YMAX(J)=0.
      Y2MAX(J)=0.
  235 CONTINUE
      DO 300 J=1,NREC1
      IF (J .EQ. 1) GO TO 260
      IF (J .EQ. NREC1) GO TO 240
C               CHECK FOR CHANGE IN KEY
      IF (KEY(J,ICOL) .EQ. KEYV) GO TO 280
C               BREAK OCCURED
  240 IC=IC+1
      X(IC)=FLOAT(KEYV)
      DO 250 I=1,4
      STAT(I,5)=STAT(I,2)/STAT(I,1)
      STAT(I,6)=SQRT(ABS((STAT(I,6)-STAT(I,2)**2/STAT(I,1))/(STAT(I,1)-
     *          1.0)))
      STAT(I,7)=STAT(I,6)**2
      STAT(I,8)=STAT(I,6)/STAT(I,5)
C               SAVE MEAN AND STD DEV FOR EACH VARIABLE FOR PLOTTING
      ICNO=(I-1)*2+1
      Y(IC,ICNO)=STAT(I,5)
      Y(IC,ICNO+1)=STAT(I,6)
      IF (STAT(I,5) .GT. YMAX(I)) YMAX(I)=STAT(I,5)
      IF (STAT(I,6) .GT. YMAX(I)) YMAX(I)=STAT(I,6)
      IF (STAT(I,4) .GT. Y2MAX(I)) Y2MAX(I)=STAT(I,4)
  250 CONTINUE
      WRITE (IO,2130) KEYV
      DO 255 I=1,4
      WRITE (IO,2080) (TITLE(M,I),M=1,5),(STAT(I,M),M=1,8)
  255 CONTINUE
      KEYV=KEY(J,ICOL)
      IF (J .EQ. NREC1) GO TO 300
  260 DO 270 I=1,4
      STAT(I,1)=0.
      STAT(I,2)=0.
      STAT(I,3)= 1.0E38
      STAT(I,4)=-1.0E38
      STAT(I,6)=0.
  270 CONTINUE
  280 IREC=KEY(J,3)
      READ (98'IREC,2110)RESVD
      DO 290 I=1,4
      DATA=RESVD(I)
      STAT(I,1)=STAT(I,1)+1.
      STAT(I,2)=STAT(I,2)+DATA
      IF (DATA .LT. STAT(I,3)) STAT(I,3)=DATA
```

```
      IF (DATA .GT. STAT(I,4)) STAT(I,4)=DATA
      STAT(I,6)=STAT(I,6)+DATA*DATA
  290 CONTINUE
  300 CONTINUE
      WRITE (IO,2090)((NABRK(J,ICOL),J=1,3),I=1,2)
      DO 310 I=1,IC
      WRITE (IO,2120) X(I),(Y(I,J),J=1,8)
  310 CONTINUE
      YMIN=0.
      DO 320 L=1,4
      I=(L-1)*2+1
      DO 315 J=1,IC
      K=J*2-1
      PLOT(K,1)=X(J)
      PLOT(K,2)=Y(J,I)
      PLOT(K,3)=11.
      PLOT(K+1,1)=X(J)
      PLOT(K+1,2)=Y(J,I+1)
      PLOT(K+1,3)=29.
  315 CONTINUE
      NTOT=2*IC
      CALL SHELR(PLOT,NTOT,60,3,JK3,JK3)
      DO 318 J=1,NTOT
      ISYM(J)=IFIX(PLOT(J,3)+0.5)
  318 CONTINUE
      CALL COAD2(PLOT(1,1),PLOT(1,2),XMAX(ICOL),XMIN(ICOL),YMAX(L),YMIN,
     .           NTOT,1,50,NSPAC(ICOL),0,0,0,ISYM)
      WRITE (IO,2100) (TITLE(M,L),M=1,5),(NABRK(M,ICOL),M=1,3)
  320 CONTINUE
  400 CONTINUE
      DO 500 IVAR=1,4
      LOC98=1
      K=1
C            READ VARIABLE
  410 READ (98'LOC98,1050,END=420)(X(J),J=1,4)
      XVALU(K,1)=X(IVAR)
      K=K+1
      GO TO 410
  420 NOCCU=K-1
C            SORT BY VALUE
      CALL SHELR (XVALU,NOCCU,3500,1,JK4,JK4)
      WRITE (IO,2140)((TITLE(J,IVAR),J=1,5),I=1,2)
C            COMPUTE 'PLOTTING POSITION'
      DO 430 I=1,NOCCU
      XVALU(I,2)=FLOAT(I)/FLOAT(NOCCU)*100.
  430 CONTINUE
      WRITE (IO,2150)((XVALU (I,J),J=1,2),I=1,NOCCU)
C            PLOT RESULTS
C            SORT FIRST COLUMN REVERSED
      CALL SHELR(XVALU,NOCCU,3500,2,JK4,JK3)
      CALL COAD2(XVALU(1,2),XVALU(1,1),100.,0.,Y2MAX(IVAR),0.,NOCCU,1,
     .           50,100,0,2,0,ISYM)
      WRITE (IO,2100) (TITLE(J,IVAR),J=1,5)
      WRITE (IO,2160)
C            COMPUTE RECURRANCE INTERVAL
      DO 440 I=1,NOCCU
      XVALU(I,2)=FLOAT(NOYRS)/FLOAT(I)
```

```
  440 CONTINUE
      WRITE (IO,2170)(TITLE(J,IVAR),J=1,5)
      WRITE (IO,2150)((XVALU (I,J),J=1,2),I=1,NOCCU)
      X2MAX=FLOAT(NOYRS)
C               PLOT RESULTS
      CALL COAD2(XVALU(1,2),XVALU(1,1),X2MAX,0.,Y2MAX(IVAR),0.,NOCCU,1,
     .            50,100,0,2,0,ISYM)
      WRITE (IO,2100) (TITLE(J,IVAR),J=1,5)
      WRITE (IO,2180)
  500 CONTINUE
      GO TO 1
  999 CALL EXIT
 1000 FORMAT (6A1,3I2,I1,12I3,T7,3A2)
 1010 FORMAT (49A1)
 1020 FORMAT (4A2,1X,I1,5I5,3A2)
C
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
 1030 FORMAT (6A1,3I2)                                                  *
C     *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *
C
 1040 FORMAT (12X,I2,4X,I2)
 1050 FORMAT (25X,F5.0,3F10.0)
 2000 FORMAT (3X,6A1,1X,2(I2,'/'),I2,5X,24I4,2X,A2)
 2010 FORMAT (4X,6A1,2X,2(A2,'/'),A2,2I5,F10.6,F10.2,F10.1)
 2020 FORMAT (3X,6A1,2X,I5,2X,2(A2,'/'),A2,2I6,F12.6,F10.2,F12.1)
 2030 FORMAT (1H1,20X,'STORM EVENT SUMMARY'/
     .           ' STATION  STORM        DATE  HOUR DURAT    INTENSITY
     .VOLUME        DELTA'/
     .           '                NO                     HOURS    INCHES/HR
     .INCHES        HOURS'/)
 2040 FORMAT (1H1,42X,'HYDROSCIENCE RAINFALL ANALYSIS PROGRAM'//
     .             50X,'HOURLY PRECIPITATION-HUNDREDTHS OF AN INCH'/
     .           '  STATION     DATE        1   2   3   4   5   6   7
     .8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24'
     ./)
 2050 FORMAT ('/*')
 2060 FORMAT (' * ',49A1,20X,'BAD DATA IN RECORD')
 2070 FORMAT (1H1,35X,'RAINFALL STATISTICS BY ',3A2,'(FOR PERIOD OF RECO
     .RD)'/1X,3A2,
     .          11X,'NUMBER',9X,'TOTAL',7X,'MINIMUM',7X,'MAXIMUM',
     .            7X,'AVERAGE',7X,'STD DEV',6X,'VARIANCE',6X,'COEF-VAR')
 2080 FORMAT (8X,5A2,F6.0,7E14.6)
 2090 FORMAT (1H1,12X,'SUMMARY OF RAINFALL STATISTICS BY ',3A2,'(FOR PER
     .IOD OF RECORD)'/
     .          1X,3A2,     5X,'DURATION',12X,'INTENSITY',12X,'VOLUME',15X
     .,'DELTA'/6X       ,4('    AVERAGE    STD DEV'))
 2100 FORMAT (40X,5A2,' VS',3A2,20X,'A=AVERAGE, S=STD. DEV.')
 2110 FORMAT (25X,F5.0,3F10.0)
 2120 FORMAT (1X,F5.0,2F10.2,2F10.4,2F10.2,2F10.0)
 2130 FORMAT (1X,I6)
 2135 FORMAT (/' TOTAL HOURS FOR THE YEAR = ',I6)
 2140 FORMAT (1H1,49X,'PROBABILITY ANALYSIS-',5A2//
     .            27X,'PERCENTAGE OF OCCURRENCE LESS THAN OR EQUAL TO TH
     .E GIVEN VALUE OF ',5A2///1X,8(3X,'VALUE',5X,'PCT'))
 2150 FORMAT (1X,16F8.3)
 2160 FORMAT (1H+,53X,'PERCENT LESS THAN OR EQUAL TO')
 2170 FORMAT (1H1,45X,'RETURN PERIOD (IN YEARS) FOR ',5A2///1X,8(3X,'VAL
```

```
     .UE',2X,'PERIOD'))
2180 FORMAT (1H+,53X,'RETURN PERIOD IN YEARS')
2190 FORMAT (///' OPERATOR-MOUNT TAPE NO. ',3A2,' AND THEN PRESS START'
     .)
2200 FORMAT (121X,A2)
2210 FORMAT (///34X,'NUMBER OF HOURS OF RAINFALL IN HUNDREDTHS OF AN IN
     .CH'/41X,'INTERVALS BETWEEN 0.00 AND 0.20 INCHES'/' MONTH     0',
     .20I5,4X,'TOTAL'/109X,A2,4X,'HOURS'/115X,'  PER'/115X,'MONTH')
2220 FORMAT (6X,21I5,I9,T2,I5)
     END
```

E.5 Example of Computer Output From Program SYNOP

The example output presented in this section demonstrates the application of program SYNOP for a rainfall analysis of U.S. Weather Bureau station 052220 in Denver, Colorado. This is the same data which is contained in the sample data set transmitted with copies of the program.

The program presents a complete summary of the rainfall history for each year of record. This includes an hourly percipitation history, a summary of each event's statistics, and a histogram of rainfall events for each month of the year. The sample output only presents this analysis for 1948 through 1950, and 1973.

The program then proceeds through a series of statistical summaries of the entire data record. These are:

- Aggregate monthly rainfall statistics
- Plots of rainfall statistics by month
- Annual rainfall statistics
- Plots of rainfall statistics by year
- Probability analysis of rainfall statistics
- Probability density function
- Return period analysis

This output will serve as a check on program SYNOP. The program input is that on card 5 and 6 in Table E-1.

HYDROSCIENCE RAINFALL ANALYSIS PROGRAM

HOURLY PRECIPAITATION-HUNDREDTHS OF AN INCH

STATION	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
052220	8/ 1/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
052220	8/ 2/48	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0
052220	8/ 4/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
052220	8/10/48	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
052220	8/19/48	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
052220	8/21/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
052220	8/24/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
052220	8/25/48	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 1/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/19/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	3	0	0	0	0
052220	9/30/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0
052220	10/ 1/48	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	10/ 5/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
052220	10/16/48	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	0	0	0	1	0	0	0
052220	10/28/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
052220	10/29/48	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/ 1/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/ 3/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2
052220	11/ 7/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	3	3	3	3	2
052220	11/ 8/48	1	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/10/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	1
052220	11/11/48	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/20/48	0	0	0	0	0	0	0	0	2	2	1	0	1	1	1	1	0	0	0	0	0	0	1	1
052220	11/21/48	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/ 1/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/22/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
052220	12/23/48	0	0	0	0	1	0	0	1	0	1	1	1	1	1	2	2	3	1	1	1	1	1	1	0
052220	12/24/48	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/27/48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

STORM EVENT SUMMARY

STATION	STORM NO	DATE	HOUR	DURAT HOURS	INTENSITY INCHES/HR	VOLUME INCHES	DELTA HOURS
052220	1	08/01/48	22	2	0.015002	0.03	0.0
052220	2	08/02/48	14	1	0.120004	0.12	15.5
052220	3	08/04/48	15	2	0.010002	0.02	50.5
052220	4	08/10/48	14	2	0.010002	0.02	142.0
052220	5	08/19/48	13	1	0.020005	0.02	214.5
052220	6	08/21/48	18	1	0.130005	0.13	53.0
052220	7	08/24/48	19	1	0.010005	0.01	73.0
052220	8	08/25/48	2	2	0.030002	0.06	7.5
052220	9	09/19/48	18	3	0.133334	0.40	616.5
052220	10	09/30/48	19	2	0.025002	0.05	264.5
052220	11	10/01/48	3	1	0.010005	0.01	7.5
052220	12	10/05/48	19	1	0.010005	0.01	112.0
052220	13	10/16/48	7	11	0.007273	0.08	257.0
052220	14	10/16/48	21	1	0.010005	0.01	9.0
052220	15	10/28/48	24	2	0.025002	0.05	291.5
052220	16	11/03/48	23	2	0.060002	0.12	143.0
052220	17	11/07/48	16	14	0.018571	0.26	95.0
052220	18	11/08/48	9	3	0.006668	0.02	11.5
052220	19	11/10/48	21	6	0.011667	0.07	61.5
052220	20	11/20/48	9	8	0.011250	0.09	229.0
052220	21	11/20/48	23	8	0.011250	0.09	14.0
052220	22	12/22/48	21	2	0.010002	0.02	763.0
052220	23	12/23/48	5	23	0.009565	0.22	18.5
052220	24	12/27/48	24	1	0.020005	0.02	104.0

NUMBER OF HOURS OF RAINFALL IN HUNDREDTHS OF AN INCH
INTERVALS BETWEEN 0.00 AND 0.20 INCHES

MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20 &>	TOTAL HOURS PER MONTH
1	744	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
2	696	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	696
3	744	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
4	720	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	720
5	744	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
6	720	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	720
7	744	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
8	732	7	2	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	744
9	716	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	720
10	731	11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
11	682	23	10	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	720
12	723	17	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
	8696	59	16	7	1	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	

TOTAL HOURS FOR THE YEAR = 8784

HYDROSCIENCE RAINFALL ANALYSIS PROGRAM

HOURLY PRECIPAITATION-HUNDREDTHS OF AN INCH

STATION	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
052220	1/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/ 2/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	9	5	5	2	3	3	2	5
052220	1/ 3/49	1	1	1	1	1	1	2	1	1	2	1	1	2	1	1	2	1	1	1	1	1	1	2	0
052220	1/ 4/49	1	2	1	1	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
052220	1/ 8/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
052220	1/ 9/49	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/23/49	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/27/49	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1	1
052220	1/28/49	1	2	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	2/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	2/12/49	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
052220	3/ 1/49	2	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/ 5/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	7	1	1	3
052220	3/ 6/49	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/ 8/49	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
052220	3/12/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	8	4	0	1	0	0
U52220	3/14/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
052220	3/23/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
052220	3/24/49	5	6	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/25/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	9	0
052220	3/28/49	0	0	0	0	0	0	0	0	1	1	1	2	3	4	5	6	6	5	6	4	2	3	4	5
052220	3/29/49	7	8	9	7	9	1	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
052220	3/30/49	1	2	4	4	4	4	2	2	2	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
052220	4/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
U52220	4/ 2/49	0	1	0	1	0	0	1	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
052220	4/ 3/49	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	4/ 8/49	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	9
052220	4/ 9/49	11	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	7	6	7	7	0
052220	4/10/49	0	0	0	2	1	0	0	2	1	4	2	0	0	1	0	0	0	0	0	0	0	0	0	0
052220	4/13/49	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2	3	5	5
052220	4/14/49	3	1	0	0	1	0	0	0	3	2	2	1	0	1	0	0	0	0	0	0	0	0	0	0
052220	4/20/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
U52220	4/21/49	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	4/26/49	0	0	0	0	0	0	0	0	1	7	6	0	0	2	9	1	1	2	1	0	0	0	0	0
052220	4/30/49	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	5/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	5/ 5/49	0	0	1	0	0	0	0	6	4	2	5	5	4	6	3	1	4	5	4	2	1	1	2	3
052220	5/ 6/49	3	2	3	5	11	4	1	4	5	6	1	3	4	10	12	3	3	3	3	2	1	1	2	3
U52220	5/ 7/49	2	3	5	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	5/11/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4	1	1	0	2	18	7	0
052220	5/13/49	0	0	0	0	0	0	2	15	24	15	2	0	0	1	6	2	0	0	0	4	0	0	0	0
052220	5/15/49	0	0	8	1	2	0	0	0	0	0	0	0	0	5	1	1	0	5	1	0	0	0	0	0
052220	5/16/49	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	4	0
052220	5/18/49	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1	1	0	0
052220	5/20/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
052220	5/21/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
052220	5/23/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
052220	5/27/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
052220	5/28/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
052220	6/ 1/49	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
052220	6/ 2/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	11	3	7
052220	6/ 3/49	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14	10	27	29	17

052220	6/ 4/49	19	3	5	3	5	8	3	2	6	1	16	1	2	1	0	0	2	6	0	0	1	2	2	2
052220	6/ 5/49	3	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	6/ 6/49	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	10	3	4
052220	6/ 7/49	1	1	0	0	1	0	2	8	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	6/ 8/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3	2	1	0	0	0	1	0	0
052220	6/12/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	2	2	4	6
052220	6/13/49	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	11	23
052220	6/14/49	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	6/17/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	6/18/49	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
052220	6/23/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	24	1	0	0	0
052220	6/26/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	0	0	0	0	0	0
052220	6/27/49	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	1	0	0	0	0	0	0
052220	6/28/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
052220	7/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0
052220	7/ 3/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
052220	7/ 5/49	0	0	0	0	0	0	0	0	0	0	0	0	0	47	4	0	0	2	0	0	0	0	0	0
052220	7/ 6/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	5	0	0	0
052220	7/ 7/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
052220	7/ 8/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
052220	7/11/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0
052220	7/13/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	0	0	0	0
052220	7/14/49	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0
052220	7/18/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
052220	7/21/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	7/24/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	4	3
052220	7/25/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
052220	7/28/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	5
052220	7/29/49	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	8/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	8/ 3/49	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	8/ 8/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	3	0	0	0	0	0	0
052220	8/ 9/49	0	0	0	0	0	0	0	0	0	0	0	0	0	14	3	0	0	0	0	0	0	0	0	0
052220	8/11/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
052220	8/12/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
052220	8/13/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
052220	8/14/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
052220	8/17/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
052220	8/19/49	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	8/24/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	12	6	2	0
052220	8/25/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
052220	8/29/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
052220	9/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 3/49	0	0	0	0	0	0	0	2	0	0	0	0	0	0	11	1	0	0	0	0	0	0	0	0
052220	9/30/49	0	0	0	0	0	0	0	0	0	9	3	0	1	1	0	0	0	0	0	0	0	0	0	0
052220	10/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	10/ 8/49	0	0	0	0	1	0	0	0	0	0	1	0	1	1	2	2	1	1	1	1	3	2	2	4
052220	10/ 9/49	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	11	1	0	0
052220	10/18/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
052220	10/19/49	0	0	0	0	0	0	1	0	1	1	1	0	0	0	1	0	0	4	11	4	7	8	4	1
052220	10/20/49	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	10/29/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1	1	1	4	1	5	10
052220	10/30/49	4	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/11/49	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/ 1/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/11/49	4	3	3	3	3	2	3	4	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/20/49	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STORM EVENT SUMMARY

STATION	STORM NO	DATE	HOUR	DURAT HOURS	INTENSITY INCHES/HR	VOLUME INCHES	DELTA HOURS
052220	25	01/02/49	15	49	0.017347	0.85	159.0
052220	26	01/08/49	23	10	0.010000	0.10	132.5
052220	27	01/23/49	10	1	0.010005	0.01	342.5
052220	28	01/27/49	9	4	0.010001	0.04	95.5
052220	29	01/27/49	19	16	0.010625	0.17	17.0
052220	30	02/12/49	12	2	0.010002	0.02	370.0
052220	31	02/12/49	18	1	0.010005	0.01	5.5
052220	32	03/01/49	1	3	0.026668	0.08	392.0
052220	33	03/05/49	19	7	0.035714	0.25	116.0
052220	34	03/08/49	1	4	0.007501	0.03	52.5
052220	35	03/08/49	20	1	0.010005	0.01	17.5
052220	36	03/12/49	18	5	0.054000	0.27	96.0
052220	37	03/14/49	17	1	0.010005	0.01	45.0
052220	38	03/23/49	21	8	0.025000	0.20	223.5
052220	39	03/25/49	21	3	0.046668	0.14	45.5
052220	40	03/28/49	9	25	0.040400	1.01	71.0
052220	41	03/29/49	19	1	0.010005	0.01	22.0
052220	42	03/30/49	1	13	0.021538	0.28	12.0
052220	43	04/01/49	23	11	0.006364	0.07	69.0
052220	44	04/02/49	13	1	0.010005	0.01	9.0
052220	45	04/03/49	9	3	0.006668	0.02	20.0
052220	46	04/08/49	10	4	0.007501	0.03	122.5
052220	47	04/08/49	23	4	0.057501	0.23	13.0
052220	48	04/09/49	10	1	0.010005	0.01	9.5
052220	49	04/09/49	19	5	0.056000	0.28	11.0
052220	50	04/10/49	4	11	0.011818	0.13	12.0
052220	51	04/13/49	11	1	0.030005	0.03	74.0
052220	52	04/13/49	21	9	0.022222	0.20	14.0
052220	53	04/14/49	9	6	0.015000	0.09	10.5
052220	54	04/20/49	17	1	0.010005	0.01	149.5
052220	55	04/20/49	24	2	0.020002	0.04	7.5
052220	56	04/26/49	9	11	0.027273	0.30	133.5
052220	57	04/30/49	7	1	0.010005	0.01	89.0
052220	58	05/05/49	3	1	0.010005	0.01	116.0
052220	59	05/05/49	8	46	0.037826	1.74	27.5
052220	60	05/11/49	15	9	0.041111	0.37	132.5
052220	61	05/13/49	7	10	0.067000	0.67	40.5
052220	62	05/13/49	20	1	0.040005	0.04	8.5
052220	63	05/15/49	3	3	0.036668	0.11	32.0
052220	64	05/15/49	14	6	0.021667	0.13	12.5
052220	65	05/16/49	13	2	0.010002	0.02	21.0
052220	66	05/16/49	22	2	0.025002	0.05	9.0
052220	67	05/18/49	13	1	0.050005	0.05	38.5
052220	68	05/19/49	21	2	0.010002	0.02	8.5
052220	69	05/20/49	15	2	0.010002	0.02	42.0
052220	70	05/21/49	19	2	0.010002	0.02	28.0
052220	71	05/23/49	17	1	0.030005	0.03	45.5
052220	72	05/27/49	18	1	0.020005	0.02	97.0
052220	73	05/28/49	15	1	0.010005	0.01	21.0
052220	74	06/01/49	12	1	0.010005	0.01	93.0
052220	75	06/02/49	20	7	0.044286	0.31	35.0
052220	76	06/03/49	19	35	0.056000	1.96	37.0
052220	77	06/06/49	7	1	0.010005	0.01	43.0

052220	78	06/06/49	17	1	0.010005	0.01	10.0
052220	79	06/06/49	22	13	0.027692	0.36	11.0
052220	80	06/08/49	15	4	0.037501	0.15	36.5
052220	81	06/08/49	22	1	0.010005	0.01	5.5
052220	82	06/12/49	19	7	0.034286	0.24	96.0
052220	83	06/13/49	15	3	0.006668	0.02	18.0
052220	84	06/13/49	23	3	0.123334	0.37	8.0
052220	85	06/17/49	15	1	0.010005	0.01	88.0
052220	86	06/18/49	14	1	0.010005	0.01	22.0
052220	87	06/23/49	19	3	0.200001	0.60	126.0
052220	88	06/26/49	17	2	0.065002	0.13	69.5
052220	89	06/27/49	12	1	0.040005	0.04	18.5
052220	90	06/27/49	17	2	0.010002	0.02	5.5
052220	91	06/28/49	15	1	0.010005	0.01	21.5
052220	92	07/01/49	16	2	0.035002	0.07	73.5
052220	93	07/03/49	17	1	0.030005	0.03	48.5
052220	94	07/05/49	14	5	0.106000	0.53	47.0
052220	95	07/06/49	17	1	0.020005	0.02	25.0
052220	96	07/06/49	21	1	0.050005	0.05	4.0
052220	97	07/07/49	20	1	0.010005	0.01	23.0
052220	98	07/08/49	17	2	0.010002	0.02	21.5
052220	99	07/11/49	16	1	0.200004	0.20	70.5
052220	100	07/13/49	17	4	0.012501	0.05	50.5
052220	101	07/14/49	3	1	0.010005	0.01	8.5
052220	102	07/14/49	15	2	0.030002	0.06	12.5
052220	103	07/18/49	23	2	0.020002	0.04	104.0
052220	104	07/21/49	16	1	0.010005	0.01	64.5
052220	105	07/24/49	21	4	0.027501	0.11	78.5
052220	106	07/25/49	16	1	0.020005	0.02	17.5
052220	107	07/28/49	19	1	0.010005	0.01	75.0
052220	108	07/28/49	23	5	0.022000	0.11	6.0
052220	109	08/03/49	6	2	0.015002	0.03	125.5
052220	110	08/08/49	17	2	0.105002	0.21	131.0
052220	111	08/09/49	14	2	0.085002	0.17	21.0
052220	112	08/11/49	16	1	0.020005	0.02	49.5
052220	113	08/12/49	23	2	0.010002	0.02	31.5
052220	114	08/13/49	15	1	0.070004	0.07	15.5
052220	115	08/14/49	23	1	0.050005	0.05	32.0
052220	116	08/17/49	15	2	0.020002	0.04	64.5
052220	117	08/19/49	11	1	0.010005	0.01	43.5
052220	118	08/24/49	19	5	0.054000	0.27	130.0
052220	119	08/25/49	17	1	0.010005	0.01	20.0
052220	120	08/29/49	23	1	0.020005	0.02	102.0
052220	121	09/03/49	8	1	0.020005	0.02	105.0
052220	122	09/03/49	15	2	0.060002	0.12	7.5
052220	123	09/30/49	10	5	0.028000	0.14	644.5
052220	124	10/08/49	5	1	0.010005	0.01	185.0
052220	125	10/08/49	11	19	0.013684	0.26	15.0
052220	126	10/09/49	15	1	0.010005	0.01	20.0
052220	127	10/09/49	21	2	0.060002	0.12	5.5
052220	128	10/18/49	19	1	0.140004	0.14	213.5
052220	129	10/19/49	7	5	0.008000	0.04	14.0
052220	130	10/19/49	15	13	0.031538	0.41	12.0
052220	131	10/29/49	16	14	0.026428	0.37	241.5
052220	132	11/11/49	9	1	0.010005	0.01	298.5
052220	133	12/11/49	1	11	0.028182	0.31	717.0
052220	134	12/20/49	5	1	0.010005	0.01	215.0

052220 135 12/20/49 9 1 0.010005 0.01 4.0

NUMBER OF HOURS OF RAINFALL IN HUNDREDTHS OF AN INCH
INTERVALS BETWEEN 0.00 AND 0.20 INCHES

MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20 &>	TOTAL HOURS PER MONTH
1	669	56	12	2	0	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	744
2	669	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	672
3	679	22	9	5	9	6	5	3	2	3	0	0	0	0	1	0	0	0	0	0	0	744
4	665	28	10	5	1	2	2	4	0	2	0	1	0	0	0	0	0	0	0	0	0	720
5	658	26	15	12	10	9	4	1	1	0	2	1	1	0	0	2	0	0	1	0	1	744
6	641	29	13	8	3	3	3	3	2	1	2	3	0	0	1	0	1	1	0	1	5	720
7	711	15	4	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	744
8	723	6	6	2	0	1	2	1	0	0	0	0	1	0	1	0	0	0	1	0	0	744
9	713	3	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	720
10	695	28	6	2	6	1	0	1	1	0	1	2	0	0	1	0	0	0	0	0	0	744
11	719	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	720
12	731	3	2	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
	8273	220	78	49	34	28	16	14	6	8	5	8	2	0	4	2	1	1	2	1	8	

TOTAL HOURS FOR THE YEAR = 8760

HYDROSCIENCE RAINFALL ANALYSIS PROGRAM

HOURLY PRECIPAITATION-HUNDREDTHS OF AN INCH

TION	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2220	1/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	1/ 2/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2220	1/ 3/50	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2220	1/14/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2220	1/24/50	0	0	1	2	6	5	7	5	4	2	1	0	0	0	0	0	0	0	0	0	0	1	1	1
2220	1/25/50	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	1/29/50	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	1/30/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2220	2/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	2/ 7/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	3	0
2220	2/ 8/50	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	2/11/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2220	2/12/50	2	1	1	1	1	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	2/28/50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2220	3/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	3/11/50	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	2	2	1	2	2	1	1
2220	3/12/50	1	1	2	2	4	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2220	3/18/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2220	4/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	4/ 3/50	0	2	0	0	4	2	2	2	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0
2220	4/ 4/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2220	4/15/50	0	0	0	0	0	0	0	0	0	0	0	0	1	21	7	8	22	13	8	55	42	1	2	0
2220	4/16/50	2	2	4	7	7	0	2	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	4/18/50	0	0	0	0	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	4/19/50	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	4/28/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	6	5	3	11	6
2220	4/29/50	4	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	5/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	5/ 4/50	0	0	0	1	1	0	1	0	0	0	0	1	2	2	2	3	7	3	4	3	4	3	7	3
2220	5/ 5/50	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	5/ 7/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	2	1	1	0	0	1
2220	5/ 9/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	14	8	5	2	0
2220	5/10/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0
2220	5/15/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2220	5/25/50	0	3	2	2	3	4	4	4	5	6	7	11	11	10	10	8	8	5	5	5	4	5	5	3
2220	5/26/50	4	4	3	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	5/27/50	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
2220	5/28/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0
2220	6/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	6/ 2/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	7	5	4
2220	6/ 3/50	1	0	1	0	0	2	5	4	4	6	4	4	0	2	1	0	0	0	0	0	0	0	0	0
2220	6/16/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82	46	57	4	17	0	0	0
2220	6/18/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	5	5
2220	6/19/50	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	6/29/50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	7/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	0	0	0	0
2220	7/ 2/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
2220	7/ 4/50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2220	7/ 5/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0
2220	7/16/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2220	7/17/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0
2220	7/18/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0

052220	7/29/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	6	0	0	0	0
052220	8/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	8/11/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
052220	8/13/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0
052220	8/16/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
052220	8/26/50	0	0	0	0	0	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0	0	0	0	0
052220	8/27/50	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 8/50	0	0	0	0	0	0	0	0	0	46	10	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 9/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
052220	9/10/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	11
052220	9/11/50	23	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	0	0	2	0
052220	9/12/50	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/15/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
052220	9/16/50	1	0	1	0	1	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0	0
052220	9/19/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	23	1	0	0	0	0	0	0
052220	10/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	2	1	2	0	0
052220	11/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/ 2/50	0	0	0	0	0	0	0	0	3	1	8	4	2	0	0	0	0	0	0	0	0	1	1	0
052220	11/ 3/50	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/ 8/50	0	0	0	0	0	0	0	2	4	4	3	3	3	3	6	9	6	3	3	2	2	1	1	0
052220	11/ 9/50	2	2	3	4	3	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/19/50	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/ 1/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/ 4/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1	1	0	1	1
052220	12/ 5/50	6	5	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	12/31/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1

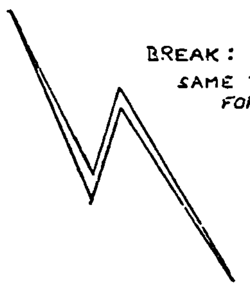
STATION	STORM NO	STORM EVENT SUMMARY DATE	HOUR	DURAT HOURS	INTENSITY INCHES/HR	VOLUME INCHES	DELTA HOURS
052220	136	01/02/50	23	10	0.004000	0.04	330.5
052220	137	01/03/50	15	1	0.010005	0.01	11.5
052220	138	01/14/50	24	1	0.020005	0.02	273.0
052220	139	01/24/50	3	9	0.036667	0.33	223.0
052220	140	01/24/50	22	5	0.010000	0.05	17.0
052220	141	01/29/50	9	1	0.010005	0.01	105.0
052220	142	01/30/50	21	1	0.010005	0.01	36.0
052220	143	02/07/50	21	6	0.013334	0.08	194.5
052220	144	02/11/50	24	10	0.011000	0.11	101.0
052220	145	02/28/50	12	1	0.010005	0.01	391.5
052220	146	03/11/50	10	4	0.005001	0.02	263.5
052220	147	03/11/50	17	20	0.014000	0.28	15.0
052220	148	03/18/50	15	1	0.010005	0.01	156.5
052220	149	04/03/50	2	7	0.017143	0.12	374.0
052220	150	04/03/50	15	7	0.010000	0.07	13.0
052220	151	04/04/50	23	1	0.010005	0.01	29.0
052220	152	04/15/50	13	20	0.106500	2.13	263.5
052220	153	04/18/50	5	2	0.055002	0.11	55.0
052220	154	04/19/50	4	1	0.010005	0.01	22.5
052220	155	04/28/50	18	12	0.044167	0.53	235.5
052220	156	05/04/50	4	4	0.007501	0.03	126.0
052220	157	05/04/50	12	15	0.031333	0.47	13.5
052220	158	05/07/50	16	9	0.014444	0.13	73.0
052220	159	05/09/50	19	5	0.080000	0.40	49.0
052220	160	05/10/50	22	2	0.050002	0.10	25.5
052220	161	05/15/50	19	1	0.010005	0.01	116.5
052220	162	05/25/50	2	29	0.051379	1.49	237.0
052220	163	05/27/50	12	2	0.020002	0.04	44.5
052220	164	05/28/50	17	1	0.130005	0.13	29.5
052220	165	06/02/50	20	20	0.027000	0.54	132.5
052220	166	06/16/50	17	5	0.412000	2.06	325.5
052220	167	06/18/50	22	5	0.142000	0.71	53.0
052220	168	06/29/50	5	1	0.010005	0.01	245.0
052220	169	07/01/50	19	2	0.055002	0.11	62.5
052220	170	07/02/50	15	1	0.030005	0.03	19.5
052220	171	07/04/50	13	1	0.010005	0.01	46.0
052220	172	07/05/50	17	2	0.020002	0.04	28.5
052220	173	07/16/50	15	1	0.010005	0.01	261.5
052220	174	07/17/50	17	2	0.025002	0.05	26.5
052220	175	07/18/50	19	2	0.035002	0.07	26.0
052220	176	07/28/50	19	2	0.120002	0.24	240.0
052220	177	08/11/50	20	1	0.100005	0.10	336.5
052220	178	08/13/50	16	5	0.008001	0.04	46.0
052220	179	08/16/50	18	1	0.010005	0.01	72.0
052220	180	08/26/50	12	2	0.045002	0.09	234.5
052220	181	08/27/50	3	3	0.010001	0.03	15.5
052220	182	09/08/50	10	2	0.280002	0.56	294.5
052220	183	09/09/50	17	1	0.010005	0.01	30.5
052220	184	09/10/50	17	2	0.010002	0.02	24.5
052220	185	09/10/50	23	4	0.095001	0.38	7.0
052220	186	09/11/50	18	6	0.015000	0.09	20.0
052220	187	09/12/50	6	1	0.010005	0.01	9.5
052220	188	09/15/50	21	9	0.005556	0.05	91.0

052220	189	09/16/50	15	2	0.040002	0.08	14.5
052220	190	09/19/50	16	3	0.126668	0.38	73.5
052220	191	10/01/50	17	6	0.020000	0.12	290.5
052220	192	11/02/50	9	5	0.036000	0.18	759.5
052220	193	11/02/50	22	4	0.007501	0.03	12.5
052220	194	11/08/50	8	25	0.029600	0.74	1[illegible]0.5
052220	195	11/19/50	11	1	0.050005	0.05	255.0
052220	196	12/04/50	18	11	0.024545	0.27	372.0

NUMBER OF HOURS OF RAINFALL IN HUNDREDTHS OF AN INCH
INTERVALS BETWEEN 0.00 AND 0.20 INCHES

MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20 &>	TOTAL HOURS PER MONTH
1	722	14	3	0	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	744
2	658	10	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	672
3	723	13	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
4	676	12	9	2	4	1	2	3	3	1	0	2	0	1	0	0	0	0	0	0	4	720
5	679	10	11	13	8	8	2	3	3	0	2	3	0	1	1	0	0	0	0	0	0	744
6	693	5	4	1	6	4	1	1	0	0	0	0	0	0	0	0	0	1	0	0	4	720
7	731	6	0	2	1	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	744
8	735	4	2	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	744
9	696	12	3	1	1	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	3	720
10	739	1	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
11	687	7	8	9	4	1	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	720
12	731	7	0	3	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
	8470	101	52	34	26	19	13	8	7	2	5	6	0	2	2	0	0	1	1	0	11	

TOTAL HOURS FOR THE YEAR = 8760



BREAK:
SAME PROCEEDURE IS REPEATED
FOR 1951 - 1972

HYDROSCIENCE RAINFALL ANALYSIS PROGRAM

STATION	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		HOURLY PRECIPAITATION-HUNDREDTHS OF AN INCH																							
052220	1/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/ 3/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
052220	1/ 7/73	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/ 8/73	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
052220	1/ 9/73	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/20/73	0	0	0	0	4	7	8	7	9	9	7	4	5	4	4	4	6	1	1	1	2	1	2	1
052220	1/21/73	0	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	1/26/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	0
052220	1/27/73	1	1	1	1	1	3	4	4	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	2/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	2/ 7/73	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
052220	2/13/73	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	2/18/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6
052220	2/19/73	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/ 2/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
052220	3/ 3/73	5	7	4	2	3	1	1	2	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/13/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	6	0	0	0	0	0	0	0
052220	3/14/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
052220	3/15/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	3/18/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	20	7	7	10	8
052220	3/19/73	2	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/21/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1	0
052220	3/24/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
052220	3/25/73	4	4	4	4	3	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	3/27/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0
052220	3/28/73	0	1	1	0	3	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
052220	3/29/73	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
052220	3/30/73	0	0	0	0	0	0	2	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
052220	4/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
052220	4/ 2/73	1	0	0	0	1	0	2	2	0	1	4	5	5	3	0	1	2	6	3	2	0	0	1	2
052220	4/ 3/73	3	8	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	4/ 6/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	7
052220	4/ 7/73	2	4	2	2	1	4	4	3	8	6	5	3	3	4	3	5	2	4	6	4	4	4	4	3
052220	4/ 8/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0
052220	4/15/73	0	0	0	0	1	0	0	0	0	1	2	1	2	2	2	1	1	1	0	0	0	0	0	0
052220	4/19/73	0	1	0	1	2	2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
052220	4/21/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	4/24/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	8	16	11	9
052220	4/25/73	10	9	2	2	3	8	5	5	1	2	2	0	0	1	0	0	0	0	0	0	0	0	0	1
052220	4/26/73	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	4/30/73	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	6	15	20	4	9	10	7	2	3
052220	5/ 1/73	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	2
052220	5/ 2/73	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	5/ 5/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	16	12
052220	5/ 6/73	1	4	8	4	16	36	28	14	16	27	14	23	23	24	25	22	13	14	12	2	1	0	0	0
052220	5/19/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
052220	5/21/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0	4
052220	5/22/73	7	6	5	1	2	2	2	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	5/24/73	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	4	4	1	0	0
052220	5/26/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
052220	5/29/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	4

052220	5/30/73	6	6	10	16	4	6	6	7	7	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	6/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	6/ 3/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	2	1	0	0	0	0
052220	6/ 4/73	0	0	0	0	0	0	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	6/12/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
052220	6/14/73	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
052220	7/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	7/ 9/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0
052220	7/12/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	13	6	1	0	0	0
052220	7/13/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
052220	7/14/73	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	7/15/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0
052220	7/16/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	7/18/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
052220	7/19/73	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	53	0	0	0	0
052220	7/20/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
052220	7/21/73	0	0	0	1	0	0	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0	0	0	0
052220	7/22/73	0	0	0	0	0	0	0	0	0	0	0	0	13	0	6	0	0	0	0	0	0	0	0	0
052220	7/23/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
052220	7/24/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	76	28	1	0	0	0	0
052220	7/30/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0	3	0	0	0	0	0
052220	7/31/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
052220	8/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	8/ 5/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
052220	8/ 6/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
052220	8/ 7/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	1	0	0	0	0	0	0	0
052220	8/11/73	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
052220	8/21/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
052220	8/24/73	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0
052220	8/28/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
052220	8/31/73	0	0	0	0	0	0	1	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/ 2/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
052220	9/ 8/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
052220	9/ 9/73	0	4	4	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8	6	0	0	0	0
052220	9/10/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
052220	9/11/73	0	0	0	0	50	4	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	1
052220	9/15/73	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
052220	9/16/73	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0
052220	9/25/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2
052220	9/26/73	3	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	9/27/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
052220	9/28/73	0	1	2	4	7	4	4	15	15	12	14	13	7	6	2	3	6	3	5	4	2	2	8	5
052220	9/29/73	5	2	1	1	1	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	10/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	10/ 3/73	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
052220	10/ 9/73	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0
052220	10/10/73	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	2
052220	10/11/73	0	0	3	6	6	4	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	10/29/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	2
052220	10/30/73	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3
052220	11/ 2/73	3	3	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
052220	11/ 3/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
052220	11/ 4/73	0	2	0	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220	11/19/73	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	5	3	3	4	9	6	2
052220	11/26/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	3	0	0

052220 11/27/73	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220 12/ 1/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220 12/ 2/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	4	4	4	3
052220 12/ 3/73	16	15	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220 12/18/73	0	0	0	0	0	0	1	2	5	5	4	4	4	4	2	2	2	5	7	2	5	3	2	1
052220 12/23/73	0	0	0	0	0	0	0	0	0	0	0	0	2	8	20	7	8	5	10	10	16	17	17	3
052220 12/24/73	1	2	4	6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220 12/25/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
052220 12/26/73	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
052220 12/29/73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
052220 12/30/73	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	0	1	0	1	0	0

STORM EVENT SUMMARY

STATION	STORM NO	DATE	HOUR	DURAT HOURS	INTENSITY INCHES/HR	VOLUME INCHES	DELTA HOURS
052220	2238	01/03/73	15	1	0.010005	0.01	107.0
052220	2239	01/03/73	21	1	0.010005	0.01	6.0
052220	2240	01/07/73	1	1	0.010005	0.01	76.0
052220	2241	01/08/73	6	1	0.010005	0.01	29.0
052220	2242	01/08/73	23	1	0.010005	0.01	17.0
052220	2243	01/09/73	5	1	0.010005	0.01	6.0
052220	2244	01/20/73	5	25	0.036800	0.92	276.0
052220	2245	01/26/73	20	15	0.022000	0.33	154.0
052220	2246	02/07/73	10	3	0.010001	0.03	272.0
052220	2247	02/13/73	11	1	0.010005	0.01	144.0
052220	2248	02/18/73	23	3	0.040001	0.12	133.0
052220	2249	03/02/73	23	13	0.029231	0.38	293.0
052220	2250	03/13/73	15	2	0.070002	0.14	251.5
052220	2251	03/14/73	23	1	0.010005	0.01	30.5
052220	2252	03/15/73	16	1	0.010005	0.01	17.0
052220	2253	03/18/73	19	12	0.053333	0.64	80.5
052220	2254	03/21/73	21	3	0.023334	0.07	69.5
052220	2255	03/24/73	22	12	0.021667	0.26	77.5
052220	2256	03/27/73	20	17	0.008235	0.14	72.5
052220	2257	03/28/73	23	5	0.008000	0.04	21.0
052220	2258	03/29/73	7	1	0.010005	0.01	6.0
052220	2259	03/29/73	22	1	0.010005	0.01	15.0
052220	2260	03/30/73	7	2	0.015002	0.03	9.5
052220	2261	03/30/73	13	1	0.020005	0.02	5.5
052220	2262	04/01/73	23	3	0.016668	0.05	59.0
052220	2263	04/02/73	5	25	0.022800	0.57	17.0
052220	2264	04/06/73	22	27	0.036666	0.99	114.0
052220	2265	04/08/73	21	3	0.013334	0.04	35.0
052220	2266	04/15/73	5	1	0.010005	0.01	151.0
052220	2267	04/15/73	10	9	0.014444	0.13	9.0
052220	2268	04/19/73	2	6	0.013334	0.08	86.5
052220	2269	04/19/73	15	1	0.010005	0.01	10.5
052220	2270	04/21/73	16	1	0.010005	0.01	49.0
052220	2271	04/24/73	15	2	0.025002	0.05	71.5
052220	2272	04/24/73	21	18	0.052222	0.94	14.0
052220	2273	04/25/73	24	7	0.008572	0.06	21.5
052220	2274	04/30/73	5	1	0.010005	0.01	98.0
052220	2275	04/30/73	11	16	0.049375	0.79	13.5
052220	2276	05/01/73	7	5	0.006001	0.03	14.5
052220	2277	05/01/73	23	2	0.025002	0.05	14.5
052220	2278	05/02/73	4	1	0.010005	0.01	4.5
052220	2279	05/05/73	18	1	0.010005	0.01	86.0
052220	2280	05/05/73	23	23	0.154347	3.55	16.0
052220	2281	05/19/73	17	1	0.040005	0.04	319.0
052220	2282	05/21/73	15	1	0.010005	0.01	46.0
052220	2283	05/21/73	19	1	0.040005	0.04	4.0
052220	2284	05/21/73	24	11	0.032727	0.36	10.0
052220	2285	05/24/73	12	1	0.010005	0.01	55.0
052220	2286	05/24/73	19	4	0.025001	0.10	8.5
052220	2287	05/26/73	15	1	0.010005	0.01	42.5
052220	2288	05/29/73	22	14	0.059286	0.83	85.5
052220	2289	06/01/73	16	1	0.010005	0.01	59.5
052220	2290	06/03/73	16	5	0.016000	0.08	50.0

052220	2291	06/04/73	9	2	0.040002	0.08	15.5
052220	2292	06/12/73	17	1	0.020005	0.02	199.5
052220	2293	06/14/73	12	1	0.010005	0.01	43.0
052220	2294	07/09/73	20	2	0.030002	0.06	608.5
052220	2295	07/12/73	18	4	0.067501	0.27	71.0
052220	2296	07/13/73	24	8	0.005000	0.04	32.0
052220	2297	07/15/73	15	5	0.006001	0.03	37.5
052220	2298	07/16/73	16	1	0.010005	0.01	23.0
052220	2299	07/18/73	21	1	0.020005	0.02	53.0
052220	2300	07/19/73	8	1	0.010005	0.01	11.0
052220	2301	07/19/73	12	4	0.005001	0.02	5.5
052220	2302	07/19/73	20	1	0.530004	0.53	6.5
052220	2303	07/20/73	15	1	0.010005	0.01	19.0
052220	2304	07/21/73	4	1	0.010005	0.01	13.0
052220	2305	07/21/73	13	2	0.045002	0.09	9.5
052220	2306	07/22/73	13	3	0.063334	0.19	24.5
052220	2307	07/23/73	24	1	0.020005	0.02	34.0
052220	2308	07/24/73	17	4	0.265001	1.06	18.5
052220	2309	07/30/73	15	5	0.016000	0.08	142.5
052220	2310	07/31/73	20	2	0.010002	0.02	27.5
052220	2311	08/05/73	16	1	0.020005	0.02	115.5
052220	2312	08/06/73	18	1	0.040005	0.04	26.0
052220	2313	08/07/73	16	2	0.475002	0.95	22.5
052220	2314	08/11/73	14	1	0.010005	0.01	93.5
052220	2315	08/21/73	17	1	0.050005	0.05	243.0
052220	2316	08/24/73	13	1	0.110004	0.11	68.0
052220	2317	08/28/73	15	1	0.010005	0.01	98.0
052220	2318	08/31/73	7	3	0.030001	0.09	65.0
052220	2319	09/02/73	18	1	0.030005	0.03	58.0
052220	2320	09/08/73	21	1	0.070004	0.07	147.0
052220	2321	09/09/73	2	4	0.030001	0.12	6.5
052220	2322	09/09/73	19	2	0.070002	0.14	16.0
052220	2323	09/10/73	15	1	0.020005	0.02	19.5
052220	2324	09/11/73	5	2	0.270002	0.54	14.5
052220	2325	09/11/73	14	1	0.110004	0.11	8.5
052220	2326	09/11/73	24	1	0.010005	0.01	10.0
052220	2327	09/15/73	9	1	0.010005	0.01	81.0
052220	2328	09/15/73	16	1	0.010005	0.01	7.0
052220	2329	09/16/73	5	1	0.010005	0.01	13.0
052220	2330	09/16/73	12	1	0.030005	0.03	7.0
052220	2331	09/16/73	20	1	0.010005	0.01	8.0
052220	2332	09/25/73	22	6	0.020000	0.12	220.5
052220	2333	09/27/73	24	33	0.049091	1.62	63.5
052220	2334	10/03/73	9	1	0.020005	0.02	113.0
052220	2335	10/03/73	17	2	0.010002	0.02	8.5
052220	2336	10/09/73	13	2	0.015002	0.03	140.0
052220	2337	10/09/73	21	1	0.010005	0.01	7.5
052220	2338	10/10/73	3	1	0.010005	0.01	6.0
052220	2339	10/10/73	16	3	0.010001	0.03	14.0
052220	2340	10/10/73	24	9	0.026667	0.24	11.0
052220	2341	10/29/73	22	4	0.027501	0.11	451.5
052220	2342	11/01/73	22	9	0.023333	0.21	74.5
052220	2343	11/02/73	23	1	0.010005	0.01	21.0
052220	2344	11/03/73	23	10	0.011000	0.11	28.5
052220	2345	11/19/73	14	11	0.035454	0.39	375.5
052220	2346	11/26/73	19	4	0.025001	0.10	169.5
052220	2347	11/27/73	2	1	0.010005	0.01	5.5

052220	2348	12/02/73	19	10	0.071000	0.71	141.5
052220	2349	12/18/73	7	18	0.033333	0.60	376.0
052220	2350	12/23/73	13	18	0.076666	1.38	126.0
052220	2351	12/25/73	24	5	0.012001	0.06	52.5
052220	2352	12/29/73	21	3	0.010001	0.03	92.0
052220	2353	12/30/73	13	2	0.015002	0.03	15.5
052220	2354	12/30/73	18	5	0.006001	0.03	6.5

NUMBER OF HOURS OF RAINFALL IN HUNDREDTHS OF AN INCH
INTERVALS BETWEEN 0.00 AND 0.20 INCHES

MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20 &>	TOTAL HOURS PER MONTH
1	701	20	3	3	8	1	2	3	1	2	0	0	0	0	0	0	0	0	0	0	0	744
2	665	4	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	672
3	683	28	10	7	6	2	1	3	2	0	1	0	0	0	0	0	0	0	0	0	1	744
4	613	35	24	10	13	6	4	2	5	2	2	1	0	0	0	1	1	0	0	0	1	720
5	679	16	6	4	9	2	5	3	1	0	1	0	2	1	3	0	4	0	0	0	8	744
6	710	5	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	720
7	709	19	3	3	0	1	3	1	0	0	0	0	0	2	0	0	0	0	0	0	3	744
8	733	4	1	1	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	744
9	664	14	9	7	8	3	3	3	2	0	0	1	1	1	1	2	0	0	0	0	1	720
10	723	10	6	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
11	687	8	13	7	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	720
12	686	14	12	3	8	5	1	3	4	0	2	0	0	0	0	1	2	2	0	0	1	744
	8253	177	90	48	57	24	24	18	15	5	6	3	3	4	4	4	7	2	0	0	16	

TOTAL HOURS FOR THE YEAR = 8760

RAINFALL STATISTICS BY MONTH(FOR PERIOD OF RECORD)

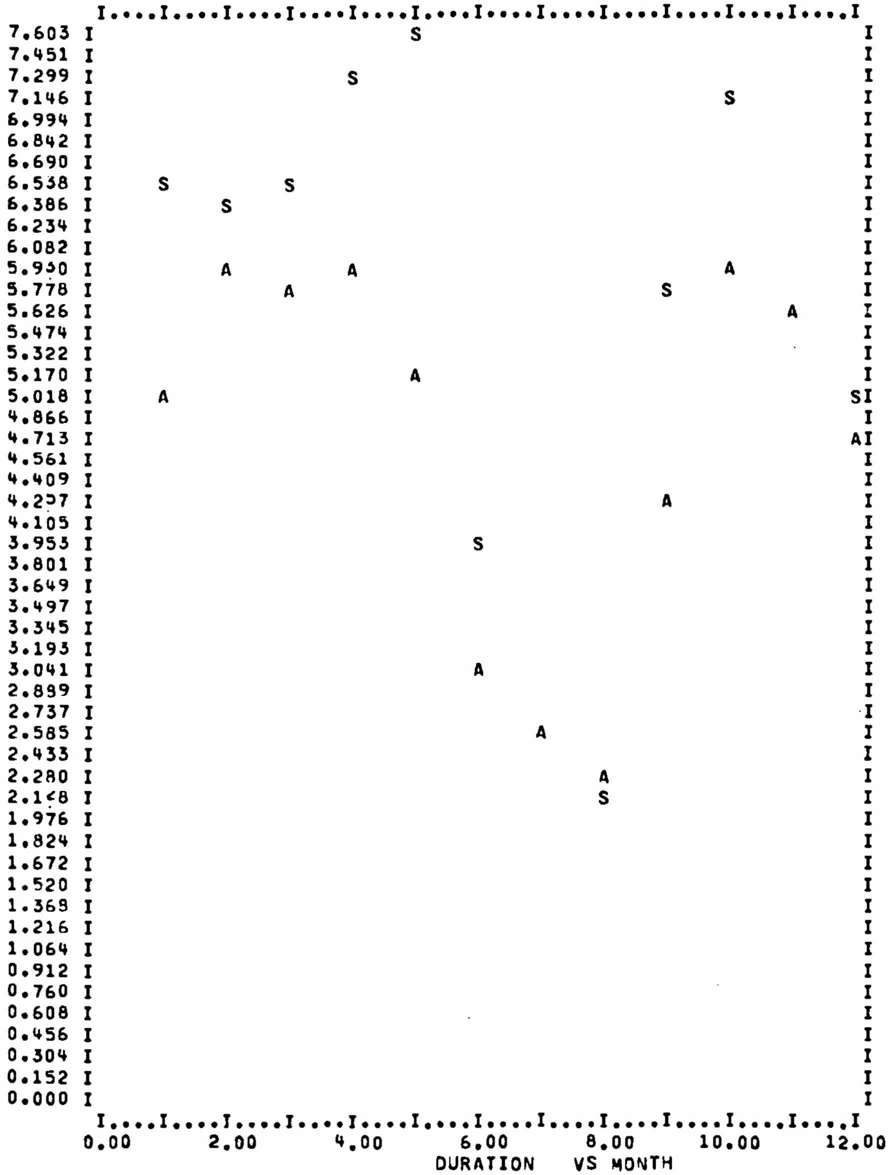
MONTH		NUMBER	TOTAL	MINIMUM	MAXIMUM	AVERAGE	STD DEV	VARIANCE	COEF-VAR
1									
	DURATION	150.	0.764000E 03	0.100000E 01	0.490000E 02	0.509333E 01	0.656750E 01	0.431321E 02	0.128943E 01
	INTENSITY	150.	0.219661E 01	0.400000E-02	0.600010E-01	0.146440E-01	0.993968E-02	0.987973E-04	0.678751E 00
	VOLUME	150.	0.139798E 02	0.100000E-01	0.104000E 01	0.931992E-01	0.162456E 00	0.263922E-01	0.174311E 01
	DELTA	150.	0.186345E 05	0.400000E 01	0.107150E 04	0.124230E 03	0.166778E 03	0.278151E 05	0.134250E 01
2									
	DURATION	142.	0.841000E 03	0.100000E 01	0.330000E 02	0.592253E 01	0.632463E 01	0.400010E 02	0.106789E 01
	INTENSITY	142.	0.253608E 01	0.500000E-02	0.750010E-01	0.178597E-01	0.126667E-01	0.160447E-03	0.709236E 00
	VOLUME	142.	0.178898E 02	0.100000E-01	0.110000E 01	0.125985E 00	0.181689E 00	0.330111E-01	0.144215E 01
	DELTA	142.	0.179610E 05	0.500000E 01	0.787000E 03	0.126485E 03	0.144351E 03	0.208374E 05	0.114124E 01
3									
	DURATION	224.	0.129700E 04	0.100000E 01	0.370000E 02	0.579017E 01	0.653762E 01	0.427405E 02	0.112908E 01
	INTENSITY	224.	0.440279E 01	0.473700E-02	0.167501E 00	0.196553E-01	0.176819E-01	0.312651E-03	0.899599E 00
	VOLUME	224.	0.304396E 02	0.100000E-01	0.170000E 01	0.135891E 00	0.223920E 00	0.501404E-01	0.164779E 01
	DELTA	224.	0.184405E 05	0.400000E 01	0.860500E 03	0.823236E 02	0.106620E 03	0.113678E 05	0.129513E 01
4									
	DURATION	224.	0.131600E 04	0.100000E 01	0.420000E 02	0.587500E 01	0.723299E 01	0.523161E 02	0.123114E 01
	INTENSITY	224.	0.603282E 01	0.600100E-02	0.240004E 00	0.269322E-01	0.317325E-01	0.100695E-02	0.117823E 01
	VOLUME	224.	0.461494E 02	0.100000E-01	0.325000E 01	0.206024E 00	0.423835E 00	0.179636E 00	0.205720E 01
	DELTA	224.	0.185880E 05	0.400000E 01	0.821500E 03	0.829821E 02	0.109177E 03	0.119196E 05	0.131567E 01
5									
	DURATION	272.	0.138900E 04	0.100000E 01	0.580000E 02	0.510661E 01	0.760314E 01	0.578077E 02	0.148888E 01
	INTENSITY	272.	0.104375E 02	0.500100E-02	0.503334E 00	0.383731E-01	0.467786E-01	0.218824E-02	0.121904E 01
	VOLUME	272.	0.660992E 02	0.100000E-01	0.433000E 01	0.243011E 00	0.528912E 00	0.279748E 00	0.217648E 01
	DELTA	272.	0.194690E 05	0.400000E 01	0.636000E 03	0.715772E 02	0.947347E 02	0.897466E 04	0.132353E 01
6									
	DURATION	257.	0.769000E 03	0.100000E 01	0.350000E 02	0.299221E 01	0.397943E 01	0.158358E 02	0.132992E 01
	INTENSITY	257.	0.131649E 02	0.666800E-02	0.650001E 00	0.512256E-01	0.737433E-01	0.543807E-02	0.143957E 01
	VOLUME	257.	0.452395E 02	0.100000E-01	0.282000E 01	0.176029E 00	0.384295E 00	0.147683E 00	0.218313E 01
	DELTA	257.	0.171550E 05	0.400000E 01	0.366500E 03	0.667509E 02	0.739571E 02	0.546965E 04	0.110795E 01
7									
	DURATION	259.	0.675000E 03	0.100000E 01	0.220000E 02	0.260617E 01	0.264855E 01	0.701484E 01	0.101626E 01
	INTENSITY	259.	0.167371E 02	0.500000E-02	0.760004E 00	0.646221E-01	0.994411E-01	0.988853E-02	0.153880E 01
	VOLUME	259.	0.450894E 02	0.100000E-01	0.205000E 01	0.174090E 00	0.297045E 00	0.882361E-01	0.170627E 01
	DELTA	259.	0.194705E 05	0.400000E 01	0.608500E 03	0.751756E 02	0.883221E 02	0.780079E 04	0.117487E 01
8									
	DURATION	233.	0.543000E 03	0.100000E 01	0.170000E 02	0.233047E 01	0.217900E 01	0.474807E 01	0.935006E 00
	INTENSITY	233.	0.135852E 02	0.500000E-02	0.675002E 00	0.583059E-01	0.944089E-01	0.891304E-02	0.161919E 01
	VOLUME	233.	0.340996E 02	0.100000E-01	0.343000E 01	0.146350E 00	0.309647E 00	0.958815E-01	0.211579E 01
	DELTA	233.	0.189285E 05	0.000000E 00	0.493000E 03	0.812382E 02	0.847613E 02	0.718449E 04	0.104336E 01
9									
	DURATION	171.	0.730000E 03	0.100000E 01	0.400000E 02	0.426900E 01	0.574129E 01	0.329624E 02	0.134487E 01
	INTENSITY	171.	0.830857E 01	0.500100E-02	0.655002E 00	0.485881E-01	0.732302E-01	0.536266E-02	0.150716E 01
	VOLUME	171.	0.351397E 02	0.100000E-01	0.164000E 01	0.205495E 00	0.334049E 00	0.111589E 00	0.162558E 01
	DELTA	171.	0.166235E 05	0.500000E 01	0.660500E 03	0.972134E 02	0.122170E 03	0.149257E 05	0.125672E 01
10									
	DURATION	132.	0.781000E 03	0.100000E 01	0.390000E 02	0.591666E 01	0.722278E 01	0.521685E 02	0.122075E 01
	INTENSITY	132.	0.368089E 01	0.600100E-02	0.170004E 00	0.278855E-01	0.281713E-01	0.793625E-03	0.101025E 01
	VOLUME	132.	0.253198E 02	0.100000E-01	0.170000E 01	0.191816E 00	0.306819E 00	0.941381E-01	0.159954E 01
	DELTA	132.	0.198020E 05	0.500000E 01	0.118150E 04	0.150015E 03	0.184240E 03	0.339446E 05	0.122814E 01
11									
	DURATION	139.	0.785000E 03	0.100000E 01	0.300000E 02	0.564748E 01	0.566308E 01	0.320704E 02	0.100276E 01
	INTENSITY	139.	0.281239E 01	0.500100E-02	0.775010E-01	0.202330E-01	0.145090E-01	0.210511E-03	0.717095E 00
	VOLUME	139.	0.187098E 02	0.100000E-01	0.820000E 00	0.134603E 00	0.174464E 00	0.304379E-01	0.129613E 01
	DELTA	139.	0.174025E 05	0.400000E 01	0.918000E 03	0.125197E 03	0.155972E 03	0.243273E 05	0.124580E 01

12

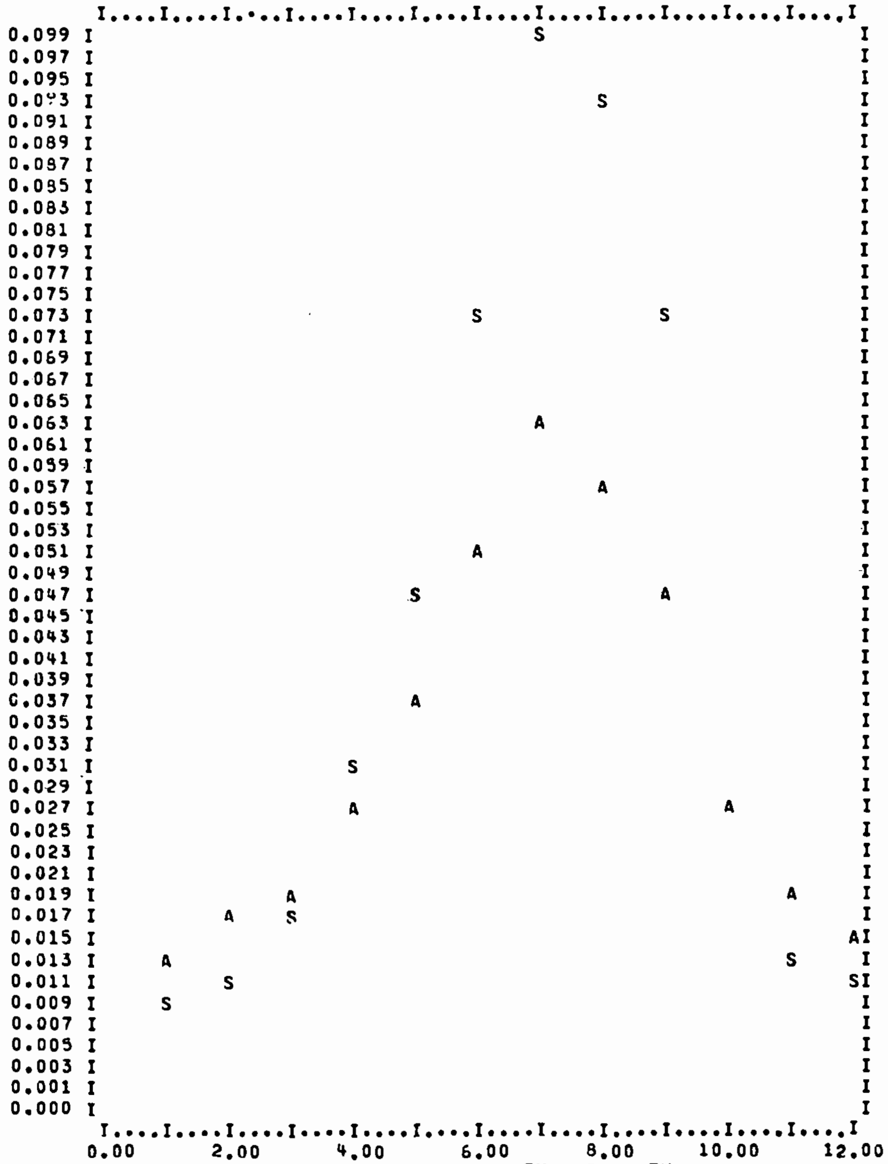
DURATION	151.	0.714000E 03	0.100000E 01	0.290000E 02	0.472847E 01	0.499324E 01	0.249324E 02	0.105599E 01
INTENSITY	151.	0.249642E 01	0.500100E-02	0.766660E-01	0.165326E-01	0.115608E-01	0.133653E-03	0.699276E 00
VOLUME	151.	0.147398E 02	0.100000E-01	0.138000E 01	0.976150E-01	0.166791E 00	0.278195E-01	0.170866E 01
DELTA	151.	0.202905E 05	0.400000E 01	0.763000E 03	0.134374E 03	0.172661E 03	0.298119E 05	0.128493E 01

SUMMARY OF RAINFALL STATISTICS BY MONTH(FOR PERIOD OF RECORD)

MONTH	DURATION		INTENSITY		VOLUME		DELTA	
	AVERAGE	STD DEV	AVERAGE	STD DEV	AVERAGE	STD DEV	AVERAGE	STD DEV
1.	5.09	6.56	0.0146	0.0099	0.09	0.16	124.	166.
2.	5.92	6.32	0.0176	0.0126	0.12	0.18	126.	144.
3.	5.79	6.53	0.0196	0.0176	0.13	0.22	82.	106.
4.	5.87	7.23	0.0269	0.0317	0.20	0.42	82.	109.
5.	5.10	7.60	0.0383	0.0467	0.24	0.52	71.	94.
6.	2.99	3.97	0.0512	0.0737	0.17	0.38	66.	73.
7.	2.60	2.64	0.0646	0.0994	0.17	0.29	75.	88.
8.	2.33	2.17	0.0583	0.0944	0.14	0.30	81.	84.
9.	4.26	5.74	0.0485	0.0732	0.20	0.33	97.	122.
10.	5.91	7.22	0.0278	0.0281	0.19	0.30	150.	184.
11.	5.64	5.66	0.0202	0.0145	0.13	0.17	125.	155.
12.	4.72	4.99	0.0165	0.0115	0.09	0.16	134.	172.

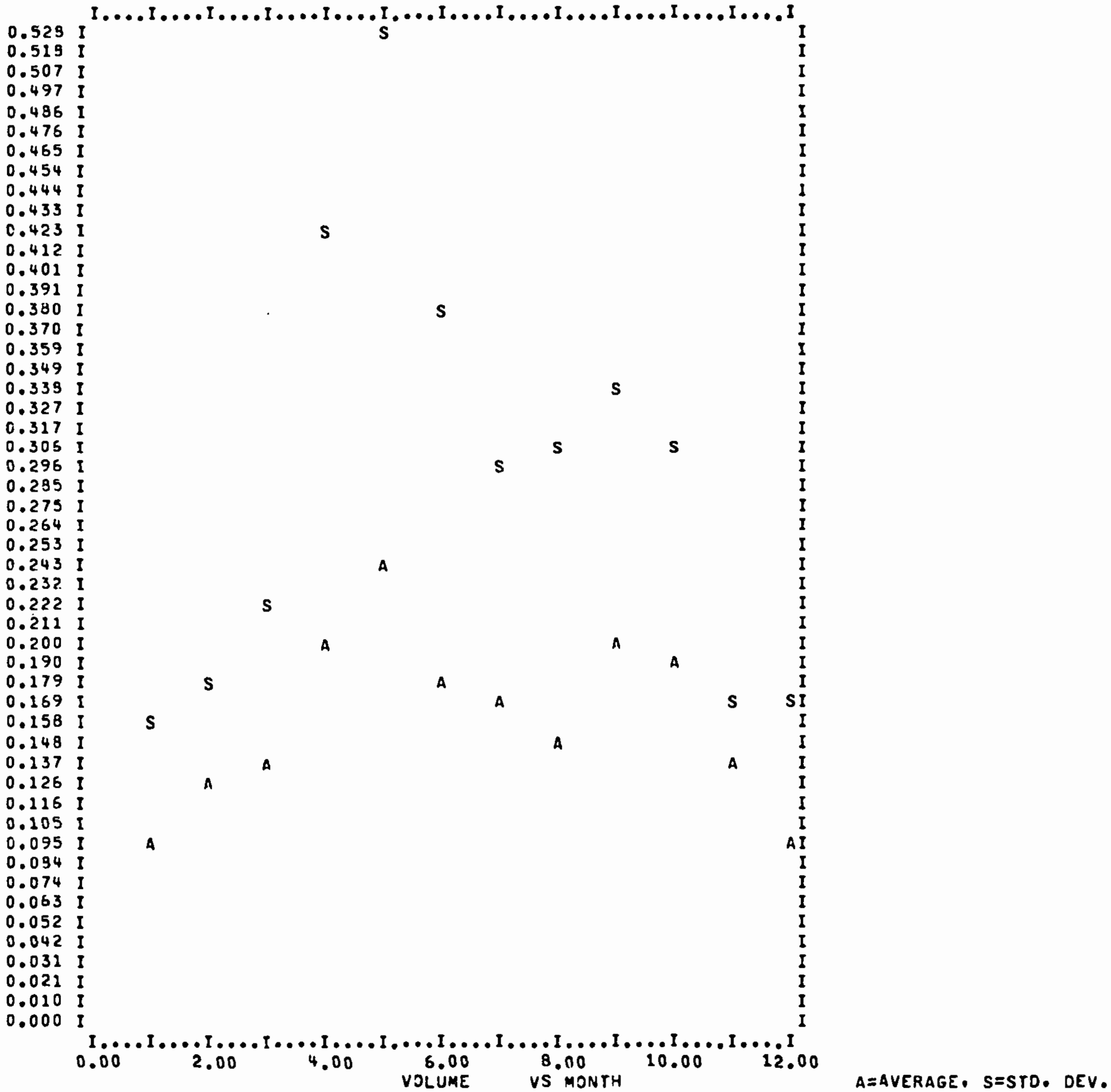


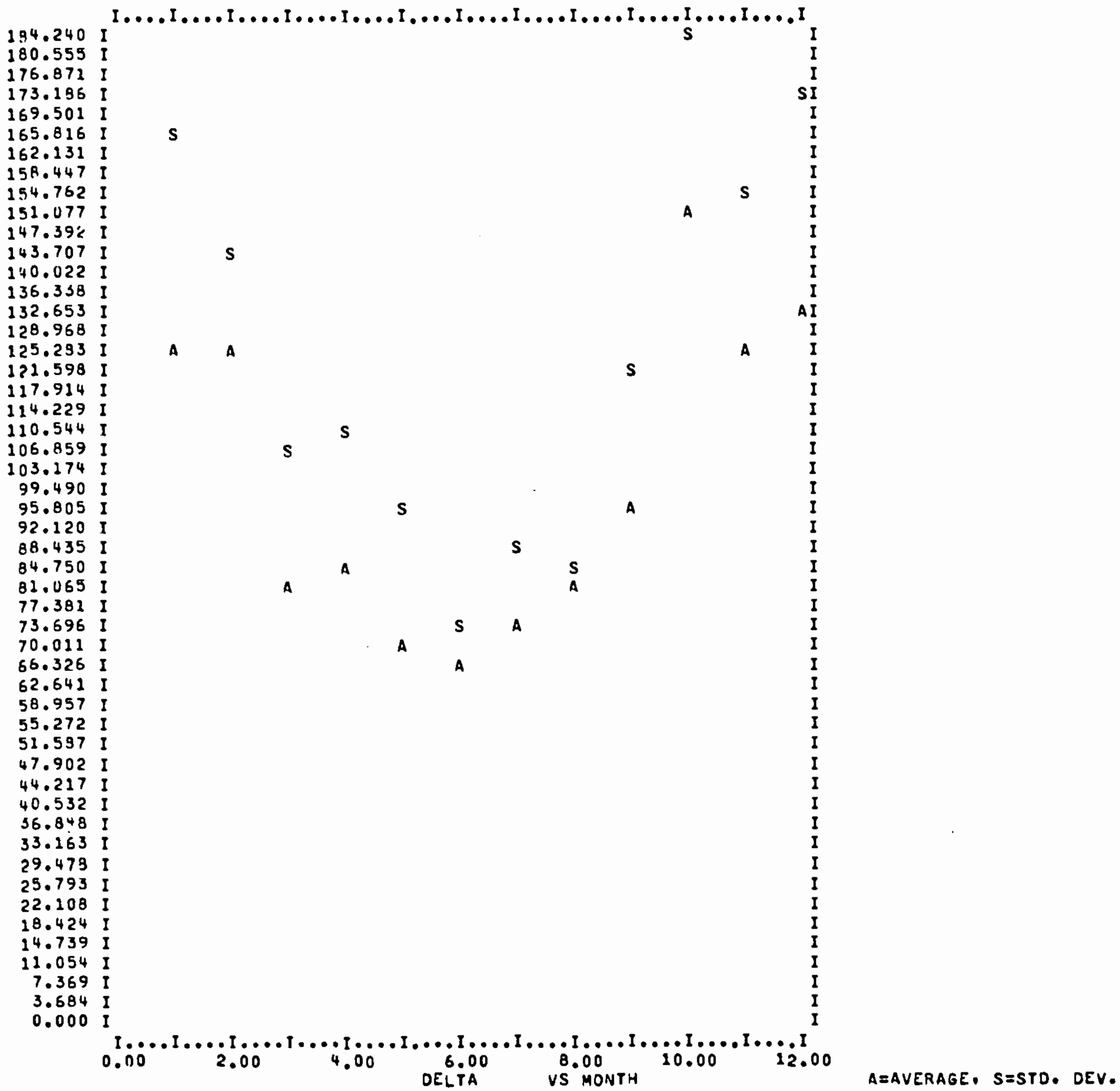
A=AVERAGE, S=STD. DEV.



INTENSITY VS MONTH

A=AVERAGE, S=STD. DEV.


0.528
0.000
0.00
2.00
4.00
6.00
8.00
10.00
12.00
VOLUME VS MONTH
A=AVERAGE. S=STD. DEV.


184.240
180.555
176.871
173.186
169.501
165.816
162.131
158.447
154.762
151.077
147.392
143.707
140.022
136.338
132.653
128.968
125.283
121.598
117.914
114.229
110.544
106.859
103.174
99.490
95.805
92.120
88.435
84.750
81.065
77.381
73.696
70.011
66.326
62.641
58.957
55.272
51.587
47.902
44.217
40.532
36.848
33.163
29.478
25.793
22.108
18.424
14.739
11.054
7.369
3.684
0.000
0.00
2.00
4.00
6.00
8.00
10.00
12.00
DELTA VS MONTH
A=AVERAGE, S=STD. DEV.

RAINFALL STATISTICS BY YEAR(FOR PERIOD OF RECORD)

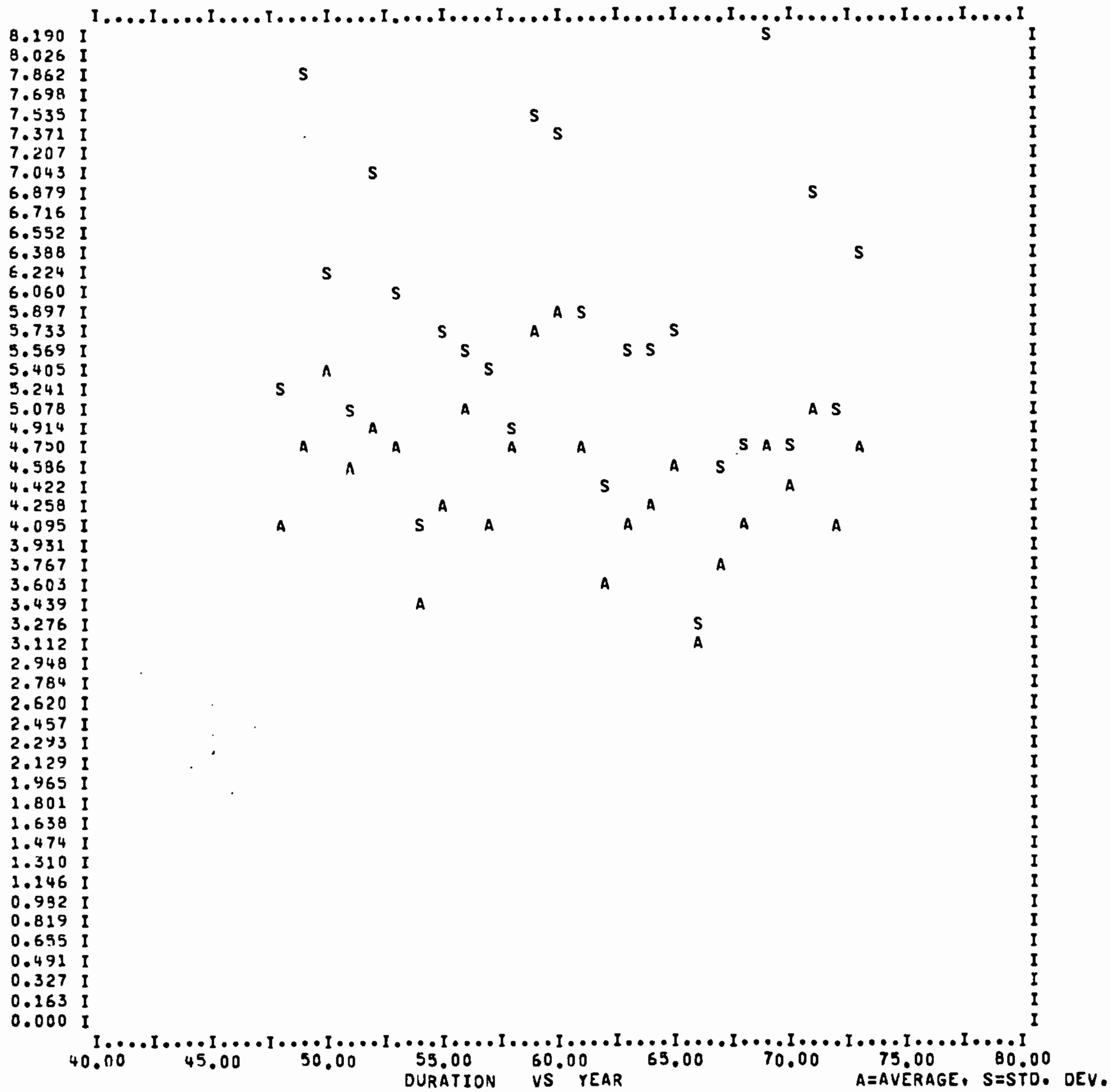
YEAR		NUMBER	TOTAL	MINIMUM	MAXIMUM	AVERAGE	STD DEV	VARIANCE	COEF-VAR
48									
	DURATION	24.	0.100000E 03	0.100000E 01	0.230000E 02	0.416666E 01	0.532154E 01	0.283188E 02	0.127717E 01
	INTENSITY	24.	0.724532E 00	0.666800E-02	0.133334E 00	0.301930E-01	0.393428E-01	0.154786E-02	0.130304E 01
	VOLUME	24.	0.192999E 01	0.100000E-01	0.400000E 00	0.804166E-01	0.947067E-01	0.896937E-02	0.117770E 01
	DELTA	24.	0.355350E 04	0.000000E 00	0.763000E 03	0.148062E 03	0.191573E 03	0.367002E 05	0.129386E 01
49									
	DURATION	111.	0.536000E 03	0.100000E 01	0.490000E 02	0.482882E 01	0.780661E 01	0.609431E 02	0.161666E 01
	INTENSITY	111.	0.336794E 01	0.636400E-02	0.200004E 00	0.303418E-01	0.339153E-01	0.115025E-02	0.111777E 01
	VOLUME	111.	0.167799E 02	0.100000E-01	0.196000E 01	0.151170E 00	0.289182E 00	0.836263E-01	0.191295E 01
	DELTA	111.	0.857700E 04	0.400000E 01	0.717000E 03	0.772702E 02	0.112657E 03	0.126917E 05	0.145797E 01
50									
	DURATION	62.	0.332000E 03	0.100000E 01	0.290000E 02	0.535483E 01	0.622290E 01	0.387244E 02	0.116210E 01
	INTENSITY	62.	0.265045E 01	0.400000E-02	0.412000E 00	0.427493E-01	0.667682E-01	0.445799E-02	0.156185E 01
	VOLUME	62.	0.139399E 02	0.100000E-01	0.213000E 01	0.224838E 00	0.424803E 00	0.180457E 00	0.188937E 01
	DELTA	62.	0.903950E 04	0.700000E 01	0.759500E 03	0.145798E 03	0.156591E 03	0.245209E 05	0.107402E 01
51									
	DURATION	110.	0.499000E 03	0.100000E 01	0.250000E 02	0.453636E 01	0.511640E 01	0.261775E 02	0.112786E 01
	INTENSITY	110.	0.429033E 01	0.571400E-02	0.650004E 00	0.390030E-01	0.798531E-01	0.637652E-02	0.204735E 01
	VOLUME	110.	0.194199E 02	0.100000E-01	0.343000E 01	0.176544E 00	0.394613E 00	0.155719E 00	0.223520E 01
	DELTA	110.	0.874300E 04	0.450000E 01	0.459500E 03	0.794818E 02	0.920243E 02	0.846948E 04	0.115780E 01
52									
	DURATION	85.	0.415000E 03	0.100000E 01	0.370000E 02	0.488235E 01	0.700410E 01	0.490574E 02	0.143457E 01
	INTENSITY	85.	0.239083E 01	0.583300E-02	0.260004E 00	0.281274E-01	0.328243E-01	0.107743E-02	0.116698E 01
	VOLUME	85.	0.135599E 02	0.100000E-01	0.150000E 01	0.159528E 00	0.305558E 00	0.933658E-01	0.191538E 01
	DELTA	85.	0.880500E 04	0.500000E 01	0.787000E 03	0.103588E 03	0.125816E 03	0.158298E 05	0.121458E 01
53									
	DURATION	86.	0.409000E 03	0.100000E 01	0.330000E 02	0.475581E 01	0.603701E 01	0.364455E 02	0.126939E 01
	INTENSITY	86.	0.270241E 01	0.500100E-02	0.350001E 00	0.314233E-01	0.450213E-01	0.202692E-02	0.143273E 01
	VOLUME	86.	0.141099E 02	0.100000E-01	0.187000E 01	0.164069E 00	0.290116E 00	0.841675E-01	0.176825E 01
	DELTA	86.	0.864450E 04	0.500000E 01	0.606000E 03	0.100517E 03	0.124448E 03	0.154873E 05	0.123807E 01
54									
	DURATION	68.	0.236000E 03	0.100000E 01	0.210000E 02	0.347058E 01	0.415545E 01	0.172677E 02	0.119733E 01
	INTENSITY	68.	0.240782E 01	0.666700E-02	0.420004E 00	0.354091E-01	0.601270E-01	0.361526E-02	0.169806E 01
	VOLUME	68.	0.750998E 01	0.100000E-01	0.115000E 01	0.110440E 00	0.191158E 00	0.365414E-01	0.173086E 01
	DELTA	68.	0.875200E 04	0.450000E 01	0.757000E 03	0.128705E 03	0.147062E 03	0.216273E 05	0.114262E 01
55									
	DURATION	82.	0.352000E 03	0.100000E 01	0.330000E 02	0.429268E 01	0.573593E 01	0.329009E 02	0.133621E 01
	INTENSITY	82.	0.407680E 01	0.666800E-02	0.655002E 00	0.497171E-01	0.846472E-01	0.716516E-02	0.170257E 01
	VOLUME	82.	0.160499E 02	0.100000E-01	0.137000E 01	0.195731E 00	0.322757E 00	0.104172E 00	0.164898E 01
	DELTA	82.	0.818550E 04	0.400000E 01	0.649000E 03	0.998231E 02	0.128251E 03	0.164484E 05	0.128478E 01
56									
	DURATION	70.	0.356000E 03	0.100000E 01	0.300000E 02	0.508571E 01	0.559954E 01	0.313548E 02	0.110103E 01
	INTENSITY	70.	0.305555E 01	0.666800E-02	0.675002E 00	0.436507E-01	0.864286E-01	0.746991E-02	0.198000E 01
	VOLUME	70.	0.137199E 02	0.100000E-01	0.161000E 01	0.195999E 00	0.322316E 00	0.103887E 00	0.164447E 01
	DELTA	70.	0.924550E 04	0.650000E 01	0.118150E 04	0.132078E 03	0.202405E 03	0.409680E 05	0.153246E 01
57									
	DURATION	111.	0.456000E 03	0.100000E 01	0.320000E 02	0.410810E 01	0.542276E 01	0.294063E 02	0.132001E 01
	INTENSITY	111.	0.430027E 01	0.500000E-02	0.240004E 00	0.387412E-01	0.466055E-01	0.217207E-02	0.120299E 01
	VOLUME	111.	0.215798E 02	0.100000E-01	0.329000E 01	0.194413E 00	0.449628E 00	0.202165E 00	0.231274E 01
	DELTA	111.	0.840450E 04	0.450000E 01	0.422000E 03	0.757162E 02	0.967613E 02	0.936276E 04	0.127794E 01
58									
	DURATION	103.	0.497000E 03	0.100000E 01	0.230000E 02	0.482524E 01	0.495554E 01	0.245573E 02	0.102700E 01
	INTENSITY	103.	0.514908E 01	0.500100E-02	0.520004E 00	0.499910E-01	0.880508E-01	0.775294E-02	0.176133E 01
	VOLUME	103.	0.187999E 02	0.100000E-01	0.151000E 01	0.182523E 00	0.262636E 00	0.689776E-01	0.143891E 01
	DELTA	103.	0.932500E 04	0.400000E 01	0.902000E 03	0.905339E 02	0.133838E 03	0.179127E 05	0.147832E 01

59								
DURATION	88.	0.504000E 03	0.100000E 01	0.420000E 02	0.572727E 01	0.745673E 01	0.556029E 02	0.130197E 01
INTENSITY	88.	0.252017E 01	0.500100E-02	0.190004E 00	0.236383E-01	0.275740E-01	0.760328E-03	0.962836E 00
VOLUME	88.	0.165399E 02	0.100000E-01	0.170000E 01	0.187953E 00	0.315179E 00	0.993378E-01	0.167689E 01
DELTA	88.	0.864950E 04	0.400000E 01	0.660500E 03	0.982897E 02	0.117992E 03	0.139221E 05	0.120045E 01
60								
DURATION	74.	0.442000E 03	0.100000E 01	0.290000E 02	0.597297E 01	0.733722E 01	0.538348E 02	0.122840E 01
INTENSITY	74.	0.253318E 01	0.571400E-02	0.320002E 00	0.342322E-01	0.472798E-01	0.223538E-02	0.138115E 01
VOLUME	74.	0.149799E 02	0.100000E-01	0.157000E 01	0.202431E 00	0.301883E 00	0.911336E-01	0.149128E 01
DELTA	74.	0.881700E 04	0.550000E 01	0.510500E 03	0.119148E 03	0.134031E 03	0.179645E 05	0.112491E 01
61								
DURATION	111.	0.519000E 03	0.100000E 01	0.330000E 02	0.467567E 01	0.584677E 01	0.341847E 02	0.125046E 01
INTENSITY	111.	0.350318E 01	0.500100E-02	0.345002E 00	0.315602E-01	0.446170E-01	0.199067E-02	0.141370E 01
VOLUME	111.	0.190098E 02	0.100000E-01	0.215000E 01	0.171260E 00	0.321136E 00	0.103128E 00	0.187513E 01
DELTA	111.	0.872850E 04	0.400000E 01	0.523000E 03	0.786351E 02	0.100344E 03	0.100689E 05	0.127607E 01
62								
DURATION	87.	0.319000E 03	0.100000E 01	0.270000E 02	0.366666E 01	0.439255E 01	0.192945E 02	0.119797E 01
INTENSITY	87.	0.188887E 01	0.500000E-02	0.120002E 00	0.217112E-01	0.200854E-01	0.403426E-03	0.925118E 00
VOLUME	87.	0.844995E 01	0.100000E-01	0.104000E 01	0.971259E-01	0.172099E 00	0.296182E-01	0.177192E 01
DELTA	87.	0.872050E 04	0.500000E 01	0.741000E 03	0.100235E 03	0.133498E 03	0.178219E 05	0.133184E 01
63								
DURATION	87.	0.362000E 03	0.100000E 01	0.290000E 02	0.416092E 01	0.549814E 01	0.302296E 02	0.132137E 01
INTENSITY	87.	0.332088E 01	0.500100E-02	0.420004E 00	0.381711E-01	0.592150E-01	0.350642E-02	0.155130E 01
VOLUME	87.	0.122299E 02	0.100000E-01	0.222000E 01	0.140574E 00	0.277338E 00	0.769168E-01	0.197290E 01
DELTA	87.	0.887000E 04	0.450000E 01	0.821500E 03	0.101954E 03	0.145820E 03	0.212636E 05	0.143025E 01
64								
DURATION	84.	0.355000E 03	0.100000E 01	0.290000E 02	0.422619E 01	0.555661E 01	0.308759E 02	0.131480E 01
INTENSITY	84.	0.223807E 01	0.500100E-02	0.130005E 00	0.266437E-01	0.259012E-01	0.670872E-03	0.972131E 00
VOLUME	84.	0.101399E 02	0.100000E-01	0.176000E 01	0.120713E 00	0.234313E 00	0.549028E-01	0.194106E 01
DELTA	84.	0.875250E 04	0.500000E 01	0.556000E 03	0.104196E 03	0.114026E 03	0.130019E 05	0.109433E 01
65								
DURATION	114.	0.532000E 03	0.100000E 01	0.370000E 02	0.466666E 01	0.569997E 01	0.324896E 02	0.122142E 01
INTENSITY	114.	0.442006E 01	0.500100E-02	0.341667E 00	0.387725E-01	0.504913E-01	0.254937E-02	0.130224E 01
VOLUME	114.	0.218698E 02	0.100000E-01	0.277000E 01	0.191841E 00	0.366855E 00	0.134582E 00	0.191228E 01
DELTA	114.	0.865150E 04	0.500000E 01	0.918000E 03	0.758903E 02	0.121041E 03	0.146511E 05	0.159495E 01
66								
DURATION	91.	0.289000E 03	0.100000E 01	0.160000E 02	0.317582E 01	0.333864E 01	0.111465E 02	0.105126E 01
INTENSITY	91.	0.408537E 01	0.500000E-02	0.640004E 00	0.448941E-01	0.826990E-01	0.683912E-02	0.184208E 01
VOLUME	91.	0.108099E 02	0.100000E-01	0.800000E 00	0.118790E 00	0.168383E 00	0.283529E-01	0.141747E 01
DELTA	91.	0.886200E 04	0.400000E 01	0.660500E 03	0.973846E 02	0.133247E 03	0.177549E 05	0.136826E 01
67								
DURATION	124.	0.477000E 03	0.100000E 01	0.260000E 02	0.384677E 01	0.455150E 01	0.207161E 02	0.118319E 01
INTENSITY	124.	0.622843E 01	0.600100E-02	0.650001E 00	0.502293E-01	0.830309E-01	0.689413E-02	0.165303E 01
VOLUME	124.	0.233098E 02	0.100000E-01	0.325000E 01	0.187982E 00	0.391811E 00	0.153515E 00	0.208429E 01
DELTA	124.	0.882900E 04	0.400000E 01	0.550000E 03	0.712016E 02	0.941286E 02	0.886020E 04	0.132200E 01
68								
DURATION	89.	0.363000E 03	0.100000E 01	0.270000E 02	0.407865E 01	0.468126E 01	0.219141E 02	0.114774E 01
INTENSITY	89.	0.324160E 01	0.500100E-02	0.390002E 00	0.364224E-01	0.517360E-01	0.267662E-02	0.142044E 01
VOLUME	89.	0.121299E 02	0.100000E-01	0.143000E 01	0.136291E 00	0.213383E 00	0.455324E-01	0.156564E 01
DELTA	89.	0.878550E 04	0.400000E 01	0.405000E 03	0.987134E 02	0.106823E 03	0.114112E 05	0.108215E 01
69								
DURATION	105.	0.497000E 03	0.100000E 01	0.580000E 02	0.473333E 01	0.819036E 01	0.670820E 02	0.173035E 01
INTENSTTY	105.	0.389684E 01	0.500100E-02	0.416668E 00	0.371128E-01	0.616595E-01	0.380189E-02	0.166140E 01
VOLUME	105.	0.215098E 02	0.100000E-01	0.433000E 01	0.204855E 00	0.510391E 00	0.260499E 00	0.249146E 01
DELTA	105.	0.874700E 04	0.400000E 01	0.420000E 03	0.833047E 02	0.930079E 02	0.865047E 04	0.111647E 01
70								
DURATION	86.	0.374000E 03	0.100000E 01	0.220000E 02	0.434883E 01	0.471235E 01	0.222062E 02	0.108358E 01

	INTENSITY	86.	0.265086E 01	0.473700E-02	0.190001E 00	0.308239E-01	0.339786E-01	0.115455E-02	0.110234E 01
	VOLUME	86.	0.137299E 02	0.100000E-01	0.282000E 01	0.159650E 00	0.362936E 00	0.131722E 00	0.227331E 01
	DELTA	86.	0.828500E 04	0.400000E 01	0.860500E 03	0.963372E 02	0.130546E 03	0.170424E 05	0.135510E 01
71									
	DURATION	78.	0.398000E 03	0.100000E 01	0.400000E 02	0.510256E 01	0.687663E 01	0.472880E 02	0.134768E 01
	INTENSITY	78.	0.264446E 01	0.600000E-02	0.760004E 00	0.339033E-01	0.905136E-01	0.819272E-02	0.266975E 01
	VOLUME	78.	0.109599E 02	0.100000E-01	0.160000E 01	0.140512E 00	0.268893E 00	0.723034E-01	0.191366E 01
	DELTA	78.	0.915750E 04	0.400000E 01	0.540000E 03	0.117403E 03	0.139766E 03	0.195346E 05	0.119047E 01
72									
	DURATION	107.	0.431000E 03	0.100000E 01	0.240000E 02	0.402803E 01	0.504406E 01	0.254425E 02	0.125223E 01
	INTENSITY	107.	0.373026E 01	0.500100E-02	0.302501E 00	0.348622E-01	0.487233E-01	0.237395E-02	0.139759E 01
	VOLUME	107.	0.168699E 02	0.100000E-01	0.304000E 01	0.157662E 00	0.359712E 00	0.129392E 00	0.228153E 01
	DELTA	107.	0.885900E 04	0.400000E 01	0.554000E 03	0.827944E 02	0.103978E 03	0.108115E 05	0.125586E 01
73									
	DURATION	117.	0.554000E 03	0.100000E 01	0.330000E 02	0.473504E 01	0.637667E 01	0.406619E 02	0.134669E 01
	INTENSITY	117.	0.437354E 01	0.500000E-02	0.530004E 00	0.373807E-01	0.732807E-01	0.537006E-02	0.196038E 01
	VOLUME	117.	0.229598E 02	0.100000E-01	0.355000E 01	0.196238E 00	0.434959E 00	0.189189E 00	0.221648E 01
	DELTA	117.	0.877600E 04	0.400000E 01	0.608500E 03	0.750085E 02	0.100784E 03	0.101574E 05	0.134363E 01

SUMMARY OF RAINFALL STATISTICS BY YEAR(FOR PERIOD OF RECORD)

YEAR	DURATION		INTENSITY		VOLUME		DELTA	
	AVERAGE	STD DEV	AVERAGE	STD DEV	AVERAGE	STD DEV	AVERAGE	STD DEV
48.	4.16	5.32	0.0301	0.0393	0.08	0.09	148.	191.
49.	4.82	7.80	0.0303	0.0339	0.15	0.28	77.	112.
50.	5.35	6.22	0.0427	0.0667	0.22	0.42	145.	156.
51.	4.53	5.11	0.0390	0.0798	0.17	0.39	79.	92.
52.	4.88	7.04	0.0281	0.0328	0.15	0.30	103.	125.
53.	4.75	6.05	0.0314	0.0450	0.16	0.29	100.	124.
54.	3.47	4.15	0.0354	0.0601	0.11	0.19	128.	147.
55.	4.29	5.73	0.0497	0.0846	0.19	0.32	99.	128.
56.	5.08	5.59	0.0436	0.0864	0.19	0.32	132.	202.
57.	4.10	5.42	0.0387	0.0466	0.19	0.44	75.	96.
58.	4.92	4.95	0.0499	0.0980	0.18	0.26	90.	133.
59.	5.72	7.45	0.0286	0.0275	0.18	0.31	98.	117.
60.	5.97	7.33	0.0342	0.0472	0.20	0.30	119.	134.
61.	4.67	5.84	0.0315	0.0446	0.17	0.32	78.	100.
62.	3.66	4.39	0.0217	0.0200	0.09	0.17	100.	133.
63.	4.16	5.49	0.0381	0.0592	0.14	0.27	101.	145.
64.	4.22	5.55	0.0266	0.0259	0.12	0.23	104.	114.
65.	4.66	5.69	0.0387	0.0504	0.19	0.36	75.	121.
66.	3.17	3.33	0.0448	0.0826	0.11	0.16	97.	133.
67.	3.84	4.55	0.0502	0.0830	0.18	0.39	71.	94.
68.	4.07	4.68	0.0364	0.0517	0.13	0.21	98.	106.
69.	4.73	8.19	0.0371	0.0616	0.20	0.51	83.	93.
70.	4.34	4.71	0.0308	0.0339	0.15	0.36	96.	130.
71.	5.10	6.87	0.0339	0.0905	0.14	0.26	117.	139.
72.	4.02	5.04	0.0348	0.0487	0.15	0.35	82.	103.
73.	4.73	6.37	0.0373	0.0732	0.19	0.43	75.	100.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1.310
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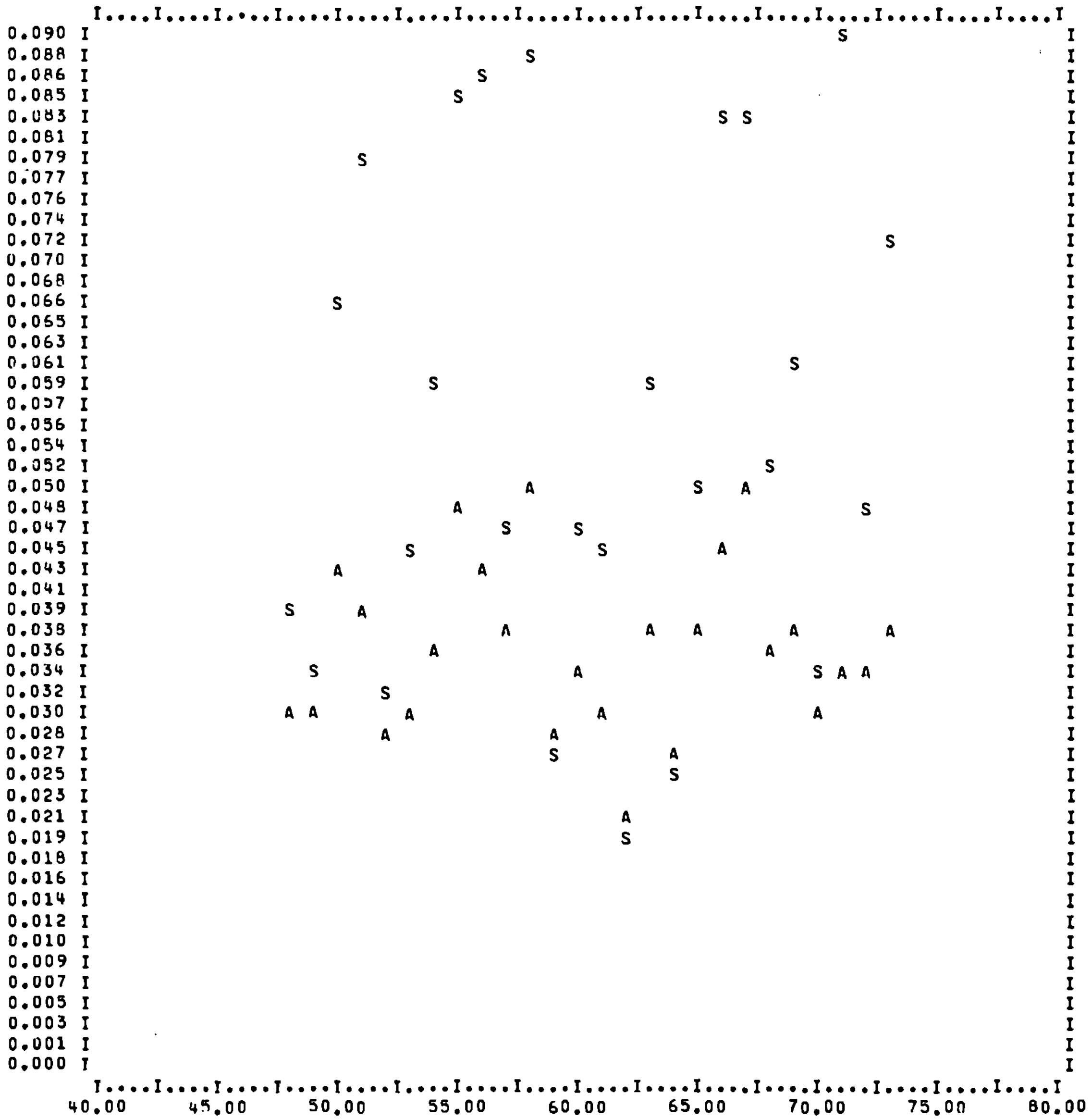
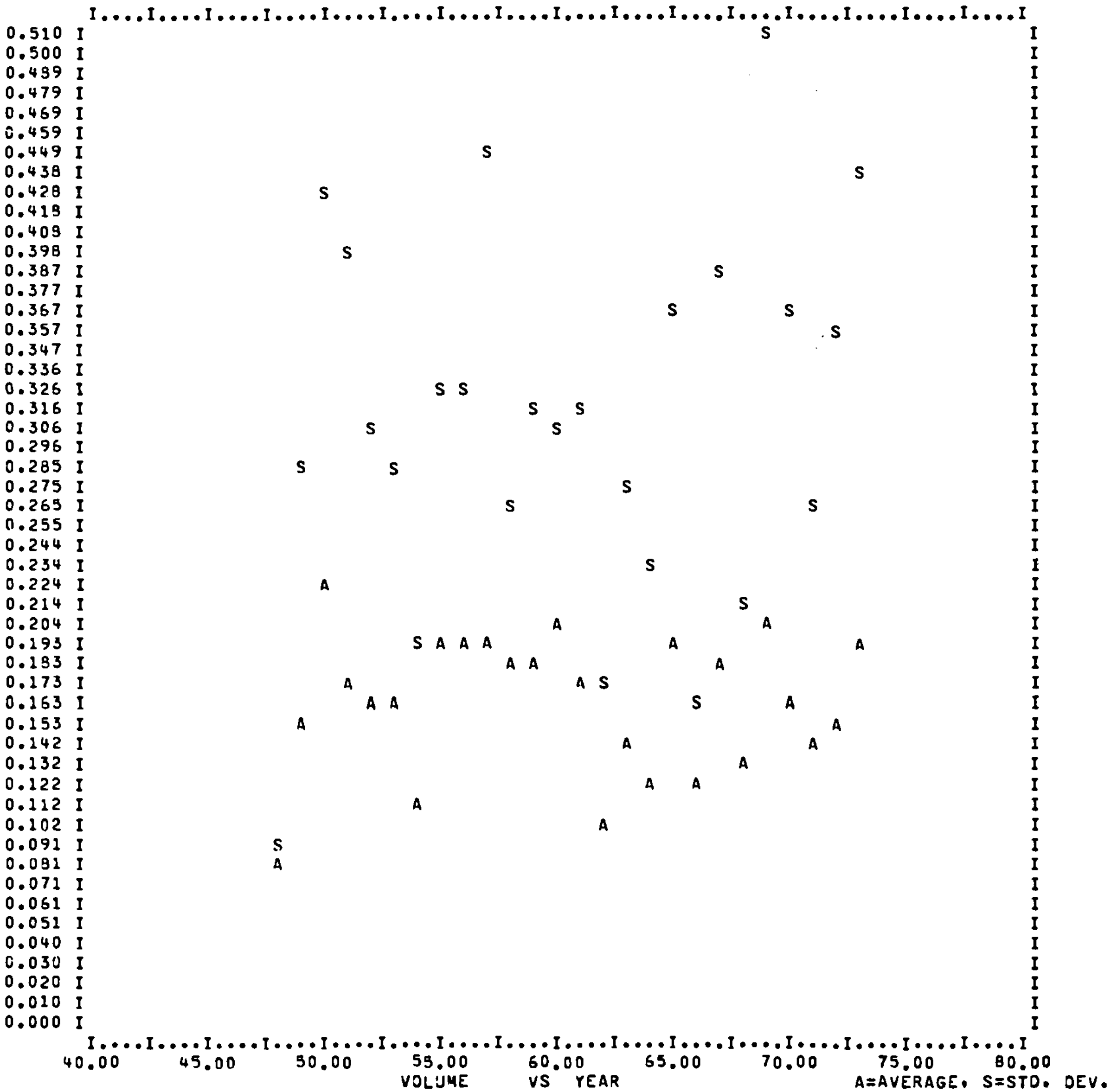
DURATION VS YEAR
A=AVERAGE, S=STD. DEV.



INTENSITY VS YEAR A=AVERAGE, S=STD. DEV.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0.163
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0.132
0.122
0.112
0.102
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0.071
0.061
0.051
0.040
0.030
0.020
0.010
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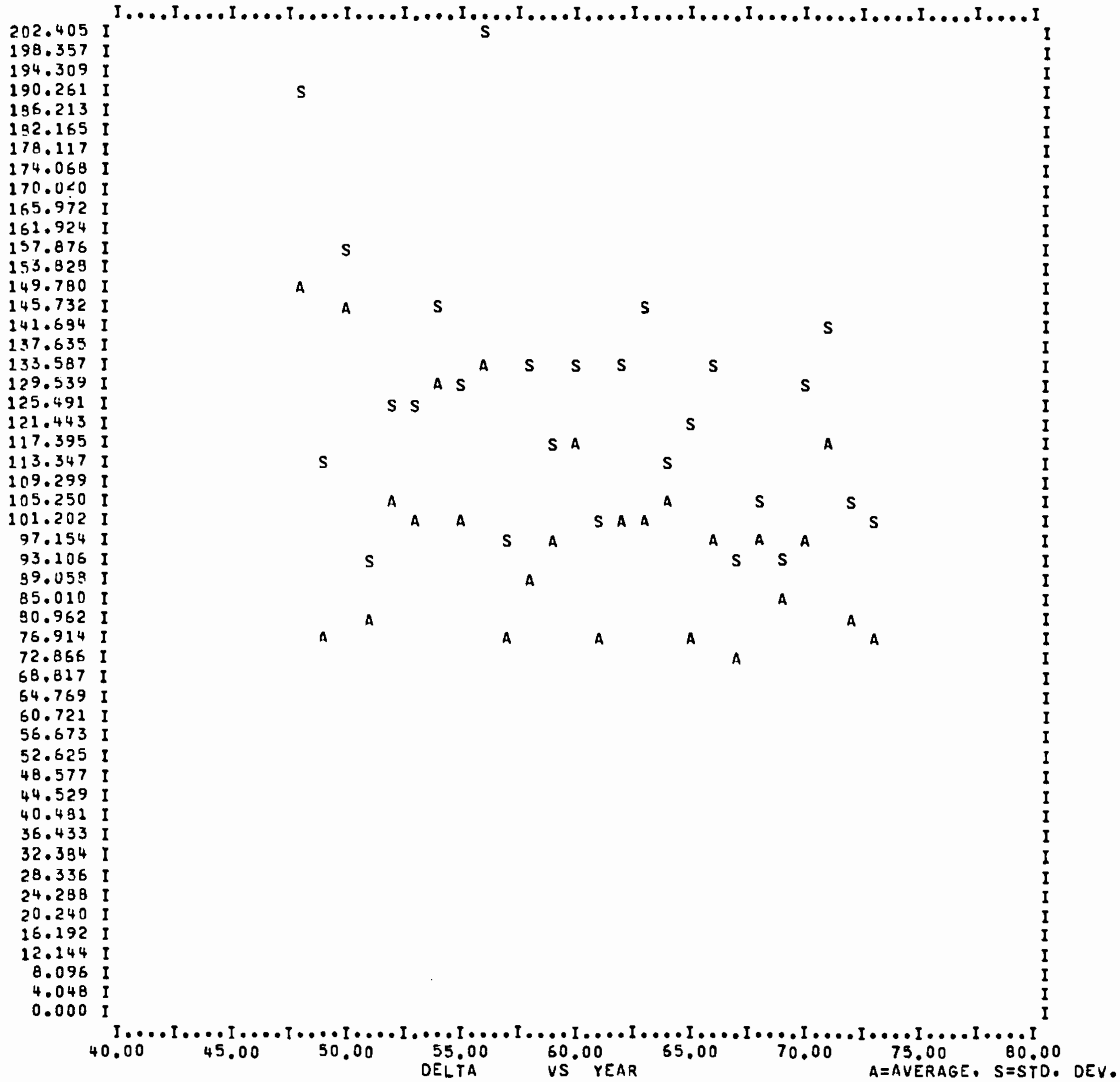
VOLUME VS YEAR
A=AVERAGE, S=STD. DEV.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12.144
8.096
4.048
0.000
40.00 45.00 50.00 55.00 60.00 65.00 70.00 75.00 80.00
DELTA VS YEAR
A=AVERAGE. S=STD. DEV.

PROBABILITY ANALYSIS-DURATION

PERCENTAGE OF OCCURRENCE LESS THAN OR EQUAL TO THE GIVEN VALUE OF DURATION

VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT
1.000	0.042	1.000	0.084	1.000	0.127	1.000	0.169	1.000	0.212	1.000	0.254	1.000	0.297	1.000	0.339
1.000	0.382	1.000	0.424	1.000	0.467	1.000	0.509	1.000	0.552	1.000	0.594	1.000	0.637	1.000	0.679
1.000	0.722	1.000	0.764	1.000	0.807	1.000	0.849	1.000	0.892	1.000	0.934	1.000	0.977	1.000	1.019
1.000	1.062	1.000	1.104	1.000	1.146	1.000	1.189	1.000	1.231	1.000	1.274	1.000	1.316	1.000	1.359
1.000	1.401	1.000	1.444	1.000	1.486	1.000	1.529	1.000	1.571	1.000	1.614	1.000	1.656	1.000	1.699
1.000	1.741	1.000	1.784	1.000	1.826	1.000	1.869	1.000	1.911	1.000	1.954	1.000	1.996	1.000	2.039
1.000	2.081	1.000	2.124	1.000	2.166	1.000	2.209	1.000	2.251	1.000	2.293	1.000	2.336	1.000	2.378
1.000	2.421	1.000	2.463	1.000	2.506	1.000	2.548	1.000	2.591	1.000	2.633	1.000	2.676	1.000	2.718
1.000	2.761	1.000	2.803	1.000	2.846	1.000	2.888	1.000	2.931	1.000	2.973	1.000	3.016	1.000	3.058
1.000	3.101	1.000	3.143	1.000	3.186	1.000	3.228	1.000	3.271	1.000	3.313	1.000	3.355	1.000	3.398
1.000	3.440	1.000	3.483	1.000	3.525	1.000	3.568	1.000	3.610	1.000	3.653	1.000	3.695	1.000	3.738
1.000	3.780	1.000	3.823	1.000	3.865	1.000	3.908	1.000	3.950	1.000	3.993	1.000	4.035	1.000	4.078
1.000	4.120	1.000	4.163	1.000	4.205	1.000	4.248	1.000	4.290	1.000	4.333	1.000	4.375	1.000	4.418
1.000	4.460	1.000	4.502	1.000	4.545	1.000	4.587	1.000	4.630	1.000	4.672	1.000	4.715	1.000	4.757
1.000	4.800	1.000	4.842	1.000	4.885	1.000	4.927	1.000	4.970	1.000	5.012	1.000	5.055	1.000	5.097
1.000	5.140	1.000	5.182	1.000	5.225	1.000	5.267	1.000	5.310	1.000	5.352	1.000	5.395	1.000	5.437
1.000	5.480	1.000	5.522	1.000	5.564	1.000	5.607	1.000	5.649	1.000	5.692	1.000	5.734	1.000	5.777
1.000	5.819	1.000	5.862	1.000	5.904	1.000	5.947	1.000	5.989	1.000	6.032	1.000	6.074	1.000	6.117
1.000	6.159	1.000	6.202	1.000	6.244	1.000	6.287	1.000	6.329	1.000	6.372	1.000	6.414	1.000	6.457
1.000	6.499	1.000	6.542	1.000	6.584	1.000	6.627	1.000	6.669	1.000	6.711	1.000	6.754	1.000	6.796
1.000	6.839	1.000	6.881	1.000	6.924	1.000	6.966	1.000	7.009	1.000	7.051	1.000	7.094	1.000	7.136
1.000	7.179	1.000	7.221	1.000	7.264	1.000	7.306	1.000	7.349	1.000	7.391	1.000	7.434	1.000	7.476
1.000	7.519	1.000	7.561	1.000	7.604	1.000	7.646	1.000	7.689	1.000	7.731	1.000	7.774	1.000	7.816
1.000	7.858	1.000	7.901	1.000	7.943	1.000	7.986	1.000	8.028	1.000	8.071	1.000	8.113	1.000	8.155
1.000	8.198	1.000	8.241	1.000	8.283	1.000	8.326	1.000	8.368	1.000	8.411	1.000	8.453	1.000	8.496
1.000	8.538	1.000	8.581	1.000	8.623	1.000	8.666	1.000	8.708	1.000	8.751	1.000	8.793	1.000	8.836
1.000	8.878	1.000	8.920	1.000	8.963	1.000	9.005	1.000	9.048	1.000	9.090	1.000	9.133	1.000	9.175
1.000	9.218	1.000	9.260	1.000	9.303	1.000	9.345	1.000	9.388	1.000	9.430	1.000	9.473	1.000	9.515
1.000	9.558	1.000	9.600	1.000	9.643	1.000	9.685	1.000	9.728	1.000	9.770	1.000	9.813	1.000	9.855
1.000	9.898	1.000	9.940	1.000	9.983	1.000	10.025	1.000	10.067	1.000	10.110	1.000	10.152	1.000	10.195
1.000	10.237	1.000	10.280	1.000	10.322	1.000	10.365	1.000	10.407	1.000	10.450	1.000	10.492	1.000	10.535
1.000	10.577	1.000	10.620	1.000	10.662	1.000	10.705	1.000	10.747	1.000	10.790	1.000	10.832	1.000	10.875
1.000	10.917	1.000	10.960	1.000	11.002	1.000	11.045	1.000	11.087	1.000	11.129	1.000	11.172	1.000	11.214
1.000	11.257	1.000	11.299	1.000	11.342	1.000	11.384	1.000	11.427	1.000	11.469	1.000	11.512	1.000	11.554
1.000	11.597	1.000	11.639	1.000	11.682	1.000	11.724	1.000	11.767	1.000	11.809	1.000	11.852	1.000	11.894
1.000	11.937	1.000	11.979	1.000	12.022	1.000	12.064	1.000	12.107	1.000	12.149	1.000	12.192	1.000	12.234
1.000	12.276	1.000	12.319	1.000	12.361	1.000	12.404	1.000	12.446	1.000	12.489	1.000	12.531	1.000	12.574
1.000	12.616	1.000	12.659	1.000	12.701	1.000	12.744	1.000	12.786	1.000	12.829	1.000	12.871	1.000	12.914
1.000	12.956	1.000	12.999	1.000	13.041	1.000	13.084	1.000	13.126	1.000	13.169	1.000	13.211	1.000	13.254
1.000	13.296	1.000	13.338	1.000	13.381	1.000	13.423	1.000	13.466	1.000	13.508	1.000	13.551	1.000	13.593
1.000	13.636	1.000	13.678	1.000	13.721	1.000	13.763	1.000	13.806	1.000	13.848	1.000	13.891	1.000	13.933
1.000	13.976	1.000	14.018	1.000	14.061	1.000	14.103	1.000	14.146	1.000	14.188	1.000	14.231	1.000	14.273
1.000	14.316	1.000	14.358	1.000	14.401	1.000	14.443	1.000	14.485	1.000	14.528	1.000	14.570	1.000	14.613
1.000	14.655	1.000	14.698	1.000	14.740	1.000	14.783	1.000	14.825	1.000	14.868	1.000	14.910	1.000	14.953
1.000	14.995	1.000	15.038	1.000	15.080	1.000	15.123	1.000	15.165	1.000	15.208	1.000	15.250	1.000	15.293
1.000	15.335	1.000	15.378	1.000	15.420	1.000	15.463	1.000	15.505	1.000	15.548	1.000	15.590	1.000	15.632
1.000	15.675	1.000	15.717	1.000	15.760	1.000	15.802	1.000	15.845	1.000	15.887	1.000	15.930	1.000	15.972
1.000	16.015	1.000	16.057	1.000	16.100	1.000	16.142	1.000	16.185	1.000	16.227	1.000	16.270	1.000	16.312
1.000	16.355	1.000	16.397	1.000	16.440	1.000	16.482	1.000	16.525	1.000	16.567	1.000	16.610	1.000	16.652
1.000	16.694	1.000	16.737	1.000	16.779	1.000	16.822	1.000	16.864	1.000	16.907	1.000	16.949	1.000	16.992
1.000	17.034	1.000	17.077	1.000	17.119	1.000	17.162	1.000	17.204	1.000	17.247	1.000	17.289	1.000	17.332

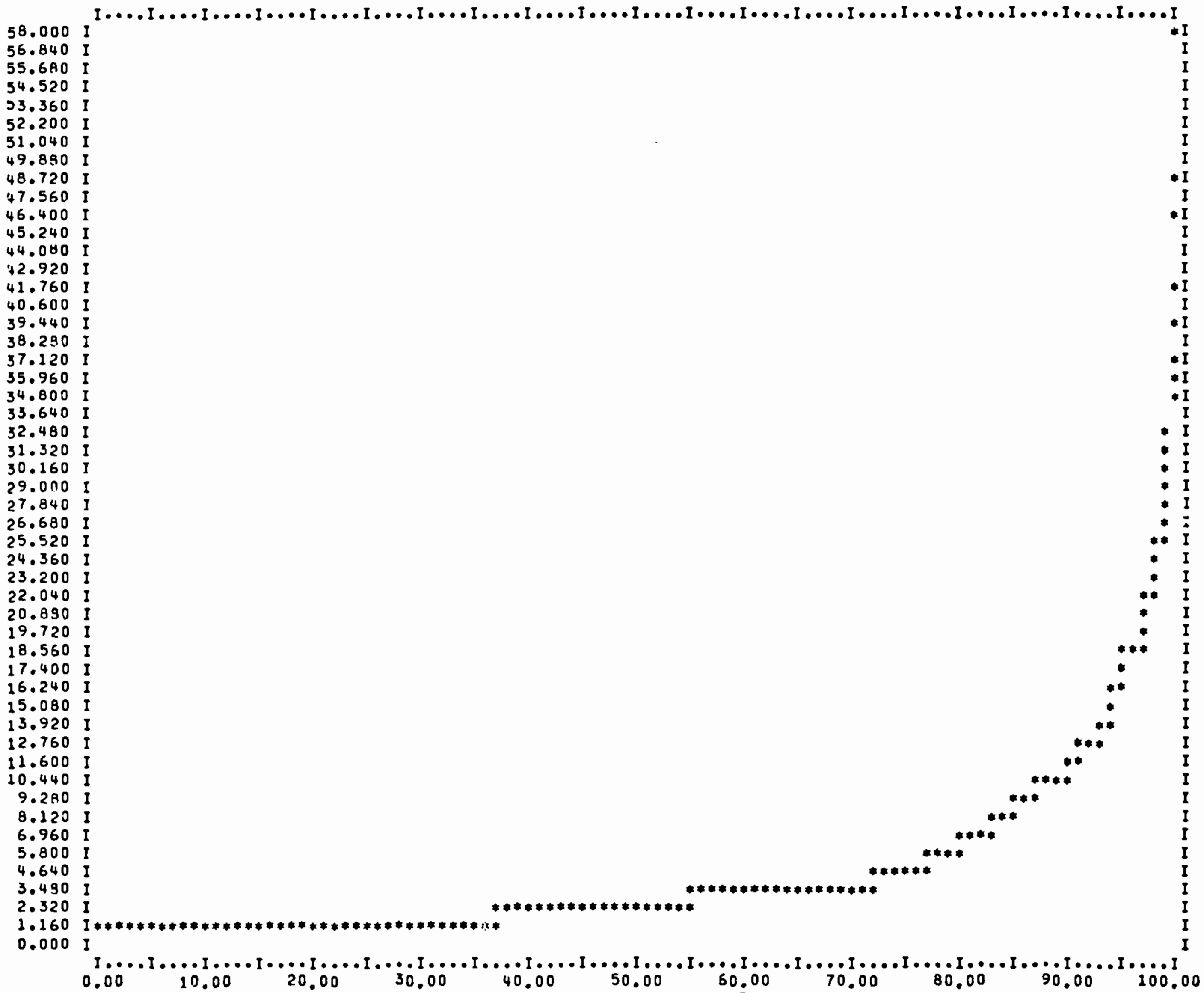
1.000	17.374	1.000	17.417	1.000	17.459	1.000	17.502	1.000	17.544	1.000	17.587	1.000	17.629	1.000	17.672
1.000	17.714	1.000	17.757	1.000	17.799	1.000	17.841	1.000	17.884	1.000	17.926	1.000	17.969	1.000	18.011
1.000	18.054	1.000	18.096	1.000	18.139	1.000	18.181	1.000	18.224	1.000	18.266	1.000	18.309	1.000	18.351
1.000	18.394	1.000	18.436	1.000	18.479	1.000	18.521	1.000	18.564	1.000	18.606	1.000	18.649	1.000	18.691
1.000	18.734	1.000	18.776	1.000	18.819	1.000	18.861	1.000	18.903	1.000	18.946	1.000	18.988	1.000	19.031
1.000	19.073	1.000	19.116	1.000	19.158	1.000	19.201	1.000	19.243	1.000	19.286	1.000	19.328	1.000	19.371
1.000	19.413	1.000	19.456	1.000	19.498	1.000	19.541	1.000	19.583	1.000	19.626	1.000	19.668	1.000	19.711
1.000	19.753	1.000	19.796	1.000	19.838	1.000	19.881	1.000	19.923	1.000	19.966	1.000	20.008	1.000	20.050
1.000	20.093	1.000	20.135	1.000	20.178	1.000	20.220	1.000	20.263	1.000	20.305	1.000	20.348	1.000	20.390
1.000	20.433	1.000	20.475	1.000	20.518	1.000	20.560	1.000	20.603	1.000	20.645	1.000	20.688	1.000	20.730
1.000	20.773	1.000	20.815	1.000	20.858	1.000	20.900	1.000	20.943	1.000	20.985	1.000	21.028	1.000	21.070
1.000	21.113	1.000	21.155	1.000	21.197	1.000	21.240	1.000	21.282	1.000	21.325	1.000	21.367	1.000	21.410
1.000	21.452	1.000	21.495	1.000	21.537	1.000	21.580	1.000	21.622	1.000	21.665	1.000	21.707	1.000	21.750
1.000	21.792	1.000	21.835	1.000	21.877	1.000	21.920	1.000	21.962	1.000	22.005	1.000	22.047	1.000	22.090
1.000	22.132	1.000	22.175	1.000	22.217	1.000	22.259	1.000	22.302	1.000	22.344	1.000	22.387	1.000	22.429
1.000	22.472	1.000	22.514	1.000	22.557	1.000	22.599	1.000	22.642	1.000	22.684	1.000	22.727	1.000	22.769
1.000	22.812	1.000	22.854	1.000	22.897	1.000	22.939	1.000	22.982	1.000	23.024	1.000	23.067	1.000	23.109
1.000	23.152	1.000	23.194	1.000	23.237	1.000	23.279	1.000	23.322	1.000	23.364	1.000	23.406	1.000	23.449
1.000	23.491	1.000	23.534	1.000	23.576	1.000	23.519	1.000	23.661	1.000	23.704	1.000	23.746	1.000	23.789
1.000	23.831	1.000	23.874	1.000	23.916	1.000	23.959	1.000	24.001	1.000	24.044	1.000	24.086	1.000	24.129
1.000	24.171	1.000	24.214	1.000	24.256	1.000	24.299	1.000	24.341	1.000	24.384	1.000	24.426	1.000	24.469
1.000	24.511	1.000	24.553	1.000	24.596	1.000	24.538	1.000	24.681	1.000	24.723	1.000	24.766	1.000	24.808
1.000	24.851	1.000	24.893	1.000	24.936	1.000	24.978	1.000	25.021	1.000	25.063	1.000	25.106	1.000	25.148
1.000	25.191	1.000	25.233	1.000	25.276	1.000	25.318	1.000	25.361	1.000	25.403	1.000	25.446	1.000	25.488
1.000	25.531	1.000	25.573	1.000	25.615	1.000	25.658	1.000	25.700	1.000	25.743	1.000	25.785	1.000	25.828
1.000	25.870	1.000	25.913	1.000	25.955	1.000	25.998	1.000	26.040	1.000	26.083	1.000	26.125	1.000	26.168
1.000	26.210	1.000	26.253	1.000	26.295	1.000	26.338	1.000	26.380	1.000	26.423	1.000	26.465	1.000	26.508
1.000	26.550	1.000	26.593	1.000	26.635	1.000	26.677	1.000	26.720	1.000	26.762	1.000	26.805	1.000	26.847
1.000	26.890	1.000	26.932	1.000	26.975	1.000	27.017	1.000	27.060	1.000	27.102	1.000	27.145	1.000	27.187
1.000	27.230	1.000	27.272	1.000	27.315	1.000	27.357	1.000	27.400	1.000	27.442	1.000	27.485	1.000	27.527
1.000	27.570	1.000	27.612	1.000	27.655	1.000	27.697	1.000	27.740	1.000	27.782	1.000	27.824	1.000	27.867
1.000	27.909	1.000	27.952	1.000	27.994	1.000	28.037	1.000	28.079	1.000	28.122	1.000	28.164	1.000	28.207
1.000	28.249	1.000	28.292	1.000	28.334	1.000	28.377	1.000	28.419	1.000	28.462	1.000	28.504	1.000	28.547
1.000	28.589	1.000	28.632	1.000	28.674	1.000	28.717	1.000	28.759	1.000	28.802	1.000	28.844	1.000	28.887
1.000	28.929	1.000	28.971	1.000	29.014	1.000	29.056	1.000	29.099	1.000	29.141	1.000	29.184	1.000	29.226
1.000	29.269	1.000	29.311	1.000	29.354	1.000	29.396	1.000	29.439	1.000	29.481	1.000	29.524	1.000	29.566
1.000	29.609	1.000	29.651	1.000	29.694	1.000	29.736	1.000	29.779	1.000	29.821	1.000	29.864	1.000	29.906
1.000	29.949	1.000	29.991	1.000	30.033	1.000	30.076	1.000	30.118	1.000	30.161	1.000	30.203	1.000	30.245
1.000	30.288	1.000	30.331	1.000	30.373	1.000	30.416	1.000	30.458	1.000	30.501	1.000	30.543	1.000	30.586
1.000	30.628	1.000	30.671	1.000	30.713	1.000	30.756	1.000	30.798	1.000	30.841	1.000	30.883	1.000	30.926
1.000	30.968	1.000	31.011	1.000	31.053	1.000	31.096	1.000	31.138	1.000	31.180	1.000	31.223	1.000	31.265
1.000	31.308	1.000	31.350	1.000	31.393	1.000	31.435	1.000	31.478	1.000	31.520	1.000	31.563	1.000	31.605
1.000	31.648	1.000	31.690	1.000	31.733	1.000	31.775	1.000	31.818	1.000	31.860	1.000	31.903	1.000	31.945
1.000	31.988	1.000	32.030	1.000	32.073	1.000	32.115	1.000	32.158	1.000	32.200	1.000	32.242	1.000	32.285
1.000	32.327	1.000	32.370	1.000	32.412	1.000	32.455	1.000	32.497	1.000	32.540	1.000	32.582	1.000	32.625
1.000	32.667	1.000	32.710	1.000	32.752	1.000	32.795	1.000	32.837	1.000	32.880	1.000	32.922	1.000	32.965
1.000	33.007	1.000	33.050	1.000	33.092	1.000	33.135	1.000	33.177	1.000	33.220	1.000	33.262	1.000	33.305
1.000	33.347	1.000	33.389	1.000	33.432	1.000	33.474	1.000	33.517	1.000	33.559	1.000	33.602	1.000	33.644
1.000	33.687	1.000	33.729	1.000	33.772	1.000	33.814	1.000	33.857	1.000	33.899	1.000	33.942	1.000	33.984
1.000	34.027	1.000	34.069	1.000	34.112	1.000	34.154	1.000	34.197	1.000	34.239	1.000	34.282	1.000	34.324
1.000	34.367	1.000	34.409	1.000	34.452	1.000	34.494	1.000	34.536	1.000	34.579	1.000	34.621	1.000	34.664
1.000	34.706	1.000	34.749	1.000	34.791	1.000	34.834	1.000	34.876	1.000	34.919	1.000	34.961	1.000	35.004
1.000	35.046	1.000	35.089	1.000	35.131	1.000	35.174	1.000	35.216	1.000	35.259	1.000	35.301	1.000	35.344
1.000	35.386	1.000	35.429	1.000	35.471	1.000	35.514	1.000	35.556	1.000	35.598	1.000	35.641	1.000	35.683
1.000	35.726	1.000	35.768	1.000	35.811	1.000	35.853	1.000	35.896	1.000	35.938	1.000	35.981	1.000	36.023
1.000	36.066	1.000	36.108	1.000	36.151	1.000	36.193	1.000	36.236	1.000	36.278	1.000	36.321	1.000	36.363
1.000	36.406	1.000	36.448	1.000	36.491	1.000	36.533	1.000	36.576	1.000	36.618	1.000	36.661	1.000	36.703

1.000	36.745	2.000	36.788	2.000	36.830	2.000	36.873	2.000	36.915	2.000	36.958	2.000	37.000	2.000	37.043
2.000	37.085	2.000	37.128	2.000	37.170	2.000	37.213	2.000	37.255	2.000	37.298	2.000	37.340	2.000	37.383
2.000	37.425	2.000	37.468	2.000	37.510	2.000	37.553	2.000	37.595	2.000	37.638	2.000	37.680	2.000	37.723
2.000	37.765	2.000	37.807	2.000	37.850	2.000	37.892	2.000	37.935	2.000	37.977	2.000	38.020	2.000	38.062
2.000	38.105	2.000	38.147	2.000	38.190	2.000	38.232	2.000	38.275	2.000	38.317	2.000	38.360	2.000	38.402
2.000	38.445	2.000	38.487	2.000	38.530	2.000	38.572	2.000	38.615	2.000	38.657	2.000	38.700	2.000	38.742
2.000	38.785	2.000	38.827	2.000	38.870	2.000	38.912	2.000	38.954	2.000	38.997	2.000	39.039	2.000	39.082
2.000	39.124	2.000	39.167	2.000	39.209	2.000	39.252	2.000	39.294	2.000	39.337	2.000	39.379	2.000	39.422
2.000	39.464	2.000	39.507	2.000	39.549	2.000	39.592	2.000	39.634	2.000	39.677	2.000	39.719	2.000	39.762
2.000	39.804	2.000	39.847	2.000	39.889	2.000	39.932	2.000	39.974	2.000	40.016	2.000	40.059	2.000	40.101
2.000	40.144	2.000	40.186	2.000	40.229	2.000	40.271	2.000	40.314	2.000	40.356	2.000	40.399	2.000	40.441
2.000	40.484	2.000	40.526	2.000	40.569	2.000	40.611	2.000	40.654	2.000	40.696	2.000	40.739	2.000	40.781
2.000	40.824	2.000	40.856	2.000	40.909	2.000	40.951	2.000	40.994	2.000	41.036	2.000	41.079	2.000	41.121
2.000	41.163	2.000	41.206	2.000	41.248	2.000	41.291	2.000	41.333	2.000	41.376	2.000	41.418	2.000	41.461
2.000	41.503	2.000	41.546	2.000	41.588	2.000	41.631	2.000	41.673	2.000	41.716	2.000	41.758	2.000	41.801
2.000	41.843	2.000	41.886	2.000	41.928	2.000	41.971	2.000	42.013	2.000	42.056	2.000	42.098	2.000	42.141
2.000	42.183	2.000	42.226	2.000	42.268	2.000	42.310	2.000	42.353	2.000	42.395	2.000	42.438	2.000	42.480
2.000	42.523	2.000	42.565	2.000	42.608	2.000	42.650	2.000	42.693	2.000	42.735	2.000	42.778	2.000	42.820
2.000	42.863	2.000	42.905	2.000	42.948	2.000	42.990	2.000	43.033	2.000	43.075	2.000	43.118	2.000	43.160
2.000	43.203	2.000	43.245	2.000	43.288	2.000	43.330	2.000	43.372	2.000	43.415	2.000	43.457	2.000	43.500
2.000	43.542	2.000	43.585	2.000	43.627	2.000	43.670	2.000	43.712	2.000	43.755	2.000	43.797	2.000	43.840
2.000	43.882	2.000	43.925	2.000	43.967	2.000	44.010	2.000	44.052	2.000	44.095	2.000	44.137	2.000	44.180
2.000	44.222	2.000	44.265	2.000	44.307	2.000	44.350	2.000	44.392	2.000	44.435	2.000	44.477	2.000	44.519
2.000	44.562	2.000	44.604	2.000	44.647	2.000	44.689	2.000	44.732	2.000	44.774	2.000	44.817	2.000	44.859
2.000	44.902	2.000	44.944	2.000	44.987	2.000	45.029	2.000	45.072	2.000	45.114	2.000	45.157	2.000	45.199
2.000	45.242	2.000	45.284	2.000	45.327	2.000	45.369	2.000	45.412	2.000	45.454	2.000	45.497	2.000	45.539
2.000	45.581	2.000	45.624	2.000	45.666	2.000	45.709	2.000	45.751	2.000	45.794	2.000	45.836	2.000	45.879
2.000	45.921	2.000	45.964	2.000	46.006	2.000	46.049	2.000	46.091	2.000	46.134	2.000	46.176	2.000	46.219
2.000	46.261	2.000	46.304	2.000	46.346	2.000	46.389	2.000	46.431	2.000	46.474	2.000	46.516	2.000	46.559
2.000	46.601	2.000	46.644	2.000	46.686	2.000	46.728	2.000	46.771	2.000	46.813	2.000	46.856	2.000	46.898
2.000	46.941	2.000	46.983	2.000	47.026	2.000	47.068	2.000	47.111	2.000	47.153	2.000	47.196	2.000	47.238
2.000	47.281	2.000	47.323	2.000	47.366	2.000	47.408	2.000	47.451	2.000	47.493	2.000	47.536	2.000	47.578
2.000	47.621	2.000	47.663	2.000	47.706	2.000	47.748	2.000	47.791	2.000	47.833	2.000	47.875	2.000	47.918
2.000	47.960	2.000	48.003	2.000	48.045	2.000	48.088	2.000	48.130	2.000	48.173	2.000	48.215	2.000	48.258
2.000	48.300	2.000	48.343	2.000	48.385	2.000	48.428	2.000	48.470	2.000	48.513	2.000	48.555	2.000	48.598
2.000	48.640	2.000	48.683	2.000	48.725	2.000	48.768	2.000	48.810	2.000	48.853	2.000	48.895	2.000	48.937
2.000	48.980	2.000	49.022	2.000	49.065	2.000	49.107	2.000	49.150	2.000	49.192	2.000	49.235	2.000	49.277
2.000	49.320	2.000	49.362	2.000	49.405	2.000	49.447	2.000	49.490	2.000	49.532	2.000	49.575	2.000	49.617
2.000	49.660	2.000	49.702	2.000	49.745	2.000	49.787	2.000	49.830	2.000	49.872	2.000	49.915	2.000	49.957
2.000	50.000	2.000	50.042	2.000	50.084	2.000	50.127	2.000	50.169	2.000	50.212	2.000	50.254	2.000	50.297
2.000	50.339	2.000	50.382	2.000	50.424	2.000	50.467	2.000	50.509	2.000	50.552	2.000	50.594	2.000	50.637
2.000	50.679	2.000	50.722	2.000	50.764	2.000	50.807	2.000	50.849	2.000	50.892	2.000	50.934	2.000	50.977
2.000	51.019	2.000	51.062	2.000	51.104	2.000	51.146	2.000	51.189	2.000	51.231	2.000	51.274	2.000	51.316
2.000	51.359	2.000	51.401	2.000	51.444	2.000	51.486	2.000	51.529	2.000	51.571	2.000	51.614	2.000	51.656
2.000	51.699	2.000	51.741	2.000	51.784	2.000	51.826	2.000	51.869	2.000	51.911	2.000	51.954	2.000	51.996
2.000	52.039	2.000	52.081	2.000	52.124	2.000	52.166	2.000	52.209	2.000	52.251	2.000	52.293	2.000	52.336
2.000	52.378	2.000	52.421	2.000	52.463	2.000	52.506	2.000	52.548	2.000	52.591	2.000	52.633	2.000	52.676
2.000	52.718	2.000	52.761	2.000	52.803	2.000	52.846	2.000	52.888	2.000	52.931	2.000	52.973	2.000	53.016
2.000	53.058	2.000	53.101	2.000	53.143	2.000	53.186	2.000	53.228	2.000	53.271	2.000	53.313	2.000	53.355
2.000	53.398	2.000	53.440	2.000	53.483	2.000	53.525	2.000	53.568	2.000	53.610	2.000	53.653	2.000	53.695
2.000	53.738	2.000	53.780	2.000	53.823	2.000	53.865	2.000	53.908	2.000	53.950	2.000	53.993	2.000	54.035
2.000	54.078	2.000	54.120	2.000	54.163	2.000	54.205	2.000	54.248	2.000	54.290	2.000	54.333	2.000	54.375
2.000	54.418	2.000	54.450	2.000	54.502	2.000	54.545	2.000	54.587	2.000	54.630	2.000	54.672	3.000	54.715
3.000	54.757	3.000	54.800	3.000	54.842	3.000	54.885	3.000	54.927	3.000	54.970	3.000	55.012	3.000	55.055
3.000	55.097	3.000	55.140	3.000	55.182	3.000	55.225	3.000	55.267	3.000	55.310	3.000	55.352	3.000	55.395
3.000	55.437	3.000	55.480	3.000	55.522	3.000	55.565	3.000	55.607	3.000	55.649	3.000	55.692	3.000	55.734
3.000	55.777	3.000	55.819	3.000	55.862	3.000	55.904	3.000	55.947	3.000	55.989	3.000	56.032	3.000	56.074

3.000	56.117	3.000	56.159	3.000	56.202	3.000	56.244	3.000	56.287	3.000	56.329	3.000	56.372	3.000	56.414
3.000	56.457	3.000	56.499	3.000	56.542	3.000	56.584	3.000	56.627	3.000	56.669	3.000	56.711	3.000	56.754
3.000	56.796	3.000	56.839	3.000	56.881	3.000	56.924	3.000	56.966	3.000	57.009	3.000	57.051	3.000	57.094
3.000	57.136	3.000	57.179	3.000	57.221	3.000	57.264	3.000	57.306	3.000	57.349	3.000	57.391	3.000	57.434
3.000	57.476	3.000	57.519	3.000	57.561	3.000	57.604	3.000	57.646	3.000	57.689	3.000	57.731	3.000	57.774
3.000	57.816	3.000	57.858	3.000	57.901	3.000	57.943	3.000	57.986	3.000	58.028	3.000	58.071	3.000	58.113
3.000	58.156	3.000	58.198	3.000	58.241	3.000	58.283	3.000	58.326	3.000	58.368	3.000	58.411	3.000	58.453
3.000	58.496	3.000	58.538	3.000	58.581	3.000	58.623	3.000	58.666	3.000	58.708	3.000	58.751	3.000	58.793
3.000	58.836	3.000	58.878	3.000	58.920	3.000	58.963	3.000	59.005	3.000	59.048	3.000	59.090	3.000	59.133
3.000	59.175	3.000	59.218	3.000	59.260	3.000	59.303	3.000	59.345	3.000	59.388	3.000	59.430	3.000	59.473
3.000	59.515	3.000	59.558	3.000	59.600	3.000	59.643	3.000	59.685	3.000	59.728	3.000	59.770	3.000	59.813
3.000	59.855	3.000	59.898	3.000	59.940	3.000	59.983	3.000	60.025	3.000	60.067	3.000	60.110	3.000	60.152
3.000	60.195	3.000	60.237	3.000	60.280	3.000	60.322	3.000	60.365	3.000	60.407	3.000	60.450	3.000	60.492
3.000	60.535	3.000	60.577	3.000	60.620	3.000	60.662	3.000	60.705	3.000	60.747	3.000	60.790	3.000	60.832
3.000	60.875	3.000	60.917	3.000	60.960	3.000	61.002	3.000	61.045	3.000	61.087	3.000	61.129	3.000	61.172
3.000	61.214	3.000	61.257	3.000	61.299	3.000	61.342	3.000	61.384	3.000	61.427	3.000	61.469	3.000	61.512
3.000	61.554	3.000	61.597	3.000	61.639	3.000	61.682	3.000	61.724	3.000	61.767	3.000	61.809	3.000	61.852
3.000	61.894	3.000	61.937	3.000	61.979	3.000	62.022	3.000	62.064	3.000	62.107	3.000	62.149	3.000	62.192
3.000	62.234	3.000	62.276	3.000	62.319	3.000	62.361	3.000	62.404	3.000	62.446	3.000	62.489	3.000	62.531
3.000	62.574	3.000	62.616	3.000	62.659	3.000	62.701	3.000	62.744	3.000	62.786	3.000	62.829	3.000	62.871
3.000	62.914	3.000	62.956	3.000	62.999	3.000	63.041	3.000	63.084	3.000	63.126	3.000	63.169	3.000	63.211
3.000	63.254	3.000	63.296	3.000	63.339	3.000	63.381	3.000	63.423	3.000	63.466	3.000	63.508	3.000	63.551
3.000	63.593	3.000	63.636	3.000	63.678	3.000	63.721	3.000	63.763	3.000	63.806	3.000	63.848	3.000	63.891
3.000	63.933	3.000	63.976	3.000	64.018	3.000	64.061	3.000	64.103	3.000	64.146	3.000	64.188	3.000	64.231
3.000	64.273	3.000	64.316	3.000	64.358	3.000	64.401	3.000	64.443	3.000	64.485	3.000	64.528	3.000	64.570
3.000	64.613	4.000	64.655	4.000	64.698	4.000	64.740	4.000	64.783	4.000	64.825	4.000	64.868	4.000	64.910
4.000	64.953	4.000	64.995	4.000	65.038	4.000	65.080	4.000	65.123	4.000	65.165	4.000	65.208	4.000	65.250
4.000	65.293	4.000	65.335	4.000	65.378	4.000	65.420	4.000	65.463	4.000	65.505	4.000	65.548	4.000	65.590
4.000	65.632	4.000	65.675	4.000	65.717	4.000	65.760	4.000	65.802	4.000	65.845	4.000	65.887	4.000	65.930
4.000	65.972	4.000	66.015	4.000	66.057	4.000	66.100	4.000	66.142	4.000	66.185	4.000	66.227	4.000	66.270
4.000	66.312	4.000	66.355	4.000	66.397	4.000	66.440	4.000	66.482	4.000	66.525	4.000	66.567	4.000	66.610
4.000	66.652	4.000	66.694	4.000	66.737	4.000	66.779	4.000	66.822	4.000	66.864	4.000	66.907	4.000	66.949
4.000	66.992	4.000	67.034	4.000	67.077	4.000	67.119	4.000	67.162	4.000	67.204	4.000	67.247	4.000	67.289
4.000	67.332	4.000	67.374	4.000	67.417	4.000	67.459	4.000	67.502	4.000	67.544	4.000	67.587	4.000	67.629
4.000	67.672	4.000	67.714	4.000	67.757	4.000	67.799	4.000	67.841	4.000	67.884	4.000	67.926	4.000	67.969
4.000	68.011	4.000	68.054	4.000	68.096	4.000	68.139	4.000	68.181	4.000	68.224	4.000	68.266	4.000	68.309
4.000	68.351	4.000	68.394	4.000	68.436	4.000	68.479	4.000	68.521	4.000	68.564	4.000	68.606	4.000	68.649
4.000	68.691	4.000	68.734	4.000	68.776	4.000	68.819	4.000	68.861	4.000	68.904	4.000	68.946	4.000	68.988
4.000	69.031	4.000	69.073	4.000	69.116	4.000	69.158	4.000	69.201	4.000	69.243	4.000	69.286	4.000	69.328
4.000	69.371	4.000	69.413	4.000	69.456	4.000	69.498	4.000	69.541	4.000	69.583	4.000	69.626	4.000	69.668
4.000	69.711	4.000	69.753	4.000	69.796	4.000	69.838	4.000	69.881	4.000	69.923	4.000	69.966	4.000	70.008
4.000	70.050	4.000	70.093	4.000	70.135	4.000	70.178	4.000	70.220	4.000	70.263	4.000	70.305	4.000	70.348
4.000	70.390	4.000	70.433	4.000	70.475	4.000	70.518	4.000	70.560	4.000	70.603	4.000	70.645	4.000	70.688
4.000	70.730	4.000	70.773	4.000	70.815	4.000	70.858	4.000	70.900	4.000	70.943	4.000	70.985	4.000	71.028
4.000	71.070	4.000	71.113	4.000	71.155	4.000	71.197	4.000	71.240	4.000	71.282	4.000	71.325	4.000	71.367
4.000	71.410	4.000	71.452	4.000	71.495	4.000	71.537	4.000	71.580	4.000	71.622	4.000	71.665	4.000	71.707
5.000	71.750	5.000	71.792	5.000	71.835	5.000	71.877	5.000	71.920	5.000	71.962	5.000	72.005	5.000	72.047
5.000	72.090	5.000	72.132	5.000	72.175	5.000	72.217	5.000	72.259	5.000	72.302	5.000	72.344	5.000	72.387
5.000	72.429	5.000	72.472	5.000	72.514	5.000	72.557	5.000	72.599	5.000	72.642	5.000	72.684	5.000	72.727
5.000	72.769	5.000	72.812	5.000	72.854	5.000	72.897	5.000	72.939	5.000	72.982	5.000	73.024	5.000	73.067
5.000	73.109	5.000	73.152	5.000	73.194	5.000	73.237	5.000	73.279	5.000	73.322	5.000	73.364	5.000	73.406
5.000	73.449	5.000	73.491	5.000	73.534	5.000	73.576	5.000	73.619	5.000	73.661	5.000	73.704	5.000	73.746
5.000	73.789	5.000	73.831	5.000	73.874	5.000	73.916	5.000	73.959	5.000	74.001	5.000	74.044	5.000	74.086
5.000	74.129	5.000	74.171	5.000	74.214	5.000	74.256	5.000	74.299	5.000	74.341	5.000	74.384	5.000	74.426
5.000	74.468	5.000	74.511	5.000	74.553	5.000	74.596	5.000	74.638	5.000	74.681	5.000	74.723	5.000	74.766
5.000	74.808	5.000	74.851	5.000	74.893	5.000	74.936	5.000	74.978	5.000	75.021	5.000	75.063	5.000	75.105
5.000	75.148	5.000	75.191	5.000	75.233	5.000	75.276	5.000	75.318	5.000	75.361	5.000	75.403	5.000	75.446

5.000	75.488	5.000	75.531	5.000	75.573	5.000	75.615	5.000	75.658	5.000	75.700	5.000	75.743	5.000	75.785
5.000	75.828	5.000	75.870	5.000	75.913	5.000	75.955	5.000	75.998	5.000	76.040	5.000	76.083	5.000	76.125
5.000	76.168	5.000	76.210	5.000	76.253	5.000	76.295	5.000	76.338	5.000	76.380	5.000	76.423	5.000	76.465
5.000	76.508	5.000	76.550	5.000	76.593	5.000	76.635	5.000	76.678	5.000	76.720	6.000	76.762	6.000	76.805
6.000	76.847	6.000	76.890	6.000	76.932	6.000	76.975	6.000	77.017	6.000	77.060	6.000	77.102	6.000	77.145
6.000	77.187	6.000	77.230	6.000	77.272	6.000	77.315	6.000	77.357	6.000	77.400	6.000	77.442	6.000	77.485
6.000	77.527	6.000	77.570	6.000	77.612	6.000	77.655	6.000	77.697	6.000	77.740	6.000	77.782	6.000	77.824
6.000	77.867	6.000	77.909	6.000	77.952	6.000	77.994	6.000	78.037	6.000	78.079	6.000	78.122	6.000	78.164
6.000	78.207	6.000	78.249	6.000	78.292	6.000	78.334	6.000	78.377	6.000	78.419	6.000	78.462	6.000	78.504
6.000	78.547	6.000	78.589	6.000	78.632	6.000	78.674	6.000	78.717	6.000	78.759	6.000	78.802	6.000	78.844
6.000	78.887	6.000	78.929	6.000	78.971	6.000	79.014	6.000	79.056	6.000	79.099	6.000	79.141	6.000	79.184
6.000	79.226	6.000	79.269	6.000	79.311	6.000	79.354	6.000	79.396	6.000	79.439	6.000	79.481	6.000	79.524
6.000	79.566	6.000	79.609	6.000	79.651	6.000	79.694	6.000	79.736	6.000	79.779	6.000	79.821	6.000	79.864
6.000	79.906	6.000	79.949	6.000	79.991	7.000	80.033	7.000	80.076	7.000	80.118	7.000	80.161	7.000	80.203
7.000	80.246	7.000	80.288	7.000	80.331	7.000	80.373	7.000	80.416	7.000	80.458	7.000	80.501	7.000	80.543
7.000	80.586	7.000	80.628	7.000	80.671	7.000	80.713	7.000	80.756	7.000	80.798	7.000	80.841	7.000	80.883
7.000	80.926	7.000	80.968	7.000	81.011	7.000	81.053	7.000	81.096	7.000	81.138	7.000	81.180	7.000	81.223
7.000	81.265	7.000	81.308	7.000	81.350	7.000	81.393	7.000	81.435	7.000	81.478	7.000	81.520	7.000	81.563
7.000	81.605	7.000	81.648	7.000	81.690	7.000	81.733	7.000	81.775	7.000	81.818	7.000	81.860	7.000	81.903
7.000	81.945	7.000	81.988	7.000	82.030	7.000	82.073	7.000	82.115	7.000	82.158	7.000	82.200	7.000	82.242
7.000	82.285	7.000	82.327	7.000	82.370	7.000	82.412	7.000	82.455	7.000	82.497	7.000	82.540	7.000	82.582
7.000	82.625	7.000	82.667	7.000	82.710	7.000	82.752	7.000	82.795	7.000	82.837	7.000	82.880	7.000	82.922
7.000	82.965	7.000	83.007	7.000	83.050	7.000	83.092	7.000	83.135	8.000	83.177	8.000	83.220	8.000	83.262
8.000	83.305	8.000	83.347	8.000	83.389	8.000	83.432	8.000	83.474	8.000	83.517	8.000	83.559	8.000	83.602
8.000	83.644	8.000	83.687	8.000	83.729	8.000	83.772	8.000	83.814	8.000	83.857	8.000	83.899	8.000	83.942
8.000	83.984	8.000	84.027	8.000	84.069	8.000	84.112	8.000	84.154	8.000	84.197	8.000	84.239	8.000	84.282
8.000	84.324	8.000	84.367	8.000	84.409	8.000	84.452	8.000	84.494	8.000	84.536	8.000	84.579	8.000	84.621
8.000	84.664	8.000	84.706	8.000	84.749	8.000	84.791	8.000	84.834	8.000	84.876	8.000	84.919	8.000	84.961
8.000	85.004	9.000	85.046	8.000	85.089	8.000	85.131	8.000	85.174	9.000	85.216	9.000	85.259	9.000	85.301
9.000	85.344	9.000	85.386	9.000	85.429	9.000	85.471	9.000	85.514	9.000	85.556	9.000	85.598	9.000	85.641
9.000	85.683	9.000	85.726	9.000	85.768	9.000	85.811	9.000	85.853	9.000	85.896	9.000	85.938	9.000	85.981
9.000	86.023	9.000	86.066	9.000	86.108	9.000	86.151	9.000	86.193	9.000	66.236	9.000	66.278	9.000	86.321
9.000	86.363	9.000	86.406	9.000	86.448	9.000	86.491	9.000	86.533	9.000	86.576	9.000	86.618	9.000	86.661
9.000	86.703	9.000	86.745	9.000	86.788	9.000	86.830	9.000	86.873	9.000	86.915	9.000	86.958	9.000	87.000
9.000	87.043	9.000	87.085	9.000	87.128	9.000	87.170	9.000	87.213	9.000	87.255	10.000	87.298	10.000	87.340
10.000	87.383	10.000	87.425	10.000	87.468	10.000	87.510	10.000	87.553	10.000	87.595	10.000	87.638	10.000	87.680
10.000	87.723	10.000	87.765	10.000	87.807	10.000	87.850	10.000	87.892	10.000	87.935	10.000	87.977	10.000	88.020
10.000	88.062	10.000	88.105	10.000	88.147	10.000	88.190	10.000	88.232	10.000	88.275	10.000	88.317	10.000	88.360
10.000	88.402	10.000	88.445	10.000	88.487	10.000	88.530	10.000	88.572	10.000	88.615	10.000	88.657	10.000	88.700
10.000	88.742	10.000	88.785	10.000	88.827	10.000	88.870	10.000	88.912	10.000	80.954	10.000	88.997	10.000	89.039
10.000	89.082	10.000	89.124	10.000	89.167	11.000	89.209	11.000	89.252	11.000	89.294	11.000	89.337	11.000	89.379
11.000	89.422	11.000	89.464	11.000	89.507	11.000	89.549	11.000	89.592	11.000	89.634	11.000	89.677	11.000	89.719
11.000	89.762	11.000	89.804	11.000	89.847	11.000	89.889	11.000	89.932	11.000	89.974	11.000	90.016	11.000	90.059
11.000	90.101	11.000	90.144	11.000	90.186	11.000	90.229	11.000	90.271	11.000	90.314	11.000	90.356	11.000	90.399
12.000	90.441	12.000	90.484	12.000	90.526	12.000	90.569	12.000	90.611	12.000	90.654	12.000	90.696	12.000	90.739
12.000	90.781	12.000	90.824	12.000	90.866	12.000	90.909	12.000	90.951	12.000	90.994	12.000	91.036	12.000	91.079
12.000	91.121	12.000	91.163	12.000	91.206	12.000	91.248	12.000	91.291	12.000	91.333	12.000	91.376	12.000	91.418
13.000	91.461	13.000	91.503	13.000	91.546	13.000	91.588	13.000	91.631	13.000	91.673	13.000	91.716	13.000	91.758
13.000	91.801	13.000	91.843	13.000	91.886	13.000	91.928	13.000	91.971	13.000	92.013	13.000	92.056	13.000	92.098
13.000	92.141	13.000	92.183	13.000	92.226	13.000	92.268	13.000	92.310	13.000	92.353	13.000	92.395	13.000	92.438
13.000	92.480	13.000	92.523	13.000	92.565	14.000	92.608	14.000	92.650	14.000	92.693	14.000	92.735	14.000	92.778
14.000	92.820	14.000	92.863	14.000	92.905	14.000	92.948	14.000	92.990	14.000	93.033	14.000	93.075	14.000	93.118
14.000	93.160	14.000	93.203	14.000	93.245	14.000	93.288	14.000	93.330	14.000	93.372	14.000	93.415	14.000	93.457
14.000	93.500	15.000	93.542	15.000	93.585	15.000	93.627	15.000	93.670	15.000	93.712	15.000	93.755	15.000	93.797
15.000	93.840	15.000	93.882	15.000	93.925	15.000	93.967	15.000	94.010	15.000	94.052	15.000	94.095	15.000	94.137
15.000	94.180	15.000	94.222	15.000	94.265	15.000	94.307	16.000	94.350	16.000	94.392	16.000	94.435	16.000	94.477
16.000	94.519	16.000	94.562	16.000	94.604	16.000	94.647	16.000	94.689	16.000	94.732	16.000	94.774	16.000	94.817

16.000	94.859	17.000	94.902	17.000	94.944	17.000	94.987	17.000	95.029	17.000	95.072	17.000	95.114	17.000	95.157
17.000	95.199	17.000	95.242	17.000	95.284	17.000	95.327	17.000	95.369	17.000	95.412	18.000	95.454	18.000	95.497
18.000	95.539	18.000	95.582	18.000	95.624	18.000	95.666	18.000	95.709	18.000	95.751	18.000	95.794	18.000	95.836
18.000	95.879	18.000	95.921	18.000	95.964	19.000	96.006	19.000	96.049	19.000	96.091	19.000	96.134	19.000	96.176
19.000	96.219	19.000	96.261	19.000	96.304	19.000	96.346	19.000	96.389	19.000	96.431	19.000	96.474	19.000	96.516
20.000	96.559	20.000	96.601	20.000	96.644	20.000	96.686	20.000	96.728	20.000	96.771	20.000	96.813	20.000	96.856
21.000	96.898	21.000	96.941	21.000	96.983	21.000	97.026	21.000	97.068	21.000	97.111	21.000	97.153	21.000	97.196
22.000	97.238	22.000	97.281	22.000	97.323	22.000	97.366	22.000	97.408	22.000	97.451	22.000	97.493	22.000	97.536
22.000	97.578	22.000	97.621	23.000	97.663	23.000	97.706	23.000	97.748	23.000	97.791	23.000	97.833	23.000	97.875
24.000	97.918	24.000	97.960	24.000	98.003	24.000	98.045	24.000	98.088	25.000	98.130	25.000	98.173	25.000	98.215
25.000	98.258	25.000	98.300	25.000	98.343	25.000	98.385	25.000	98.428	25.000	98.470	26.000	98.513	26.000	98.555
26.000	98.598	27.000	98.640	27.000	98.683	27.000	98.725	27.000	98.768	27.000	98.810	27.000	98.853	28.000	98.895
28.000	98.937	29.000	98.980	29.000	99.022	29.000	99.065	29.000	99.107	29.000	99.150	30.000	99.192	30.000	99.235
31.000	99.277	32.000	99.320	33.000	99.362	33.000	99.405	33.000	99.447	33.000	99.490	35.000	99.532	36.000	99.575
36.000	99.617	37.000	99.660	37.000	99.702	37.000	99.745	39.000	99.787	40.000	99.830	42.000	99.872	46.000	99.915
49.000	99.957	58.000	100.000												



DURATION VS PERCENT LESS THAN OR EQUAL TO

RETURN PERIOD (IN YEARS) FOR DURATION

VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD
58.000	26.000	49.000	13.000	46.000	8.666	42.000	6.500	40.000	5.200	39.000	4.333	37.000	3.714	37.000	3.250
37.000	2.888	36.000	2.600	36.000	2.363	35.000	2.166	33.000	2.000	33.000	1.857	33.000	1.733	33.000	1.625
32.000	1.529	31.000	1.444	30.000	1.368	30.000	1.300	29.000	1.238	29.000	1.181	29.000	1.130	29.000	1.083
29.000	1.040	28.000	1.000	28.000	0.962	27.000	0.928	27.000	0.896	27.000	0.866	27.000	0.838	27.000	0.812
27.000	0.787	26.000	0.754	26.000	0.742	26.000	0.722	25.000	0.702	25.000	0.684	25.000	0.666	25.000	0.650
25.000	0.634	25.000	0.619	25.000	0.604	25.000	0.590	25.000	0.577	24.000	0.565	24.000	0.553	24.000	0.541
24.000	0.530	24.000	0.520	23.000	0.509	23.000	0.500	23.000	0.490	23.000	0.481	23.000	0.472	23.000	0.464
22.000	0.456	22.000	0.448	22.000	0.440	22.000	0.433	22.000	0.426	22.000	0.419	22.000	0.412	22.000	0.406
22.000	0.400	22.000	0.393	21.000	0.388	21.000	0.382	21.000	0.376	21.000	0.371	21.000	0.366	21.000	0.361
21.000	0.356	21.000	0.351	20.000	0.346	20.000	0.342	20.000	0.337	20.000	0.333	20.000	0.329	20.000	0.325
20.000	0.320	20.000	0.317	19.000	0.313	19.000	0.309	19.000	0.305	19.000	0.302	19.000	0.298	19.000	0.295
19.000	0.292	19.000	0.288	19.000	0.285	19.000	0.282	19.000	0.279	19.000	0.276	19.000	0.273	18.000	0.270
18.000	0.268	18.000	0.265	18.000	0.262	18.000	0.260	18.000	0.257	18.000	0.254	18.000	0.252	18.000	0.250
18.000	0.247	18.000	0.245	18.000	0.242	18.000	0.240	17.000	0.238	17.000	0.236	17.000	0.234	17.000	0.232
17.000	0.230	17.000	0.228	17.000	0.226	17.000	0.224	17.000	0.222	17.000	0.220	17.000	0.218	17.000	0.216
17.000	0.214	16.000	0.213	16.000	0.211	16.000	0.209	16.000	0.208	16.000	0.206	16.000	0.204	16.000	0.203
16.000	0.201	16.000	0.200	16.000	0.198	16.000	0.196	16.000	0.195	16.000	0.194	15.000	0.192	15.000	0.191
15.000	0.189	15.000	0.188	15.000	0.187	15.000	0.185	15.000	0.184	15.000	0.183	15.000	0.181	15.000	0.180
15.000	0.179	15.000	0.178	15.000	0.176	15.000	0.175	15.000	0.174	15.000	0.173	15.000	0.172	15.000	0.171
15.000	0.169	14.000	0.168	14.000	0.167	14.000	0.166	14.000	0.165	14.000	0.164	14.000	0.163	14.000	0.162
14.000	0.161	14.000	0.160	14.000	0.159	14.000	0.158	14.000	0.157	14.000	0.156	14.000	0.155	14.000	0.154
14.000	0.153	14.000	0.152	14.000	0.152	14.000	0.151	14.000	0.150	14.000	0.149	14.000	0.148	13.000	0.147
13.000	0.146	13.000	0.146	13.000	0.145	13.000	0.144	13.000	0.143	13.000	0.142	13.000	0.142	13.000	0.141
13.000	0.140	13.000	0.139	13.000	0.139	13.000	0.138	13.000	0.137	13.000	0.136	13.000	0.136	13.000	0.135
13.000	0.134	13.000	0.134	13.000	0.133	13.000	0.132	13.000	0.131	13.000	0.131	13.000	0.130	13.000	0.130
13.000	0.129	13.000	0.128	12.000	0.128	12.000	0.127	12.000	0.126	12.000	0.126	12.000	0.125	12.000	0.125
12.000	0.124	12.000	0.123	12.000	0.123	12.000	0.122	12.000	0.122	12.000	0.121	12.000	0.120	12.000	0.120
12.000	0.119	12.000	0.119	12.000	0.118	12.000	0.118	12.000	0.117	12.000	0.117	12.000	0.116	12.000	0.116
12.000	0.115	12.000	0.115	11.000	0.114	11.000	0.114	11.000	0.113	11.000	0.113	11.000	0.112	11.000	0.112
11.000	0.111	11.000	0.111	11.000	0.110	11.000	0.110	11.000	0.109	11.000	0.109	11.000	0.108	11.000	0.108
11.000	0.107	11.000	0.107	11.000	0.106	11.000	0.106	11.000	0.106	11.000	0.105	11.000	0.105	11.000	0.104
11.000	0.104	11.000	0.104	11.000	0.103	11.000	0.103	11.000	0.102	11.000	0.102	11.000	0.101	10.000	0.101
10.000	0.101	10.000	0.100	10.000	0.100	10.000	0.100	10.000	0.099	10.000	0.099	10.000	0.098	10.000	0.098
10.000	0.098	10.000	0.097	10.000	0.097	10.000	0.097	10.000	0.096	10.000	0.096	10.000	0.095	10.000	0.095
10.000	0.095	10.000	0.094	10.000	0.094	10.000	0.094	10.000	0.093	10.000	0.093	10.000	0.093	10.000	0.092
10.000	0.092	10.000	0.092	10.000	0.091	10.000	0.091	10.000	0.091	10.000	0.090	10.000	0.090	10.000	0.090
10.000	0.089	10.000	0.089	10.000	0.089	10.000	0.089	10.000	0.088	10.000	0.088	10.000	0.088	10.000	0.087
10.000	0.087	10.000	0.087	10.000	0.086	10.000	0.086	9.000	0.086	9.000	0.086	9.000	0.085	9.000	0.085
9.000	0.085	9.000	0.084	9.000	0.084	9.000	0.084	9.000	0.084	9.000	0.083	9.000	0.083	9.000	0.083
9.000	0.083	9.000	0.082	9.000	0.082	9.000	0.082	9.000	0.082	9.000	0.081	9.000	0.081	9.000	0.081
9.000	0.080	9.000	0.080	9.000	0.080	9.000	0.080	9.000	0.080	9.000	0.079	9.000	0.079	9.000	0.079
9.000	0.079	9.000	0.078	9.000	0.078	9.000	0.078	9.000	0.078	9.000	0.077	9.000	0.077	9.000	0.077
9.000	0.077	9.000	0.076	9.000	0.076	9.000	0.076	9.000	0.076	9.000	0.076	9.000	0.075	9.000	0.075
9.000	0.075	9.000	0.075	9.000	0.074	9.000	0.074	9.000	0.074	8.000	0.074	8.000	0.074	8.000	0.073
8.000	0.073	8.000	0.073	8.000	0.073	8.000	0.073	8.000	0.072	8.000	0.072	8.000	0.072	8.000	0.072
8.000	0.072	8.000	0.071	8.000	0.071	8.000	0.071	8.000	0.071	8.000	0.071	8.000	0.070	8.000	0.070
8.000	0.070	8.000	0.070	8.000	0.070	8.000	0.059	8.000	0.069	8.000	0.069	8.000	0.069	8.000	0.069
8.000	0.068	8.000	0.068	8.000	0.068	8.000	0.068	8.000	0.068	8.000	0.068	8.000	0.067	8.000	0.067
8.000	0.067	8.000	0.067	8.000	0.067	8.000	0.067	8.000	0.066	8.000	0.066	8.000	0.066	8.000	0.066
8.000	0.066	8.000	0.065	8.000	0.065	8.000	0.065	8.000	0.065	7.000	0.065	7.000	0.065	7.000	0.065
7.000	0.064	7.000	0.064	7.000	0.064	7.000	0.064	7.000	0.064	7.000	0.064	7.000	0.063	7.000	0.063
7.000	0.063	7.000	0.063	7.000	0.063	7.000	0.063	7.000	0.062	7.000	0.062	7.000	0.062	7.000	0.062
7.000	0.062	7.000	0.062	7.000	0.062	7.000	0.061	7.000	0.061	7.000	0.061	7.000	0.061	7.000	0.061

7.000	0.061	7.000	0.051	7.000	0.060	7.000	0.060	7.000	0.060	7.000	0.060	7.000	0.060	7.000	0.060
7.000	0.060	7.000	0.059	7.000	0.059	7.000	0.059	7.000	0.059	7.000	0.059	7.000	0.059	7.000	0.059
7.000	0.058	7.000	0.058	7.000	0.058	7.000	0.058	7.000	0.058	7.000	0.058	7.000	0.058	7.000	0.058
7.000	0.057	7.000	0.057	7.000	0.057	7.000	0.057	7.000	0.057	7.000	0.057	7.000	0.057	7.000	0.057
7.000	0.056	7.000	0.056	7.000	0.056	7.000	0.056	7.000	0.056	7.000	0.056	7.000	0.056	7.000	0.056
7.000	0.055	7.000	0.055	7.000	0.055	7.000	0.055	7.000	0.055	7.000	0.055	7.000	0.055	6.000	0.055
6.000	0.054	6.000	0.054	6.000	0.054	6.000	0.054	6.000	0.054	6.000	0.054	6.000	0.054	6.000	0.054
6.000	0.054	6.000	0.053	6.000	0.053	6.000	0.053	6.000	0.053	6.000	0.053	6.000	0.053	6.000	0.053
6.000	0.053	6.000	0.053	6.000	0.052	6.000	0.052	6.000	0.052	6.000	0.052	6.000	0.052	6.000	0.052
6.000	0.052	6.000	0.052	6.000	0.052	6.000	0.052	6.000	0.051	6.000	0.051	6.000	0.051	6.000	0.051
6.000	0.051	6.000	0.051	6.000	0.051	6.000	0.051	6.000	0.051	6.000	0.050	6.000	0.050	6.000	0.050
6.000	0.050	6.000	0.050	6.000	0.050	6.000	0.050	6.000	0.050	6.000	0.050	6.000	0.050	6.000	0.050
6.000	0.049	6.000	0.049	6.000	0.049	6.000	0.049	6.000	0.049	6.000	0.049	6.000	0.049	6.000	0.049
6.000	0.049	6.000	0.049	6.000	0.048	6.000	0.048	6.000	0.048	6.000	0.048	6.000	0.048	6.000	0.048
6.000	0.048	6.000	0.048	6.000	0.048	6.000	0.048	6.000	0.048	6.000	0.047	6.000	0.047	6.000	0.047
6.000	0.047	6.000	0.047	6.000	0.047	6.000	0.047	5.000	0.047	5.000	0.047	5.000	0.047	5.000	0.047
5.000	0.047	5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.045
5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.046	5.000	0.045	5.000	0.045	5.000	0.045
5.000	0.045	5.000	0.045	5.000	0.045	5.000	0.045	5.000	0.045	5.000	0.045	5.000	0.045	5.000	0.045
5.000	0.045	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044
5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.044	5.000	0.043	5.000	0.043
5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.043
5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.043	5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.042
5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.042
5.000	0.042	5.000	0.042	5.000	0.042	5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041
5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041	5.000	0.041
5.000	0.041	5.000	0.041	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040
5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040	5.000	0.040
5.000	0.040	5.000	0.040	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039
5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039	5.000	0.039
5.000	0.039	5.000	0.039	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038
4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038
4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.038	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037
4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037
4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.037	4.000	0.036	4.000	0.036
4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036
4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036	4.000	0.036
4.000	0.036	4.000	0.036	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035
4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035
4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.035	4.000	0.034	4.000	0.034
4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034
4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034
4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.034	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033
4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033
4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.033
4.000	0.033	4.000	0.033	4.000	0.033	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032
4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032
4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032
4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.032	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031
4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031
4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031	4.000	0.031
4.000	0.031	3.000	0.031	3.000	0.031	3.000	0.031	3.000	0.031	3.000	0.031	3.000	0.030	3.000	0.030
3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030
3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030
3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030	3.000	0.030
3.000	0.030	3.000	0.030	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029
3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029

3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029
3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029	3.000	0.029
3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028
3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028
3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028
3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028	3.000	0.028
3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027
3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027
3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027
3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027	3.000	0.027
3.000	0.027	3.000	0.027	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026
3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026
3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026
3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026
3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026	3.000	0.026
3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025
3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025
3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025
3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025
3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025	3.000	0.025
3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024
3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024
3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024	3.000	0.024
3.000	0.024	3.000	0.024	3.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024
2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.024
2.000	0.024	2.000	0.024	2.000	0.024	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023
2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023
2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023
2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023
2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023
2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023	2.000	0.023
2.000	0.023	2.000	0.023	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022
2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022
2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022
2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022
2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022
2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022
2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.022	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021
2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.021	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020
2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.020	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019

2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019	2.000	0.019
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
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2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018
2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.018	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017
2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017
2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017
2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017
2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017
2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017	2.000	0.017
2.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017
1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017
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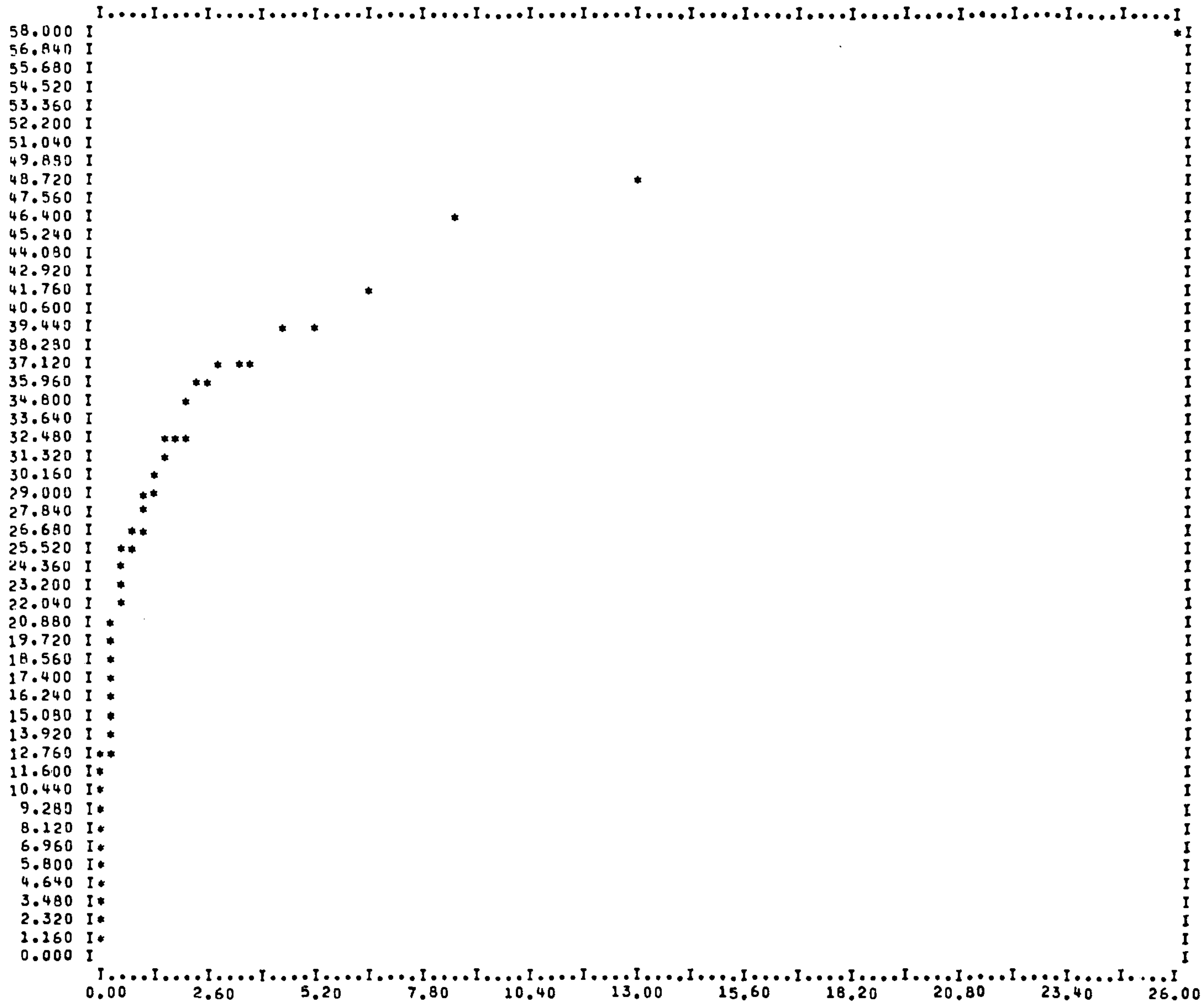
1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017
1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017	1.000	0.017
1.000	0.017	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016	1.000	0.016
1.000	0.016	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015
1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.015	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014

1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014	1.000	0.014
1.000	0.014	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013	1.000	0.013
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012
1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.012	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011

1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011	1.000	0.011
1.000	0.011	1.000	0.011												



DURATION VS RETURN PERIOD IN YEARS

PROBABILITY ANALYSIS-INTENSITY

PERCENTAGE OF OCCURRENCE LESS THAN OR EQUAL TO THE GIVEN VALUE OF INTENSITY

VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT
0.004	0.042	0.004	0.084	0.005	0.127	0.005	0.169	0.005	0.212	0.005	0.254	0.005	0.297	0.005	0.339
0.005	0.382	0.005	0.424	0.005	0.467	0.005	0.509	0.005	0.552	0.005	0.594	0.005	0.637	0.005	0.679
0.005	0.722	0.005	0.764	0.005	0.807	0.005	0.849	0.005	0.892	0.005	0.934	0.005	0.977	0.005	1.019
0.005	1.062	0.005	1.104	0.006	1.146	0.006	1.189	0.006	1.231	0.006	1.274	0.006	1.316	0.006	1.359
0.006	1.401	0.006	1.444	0.006	1.486	0.006	1.529	0.006	1.571	0.006	1.614	0.006	1.656	0.006	1.699
0.006	1.741	0.006	1.784	0.006	1.826	0.006	1.869	0.006	1.911	0.006	1.954	0.006	1.996	0.006	2.039
0.006	2.081	0.006	2.124	0.006	2.166	0.006	2.209	0.006	2.251	0.006	2.293	0.006	2.336	0.006	2.378
0.006	2.421	0.006	2.463	0.006	2.506	0.006	2.548	0.006	2.591	0.006	2.633	0.006	2.676	0.006	2.718
0.006	2.761	0.006	2.803	0.006	2.846	0.006	2.888	0.006	2.931	0.006	2.973	0.006	3.016	0.006	3.058
0.006	3.101	0.006	3.143	0.007	3.186	0.007	3.228	0.007	3.271	0.007	3.313	0.007	3.355	0.007	3.398
0.007	3.440	0.007	3.483	0.007	3.525	0.007	3.568	0.007	3.610	0.007	3.653	0.007	3.695	0.007	3.738
0.007	3.780	0.007	3.823	0.007	3.865	0.007	3.908	0.007	3.950	0.007	3.993	0.007	4.035	0.007	4.078
0.007	4.120	0.007	4.163	0.007	4.205	0.007	4.248	0.007	4.290	0.007	4.333	0.007	4.375	0.007	4.418
0.007	4.460	0.007	4.502	0.007	4.545	0.007	4.587	0.007	4.630	0.007	4.672	0.007	4.715	0.007	4.757
0.007	4.800	0.008	4.842	0.008	4.885	0.008	4.927	0.008	4.970	0.008	5.012	0.008	5.055	0.008	5.097
0.008	5.140	0.008	5.182	0.008	5.225	0.008	5.267	0.008	5.310	0.008	5.352	0.008	5.395	0.008	5.437
0.008	5.480	0.008	5.522	0.008	5.564	0.008	5.607	0.008	5.649	0.008	5.692	0.008	5.734	0.008	5.777
0.008	5.819	0.008	5.862	0.008	5.904	0.008	5.947	0.008	5.989	0.008	6.032	0.008	6.074	0.009	6.117
0.009	6.159	0.009	6.202	0.009	6.244	0.010	6.287	0.010	6.329	0.010	6.372	0.010	6.414	0.010	6.457
0.010	6.499	0.010	6.542	0.010	6.584	0.010	6.627	0.010	6.669	0.010	6.711	0.010	6.754	0.010	6.796
0.010	6.839	0.010	6.881	0.010	6.924	0.010	6.966	0.010	7.009	0.010	7.051	0.010	7.094	0.010	7.136
0.010	7.179	0.010	7.221	0.010	7.264	0.010	7.306	0.010	7.349	0.010	7.391	0.010	7.434	0.010	7.476
0.010	7.519	0.010	7.561	0.010	7.604	0.010	7.646	0.010	7.689	0.010	7.731	0.010	7.774	0.010	7.816
0.010	7.858	0.010	7.901	0.010	7.943	0.010	7.986	0.010	8.028	0.010	8.071	0.010	8.113	0.010	8.156
0.010	8.198	0.010	8.241	0.010	8.283	0.010	8.326	0.010	8.368	0.010	8.411	0.010	8.453	0.010	8.496
0.010	8.538	0.010	8.581	0.010	8.623	0.010	8.666	0.010	8.708	0.010	8.751	0.010	8.793	0.010	8.836
0.010	8.878	0.010	8.920	0.010	8.963	0.010	9.005	0.010	9.048	0.010	9.090	0.010	9.133	0.010	9.175
0.010	9.218	0.010	9.260	0.010	9.303	0.010	9.345	0.010	9.388	0.010	9.430	0.010	9.473	0.010	9.515
0.010	9.558	0.010	9.600	0.010	9.643	0.010	9.685	0.010	9.728	0.010	9.770	0.010	9.813	0.010	9.855
0.010	9.898	0.010	9.940	0.010	9.983	0.010	10.025	0.010	10.067	0.010	10.110	0.010	10.152	0.010	10.195
0.010	10.237	0.010	10.280	0.010	10.322	0.010	10.365	0.010	10.407	0.010	10.450	0.010	10.492	0.010	10.535
0.010	10.577	0.010	10.620	0.010	10.662	0.010	10.705	0.010	10.747	0.010	10.790	0.010	10.832	0.010	10.875
0.010	10.917	0.010	10.960	0.010	11.002	0.010	11.045	0.010	11.087	0.010	11.129	0.010	11.172	0.010	11.214
0.010	11.257	0.010	11.299	0.010	11.342	0.010	11.384	0.010	11.427	0.010	11.469	0.010	11.512	0.010	11.554
0.010	11.597	0.010	11.639	0.010	11.682	0.010	11.724	0.010	11.767	0.010	11.809	0.010	11.852	0.010	11.894
0.010	11.937	0.010	11.979	0.010	12.022	0.010	12.064	0.010	12.107	0.010	12.149	0.010	12.192	0.010	12.234
0.010	12.276	0.010	12.319	0.010	12.361	0.010	12.404	0.010	12.446	0.010	12.489	0.010	12.531	0.010	12.574
0.010	12.616	0.010	12.659	0.010	12.701	0.010	12.744	0.010	12.786	0.010	12.829	0.010	12.871	0.010	12.914
0.010	12.956	0.010	12.999	0.010	13.041	0.010	13.084	0.010	13.126	0.010	13.169	0.010	13.211	0.010	13.254
0.010	13.296	0.010	13.338	0.010	13.381	0.010	13.423	0.010	13.466	0.010	13.508	0.010	13.551	0.010	13.593
0.010	13.636	0.010	13.678	0.010	13.721	0.010	13.763	0.010	13.806	0.010	13.848	0.010	13.891	0.010	13.933
0.010	13.976	0.010	14.018	0.010	14.061	0.010	14.103	0.010	14.146	0.010	14.188	0.010	14.231	0.010	14.273
0.010	14.316	0.010	14.358	0.010	14.401	0.010	14.443	0.010	14.485	0.010	14.528	0.010	14.570	0.010	14.613
0.010	14.655	0.010	14.698	0.010	14.740	0.010	14.783	0.010	14.825	0.010	14.868	0.010	14.910	0.010	14.953
0.010	14.995	0.010	15.038	0.010	15.080	0.010	15.123	0.010	15.165	0.010	15.208	0.010	15.250	0.010	15.293
0.010	15.335	0.010	15.378	0.010	15.420	0.010	15.463	0.010	15.505	0.010	15.548	0.010	15.590	0.010	15.632
0.010	15.675	0.010	15.717	0.010	15.760	0.010	15.802	0.010	15.845	0.010	15.887	0.010	15.930	0.010	15.972
0.010	16.015	0.010	16.057	0.010	16.100	0.010	16.142	0.010	16.185	0.010	16.227	0.010	16.270	0.010	16.312
0.010	16.355	0.010	16.397	0.010	16.440	0.010	16.482	0.010	16.525	0.010	16.567	0.010	16.610	0.010	16.652
0.010	16.694	0.010	16.737	0.010	16.779	0.010	16.822	0.010	16.864	0.010	16.907	0.010	16.949	0.010	16.992
0.010	17.034	0.010	17.077	0.010	17.119	0.010	17.162	0.010	17.204	0.010	17.247	0.010	17.289	0.010	17.332

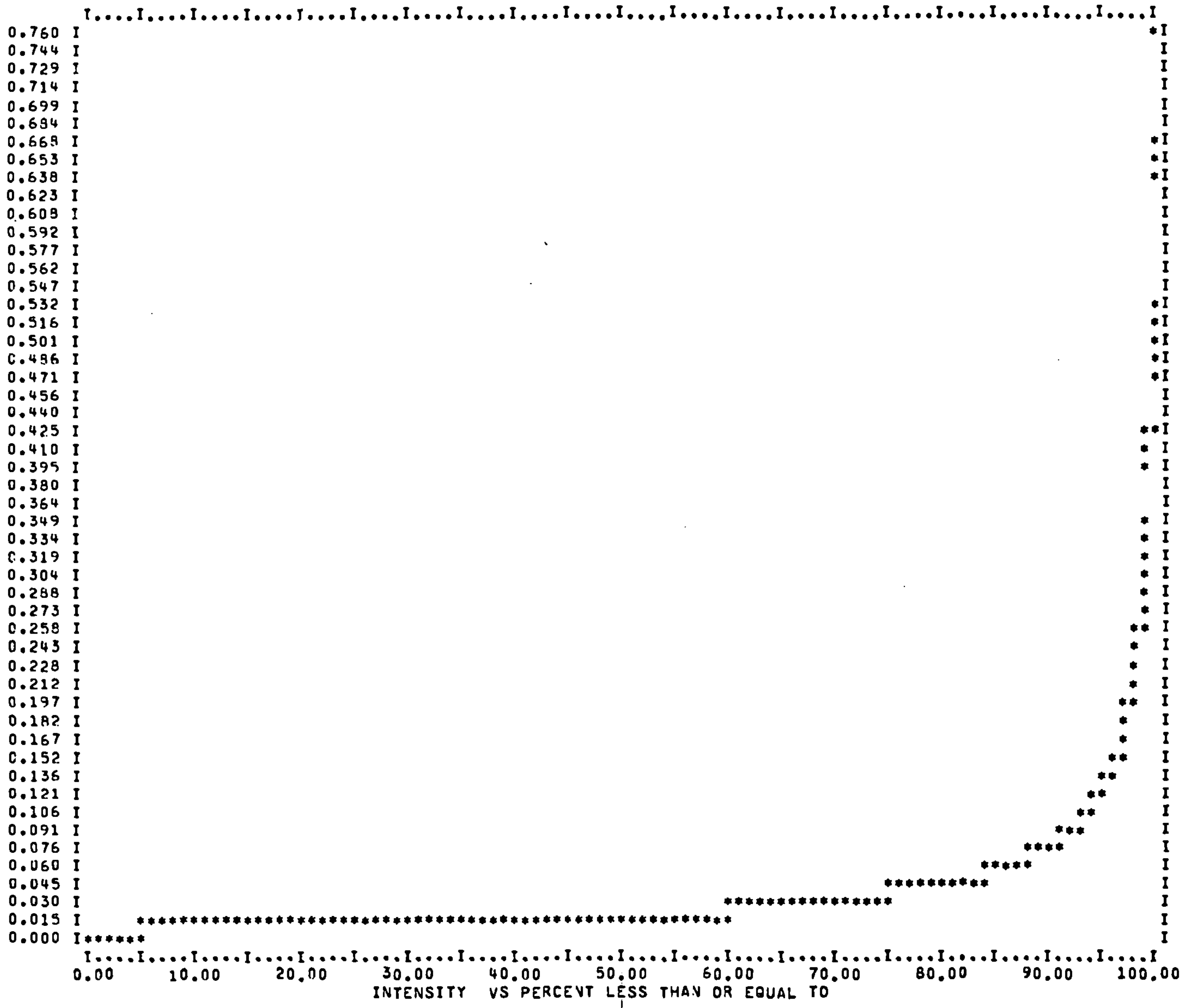
0.010	17.374	0.010	17.417	0.010	17.459	0.010	17.502	0.010	17.544	0.010	17.587	0.010	17.629	0.010	17.672
0.010	17.714	0.010	17.757	0.010	17.799	0.010	17.841	0.010	17.884	0.010	17.926	0.010	17.969	0.010	18.011
0.010	18.054	0.010	18.096	0.010	18.139	0.010	18.181	0.010	18.224	0.010	18.266	0.010	18.309	0.010	18.351
0.010	18.394	0.010	18.436	0.010	18.479	0.010	18.521	0.010	18.564	0.010	18.606	0.010	18.649	0.010	18.691
0.010	18.734	0.010	18.776	0.010	18.819	0.010	18.861	0.010	18.903	0.010	18.946	0.010	18.988	0.010	19.031
0.010	19.073	0.010	19.116	0.010	19.158	0.010	19.201	0.010	19.243	0.010	19.286	0.010	19.328	0.010	19.371
0.010	19.413	0.010	19.456	0.010	19.498	0.010	19.541	0.010	19.583	0.010	19.626	0.010	19.668	0.010	19.711
0.010	19.753	0.010	19.796	0.010	19.838	0.010	19.881	0.010	19.923	0.010	19.966	0.010	20.008	0.010	20.050
0.010	20.093	0.010	20.135	0.010	20.178	0.010	20.220	0.010	20.263	0.010	20.305	0.010	20.348	0.010	20.390
0.010	20.433	0.010	20.475	0.010	20.518	0.010	20.560	0.010	20.603	0.010	20.645	0.010	20.688	0.010	20.730
0.010	20.773	0.010	20.815	0.010	20.858	0.010	20.900	0.010	20.943	0.010	20.985	0.010	21.028	0.010	21.070
0.010	21.113	0.010	21.155	0.010	21.197	0.010	21.240	0.010	21.282	0.010	21.325	0.010	21.367	0.010	21.410
0.010	21.452	0.010	21.495	0.010	21.537	0.010	21.580	0.010	21.622	0.010	21.665	0.010	21.707	0.010	21.750
0.010	21.792	0.010	21.835	0.010	21.877	0.010	21.920	0.010	21.962	0.010	22.005	0.010	22.047	0.010	22.090
0.010	22.132	0.010	22.175	0.010	22.217	0.010	22.259	0.010	22.302	0.010	22.344	0.010	22.387	0.010	22.429
0.010	22.472	0.010	22.514	0.010	22.557	0.010	22.599	0.010	22.642	0.010	22.684	0.010	22.727	0.010	22.769
0.010	22.812	0.010	22.854	0.010	22.897	0.010	22.939	0.010	22.982	0.010	23.024	0.010	23.067	0.010	23.109
0.010	23.152	0.010	23.194	0.010	23.237	0.010	23.279	0.010	23.322	0.010	23.364	0.010	23.406	0.010	23.449
0.010	23.491	0.010	23.534	0.010	23.576	0.010	23.619	0.010	23.661	0.010	23.704	0.010	23.746	0.010	23.789
0.010	23.831	0.010	23.874	0.010	23.916	0.010	23.959	0.010	24.001	0.010	24.044	0.010	24.086	0.010	24.129
0.010	24.171	0.010	24.214	0.010	24.256	0.010	24.299	0.010	24.341	0.010	24.384	0.010	24.426	0.010	24.468
0.010	24.511	0.010	24.553	0.010	24.596	0.010	24.638	0.010	24.681	0.010	24.723	0.010	24.766	0.010	24.808
0.010	24.851	0.010	24.893	0.010	24.936	0.010	24.978	0.010	25.021	0.010	25.063	0.010	25.106	0.010	25.148
0.010	25.191	0.010	25.233	0.010	25.276	0.010	25.318	0.010	25.361	0.010	25.403	0.010	25.446	0.010	25.488
0.010	25.531	0.010	25.573	0.010	25.615	0.010	25.658	0.010	25.700	0.010	25.743	0.010	25.785	0.010	25.828
0.010	25.870	0.010	25.913	0.010	25.955	0.010	25.998	0.010	26.040	0.010	26.083	0.010	26.125	0.010	26.168
0.010	26.210	0.010	26.253	0.010	26.295	0.010	26.338	0.010	26.380	0.010	26.423	0.010	26.465	0.010	26.508
0.010	26.550	0.010	26.593	0.010	26.635	0.010	26.677	0.010	26.720	0.010	26.762	0.010	26.805	0.010	26.847
0.010	26.890	0.010	26.932	0.010	26.975	0.010	27.017	0.010	27.060	0.010	27.102	0.010	27.145	0.010	27.187
0.010	27.230	0.010	27.272	0.010	27.315	0.010	27.357	0.010	27.400	0.010	27.442	0.010	27.485	0.010	27.527
0.010	27.570	0.010	27.612	0.010	27.655	0.010	27.697	0.010	27.740	0.010	27.782	0.010	27.824	0.010	27.867
0.010	27.909	0.010	27.952	0.010	27.994	0.010	28.037	0.010	28.079	0.010	28.122	0.010	28.164	0.010	28.207
0.010	28.249	0.010	28.292	0.010	28.334	0.010	28.377	0.010	28.419	0.010	28.462	0.010	28.504	0.010	28.547
0.010	28.589	0.010	28.632	0.010	28.674	0.010	28.717	0.010	28.759	0.010	28.802	0.010	28.844	0.010	28.887
0.010	28.929	0.010	28.971	0.010	29.014	0.010	29.056	0.010	29.099	0.010	29.141	0.010	29.184	0.010	29.226
0.010	29.269	0.010	29.311	0.010	29.354	0.010	29.396	0.010	29.439	0.010	29.481	0.010	29.524	0.010	29.566
0.010	29.609	0.010	29.651	0.010	29.694	0.010	29.736	0.010	29.779	0.010	29.821	0.010	29.864	0.010	29.906
0.010	29.949	0.010	29.991	0.010	30.033	0.010	30.076	0.010	30.118	0.010	30.161	0.010	30.203	0.010	30.245
0.010	30.288	0.010	30.331	0.010	30.373	0.010	30.416	0.010	30.458	0.010	30.501	0.010	30.543	0.010	30.585
0.010	30.628	0.010	30.671	0.010	30.713	0.010	30.756	0.010	30.798	0.010	30.841	0.010	30.883	0.010	30.925
0.010	30.968	0.010	31.011	0.010	31.053	0.010	31.096	0.010	31.138	0.010	31.180	0.010	31.223	0.010	31.265
0.010	31.308	0.010	31.350	0.010	31.393	0.010	31.435	0.010	31.478	0.010	31.520	0.010	31.563	0.010	31.605
0.010	31.648	0.010	31.690	0.010	31.733	0.010	31.775	0.010	31.818	0.010	31.860	0.010	31.903	0.010	31.945
0.010	31.988	0.010	32.030	0.010	32.073	0.010	32.115	0.010	32.158	0.010	32.200	0.010	32.242	0.010	32.285
0.010	32.327	0.010	32.370	0.010	32.412	0.010	32.455	0.010	32.497	0.010	32.540	0.010	32.582	0.010	32.625
0.010	32.667	0.010	32.710	0.010	32.752	0.010	32.795	0.010	32.837	0.010	32.880	0.010	32.922	0.010	32.965
0.010	33.007	0.010	33.050	0.010	33.092	0.010	33.135	0.010	33.177	0.010	33.220	0.010	33.262	0.010	33.305
0.010	33.347	0.010	33.389	0.010	33.432	0.010	33.474	0.010	33.517	0.010	33.559	0.010	33.602	0.010	33.644
0.010	33.687	0.010	33.729	0.010	33.772	0.010	33.814	0.010	33.857	0.010	33.899	0.010	33.942	0.010	33.984
0.010	34.027	0.010	34.069	0.010	34.112	0.010	34.154	0.010	34.197	0.010	34.239	0.010	34.282	0.010	34.324
0.010	34.367	0.010	34.409	0.010	34.452	0.010	34.494	0.010	34.536	0.010	34.579	0.010	34.621	0.010	34.664
0.010	34.706	0.010	34.749	0.010	34.791	0.010	34.834	0.010	34.876	0.010	34.919	0.010	34.961	0.010	35.004
0.010	35.046	0.010	35.089	0.010	35.131	0.010	35.174	0.010	35.216	0.010	35.259	0.010	35.301	0.010	35.344
0.010	35.386	0.010	35.429	0.010	35.471	0.010	35.514	0.010	35.556	0.010	35.598	0.010	35.641	0.010	35.683
0.010	35.726	0.010	35.768	0.010	35.811	0.010	35.853	0.010	35.896	0.010	35.938	0.010	35.981	0.010	36.023
0.010	36.066	0.010	36.108	0.010	36.151	0.010	36.193	0.010	36.236	0.010	36.278	0.010	36.321	0.010	36.363
0.010	36.406	0.010	36.448	0.010	36.491	0.010	36.533	0.010	36.576	0.010	36.618	0.010	36.661	0.010	36.703

0.010	36.745	0.010	36.788	0.010	36.830	0.010	36.873	0.010	36.915	0.010	36.958	0.010	37.000	0.010	37.043
0.010	37.085	0.010	37.128	0.010	37.170	0.010	37.213	0.010	37.255	0.010	37.298	0.010	37.340	0.010	37.383
0.010	37.425	0.010	37.468	0.010	37.510	0.010	37.553	0.010	37.595	0.010	37.638	0.010	37.680	0.010	37.723
0.010	37.765	0.010	37.807	0.010	37.850	0.010	37.892	0.010	37.935	0.010	37.977	0.010	38.020	0.010	38.062
0.010	38.105	0.010	38.147	0.010	38.190	0.011	38.232	0.011	38.275	0.011	38.317	0.011	38.360	0.011	38.402
0.011	38.445	0.011	38.487	0.011	38.530	0.011	38.572	0.011	38.615	0.011	38.657	0.011	38.700	0.011	38.742
0.011	38.785	0.011	38.827	0.011	38.870	0.011	38.912	0.011	38.954	0.011	38.997	0.011	39.039	0.011	39.082
0.011	39.124	0.011	39.167	0.011	39.209	0.012	39.252	0.012	39.294	0.012	39.337	0.012	39.379	0.012	39.422
0.012	39.464	0.012	39.507	0.012	39.549	0.012	39.592	0.012	39.634	0.012	39.677	0.012	39.719	0.012	39.762
0.012	39.804	0.012	39.847	0.012	39.889	0.012	39.932	0.012	39.974	0.012	40.016	0.012	40.059	0.012	40.101
0.012	40.144	0.012	40.186	0.012	40.229	0.012	40.271	0.012	40.314	0.012	40.356	0.012	40.399	0.012	40.441
0.012	40.484	0.012	40.526	0.012	40.569	0.012	40.611	0.012	40.654	0.012	40.696	0.012	40.739	0.012	40.781
0.012	40.824	0.012	40.866	0.012	40.909	0.012	40.951	0.012	40.994	0.012	41.036	0.012	41.079	0.012	41.121
0.013	41.163	0.013	41.206	0.013	41.248	0.013	41.291	0.013	41.333	0.013	41.376	0.013	41.418	0.013	41.461
0.013	41.503	0.013	41.546	0.013	41.588	0.013	41.631	0.013	41.673	0.013	41.716	0.013	41.758	0.013	41.801
0.013	41.843	0.013	41.886	0.013	41.928	0.013	41.971	0.013	42.013	0.013	42.056	0.013	42.098	0.013	42.141
0.013	42.183	0.013	42.226	0.013	42.268	0.013	42.310	0.013	42.353	0.013	42.395	0.013	42.438	0.014	42.480
0.014	42.523	0.014	42.565	0.014	42.608	0.014	42.650	0.014	42.693	0.014	42.735	0.014	42.778	0.014	42.820
0.014	42.863	0.014	42.905	0.014	42.948	0.014	42.990	0.014	43.033	0.014	43.075	0.014	43.118	0.014	43.160
0.014	43.203	0.014	43.245	0.014	43.288	0.014	43.330	0.015	43.372	0.015	43.415	0.015	43.457	0.015	43.500
0.015	43.542	0.015	43.585	0.015	43.627	0.015	43.670	0.015	43.712	0.015	43.755	0.015	43.797	0.015	43.840
0.015	43.882	0.015	43.925	0.015	43.967	0.015	44.010	0.015	44.052	0.015	44.095	0.015	44.137	0.015	44.180
0.015	44.222	0.015	44.265	0.015	44.307	0.015	44.350	0.015	44.392	0.015	44.435	0.015	44.477	0.015	44.519
0.015	44.562	0.015	44.604	0.015	44.647	0.015	44.689	0.015	44.732	0.015	44.774	0.015	44.817	0.015	44.859
0.015	44.902	0.015	44.944	0.015	44.987	0.015	45.029	0.015	45.072	0.015	45.114	0.015	45.157	0.015	45.199
0.015	45.242	0.015	45.284	0.015	45.327	0.015	45.369	0.015	45.412	0.015	45.454	0.015	45.497	0.015	45.539
0.015	45.581	0.015	45.624	0.015	45.666	0.015	45.709	0.015	45.751	0.015	45.794	0.015	45.836	0.015	45.879
0.015	45.921	0.015	45.964	0.015	46.006	0.015	46.049	0.015	46.091	0.015	46.134	0.015	46.176	0.015	46.219
0.015	46.261	0.015	46.304	0.015	46.346	0.015	46.389	0.016	46.431	0.016	46.474	0.015	46.516	0.016	46.559
0.016	46.601	0.016	46.644	0.016	46.686	0.016	46.728	0.016	46.771	0.016	46.813	0.016	46.856	0.016	46.898
0.016	46.941	0.016	46.983	0.016	47.026	0.016	47.068	0.016	47.111	0.016	47.153	0.016	47.196	0.016	47.238
0.016	47.281	0.016	47.323	0.016	47.366	0.016	47.408	0.016	47.451	0.016	47.493	0.016	47.536	0.017	47.578
0.017	47.621	0.017	47.663	0.017	47.706	0.017	47.748	0.017	47.791	0.017	47.833	0.017	47.875	0.017	47.918
0.017	47.960	0.017	48.003	0.017	48.045	0.017	48.088	0.017	48.130	0.017	48.173	0.017	48.215	0.017	48.258
0.017	48.300	0.018	48.343	0.018	48.385	0.018	48.428	0.018	48.470	0.018	48.513	0.018	48.555	0.018	48.598
0.018	48.640	0.018	48.683	0.018	48.725	0.018	48.768	0.018	48.810	0.018	48.853	0.018	48.895	0.018	48.937
0.018	48.980	0.018	49.022	0.018	49.065	0.018	49.107	0.018	49.150	0.018	49.192	0.019	49.235	0.019	49.277
0.019	49.320	0.019	49.362	0.020	49.405	0.020	49.447	0.020	49.490	0.020	49.532	0.020	49.575	0.020	49.617
0.020	49.660	0.020	49.702	0.020	49.745	0.020	49.787	0.020	49.830	0.020	49.872	0.020	49.915	0.020	49.957
0.020	50.000	0.020	50.042	0.020	50.084	0.020	50.127	0.020	50.169	0.020	50.212	0.020	50.254	0.020	50.297
0.020	50.339	0.020	50.382	0.020	50.424	0.020	50.467	0.020	50.509	0.020	50.552	0.020	50.594	0.020	50.637
0.020	50.679	0.020	50.722	0.020	50.764	0.020	50.807	0.020	50.849	0.020	50.892	0.020	50.934	0.020	50.977
0.020	51.019	0.020	51.062	0.020	51.104	0.020	51.146	0.020	51.189	0.020	51.231	0.020	51.274	0.020	51.316
0.020	51.359	0.020	51.401	0.020	51.444	0.020	51.486	0.020	51.529	0.020	51.571	0.020	51.614	0.020	51.656
0.020	51.699	0.020	51.741	0.020	51.784	0.020	51.826	0.020	51.869	0.020	51.911	0.020	51.954	0.020	51.996
0.020	52.039	0.020	52.081	0.020	52.124	0.020	52.166	0.020	52.209	0.020	52.251	0.020	52.293	0.020	52.336
0.020	52.378	0.020	52.421	0.020	52.463	0.020	52.506	0.020	52.548	0.020	52.591	0.020	52.633	0.020	52.676
0.020	52.718	0.020	52.761	0.020	52.803	0.020	52.846	0.020	52.888	0.020	52.931	0.020	52.973	0.020	53.016
0.020	53.058	0.020	53.101	0.020	53.143	0.020	53.186	0.020	53.228	0.020	53.271	0.020	53.313	0.020	53.355
0.020	53.398	0.020	53.440	0.020	53.483	0.020	53.525	0.020	53.568	0.020	53.610	0.020	53.653	0.020	53.695
0.020	53.738	0.020	53.780	0.020	53.823	0.020	53.865	0.020	53.908	0.020	53.950	0.020	53.993	0.020	54.035
0.020	54.078	0.020	54.120	0.020	54.163	0.020	54.205	0.020	54.248	0.020	54.290	0.020	54.333	0.020	54.375
0.020	54.418	0.020	54.460	0.020	54.502	0.020	54.545	0.020	54.587	0.020	54.630	0.020	54.672	0.020	54.715
0.020	54.757	0.020	54.800	0.020	54.842	0.020	54.885	0.020	54.927	0.020	54.970	0.020	55.012	0.020	55.055
0.020	55.097	0.020	55.140	0.020	55.182	0.020	55.225	0.020	55.267	0.020	55.310	0.020	55.352	0.020	55.395
0.020	55.437	0.020	55.480	0.020	55.522	0.020	55.565	0.020	55.607	0.020	55.649	0.020	55.692	0.020	55.734
0.020	55.777	0.020	55.819	0.020	55.862	0.020	55.904	0.020	55.947	0.020	55.989	0.020	56.032	0.020	56.074

0.020	56.117	0.020	56.159	0.020	56.202	0.020	56.244	0.020	56.287	0.020	56.329	0.020	56.372	0.020	56.414
0.020	56.457	0.020	56.499	0.020	56.542	0.020	56.584	0.020	56.627	0.020	56.669	0.020	56.711	0.020	56.754
0.020	56.796	0.020	56.839	0.020	56.881	0.020	56.924	0.020	56.966	0.020	57.009	0.020	57.051	0.020	57.094
0.020	57.136	0.020	57.179	0.020	57.221	0.020	57.264	0.020	57.306	0.020	57.349	0.020	57.391	0.020	57.434
0.020	57.476	0.020	57.519	0.020	57.561	0.020	57.604	0.020	57.646	0.020	57.689	0.020	57.731	0.020	57.774
0.020	57.816	0.020	57.858	0.020	57.901	0.020	57.943	0.020	57.986	0.020	58.028	0.020	58.071	0.020	58.113
0.020	58.156	0.020	58.198	0.020	58.241	0.020	58.283	0.020	58.326	0.021	58.368	0.021	58.411	0.021	58.453
0.021	58.496	0.021	58.538	0.021	58.581	0.021	58.623	0.021	58.666	0.021	58.708	0.021	58.751	0.021	58.793
0.021	58.836	0.021	58.878	0.021	58.920	0.022	58.963	0.022	59.005	0.022	59.048	0.022	59.090	0.022	59.133
0.022	59.175	0.022	59.218	0.022	59.260	0.022	59.303	0.022	59.345	0.022	59.388	0.022	59.430	0.022	59.473
0.022	59.515	0.022	59.558	0.022	59.600	0.022	59.643	0.022	59.685	0.022	59.728	0.022	59.770	0.022	59.813
0.022	59.855	0.022	59.898	0.022	59.940	0.023	59.983	0.023	60.025	0.023	60.067	0.023	60.110	0.023	60.152
0.023	60.195	0.023	60.237	0.023	60.280	0.023	60.322	0.023	60.365	0.023	60.407	0.023	60.450	0.023	60.492
0.023	60.535	0.023	60.577	0.023	60.620	0.023	60.662	0.023	60.705	0.023	60.747	0.023	60.790	0.023	60.832
0.023	60.875	0.023	60.917	0.023	60.960	0.023	61.002	0.023	61.045	0.024	61.087	0.024	61.129	0.024	61.172
0.024	61.214	0.024	61.257	0.024	61.299	0.024	61.342	0.024	61.384	0.024	61.427	0.024	61.469	0.024	61.512
0.024	61.554	0.024	61.597	0.024	61.639	0.025	61.682	0.025	61.724	0.025	61.767	0.025	61.809	0.025	61.852
0.025	61.894	0.025	61.937	0.025	61.979	0.025	62.022	0.025	62.064	0.025	62.107	0.025	62.149	0.025	62.192
0.025	62.234	0.025	62.276	0.025	62.319	0.025	62.361	0.025	62.404	0.025	62.446	0.025	62.489	0.025	62.531
0.025	62.574	0.025	62.616	0.025	62.659	0.025	62.701	0.025	62.744	0.025	62.786	0.025	62.829	0.025	62.871
0.025	62.914	0.025	62.956	0.025	62.999	0.025	63.041	0.025	63.084	0.025	63.126	0.025	63.169	0.025	63.211
0.025	63.254	0.025	63.296	0.025	63.339	0.025	63.381	0.025	63.423	0.025	63.466	0.025	63.508	0.025	63.551
0.025	63.593	0.025	63.636	0.025	63.678	0.025	63.721	0.025	63.763	0.025	63.806	0.025	63.848	0.025	63.891
0.025	63.933	0.026	63.976	0.026	64.018	0.026	64.061	0.026	64.103	0.026	64.146	0.026	64.188	0.026	64.231
0.026	64.273	0.026	64.316	0.026	64.358	0.026	64.401	0.026	64.443	0.026	64.485	0.026	64.528	0.026	64.570
0.026	64.613	0.026	64.655	0.026	64.698	0.026	64.740	0.026	64.783	0.026	64.825	0.026	64.868	0.026	64.910
0.026	64.953	0.026	64.995	0.026	65.038	0.027	65.080	0.027	65.123	0.027	65.165	0.027	65.208	0.027	65.250
0.027	65.293	0.027	65.335	0.027	65.378	0.027	65.420	0.027	65.463	0.027	65.505	0.027	65.548	0.027	65.590
0.027	65.632	0.027	65.675	0.027	65.717	0.028	65.760	0.028	65.802	0.028	65.845	0.028	65.887	0.028	65.930
0.028	65.972	0.028	66.015	0.028	66.057	0.028	66.100	0.028	66.142	0.028	66.185	0.028	66.227	0.028	66.270
0.028	66.312	0.028	66.355	0.029	66.397	0.029	66.440	0.029	66.482	0.029	66.525	0.029	66.567	0.029	66.610
0.029	66.652	0.030	66.694	0.030	66.737	0.030	66.779	0.030	66.822	0.030	66.864	0.030	66.907	0.030	66.949
0.030	66.992	0.030	67.034	0.030	67.077	0.030	67.119	0.030	67.162	0.030	67.204	0.030	67.247	0.030	67.289
0.030	67.332	0.030	67.374	0.030	67.417	0.030	67.459	0.030	67.502	0.030	67.544	0.030	67.587	0.030	67.629
0.030	67.672	0.030	67.714	0.030	67.757	0.030	67.799	0.030	67.841	0.030	67.884	0.030	67.926	0.030	67.969
0.030	68.011	0.030	68.054	0.030	68.096	0.030	68.139	0.030	68.181	0.030	68.224	0.030	68.266	0.030	68.309
0.030	68.351	0.030	68.394	0.030	68.436	0.030	68.479	0.030	68.521	0.030	68.564	0.030	68.606	0.030	68.649
0.030	68.691	0.030	68.734	0.030	68.776	0.030	68.819	0.030	68.861	0.030	68.904	0.030	68.946	0.030	68.989
0.030	69.031	0.030	69.073	0.030	69.116	0.030	69.158	0.030	69.201	0.030	69.243	0.030	69.286	0.030	69.329
0.030	69.371	0.030	69.413	0.030	69.456	0.030	69.498	0.030	69.541	0.030	69.583	0.030	69.626	0.030	69.669
0.030	69.711	0.030	69.753	0.030	69.796	0.030	69.838	0.030	69.881	0.030	69.923	0.030	69.966	0.030	70.008
0.030	70.050	0.030	70.093	0.030	70.135	0.030	70.178	0.030	70.220	0.030	70.263	0.030	70.305	0.030	70.348
0.030	70.390	0.030	70.433	0.030	70.475	0.030	70.518	0.030	70.560	0.030	70.603	0.030	70.645	0.030	70.688
0.030	70.730	0.030	70.773	0.030	70.815	0.030	70.858	0.030	70.900	0.030	70.943	0.030	70.985	0.031	71.028
0.031	71.070	0.031	71.113	0.031	71.155	0.031	71.197	0.031	71.240	0.031	71.282	0.031	71.325	0.032	71.367
0.032	71.410	0.032	71.452	0.032	71.495	0.032	71.537	0.032	71.580	0.032	71.622	0.032	71.665	0.032	71.707
0.032	71.750	0.032	71.792	0.032	71.835	0.032	71.877	0.032	71.920	0.032	71.962	0.032	72.005	0.032	72.047
0.032	72.090	0.033	72.132	0.033	72.175	0.033	72.217	0.033	72.259	0.033	72.302	0.033	72.344	0.033	72.387
0.033	72.429	0.033	72.472	0.033	72.514	0.033	72.557	0.033	72.599	0.033	72.642	0.033	72.684	0.033	72.727
0.033	72.769	0.033	72.812	0.033	72.854	0.033	72.897	0.034	72.939	0.034	72.982	0.034	73.024	0.034	73.067
0.034	73.109	0.034	73.152	0.034	73.194	0.034	73.237	0.034	73.279	0.035	73.322	0.035	73.364	0.035	73.406
0.035	73.449	0.035	73.491	0.035	73.534	0.035	73.576	0.035	73.619	0.035	73.661	0.035	73.704	0.035	73.746
0.035	73.789	0.035	73.831	0.035	73.874	0.035	73.916	0.035	73.959	0.035	74.001	0.035	74.044	0.035	74.086
0.035	74.129	0.035	74.171	0.035	74.214	0.035	74.256	0.035	74.299	0.036	74.341	0.036	74.384	0.036	74.426
0.036	74.468	0.036	74.511	0.036	74.553	0.036	74.596	0.036	74.638	0.036	74.681	0.036	74.723	0.036	74.766
0.036	74.808	0.036	74.851	0.037	74.893	0.037	74.936	0.037	74.978	0.037	75.021	0.037	75.063	0.037	75.106
0.037	75.148	0.037	75.191	0.038	75.233	0.038	75.276	0.038	75.318	0.038	75.361	0.038	75.403	0.038	75.446

0.038	75.488	0.038	75.531	0.039	75.573	0.039	75.615	0.039	75.658	0.040	75.700	0.040	75.743	0.040	75.785
0.040	75.828	0.040	75.870	0.040	75.913	0.040	75.955	0.040	75.998	0.040	76.040	0.040	76.083	0.040	76.125
0.040	76.168	0.040	76.210	0.040	76.253	0.040	76.295	0.040	76.338	0.040	76.380	0.040	76.423	0.040	76.465
0.040	76.508	0.040	76.550	0.040	76.593	0.040	76.635	0.040	76.678	0.040	76.720	0.040	76.762	0.040	76.805
0.040	76.847	0.040	76.890	0.040	76.932	0.040	76.975	0.040	77.017	0.040	77.060	0.040	77.102	0.040	77.145
0.040	77.187	0.040	77.230	0.040	77.272	0.040	77.315	0.040	77.357	0.040	77.400	0.040	77.442	0.040	77.485
0.040	77.527	0.040	77.570	0.040	77.612	0.040	77.655	0.040	77.697	0.040	77.740	0.040	77.782	0.040	77.824
0.040	77.867	0.040	77.909	0.040	77.952	0.040	77.994	0.040	78.037	0.040	78.079	0.040	78.122	0.040	78.164
0.040	78.207	0.041	78.249	0.041	78.292	0.041	78.334	0.042	78.377	0.042	78.419	0.042	78.462	0.042	78.504
0.042	78.547	0.042	78.589	0.042	78.632	0.042	78.674	0.042	78.717	0.043	78.759	0.043	78.802	0.043	78.844
0.043	78.887	0.044	78.929	0.044	78.971	0.044	79.014	0.044	79.056	0.044	79.099	0.044	79.141	0.044	79.184
0.044	79.226	0.044	79.269	0.045	79.311	0.045	79.354	0.045	79.396	0.045	79.439	0.045	79.481	0.045	79.524
0.045	79.566	0.045	79.609	0.045	79.651	0.045	79.694	0.045	79.736	0.045	79.779	0.045	79.821	0.045	79.864
0.045	79.906	0.045	79.949	0.045	79.991	0.045	80.033	0.045	80.076	0.045	80.118	0.045	80.161	0.045	80.203
0.045	80.246	0.045	80.288	0.045	80.331	0.045	80.373	0.045	80.416	0.046	80.458	0.046	80.501	0.046	80.543
0.046	80.586	0.046	80.628	0.046	80.671	0.047	80.713	0.047	80.756	0.047	80.798	0.047	80.841	0.047	80.883
0.047	80.926	0.048	80.968	0.048	81.011	0.048	81.053	0.048	81.096	0.048	81.138	0.048	81.180	0.049	81.223
0.049	81.265	0.049	81.308	0.050	81.350	0.050	81.393	0.050	81.435	0.050	81.478	0.050	81.520	0.050	81.563
0.050	81.605	0.050	81.648	0.050	81.690	0.050	81.733	0.050	81.775	0.050	81.818	0.050	81.860	0.050	81.903
0.050	81.945	0.050	81.988	0.050	82.030	0.050	82.073	0.050	82.115	0.050	82.158	0.050	82.200	0.050	82.242
0.050	82.285	0.050	82.327	0.050	82.370	0.050	82.412	0.050	82.455	0.050	82.497	0.050	82.540	0.050	82.582
0.050	82.625	0.050	82.667	0.050	82.710	0.050	82.752	0.050	82.795	0.050	82.837	0.050	82.880	0.050	82.922
0.050	82.965	0.051	83.007	0.051	83.050	0.051	83.092	0.051	83.135	0.051	83.177	0.052	83.220	0.052	83.262
0.052	83.305	0.052	83.347	0.052	83.389	0.052	83.432	0.052	83.474	0.053	83.517	0.053	83.559	0.053	83.602
0.053	83.644	0.053	83.687	0.053	83.729	0.053	83.772	0.053	83.814	0.053	83.857	0.054	83.899	0.054	83.942
0.054	83.984	0.054	84.027	0.054	84.069	0.054	84.112	0.054	84.154	0.054	84.197	0.054	84.239	0.055	84.282
0.055	84.324	0.055	84.367	0.055	84.409	0.055	84.452	0.055	84.494	0.055	84.536	0.055	84.579	0.055	84.621
0.055	84.664	0.055	84.706	0.055	84.749	0.056	84.791	0.056	84.834	0.056	84.876	0.056	84.919	0.056	84.961
0.056	85.004	0.056	85.046	0.056	85.089	0.056	85.131	0.056	85.174	0.056	85.216	0.057	85.259	0.057	85.301
0.058	85.344	0.059	85.386	0.060	85.429	0.060	85.471	0.060	85.514	0.060	85.556	0.060	85.598	0.060	85.641
0.060	85.683	0.060	85.726	0.060	85.768	0.060	85.811	0.060	85.853	0.060	85.896	0.060	85.938	0.060	85.981
0.060	86.023	0.060	86.066	0.060	86.108	0.060	86.151	0.060	86.193	0.060	86.236	0.060	86.278	0.060	86.321
0.060	86.363	0.060	86.406	0.060	86.448	0.060	86.491	0.060	86.533	0.060	86.576	0.060	86.618	0.060	86.661
0.060	86.703	0.060	86.745	0.060	86.788	0.060	86.830	0.060	86.873	0.060	86.915	0.061	86.958	0.061	87.000
0.061	87.043	0.062	87.085	0.062	87.128	0.062	87.170	0.063	87.213	0.063	87.255	0.063	87.298	0.063	87.340
0.063	87.383	0.064	87.425	0.065	87.468	0.065	87.510	0.065	87.553	0.065	87.595	0.065	87.638	0.065	87.680
0.065	87.723	0.065	87.765	0.065	87.807	0.065	87.850	0.066	87.892	0.066	87.935	0.067	87.977	0.067	88.020
0.067	88.062	0.067	88.105	0.067	88.147	0.070	88.190	0.070	88.232	0.070	88.275	0.070	88.317	0.070	88.360
0.070	88.402	0.070	88.445	0.070	88.487	0.070	88.530	0.070	88.572	0.070	88.615	0.070	88.657	0.070	88.700
0.070	88.742	0.070	88.785	0.070	88.827	0.070	88.870	0.070	88.912	0.070	88.954	0.070	88.997	0.070	89.039
0.071	89.082	0.071	89.124	0.072	89.167	0.072	89.209	0.073	89.252	0.073	89.294	0.073	89.337	0.073	89.379
0.073	89.422	0.074	89.464	0.074	89.507	0.074	89.549	0.075	89.592	0.075	89.634	0.075	89.677	0.075	89.719
0.076	89.762	0.076	89.804	0.076	89.847	0.076	89.889	0.076	89.932	0.077	89.974	0.077	90.016	0.077	90.059
0.077	90.101	0.080	90.144	0.080	90.186	0.080	90.229	0.080	90.271	0.080	90.314	0.080	90.356	0.080	90.399
0.080	90.441	0.080	90.484	0.080	90.526	0.080	90.569	0.080	90.611	0.080	90.654	0.080	90.696	0.080	90.739
0.080	90.781	0.082	90.824	0.082	90.866	0.082	90.909	0.083	90.951	0.083	90.994	0.084	91.036	0.084	91.079
0.085	91.121	0.085	91.163	0.085	91.206	0.085	91.248	0.085	91.291	0.086	91.333	0.087	91.376	0.087	91.418
0.088	91.461	0.088	91.503	0.090	91.546	0.090	91.588	0.090	91.631	0.090	91.673	0.090	91.716	0.090	91.758
0.090	91.801	0.090	91.843	0.090	91.886	0.090	91.928	0.090	91.971	0.090	92.013	0.090	92.056	0.091	92.098
0.092	92.141	0.092	92.183	0.092	92.226	0.094	92.268	0.095	92.310	0.095	92.353	0.095	92.395	0.095	92.438
0.095	92.480	0.095	92.523	0.095	92.565	0.095	92.608	0.096	92.650	0.096	92.693	0.097	92.735	0.097	92.778
0.100	92.820	0.100	92.863	0.100	92.905	0.100	92.948	0.100	92.990	0.100	93.033	0.100	93.075	0.100	93.118
0.100	93.160	0.100	93.203	0.105	93.245	0.105	93.288	0.105	93.330	0.105	93.372	0.105	93.415	0.106	93.457
0.106	93.500	0.106	93.542	0.106	93.585	0.107	93.627	0.110	93.670	0.110	93.712	0.110	93.755	0.110	93.797
0.110	93.840	0.110	93.882	0.112	93.925	0.112	93.967	0.114	94.010	0.115	94.052	0.115	94.095	0.118	94.137
0.120	94.180	0.120	94.222	0.120	94.265	0.120	94.307	0.120	94.350	0.120	94.392	0.120	94.435	0.120	94.477
0.120	94.519	0.120	94.562	0.120	94.604	0.120	94.647	0.120	94.689	0.120	94.732	0.123	94.774	0.123	94.817

0.123	94.859	0.125	94.902	0.125	94.944	0.125	94.987	0.126	95.029	0.126	95.072	0.127	95.114	0.128	95.157
0.130	95.199	0.130	95.242	0.130	95.284	0.130	95.327	0.130	95.369	0.130	95.412	0.130	95.454	0.130	95.497
0.130	95.539	0.130	95.582	0.130	95.624	0.130	95.666	0.133	95.709	0.135	95.751	0.135	95.794	0.136	95.835
0.136	95.879	0.137	95.921	0.138	95.964	0.138	96.006	0.140	96.049	0.140	96.091	0.140	96.134	0.140	96.176
0.140	96.219	0.140	96.261	0.140	96.304	0.142	96.346	0.146	96.389	0.147	96.431	0.150	96.474	0.154	96.515
0.155	96.559	0.155	96.601	0.160	96.644	0.160	96.686	0.160	96.728	0.160	96.771	0.160	96.813	0.163	96.855
0.165	96.898	0.167	96.941	0.167	96.983	0.170	97.026	0.170	97.068	0.170	97.111	0.172	97.153	0.176	97.196
0.180	97.238	0.180	97.281	0.183	97.323	0.190	97.366	0.190	97.408	0.190	97.451	0.190	97.493	0.191	97.536
0.195	97.578	0.200	97.621	0.200	97.663	0.200	97.706	0.200	97.748	0.200	97.791	0.200	97.833	0.201	97.875
0.210	97.918	0.210	97.960	0.213	98.003	0.216	98.045	0.216	98.088	0.220	98.130	0.228	98.173	0.230	98.215
0.230	98.258	0.233	98.300	0.235	98.343	0.240	98.385	0.240	98.428	0.260	98.470	0.265	98.513	0.266	98.555
0.270	98.598	0.270	98.640	0.270	98.683	0.272	98.725	0.275	98.768	0.276	98.810	0.280	98.853	0.290	98.895
0.302	98.937	0.320	98.980	0.325	99.022	0.330	99.065	0.341	99.107	0.345	99.150	0.350	99.192	0.350	99.235
0.350	99.277	0.390	99.320	0.390	99.362	0.412	99.405	0.416	99.447	0.420	99.490	0.420	99.532	0.475	99.575
0.480	99.617	0.503	99.660	0.520	99.702	0.530	99.745	0.640	99.787	0.650	99.830	0.650	99.872	0.655	99.915
0.675	99.957	0.760	100.000												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INTENSITY VS PERCENT LESS THAN OR EQUAL TO

RETURN PERIOD (IN YEARS) FOR INTENSITY

VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD
0.760	26.000	0.675	13.000	0.655	8.666	0.650	6.500	0.650	5.200	0.640	4.333	0.530	3.714	0.520	3.250
0.503	2.888	0.480	2.600	0.475	2.363	0.420	2.166	0.420	2.000	0.416	1.857	0.412	1.733	0.390	1.625
0.390	1.529	0.350	1.444	0.350	1.368	0.350	1.300	0.345	1.238	0.341	1.181	0.330	1.130	0.325	1.083
0.320	1.040	0.302	1.000	0.290	0.962	0.280	0.928	0.276	0.896	0.275	0.866	0.272	0.838	0.270	0.812
0.270	0.787	0.270	0.754	0.266	0.742	0.265	0.722	0.260	0.702	0.240	0.684	0.240	0.666	0.235	0.650
0.233	0.634	0.230	0.619	0.230	0.604	0.228	0.590	0.220	0.577	0.216	0.565	0.216	0.553	0.213	0.541
0.210	0.530	0.210	0.520	0.201	0.509	0.200	0.500	0.200	0.490	0.200	0.481	0.200	0.472	0.200	0.464
0.200	0.456	0.195	0.448	0.191	0.440	0.190	0.433	0.190	0.426	0.190	0.419	0.190	0.412	0.183	0.405
0.180	0.400	0.180	0.393	0.176	0.388	0.172	0.382	0.170	0.376	0.170	0.371	0.170	0.366	0.167	0.361
0.167	0.356	0.165	0.351	0.163	0.346	0.160	0.342	0.160	0.337	0.160	0.333	0.160	0.329	0.160	0.325
0.155	0.320	0.155	0.317	0.154	0.313	0.150	0.309	0.147	0.305	0.146	0.302	0.142	0.298	0.140	0.295
0.140	0.292	0.140	0.288	0.140	0.285	0.140	0.282	0.140	0.279	0.140	0.276	0.138	0.273	0.138	0.270
0.137	0.268	0.136	0.265	0.136	0.262	0.135	0.260	0.135	0.257	0.133	0.254	0.130	0.252	0.130	0.250
0.130	0.247	0.130	0.245	0.130	0.242	0.130	0.240	0.130	0.238	0.130	0.236	0.130	0.234	0.130	0.232
0.130	0.230	0.130	0.228	0.128	0.226	0.127	0.224	0.126	0.222	0.126	0.220	0.125	0.218	0.125	0.215
0.125	0.214	0.123	0.213	0.123	0.211	0.123	0.209	0.120	0.208	0.120	0.206	0.120	0.204	0.120	0.203
0.120	0.201	0.120	0.200	0.120	0.198	0.120	0.196	0.120	0.195	0.120	0.194	0.120	0.192	0.120	0.191
0.120	0.189	0.120	0.188	0.118	0.187	0.115	0.185	0.115	0.184	0.114	0.183	0.112	0.181	0.112	0.180
0.110	0.179	0.110	0.178	0.110	0.176	0.110	0.175	0.110	0.174	0.110	0.173	0.107	0.172	0.106	0.171
0.106	0.169	0.106	0.168	0.106	0.167	0.105	0.166	0.105	0.165	0.105	0.164	0.105	0.163	0.105	0.162
0.100	0.161	0.100	0.160	0.100	0.159	0.100	0.158	0.100	0.157	0.100	0.156	0.100	0.155	0.100	0.154
0.100	0.153	0.100	0.152	0.097	0.152	0.097	0.151	0.096	0.150	0.096	0.149	0.095	0.148	0.095	0.147
0.095	0.146	0.095	0.146	0.095	0.145	0.095	0.144	0.095	0.143	0.095	0.142	0.094	0.142	0.092	0.141
0.092	0.140	0.092	0.139	0.091	0.139	0.090	0.138	0.090	0.137	0.090	0.136	0.090	0.136	0.090	0.135
0.090	0.134	0.090	0.134	0.090	0.133	0.090	0.132	0.090	0.131	0.090	0.131	0.090	0.130	0.090	0.130
0.088	0.129	0.088	0.128	0.087	0.128	0.087	0.127	0.086	0.126	0.085	0.126	0.085	0.125	0.085	0.125
0.085	0.124	0.085	0.123	0.084	0.123	0.084	0.122	0.083	0.122	0.083	0.121	0.082	0.120	0.082	0.120
0.082	0.119	0.080	0.119	0.080	0.118	0.080	0.118	0.080	0.117	0.080	0.117	0.080	0.116	0.080	0.116
0.080	0.115	0.080	0.115	0.080	0.114	0.080	0.114	0.080	0.113	0.080	0.113	0.080	0.112	0.080	0.112
0.080	0.111	0.077	0.111	0.077	0.110	0.077	0.110	0.077	0.109	0.076	0.109	0.076	0.108	0.076	0.108
0.076	0.107	0.076	0.107	0.075	0.106	0.075	0.106	0.075	0.106	0.075	0.105	0.074	0.105	0.074	0.104
0.074	0.104	0.073	0.104	0.073	0.103	0.073	0.103	0.073	0.102	0.073	0.102	0.072	0.101	0.072	0.101
0.071	0.101	0.071	0.100	0.070	0.100	0.070	0.100	0.070	0.099	0.070	0.099	0.070	0.098	0.070	0.098
0.070	0.098	0.070	0.097	0.070	0.097	0.070	0.097	0.070	0.096	0.070	0.096	0.070	0.095	0.070	0.095
0.070	0.095	0.070	0.094	0.070	0.094	0.070	0.094	0.070	0.093	0.070	0.093	0.070	0.093	0.067	0.092
0.067	0.092	0.067	0.092	0.067	0.091	0.067	0.091	0.066	0.091	0.066	0.090	0.065	0.090	0.065	0.090
0.065	0.089	0.065	0.089	0.065	0.089	0.065	0.089	0.065	0.088	0.065	0.088	0.065	0.088	0.065	0.087
0.064	0.087	0.063	0.087	0.063	0.086	0.063	0.086	0.063	0.086	0.063	0.086	0.062	0.085	0.062	0.085
0.062	0.085	0.061	0.084	0.061	0.084	0.061	0.084	0.060	0.084	0.060	0.083	0.060	0.083	0.060	0.083
0.060	0.083	0.060	0.082	0.060	0.082	0.060	0.082	0.060	0.082	0.060	0.081	0.060	0.081	0.060	0.081
0.060	0.080	0.060	0.080	0.060	0.080	0.060	0.080	0.060	0.080	0.060	0.079	0.060	0.079	0.060	0.079
0.060	0.079	0.060	0.078	0.060	0.078	0.060	0.078	0.060	0.078	0.060	0.077	0.060	0.077	0.060	0.077
0.060	0.077	0.060	0.076	0.060	0.076	0.060	0.076	0.060	0.076	0.060	0.076	0.060	0.075	0.060	0.075
0.059	0.075	0.058	0.075	0.057	0.074	0.057	0.074	0.056	0.074	0.056	0.074	0.056	0.074	0.056	0.073
0.056	0.073	0.056	0.073	0.056	0.073	0.056	0.073	0.056	0.072	0.056	0.072	0.056	0.072	0.055	0.072
0.055	0.072	0.055	0.071	0.055	0.071	0.055	0.071	0.055	0.071	0.055	0.071	0.055	0.070	0.055	0.070
0.055	0.070	0.055	0.070	0.055	0.070	0.054	0.069	0.054	0.069	0.054	0.069	0.054	0.069	0.054	0.069
0.054	0.068	0.054	0.068	0.054	0.068	0.054	0.068	0.053	0.068	0.053	0.068	0.053	0.067	0.053	0.067
0.053	0.067	0.053	0.067	0.053	0.067	0.053	0.067	0.053	0.066	0.052	0.066	0.052	0.066	0.052	0.066
0.052	0.066	0.052	0.065	0.052	0.065	0.052	0.065	0.051	0.065	0.051	0.065	0.051	0.065	0.051	0.065
0.051	0.064	0.050	0.064	0.050	0.064	0.050	0.064	0.050	0.064	0.050	0.064	0.050	0.063	0.050	0.063
0.050	0.063	0.050	0.063	0.050	0.063	0.050	0.063	0.050	0.062	0.050	0.062	0.050	0.062	0.050	0.062
0.050	0.062	0.050	0.062	0.050	0.062	0.050	0.061	0.050	0.061	0.050	0.061	0.050	0.061	0.050	0.061

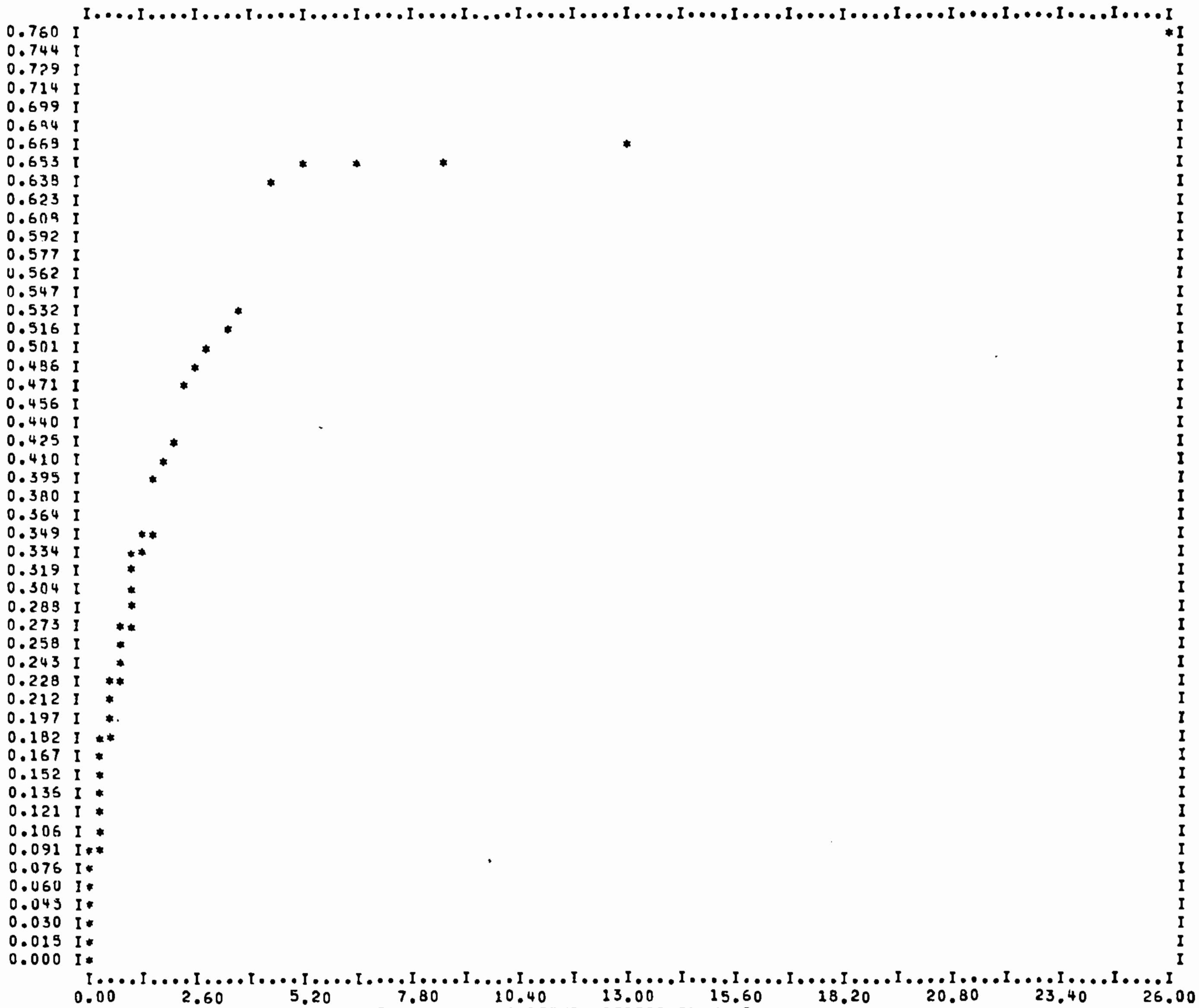
0.050	0.061	0.050	0.061	0.050	0.060	0.050	0.060	0.050	0.060	0.050	0.060	0.050	0.060	0.050	0.060
0.050	0.060	0.050	0.059	0.050	0.059	0.050	0.059	0.050	0.059	0.050	0.059	0.050	0.059	0.050	0.059
0.049	0.058	0.049	0.058	0.049	0.058	0.048	0.058	0.048	0.058	0.048	0.058	0.048	0.058	0.048	0.058
0.048	0.057	0.047	0.057	0.047	0.057	0.047	0.057	0.047	0.057	0.047	0.057	0.047	0.057	0.046	0.057
0.046	0.056	0.046	0.056	0.046	0.056	0.046	0.056	0.046	0.056	0.045	0.056	0.045	0.056	0.045	0.056
0.045	0.055	0.045	0.055	0.045	0.055	0.045	0.055	0.045	0.055	0.045	0.055	0.045	0.055	0.045	0.055
0.045	0.054	0.045	0.054	0.045	0.054	0.045	0.054	0.045	0.054	0.045	0.054	0.045	0.054	0.045	0.054
0.045	0.054	0.045	0.053	0.045	0.053	0.045	0.053	0.045	0.053	0.045	0.053	0.045	0.053	0.045	0.053
0.044	0.053	0.044	0.053	0.044	0.052	0.044	0.052	0.044	0.052	0.044	0.052	0.044	0.052	0.044	0.052
0.044	0.052	0.043	0.052	0.043	0.052	0.043	0.052	0.043	0.051	0.042	0.051	0.042	0.051	0.042	0.051
0.042	0.051	0.042	0.051	0.042	0.051	0.042	0.051	0.042	0.051	0.042	0.050	0.041	0.050	0.041	0.050
0.041	0.050	0.040	0.050	0.040	0.050	0.040	0.050	0.040	0.050	0.040	0.050	0.040	0.050	0.040	0.050
0.040	0.049	0.040	0.049	0.040	0.049	0.040	0.049	0.040	0.049	0.040	0.049	0.040	0.049	0.040	0.049
0.040	0.049	0.040	0.049	0.040	0.048	0.040	0.048	0.040	0.048	0.040	0.048	0.040	0.048	0.040	0.048
0.040	0.048	0.040	0.048	0.040	0.048	0.040	0.048	0.040	0.048	0.040	0.047	0.040	0.047	0.040	0.047
0.040	0.047	0.040	0.047	0.040	0.047	0.040	0.047	0.040	0.047	0.040	0.047	0.040	0.047	0.040	0.047
0.040	0.047	0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.046
0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.046	0.040	0.045	0.040	0.045	0.040	0.045
0.040	0.045	0.040	0.045	0.040	0.045	0.040	0.045	0.040	0.045	0.039	0.045	0.039	0.045	0.039	0.045
0.038	0.045	0.038	0.044	0.038	0.044	0.038	0.044	0.038	0.044	0.038	0.044	0.038	0.044	0.038	0.044
0.037	0.044	0.037	0.044	0.037	0.044	0.037	0.044	0.037	0.044	0.037	0.044	0.037	0.043	0.037	0.043
0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.043
0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.043	0.036	0.042	0.035	0.042	0.035	0.042	0.035	0.042
0.035	0.042	0.035	0.042	0.035	0.042	0.035	0.042	0.035	0.042	0.035	0.042	0.035	0.042	0.035	0.042
0.035	0.042	0.035	0.042	0.035	0.042	0.035	0.041	0.035	0.041	0.035	0.041	0.035	0.041	0.035	0.041
0.035	0.041	0.035	0.041	0.035	0.041	0.035	0.041	0.035	0.041	0.034	0.041	0.034	0.041	0.034	0.041
0.034	0.041	0.034	0.041	0.034	0.040	0.034	0.040	0.034	0.040	0.034	0.040	0.033	0.040	0.033	0.040
0.033	0.040	0.033	0.040	0.033	0.040	0.033	0.040	0.033	0.040	0.033	0.040	0.033	0.040	0.033	0.040
0.033	0.040	0.033	0.040	0.033	0.039	0.033	0.039	0.033	0.039	0.033	0.039	0.033	0.039	0.033	0.039
0.033	0.039	0.032	0.039	0.032	0.039	0.032	0.039	0.032	0.039	0.032	0.039	0.032	0.039	0.032	0.039
0.032	0.039	0.032	0.039	0.032	0.038	0.032	0.038	0.032	0.038	0.032	0.038	0.032	0.038	0.032	0.038
0.032	0.038	0.032	0.038	0.032	0.038	0.031	0.038	0.031	0.038	0.031	0.038	0.031	0.038	0.031	0.038
0.031	0.038	0.031	0.038	0.031	0.038	0.030	0.038	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037
0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037
0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.037	0.030	0.036	0.030	0.036
0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.035
0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.036	0.030	0.035
0.030	0.036	0.030	0.036	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035
0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035
0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.035	0.030	0.034	0.030	0.034
0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034
0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034
0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.034	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033
0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033
0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033	0.030	0.033
0.030	0.033	0.029	0.033	0.029	0.033	0.029	0.032	0.029	0.032	0.029	0.032	0.029	0.032	0.029	0.032
0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032
0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.028	0.032	0.027	0.032
0.027	0.032	0.027	0.032	0.027	0.032	0.027	0.032	0.027	0.031	0.027	0.031	0.027	0.031	0.027	0.031
0.027	0.031	0.027	0.031	0.027	0.031	0.027	0.031	0.027	0.031	0.027	0.031	0.027	0.031	0.026	0.031
0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031
0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.031	0.026	0.030	0.026	0.030
0.026	0.030	0.026	0.030	0.026	0.030	0.026	0.030	0.026	0.030	0.026	0.030	0.026	0.030	0.026	0.030
0.026	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030
0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030
0.025	0.030	0.025	0.030	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029
0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029

0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029
0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029	0.025	0.029
0.025	0.028	0.025	0.028	0.025	0.028	0.025	0.028	0.025	0.028	0.025	0.028	0.025	0.028	0.024	0.029
0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.029
0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.028	0.024	0.028	0.023	0.028	0.023	0.028	0.023	0.029
0.023	0.028	0.023	0.028	0.023	0.028	0.023	0.028	0.023	0.028	0.023	0.028	0.023	0.028	0.023	0.029
0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027
0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.023	0.027	0.022	0.027
0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027
0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027	0.022	0.027
0.022	0.027	0.022	0.027	0.022	0.026	0.022	0.026	0.022	0.026	0.022	0.026	0.022	0.026	0.021	0.025
0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.025
0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.026	0.021	0.026	0.020	0.026	0.020	0.026	0.020	0.025
0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.025
0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.026	0.020	0.025
0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025
0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025
0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025
0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025
0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025
0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024
0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024
0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024
0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024
0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024
0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023
0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023
0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023
0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023
0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023
0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023	0.020	0.023
0.020	0.023	0.020	0.023	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022
0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022
0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022
0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022
0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022
0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022
0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.022	0.020	0.021	0.020	0.021	0.020	0.021
0.020	0.021	0.020	0.021	0.020	0.021	0.020	0.021	0.020	0.021	0.020	0.021	0.020	0.021	0.020	0.021
0.019	0.021	0.019	0.021	0.019	0.021	0.019	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021
0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021
0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021	0.018	0.021
0.018	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021
0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021	0.017	0.021
0.017	0.021	0.017	0.021	0.017	0.021	0.016	0.021	0.016	0.021	0.016	0.021	0.016	0.020	0.016	0.020
0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.015	0.020	0.016	0.020
0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020
0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.015	0.020	0.015	0.020
0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020
0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020
0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020
0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020
0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.020	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019
0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019
0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019
0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019
0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.015	0.019	0.014	0.019	0.014	0.019

0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019
0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019	0.014	0.019
0.014	0.019	0.014	0.019	0.014	0.019	0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019
0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019	0.013	0.019
0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018
0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018	0.013	0.018
0.013	0.018	0.013	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018
0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018
0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018
0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018
0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018
0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.012	0.018	0.011	0.018
0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.018
0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.018	0.011	0.017	0.011	0.017	0.011	0.017	0.011	0.017
0.011	0.017	0.011	0.017	0.011	0.017	0.011	0.017	0.011	0.017	0.011	0.017	0.011	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017	0.010	0.017
0.010	0.017	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016	0.010	0.016
0.010	0.016	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015
0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.015	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014

0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
0.010	0.014	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.009	0.011
0.009	0.011	0.009	0.011	0.009	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011
0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.009	0.011	0.008	0.011
0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011
0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011
0.008	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011

0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011
0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011
0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011
0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011	0.007	0.011
0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011
0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011
0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.005	0.011	0.006	0.011
0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011
0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.005	0.011	0.006	0.011
0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011	0.006	0.011
0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011
0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011
0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011	0.005	0.011
0.004	0.011	0.004	0.011												



INTENSITY VS RETURN PERIOD IN YEARS

PROBABILITY ANALYSIS-VOLUME

PERCENTAGE OF OCCURRENCE LESS THAN OR EQUAL TO THE GIVEN VALUE OF VOLUME

VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT
0.010	0.042	0.010	0.084	0.010	0.127	0.010	0.169	0.010	0.212	0.010	0.254	0.010	0.297	0.010	0.339
0.010	0.382	0.010	0.424	0.010	0.467	0.010	0.509	0.010	0.552	0.010	0.594	0.010	0.637	0.010	0.679
0.010	0.722	0.010	0.764	0.010	0.807	0.010	0.849	0.010	0.892	0.010	0.934	0.010	0.977	0.010	1.019
0.010	1.062	0.010	1.104	0.010	1.146	0.010	1.189	0.010	1.231	0.010	1.274	0.010	1.316	0.010	1.359
0.010	1.401	0.010	1.444	0.010	1.486	0.010	1.529	0.010	1.571	0.010	1.614	0.010	1.656	0.010	1.699
0.010	1.741	0.010	1.784	0.010	1.826	0.010	1.869	0.010	1.911	0.010	1.954	0.010	1.996	0.010	2.039
0.010	2.081	0.010	2.124	0.010	2.166	0.010	2.209	0.010	2.251	0.010	2.293	0.010	2.336	0.010	2.378
0.010	2.421	0.010	2.463	0.010	2.506	0.010	2.548	0.010	2.591	0.010	2.633	0.010	2.676	0.010	2.718
0.010	2.761	0.010	2.803	0.010	2.846	0.010	2.888	0.010	2.931	0.010	2.973	0.010	3.016	0.010	3.058
0.010	3.101	0.010	3.143	0.010	3.186	0.010	3.228	0.010	3.271	0.010	3.313	0.010	3.355	0.010	3.398
0.010	3.440	0.010	3.483	0.010	3.525	0.010	3.568	0.010	3.610	0.010	3.653	0.010	3.695	0.010	3.738
0.010	3.780	0.010	3.823	0.010	3.865	0.010	3.908	0.010	3.950	0.010	3.993	0.010	4.035	0.010	4.078
0.010	4.120	0.010	4.163	0.010	4.205	0.010	4.248	0.010	4.290	0.010	4.333	0.010	4.375	0.010	4.418
0.010	4.460	0.010	4.502	0.010	4.545	0.010	4.587	0.010	4.630	0.010	4.672	0.010	4.715	0.010	4.757
0.010	4.800	0.010	4.842	0.010	4.885	0.010	4.927	0.010	4.970	0.010	5.012	0.010	5.055	0.010	5.097
0.010	5.140	0.010	5.182	0.010	5.225	0.010	5.267	0.010	5.310	0.010	5.352	0.010	5.395	0.010	5.437
0.010	5.480	0.010	5.522	0.010	5.564	0.010	5.607	0.010	5.649	0.010	5.692	0.010	5.734	0.010	5.777
0.010	5.819	0.010	5.862	0.010	5.904	0.010	5.947	0.010	5.989	0.010	6.032	0.010	6.074	0.010	6.117
0.010	6.159	0.010	6.202	0.010	6.244	0.010	6.287	0.010	6.329	0.010	6.372	0.010	6.414	0.010	6.457
0.010	6.499	0.010	6.542	0.010	6.584	0.010	6.627	0.010	6.669	0.010	6.711	0.010	6.754	0.010	6.796
0.010	6.839	0.010	6.881	0.010	6.924	0.010	6.966	0.010	7.009	0.010	7.051	0.010	7.094	0.010	7.136
0.010	7.179	0.010	7.221	0.010	7.264	0.010	7.306	0.010	7.349	0.010	7.391	0.010	7.434	0.010	7.476
0.010	7.519	0.010	7.561	0.010	7.604	0.010	7.646	0.010	7.689	0.010	7.731	0.010	7.774	0.010	7.816
0.010	7.858	0.010	7.901	0.010	7.943	0.010	7.986	0.010	8.028	0.010	8.071	0.010	8.113	0.010	8.156
0.010	8.198	0.010	8.241	0.010	8.283	0.010	8.326	0.010	8.368	0.010	8.411	0.010	8.453	0.010	8.496
0.010	8.538	0.010	8.581	0.010	8.623	0.010	8.666	0.010	8.708	0.010	8.751	0.010	8.793	0.010	8.836
0.010	8.878	0.010	8.920	0.010	8.963	0.010	9.005	0.010	9.048	0.010	9.090	0.010	9.133	0.010	9.175
0.010	9.218	0.010	9.260	0.010	9.303	0.010	9.345	0.010	9.388	0.010	9.430	0.010	9.473	0.010	9.515
0.010	9.558	0.010	9.600	0.010	9.643	0.010	9.685	0.010	9.728	0.010	9.770	0.010	9.813	0.010	9.855
0.010	9.898	0.010	9.940	0.010	9.983	0.010	10.025	0.010	10.067	0.010	10.110	0.010	10.152	0.010	10.195
0.010	10.237	0.010	10.280	0.010	10.322	0.010	10.365	0.010	10.407	0.010	10.450	0.010	10.492	0.010	10.535
0.010	10.577	0.010	10.620	0.010	10.662	0.010	10.705	0.010	10.747	0.010	10.790	0.010	10.832	0.010	10.875
0.010	10.917	0.010	10.960	0.010	11.002	0.010	11.045	0.010	11.087	0.010	11.129	0.010	11.172	0.010	11.214
0.010	11.257	0.010	11.299	0.010	11.342	0.010	11.384	0.010	11.427	0.010	11.469	0.010	11.512	0.010	11.554
0.010	11.597	0.010	11.639	0.010	11.682	0.010	11.724	0.010	11.767	0.010	11.809	0.010	11.852	0.010	11.894
0.010	11.937	0.010	11.979	0.010	12.022	0.010	12.064	0.010	12.107	0.010	12.149	0.010	12.192	0.010	12.234
0.010	12.276	0.010	12.319	0.010	12.361	0.010	12.404	0.010	12.446	0.010	12.489	0.010	12.531	0.010	12.574
0.010	12.616	0.010	12.659	0.010	12.701	0.010	12.744	0.010	12.786	0.010	12.829	0.010	12.871	0.010	12.914
0.010	12.956	0.010	12.999	0.010	13.041	0.010	13.084	0.010	13.126	0.010	13.169	0.010	13.211	0.010	13.254
0.010	13.296	0.010	13.338	0.010	13.381	0.010	13.423	0.010	13.466	0.010	13.508	0.010	13.551	0.010	13.593
0.010	13.636	0.010	13.678	0.010	13.721	0.010	13.763	0.010	13.806	0.010	13.848	0.010	13.891	0.010	13.933
0.010	13.976	0.010	14.018	0.010	14.061	0.010	14.103	0.010	14.146	0.010	14.188	0.010	14.231	0.010	14.273
0.010	14.316	0.010	14.358	0.010	14.401	0.010	14.443	0.010	14.485	0.010	14.528	0.010	14.570	0.010	14.613
0.010	14.655	0.010	14.698	0.010	14.740	0.010	14.783	0.010	14.825	0.010	14.868	0.010	14.910	0.010	14.953
0.010	14.995	0.010	15.038	0.010	15.080	0.010	15.123	0.010	15.165	0.010	15.208	0.010	15.250	0.010	15.293
0.010	15.335	0.010	15.378	0.010	15.420	0.010	15.463	0.010	15.505	0.010	15.548	0.010	15.590	0.010	15.632
0.010	15.675	0.010	15.717	0.010	15.760	0.010	15.802	0.010	15.845	0.010	15.887	0.010	15.930	0.010	15.972
0.010	16.015	0.010	16.057	0.010	16.100	0.010	16.142	0.010	16.185	0.010	16.227	0.010	16.270	0.010	16.312
0.010	16.355	0.010	16.397	0.010	16.440	0.010	16.482	0.010	16.525	0.010	16.567	0.010	16.610	0.010	16.652
0.010	16.694	0.010	16.737	0.010	16.779	0.010	16.822	0.010	16.864	0.010	16.907	0.010	16.949	0.010	16.992
0.010	17.034	0.010	17.077	0.010	17.119	0.010	17.162	0.010	17.204	0.010	17.247	0.010	17.289	0.010	17.332

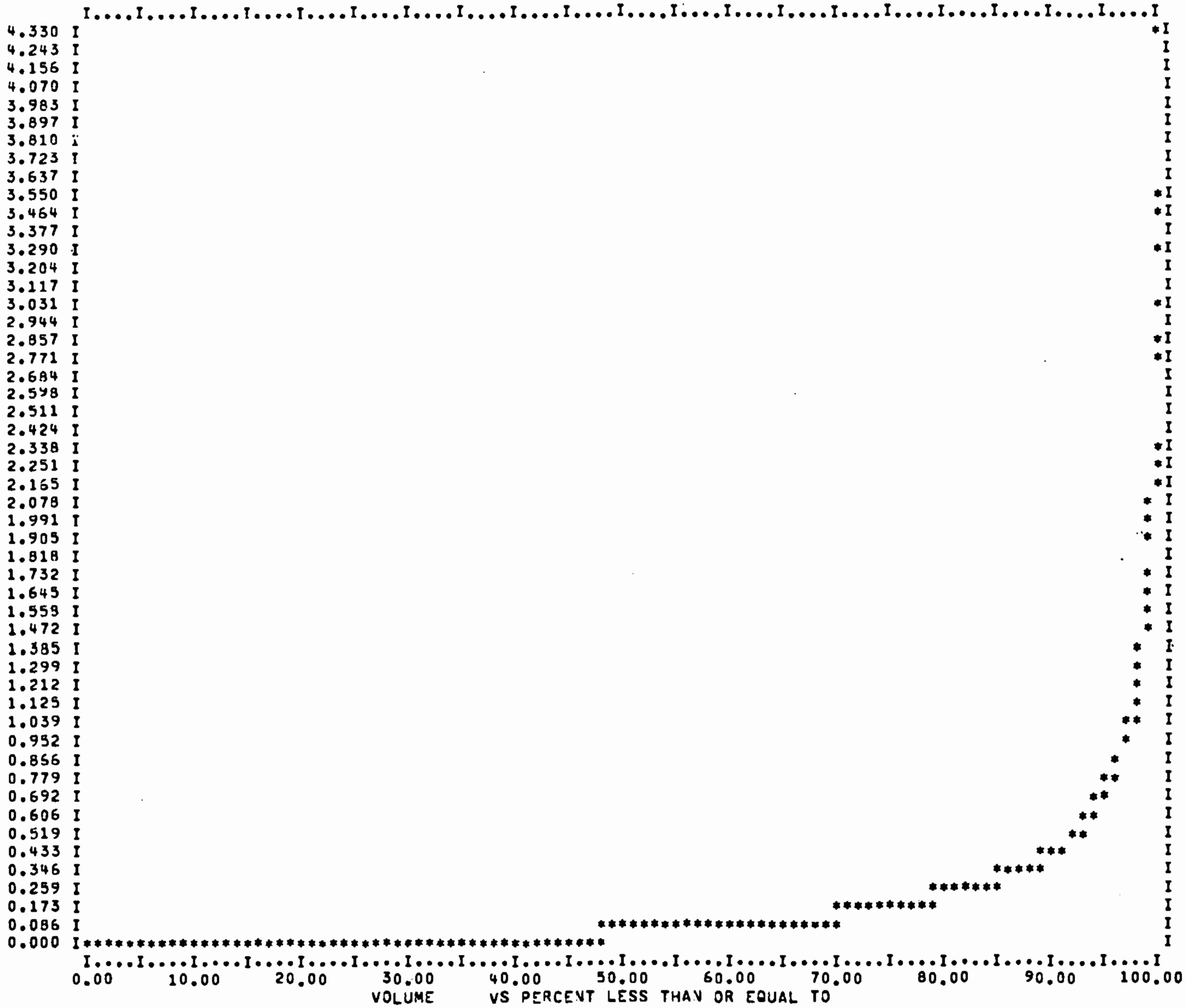
0.010	17.374	0.010	17.417	0.010	17.459	0.010	17.502	0.010	17.544	0.010	17.587	0.010	17.629	0.010	17.672
0.010	17.714	0.010	17.757	0.010	17.799	0.010	17.841	0.010	17.884	0.010	17.926	0.010	17.969	0.010	18.011
0.010	18.054	0.010	18.096	0.010	18.139	0.010	18.181	0.010	18.224	0.010	18.266	0.010	18.309	0.010	18.351
0.010	18.394	0.010	18.436	0.010	18.479	0.010	18.521	0.010	18.564	0.010	18.606	0.010	18.649	0.010	18.691
0.010	18.734	0.010	18.776	0.010	18.819	0.010	18.861	0.010	18.903	0.010	18.946	0.010	18.989	0.010	19.031
0.010	19.073	0.010	19.116	0.010	19.158	0.010	19.201	0.010	19.243	0.010	19.286	0.010	19.328	0.010	19.371
0.010	19.413	0.010	19.456	0.010	19.498	0.010	19.541	0.010	19.583	0.010	19.626	0.010	19.668	0.010	19.711
0.010	19.753	0.010	19.796	0.010	19.838	0.010	19.881	0.010	19.923	0.010	19.966	0.010	20.008	0.010	20.050
0.010	20.093	0.010	20.135	0.010	20.178	0.010	20.220	0.010	20.263	0.010	20.305	0.010	20.348	0.010	20.390
0.010	20.433	0.010	20.475	0.010	20.518	0.010	20.560	0.010	20.603	0.010	20.645	0.010	20.688	0.010	20.730
0.010	20.773	0.010	20.815	0.010	20.858	0.010	20.900	0.010	20.943	0.010	20.985	0.010	21.028	0.010	21.070
0.010	21.113	0.010	21.155	0.010	21.197	0.010	21.240	0.010	21.282	0.010	21.325	0.010	21.367	0.010	21.410
0.010	21.452	0.010	21.495	0.010	21.537	0.010	21.580	0.010	21.622	0.010	21.665	0.010	21.707	0.010	21.750
0.010	21.792	0.010	21.835	0.010	21.877	0.010	21.920	0.010	21.962	0.010	22.005	0.010	22.047	0.010	22.090
0.010	22.132	0.010	22.175	0.010	22.217	0.010	22.259	0.010	22.302	0.010	22.344	0.010	22.387	0.010	22.429
0.010	22.472	0.010	22.514	0.010	22.557	0.010	22.599	0.010	22.642	0.010	22.684	0.010	22.727	0.010	22.769
0.020	22.812	0.020	22.854	0.020	22.897	0.020	22.939	0.020	22.982	0.020	23.024	0.020	23.067	0.020	23.109
0.020	23.152	0.020	23.194	0.020	23.237	0.020	23.279	0.020	23.322	0.020	23.364	0.020	23.406	0.020	23.449
0.020	23.491	0.020	23.534	0.020	23.576	0.020	23.619	0.020	23.661	0.020	23.704	0.020	23.746	0.020	23.789
0.020	23.831	0.020	23.874	0.020	23.916	0.020	23.959	0.020	24.001	0.020	24.044	0.020	24.086	0.020	24.129
0.020	24.171	0.020	24.214	0.020	24.256	0.020	24.299	0.020	24.341	0.020	24.384	0.020	24.426	0.020	24.469
0.020	24.511	0.020	24.553	0.020	24.596	0.020	24.638	0.020	24.681	0.020	24.723	0.020	24.765	0.020	24.808
0.020	24.851	0.020	24.893	0.020	24.936	0.020	24.978	0.020	25.021	0.020	25.063	0.020	25.106	0.020	25.148
0.020	25.191	0.020	25.233	0.020	25.276	0.020	25.318	0.020	25.361	0.020	25.403	0.020	25.446	0.020	25.488
0.020	25.531	0.020	25.573	0.020	25.615	0.020	25.658	0.020	25.700	0.020	25.743	0.020	25.785	0.020	25.828
0.020	25.870	0.020	25.913	0.020	25.955	0.020	25.998	0.020	26.040	0.020	26.083	0.020	26.125	0.020	26.168
0.020	26.210	0.020	26.253	0.020	26.295	0.020	26.338	0.020	26.380	0.020	26.423	0.020	26.465	0.020	26.508
0.020	26.550	0.020	26.593	0.020	26.635	0.020	26.677	0.020	26.720	0.020	26.762	0.020	26.805	0.020	26.847
0.020	26.890	0.020	26.932	0.020	26.975	0.020	27.017	0.020	27.060	0.020	27.102	0.020	27.145	0.020	27.187
0.020	27.230	0.020	27.272	0.020	27.315	0.020	27.357	0.020	27.400	0.020	27.442	0.020	27.485	0.020	27.527
0.020	27.570	0.020	27.612	0.020	27.655	0.020	27.697	0.020	27.740	0.020	27.782	0.020	27.824	0.020	27.867
0.020	27.909	0.020	27.952	0.020	27.994	0.020	28.037	0.020	28.079	0.020	28.122	0.020	28.164	0.020	28.207
0.020	28.249	0.020	28.292	0.020	28.334	0.020	28.377	0.020	28.419	0.020	28.462	0.020	28.504	0.020	28.547
0.020	28.589	0.020	28.632	0.020	28.674	0.020	28.717	0.020	28.759	0.020	28.802	0.020	28.844	0.020	28.887
0.020	28.929	0.020	28.971	0.020	29.014	0.020	29.056	0.020	29.099	0.020	29.141	0.020	29.184	0.020	29.226
0.020	29.269	0.020	29.311	0.020	29.354	0.020	29.396	0.020	29.439	0.020	29.481	0.020	29.524	0.020	29.566
0.020	29.609	0.020	29.651	0.020	29.694	0.020	29.736	0.020	29.779	0.020	29.821	0.020	29.864	0.020	29.906
0.020	29.949	0.020	29.991	0.020	30.033	0.020	30.076	0.020	30.118	0.020	30.161	0.020	30.203	0.020	30.245
0.020	30.288	0.020	30.331	0.020	30.373	0.020	30.416	0.020	30.458	0.020	30.501	0.020	30.543	0.020	30.586
0.020	30.628	0.020	30.671	0.020	30.713	0.020	30.756	0.020	30.798	0.020	30.841	0.020	30.883	0.020	30.925
0.020	30.968	0.020	31.011	0.020	31.053	0.020	31.096	0.020	31.138	0.020	31.180	0.020	31.223	0.020	31.265
0.020	31.308	0.020	31.350	0.020	31.393	0.020	31.435	0.020	31.478	0.020	31.520	0.020	31.563	0.020	31.605
0.020	31.648	0.020	31.690	0.020	31.733	0.020	31.775	0.020	31.818	0.020	31.860	0.020	31.903	0.020	31.945
0.020	31.988	0.020	32.030	0.020	32.073	0.020	32.115	0.020	32.158	0.020	32.200	0.020	32.242	0.020	32.285
0.020	32.327	0.020	32.370	0.020	32.412	0.020	32.455	0.020	32.497	0.020	32.540	0.020	32.582	0.020	32.625
0.020	32.667	0.020	32.710	0.020	32.752	0.020	32.795	0.020	32.837	0.020	32.880	0.020	32.922	0.020	32.965
0.020	33.007	0.020	33.050	0.020	33.092	0.020	33.135	0.020	33.177	0.020	33.220	0.020	33.262	0.020	33.305
0.020	33.347	0.020	33.389	0.020	33.432	0.020	33.474	0.020	33.517	0.020	33.559	0.020	33.602	0.020	33.644
0.020	33.687	0.020	33.729	0.020	33.772	0.020	33.814	0.020	33.857	0.020	33.899	0.020	33.942	0.020	33.984
0.020	34.027	0.020	34.069	0.020	34.112	0.020	34.154	0.020	34.197	0.020	34.239	0.020	34.282	0.020	34.324
0.020	34.367	0.020	34.409	0.020	34.452	0.020	34.494	0.020	34.536	0.020	34.579	0.020	34.621	0.020	34.664
0.020	34.706	0.020	34.749	0.020	34.791	0.020	34.834	0.020	34.876	0.020	34.919	0.020	34.961	0.020	35.004
0.020	35.046	0.020	35.089	0.020	35.131	0.020	35.174	0.020	35.216	0.020	35.259	0.020	35.301	0.020	35.344
0.020	35.386	0.020	35.429	0.020	35.471	0.020	35.514	0.020	35.556	0.020	35.598	0.020	35.641	0.020	35.683
0.020	35.726	0.020	35.768	0.020	35.811	0.020	35.853	0.020	35.896	0.020	35.938	0.020	35.981	0.020	36.023
0.020	36.066	0.020	36.108	0.020	36.151	0.030	36.193	0.030	36.236	0.030	36.278	0.030	36.321	0.030	36.363
0.030	36.406	0.030	36.448	0.030	36.491	0.030	36.533	0.030	36.576	0.030	36.618	0.030	36.661	0.030	36.703

0.030	36.745	0.030	36.788	0.030	36.830	0.030	36.873	0.030	36.915	0.030	36.958	0.030	37.000	0.030	37.043
0.030	37.085	0.030	37.128	0.030	37.170	0.030	37.213	0.030	37.255	0.030	37.298	0.030	37.340	0.030	37.383
0.030	37.425	0.030	37.468	0.030	37.510	0.030	37.553	0.030	37.595	0.030	37.638	0.030	37.680	0.030	37.723
0.030	37.765	0.030	37.807	0.030	37.850	0.030	37.892	0.030	37.935	0.030	37.977	0.030	38.020	0.030	38.062
0.030	38.105	0.030	38.147	0.030	38.190	0.030	38.232	0.030	38.275	0.030	38.317	0.030	38.360	0.030	38.402
0.030	38.445	0.030	38.487	0.030	38.530	0.030	38.572	0.030	38.615	0.030	38.657	0.030	38.700	0.030	38.742
0.030	38.785	0.030	38.827	0.030	38.870	0.030	38.912	0.030	38.954	0.030	38.997	0.030	39.039	0.030	39.082
0.030	39.124	0.030	39.167	0.030	39.209	0.030	39.252	0.030	39.294	0.030	39.337	0.030	39.379	0.030	39.422
0.030	39.464	0.030	39.507	0.030	39.549	0.030	39.592	0.030	39.634	0.030	39.677	0.030	39.719	0.030	39.762
0.030	39.804	0.030	39.847	0.030	39.889	0.030	39.932	0.030	39.974	0.030	40.016	0.030	40.059	0.030	40.101
0.030	40.144	0.030	40.186	0.030	40.229	0.030	40.271	0.030	40.314	0.030	40.356	0.030	40.399	0.030	40.441
0.030	40.484	0.030	40.526	0.030	40.569	0.030	40.611	0.030	40.654	0.030	40.696	0.030	40.739	0.030	40.781
0.030	40.824	0.030	40.866	0.030	40.909	0.030	40.951	0.030	40.994	0.030	41.036	0.030	41.079	0.030	41.121
0.030	41.163	0.030	41.206	0.030	41.248	0.030	41.291	0.030	41.333	0.030	41.376	0.030	41.418	0.030	41.461
0.030	41.503	0.030	41.546	0.030	41.588	0.030	41.631	0.030	41.673	0.030	41.716	0.030	41.758	0.030	41.801
0.030	41.843	0.030	41.886	0.030	41.928	0.030	41.971	0.030	42.013	0.030	42.056	0.030	42.098	0.030	42.141
0.030	42.183	0.030	42.226	0.030	42.268	0.030	42.310	0.030	42.353	0.030	42.395	0.030	42.438	0.030	42.480
0.030	42.523	0.030	42.565	0.030	42.608	0.030	42.650	0.030	42.693	0.030	42.735	0.030	42.778	0.030	42.820
0.030	42.863	0.030	42.905	0.030	42.948	0.030	42.990	0.030	43.033	0.030	43.075	0.030	43.118	0.030	43.160
0.030	43.203	0.030	43.245	0.030	43.288	0.030	43.330	0.030	43.372	0.030	43.415	0.030	43.457	0.040	43.500
0.040	43.542	0.040	43.585	0.040	43.627	0.040	43.670	0.040	43.712	0.040	43.755	0.040	43.797	0.040	43.840
0.040	43.882	0.040	43.925	0.040	43.967	0.040	44.010	0.040	44.052	0.040	44.095	0.040	44.137	0.040	44.180
0.040	44.222	0.040	44.265	0.040	44.307	0.040	44.350	0.040	44.392	0.040	44.435	0.040	44.477	0.040	44.519
0.040	44.562	0.040	44.604	0.040	44.647	0.040	44.689	0.040	44.732	0.040	44.774	0.040	44.817	0.040	44.859
0.040	44.902	0.040	44.944	0.040	44.987	0.040	45.029	0.040	45.072	0.040	45.114	0.040	45.157	0.040	45.199
0.040	45.242	0.040	45.284	0.040	45.327	0.040	45.369	0.040	45.412	0.040	45.454	0.040	45.497	0.040	45.539
0.040	45.581	0.040	45.624	0.040	45.666	0.040	45.709	0.040	45.751	0.040	45.794	0.040	45.836	0.040	45.879
0.040	45.921	0.040	45.964	0.040	46.006	0.040	46.049	0.040	46.091	0.040	46.134	0.040	46.176	0.040	46.219
0.040	46.261	0.040	46.304	0.040	46.346	0.040	46.389	0.040	46.431	0.040	46.474	0.040	46.516	0.040	46.559
0.040	46.601	0.040	46.644	0.040	46.686	0.040	46.728	0.040	46.771	0.040	46.813	0.040	46.856	0.040	46.898
0.040	46.941	0.040	46.983	0.040	47.026	0.040	47.068	0.040	47.111	0.040	47.153	0.040	47.196	0.040	47.238
0.040	47.281	0.040	47.323	0.040	47.366	0.040	47.408	0.040	47.451	0.040	47.493	0.040	47.536	0.040	47.578
0.040	47.621	0.040	47.663	0.040	47.706	0.040	47.748	0.040	47.791	0.040	47.833	0.040	47.875	0.040	47.918
0.040	47.960	0.040	48.003	0.040	48.045	0.040	48.088	0.040	48.130	0.040	48.173	0.040	48.215	0.040	48.258
0.040	48.300	0.040	48.343	0.040	48.385	0.050	48.428	0.050	48.470	0.050	48.513	0.050	48.555	0.050	48.598
0.050	48.640	0.050	48.683	0.050	48.725	0.050	48.768	0.050	48.810	0.050	48.853	0.050	48.895	0.050	48.937
0.050	48.980	0.050	49.022	0.050	49.065	0.050	49.107	0.050	49.150	0.050	49.192	0.050	49.235	0.050	49.277
0.050	49.320	0.050	49.362	0.050	49.405	0.050	49.447	0.050	49.490	0.050	49.532	0.050	49.575	0.050	49.617
0.050	49.660	0.050	49.702	0.050	49.745	0.050	49.787	0.050	49.830	0.050	49.872	0.050	49.915	0.050	49.957
0.050	50.000	0.050	50.042	0.050	50.084	0.050	50.127	0.050	50.169	0.050	50.212	0.050	50.254	0.050	50.297
0.050	50.339	0.050	50.382	0.050	50.424	0.050	50.467	0.050	50.509	0.050	50.552	0.050	50.594	0.050	50.637
0.050	50.679	0.050	50.722	0.050	50.764	0.050	50.807	0.050	50.849	0.050	50.892	0.050	50.934	0.050	50.977
0.050	51.019	0.050	51.062	0.050	51.104	0.050	51.146	0.050	51.189	0.050	51.231	0.050	51.274	0.050	51.316
0.050	51.359	0.050	51.401	0.050	51.444	0.050	51.486	0.050	51.529	0.050	51.571	0.050	51.614	0.050	51.656
0.050	51.699	0.050	51.741	0.050	51.784	0.050	51.826	0.050	51.869	0.050	51.911	0.050	51.954	0.050	51.996
0.050	52.039	0.050	52.081	0.050	52.124	0.050	52.166	0.060	52.209	0.060	52.251	0.060	52.293	0.060	52.336
0.060	52.378	0.060	52.421	0.060	52.463	0.060	52.506	0.060	52.548	0.060	52.591	0.060	52.633	0.060	52.676
0.060	52.718	0.060	52.761	0.060	52.803	0.060	52.846	0.060	52.888	0.060	52.931	0.060	52.973	0.060	53.016
0.060	53.058	0.060	53.101	0.060	53.143	0.060	53.186	0.060	53.228	0.060	53.271	0.060	53.313	0.060	53.355
0.060	53.398	0.060	53.440	0.060	53.483	0.060	53.525	0.060	53.568	0.060	53.610	0.060	53.653	0.060	53.695
0.060	53.738	0.060	53.780	0.060	53.823	0.060	53.865	0.060	53.908	0.060	53.950	0.060	53.993	0.060	54.035
0.060	54.078	0.060	54.120	0.060	54.163	0.060	54.205	0.060	54.248	0.060	54.290	0.060	54.333	0.060	54.375
0.060	54.418	0.060	54.460	0.060	54.502	0.060	54.545	0.060	54.587	0.060	54.630	0.060	54.672	0.060	54.715
0.060	54.757	0.060	54.800	0.060	54.842	0.060	54.885	0.060	54.927	0.060	54.970	0.060	55.012	0.060	55.055
0.060	55.097	0.060	55.140	0.060	55.182	0.060	55.225	0.060	55.267	0.060	55.310	0.060	55.352	0.060	55.395
0.060	55.437	0.060	55.480	0.060	55.522	0.060	55.565	0.060	55.607	0.060	55.649	0.060	55.692	0.060	55.734
0.060	55.777	0.060	55.819	0.060	55.862	0.060	55.904	0.060	55.947	0.060	55.989	0.060	56.032	0.060	56.074

0.060	56.117	0.060	56.159	0.060	56.202	0.060	56.244	0.060	56.287	0.060	56.329	0.060	56.372	0.060	56.414
0.060	56.457	0.060	56.499	0.060	56.542	0.070	56.584	0.070	56.627	0.070	56.669	0.070	56.711	0.070	56.754
0.070	56.796	0.070	56.839	0.070	56.881	0.070	56.924	0.070	56.966	0.070	57.009	0.070	57.051	0.070	57.094
0.070	57.136	0.070	57.179	0.070	57.221	0.070	57.264	0.070	57.306	0.070	57.349	0.070	57.391	0.070	57.434
0.070	57.476	0.070	57.519	0.070	57.561	0.070	57.604	0.070	57.646	0.070	57.689	0.070	57.731	0.070	57.774
0.070	57.816	0.070	57.858	0.070	57.901	0.070	57.943	0.070	57.986	0.070	58.028	0.070	58.071	0.070	58.113
0.070	58.156	0.070	58.198	0.070	58.241	0.070	58.283	0.070	58.326	0.070	58.368	0.070	58.411	0.070	58.453
0.070	58.496	0.070	58.538	0.070	58.581	0.070	58.623	0.070	58.666	0.070	58.708	0.070	58.751	0.070	58.793
0.070	58.836	0.070	58.878	0.070	58.920	0.070	58.963	0.070	59.005	0.070	59.048	0.070	59.090	0.070	59.133
0.070	59.175	0.070	59.218	0.070	59.260	0.070	59.303	0.070	59.345	0.070	59.388	0.070	59.430	0.070	59.473
0.070	59.515	0.070	59.558	0.070	59.600	0.070	59.643	0.070	59.685	0.080	59.728	0.080	59.770	0.080	59.813
0.080	59.855	0.080	59.898	0.080	59.940	0.080	59.983	0.080	60.025	0.080	60.067	0.080	60.110	0.080	60.152
0.080	60.195	0.080	60.237	0.080	60.280	0.080	60.322	0.080	60.365	0.080	60.407	0.080	60.450	0.080	60.492
0.080	60.535	0.080	60.577	0.080	60.620	0.080	60.662	0.080	60.705	0.080	60.747	0.080	60.790	0.080	60.832
0.080	60.875	0.080	60.917	0.080	60.960	0.080	61.002	0.080	61.045	0.080	61.087	0.080	61.129	0.080	61.172
0.080	61.214	0.080	61.257	0.080	61.299	0.080	61.342	0.080	61.384	0.080	61.427	0.080	61.469	0.080	61.512
0.080	61.554	0.080	61.597	0.080	61.639	0.080	61.682	0.080	61.724	0.080	61.767	0.080	61.809	0.080	61.852
0.080	61.894	0.080	61.937	0.090	61.979	0.090	62.022	0.090	62.064	0.090	62.107	0.090	62.149	0.090	62.192
0.090	62.234	0.090	62.276	0.090	62.319	0.090	62.361	0.090	62.404	0.090	62.446	0.090	62.489	0.090	62.531
0.090	62.574	0.090	62.616	0.090	62.659	0.090	62.701	0.090	62.744	0.090	62.786	0.090	62.829	0.090	62.871
0.090	62.914	0.090	62.956	0.090	62.999	0.090	63.041	0.090	63.084	0.090	63.126	0.090	63.169	0.090	63.211
0.090	63.254	0.090	63.296	0.090	63.339	0.090	63.381	0.090	63.423	0.090	63.466	0.090	63.508	0.090	63.551
0.090	63.593	0.090	63.636	0.090	63.678	0.090	63.721	0.090	63.763	0.090	63.806	0.090	63.848	0.090	63.891
0.090	63.933	0.090	63.976	0.090	64.018	0.090	64.061	0.090	64.103	0.090	64.146	0.090	64.188	0.090	64.231
0.090	64.273	0.090	64.316	0.090	64.358	0.100	64.401	0.100	64.443	0.100	64.485	0.100	64.528	0.100	64.570
0.100	64.613	0.100	64.655	0.100	64.698	0.100	64.740	0.100	64.783	0.100	64.825	0.100	64.868	0.100	64.910
0.100	64.953	0.100	64.995	0.100	65.038	0.100	65.080	0.100	65.123	0.100	65.165	0.100	65.208	0.100	65.250
0.100	65.293	0.100	65.335	0.100	65.378	0.100	65.420	0.100	65.463	0.100	65.505	0.100	65.548	0.100	65.590
0.100	65.632	0.100	65.675	0.100	65.717	0.100	65.760	0.100	65.802	0.100	65.845	0.100	65.887	0.100	65.930
0.100	65.972	0.100	66.015	0.100	66.057	0.100	66.100	0.100	66.142	0.100	66.185	0.100	66.227	0.100	66.270
0.100	66.312	0.100	66.355	0.100	66.397	0.100	66.440	0.100	66.482	0.100	66.525	0.110	66.567	0.110	66.610
0.110	66.652	0.110	66.694	0.110	66.737	0.110	66.779	0.110	66.822	0.110	66.864	0.110	66.907	0.110	66.949
0.110	66.992	0.110	67.034	0.110	67.077	0.110	67.119	0.110	67.162	0.110	67.204	0.110	67.247	0.110	67.289
0.110	67.332	0.110	67.374	0.110	67.417	0.110	67.459	0.110	67.502	0.110	67.544	0.110	67.587	0.110	67.629
0.110	67.672	0.110	67.714	0.110	67.757	0.110	67.799	0.110	67.841	0.110	67.884	0.110	67.926	0.110	67.969
0.110	68.011	0.110	68.054	0.110	68.096	0.110	68.139	0.110	68.181	0.110	68.224	0.110	68.266	0.120	68.309
0.120	68.351	0.120	68.394	0.120	68.436	0.120	68.479	0.120	68.521	0.120	68.564	0.120	68.606	0.120	68.649
0.120	68.691	0.120	68.734	0.120	68.776	0.120	68.819	0.120	68.861	0.120	68.904	0.120	68.946	0.120	68.988
0.120	69.031	0.120	69.073	0.120	69.116	0.120	69.158	0.120	69.201	0.120	69.243	0.120	69.286	0.120	69.328
0.120	69.371	0.120	69.413	0.120	69.456	0.120	69.498	0.120	69.541	0.120	69.583	0.120	69.626	0.120	69.668
0.120	69.711	0.120	69.753	0.120	69.796	0.120	69.838	0.120	69.881	0.120	69.923	0.120	69.966	0.120	70.008
0.120	70.050	0.130	70.093	0.130	70.135	0.130	70.178	0.130	70.220	0.130	70.263	0.130	70.305	0.130	70.348
0.130	70.390	0.130	70.433	0.130	70.475	0.130	70.518	0.130	70.560	0.130	70.603	0.130	70.645	0.130	70.688
0.130	70.730	0.130	70.773	0.130	70.815	0.130	70.858	0.130	70.900	0.130	70.943	0.130	70.985	0.130	71.028
0.130	71.070	0.130	71.113	0.130	71.155	0.130	71.197	0.130	71.240	0.130	71.282	0.130	71.325	0.130	71.367
0.130	71.410	0.130	71.452	0.130	71.495	0.130	71.537	0.130	71.580	0.130	71.622	0.130	71.665	0.140	71.707
0.140	71.750	0.140	71.792	0.140	71.835	0.140	71.877	0.140	71.920	0.140	71.962	0.140	72.005	0.140	72.047
0.140	72.090	0.140	72.132	0.140	72.175	0.140	72.217	0.140	72.259	0.140	72.302	0.140	72.344	0.140	72.387
0.140	72.429	0.140	72.472	0.140	72.514	0.140	72.557	0.140	72.599	0.140	72.642	0.140	72.684	0.140	72.727
0.140	72.769	0.140	72.812	0.140	72.854	0.140	72.897	0.150	72.939	0.150	72.982	0.150	73.024	0.150	73.067
0.150	73.109	0.150	73.152	0.150	73.194	0.150	73.237	0.150	73.279	0.150	73.322	0.150	73.364	0.150	73.406
0.150	73.449	0.150	73.491	0.150	73.534	0.150	73.576	0.150	73.619	0.150	73.661	0.150	73.704	0.150	73.746
0.150	73.789	0.150	73.831	0.150	73.874	0.160	73.916	0.160	73.959	0.160	74.001	0.160	74.044	0.160	74.086
0.160	74.129	0.160	74.171	0.160	74.214	0.160	74.256	0.160	74.299	0.160	74.341	0.160	74.384	0.160	74.426
0.160	74.468	0.160	74.511	0.160	74.553	0.160	74.596	0.170	74.638	0.170	74.681	0.170	74.723	0.170	74.765
0.170	74.808	0.170	74.851	0.170	74.893	0.170	74.936	0.170	74.978	0.170	75.021	0.170	75.063	0.170	75.105
0.170	75.148	0.170	75.191	0.170	75.233	0.170	75.276	0.170	75.318	0.170	75.361	0.170	75.403	0.170	75.445

0.180	75.488	0.180	75.531	0.180	75.573	0.180	75.515	0.180	75.658	0.180	75.700	0.180	75.743	0.180	75.785
0.180	75.828	0.180	75.870	0.180	75.913	0.180	75.955	0.180	75.998	0.180	76.040	0.180	76.083	0.180	76.125
0.180	76.168	0.180	76.210	0.180	76.253	0.180	76.295	0.180	76.338	0.180	76.380	0.180	76.423	0.180	76.465
0.180	76.508	0.180	76.550	0.180	76.593	0.180	76.635	0.180	76.678	0.180	76.720	0.180	76.762	0.180	76.805
0.180	76.847	0.180	76.890	0.180	76.932	0.180	76.975	0.190	77.017	0.190	77.060	0.190	77.102	0.190	77.145
0.190	77.187	0.190	77.230	0.190	77.272	0.190	77.315	0.190	77.357	0.190	77.400	0.190	77.442	0.190	77.485
0.190	77.527	0.190	77.570	0.190	77.612	0.190	77.655	0.190	77.697	0.190	77.740	0.190	77.782	0.190	77.824
0.190	77.867	0.200	77.909	0.200	77.952	0.200	77.994	0.200	78.037	0.200	78.079	0.200	78.122	0.200	78.164
0.200	78.207	0.200	78.249	0.200	78.292	0.200	78.334	0.200	78.377	0.200	78.419	0.200	78.462	0.200	78.504
0.200	78.547	0.210	78.589	0.210	78.632	0.210	78.674	0.210	78.717	0.210	78.759	0.210	78.802	0.210	78.844
0.210	78.887	0.210	78.929	0.210	78.971	0.210	79.014	0.210	79.056	0.210	79.099	0.210	79.141	0.210	79.184
0.210	79.226	0.210	79.269	0.210	79.311	0.210	79.354	0.210	79.396	0.220	79.439	0.220	79.481	0.220	79.524
0.220	79.566	0.220	79.609	0.220	79.651	0.220	79.694	0.220	79.736	0.220	79.779	0.220	79.821	0.220	79.864
0.220	79.906	0.220	79.949	0.220	79.991	0.220	80.033	0.220	80.076	0.220	80.118	0.220	80.161	0.220	80.203
0.230	80.246	0.230	80.288	0.230	80.331	0.230	80.373	0.230	80.416	0.230	80.458	0.230	80.501	0.230	80.543
0.230	80.586	0.230	80.628	0.240	80.671	0.240	80.713	0.240	80.756	0.240	80.798	0.240	80.841	0.240	80.883
0.240	80.926	0.240	80.968	0.240	81.011	0.240	81.053	0.240	81.096	0.240	81.138	0.240	81.180	0.240	81.223
0.240	81.265	0.240	81.308	0.240	81.350	0.240	81.393	0.240	81.435	0.250	81.478	0.250	81.520	0.250	81.563
0.250	81.605	0.250	81.648	0.250	81.690	0.250	81.733	0.250	81.775	0.250	81.818	0.250	81.860	0.250	81.903
0.260	81.945	0.260	81.988	0.260	82.030	0.260	82.073	0.260	82.115	0.260	82.158	0.260	82.200	0.260	82.242
0.260	82.285	0.260	82.327	0.260	82.370	0.260	82.412	0.260	82.455	0.260	82.497	0.270	82.540	0.270	82.582
0.270	82.625	0.270	82.667	0.270	82.710	0.270	82.752	0.270	82.795	0.270	82.837	0.270	82.880	0.270	82.922
0.270	82.965	0.270	83.007	0.270	83.050	0.270	83.092	0.270	83.135	0.270	83.177	0.270	83.220	0.270	83.262
0.270	83.305	0.270	83.347	0.270	83.389	0.280	83.432	0.280	83.474	0.280	83.517	0.280	83.559	0.280	83.602
0.280	83.644	0.280	83.687	0.280	83.729	0.280	83.772	0.280	83.814	0.280	83.857	0.280	83.899	0.280	83.942
0.280	83.984	0.280	84.027	0.280	84.069	0.280	84.112	0.280	84.154	0.280	84.197	0.280	84.239	0.280	84.282
0.290	84.324	0.290	84.367	0.290	84.409	0.290	84.452	0.290	84.494	0.290	84.536	0.290	84.579	0.290	84.621
0.300	84.664	0.300	84.706	0.300	84.749	0.300	84.791	0.300	84.834	0.300	84.876	0.300	84.919	0.300	84.961
0.300	85.004	0.300	85.046	0.310	85.089	0.310	85.131	0.310	85.174	0.310	85.216	0.310	85.259	0.310	85.301
0.310	85.344	0.310	85.386	0.310	85.429	0.310	85.471	0.310	85.514	0.310	85.556	0.320	85.598	0.320	85.641
0.320	85.683	0.320	85.726	0.320	85.768	0.320	85.811	0.320	85.853	0.320	85.896	0.320	85.938	0.320	85.981
0.320	86.023	0.330	86.066	0.330	86.108	0.330	86.151	0.330	86.193	0.330	86.236	0.330	86.278	0.330	86.321
0.330	86.363	0.330	86.406	0.330	86.448	0.330	86.491	0.330	86.533	0.330	86.576	0.330	86.618	0.340	86.661
0.340	86.703	0.340	86.745	0.340	86.788	0.340	86.830	0.340	86.873	0.350	86.915	0.350	86.958	0.350	87.000
0.350	87.043	0.350	87.085	0.350	87.128	0.350	87.170	0.350	87.213	0.350	87.255	0.350	87.298	0.360	87.340
0.360	87.383	0.360	87.425	0.360	87.468	0.360	87.510	0.360	87.553	0.360	87.595	0.360	87.638	0.360	87.680
0.360	87.723	0.360	87.765	0.360	87.807	0.360	87.850	0.360	87.892	0.370	87.935	0.370	87.977	0.370	88.020
0.370	88.062	0.370	88.105	0.370	88.147	0.370	88.190	0.370	88.232	0.370	88.275	0.370	88.317	0.370	88.360
0.380	88.402	0.380	88.445	0.380	88.487	0.380	88.530	0.380	88.572	0.380	88.615	0.380	88.657	0.380	88.700
0.380	88.742	0.380	88.785	0.380	88.827	0.380	88.870	0.380	88.912	0.380	88.954	0.390	88.997	0.390	89.039
0.390	89.082	0.390	89.124	0.390	89.167	0.390	89.209	0.390	89.252	0.400	89.294	0.400	89.337	0.400	89.379
0.400	89.422	0.400	89.464	0.400	89.507	0.400	89.549	0.400	89.592	0.400	89.634	0.400	89.677	0.400	89.719
0.400	89.762	0.400	89.804	0.410	89.847	0.410	89.889	0.410	89.932	0.410	89.974	0.410	90.016	0.420	90.059
0.420	90.101	0.420	90.144	0.420	90.186	0.420	90.229	0.420	90.271	0.420	90.314	0.420	90.356	0.430	90.399
0.430	90.441	0.430	90.484	0.430	90.526	0.430	90.569	0.440	90.611	0.450	90.654	0.450	90.696	0.450	90.739
0.450	90.781	0.450	90.824	0.450	90.866	0.460	90.909	0.460	90.951	0.460	90.994	0.460	91.036	0.460	91.079
0.460	91.121	0.470	91.163	0.470	91.206	0.470	91.248	0.470	91.291	0.470	91.333	0.470	91.376	0.470	91.418
0.470	91.461	0.480	91.503	0.480	91.546	0.480	91.588	0.480	91.631	0.480	91.673	0.480	91.716	0.480	91.758
0.480	91.801	0.490	91.843	0.490	91.886	0.500	91.928	0.500	91.971	0.500	92.013	0.510	92.056	0.510	92.098
0.520	92.141	0.520	92.183	0.530	92.226	0.530	92.268	0.530	92.310	0.530	92.353	0.530	92.395	0.530	92.438
0.540	92.480	0.540	92.523	0.540	92.565	0.540	92.608	0.540	92.650	0.540	92.693	0.540	92.735	0.540	92.778
0.550	92.820	0.550	92.863	0.550	92.905	0.550	92.948	0.550	92.990	0.560	93.033	0.560	93.075	0.560	93.118
0.570	93.160	0.570	93.203	0.570	93.245	0.570	93.288	0.580	93.330	0.590	93.372	0.600	93.415	0.600	93.457
0.600	93.500	0.600	93.542	0.610	93.585	0.610	93.627	0.620	93.670	0.620	93.712	0.620	93.755	0.620	93.797
0.630	93.840	0.640	93.882	0.640	93.925	0.640	93.967	0.640	94.010	0.640	94.052	0.650	94.095	0.650	94.137
0.650	94.180	0.650	94.222	0.650	94.265	0.650	94.307	0.660	94.350	0.660	94.392	0.660	94.435	0.670	94.477
0.670	94.519	0.670	94.562	0.670	94.604	0.680	94.647	0.680	94.689	0.680	94.732	0.680	94.774	0.690	94.817

0.690	94.859	0.690	94.902	0.700	94.944	0.700	94.987	0.700	95.029	0.710	95.072	0.710	95.114	0.710	95.157
0.720	95.199	0.720	95.242	0.720	95.284	0.720	95.327	0.730	95.369	0.740	95.412	0.750	95.454	0.750	95.497
0.760	95.539	0.760	95.582	0.760	95.624	0.780	95.666	0.790	95.709	0.790	95.751	0.800	95.794	0.800	95.836
0.800	95.879	0.800	95.921	0.820	95.964	0.820	96.006	0.820	96.049	0.820	96.091	0.830	96.134	0.830	96.176
0.850	96.219	0.850	96.261	0.870	96.304	0.870	96.346	0.870	96.389	0.880	96.431	0.890	96.474	0.910	96.516
0.920	96.559	0.920	96.601	0.930	96.644	0.940	96.686	0.950	96.728	0.950	96.771	0.970	96.813	0.970	96.856
0.990	96.898	0.990	96.941	0.990	96.983	0.990	97.026	1.000	97.068	1.010	97.111	1.010	97.153	1.030	97.196
1.040	97.238	1.050	97.281	1.050	97.323	1.060	97.366	1.070	97.408	1.070	97.451	1.080	97.493	1.080	97.536
1.090	97.578	1.100	97.621	1.110	97.663	1.110	97.706	1.150	97.748	1.160	97.791	1.160	97.833	1.200	97.875
1.200	97.918	1.210	97.960	1.210	98.003	1.240	98.045	1.250	98.088	1.260	98.130	1.280	98.173	1.300	98.215
1.310	98.258	1.350	98.300	1.360	98.343	1.370	98.385	1.380	98.428	1.390	98.470	1.430	98.513	1.430	98.555
1.460	98.598	1.460	98.640	1.490	98.683	1.500	98.725	1.510	98.768	1.510	98.810	1.570	98.853	1.600	98.895
1.610	98.937	1.620	98.980	1.640	99.022	1.660	99.065	1.700	99.107	1.700	99.150	1.740	99.192	1.760	99.235
1.870	99.277	1.950	99.320	1.960	99.362	2.050	99.405	2.060	99.447	2.120	99.490	2.130	99.532	2.150	99.575
2.220	99.617	2.380	99.660	2.770	99.702	2.820	99.745	3.040	99.787	3.250	99.830	3.290	99.872	3.430	99.915
3.550	99.957	4.330	100.000												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VOLUME VS PERCENT LESS THAN OR EQUAL TO

RETURN PERIOD (IN YEARS) FOR VOLUME

VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD
4.330	26.000	3.550	13.000	3.430	8.666	3.290	6.500	3.250	5.200	3.040	4.333	2.820	3.714	2.770	3.250
2.380	2.888	2.220	2.600	2.150	2.363	2.130	2.166	2.120	2.000	2.060	1.857	2.050	1.733	1.960	1.625
1.950	1.529	1.870	1.444	1.760	1.368	1.740	1.300	1.700	1.238	1.700	1.181	1.660	1.130	1.640	1.083
1.620	1.040	1.610	1.000	1.600	0.962	1.570	0.928	1.510	0.896	1.510	0.866	1.500	0.838	1.490	0.812
1.460	0.787	1.460	0.764	1.430	0.742	1.430	0.722	1.390	0.702	1.380	0.684	1.370	0.666	1.360	0.650
1.350	0.634	1.310	0.619	1.300	0.604	1.280	0.590	1.260	0.577	1.250	0.565	1.240	0.553	1.210	0.541
1.210	0.530	1.200	0.520	1.200	0.509	1.160	0.500	1.160	0.490	1.150	0.481	1.110	0.472	1.110	0.464
1.100	0.456	1.090	0.448	1.080	0.440	1.080	0.433	1.070	0.426	1.070	0.419	1.060	0.412	1.050	0.405
1.050	0.400	1.040	0.393	1.030	0.388	1.010	0.382	1.010	0.376	1.000	0.371	0.990	0.366	0.990	0.361
0.990	0.356	0.980	0.351	0.970	0.346	0.970	0.342	0.950	0.337	0.950	0.333	0.940	0.329	0.930	0.325
0.920	0.320	0.920	0.317	0.910	0.313	0.890	0.309	0.880	0.305	0.870	0.302	0.870	0.298	0.870	0.295
0.850	0.292	0.850	0.288	0.830	0.285	0.830	0.282	0.820	0.279	0.820	0.276	0.820	0.273	0.820	0.270
0.800	0.268	0.800	0.265	0.800	0.262	0.800	0.260	0.790	0.257	0.790	0.254	0.780	0.252	0.760	0.250
0.760	0.247	0.760	0.245	0.750	0.242	0.750	0.240	0.740	0.238	0.730	0.236	0.720	0.234	0.720	0.232
0.720	0.230	0.720	0.228	0.710	0.226	0.710	0.224	0.710	0.222	0.700	0.220	0.700	0.218	0.700	0.216
0.690	0.214	0.690	0.213	0.690	0.211	0.680	0.209	0.680	0.208	0.680	0.206	0.680	0.204	0.670	0.203
0.670	0.201	0.670	0.200	0.670	0.198	0.660	0.196	0.660	0.195	0.660	0.194	0.650	0.192	0.650	0.191
0.650	0.189	0.650	0.188	0.650	0.187	0.650	0.185	0.640	0.184	0.640	0.183	0.640	0.181	0.640	0.180
0.640	0.179	0.630	0.178	0.620	0.176	0.620	0.175	0.620	0.174	0.620	0.173	0.610	0.172	0.610	0.171
0.600	0.169	0.600	0.168	0.600	0.167	0.600	0.166	0.590	0.165	0.580	0.164	0.570	0.163	0.570	0.162
0.570	0.161	0.570	0.160	0.560	0.159	0.560	0.158	0.560	0.157	0.550	0.156	0.550	0.155	0.550	0.154
0.550	0.153	0.550	0.152	0.540	0.152	0.540	0.151	0.540	0.150	0.540	0.149	0.540	0.148	0.540	0.147
0.540	0.146	0.540	0.146	0.530	0.145	0.530	0.144	0.530	0.143	0.530	0.142	0.530	0.142	0.530	0.141
0.520	0.140	0.520	0.139	0.510	0.139	0.510	0.138	0.500	0.137	0.500	0.136	0.500	0.136	0.490	0.135
0.490	0.134	0.480	0.134	0.480	0.133	0.480	0.132	0.480	0.131	0.480	0.131	0.480	0.130	0.480	0.130
0.480	0.129	0.470	0.128	0.470	0.128	0.470	0.127	0.470	0.126	0.470	0.126	0.470	0.125	0.470	0.125
0.470	0.124	0.460	0.123	0.460	0.123	0.460	0.122	0.460	0.122	0.460	0.121	0.460	0.120	0.450	0.120
0.450	0.119	0.450	0.119	0.450	0.118	0.450	0.118	0.450	0.117	0.440	0.117	0.430	0.116	0.430	0.116
0.430	0.115	0.430	0.115	0.430	0.114	0.420	0.114	0.420	0.113	0.420	0.113	0.420	0.112	0.420	0.112
0.420	0.111	0.420	0.111	0.420	0.110	0.410	0.110	0.410	0.109	0.410	0.109	0.410	0.108	0.410	0.108
0.400	0.107	0.400	0.107	0.400	0.106	0.400	0.106	0.400	0.106	0.400	0.105	0.400	0.105	0.400	0.104
0.400	0.104	0.400	0.104	0.400	0.103	0.400	0.103	0.400	0.102	0.390	0.102	0.390	0.101	0.390	0.101
0.390	0.101	0.390	0.100	0.390	0.100	0.390	0.100	0.380	0.099	0.380	0.099	0.380	0.098	0.380	0.098
0.380	0.098	0.380	0.097	0.380	0.097	0.380	0.097	0.380	0.096	0.380	0.096	0.380	0.095	0.380	0.095
0.380	0.095	0.380	0.094	0.370	0.094	0.370	0.094	0.370	0.093	0.370	0.093	0.370	0.093	0.370	0.092
0.370	0.092	0.370	0.092	0.370	0.091	0.370	0.091	0.370	0.091	0.360	0.090	0.360	0.090	0.360	0.090
0.360	0.089	0.360	0.089	0.360	0.089	0.360	0.089	0.360	0.088	0.360	0.088	0.360	0.088	0.360	0.087
0.360	0.087	0.360	0.087	0.360	0.086	0.350	0.086	0.350	0.086	0.350	0.086	0.350	0.085	0.350	0.085
0.350	0.085	0.350	0.084	0.350	0.084	0.350	0.084	0.350	0.084	0.340	0.083	0.340	0.083	0.340	0.083
0.340	0.083	0.340	0.082	0.340	0.082	0.330	0.082	0.330	0.082	0.330	0.081	0.330	0.081	0.330	0.081
0.330	0.080	0.330	0.080	0.330	0.080	0.330	0.080	0.330	0.080	0.330	0.079	0.330	0.079	0.330	0.079
0.330	0.079	0.320	0.078	0.320	0.078	0.320	0.078	0.320	0.078	0.320	0.077	0.320	0.077	0.320	0.077
0.320	0.077	0.320	0.076	0.320	0.076	0.320	0.076	0.310	0.076	0.310	0.076	0.310	0.075	0.310	0.075
0.310	0.075	0.310	0.075	0.310	0.074	0.310	0.074	0.310	0.074	0.310	0.074	0.310	0.074	0.310	0.073
0.300	0.073	0.300	0.073	0.300	0.073	0.300	0.073	0.300	0.072	0.300	0.072	0.300	0.072	0.300	0.072
0.300	0.072	0.300	0.071	0.290	0.071	0.290	0.071	0.290	0.071	0.290	0.071	0.290	0.070	0.290	0.070
0.290	0.070	0.290	0.070	0.280	0.070	0.280	0.069	0.280	0.069	0.280	0.069	0.280	0.069	0.280	0.069
0.280	0.068	0.280	0.068	0.280	0.068	0.280	0.068	0.280	0.068	0.280	0.068	0.280	0.067	0.280	0.067
0.280	0.067	0.280	0.067	0.280	0.067	0.280	0.067	0.280	0.066	0.280	0.066	0.280	0.066	0.270	0.066
0.270	0.066	0.270	0.065	0.270	0.065	0.270	0.065	0.270	0.065	0.270	0.065	0.270	0.065	0.270	0.065
0.270	0.064	0.270	0.064	0.270	0.064	0.270	0.064	0.270	0.064	0.270	0.064	0.270	0.063	0.270	0.063
0.270	0.063	0.270	0.063	0.270	0.063	0.270	0.063	0.260	0.062	0.260	0.062	0.260	0.062	0.260	0.062
0.260	0.062	0.260	0.062	0.260	0.062	0.260	0.061	0.260	0.061	0.260	0.061	0.260	0.061	0.260	0.061

0.260	0.061	0.260	0.061	0.250	0.060	0.250	0.060	0.250	0.060	0.250	0.060	0.250	0.060	0.250	0.060
0.250	0.060	0.250	0.059	0.250	0.059	0.250	0.059	0.250	0.059	0.240	0.059	0.240	0.059	0.240	0.059
0.240	0.058	0.240	0.058	0.240	0.058	0.240	0.058	0.240	0.058	0.240	0.058	0.240	0.058	0.240	0.058
0.240	0.057	0.240	0.057	0.240	0.057	0.240	0.057	0.240	0.057	0.240	0.057	0.240	0.057	0.240	0.057
0.230	0.056	0.230	0.056	0.230	0.056	0.230	0.056	0.230	0.056	0.230	0.056	0.230	0.056	0.230	0.056
0.230	0.055	0.230	0.055	0.220	0.055	0.220	0.055	0.220	0.055	0.220	0.055	0.220	0.055	0.220	0.055
0.220	0.054	0.220	0.054	0.220	0.054	0.220	0.054	0.220	0.054	0.220	0.054	0.220	0.054	0.220	0.054
0.220	0.054	0.220	0.053	0.220	0.053	0.220	0.053	0.220	0.053	0.210	0.053	0.210	0.053	0.210	0.053
0.210	0.053	0.210	0.053	0.210	0.052	0.210	0.052	0.210	0.052	0.210	0.052	0.210	0.052	0.210	0.052
0.210	0.052	0.210	0.052	0.210	0.052	0.210	0.052	0.210	0.051	0.210	0.051	0.210	0.051	0.210	0.051
0.210	0.051	0.200	0.051	0.200	0.051	0.200	0.051	0.200	0.051	0.200	0.050	0.200	0.050	0.200	0.050
0.200	0.050	0.200	0.050	0.200	0.050	0.200	0.050	0.200	0.050	0.200	0.050	0.200	0.050	0.200	0.050
0.200	0.049	0.190	0.049	0.190	0.049	0.190	0.049	0.190	0.049	0.190	0.049	0.190	0.049	0.190	0.049
0.190	0.049	0.190	0.049	0.190	0.048	0.190	0.048	0.190	0.048	0.190	0.048	0.190	0.048	0.190	0.048
0.190	0.048	0.190	0.048	0.190	0.048	0.190	0.048	0.190	0.048	0.190	0.047	0.180	0.047	0.180	0.047
0.180	0.047	0.180	0.047	0.180	0.047	0.180	0.047	0.180	0.047	0.180	0.047	0.180	0.047	0.180	0.047
0.180	0.047	0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.046
0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.046	0.180	0.045	0.180	0.045	0.180	0.045
0.180	0.045	0.180	0.045	0.180	0.045	0.180	0.045	0.180	0.045	0.180	0.045	0.180	0.045	0.180	0.045
0.180	0.045	0.180	0.044	0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.044
0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.044	0.170	0.043	0.170	0.043
0.170	0.043	0.170	0.043	0.170	0.043	0.170	0.043	0.170	0.043	0.170	0.043	0.160	0.043	0.160	0.043
0.160	0.043	0.160	0.043	0.160	0.043	0.160	0.043	0.160	0.042	0.160	0.042	0.160	0.042	0.160	0.042
0.160	0.042	0.160	0.042	0.160	0.042	0.150	0.042	0.160	0.042	0.160	0.042	0.150	0.042	0.150	0.042
0.150	0.042	0.150	0.042	0.150	0.042	0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041
0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041	0.150	0.041
0.150	0.041	0.150	0.041	0.150	0.040	0.150	0.040	0.150	0.040	0.150	0.040	0.140	0.040	0.140	0.040
0.140	0.040	0.140	0.040	0.140	0.040	0.140	0.040	0.140	0.040	0.140	0.040	0.140	0.040	0.140	0.040
0.140	0.040	0.140	0.040	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039
0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039	0.140	0.039
0.140	0.039	0.140	0.039	0.140	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038
0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038
0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.038	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037
0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037
0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.037	0.130	0.036	0.130	0.036
0.130	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036
0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.036	0.120	0.035
0.120	0.036	0.120	0.036	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035
0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035
0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.035	0.120	0.034	0.120	0.034
0.120	0.034	0.120	0.034	0.120	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034
0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034
0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.034	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033
0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033
0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.033
0.110	0.033	0.110	0.033	0.110	0.033	0.110	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032
0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032
0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032
0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.032	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031
0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031
0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031
0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.031	0.100	0.030	0.090	0.030
0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030
0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030
0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030	0.090	0.030
0.090	0.030	0.090	0.030	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029
0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029

0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029
0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029	0.090	0.029
0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028
0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028
0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028
0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028	0.080	0.028
0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027
0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027
0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.080	0.027	0.070	0.027	0.070	0.027	0.070	0.027
0.070	0.027	0.070	0.027	0.070	0.027	0.070	0.027	0.070	0.027	0.070	0.027	0.070	0.027	0.070	0.027
0.070	0.027	0.070	0.027	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026
0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026
0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026
0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026
0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026	0.070	0.026
0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025
0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025
0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.070	0.025	0.060	0.025
0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025
0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025	0.060	0.025
0.060	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.060	0.024	0.060	0.024	0.060	0.024	0.060	0.024
0.060	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.050	0.024
0.060	0.024	0.060	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.050	0.024
0.060	0.024	0.050	0.024	0.050	0.024	0.050	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.060	0.024
0.060	0.024	0.060	0.024	0.050	0.024	0.050	0.024	0.060	0.024	0.050	0.024	0.060	0.024	0.060	0.024
0.060	0.024	0.060	0.024	0.050	0.024	0.050	0.023	0.060	0.023	0.060	0.023	0.060	0.023	0.060	0.023
0.060	0.023	0.060	0.023	0.050	0.023	0.060	0.023	0.060	0.023	0.060	0.023	0.060	0.023	0.060	0.023
0.060	0.023	0.060	0.023	0.060	0.023	0.050	0.023	0.060	0.023	0.060	0.023	0.060	0.023	0.060	0.023
0.060	0.023	0.060	0.023	0.050	0.023	0.060	0.023	0.060	0.023	0.050	0.023	0.060	0.023	0.060	0.023
0.060	0.023	0.060	0.023	0.060	0.023	0.050	0.023	0.060	0.023	0.050	0.023	0.050	0.023	0.060	0.023
0.060	0.023	0.050	0.023	0.050	0.023	0.050	0.023	0.060	0.023	0.050	0.023	0.050	0.023	0.050	0.023
0.050	0.023	0.050	0.023	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022
0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022
0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022
0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022
0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022
0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022
0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.022	0.050	0.021	0.050	0.021	0.050	0.021
0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021
0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021
0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021
0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.050	0.021	0.040	0.021
0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021
0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021
0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.021	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020
0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.020	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019
0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019
0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019
0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019	0.040	0.019
0.040	0.019	0.040	0.019	0.040	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019

0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019
0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019
0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019
0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019	0.030	0.019
0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018
0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018	0.030	0.018
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0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017
0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017
0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017	0.030	0.017
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0.020	0.017	0.020	0.017	0.020	0.017	0.020	0.017	0.020	0.017	0.020	0.017	0.020	0.017	0.020	0.017
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0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016	0.020	0.016
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0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014
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0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014	0.020	0.014
0.020	0.014	0.020	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
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0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014	0.010	0.014
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0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
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0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013	0.010	0.013
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0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012	0.010	0.012
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0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
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0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
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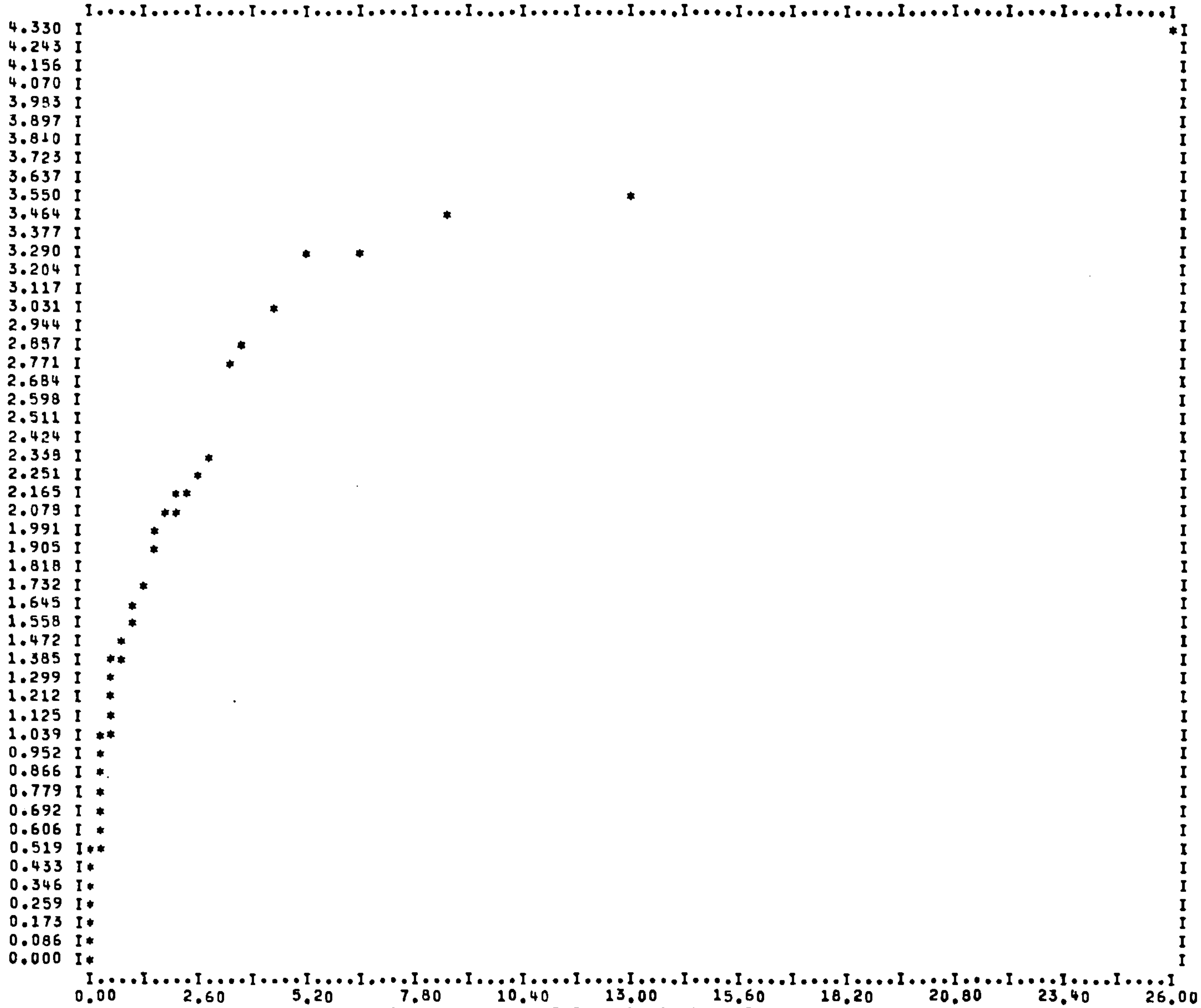
0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011	0.010	0.011
0.010	0.011	0.010	0.011												



VOLUME VS RETURN PERIOD IN YEARS

PROBABILITY ANALYSIS-DELTA

PERCENTAGE OF OCCURRENCE LESS THAN OR EQUAL TO THE GIVEN VALUE OF DELTA

VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT	VALUE	PCT
0.000	0.042	4.000	0.084	4.000	0.127	4.000	0.169	4.000	0.212	4.000	0.254	4.000	0.297	4.000	0.339
4.000	0.382	4.000	0.424	4.000	0.467	4.000	0.509	4.000	0.552	4.000	0.594	4.000	0.637	4.000	0.679
4.000	0.722	4.000	0.764	4.000	0.807	4.500	0.849	4.500	0.892	4.500	0.934	4.500	0.977	4.500	1.019
4.500	1.062	4.500	1.104	4.500	1.146	4.500	1.189	4.500	1.231	4.500	1.274	4.500	1.316	5.000	1.359
5.000	1.401	5.000	1.444	5.000	1.486	5.000	1.529	5.000	1.571	5.000	1.614	5.000	1.656	5.000	1.699
5.000	1.741	5.000	1.784	5.000	1.826	5.000	1.869	5.000	1.911	5.000	1.954	5.000	1.996	5.000	2.039
5.000	2.081	5.000	2.124	5.000	2.166	5.000	2.209	5.500	2.251	5.500	2.293	5.500	2.336	5.500	2.378
5.500	2.421	5.500	2.463	5.500	2.506	5.500	2.548	5.500	2.591	5.500	2.633	5.500	2.676	5.500	2.719
5.500	2.761	5.500	2.803	5.500	2.846	5.500	2.888	5.500	2.931	5.500	2.973	5.500	3.016	5.500	3.059
5.500	3.101	5.500	3.143	5.500	3.186	5.500	3.228	5.500	3.271	5.500	3.313	5.500	3.355	5.500	3.398
5.500	3.440	5.500	3.483	5.500	3.525	6.000	3.568	6.000	3.610	6.000	3.653	6.000	3.695	6.000	3.738
6.000	3.780	6.000	3.823	6.000	3.865	6.000	3.908	6.000	3.950	6.000	3.993	6.000	4.035	6.000	4.078
6.000	4.120	6.000	4.163	6.000	4.205	6.000	4.248	6.000	4.290	6.000	4.333	6.000	4.375	6.000	4.418
6.000	4.460	6.000	4.502	6.000	4.545	6.000	4.587	6.000	4.630	6.000	4.672	6.000	4.715	6.000	4.757
6.000	4.800	6.000	4.842	6.000	4.885	6.000	4.927	6.000	4.970	6.000	5.012	6.000	5.055	6.000	5.097
6.000	5.140	6.000	5.182	6.000	5.225	6.000	5.267	6.000	5.310	6.500	5.352	6.500	5.395	6.500	5.437
6.500	5.480	6.500	5.522	6.500	5.564	6.500	5.607	6.500	5.649	6.500	5.692	6.500	5.734	6.500	5.777
6.500	5.819	6.500	5.862	6.500	5.904	6.500	5.947	6.500	5.989	6.500	6.032	6.500	6.074	6.500	6.117
6.500	6.159	6.500	6.202	6.500	6.244	6.500	6.287	6.500	6.329	6.500	6.372	6.500	6.414	7.000	6.457
7.000	6.499	7.000	6.542	7.000	6.584	7.000	6.627	7.000	6.669	7.000	6.711	7.000	6.754	7.000	6.796
7.000	6.839	7.000	6.881	7.000	6.924	7.000	6.966	7.000	7.009	7.000	7.051	7.000	7.094	7.000	7.136
7.000	7.179	7.000	7.221	7.000	7.264	7.000	7.306	7.000	7.349	7.000	7.391	7.000	7.434	7.000	7.476
7.000	7.519	7.000	7.561	7.500	7.604	7.500	7.646	7.500	7.689	7.500	7.731	7.500	7.774	7.500	7.816
7.500	7.858	7.500	7.901	7.500	7.943	7.500	7.986	7.500	8.028	7.500	8.071	7.500	8.113	7.500	8.156
7.500	8.198	7.500	8.241	7.500	8.283	7.500	8.326	7.500	8.368	7.500	8.411	7.500	8.453	7.500	8.495
7.500	8.538	7.500	8.581	7.500	8.623	7.500	8.666	7.500	8.708	7.500	8.751	7.500	8.793	7.500	8.836
8.000	8.878	8.000	8.920	8.000	8.963	8.000	9.005	8.000	9.048	8.000	9.090	8.000	9.133	8.000	9.175
8.000	9.218	8.000	9.260	8.000	9.303	8.000	9.345	8.000	9.388	8.000	9.430	8.000	9.473	8.000	9.515
8.000	9.558	8.000	9.600	8.000	9.643	8.000	9.685	8.000	9.728	8.000	9.770	8.000	9.813	8.000	9.855
8.000	9.898	8.000	9.940	8.000	9.983	8.000	10.025	8.000	10.067	8.000	10.110	8.500	10.152	8.500	10.195
8.500	10.237	8.500	10.280	8.500	10.322	8.500	10.365	8.500	10.407	8.500	10.450	8.500	10.492	8.500	10.535
8.500	10.577	8.500	10.620	8.500	10.662	8.500	10.705	8.500	10.747	8.500	10.790	8.500	10.832	8.500	10.875
8.500	10.917	8.500	10.960	8.500	11.002	8.500	11.045	8.500	11.087	8.500	11.129	8.500	11.172	8.500	11.214
8.500	11.257	8.500	11.299	8.500	11.342	8.500	11.384	8.500	11.427	9.000	11.469	9.000	11.512	9.000	11.554
9.000	11.597	9.000	11.639	9.000	11.682	9.000	11.724	9.000	11.767	9.000	11.809	9.000	11.852	9.000	11.894
9.000	11.937	9.000	11.979	9.000	12.022	9.000	12.064	9.000	12.107	9.000	12.149	9.000	12.192	9.000	12.234
9.000	12.276	9.000	12.319	9.000	12.361	9.000	12.404	9.000	12.446	9.000	12.489	9.000	12.531	9.000	12.574
9.000	12.616	9.000	12.659	9.000	12.701	9.000	12.744	9.500	12.786	9.500	12.829	9.500	12.871	9.500	12.914
9.500	12.956	9.500	12.999	9.500	13.041	9.500	13.084	9.500	13.126	9.500	13.169	9.500	13.211	9.500	13.254
9.500	13.296	9.500	13.338	9.500	13.381	9.500	13.423	9.500	13.466	9.500	13.508	9.500	13.551	9.500	13.593
9.500	13.636	9.500	13.678	9.500	13.721	9.500	13.763	9.500	13.806	9.500	13.848	9.500	13.891	10.000	13.933
10.000	13.976	10.000	14.018	10.000	14.061	10.000	14.103	10.000	14.146	10.000	14.188	10.000	14.231	10.000	14.273
10.000	14.316	10.000	14.358	10.000	14.401	10.000	14.443	10.000	14.485	10.000	14.528	10.000	14.570	10.000	14.613
10.000	14.655	10.000	14.698	10.000	14.740	10.000	14.783	10.000	14.825	10.000	14.868	10.000	14.910	10.000	14.953
10.000	14.995	10.000	15.038	10.000	15.080	10.000	15.123	10.000	15.165	10.000	15.208	10.000	15.250	10.000	15.293
10.500	15.335	10.500	15.378	10.500	15.420	10.500	15.463	10.500	15.505	10.500	15.548	10.500	15.590	10.500	15.632
10.500	15.675	10.500	15.717	10.500	15.760	10.500	15.802	10.500	15.845	10.500	15.887	10.500	15.930	10.500	15.972
10.500	16.015	10.500	16.057	10.500	16.100	10.500	16.142	10.500	16.185	10.500	16.227	10.500	16.270	10.500	16.312
10.500	16.355	10.500	16.397	11.000	16.440	11.000	16.482	11.000	16.525	11.000	16.567	11.000	16.610	11.000	16.652
11.000	16.694	11.000	16.737	11.000	16.779	11.000	16.822	11.000	16.864	11.000	16.907	11.000	16.949	11.000	16.992
11.000	17.034	11.000	17.077	11.000	17.119	11.000	17.162	11.000	17.204	11.000	17.247	11.500	17.289	11.500	17.332

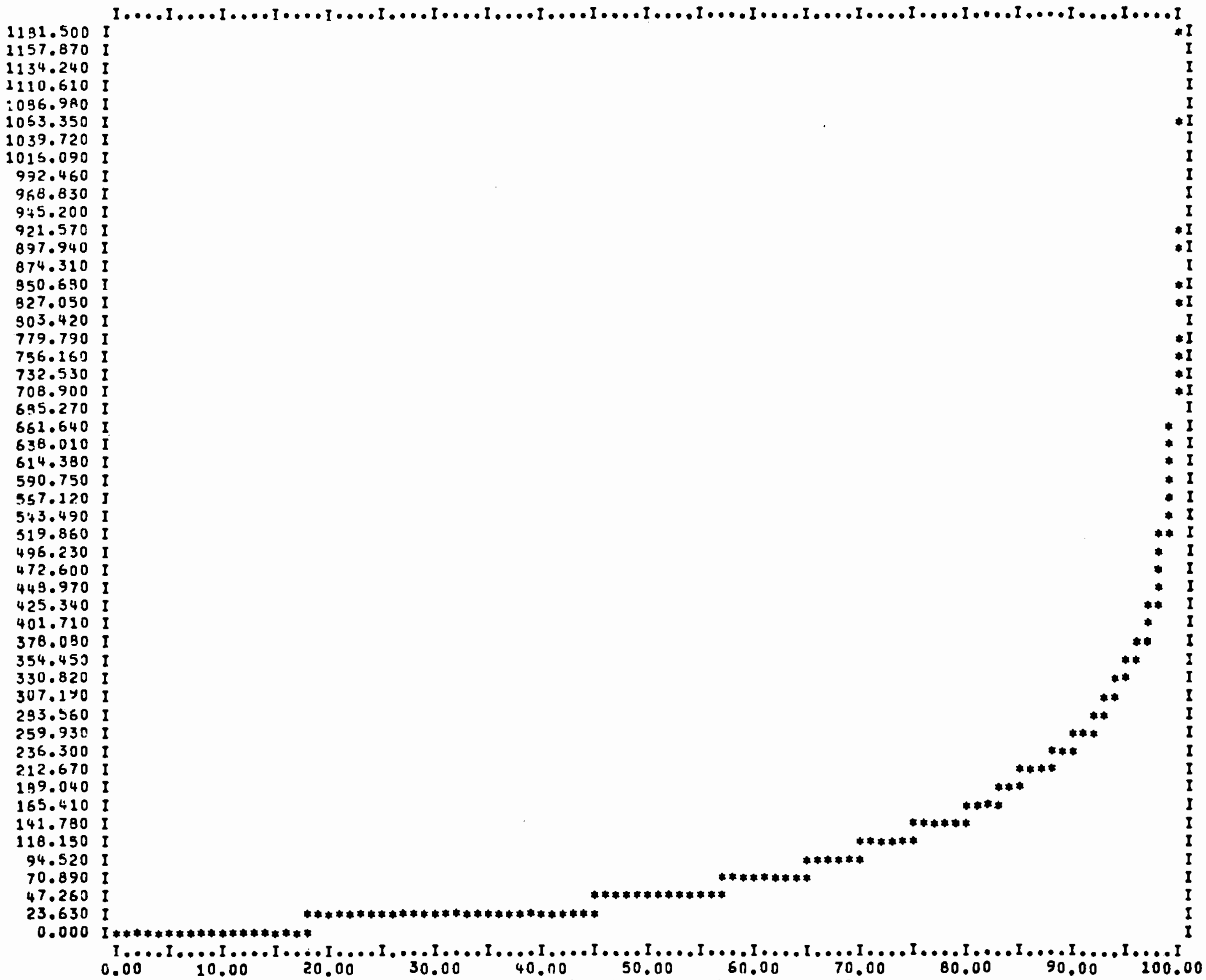
11.500	17.374	11.500	17.417	11.500	17.459	11.500	17.502	11.500	17.544	11.500	17.587	11.500	17.629	11.500	17.672
11.500	17.714	11.500	17.757	11.500	17.799	11.500	17.841	11.500	17.884	11.500	17.926	11.500	17.969	11.500	18.011
11.500	18.054	11.500	18.096	11.500	18.139	11.500	18.181	11.500	18.224	11.500	18.266	12.000	18.309	12.000	18.351
12.000	18.394	12.000	18.436	12.000	18.479	12.000	18.521	12.000	18.564	12.000	18.606	12.000	18.649	12.000	18.691
12.000	18.734	12.000	18.776	12.000	18.819	12.000	18.861	12.000	18.903	12.000	18.946	12.000	18.988	12.000	19.031
12.000	19.073	12.500	19.116	12.500	19.158	12.500	19.201	12.500	19.243	12.500	19.286	12.500	19.328	12.500	19.371
12.500	19.413	12.500	19.456	12.500	19.498	12.500	19.541	12.500	19.583	12.500	19.626	12.500	19.668	13.000	19.711
13.000	19.753	13.000	19.796	13.000	19.838	13.000	19.881	13.000	19.923	13.000	19.966	13.000	20.008	13.000	20.050
13.000	20.093	13.000	20.135	13.000	20.178	13.000	20.220	13.000	20.263	13.000	20.305	13.000	20.348	13.000	20.390
13.000	20.433	13.000	20.475	13.000	20.518	13.000	20.560	13.000	20.603	13.000	20.645	13.000	20.688	13.000	20.730
13.500	20.773	13.500	20.815	13.500	20.858	13.500	20.900	13.500	20.943	13.500	20.985	13.500	21.028	13.500	21.070
13.500	21.113	13.500	21.155	13.500	21.197	13.500	21.240	13.500	21.282	13.500	21.325	13.500	21.367	13.500	21.410
13.500	21.452	13.500	21.495	13.500	21.537	14.000	21.580	14.000	21.622	14.000	21.665	14.000	21.707	14.000	21.750
14.000	21.792	14.000	21.835	14.000	21.877	14.000	21.920	14.000	21.962	14.000	22.005	14.000	22.047	14.000	22.090
14.000	22.132	14.000	22.175	14.000	22.217	14.000	22.259	14.000	22.302	14.000	22.344	14.000	22.387	14.000	22.429
14.000	22.472	14.000	22.514	14.000	22.557	14.000	22.599	14.000	22.642	14.000	22.684	14.000	22.727	14.000	22.769
14.500	22.812	14.500	22.854	14.500	22.897	14.500	22.939	14.500	22.982	14.500	23.024	14.500	23.067	14.500	23.109
14.500	23.152	14.500	23.194	14.500	23.237	14.500	23.279	14.500	23.322	14.500	23.364	14.500	23.406	14.500	23.449
14.500	23.491	14.500	23.534	15.000	23.576	15.000	23.619	15.000	23.661	15.000	23.704	15.000	23.746	15.000	23.789
15.000	23.831	15.000	23.874	15.000	23.916	15.000	23.959	15.000	24.001	15.000	24.044	15.000	24.086	15.000	24.129
15.000	24.171	15.000	24.214	15.000	24.256	15.000	24.299	15.500	24.341	15.500	24.384	15.500	24.426	15.500	24.469
15.500	24.511	15.500	24.553	15.500	24.596	15.500	24.638	15.500	24.681	15.500	24.723	15.500	24.766	15.500	24.808
15.500	24.851	15.500	24.893	15.500	24.936	15.500	24.978	15.500	25.021	15.500	25.063	16.000	25.106	16.000	25.149
16.000	25.191	16.000	25.233	16.000	25.276	16.000	25.318	16.000	25.361	16.000	25.403	16.000	25.446	16.000	25.488
16.000	25.531	16.000	25.573	16.500	25.615	16.500	25.658	16.500	25.700	16.500	25.743	16.500	25.785	16.500	25.828
16.500	25.870	16.500	25.913	16.500	25.955	16.500	25.998	16.500	26.040	16.500	26.083	17.000	26.125	17.000	26.168
17.000	26.210	17.000	26.253	17.000	26.295	17.000	26.338	17.000	26.380	17.000	26.423	17.000	26.465	17.000	26.508
17.000	26.550	17.000	26.593	17.000	26.635	17.000	26.677	17.000	26.720	17.000	26.762	17.000	26.805	17.000	26.847
17.000	26.890	17.000	26.932	17.000	26.975	17.000	27.017	17.000	27.060	17.000	27.102	17.500	27.145	17.500	27.187
17.500	27.230	17.500	27.272	17.500	27.315	17.500	27.357	17.500	27.400	17.500	27.442	17.500	27.485	17.500	27.527
17.500	27.570	17.500	27.612	17.500	27.655	17.500	27.697	17.500	27.740	17.500	27.782	17.500	27.824	18.000	27.867
18.000	27.909	18.000	27.952	18.000	27.994	18.000	28.037	18.000	28.079	18.000	28.122	18.000	28.164	18.000	28.207
18.000	28.249	18.000	28.292	18.000	28.334	18.000	28.377	18.000	28.419	18.000	28.462	18.000	28.504	18.000	28.547
18.500	28.589	18.500	28.632	18.500	28.674	18.500	28.717	18.500	28.759	18.500	28.802	18.500	28.844	18.500	28.887
18.500	28.929	18.500	28.971	18.500	29.014	18.500	29.056	18.500	29.099	18.500	29.141	18.500	29.184	18.500	29.226
18.500	29.269	18.500	29.311	18.500	29.354	19.000	29.396	19.000	29.439	19.000	29.481	19.000	29.524	19.000	29.566
19.000	29.609	19.000	29.651	19.000	29.694	19.000	29.736	19.000	29.779	19.000	29.821	19.000	29.864	19.000	29.906
19.000	29.949	19.000	29.991	19.000	30.033	19.000	30.076	19.500	30.118	19.500	30.161	19.500	30.203	19.500	30.246
19.500	30.288	19.500	30.331	19.500	30.373	19.500	30.416	19.500	30.458	19.500	30.501	19.500	30.543	19.500	30.586
19.500	30.628	19.500	30.671	19.500	30.713	20.000	30.756	20.000	30.798	20.000	30.841	20.000	30.883	20.000	30.925
20.000	30.968	20.000	31.011	20.000	31.053	20.000	31.096	20.000	31.138	20.000	31.180	20.000	31.223	20.000	31.265
20.000	31.308	20.000	31.350	20.000	31.393	20.000	31.435	20.000	31.478	20.000	31.520	20.000	31.563	20.000	31.605
20.000	31.648	20.000	31.690	20.000	31.733	20.500	31.775	20.500	31.818	20.500	31.860	20.500	31.903	20.500	31.945
20.500	31.988	20.500	32.030	20.500	32.073	20.500	32.115	20.500	32.158	20.500	32.200	20.500	32.242	20.500	32.285
20.500	32.327	20.500	32.370	20.500	32.412	21.000	32.455	21.000	32.497	21.000	32.540	21.000	32.582	21.000	32.625
21.000	32.667	21.000	32.710	21.000	32.752	21.000	32.795	21.000	32.837	21.000	32.880	21.000	32.922	21.000	32.965
21.000	33.007	21.000	33.050	21.000	33.092	21.000	33.135	21.500	33.177	21.500	33.220	21.500	33.262	21.500	33.305
21.500	33.347	21.500	33.389	21.500	33.432	21.500	33.474	21.500	33.517	21.500	33.559	21.500	33.602	21.500	33.644
21.500	33.687	21.500	33.729	21.500	33.772	21.500	33.814	21.500	33.857	22.000	33.899	22.000	33.942	22.000	33.984
22.000	34.027	22.000	34.069	22.000	34.112	22.000	34.154	22.000	34.197	22.000	34.239	22.000	34.282	22.000	34.324
22.000	34.367	22.000	34.409	22.000	34.452	22.000	34.494	22.000	34.536	22.000	34.579	22.000	34.621	22.000	34.664
22.500	34.706	22.500	34.749	22.500	34.791	22.500	34.834	22.500	34.876	22.500	34.919	22.500	34.961	22.500	35.004
22.500	35.046	22.500	35.089	22.500	35.131	22.500	35.174	22.500	35.216	22.500	35.259	22.500	35.301	22.500	35.344
23.000	35.386	23.000	35.429	23.000	35.471	23.000	35.514	23.000	35.556	23.000	35.598	23.000	35.641	23.000	35.683
23.000	35.726	23.000	35.768	23.000	35.811	23.000	35.853	23.000	35.896	23.000	35.938	23.000	35.981	23.000	36.023
23.500	36.066	23.500	36.108	23.500	36.151	23.500	36.193	23.500	36.236	23.500	36.278	23.500	36.321	23.500	36.363
23.500	36.406	23.500	36.448	23.500	36.491	23.500	36.533	23.500	36.576	23.500	36.618	23.500	36.661	23.500	36.703

23.500	36.745	23.500	36.788	23.500	36.830	23.500	36.873	23.500	36.915	24.000	36.958	24.000	37.000	24.000	37.043
24.000	37.085	24.000	37.128	24.000	37.170	24.000	37.213	24.000	37.255	24.000	37.298	24.000	37.340	24.000	37.383
24.000	37.425	24.000	37.468	24.000	37.510	24.000	37.553	24.000	37.595	24.000	37.638	24.500	37.680	24.500	37.723
24.500	37.765	24.500	37.807	24.500	37.850	24.500	37.892	24.500	37.935	24.500	37.977	24.500	38.020	24.500	38.062
24.500	38.105	24.500	38.147	25.000	38.190	25.000	38.232	25.000	38.275	25.000	38.317	25.000	38.360	25.000	38.402
25.000	38.445	25.000	38.487	25.000	38.530	25.000	38.572	25.000	38.615	25.000	38.657	25.000	38.700	25.000	38.742
25.000	38.785	25.500	38.827	25.500	38.870	25.500	38.912	25.500	38.954	25.500	38.997	25.500	39.039	25.500	39.082
25.500	39.124	25.500	39.167	26.000	39.209	26.000	39.252	26.000	39.294	26.000	39.337	26.000	39.379	26.000	39.422
26.000	39.464	26.000	39.507	26.000	39.549	26.000	39.592	26.000	39.634	26.000	39.677	26.000	39.719	26.000	39.762
26.000	39.804	26.000	39.847	26.000	39.889	26.000	39.932	26.000	39.974	26.000	40.016	26.500	40.059	26.500	40.101
26.500	40.144	26.500	40.186	26.500	40.229	26.500	40.271	26.500	40.314	26.500	40.356	26.500	40.399	26.500	40.441
26.500	40.484	26.500	40.526	27.000	40.569	27.000	40.611	27.000	40.654	27.000	40.696	27.000	40.739	27.000	40.781
27.000	40.824	27.000	40.866	27.000	40.909	27.000	40.951	27.000	40.994	27.500	41.036	27.500	41.079	27.500	41.121
27.500	41.163	27.500	41.206	27.500	41.248	27.500	41.291	27.500	41.333	27.500	41.376	27.500	41.418	27.500	41.461
27.500	41.503	27.500	41.546	27.500	41.588	28.000	41.631	28.000	41.673	28.000	41.716	28.000	41.759	28.000	41.801
28.000	41.843	28.000	41.886	28.000	41.928	28.000	41.971	28.000	42.013	28.500	42.056	28.500	42.098	28.500	42.141
28.500	42.183	28.500	42.226	28.500	42.268	28.500	42.310	28.500	42.353	28.500	42.395	28.500	42.438	28.500	42.480
28.500	42.523	28.500	42.565	29.000	42.608	29.000	42.650	29.000	42.693	29.000	42.735	29.000	42.778	29.000	42.820
29.000	42.863	29.000	42.905	29.000	42.948	29.000	42.990	29.500	43.033	29.500	43.075	29.500	43.118	29.500	43.160
29.500	43.203	30.000	43.245	30.000	43.288	30.000	43.330	30.000	43.372	30.500	43.415	30.500	43.457	30.500	43.500
30.500	43.542	30.500	43.585	30.500	43.627	31.000	43.670	31.000	43.712	31.500	43.755	31.500	43.797	31.500	43.840
31.500	43.882	31.500	43.925	31.500	43.967	31.500	44.010	31.500	44.052	31.500	44.095	32.000	44.137	32.000	44.180
32.000	44.222	32.000	44.265	32.000	44.307	32.000	44.350	32.000	44.392	32.000	44.435	32.000	44.477	32.500	44.519
32.500	44.562	33.000	44.604	33.000	44.647	33.500	44.689	33.500	44.732	33.500	44.774	33.500	44.817	34.000	44.859
34.000	44.902	34.000	44.944	34.000	44.987	34.000	45.029	34.000	45.072	34.500	45.114	34.500	45.157	34.500	45.199
35.000	45.242	35.000	45.284	35.000	45.327	35.000	45.369	35.500	45.412	35.500	45.454	35.500	45.497	35.500	45.539
36.000	45.581	36.000	45.624	36.000	45.666	36.000	45.709	36.000	45.751	36.000	45.794	36.000	45.836	36.000	45.879
36.000	45.921	36.500	45.964	36.500	46.006	36.500	46.049	36.500	46.091	36.500	46.134	37.000	46.176	37.000	46.219
37.000	46.261	37.000	46.304	37.000	46.346	37.500	46.389	37.500	46.431	37.500	46.474	38.000	46.516	38.000	46.559
38.000	46.601	38.000	46.644	38.000	46.686	38.000	46.728	38.000	46.771	38.500	46.813	38.500	46.856	38.500	46.898
38.500	46.941	38.500	46.983	38.500	47.026	38.500	47.068	38.500	47.111	39.000	47.153	39.000	47.196	39.000	47.238
39.000	47.281	39.000	47.323	39.000	47.366	39.500	47.408	39.500	47.451	39.500	47.493	39.500	47.536	40.000	47.578
40.000	47.621	40.000	47.663	40.000	47.706	40.000	47.748	40.500	47.791	40.500	47.833	40.500	47.875	40.500	47.918
40.500	47.960	40.500	48.003	40.500	48.045	41.000	48.088	41.500	48.130	41.500	48.173	41.500	48.215	42.000	48.258
42.000	48.300	42.000	48.343	42.000	48.385	42.000	48.428	42.000	48.470	42.500	48.513	42.500	48.555	42.500	48.598
42.500	48.640	43.000	48.683	43.000	48.725	43.000	48.768	43.000	48.810	43.000	48.853	43.000	48.895	43.000	48.937
43.000	48.980	43.500	49.022	43.500	49.065	43.500	49.107	43.500	49.150	43.500	49.192	44.000	49.235	44.000	49.277
44.000	49.320	44.000	49.362	44.000	49.405	44.000	49.447	44.000	49.490	44.000	49.532	44.000	49.575	44.500	49.617
44.500	49.660	44.500	49.702	44.500	49.745	44.500	49.787	44.500	49.830	44.500	49.872	44.500	49.915	44.500	49.957
44.500	50.000	44.500	50.042	44.500	50.084	45.000	50.127	45.000	50.169	45.000	50.212	45.000	50.254	45.500	50.297
45.500	50.339	45.500	50.382	45.500	50.424	45.500	50.467	45.500	50.509	45.500	50.552	45.500	50.594	46.000	50.637
46.000	50.679	46.000	50.722	46.000	50.764	46.000	50.807	46.000	50.849	46.000	50.892	46.000	50.934	46.000	50.977
46.000	51.019	46.000	51.062	46.000	51.104	46.500	51.146	46.500	51.189	46.500	51.231	46.500	51.274	46.500	51.316
46.500	51.359	46.500	51.401	46.500	51.444	46.500	51.486	47.000	51.529	47.000	51.571	47.000	51.614	47.000	51.656
47.000	51.699	47.000	51.741	47.000	51.784	47.000	51.826	47.000	51.869	47.000	51.911	47.000	51.954	47.500	51.996
47.500	52.039	47.500	52.081	47.500	52.124	47.500	52.166	47.500	52.209	47.500	52.251	47.500	52.293	48.000	52.336
48.000	52.378	48.000	52.421	48.000	52.463	48.000	52.506	48.000	52.548	48.000	52.591	48.000	52.633	48.000	52.676
48.500	52.718	48.500	52.761	48.500	52.803	48.500	52.846	48.500	52.888	48.500	52.931	48.500	52.973	48.500	53.016
49.000	53.058	49.000	53.101	49.000	53.143	49.000	53.186	49.000	53.228	49.000	53.271	49.000	53.313	49.000	53.355
49.000	53.398	49.000	53.440	49.000	53.483	49.500	53.525	49.500	53.568	49.500	53.610	49.500	53.653	50.000	53.695
50.000	53.738	50.000	53.780	50.000	53.823	50.000	53.865	50.000	53.908	50.500	53.950	50.500	53.993	50.500	54.035
50.500	54.078	50.500	54.120	50.500	54.163	50.500	54.205	51.000	54.248	51.000	54.290	51.000	54.333	51.000	54.375
51.000	54.418	51.000	54.460	51.500	54.502	51.500	54.545	51.500	54.587	51.500	54.630	51.500	54.672	52.000	54.715
52.000	54.757	52.000	54.800	52.000	54.842	52.000	54.885	52.000	54.927	52.500	54.970	52.500	55.012	52.500	55.055
53.000	55.097	53.000	55.140	53.000	55.182	53.000	55.225	53.500	55.267	53.500	55.310	53.500	55.352	53.500	55.395
53.500	55.437	54.000	55.480	54.000	55.522	54.500	55.565	55.000	55.607	55.000	55.649	55.000	55.692	55.000	55.734
55.000	55.777	55.500	55.819	55.500	55.862	56.000	55.904	56.000	55.947	57.000	55.989	57.000	56.032	57.000	56.074

57.000	56.117	57.000	56.159	57.000	56.202	57.000	56.244	57.500	56.287	57.500	56.329	57.500	56.372	57.500	56.414
58.000	56.457	58.000	56.499	58.000	56.542	58.000	56.584	58.500	56.627	58.500	56.669	59.000	56.711	59.000	56.754
59.000	56.796	59.000	56.839	59.000	56.881	59.500	56.924	59.500	56.966	59.500	57.009	60.000	57.051	60.000	57.094
60.000	57.136	60.000	57.179	60.500	57.221	60.500	57.264	61.000	57.306	61.000	57.349	61.000	57.391	61.500	57.434
62.000	57.476	62.000	57.519	62.500	57.561	62.500	57.604	63.000	57.646	63.000	57.689	63.000	57.731	63.000	57.774
63.500	57.816	63.500	57.858	63.500	57.901	63.500	57.943	64.000	57.986	64.000	58.028	64.000	58.071	64.000	58.113
64.500	58.156	64.500	58.198	64.500	58.241	64.500	58.283	64.500	58.326	65.000	58.368	65.000	58.411	65.000	58.453
65.000	58.496	65.000	58.538	65.000	58.581	65.000	58.623	65.500	58.666	65.500	58.708	66.000	58.751	66.000	58.793
66.000	58.836	66.000	58.878	66.500	58.920	66.500	58.963	66.500	59.005	66.500	59.048	67.000	59.090	67.000	59.133
67.000	59.175	67.000	59.218	67.000	59.260	67.500	59.303	67.500	59.345	67.500	59.388	67.500	59.430	67.500	59.473
68.000	59.515	69.000	59.558	68.000	59.600	68.500	59.643	69.000	59.685	69.000	59.728	69.000	59.770	69.000	59.813
69.000	59.855	69.000	59.898	69.000	59.940	69.500	59.983	69.500	60.025	69.500	60.067	69.500	60.110	70.000	60.152
70.000	60.195	70.000	60.237	70.500	60.280	70.500	60.322	70.500	60.365	71.000	60.407	71.000	60.450	71.000	60.492
71.000	60.535	71.000	60.577	71.000	60.620	71.000	60.662	71.500	60.705	71.500	60.747	71.500	60.790	71.500	60.832
71.500	60.875	72.000	60.917	72.000	60.960	72.000	61.002	72.000	61.045	72.000	61.087	72.000	61.129	72.000	61.172
72.500	61.214	72.500	61.257	72.500	61.299	72.500	61.342	72.500	61.384	73.000	61.427	73.000	61.469	73.000	61.512
73.000	61.554	73.000	61.597	73.500	61.639	73.500	61.682	73.500	61.724	73.500	61.767	73.500	61.809	73.500	61.852
73.500	61.894	74.000	61.937	74.000	61.979	74.000	62.022	74.000	62.064	74.500	62.107	74.500	62.149	75.000	62.192
75.000	62.234	75.000	62.276	75.000	62.319	75.000	62.361	75.000	62.404	75.000	62.446	75.000	62.489	75.500	62.531
75.500	62.574	76.000	62.616	76.000	62.659	76.000	62.701	76.000	62.744	76.500	62.786	76.500	62.829	76.500	62.871
76.500	62.914	76.500	62.956	77.000	62.999	77.000	63.041	77.000	63.084	77.000	63.126	77.000	63.169	77.500	63.211
77.500	63.254	77.500	63.296	77.500	63.339	77.500	63.381	78.000	63.423	78.000	63.466	78.000	63.508	78.500	63.551
78.500	63.593	78.500	63.636	79.000	63.678	79.000	63.721	79.000	63.763	79.000	63.806	79.000	63.848	79.500	63.891
79.500	63.933	80.000	63.976	80.000	64.018	80.000	64.061	80.000	64.103	80.000	64.146	80.000	64.188	80.500	64.231
80.500	64.273	81.000	64.315	81.000	64.358	81.000	64.401	81.000	64.443	81.000	64.485	81.500	64.528	82.500	64.570
83.000	64.613	83.500	64.655	83.500	64.698	83.500	64.740	84.000	64.783	84.000	64.825	84.000	64.868	85.000	64.910
85.500	64.953	85.500	64.995	85.500	65.038	85.500	65.080	86.000	65.123	86.000	65.165	86.500	65.208	86.500	65.250
86.500	65.293	87.000	65.335	87.000	65.378	87.000	65.420	87.000	65.463	87.000	65.505	87.500	65.548	88.000	65.590
88.000	65.632	89.000	65.675	89.000	65.717	89.000	65.760	89.500	65.802	89.500	65.845	90.000	65.887	90.000	65.930
91.000	65.972	91.000	66.015	91.000	66.057	91.500	66.100	91.500	66.142	91.500	66.185	91.500	66.227	92.000	66.270
92.000	66.312	92.000	66.355	92.500	66.397	92.500	66.440	92.500	66.482	92.500	66.525	92.500	66.567	92.500	66.610
93.000	66.652	93.000	66.694	93.000	66.737	93.500	66.779	93.500	66.822	93.500	66.864	94.000	66.907	94.000	66.949
94.000	66.992	94.000	67.034	94.000	67.077	94.500	67.119	94.500	67.162	95.000	67.204	95.000	67.247	95.000	67.289
95.000	67.332	95.000	67.374	95.500	67.417	95.500	67.459	95.500	67.502	95.500	67.544	95.500	67.587	95.500	67.629
96.000	67.672	96.000	67.714	96.000	67.757	96.000	67.799	96.000	67.841	96.000	67.884	96.000	67.925	96.500	67.969
96.500	68.011	96.500	68.054	96.500	68.096	97.000	68.139	97.000	68.181	97.000	68.224	97.000	68.266	97.500	68.309
97.500	68.351	97.500	68.394	98.000	68.436	98.000	68.479	98.000	68.521	98.000	68.564	98.000	68.606	98.000	68.649
98.000	68.691	98.500	68.734	98.500	68.776	98.500	68.819	99.000	68.861	99.500	68.904	99.500	68.946	100.000	68.988
100.000	69.031	100.500	69.073	101.000	69.116	101.000	69.158	101.500	69.201	101.500	69.243	101.500	69.286	102.000	69.328
102.000	69.371	102.500	69.413	102.500	69.456	102.500	69.498	102.500	69.541	104.000	69.583	104.000	69.626	104.000	69.669
104.500	69.711	104.500	69.753	104.500	69.796	105.000	69.838	105.000	69.881	105.000	69.923	105.000	69.966	105.000	70.008
105.500	70.050	106.000	70.093	106.000	70.135	106.000	70.178	106.500	70.220	107.000	70.263	107.000	70.305	107.000	70.348
107.000	70.390	107.500	70.433	107.500	70.475	107.500	70.518	108.500	70.560	109.000	70.603	109.000	70.645	109.500	70.688
109.500	70.730	109.500	70.773	110.000	70.815	110.500	70.858	110.500	70.900	110.500	70.943	110.500	70.985	111.000	71.028
111.500	71.070	111.500	71.113	111.500	71.155	112.000	71.197	112.000	71.240	112.500	71.282	112.500	71.325	112.500	71.367
113.000	71.410	113.000	71.452	113.000	71.495	113.000	71.537	113.500	71.580	113.500	71.622	113.500	71.665	113.500	71.707
113.500	71.750	113.500	71.792	114.000	71.835	114.500	71.877	114.500	71.920	115.000	71.962	115.000	72.005	115.000	72.047
115.000	72.090	115.500	72.132	115.500	72.175	115.500	72.217	115.500	72.259	115.500	72.302	116.000	72.344	116.000	72.387
116.000	72.429	116.000	72.472	116.500	72.514	116.500	72.557	117.000	72.599	117.500	72.642	117.500	72.684	118.000	72.727
118.500	72.769	118.500	72.812	118.500	72.854	119.000	72.897	119.000	72.939	119.000	72.982	119.500	73.024	119.500	73.067
119.500	73.109	120.000	73.152	120.000	73.194	120.000	73.237	120.500	73.279	120.500	73.322	120.500	73.364	121.000	73.406
121.000	73.449	121.000	73.491	121.500	73.534	121.500	73.576	121.500	73.619	121.500	73.661	122.000	73.704	122.000	73.746
122.000	73.789	122.500	73.831	122.500	73.874	123.000	73.916	123.000	73.959	123.000	74.001	123.500	74.044	124.000	74.086
124.000	74.129	124.000	74.171	124.000	74.214	124.500	74.256	124.500	74.299	125.000	74.341	125.000	74.384	125.000	74.425
125.500	74.468	125.500	74.511	125.500	74.553	126.000	74.596	126.000	74.638	126.000	74.681	126.500	74.723	125.500	74.765
126.500	74.808	127.000	74.851	127.000	74.893	127.500	74.936	127.500	74.978	128.000	75.021	128.500	75.063	129.000	75.105
129.500	75.148	129.500	75.191	129.500	75.233	130.000	75.276	130.000	75.318	130.000	75.361	130.500	75.403	130.500	75.445

131.000	75.488	131.000	75.531	131.500	75.573	132.000	75.615	132.000	75.658	132.000	75.700	132.000	75.743	132.500	75.785
132.500	75.828	132.500	75.870	133.000	75.913	133.000	75.955	133.000	75.998	133.500	76.040	134.000	76.083	134.000	76.125
134.000	76.168	134.000	76.210	134.500	76.253	134.500	76.295	134.500	76.338	135.500	76.380	135.500	76.423	135.500	76.465
136.500	76.508	136.500	76.550	137.000	76.593	137.000	76.635	137.500	76.678	137.500	76.720	138.000	76.762	138.000	76.805
138.500	76.847	138.500	76.890	138.500	76.932	138.500	76.975	139.000	77.017	139.000	77.060	139.500	77.102	140.000	77.145
140.000	77.187	140.000	77.230	140.000	77.272	140.000	77.315	140.000	77.357	140.500	77.400	140.500	77.442	140.500	77.485
141.000	77.527	141.000	77.570	141.500	77.612	142.000	77.655	142.000	77.697	142.000	77.740	142.000	77.782	142.000	77.824
142.000	77.867	142.500	77.909	142.500	77.952	142.500	77.994	143.000	78.037	143.500	78.079	143.500	78.122	143.500	78.164
143.500	78.207	144.000	78.249	144.000	78.292	145.000	78.334	145.000	78.377	145.000	78.419	145.500	78.462	145.500	78.504
145.500	78.547	145.500	78.589	145.500	78.632	146.000	78.674	146.000	78.717	146.500	78.759	146.500	78.802	147.000	78.844
147.000	78.887	147.000	78.929	147.000	78.971	147.000	79.014	148.000	79.056	148.000	79.099	149.000	79.141	149.500	79.184
150.500	79.226	150.500	79.269	150.500	79.311	150.500	79.354	151.000	79.396	151.000	79.439	151.000	79.481	151.500	79.524
152.000	79.566	152.000	79.609	152.000	79.651	153.000	79.694	153.000	79.736	153.500	79.779	153.500	79.821	154.000	79.864
154.500	79.906	155.000	79.949	155.000	79.991	155.000	80.033	155.500	80.076	155.500	80.118	156.000	80.161	156.500	80.203
156.500	80.246	156.500	80.288	156.500	80.331	156.500	80.373	157.500	80.416	157.500	80.458	158.000	80.501	158.000	80.543
158.000	80.586	159.000	80.628	159.500	80.671	160.000	80.713	160.000	80.756	160.500	80.798	161.000	80.841	162.000	80.883
162.000	80.926	162.000	80.968	162.000	81.011	162.500	81.053	163.000	81.096	164.000	81.138	164.500	81.180	165.000	81.223
165.500	81.265	165.500	81.308	166.000	81.350	166.000	81.393	166.500	81.435	166.500	81.478	166.500	81.520	166.500	81.563
167.000	81.605	167.000	81.648	167.000	81.690	167.000	81.733	167.500	81.775	167.500	81.818	168.000	81.860	168.000	81.903
168.500	81.945	168.500	81.988	168.500	82.030	168.500	82.073	169.500	82.115	170.000	82.158	170.000	82.200	171.000	82.242
171.000	82.285	172.000	82.327	172.000	82.370	172.500	82.412	173.000	82.455	173.000	82.497	173.000	82.540	173.500	82.582
174.000	82.625	174.000	82.667	174.500	82.710	176.000	82.752	176.000	82.795	176.000	82.837	176.500	82.880	177.500	82.922
178.500	82.965	179.000	83.007	179.500	83.050	179.500	83.092	180.000	83.135	181.000	83.177	181.000	83.220	181.000	83.262
181.500	83.305	182.500	83.347	182.500	83.389	182.500	83.432	183.000	83.474	183.000	83.517	183.000	83.559	183.500	83.602
185.000	83.644	185.000	83.687	185.000	83.729	185.500	83.772	186.000	83.814	186.000	83.857	186.000	83.899	186.000	83.942
186.500	83.984	186.500	84.027	186.500	84.069	187.000	84.112	187.000	84.154	187.500	84.197	187.500	84.239	188.000	84.282
188.500	84.324	188.500	84.367	188.500	84.409	189.000	84.452	189.500	84.494	191.000	84.536	192.000	84.579	192.500	84.621
193.000	84.664	193.000	84.706	194.500	84.749	195.000	84.791	195.500	84.834	197.000	84.876	198.000	84.919	198.500	84.961
198.500	85.004	199.000	85.046	199.500	85.089	199.500	85.131	199.500	85.174	200.000	85.216	200.000	85.259	200.500	85.301
201.500	85.344	202.000	85.386	202.500	85.429	202.500	85.471	204.000	85.514	204.500	85.556	204.500	85.598	205.000	85.641
205.500	85.683	205.500	85.726	206.000	85.768	206.500	85.811	207.000	85.853	207.500	85.896	208.000	85.938	208.000	85.981
208.000	86.023	208.500	86.066	210.000	86.108	210.500	86.151	211.000	86.193	211.000	86.236	211.000	86.278	211.000	86.321
211.000	86.363	212.000	86.406	212.000	86.448	212.000	86.491	213.500	86.533	213.500	86.576	213.500	86.618	214.000	86.661
214.500	86.703	214.500	86.745	214.500	86.788	214.500	86.830	214.500	86.873	215.000	86.915	215.000	86.958	215.000	87.000
216.000	87.043	216.000	87.085	216.500	87.128	216.500	87.170	217.000	87.213	217.000	87.255	218.000	87.298	219.000	87.340
219.500	87.383	220.000	87.425	220.500	87.468	221.000	87.510	221.000	87.553	221.500	87.595	223.000	87.638	223.000	87.680
223.500	87.723	223.500	87.765	223.500	87.807	224.000	87.850	224.000	87.892	224.500	87.935	224.500	87.977	225.000	88.020
225.500	88.062	225.500	88.105	226.000	88.147	229.000	88.190	229.000	88.232	229.500	88.275	230.500	88.317	231.000	88.360
232.500	88.402	233.000	88.445	233.000	88.487	233.500	88.530	234.500	88.572	235.000	88.615	235.500	88.657	235.500	88.700
235.500	88.742	236.000	88.785	236.000	88.827	236.000	88.870	237.000	88.912	237.000	88.954	237.500	88.997	238.500	89.039
238.500	89.082	239.000	89.124	239.000	89.167	239.500	89.209	240.000	89.252	240.000	89.294	240.500	89.337	241.500	89.379
242.000	89.422	242.500	89.464	242.500	89.507	242.500	89.549	242.500	89.592	243.000	89.634	243.000	89.677	243.000	89.719
243.500	89.762	244.000	89.804	244.500	89.847	245.000	89.889	246.000	89.932	246.000	89.974	246.500	90.016	247.000	90.059
248.000	90.101	249.000	90.144	249.500	90.186	251.000	90.229	251.500	90.271	252.000	90.314	252.500	90.356	253.000	90.399
253.000	90.441	254.500	90.484	255.000	90.526	255.000	90.569	256.000	90.611	256.000	90.654	257.000	90.696	257.000	90.739
257.000	90.781	257.500	90.824	257.500	90.866	258.500	90.909	259.000	90.951	260.500	90.994	260.500	91.036	261.500	91.079
262.500	91.121	263.000	91.163	263.000	91.206	263.000	91.248	263.500	91.291	263.500	91.333	263.500	91.376	263.500	91.418
264.500	91.461	264.500	91.503	265.000	91.546	266.500	91.588	267.000	91.631	268.000	91.673	268.000	91.716	269.500	91.758
271.500	91.801	272.000	91.843	273.000	91.886	274.500	91.928	274.500	91.971	275.000	92.013	276.000	92.056	276.000	92.098
277.500	92.141	279.000	92.183	287.000	92.226	287.500	92.268	287.500	92.310	287.500	92.353	288.500	92.395	289.000	92.438
289.000	92.480	289.000	92.523	289.500	92.565	290.000	92.608	290.500	92.650	291.500	92.693	292.000	92.735	293.000	92.778
293.000	92.820	294.000	92.863	294.500	92.905	295.500	92.948	296.000	92.990	297.000	93.033	298.500	93.075	299.000	93.118
299.000	93.160	301.000	93.203	301.000	93.245	303.500	93.288	304.500	93.330	305.000	93.372	305.500	93.415	309.500	93.457
309.500	93.500	314.000	93.542	317.000	93.585	317.500	93.627	318.000	93.670	318.000	93.712	319.000	93.755	319.000	93.797
319.500	93.840	322.500	93.882	322.500	93.925	323.000	93.967	325.500	94.010	325.500	94.052	328.000	94.095	328.000	94.137
328.500	94.180	329.000	94.222	329.000	94.265	330.000	94.307	330.500	94.350	330.500	94.392	330.500	94.435	331.000	94.477
331.500	94.519	332.500	94.562	333.500	94.604	334.500	94.647	334.500	94.689	335.000	94.732	335.500	94.774	336.500	94.817

337.500	94.859	338.000	94.902	338.000	94.944	338.500	94.987	338.500	95.029	339.000	95.072	340.000	95.114	340.000	95.157
340.000	95.199	342.500	95.242	344.500	95.284	344.500	95.327	346.000	95.369	350.000	95.412	351.000	95.454	351.500	95.497
358.500	95.539	358.500	95.582	360.000	95.624	360.000	95.666	362.000	95.709	363.000	95.751	365.000	95.794	366.500	95.836
369.000	95.879	370.000	95.921	371.500	95.964	372.000	96.006	373.000	96.049	373.500	96.091	374.000	96.134	375.000	96.176
375.500	96.219	376.000	96.261	378.500	96.304	379.000	96.346	380.000	96.389	383.000	96.431	387.000	96.474	388.500	96.516
391.500	96.559	392.000	96.601	392.500	96.644	394.000	96.686	397.000	96.728	397.500	96.771	399.000	96.813	399.000	96.856
401.500	96.898	402.500	96.941	405.000	96.983	405.000	97.026	406.000	97.068	408.000	97.111	408.500	97.153	408.500	97.196
410.000	97.238	411.500	97.281	416.000	97.323	416.500	97.366	419.500	97.408	420.000	97.451	422.000	97.493	422.000	97.536
430.000	97.578	432.000	97.621	435.500	97.663	438.000	97.706	442.000	97.748	443.500	97.791	451.500	97.833	456.500	97.875
459.000	97.918	459.000	97.960	459.500	98.003	462.000	98.045	464.500	98.088	473.000	98.130	476.500	98.173	481.500	98.215
486.500	98.258	493.000	98.300	496.500	98.343	499.000	98.385	509.000	98.428	510.500	98.470	521.000	98.513	523.000	98.555
530.000	98.598	537.000	98.640	538.000	98.683	540.000	98.725	547.000	98.768	550.000	98.810	554.000	98.853	556.000	98.895
566.000	98.937	569.500	98.980	579.500	99.022	606.000	99.065	608.500	99.107	616.500	99.150	636.000	99.192	636.500	99.235
644.500	99.277	647.500	99.320	649.000	99.362	649.500	99.405	660.500	99.447	660.500	99.490	717.000	99.532	741.000	99.575
757.000	99.617	759.500	99.660	763.000	99.702	787.000	99.745	821.500	99.787	860.500	99.830	902.000	99.872	918.000	99.915
1071.500	99.957	1181.500	100.000												



DELTA VS PERCENT LESS THAN OR EQUAL TO

RETURN PERIOD (IN YEARS) FOR DELTA

VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD	VALUE	PERIOD
1181.500	26.000	1071.500	13.000	918.000	8.666	902.000	6.500	860.500	5.200	821.500	4.333	787.000	3.714	763.000	3.250
759.500	2.888	757.000	2.600	741.000	2.363	717.000	2.166	660.500	2.000	660.500	1.857	649.500	1.733	649.000	1.625
647.500	1.529	644.500	1.444	636.500	1.368	636.000	1.300	616.500	1.238	608.500	1.181	606.000	1.130	579.500	1.083
569.500	1.040	566.000	1.000	556.000	0.962	554.000	0.928	550.000	0.896	547.000	0.866	540.000	0.838	538.000	0.812
537.000	0.787	530.000	0.764	523.000	0.742	521.000	0.722	510.500	0.702	509.000	0.684	499.000	0.666	496.500	0.650
493.000	0.634	486.500	0.619	481.500	0.604	476.500	0.590	473.000	0.577	464.500	0.565	462.000	0.553	459.500	0.541
459.000	0.530	459.000	0.520	456.500	0.509	451.500	0.500	443.500	0.490	442.000	0.481	438.000	0.472	435.500	0.464
432.000	0.456	430.000	0.448	422.000	0.440	422.000	0.433	420.000	0.426	419.500	0.419	415.500	0.412	416.000	0.405
411.500	0.400	410.000	0.393	408.500	0.388	408.500	0.382	408.000	0.376	406.000	0.371	405.000	0.366	405.000	0.361
402.500	0.356	401.500	0.351	399.000	0.346	399.000	0.342	397.500	0.337	397.000	0.333	394.000	0.329	392.500	0.325
392.000	0.320	391.500	0.317	398.500	0.313	387.000	0.309	383.000	0.305	380.000	0.302	379.000	0.298	378.500	0.295
376.000	0.292	375.500	0.288	375.000	0.285	374.000	0.282	373.500	0.279	373.000	0.276	372.000	0.273	371.500	0.270
370.000	0.268	369.000	0.265	366.500	0.262	365.000	0.260	363.000	0.257	362.000	0.254	360.000	0.252	360.000	0.250
358.500	0.247	358.500	0.245	351.500	0.242	351.000	0.240	350.000	0.238	346.000	0.236	344.500	0.234	344.500	0.232
342.500	0.230	340.000	0.228	340.000	0.226	340.000	0.224	339.000	0.222	338.500	0.220	338.500	0.218	338.000	0.216
338.000	0.214	337.500	0.213	336.500	0.211	335.500	0.209	335.000	0.208	334.500	0.206	334.500	0.204	333.500	0.203
332.500	0.201	331.500	0.200	331.000	0.198	330.500	0.196	330.500	0.195	330.500	0.194	330.000	0.192	329.000	0.191
329.000	0.189	328.500	0.188	328.000	0.187	328.000	0.185	325.500	0.184	325.500	0.183	323.000	0.181	322.500	0.180
322.500	0.179	319.500	0.178	319.000	0.176	319.000	0.175	318.000	0.174	318.000	0.173	317.500	0.172	317.000	0.171
314.000	0.169	309.500	0.168	309.500	0.167	305.500	0.166	305.000	0.165	304.500	0.164	303.500	0.163	301.000	0.162
301.000	0.161	299.000	0.160	299.000	0.159	298.500	0.158	297.000	0.157	296.000	0.156	295.500	0.155	294.500	0.154
294.000	0.153	293.000	0.152	293.000	0.152	292.000	0.151	291.500	0.150	290.500	0.149	290.000	0.148	289.500	0.147
289.000	0.146	289.000	0.146	289.000	0.145	288.500	0.144	287.500	0.143	287.500	0.142	287.500	0.142	287.000	0.141
279.000	0.140	277.500	0.139	276.000	0.139	276.000	0.138	275.000	0.137	274.500	0.136	274.500	0.136	273.000	0.135
272.000	0.134	271.500	0.134	269.500	0.133	268.000	0.132	268.000	0.131	267.000	0.131	266.500	0.130	265.000	0.130
264.500	0.129	264.500	0.128	263.500	0.128	263.500	0.127	263.500	0.126	263.500	0.126	263.000	0.125	263.000	0.125
263.000	0.124	262.500	0.123	261.500	0.123	260.500	0.122	260.500	0.122	259.000	0.121	258.500	0.120	257.500	0.120
257.500	0.119	257.000	0.119	257.000	0.118	257.000	0.118	256.000	0.117	256.000	0.117	255.000	0.116	255.000	0.115
254.500	0.115	253.000	0.115	253.000	0.114	252.500	0.114	252.000	0.113	251.500	0.113	251.000	0.112	249.500	0.112
249.000	0.111	248.000	0.111	247.000	0.110	246.500	0.110	246.000	0.109	246.000	0.109	245.000	0.108	244.500	0.108
244.000	0.107	243.500	0.107	243.000	0.106	243.000	0.106	243.000	0.106	242.500	0.105	242.500	0.105	242.500	0.104
242.500	0.104	242.000	0.104	241.500	0.103	240.500	0.103	240.000	0.102	240.000	0.102	239.500	0.101	239.000	0.101
239.000	0.101	238.500	0.100	238.500	0.100	237.500	0.100	237.000	0.099	237.000	0.099	236.000	0.098	236.000	0.098
236.000	0.098	235.500	0.097	235.500	0.097	235.500	0.097	235.000	0.096	234.500	0.096	233.500	0.095	233.000	0.095
233.000	0.095	232.500	0.094	231.000	0.094	230.500	0.094	229.500	0.093	229.000	0.093	229.000	0.093	226.000	0.092
225.500	0.092	225.500	0.092	225.000	0.091	224.500	0.091	224.500	0.091	224.000	0.090	224.000	0.090	223.500	0.090
223.500	0.089	223.500	0.089	223.000	0.089	223.000	0.089	221.500	0.088	221.000	0.088	221.000	0.088	220.500	0.087
220.000	0.087	219.500	0.087	219.000	0.086	218.000	0.086	217.000	0.086	217.000	0.086	216.500	0.085	216.500	0.085
216.000	0.085	216.000	0.084	215.000	0.084	215.000	0.084	215.000	0.084	214.500	0.083	214.500	0.083	214.500	0.083
214.500	0.083	214.500	0.082	214.000	0.082	213.500	0.082	213.500	0.082	213.500	0.081	212.000	0.081	212.000	0.081
212.000	0.080	211.000	0.080	211.000	0.080	211.000	0.080	211.000	0.080	211.000	0.079	210.500	0.079	210.000	0.079
208.500	0.079	208.000	0.078	208.000	0.078	208.000	0.078	207.500	0.078	207.000	0.077	206.500	0.077	206.000	0.077
205.500	0.077	205.500	0.076	205.000	0.076	204.500	0.076	204.500	0.076	204.000	0.076	202.500	0.075	202.500	0.075
202.000	0.075	201.500	0.075	200.500	0.074	200.000	0.074	200.000	0.074	199.500	0.074	199.500	0.074	199.500	0.073
199.000	0.073	198.500	0.073	198.500	0.073	198.000	0.073	197.000	0.072	195.500	0.072	195.000	0.072	194.500	0.072
193.000	0.072	193.000	0.071	192.500	0.071	192.000	0.071	191.000	0.071	189.500	0.071	189.000	0.070	188.500	0.070
188.500	0.070	188.500	0.070	188.000	0.070	187.500	0.069	187.500	0.069	187.000	0.069	187.000	0.069	186.500	0.069
186.500	0.068	186.500	0.068	186.000	0.068	186.000	0.068	186.000	0.068	186.000	0.068	185.500	0.067	185.000	0.067
185.000	0.067	185.000	0.067	183.500	0.067	183.000	0.067	183.000	0.066	183.000	0.066	182.500	0.066	182.500	0.066
182.500	0.066	181.500	0.065	181.000	0.065	181.000	0.065	181.000	0.065	180.000	0.065	179.500	0.065	179.500	0.065
179.000	0.064	178.500	0.064	177.500	0.064	176.500	0.064	176.000	0.064	176.000	0.064	176.000	0.063	174.500	0.063
174.000	0.063	174.000	0.063	173.500	0.063	173.000	0.063	173.000	0.062	173.000	0.062	172.500	0.062	172.000	0.062
172.000	0.062	171.000	0.062	171.000	0.062	170.000	0.061	170.000	0.061	169.500	0.061	168.500	0.061	168.500	0.061

168.500	0.061	168.500	0.051	168.000	0.060	168.000	0.060	167.500	0.060	167.500	0.060	167.000	0.060	167.000	0.060
167.000	0.060	167.000	0.059	166.500	0.059	166.500	0.059	166.500	0.059	166.500	0.059	166.000	0.059	166.000	0.059
165.500	0.058	165.500	0.058	165.000	0.058	164.500	0.058	164.000	0.058	163.000	0.058	162.500	0.058	162.000	0.058
162.000	0.057	162.000	0.057	162.000	0.057	161.000	0.057	160.500	0.057	160.000	0.057	160.000	0.057	159.500	0.057
159.000	0.056	158.000	0.056	158.000	0.056	158.000	0.056	157.500	0.056	157.500	0.056	156.500	0.056	156.500	0.056
156.500	0.055	156.500	0.055	156.500	0.055	156.000	0.055	155.500	0.055	155.500	0.055	155.000	0.055	155.000	0.055
155.000	0.054	154.500	0.054	154.000	0.054	153.500	0.054	153.500	0.054	153.000	0.054	153.000	0.054	152.000	0.054
152.000	0.054	152.000	0.053	151.500	0.053	151.000	0.053	151.000	0.053	151.000	0.053	150.500	0.053	150.500	0.053
150.500	0.053	150.500	0.053	149.500	0.052	149.000	0.052	148.000	0.052	148.000	0.052	147.000	0.052	147.000	0.052
147.000	0.052	147.000	0.052	147.000	0.052	146.500	0.052	146.500	0.051	146.000	0.051	146.000	0.051	145.500	0.051
145.500	0.051	145.500	0.051	145.500	0.051	145.500	0.051	145.000	0.051	145.000	0.050	145.000	0.050	144.000	0.050
144.000	0.050	143.500	0.050	143.500	0.050	143.500	0.050	143.500	0.050	143.000	0.050	142.500	0.050	142.500	0.050
142.500	0.049	142.000	0.049	142.000	0.049	142.000	0.049	142.000	0.049	142.000	0.049	142.000	0.049	141.500	0.049
141.000	0.049	141.000	0.049	140.500	0.048	140.500	0.048	140.500	0.048	140.000	0.048	140.000	0.048	140.000	0.048
140.000	0.048	140.000	0.048	140.000	0.048	139.500	0.048	139.000	0.048	139.000	0.047	138.500	0.047	138.500	0.047
138.500	0.047	138.500	0.047	138.000	0.047	138.000	0.047	137.500	0.047	137.500	0.047	137.000	0.047	137.000	0.047
136.500	0.047	136.500	0.046	135.500	0.046	135.500	0.046	135.500	0.046	134.500	0.046	134.500	0.046	134.500	0.046
134.000	0.046	134.000	0.046	134.000	0.046	134.000	0.046	133.500	0.046	133.000	0.045	133.000	0.045	133.000	0.045
132.500	0.045	132.500	0.045	132.500	0.045	132.000	0.045	132.000	0.045	132.000	0.045	132.000	0.045	131.500	0.045
131.000	0.045	131.000	0.044	130.500	0.044	130.500	0.044	130.000	0.044	130.000	0.044	130.000	0.044	129.500	0.044
129.500	0.044	129.500	0.044	129.000	0.044	128.500	0.044	128.000	0.044	127.500	0.044	127.500	0.043	127.000	0.043
127.000	0.043	126.500	0.043	126.500	0.043	126.500	0.043	126.000	0.043	126.000	0.043	126.000	0.043	125.500	0.043
125.500	0.043	125.500	0.043	125.000	0.043	125.000	0.043	125.000	0.042	124.500	0.042	124.500	0.042	124.000	0.042
124.000	0.042	124.000	0.042	124.000	0.042	123.500	0.042	123.000	0.042	123.000	0.042	123.000	0.042	122.500	0.042
122.500	0.042	122.000	0.042	122.000	0.042	122.000	0.041	121.500	0.041	121.500	0.041	121.500	0.041	121.500	0.041
121.000	0.041	121.000	0.041	121.000	0.041	120.500	0.041	120.500	0.041	120.500	0.041	120.000	0.041	120.000	0.041
120.000	0.041	119.500	0.041	119.500	0.040	119.500	0.040	119.000	0.040	119.000	0.040	119.000	0.040	118.500	0.040
118.500	0.040	118.500	0.040	118.000	0.040	117.500	0.040	117.500	0.040	117.000	0.040	116.500	0.040	116.500	0.040
116.000	0.040	116.000	0.040	116.000	0.039	116.000	0.039	115.500	0.039	115.500	0.039	115.500	0.039	115.500	0.039
115.500	0.039	115.000	0.039	115.000	0.039	115.000	0.039	115.000	0.039	114.500	0.039	114.500	0.039	114.000	0.039
113.500	0.039	113.500	0.039	113.500	0.038	113.500	0.038	113.500	0.038	113.500	0.038	113.000	0.038	113.000	0.038
113.000	0.038	113.000	0.038	112.500	0.038	112.500	0.038	112.500	0.038	112.000	0.038	112.000	0.038	111.500	0.038
111.500	0.038	111.500	0.038	111.000	0.038	110.500	0.038	110.500	0.037	110.500	0.037	110.500	0.037	110.000	0.037
109.500	0.037	109.500	0.037	109.500	0.037	109.000	0.037	109.000	0.037	108.500	0.037	107.500	0.037	107.500	0.037
107.500	0.037	107.000	0.037	107.000	0.037	107.000	0.037	107.000	0.037	106.500	0.037	106.000	0.036	106.000	0.036
106.000	0.036	105.500	0.036	105.000	0.036	105.000	0.036	105.000	0.036	105.000	0.036	105.000	0.036	104.500	0.036
104.500	0.036	104.500	0.036	104.000	0.036	104.000	0.036	104.000	0.036	102.500	0.036	102.500	0.036	102.500	0.036
102.500	0.036	102.000	0.036	102.000	0.035	101.500	0.035	101.500	0.035	101.500	0.035	101.000	0.035	101.000	0.035
100.500	0.035	100.000	0.035	100.000	0.035	99.500	0.035	99.500	0.035	99.000	0.035	98.500	0.035	98.500	0.035
98.500	0.035	98.000	0.035	98.000	0.035	98.000	0.035	98.000	0.035	98.000	0.035	98.000	0.034	98.000	0.034
97.500	0.034	97.500	0.034	97.500	0.034	97.000	0.034	97.000	0.034	97.000	0.034	97.000	0.034	96.500	0.034
96.500	0.034	96.500	0.034	96.500	0.034	96.000	0.034	96.000	0.034	96.000	0.034	96.000	0.034	96.000	0.034
96.000	0.034	96.000	0.034	95.500	0.034	95.500	0.034	95.500	0.033	95.500	0.033	95.500	0.033	95.500	0.033
95.000	0.033	95.000	0.033	95.000	0.033	95.000	0.033	95.000	0.033	94.500	0.033	94.500	0.033	94.000	0.033
94.000	0.033	94.000	0.033	94.000	0.033	94.000	0.033	93.500	0.033	93.500	0.033	93.500	0.033	93.000	0.033
93.000	0.033	93.000	0.033	92.500	0.033	92.500	0.032	92.500	0.032	92.500	0.032	92.500	0.032	92.500	0.032
92.000	0.032	92.000	0.032	92.000	0.032	91.500	0.032	91.500	0.032	91.500	0.032	91.500	0.032	91.000	0.032
91.000	0.032	91.000	0.032	90.000	0.032	90.000	0.032	89.500	0.032	89.500	0.032	89.000	0.032	89.000	0.032
89.000	0.032	88.000	0.032	88.000	0.032	87.500	0.032	87.000	0.031	87.000	0.031	87.000	0.031	87.000	0.031
87.000	0.031	86.500	0.031	86.500	0.031	86.500	0.031	86.000	0.031	86.000	0.031	85.500	0.031	85.500	0.031
85.500	0.031	85.500	0.031	95.000	0.031	84.000	0.031	84.000	0.031	84.000	0.031	83.500	0.031	83.500	0.031
83.500	0.031	83.000	0.031	82.500	0.031	81.500	0.031	81.000	0.031	81.000	0.031	81.000	0.030	81.000	0.030
81.000	0.030	80.500	0.030	90.500	0.030	90.000	0.030	80.000	0.030	80.000	0.030	80.000	0.030	80.000	0.030
80.000	0.030	79.500	0.030	79.500	0.030	79.000	0.030	79.000	0.030	79.000	0.030	79.000	0.030	79.000	0.030
78.500	0.030	78.500	0.030	78.500	0.030	78.000	0.030	78.000	0.030	78.000	0.030	77.500	0.030	77.500	0.030
77.500	0.030	77.500	0.030	77.500	0.029	77.000	0.029	77.000	0.029	77.000	0.029	77.000	0.029	77.000	0.029
76.500	0.029	76.500	0.029	76.500	0.029	76.500	0.029	76.500	0.029	76.000	0.029	76.000	0.029	76.000	0.029

76.000	0.029	75.500	0.029	75.500	0.029	75.000	0.029	75.000	0.029	75.000	0.029	75.000	0.029	75.000	0.029
75.000	0.029	75.000	0.029	75.000	0.029	74.500	0.029	74.500	0.029	74.000	0.029	74.000	0.029	74.000	0.029
74.000	0.028	73.500	0.028	73.500	0.028	73.500	0.028	73.500	0.028	73.500	0.028	73.500	0.028	73.500	0.028
73.000	0.028	73.000	0.028	73.000	0.028	73.000	0.028	73.000	0.028	72.500	0.028	72.500	0.028	72.500	0.028
72.500	0.028	72.500	0.028	72.000	0.028	72.000	0.028	72.000	0.028	72.000	0.028	72.000	0.028	72.000	0.028
72.000	0.028	71.500	0.028	71.500	0.028	71.500	0.028	71.500	0.028	71.500	0.028	71.000	0.028	71.000	0.028
71.000	0.027	71.000	0.027	71.000	0.027	71.000	0.027	71.000	0.027	70.500	0.027	70.500	0.027	70.500	0.027
70.000	0.027	70.000	0.027	70.000	0.027	69.500	0.027	69.500	0.027	69.500	0.027	69.500	0.027	69.000	0.027
69.000	0.027	69.000	0.027	69.000	0.027	69.000	0.027	69.000	0.027	69.000	0.027	68.500	0.027	68.000	0.027
68.000	0.027	68.000	0.027	67.500	0.027	67.500	0.027	67.500	0.027	67.500	0.027	67.500	0.027	67.000	0.027
67.000	0.027	67.000	0.027	67.000	0.026	67.000	0.026	66.500	0.026	66.500	0.026	66.500	0.026	66.500	0.026
66.000	0.026	66.000	0.026	66.000	0.026	66.000	0.026	65.500	0.026	65.500	0.026	65.000	0.026	65.000	0.026
65.000	0.026	65.000	0.026	65.000	0.026	65.000	0.026	65.000	0.026	64.500	0.026	64.500	0.026	64.500	0.026
64.500	0.026	64.500	0.026	64.000	0.026	64.000	0.026	64.000	0.026	64.000	0.026	63.500	0.026	63.500	0.026
63.500	0.026	63.500	0.026	63.000	0.026	63.000	0.026	63.000	0.026	63.000	0.026	62.500	0.026	62.500	0.026
62.000	0.025	62.000	0.025	61.500	0.025	61.000	0.025	61.000	0.025	61.000	0.025	60.500	0.025	60.500	0.025
60.000	0.025	60.000	0.025	60.000	0.025	60.000	0.025	59.500	0.025	59.500	0.025	59.500	0.025	59.000	0.025
59.000	0.025	59.000	0.025	59.000	0.025	59.000	0.025	58.500	0.025	58.500	0.025	58.000	0.025	58.000	0.025
58.000	0.025	58.000	0.025	57.500	0.025	57.500	0.025	57.500	0.025	57.500	0.025	57.000	0.025	57.000	0.025
57.000	0.025	57.000	0.025	57.000	0.025	57.000	0.025	57.000	0.025	56.000	0.025	56.000	0.025	55.500	0.025
55.500	0.024	55.000	0.024	55.000	0.024	55.000	0.024	55.000	0.024	55.000	0.024	54.500	0.024	54.000	0.024
54.000	0.024	53.500	0.024	53.500	0.024	53.500	0.024	53.500	0.024	53.500	0.024	53.000	0.024	53.000	0.024
53.000	0.024	53.000	0.024	52.500	0.024	52.500	0.024	52.500	0.024	52.000	0.024	52.000	0.024	52.000	0.024
52.000	0.024	52.000	0.024	52.000	0.024	51.500	0.024	51.500	0.024	51.500	0.024	51.500	0.024	51.500	0.024
51.000	0.024	51.000	0.024	51.000	0.024	51.000	0.024	51.000	0.024	51.000	0.024	50.500	0.024	50.500	0.024
50.500	0.024	50.500	0.024	50.500	0.024	50.500	0.023	50.500	0.023	50.000	0.023	50.000	0.023	50.000	0.023
50.000	0.023	50.000	0.023	50.000	0.023	49.500	0.023	49.500	0.023	49.500	0.023	49.500	0.023	49.000	0.023
49.000	0.023	49.000	0.023	49.000	0.023	49.000	0.023	49.000	0.023	49.000	0.023	49.000	0.023	49.000	0.023
49.000	0.023	49.000	0.023	48.500	0.023	48.500	0.023	48.500	0.023	48.500	0.023	48.500	0.023	48.500	0.023
48.500	0.023	48.500	0.023	48.000	0.023	48.000	0.023	48.000	0.023	48.000	0.023	48.000	0.023	48.000	0.023
48.000	0.023	48.000	0.023	48.000	0.023	47.500	0.023	47.500	0.023	47.500	0.023	47.500	0.023	47.500	0.023
47.500	0.023	47.500	0.023	47.500	0.022	47.000	0.022	47.000	0.022	47.000	0.022	47.000	0.022	47.000	0.022
47.000	0.022	47.000	0.022	47.000	0.022	47.000	0.022	47.000	0.022	47.000	0.022	46.500	0.022	46.500	0.022
46.500	0.022	46.500	0.022	46.500	0.022	46.500	0.022	46.500	0.022	46.500	0.022	46.500	0.022	46.000	0.022
46.000	0.022	46.000	0.022	46.000	0.022	46.000	0.022	46.000	0.022	46.000	0.022	46.000	0.022	46.000	0.022
46.000	0.022	46.000	0.022	46.000	0.022	45.500	0.022	45.500	0.022	45.500	0.022	45.500	0.022	45.500	0.022
45.500	0.022	45.500	0.022	45.500	0.022	45.000	0.022	45.000	0.022	45.000	0.022	45.000	0.022	44.500	0.022
44.500	0.022	44.500	0.022	44.500	0.022	44.500	0.022	44.500	0.022	44.500	0.021	44.500	0.021	44.500	0.021
44.500	0.021	44.500	0.021	44.500	0.021	44.000	0.021	44.000	0.021	44.000	0.021	44.000	0.021	44.000	0.021
44.000	0.021	44.000	0.021	44.000	0.021	44.000	0.021	43.500	0.021	43.500	0.021	43.500	0.021	43.500	0.021
43.500	0.021	43.000	0.021	43.000	0.021	43.000	0.021	43.000	0.021	43.000	0.021	43.000	0.021	43.000	0.021
43.000	0.021	42.500	0.021	42.500	0.021	42.500	0.021	42.500	0.021	42.000	0.021	42.000	0.021	42.000	0.021
42.000	0.021	42.000	0.021	42.000	0.021	41.500	0.021	41.500	0.021	41.500	0.021	41.000	0.021	40.500	0.021
40.500	0.021	40.500	0.021	40.500	0.021	40.500	0.021	40.500	0.021	40.500	0.021	40.000	0.021	40.000	0.021
40.000	0.021	40.000	0.021	40.000	0.021	39.500	0.021	39.500	0.021	39.500	0.021	39.500	0.020	39.000	0.020
39.000	0.020	39.000	0.020	39.000	0.020	39.000	0.020	39.000	0.020	38.500	0.020	38.500	0.020	38.500	0.020
38.500	0.020	38.500	0.020	38.500	0.020	38.500	0.020	38.500	0.020	38.000	0.020	38.000	0.020	38.000	0.020
38.000	0.020	38.000	0.020	38.000	0.020	38.000	0.020	37.500	0.020	37.500	0.020	37.500	0.020	37.000	0.020
37.000	0.020	37.000	0.020	37.000	0.020	37.000	0.020	36.500	0.020	36.500	0.020	36.500	0.020	36.500	0.020
36.500	0.020	36.000	0.020	36.000	0.020	36.000	0.020	36.000	0.020	36.000	0.020	36.000	0.020	36.000	0.020
36.000	0.020	36.000	0.020	35.500	0.020	35.500	0.020	35.500	0.020	35.500	0.020	35.000	0.020	35.000	0.020
35.000	0.020	35.000	0.020	34.500	0.020	34.500	0.020	34.500	0.020	34.000	0.020	34.000	0.020	34.000	0.020
34.000	0.020	34.000	0.020	34.000	0.020	33.500	0.020	33.500	0.019	33.500	0.019	33.500	0.019	33.000	0.019
33.000	0.019	32.500	0.019	32.500	0.019	32.000	0.019	32.000	0.019	32.000	0.019	32.000	0.019	32.000	0.019
32.000	0.019	32.000	0.019	32.000	0.019	32.000	0.019	31.500	0.019	31.500	0.019	31.500	0.019	31.500	0.019
31.500	0.019	31.500	0.019	31.500	0.019	31.500	0.019	31.500	0.019	31.000	0.019	31.000	0.019	30.500	0.019
30.500	0.019	30.500	0.019	30.500	0.019	30.500	0.019	30.500	0.019	30.000	0.019	30.000	0.019	30.000	0.019

30.000	0.019	29.500	0.019	29.500	0.019	29.500	0.019	29.500	0.019	29.500	0.019	29.000	0.019	29.000	0.019
29.000	0.019	29.000	0.019	29.000	0.019	29.000	0.019	29.000	0.019	29.000	0.019	29.000	0.019	29.000	0.019
28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019
28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019	28.500	0.019	28.000	0.019	28.000	0.019	28.000	0.019
28.000	0.018	28.000	0.018	28.000	0.018	28.000	0.018	28.000	0.018	28.000	0.018	28.000	0.018	27.500	0.018
27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018
27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018	27.500	0.018	27.000	0.018	27.000	0.018	27.000	0.018
27.000	0.018	27.000	0.018	27.000	0.018	27.000	0.018	27.000	0.018	27.000	0.018	27.000	0.018	27.000	0.018
26.500	0.018	26.500	0.018	26.500	0.018	26.500	0.018	26.500	0.018	26.500	0.018	26.500	0.018	26.500	0.018
26.500	0.018	26.500	0.018	26.500	0.018	26.500	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018
26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018
26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018	26.000	0.018
25.500	0.018	25.500	0.018	25.500	0.018	25.500	0.018	25.500	0.018	25.500	0.018	25.500	0.018	25.500	0.018
25.500	0.018	25.000	0.018	25.000	0.018	25.000	0.018	25.000	0.017	25.000	0.017	25.000	0.017	25.000	0.017
25.000	0.017	25.000	0.017	25.000	0.017	25.000	0.017	25.000	0.017	25.000	0.017	25.000	0.017	25.000	0.017
24.500	0.017	24.500	0.017	24.500	0.017	24.500	0.017	24.500	0.017	24.500	0.017	24.500	0.017	24.500	0.017
24.500	0.017	24.500	0.017	24.500	0.017	24.500	0.017	24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017
24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017
24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017	24.000	0.017	23.500	0.017	23.500	0.017	23.500	0.017
23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017
23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017	23.500	0.017
23.500	0.017	23.500	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017
23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017	23.000	0.017
23.000	0.017	23.000	0.017	22.500	0.017	22.500	0.017	22.500	0.017	22.500	0.017	22.500	0.017	22.500	0.017
22.500	0.017	22.500	0.016	22.500	0.016	22.500	0.016	22.500	0.016	22.500	0.016	22.500	0.016	22.500	0.016
22.500	0.016	22.500	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016
22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016
22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	22.000	0.016	21.500	0.016	21.500	0.016	21.500	0.016
21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016
21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.500	0.016	21.000	0.016	21.000	0.016
21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016
21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	21.000	0.016	20.500	0.016
20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016
20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.500	0.016	20.000	0.016
20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016
20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016	20.000	0.016
20.000	0.016	20.000	0.015	20.000	0.015	20.000	0.015	20.000	0.015	20.000	0.015	20.000	0.015	19.500	0.015
19.500	0.015	19.500	0.015	19.500	0.015	19.500	0.015	19.500	0.015,	19.500	0.015	19;500	0.015	19.500	0.015
19.500	0.015	19.500	0.015	19.500	0.015	19.500	0.015	19.500	0.015	19.500	0.015	19.000	0.015	19.000	0.015
19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015
19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	19.000	0.015	18.500	0.015
18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015
18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015	18.500	0.015
18.500	0.015	18.500	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015
18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015	18.000	0.015
18.000	0.015	18.000	0.015	18.000	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015
17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015
17.500	0.015	17.500	0.015	17.500	0.015	17.500	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015
17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015
17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.015	17.000	0.014	17.000	0.014	17.000	0.014
17.000	0.014	17.000	0.014	17.000	0.014	17.000	0.014	16.500	0.014	16.500	0.014	16.500	0.014	16.500	0.014
16.500	0.014	16.500	0.014	16.500	0.014	16.500	0.014	16.500	0.014	16.500	0.014	16.500	0.014	16.500	0.014
16.000	0.014	16.000	0.014	16.000	0.014	16.000	0.014	16.000	0.014	16.000	0.014	16.000	0.014	16.000	0.014
16.000	0.014	16.000	0.014	16.000	0.014	16.000	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014
15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014
15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.500	0.014	15.000	0.014	15.000	0.014
15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014

15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014	15.000	0.014
14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014
14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014	14.500	0.014
14.500	0.014	14.500	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014
14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014
14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014
14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	14.000	0.014	13.500	0.014
13.500	0.014	13.500	0.014	13.500	0.014	13.500	0.014	13.500	0.014	13.500	0.014	13.500	0.014	13.500	0.014
13.500	0.014	13.500	0.013	13.500	0.013	13.500	0.013	13.500	0.013	13.500	0.013	13.500	0.013	13.500	0.013
13.500	0.013	13.500	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013
13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013
13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013	13.000	0.013
13.000	0.013	13.000	0.013	13.000	0.013	12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013
12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013	12.500	0.013
12.500	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013
12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013
12.000	0.013	12.000	0.013	12.000	0.013	12.000	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013
11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013
11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013
11.500	0.013	11.500	0.013	11.500	0.013	11.500	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013
11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013
11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013	11.000	0.013
10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013
10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013
10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013	10.500	0.013
10.500	0.013	10.500	0.013	10.000	0.013	10.000	0.013	10.000	0.013	10.000	0.013	10.000	0.013	10.000	0.013
10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012
10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012
10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012	10.000	0.012
10.000	0.012	10.000	0.012	10.000	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012
9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012
9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012
9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.500	0.012	9.000	0.012	9.000	0.012
9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012
9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012
9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012
9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	9.000	0.012	8.500	0.012	8.500	0.012	8.500	0.012
8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012
8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012
8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012
8.500	0.012	8.500	0.012	8.500	0.012	8.500	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012
8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012
8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012
8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012	8.000	0.012
8.000	0.012	8.000	0.012	7.500	0.012	7.500	0.012	7.500	0.012	7.500	0.012	7.500	0.012	7.500	0.012
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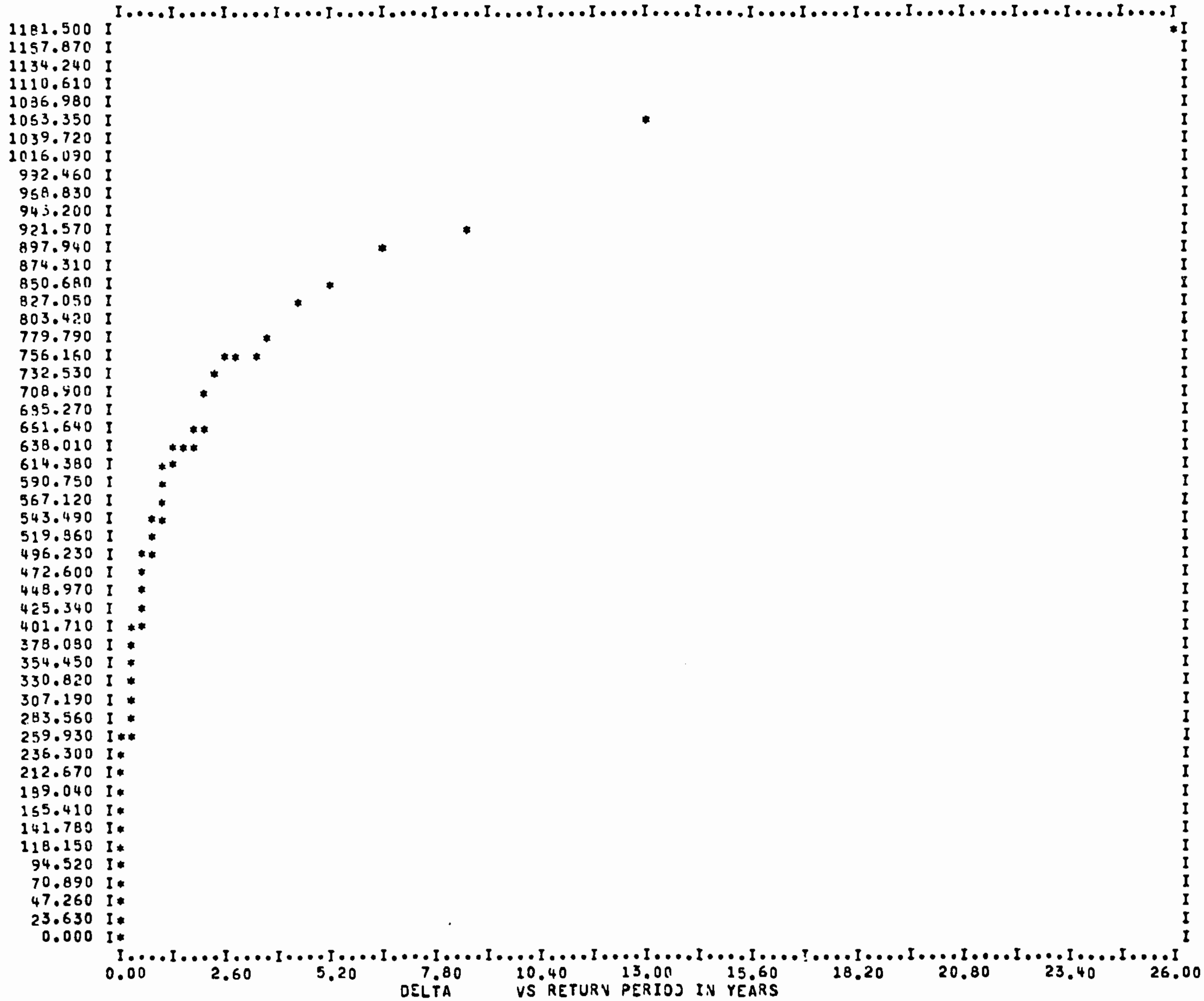
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23.40
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DELTA VS RETURN PERIOD IN YEARS

APPENDIX I

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APPENDIX J

GLOSSARY

Abatement - The lessening of pollution effects.

Access Time - Time required by computer to locate a word in core memory and transfer the word to a register.

Acre Foot - A unit for measuring the volume of water. It is equal to the amount of water needed to cover one acre of land with water one foot deep.

The Act - Public Law 92-500. "Federal Water Pollution Control Act Amendments of 1972."

Address - Name or number which identifies a particular storage location in the computer.

Advanced Waste Treatment - A further degree of treatment of wastewater, over and above so-called secondary treatment, in order to further purify these effluent waters by the removal of additional amounts or types of pollutants, or their modification into non-polluting forms.

Advection - The hydraulic mechanism by which water quality constituents are transported in the direction of the water flow.

Aerated Lagoon - A natural or artificial wastewater treatment lagoon (generally from 4 to 12 feet deep) in which mechanical or diffused-air aeration is used to supplement the oxygen supply.

Aeration - The act of exposing to the action of air, such as, to mix or charge with air.

Aerosol - A suspension of fine solid or liquid particles in air or gas.

Agricultural Land - Land in farms regularly used for agricultural production. The term includes all land devoted to crop or livestock enterprises; for example, the farmstead lands, drainage and irrigation ditches, water supply, cropland, and grazing land of every kind in farms.

Agronomic Practices - The soil and crop activities employed in the production of farm crops, such as selecting seed, seedbed preparation, fertilizing, liming, manuring, seeding, cultivation, harvesting, curing, crop sequence, crop rotations, cover crops, stripcropping, pasture development, etc.

Air Flotation Treatment - In this system, air bubbles are formed by introducing the gas phase directly into the liquid phase through a revolving impeller or through diffusers. Flotation is used to remove suspended matter and to concentrate biological sludges. Aeration alone for a short period is not particularly effective in bringing about the flotation of solids.

Algae - Any of numerous chlorophyll-containing plants of the phylum thallophyta that grow in either sea water or fresh water; seaweeds and pond scum are algae.

Algorithm - A rule or procedure for solving a logical or mathematical problem, frequently as incorporated into computer programs.

Alkaline - Having the qualities of a base; i.e., a pH above 7.0.

Alluvial - Of or pertaining to alluvium.

Alluvium - Clay, silt, sand, gravel, or other rock materials transported by flowing water and deposited in comparatively recent geologic time as sorted or semi-sorted sediments in riverbeds, estuaries, floodplains, and in fans at the base of mountain slopes.

Ambient - Completely surrounding or encompassing.

Amenable Industrial Wastes - Industrial wastewaters which contain no concentrations of substances which adversely affect sewer systems or inhibit the operation of sewage treatment processes which depend on biological reactions.

Ammonia-Nitrogen (NH_4) - A form of nitrogen which is an essential nutrient to plants (can cause algal blooms if all nutrients are present in sufficient quantities). A product of natural decomposition of fecal matter, urea and other animal protein.

Ammonification - The biochemical process whereby ammonia-nitrogen is released from nitrogen-containing organic compounds.

Ammonium Fixation - The adsorption or absorption of ammonium ions by the mineral or organic fractions of the soil in a manner that they are relatively unexchangeable by the usual methods of cation exchange.

Amortization Period - The period of time over which the cost of a capital item is amortized.

Analog - The representation of a numerical quantity by some physical variable; e.g., translation, rotation, voltage or resistance.

Analysis of Variance - A statistical technique which analyzes the variance which can be attributed to each of several factors which were varied singly or in combination.

Angle of Repose - The angle which the sloping face of a bank of loose earth, or gravel, or other material makes with the horizontal.

Actual Cost - Total annual expense of operating a treatment plant, including capital charges, fuel, power, chemicals, supplies and maintenance materials, taxes, insurance, and any other costs of operation.

Antecedent Conditions - Initial conditions in catchment as determined from hydrologic events prior to storm.

Antecedent Moisture Conditions (AMC) - The degree of wetness of a watershed at the beginning of a storm.

Antecedent Precipitation Index (API) - An indicator of the amount of water (in inches) present in the soil at any given time. The calculation of the API is based on the assumption that, during time periods of no precipitation, the soil moisture decreases logarithmically with time.

Application Rate - The rate at which a liquid is dosed to the land (in./hr, ft/yr, etc.).

Aquifer - Any geological formation that contains water, especially one that supplies wells and springs.

Area Rainfall Distribution Factor - The ratio of the rainfall in a selected area to that measured at a reference rainfall gage.

Artesian - The occurrence of groundwater under sufficient pressure to rise above the upper surface of the aquifer.

Artesian Aquifer - An aquifer overlain by a confining bed and containing water under artesian conditions.

Artificial Recharge - The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration from streams, wells, or spreading basins.

ASCII Code - American Standard Code for Information Interchange; a special eight channel paper tape code developed to facilitate data transmission between machines manufactured by different companies.

Asphalt Concrete - A paving material consisting of aggregate bound with asphalt, made by heating both materials to around 300°F, followed by mixing, delivering, spreading, and compacting while still hot.

Attenuation - The reduction of the magnitude of an event, as the reduction and spreading out of the impact of storm effects.

Autoanalyzer - Copywritten term referring to equipment which automates chemical tests on samples.

Available Nutrient - That portion of any element or compound in the soil that readily can be absorbed and assimilated by growing plants.

Average Cleansing Efficiency - The percent of deposited solids removed from a given length of sewer.

Backfill - That material that is used to cover a sewer in a trench extending from the sewer or select fill to the ground surface.

Background - A description of pollutant levels arising from natural sources, and not because of man's immediate activities.

Backwater Curve - The longitudinal shape of the water surface in a stream or open conduit where such water surface is raised above its normal level by a natural or artificial constriction or a change in grade.

Backwater Gate - A gate installed at the end of a drain or outlet pipe to prevent the backward flow of water or wastewater. Generally used on sewer outlets into streams to prevent backward flow during times of flood or high tide. Also called a tide gate.

Bar Screen - A screen composed of parallel bars, either vertical or inclined, placed in a waterway to catch debris, and from which the screenings may be raked. (Also called a rack).

Base Flow - Stream discharge derived from groundwater sources. Sometimes considered to include flows from regulated lakes or reservoirs. Fluctuates much less than storm runoff.

Baseline Sample - A sample collected during dry-weather flow (i.e., it does does not consist of runoff from a specific precipitation event).

Basin - The term "basin" means the streams, rivers, tributaries, and lakes and the total land and surface water area contained in one of the major or minor basins defined by EPA, or any other basin unit as agreed upon by the state(s) and the Regional Administrator.

Beneficial Use of Water - The use of water for any purpose from which benefits are derived, such as domestic, irrigation, industrial supply, power development, or recreation.

Benthic Deposits - Deposits of living, bottom dwelling organisms in a stream.

Bentonite - A clay with a high content of montmorillonite. It has an expanding lattice structure which enables it to absorb large amounts of water.

Best Available Technology (BAT) - "Not later than July 1, 1983, effluent limitations for categories and classes of point sources, other than publicly owned treatment works, ...shall require application of the best available technology economically achievable for such category or class, which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b)(2) of this Act...." (Act, Section 301(b)(2)(A)).

Best Practicable Control Technology (BPCT) - "Not later than July 1, 1977, effluent limitations for point sources, other than publicly owned treatment works, shall require the application of the best practicable control technology currently available as defined by the Administrator pursuant to

Section (304(b) of this Act..." (Act, Section 301(b)(1)(A). This is also referred to as Best Practical Technology (BPT).

Best Practicable Waste Treatment Technology (BPWTT) - "Waste treatment management plans and practices shall provide for the application of the best practicable waste treatment technology before any discharge into receiving waters, including reclaiming and recycling of water and confined disposal of pollutants so they will not migrate to cause water or other environmental pollution...." (Act, Section 201(b)).

Binary - The representation of a numerical quantity by use of the two digits 0 and 1.

Binary Coded Decimal (BCD) - A computer coding system.

BOD_5- Five-day Biochemical Oxygen Demand: A standard test for the amount of oxygen utilized in aerobic decomposition of a waste material during a five-day incubation at a specified constant temperature.

Biological Treatment Processes - Means of treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Trickling filters, activated sludge processes, and lagoons are examples.

Biome - A major biotic community including all plant and animal life, e.g., the North American Boreal forest, European deciduous forest.

Bit - A basic unit of computer storage, symbolically capable of representing only a "1" or a "0".

Bituminous - Any of various natural substances consisting mainly of hydrocarbons, such as asphalt, coal tar, pitch, maltha, gilsonite, etc.

Bond - A written promise to pay a specified sum of money (called the face value) at a fixed time in the future (called the date of maturity) and carrying interest at a fixed rate, payable periodically. The difference between a note and a bond is that the latter usually runs for a longer period of time and requires greater formality.

Bond Discount - The excess of the face value of a bond over the price for which it is acquired or sold.

Bond Premium - The excess of the price at which a bond is acquired or sold over its face value.

Boreal Forest - The forest extending across northern North America, consisting chiefly of conifers.

Brackish Water - Water containing dissolved minerals in excess of acceptable normal municipal, domestic, and irrigation standards, but less than that of sea water.

Buffer Strips - Strips of grass or other erosion-resisting vegetation between or below cultivated strips or fields.

Bypass - A pipe line which diverts wastewater flows away from or around, pumping or treatment facilities - or bypasses them - in order to limit the flows delivered to such facilities and prevent surcharging or adversely affecting their operation or performance.

Byte - A few bits (typically 6 or 8, depending upon the computer) of computer storage, required to store one character.

Calibration - The procedure of assigning values to the uncertain or unknown parameters in simulation model and adjusting them until model predictions correspond acceptably closely with observed prototype behavior.

Capital Charges - The portion of annual cost due to capital expense. Its components include depreciable capital charges, nondepreciable capital charges, and amortizable capital charges.

Capital Intensive - Measure requiring initial capital outlays for its development and relatively little cost for operation and maintenance.

Capital Investment - The total original cost of installed facilities including process and ancillary facilities, indirect construction cost, land, start-up costs, and working capital.

Carrying Charge Multiplier - The sum of "Interest Rate" and "Sinking Fund Factor"; when multiplied by bond principal yields capital charge.

Catch Basin - A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Catchment - Surface drainage area.

Channel - An elemental one-dimensional flow path having the usual properties of a water channel, which is used to construct certain receiving water simulation models. Also used in discussing the river channel itself.

Check Dam - Small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.

Chemical Coagulation - The destabilization and initial aggregation of colloidal and finely divided suspended matter in wastewater by the addition of a floc-forming chemical.

Chemical Oxygen Demand (COD) - A standard test which measures the total quantity of oxygen required for oxidation of organic (carbonaceous) matter to carbon dioxide and water using a strong oxidizing agent (dichromate) under acid conditions.

Chemical Weathering - Chemical reactions such as hydrolysis, or oxidation, by which rocks and minerals are broken down into soil.

Chlorine Demand - The demand for chlorine in a volume of water caused by organic and inorganic reductants. This quantity is defined as the difference between an initial chlorine concentration in a specific volume of water and the total available chlorine remaining at the end of a contact period.

Clay - The smallest mineral particles in soil, less than .004 mm in diameter; soil that contains at least 40 percent clay particles, less than 45 percent sand, and less than 40 percent silt.

Clay Seal - A barrier constructed of impermeable clay that stops the flow of water.

Clear Cutting - The felling of all trees in an area at one time.

Closed Basin - A basin is considered closed with respect to surface flow if its topography prevents the occurrence of visible outflow. It is closed hydrologically if neither surface nor underground outflow can occur.

Cohesion - The capacity of a soil to resist shearing stress, exclusive of functional resistance.

Cohesive Soil - A soil that when unconfined has considerable strength when air-dried and significant cohesion when submerged.

Coliform Bacteria - All the aerobic and facultative anaerobic, gram-negative nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. Used as an indicator of bacterial pollution.

Collector Sewer - A sewer located in the public way which collects the wastewaters discharged through building sewers and conducts such flows into larger interceptor sewers and pumping and treatment works. (Referred to also as "street sewer".)

Combined Sewer - A sewer receiving both surface runoff and sewage.

Commercial Forest - The forest which is both available and suitable for growing continuous crops of raw logs or other industrial timber products, judged capable of growing at least 20 ft^3 of timber per acre per year.

Compiler - A programmed component of a computer, which converts sophisticated programming language into elementary instructions and binary code.

Complete Sewer Separation - Separation of all public combined sewers into two separate and independent sewer systems, one for the handling of sanitary sewage and industrial and commercial wastes and the other for the handling of storm water flow.

Composite Sample - Any one of a number of types of integrated samples comprised of a number of sub-samples (aliquots) taken over a given time period and intended to represent average flow characteristics.

Concentration - The quantity of a given constituent in a unit volume or weight of water.

Conductivity - A measure of the ability of a material to conduct an electric current, the reciprocal of resistivity.

Confidence Interval - A mathematical method of stating both how close the value of a sample statistic is likely to be to the value of a universe parameter and the calculated or desired probability of that accuracy occurring.

Confined Aquifer - An aquifer which is bounded above and below by formations of impermeable or relatively impermeable material.

Connate Water - Water that was deposited simultaneously with the sediments, and has not since then existed as surface water or as atmospheric moisture.

Conservation - The protection, improvement, and use of natural resources according to principles that will assure their highest economic or social benefits.

Conservative Constituents - Materials carried in the hydrologic system which, on a class basis, do not interact with the chemical, physical, or biological elements of the environment to a significant extent, i.e., do not decay significantly as a function of time.

Conservative Substance - Non-interacting substance, undergoing no kinetic reaction; examples are salinity, total dissolved solids, total nitrogen, total phosphorus.

Consumptive Use (Water) - The sum of the quantity of water used by vegetative growth in transpiration or building of plant tissue and the quantity evaporated from adjacent soil or plant surfaces in a given specified time. Also referred to as Evapotranspiration.

Contamination - The degredation of natural water quality as a result of man's activities, to the extent that its usefulness is impaired.

Continuous Model - A model which simulates continuously varying processes over a long period of time, typically many years.

Contour Furrows - Furrows plowed approximately on the contour on pasture or rangeland to prevent soil loss and increase infiltration. Also, furrows laid out approximately on the contour for irrigation purposes.

Contractor's Indirect Field Costs - The contractor's construction costs for his supervision, construction equipment, small tools, consumables, temporary facilities, temporary services, support labor, insurance, taxes and miscellaneous field costs.

Convective Precipitation - Precipitation caused by lifting due to convective currents, as in thunderstorms.

Conventional Tillage - Land prepared by turning with a mold-board plow, discing, harrowing and cultivation of row crops.

Core City - The major jurisdiction within the SMSA.

Coshocton Wheel - A runoff sampler that divides the flow from an experimental area and retains a proportional part of it in a storage tank.

Cost-Effectiveness Analysis - The procedure for economic evaluation of wastewater treatment alternatives.

Coupled Constituent - A constituent whose nonconservative behavior is affected by the presence of a second constituent.

Cover Crop - A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards.

Critical Depth - The depth of water flowing in an open channel or partially filled conduit corresponding to one of the recognized critical velocities.

Critical Point - The point in a stream segment at which a water quality parameter reaches its worst value.

Curb Length - The distance of single street curb, or the length of one side of a street or other thoroughfare. Distinguished from street-length which normally represents two or more curb lengths.

Degree Days - Sum of negative departures of average daily temperature from 65°F; used to determine demand for fuel for heating purposes and snow melt calculations.

Demersal Fish - The resident fish species for a particular water body.

Demineralization - The process of reducing the concentration or removing the mineral salts from water.

Demographic - Pertaining to the science of vital and special statistics, especially with regard to population density and capacity for expansion or decline.

Denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Dependent Variable - Variable whose values are functionally determined by the independent variable.

Depletion (Ground Water) - The withdrawal of water from a groundwater source at a rate greater than its rate of replenishment, usually over an extended period of several years.

Depreciable Capital - Total plant cost less cost of land, salvage value, and working capital.

Depression Storage - Watershed capacity to retain water in puddles, ditches, depressions and on foliage.

Design Storm - A selected rainfall pattern of specified amount, intensity, duration, and frequency which is used as a design basis.

Desilting Area - An area of grass, shrubs, or other vegetation used for inducing deposition of silt and other debris from flowing water, located above a stock tank, pond, field, or other area needing protection from sediment accumulation.

Detention Dam - A dam constructed for the purpose of temporary storage of streamflow or surface runoff and for releasing the stored water at controlled rates.

Detention - The slowing, dampening, or attenuating of flows either entering the sewer system or within the sewer system by temporarily holding the water on a surface area, in a storage basin, or within the sewer itself.

Detention Time - The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Dielectric Constant - A measure of the ability of a material to hold a charge.

Diffusion - A process by which water quality constituents are transported, primarily depending upon the concentration gradients.

Digestion - The anaerobic or aerobic decomposition of organic matter resulting in partial gasification, liquefaction, and mineralization.

Dilution Ratio - The ratio of the quantity of combined sewer overflow or storm sewer discharge to the average quantity of diluting water available after initial mixing at the point of disposal or at any point under consideration. This is not only used with respect to sewer overflows but also it is used for any point or nonpoint sources of pollution.

Direct Capital Investment - The costs of construction associated with specific constructed equipment. This item includes purchase and installation of all equipment, buildings, and facilities and the cost (or value) of the land associated with them.

Direct Connection - Any opening, pipe, or other arrangement permitting storm water to directly enter a sanitary sewer.

Directly Connected Paved Area - The paved portion of a basin from which runoff water can reach a sewer without first passing over grassed area.

Direct Runoff - The water that enters stream channels during a storm or soon after. It may consist of rainfall on the stream surface, surface runoff, and seepage of infiltrated water.

Disinfection - The art of killing the larger portion of microorganisms in or on a substance with the probability that all pathogenic bacteria are killed by the agent used.

Dispersion - The mixing of polluted fluids with a large volume of water in a stream, estuary, or other body of water.

Dispersion, Longitudinal - The process by which prototype concentrations are changed as a result of the non-uniform velocity distribution at a channel cross-section.

Dispersion, Soil - The breaking down of soil aggregates into individual particles, resulting in single-grain structure. Ease of dispersion is an important factor influencing the erodibility of soils. Generally speaking, the more easily dispersed the soil, the more erodible it is.

Disposal Field - Area used for spreading liquid effluent for separation of wastes from water, degradation of impurities, and improvement of drainage waters. Synonymous with infiltration field.

Dissolved Solids (DS) - The total amount of dissolved material, organic and inorganic, contained in solution in water or wastes.

Distributed Load - A constituent load which enters the receiving water over a considerable distance, as in the case of groundwater seepage, rather than at a point as with a sewer outfall.

Diversity (Ecological) - Variety of species of plants and animals that compose a biotic community or ecosystem; often expressed as total number of different species.

DO - Dissolved oxygen, the amount of gaseous oxygen dissolved in a liquid sample.

DO Deficit - The extent by which the dissolved oxygen concentration falls below its saturation level.

Drainability - ability of the soil system to accept and transmit water by infiltration and percolation.

Drainage Basin - A geographical area or region which is so sloped and contoured that surface runoff from streams and other natural watercourses is carried away by a single drainage system by gravity to a common outlet or outlets; also referred to as a watershed or drainage area.

Drainage Density - Ratio of the total length of all drainage channels in a drainage basin to the area of that basin.

Drawdown - The lowering of the water table or piezometric surface caused by pumping or artesian flow.

Drop Spillway - Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Dry Weather Flow - The combination of sanitary sewage, and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year. Also that flow in streams during dry seasons.

Dual Treatment - Those processes or facilities designed for operating on both dry and wet-weather flows.

Dynamic - A process which may vary freely with time.

Dynamic Equilibrium - A process which may vary with time, but only over a limited period (e.g., one day) which repeats itself in cycles. Also known as dynamic steady state.

Dynamic Regulator - A semiautomatic or automatic regulator device which may or may not have movable parts that are sensitive to hydraulic conditions at their points of installation and are capable of adjusting themselves to variations in such conditions or of being adjusted by remote control to meet hydraulic conditions at points of installation or at other points in the total combined sewer system.

Ecosystem - A total organic community in a defined area or time frame.

Edge Effect - The influence of two communities upon their border, whereby composition, density, and diversity are affected, usually being more complex and greater than the two distinct communities (e.g., grassland bordering a woodland).

Effluent Limited Segments - "Any segment were it is known that water quality is meeting and will continue to meet applicable water quality standards or where there is adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Sections 301(b)(1)(A) and 301(b)(1)(B) of the Act." (40 CFR 130.11(d)(2).

Effluent Limitation - "The term 'effluent limitation' means any restriction established by a State or the Administrator on quantities, rates, and concentrations or chemical, physical, biological, and other constituents which are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean, including schedules of compliance." (Act, sec. 502 (11).

Effluent Standard - A restriction on the quantities or concentrations of constituents from an effluent source.

Emissions - Effluents discharged into the environment, specified as weight per unit time for a given pollutant from a given source.

Enterococci - A group of bacteria consisting of anaerobic spore-forming rods which indicate recent fecal pollution, sometimes referred to as fecal streptococci.

Entry Time - The time in minutes for runoff water to flow from the most remote point on the directly connected paved area to a specified inlet.

Equalization - The averaging (or method for averaging) of variations in flow and composition of a liquid.

Equivalent Days of Accumulation (EDA) - A measure of the relative days of accumulation of pollutants on a street surface as a function of rainfall and sweeping history and respective removal efficiencies.

Equivalent Uniform Depth (E.U.D.) - The average amount of rainfall over an area developed from the constituent rain gage stations and their associated Thiessen Polygons contained within the network of gaging stations.

Erosion, Sheet - The removal of a fairly uniform layer of soil from the land surface by runoff water.

Estuary - The mouth of a river, where tidal effects are evident and where fresh water and sea water mix.

Eutrophication - The progressive enrichment of surface waters particularly non-flowing bodies of water such as lakes and ponds, with dissolved nutrients, such as phosphorous and nitrogen compounds, which accelerate the growth of algae and higher forms of plant life and result in the utilization of the useable oxygen content of the waters at the expense of other aquatic life forms.

Evapotranspiration - The combined processes of evaporation from land, water, and other surfaces, and transpiration by plants.

Event Model - A model which simulates the processes occurring in just a single event, typically for a near-steady-state condition or for only one major variation during a relatively short period of time.

Exchange Coefficient - The fraction of material leaving an embayment during ebb tide, which returns on the following flood tide.

Executive Program - A program, often supplied with a computer, which controls loading and relocation of all software (much unknown to the programmer) required to execute a job entered by a programmer.

Exfiltration - The leakage or discharge of flows being carried by sewers out into the ground through leaks in pipes, joints, manholes or other sewer system structures; the reverse of "infiltration."

Extraneous Flow - That portion of the liquid carried in the sewer that is not normally classified as sanitary, commercial, or industrial waste or sewage.

Factorial Arrangement - A method for apportioning the number of tests required for an Analysis of Variance. Given the formula $N=X^k$ where X is the number of independent variables and k is the number of levels (factors).

Fecal Coliform - Fecal coliform are indicators of human and animal pollution and are expressed as numbers of bacteria per volume of sample.

Feedlot - A relatively small, confined land area for raising and fattening cattle.

Filter Strip - Strip of permanent vegetation above farm ponds, diversion terraces, and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

First Flush - The condition, often occurring in storm sewer discharges and combined sewer overflows, in which a disproportionately high pollutional load is carried in the first portion of the discharge or overflow.

Floatable Trap - A device or structural configuration which intercepts floatable solids and retains these materials at a desired location until removed and disposed of by predetermined means.

Flooding - A method of surface application of water which includes border strip, contour check, and spreading methods.

Floodplain - The flat ground along a stream course which is covered by water at flood stage.

Flow Augmentation - The addition of water or wastewater effluents to surface water sources, for the purpose of increasing the volume of such waters as rivers, lakes or other inland bodies of surface water; in the case of groundwater, the addition of wastewater effluents which will increase the volume of the underground water source and raise or help maintain the groundwater table.

Fluvial Sediment - Those deposits produced by stream or river action.

Food Chain - Refers to the dependence for food of organisms upon each other in a series, beginning with plants and ending with the largest carnivores.

Food Web - The combination of all of the food chains in a community.

Form Factor (FF) - An indicator of the drainage characteristics of a watershed.

Foundation Drain - A pipe or series of pipes which collects groundwater from the foundation or footing of structures and discharges these waters into sanitary, combined or storm sewers, or to other points of disposal, for the purpose of draining unwanted waters away from such structures.

Frequency Distribution - A curve which shows the arrangement or distribution of the occurrences of events or quantities pertaining to a single element in order of their magnitude.

Frequency of Storm (Design Storm Frequency) - The anticipated period in years which will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows which occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

F Value - A number corresponding to the degree of confidence of a certain statistical correlation. A correlation with an "F" less than one is generally discounted.

General Obligation Bonds - Bonds secured by the issuer's pledge of full faith, credit, and taxing power for payment.

Geomorphic Province - A region in which the majority of land features have a degree of similarity as to its origin and development.

Grade Stabilization Structure - A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further head-cutting or lowering of the channel grade.

Grassed Waterway - A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from cropland.

Grease - In sewage, grease includes fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils, and other nonfatty materials. Substances soluble in n-hexane.

Grit - Heavier and larger solids which, because of their size and specific gravity, settle more readily to the floor of a swirl concentrator chamber by the phenomenon of gravity classification.

Ground Water Infiltration - The seepage of groundwater into an opening in a sewer.

Ground Water Basin - A ground water reservoir together with all the overlying land surface and the underlying aquifers that contribute water to the reservoir. In some cases, the boundaries of successively deeper aquifers may differ in a way that creates difficulty in defining the limits of the basin.

Ground Water Recharge - Inflow to a ground water reservoir.

Ground Water Reservoir - An aquifer or aquifer system in which ground water is stored. The water may be placed in the aquifer by artificial or natural means.

Ground Water Storage Capacity - The reservoir space contained in a given volume of deposits. Under optimum conditions of use, the useable ground water storage capacity volume of water that can be alternately extracted and replaced in the deposit, within specified economic limitations.

Groundwater Table - The free surface of the groundwater, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

Gully - A channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains or during the melting of snow.

Gully Control Plantings - The planting of forage, legume, or woody plant seeds, seedlings, cuttings, or transplants in gullies to establish or reestablish a vegetative cover adequate to control runoff and erosion.

Hardness - A property of water caused by the presence of calcium and magnesium, which is reflected in the amount of soap necessary to form suds and incrustations in appliances and pipes when the water is heated. It is expressed as an equivalent amount of calcium carbonate.

Hardware Computer - The physical equipment and devices which comprise a computer or computer system component.

Hard Water - Water with over 60 mg/l of hardness.

Heat Budget - The accounting of the various factors governing water temperature.

Heavy Metals - Metallic elements with high molecular weights, generally toxic in low concentrations to plant and animal life. Examples are: mercury, chromium, cadmium, arsenic, and lead.

Herbicide - A chemical substance used for killing plants, especially weeds.

Higher Heating Value - Heat released in combustion of dry fuel where combustion gases are cooled to 66^{o}F and all water vapor is condensed prior to release to the atmosphere.

Homogeneous - Consisting throughout of identical or closely similar material whose proportions and properties do not vary.

Humus - That more or less stable fraction of the soil organic matter remaining after the major portion of added plant and animal residues have decomposed; usually amorphous and dark colored.

Hydraulic Barrier - A means of augmenting the groundwater volume and raising the level of the water table in order to create hydraulic gradients higher than the level of surrounding waters which would tend to inflow or infilter into the groundwater aquifer and introduce contaminants or other unwanted substances which could adversely affect its quality.

Hydraulic Radius - A measure of the depths of flow in a conduit or channel; more formally it is the cross-sectional area of flow divided by the perimeter of the channel in contact with the fluid.

Hyetograph - An intensity-time graph for rainfall derived from direct measurements.

Hydrograph - A flow versus time graph derived from direct measurement.

Hydrological - Pertains to the branch of hydrology that treats surface and groundwater; its occurrence and movements; its replenishment and depletion; the properties of rocks which control groundwater movement and storage; and the methods of investigation and utilization of groundwater.

Hydrological Budget - An accounting of all inflow to, outflow from, and changes in storage within a hydrologic unit such as a drainage basin, soil zone, aquifer, lake, or project area.

Hydrologic Cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrology - The science dealing with water in the atmosphere, on the earth's surface, and underground; its properties, laws, geographical distribution, etc.

Illicit Connection - An unauthorized connection from a residence, apartment, etc., which introduces liquid other than sewage (usually stormwater) into the sanitary sewer.

Impervious - Not permitting penetration or passage (e.g., of water).

Independent Variable - A parameter which can be directly manipulated and which mathematically, has a correlation coefficient of zero.

Indirect Capital Investment - Capital costs not directly associated with or charged directly to a single cost item. Usually consists of engineering and design; construction expenses such as temporary construction facilities, construction equipment, tools, supplies and utilities, construction supervision and field engineering, and payroll burden; contractor's fees; plant start-up; and interest during construction.

Indirect Runoff - That portion of runoff that contributes to the runoff pollution that enters receiving water as point discharges from separate storm sewer systems and as general surface runoff.

Industrial Waste - The liquid wastes from industrial processes as distinct from domestic or sanitary sewage.

Infiltration - The water entering a sewer system, including sewer service connections, from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, and manhole walls. Infiltration does not include, and is distinguished from, inflow. Infiltration includes all extraneous water during wet weather, i.e., groundwater and surface water.

Infiltration, Gross - The total infiltration entering a sanitary sewer by direct connections and by percolation through the soil.

Infiltration Inflow - A combination of infiltration and inflow waste water volumes in sewer lines that permits no distinction between the two basic sources and has the same effect of usurping the capacities of sewer systems and other sewerage system facilities.

Infiltration-Percolation - An approach to land application in which large volumes of wastewater are applied to the land, infiltrate the surface, and percolate through the soil pores.

Infiltration Rate - A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions, including the presence of an excess of water.

Infiltration Specification - A condition for acceptance of a sanitary sewer from a contractor by a sewer authority. This specification limits the amount of infiltration acceptable in a sewer system.

Inflow - The water discharged into a sewer system, including service connections, from such sources as, but not limited to, roof leaders, cellar, yard and area drains, foundation drains, cooling water dischargers, drains from spring and swampy area, manhole covers, cross connections from storm sewers and combined sewers, catch basin, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

Initial Abstraction - Initial precipitation loss including interception and depression storage.

Inplace Pollution Source - Time build-up of pollutant load deposited in a receiving stream-bed and existing as a load upon that receiving water.

In-System Storage - Facilities or the capacity for holding or retaining of flows of sewage and other wastes in subterranean storage chambers or other portions of the sewer system in order to minimize overflows from combined sewers and permit the treatment of large volumes of such flows.

Intercepted Surface Runoff - That portion of surface runoff that enters a sewer, either storm or combined, directly through catch basins, inlets, etc.

Interception Ratio - Pertaining to combined sewer regulators, it is the ratio of the maximum flow which can be directed to the interceptor sewer to the normal dry-weather flow.

Interceptor Sewer - A sewer which receives dry-weather flows from a combined collection sewer system and pre-determined additional amounts of storm flow by means of any form of regulating device and then conducts these flows to point by treatment or discharge.

Invert - The lowest point on the inside of a sewer or other conduit.

Irrigation Return Flow - Irrigation water which is not consumed in evaporation or plant growth, and which returns to a surface stream or groundwater reservoir.

Isoquants - Curves representing combinations of the inputs yielding the same amount of output.

Junction - In rivers, the point of connection of two upstream stretches or segments. In some estuary models a junction is a segment of the estuary.

Kinetics - The dynamics of physical, chemical and biological reaction processes. Distinct from kinematics in that mass effects are considered.

Lacustrine - Deposits which have accumulated in lakes or marshes.

Lagoon - A shallow pond, usually man-made, to treat municipal or industrial wastewater.

Land Application - The discharge of wastewaters onto land areas, as an alternative treatment procedure to conventional method or disposal of effluents into surface water sources.

Land Cost - Cost of land acquisition including surveys, condemnation proceedings, fees, taxes, leases, and other financial and legal actions.

Land Subsidence - The lowering of the natural land surface in response to earth movements; lowering of fluid pressure; removal of underlaying supporting material by mining or solution of solids, either artificially or from natural cuases; hydrocompaction; etc.

Land Use - Differentiating the spatial arrangements and activity patterns of land areas.

Land Use Controls - Methods for regulating the uses to which a given land area may be put, including such things as zoning, subdivision regulation, and flood-plain regulation.

Lateral Sewer - A sewer which receives wastes only from the house connections.

Leachate - The liquid that has percolated through the soil or other media and has extracted dissolved or suspended materials from it.

Leaching - The removal of chemical or physical components from soil or other media by dissolution or physical adsorption action of percolating water.

Linked Constituent - A constituent whose nonconservative behavior is affected by the presence of one or more other constituents.

Limited Body Contact Recreation - Use of natural waters, such as rivers, lakes, and coastal waters, for recreational purposes which do not represent deliberate or planned total body immersion such as swimming or bathing; thus, use of waters for boating, fishing, and related sports.

Loading - The dry weight, in pounds, of some material that is being added to a process or disposed of.

Loadograph - A graph of pollutant load as a function of time over a defined period of time (pollutograph).

Logic - The science of combining electronic components in order to define the interactions of signals in an automatic data processing system.

Main Sewer - A sewer to which one or more branch sewers are tributary and which serves a large territory; also called a trunk sewer.

Materials Balance - An accounting of all transfers of mass from one point or state to other points or states, such that the total original mass is entirely accounted for (Also Mass Balance).

Mathematical Model - The characterization of a process or concept in terms of mathematics, which allows the manipulation of variables in an equation to determine how the process would act in different situations.

Mean Velocity - The average velocity of a stream flowing in a channel or conduit at a given cross section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Mechanical Practices - Those management techniques for soil and water conservation that primarily change the surface of the land or that store, convey, regulate, or dispose of runoff water without excessive erosion.

Mesophyte - A plant growing under conditions of well-balanced moisture supply, as distinguished from one which grows under dry or desert conditions (xerophytes) or very wet conditions (hydrophytes).

Microstrainer - Variable low-speed (up to 4 to 7 rpm), continuously backwashed, rotating drum filters operating under gravity conditions.

Mineralization - The process of accumulation of mineral elements and/or compounds in soil or water.

Mixing Intensity - The degree of turbulence created by the expenditure of mechanical energy.

Most Probable Number (MPN) - A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Mulching - The addition of materials (usually organic) to the land surface to curtail erosion or retain soil moisture.

Multiple Tube Technique - A technique to determine the density of coliform bacteria in a given volume of water carried out by dividing the sample into multiple portions and testing each portion individually.

Municipal Bonds - Bonds issued by a state, territory, or possession of the United States, or by any municipality, political subdivision, or public agency or instrumentality.

Natural Erosion - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man.

Natural Leaching - The removal by a solvent of the more soluble minerals in soil or rocks by percolating waters.

Neutralization - The process of adding an acid or alkaline material to waste water to adjust its pH to a neutral position of 7.0.

Nitrate (NO_3) - A form of nitrogen which is an essential nutrient to plants (can cause algal blooms if all other nutrients are present in sufficient quantities). Product of bacteria oxidation of other forms of nitrogen, from the atmosphere during electrical storms and from fertilizer manufacturing.

Nitrification - The biological oxidation of ammonium salts to nitrites and the further oxidation of nitrites to nitrates.

Nitrogen (Ammonia) - A product of microbiologic activity sometimes accepted as evidence of sanitary pollution in surface waters.

Nitrogen, Available - Usually ammonium, nitrite, and nitrate ions, and certain simple amines are available for plant growth. A small fraction of organic or total nitrogen in the soil is available at any time.

Nonconservative Constituent - A constituent whose total mass undergoes time-dependent interaction in receiving waters through physical, chemical or biological reactions.

Nondepreciable Capital - Land and working capital and salvage value of depreciable capital.

Nonpoint Source Pollution - A pollutant which enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Nonsewered Urban Runoff - Surface runoff in an urban drainage area which drains into a receiving stream without passing through a sewer system.

Non-Stationary Source - Mobile activity which produces air pollutant emissions.

Numerical Dispersion - Error in models using numerical approximations, caused by the use of grids of discrete size. Also called discretization error.

Nutrient - A substance necessary for the growth and reproduction of organisms.

Nutrient, Available - That portion of any element or compound in the soil that can be readily absorbed and assimilated by growing plants.

Off-System Storage - Facilities for holding or retaining excess flows from combined sewers, over and above the carrying capacity of the interceptor sewers, in chambers, tanks, lagoons, ponds, or other basins which are not a part of the subsurface sewer system.

Organic Nitrogen - Nitrogen combined in organic molecules such as protein, amines, and amino acids. Gradually converted to ammonia-nitrogen and to nitrites and nitrates if aerobic conditions prevail.

Outfall - The point, location, or structure where wastewater or drainage discharges from a sewer to a receiving body of water.

Overflow - A pipe line or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regulator device has allowed the portion of the flow which can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Overland Flow Irrigation - A process of land application of wastewater which provides spray distribution onto gently sloping soil of relatively impervious nature, such as clays, for the purpose of attaining aerobic bio-treatment of the exposed flow in contact with ground cover vegetation, followed by the collection of runoff waters in intercepting ditches or channels and the return of the wastewater back to the spray system or its discharge into receiving waters; sometimes called spray runoff.

ORP - Oxidation Reduction Potential: A measurement of relative concentrations of oxidants and reductants in solution.

Oxidation Pond - A basin for the retention of wastewater, on a batch or continuous flow basis, where organic materials can undergo aerobic stabilization in the presence of adequate oxygen made available by either natural or various mechanical means of aeration and mixing.

Partial Separation - Removal of some portion of all the elements of storm drainage into a combined sewer; e.g., streets and parking areas only, leaving roof and foundation drainage to enter the combined sewer.

Pathogen - A microorganism capable of causing disease.

Percolation - The movement of water beneath the ground surface both vertically and horizontally, but above the groundwater table.

Perennial Yield (Ground Water) - The amount of usable water of a ground water reservoir that can be withdrawn and consumed economically each year for an indefinite period of time. It cannot exceed the natural recharge to that ground water reservoir.

Periodic Flushing - Systematic introduction of liquid into sewers at relatively high rates.

Permeability Coefficient - The volume of water, in cubic feet, under a head of one foot, that will pass through a square foot of porous surface in one day.

Pervious - Allowing movement of water.

Pesticides - Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algalcides rodent poisons, nematode poisons, fungicides, and growth regulators.

Phosphorus, Available - Inorganic phosphorus which is readily available for plant growth.

Photogrammetry - The science of making surveys and maps through the use of photographs.

Physical-Chemical Treatment - A method of semi-advanced or advanced wastewater treatment which combines the use of chemicals, such as activated carbon or lime, to induce reactions such as coagulation, absorption or adsorption of pollutional substances, with processes which physically remove unwanted contaminants by such means as straining, screening, settling or filtering.

Physiographic Province - A region, all parts of which are similar in geologic structure and climate and which consequently has a unified geomorphic history.

Pipe Tests - Various methods for testing sewer lines (after construction and in service) to ascertain whether or not infiltration allowances have been met, and locating the sources of infiltration that exceed construction specifications. Such tests include infiltration tests, exfiltration tests, air tests, and such means as smoke bomb tests to locate sources of infiltration in new and existing sewer lines.

Planning Process - Strategy for directing resources, establishing priorities, scheduling actions, and reporting programs toward achievement of program objectives.

Plant Operating Factor - The ratio of average annual volume flow of wastewater divided by design capacity annual flow of wastewater.

Plug Flow - The passage of liquid through a chamber such that all increments of liquid move only in the direction of flow and at equal velocity.

Plume - An area of contaminated water originating from a point source and influenced by such factors as the local water flow pattern, density of pollutant, and characteristics of the dissimilar streams.

Point Source - "The term 'point source' means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged." (Act, Section 502(14).

Pollutant - "The term 'pollutant' means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water." (Act, Section 502(6).

Pollution Parameters - The physical, chemical, and bacterial contaminants which can be quantified to indicate pollution levels.

Pollutograph - A graph of pollutant concentration as a function of time during a rainfall/runoff event.

Polychlorinated Biphenyls (PCB) - Organochlorine compounds of a pesticidal nature which are usually used for industrial purposes (such as plastic manufacture).

Population Equivalent of Industrial Wastewater - The calculated number of people contributing sewage equal in strength to a unit volume of the wastes discharged into a sewer system, in terms of biochemical oxygen demand; a common base for computing the population equivalent is that one person contributes 0.17 pounds of 5-day BOD in the form of sanitary sewage per day.

Porous Pavement - A pavement through which water can flow at significant rates.

Practice Factor "P" - A factor based on a maximum value of 1.0 that reflects the effectiveness of supporting conservation practices in controlling erosion. The factor is used in the Universal Soil Loss Equation.

Pretreatment - The removal of material such as gross solids, grit, grease, and scum from sewage flows prior to physical, biological, or physical-chemical treatment processes to improve treatability. Pretreatment may include screening, grit removal, skimming, preaeration, and flocculation.

Primary Treatment - Processes or methods, that serve as the first stage treatment of sewage and other wastes intended for the removal of suspended and settleable solids by gravity sedimentation; provides no changes in dissolved and colloidal matter in the sewage or wastes flows.

Probability Curve - A curve that expresses the cumulative frequency of occurence of a given event, based on an extended period of past occurrences.

Production Well - A well from which ground water is obtained.

Proprietary Model - A computer model developed privately by a consultant/contractor who charges for its use.

Purging - The act of reversing flow or using high pressure liquid or gas to clear a pipeline of a plug of solids.

R Value - Multiple regression value: The correlation value to many independent variables with a single dependent variable, e.g., air temperature and solar radiation on water temperature.

Rainfall Intensity - The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Rational Method - A means of computing storm drainage flow rates (Q) by use of the formula Q=ciA; where c is a coefficient describing the physical drainage area, i is the rainfall intensity and A is the area.

Raw Sewage Sludge - The accumulated suspended and setteable solids of sewage deposited in tanks or basin mixed with water to form a semi-liquid mass.

Reach - The smallest subdivision of the drainage system consisting of a uniform length of open channel or underground conduit. Also, a discrete portion of river, stream or creek. For modeling purposes a reach is somewhat homogeneous in its physical characteristics.

Reaeration - The process entraining air in liquids such as wastewater effluents, etc. Reaeration is proportional to the dissolved oxygen deficit; its rate will increase with increasing deficit.

Real Time Control - The remote control of sewerage systems by digital computer. Can either be fully automated or can be partially manually controlled by the computer operator.

Recharge Basin - A basin provided to increase infiltration for the purpose of replenishing ground water supply.

Regulator - A structure installed in a canal, conduit, or channel to control the flow of water or wastewater at intake, or to control the water level in a canal, channel, or treatment unit. In the context of combined sewers, a regulator is a device or apparatus for controlling the quantity and quality of admixtures of sewage and storm water admitted from a combined sewer collector sewer into an interceptor sewer or pumping or treatment facility, thereby determining the amount and quality of the flows discharged through an overflow device to receiving waters, or to retention or treatment facilities.

Relative Correlation - A measure of the ability of a general relationship to predict the value of an experimental parameter.

Relief Ratio - The ratio between the relief (maximum difference in elevation) of watershed and the maximum length of watershed.

Residential Density - The number of persons per unit of residential land area. Net density includes only occupied land. Gross density includes unoccupied portions of residential areas, such as roads and open space.

Residual Wastes - Those solid, liquid, or sludge substances from man's activities in the urban, agricultural, mining and industrial environment which are not discharged to water after collection and necessary treatment.

Retention - The storage of stormwater to prevent it from entering the sewer system; may be temporary or permanent.

Return Flow - That part of a diverted flow which is not consumptively used and which returns to a source of supply (surface or underground).

Riparian Rights - A principle of common Law which requires that any user of waters adjoining or flowing through his lands must so use and protect them that he will enable his neighbor to utilize the same waters undiminished in quantity and undefiled in quality.

Riprap - Rough stone of various sizes placed compactly or irregularly to prevent erosion.

Roof Leader - A drain or pipe that conducts storm water from the roof of a structure, downward and thence into a sewer for removal from the property, or onto or into the ground for runoff or seepage disposal.

Routine - A sequence of computer instructions which performs a specific computational function within a larger program.

Routing - Storing, regulating, diverting or otherwise controlling the peak flows of wastewater through a collection system according to some prearranged plan.

Runoff - That portion of the precipitation on a drainage area that is discharged from the area in stream channels.

Runoff Coefficient - Fraction of rainfall that appears as runoff after subtracting depression storage and interception. Typically accounts for infiltration into ground and evaporation.

Sag Curve - A curve which describes the gradual drop to some minimum value followed by an increase to normal levels of the dissolved oxygen in a flowing stream following the addition of some oxygen demanding material such as sewage.

Salinity - Salt content concentration of dissolved mineral salts in water or soil.

Salinization - The process of accumulation of soluble salts in soil or water.

Salt Water Barrier - A physical facility or method of operation designed to prevent the intrusion of salt water into a body of fresh water. In underground water management a barrier may be created by injection of relatively fresh water to create a hydraulic barrier against salt water intrusion.

Salt Water Intrusion - The invasion of a body of fresh water by salt water. It can occur either in surface or groundwater bodies.

Salt Wedge - A wedge shaped volume of salt water beneath a body of fresh water where a river and ocean meet in an estuary area.

Sanitary Sewer - A sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with minor quantities of ground, storm, and surface waters that are not admitted intentionally.

Scour - The clearing and digging action of flowing air or water, especially the downward erosion by stream water in sweeping away mud and silt on the outside of a curve or during a flood.

Scum Ring - A circular plate or baffle encircling the overflow weir, located at a predetermined distance from the weir and at a depth that will cause it to retain floatables and scum and prevent them from passing over the weir crest with the clarified liquid.

Secchi Disk - A disk, painted in four quadrants of alternating black and white, which is lowered into a body of water. The measured depth at which the disk is no longer visible from the surface is a measure of relative transparency.

Secondary Treatment - Processes or methods for the supplemental treatment of sewage and other wastes, usually following primary treatment, to effect additional improvement in the quality of the treated wastes by biological means of various types, including activated sludge treatment or trickling filter treatment; designed to remove or modify organic matter. Treatment of wastewater which meets the standards set forth in 40 CFR 133.

Section - A portion of a river basin, generally larger than a segment, which is bounded by headwaters or major river junctions.

Sedimentation - The process of subsidence and deposition of suspended matter carried by water, sewage, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point where it can transport the suspended material.

Sediment Delivery Ratio - The fraction of the soil eroded from upland sources that actually reaches a continuous stream channel or storage reservoir.

Seepage Rate - Calculated from the porous permeability coefficient, is the inches of rain that would pass through porous pavement in one hour, with no water standing on the surface. A head exists due to the thickness of the pavement.

Segment - A discrete portion of a water body of somewhat homogenous character, as represented in mathematical models.

Separate Sanitary Sewer - A sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants and institutions, together with minor quantities of ground, storm and surface waters that are not admitted unintentionally.

Separate Storm Sewer - A sewer that carries storm water and surface waters, street wash and other wash waters, or drainage, but excludes domestic wastewater and industrial wastes.

Service Life - The period during which the use of a property is economically feasible; synonymous with "economic life" and "useful life."

Sewer-Use Ordinance - A regulation, code, or ordinance enacted by a jurisdiction to specify the types and volumes of waste waters that can be discharged into sewer system, the waste waters that cannot be so discharged, and the fees or charges to be imposed for the privilege of discharging those wastes and volumes which are permitted.

Side Weir - A regulator which is essentially a long slot cut into the side of a sewer. Normal dry weather flow continues through the sewer while the increased depth during a storm will allow excessive flows to exit through the slot to some alternate point as an overflow.

Simulation - Representation of physical systems and phenomena by computers, models and other equipment.

Single Process Unit - A water treatment facility designed and constructed to carry out one or more steps in the wastewater treatment process; if geographically distinct, usually defined by all facilities within the battery limit. Includes all equipment, instrumentation, piping, accessory electrical equipment, plant site improvement, plant structures, and buildings directly associated with the unit.

Singular Constituent - A constituent whose behavior is not affected by the presence of other constituents.

Sinking Fund Bonds - Bonds issued under an agreement which requires the utility to set aside periodically a sum which, with accrued earnings, will be sufficient to redeem the bonds at their stated date of maturity.

Sludge Digestion - A process by which organic or volatile matter in sludge is gasified, liquefied, mineralized, or converted into more stable organic matter through the activities of living organisms.

Sluice Gate - A vertically sliding gate of any shape used to control or shut off flow in a sewer or other channel.

SMSA - Except in the New England states, a standard metropolitan statistical area is a county or group of contiguous counties which contain at least one city of 50,000 inhabitants. In the New England states, SMSA's consist of towns and cities instead of counties.

Soft Water - Water containing 60 mg/l or less of hardness.

Spoiler (Energy Dissipating Baffle) - A plate or structural plane constructed from the scum ring to the weir plate in a swirl concentrator chamber for the purpose of preventing or dampening the development of free vertex flow conditions and minimizing agitation and rotational flow over the discharge weir.

Spray Irrigation - The application of wastewater to land areas by means of stationary or moving sprays which distribute the liquid in sheet, particle or aerosol mist form.

Stability - A characteristic of numerical models. Unstable models develop large numerical errors as computations proceed. Numerical errors reduce in stable models as computations proceed.

Stabilized Grade - The slope of a channel at which neither erosion nor deposition occurs.

Standard Methods - Methods of analysis of water sewage and sludge approved by a Joint Committee by the American Public Health Association, American Water Works Association, and Federation of Sewage Works Association.

Static Regulator - A regulator which has no moving parts or has movable parts which are insensitive to hydraulic conditions at the point of installation and which are not capable of adjusting themselves to meet varying flow or level conditions in the regulator-overflow structure.

Steady-State - Quantities (e.g., inputs and solution) which do not vary with time (but may vary over space).

Step Function - A mathematical function that rises in zero time to unity and remains at unity for all time (a normalized D.C. voltage, for example).

Stepwise Regression - A statistical technique whereby a sequence of linear regression equations are computed in a stepwise manner, e.g. each independent variable is entered into the equation as it becomes the greatest remaining effect upon the variability of the dependent variable.

Stochastic - The property of being random with respect to time.

Storm Frequency - The time interval between major storms of predetermined intensity and volumes of runoff for which storm sewers and combined sewers, and such appurtenant structures as swirl concentrator chambers, are designed and constructed to handle hydraulically without surcharging and backflooding: e.g, a five-year, ten-year or twenty-year storm.

Storm Sewer - A sewer which carries storm water and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. (Also called a Storm Drain).

Storm Water Infiltration - The entrance of stormwater into a sanitary sewer.

Subarea - A subdivision of a subcatchment (generally based upon a single land use but may be identical to a subcatchment).

Sub-Basin - A physical division of a larger basin which is associated with one reach of the storm drainage system.

Subcatchment - A subdivision of a drainage basin (generally determined by topography and pipe network configuration).

Subdrain - A pervious backfilled trench containing a pipe or stone for the purpose of intercepting groundwater or seepage.

Subroutine - Computer programming terminology which refers to a small program for an operation that is repeated many times within the main program.

Surcharge - The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.

Surface Runoff - Precipitation that falls onto the surfaces of roofs, streets, ground, etc., and is not absorbed or retained by that surface, thereby collecting and running off.

Telemetry - Data transmission over long distances via telephone or telegraph lines by electromagnetic means.

Terrace - An embankment or combination of an embankment and channel constructed across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Tertiary Treatment - A third stage of treatment of sewage and other wastes, following primary and secondary treatment, for the purpose of further improving the quality of the treated waters by the removal or modification of constituents which have not been removed or modified by previous treatment steps.

Thermocline - A layer in a thermally stratified body of water in which the temperature changes rapidly within a small increment of depth relative to the remainder of the water body.

Thiessen Polygon - A device for determining the zone within which data taken at a rain gage station are applicable in a network of gaging stations.

Tidal Averaging - Averaging of processes such as water currents and pollutant transport over an entire tidal cycle. This averaging may reduce or eliminate the need to solve for time variations in tidally influenced waters.

Time Sharing - Use of a computer or device for two or more purposes during the same overall time interval, done by interspersing component actions in time.

Topographic Factor "LS" - A dimensionless factor used in the Universal Soil Loss Equation to represent the combined effects of slope length and steepness.

Topography - General term to include characteristics of the ground surface such as plains, hills, mountains; degree of relief, steepness of slopes, and other physiographic features.

Total Dissolved Solids - The dissolved salt loading in surface and subsurface waters.

Total Solids - The solids in water, sewage, or other liquids. It includes the dissolved, filterable, and nonfilterable solids.

Toxic Metals - Any metal substances in wastewater which could be toxic or poisonous to grasses, to crops, or to groundwater, and which could adversely affect those who ingest or imbibe these substances; common examples of toxic metals are copper, cadmium and boron.

Transient - A temporary and brief time-varying solution during readjustment to equilibrium or dynamic equilibrium, resulting from a sudden change in input(s).

Transpiration - The process by which plants of all types of agricultural, horticultural and silvicultural growths dissipate water or moisture into the atmosphere from stomata of leaves or other surfaces, in the form of a vapor; dissipation of water by direct evaporation from the surface of plants, bark or other membranes, stomata, and lenticula into the atmosphere.

Trickling Filter - A filter consisting of an artificial bed of coarse material, such as broken stone, clinkers, slate, slats, brush, or plastic materials, over which sewage is distributed or applied in drops, films, or spray from troughs, drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the sewage.

Ultimate Oxygen Demand - The total amount of oxygen that is utilized by bacteria in the decomposition of sewage. This includes both the carbonaceous BOD and nitrogenous BOD.

Uncontrolled Storage - Storage not controlled by any remotely operated gates but depending entirely on weir or river elevations.

Underdrain System - A system of pipes or ducts, placed underground, to intercept and collect percolated wastewaters and to return these waters to a predetermined location for a predetermined purpose, often to prevent the discharge of such underground water into water sources which it is intended to protect.

Universal Soil Loss Equation - Predicts the short-term rates of soil loss for localized areas. This equation takes into account the influence of the total rainfall energy for a specific area rather than rainfall amount.

Urbanized Area - Central city, or cities, and surrounding closely settled territory. Central city (cities) have population of 50,000 or more. Peripheral areas with population density of 1,000 persons per acre or more are included.

Urban Runoff - Surface runoff from an urban drainage area that reaches a stream or other body of water or a sewer.

Vadose Water - Groundwater suspended or in circulation above the normal groundwater table.

Velocity Gradient - The unit measure of mixing intensity. It is defined as the difference in velocity of two parallel planes of fluid divided by the distance between the two planes, and has the dimensions of $\frac{ft/sec}{ft}$.

Verification (model) - The act of testing a model's accuracy using a different simulation period, i.e., an independent set of input and output data, from that used in calibration.

Virus - Any of a group of ultramicroscopic biological infectious agents that reproduce only in living cells; therefore considered evidence of human pollution.

Volatile Solids - The quantity of solids in water, sewage or other liquid lost on ignition of the total solids at 600°C.

Waste Load Allocation - A waste load allocation for a stream segment is the assignment of target pollutant loads to point and nonpoint sources so as to achieve water quality standards in the most effective manner.

Wastewater Reclamation - The process of treating salvaged water from municipal, industrial, or agricultural wastewater sources for beneficial uses, whether by means of special facilities or through natural processes.

Water Control (Soil and Water Conservation) - The physical control of water by such measures as conservation practices on the land, channel improvements, and installation of structures for water retardation and sediment detention.

Water Desalination - The removal of dissolved salts from a saline water supply.

Water Quality - A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Quality Limited Segments - "Any segment where it is known that water quality does not meet applicable water quality standards, and is not expected to meet applicable water quality standards even after the application of the effluent limitations required by sections 201(b)(1)(A) and

301(b)(1)(B) of the Act." (40 CFR 130.11 (d)(1)).

Water Right - A legally protected right to take possession of water occurring in a water supply and to divert that water and put it to beneficial use.

Watershed - The region drained by or contributing water to a stream, lake, or other body of water.

Water Table - The upper surface of the free groundwater in a zone of saturation except when separated by an underlying of groundwater by unsaturated material.

Water-Table Aquifer - An aquifer containing water under water-table conditions.

Wet-Weather to Dry-Weather Ratio - An "indicator" of the capacity of an interceptor sewer, as designed to carry the higher flows resulting from periods of storm, compared to the capacity provided by design to handle flows during dry weather.

Wet Weather Flow - A combination of dry weather flows, infiltration, and inflow which occurs as a result of rainstorms.

Windbreak - (1) A living barrier of trees or combination of trees and shrubs located adjacent to farm or ranch headquarters and designed to protect the area from cold or hot winds and drifting snow. Also headquarters and livestock windbreaks. (2) A narrow barrier of living trees or combination of trees and shrubs, usually from one to five rows, established within or around a field for the protection of land and crops. May also consist of narrow strips of annual crops, such as corn or sorghum.

Zero Pollution - A degree of pollution control or prevention which eliminates the addition of any contaminants or unwanted foreign material into surface water sources; incorrectly interpreted as "zero discharge" of any effluents into watercourses (land application of wastewater effluents has been suggested as one means of establishing "zero pollution" conditions).

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MODEL
APPLICABILITY SUMMARY

WATER QUALITY
DATA BASES & METHODS

LAND USE
DATA BASES & METHODS

BEST
MANAGEMENT PRACTICES

BIBLIOGRAPHY

NOTES