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Guide to the Preparation of Operational Plans for Sewage Treatment Facilities

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GUIDE TO THE PREPARATION OF OPERATIONAL PLANS FOR SEWAGE TREATMENT FACILITIES

by

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ABSTRACT

A proceduralized methodology is provided to guide the initial and ongoing planning necessary for extracting maximum potential from wastewater treatment plants. The objective of the planning activities is the development of conceptual and applied tools for direct use by plant personnel in optimizing the cost-effectiveness of their plant, complementing the design engineering of the physical plant.

The main body of the Guide is divided into five major steps, representing a proceduralized methodology for developing operational planning materials. The content and sequencing of these steps are designed to rationally combine operational planning and design engineering. Heavy emphasis is placed on general methods and principles which can be applied to a wide variety of specific treatment plant designs and situations.

The four appendixes of the Guide provide a detailed classification and description of planning materials deemed essential to plant functions of management, operations, and maintenance. Job descriptions, plant manuals, checklists, reference materials, task schedules, decision tables, and operating records are among the specific materials designed to support the above personnel functions. Thus, the appendixes serve to define the nature of the planning outputs while the five procedural steps of the main body provide a framework for their development.

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INTRODUCTION AND OVERVIEW

This Guide is directed toward achieving maximum effectiveness and efficiency of operations from the technical capabilities built into modern wastewater treatment plants. The activities outlined here emphasize planning for operations and derivation of operational support information during development such that management, operator, and maintenance personnel will be able to exploit the full physical-chemical-biological potential of the plant almost immediately after it goes on line.

Intended users and uses of the guide include the following:

1. Personnel involved in research, development, pilot plant operation, and full-scale demonstrations aimed at the generation of improved techniques for the processing of wastewater. Such personnel can use the guide for two different purposes:

    a. To generate a pool of operationally relevant information about the techniques so that others who make specific applications of the techniques will not have to generate all of the basic operational information anew with each application. Thus, it is hoped that the operational legacy from research, development, pilot plant operation, and full-scale demonstrations may begin to approach the quality of technical legacy.

    b. To define the special needs for further operational analysis and planning as the techniques are incorporated in specific equipment and facility designs.

2. Manufacturers and vendors of wastewater treatment equipment. Such personnel can use the guide to identify the kinds of

operational support information which will enhance consideration of the equipment as candidate components for wastewater treatment plants. Vendors can expect verified operational support information to be an increasing requirement as wastewater treatment systems become increasingly sophisticated and complex, and as the techniques for advanced operational planning become increasingly refined.

3. District sanitary engineers and others responsible for the procurement of new or upgraded treatment facilities should find this Guide useful in defining operational planning output which they will require in conjunction with design, construction, installation, and shakedown.

4. Consultants, design engineers, and architects should use the Guide in specifying operational planning requirements for vendors, in evaluating operational information from suppliers, in preparing supplementary-operational planning information, and in melding operational planning data into an articulated system of information support to plant operations.

5. Operating personnel, particularly plant managers, can use the Guide to help identify operational planning information which they should recommend to be acquired along with new equipment or facilities, to help judge whether prescribed operational planning information meets the needs of operating personnel, and to suggest ways in which operating personnel might supplement informational aids supplied as part of formal procurement.

A schematic overview of the Guide structure and contents is presented as Figure 1.

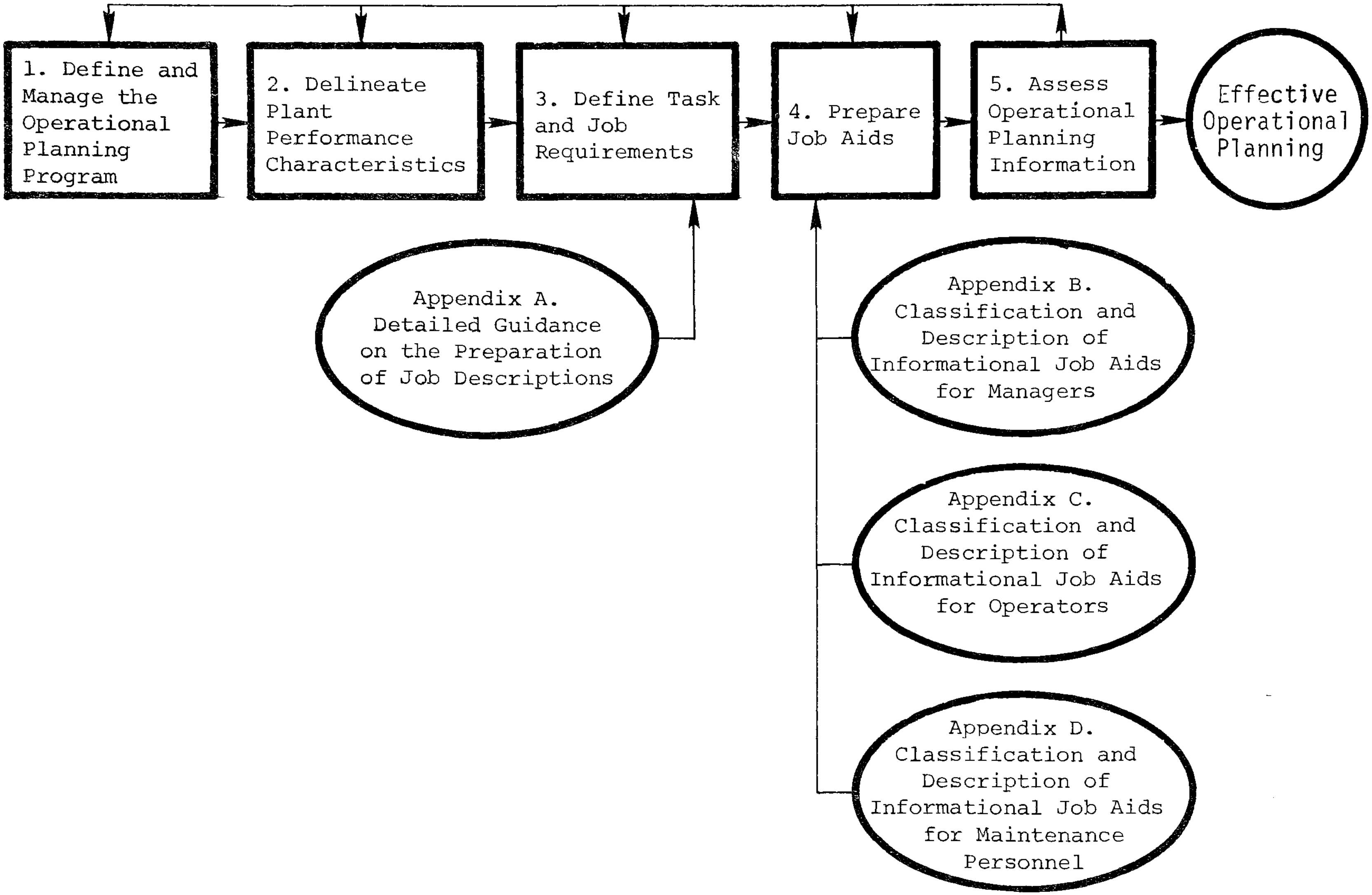


Figure 1. Schematic Overview of the Guide

1. DEFINE AND MANAGE THE OPERATIONAL PLANNING PROGRAM

The first step toward effective operational planning is to define specifically what the nature and intent of the planning effort should be and then to manage resources of manpower, time, money, and technology so as to accomplish the intended objectives. As shown in schematic form in Figure 2, definition of an operational planning program involves at least a half-dozen discernable substeps. However, once a coherent program of operational planning actually begins, there must be not only effective management of the program previously defined but flexibility in adapting to needs for further program definition as such needs emerge from experience in managing the operational planning effort.

How to carry out the six main substeps involved in definition and management of an operational planning program is described below.

1.1 Relate the Program to Overall Plant Development

Three factors point up the need to relate the operational planning program to overall plant development:

1. Each stage of development, as suggested in Figure 3, can make its own unique contribution to effective operational planning, making it desirable that exploitation of each stage for operational planning purposes be explicitly programmed.

2. The particular combination of developmental activities and stages tends to be highly varied from one specific application to another, making it necessary that an operational planning program be tailored to the particular developmental effort rather than following an inflexible routine.

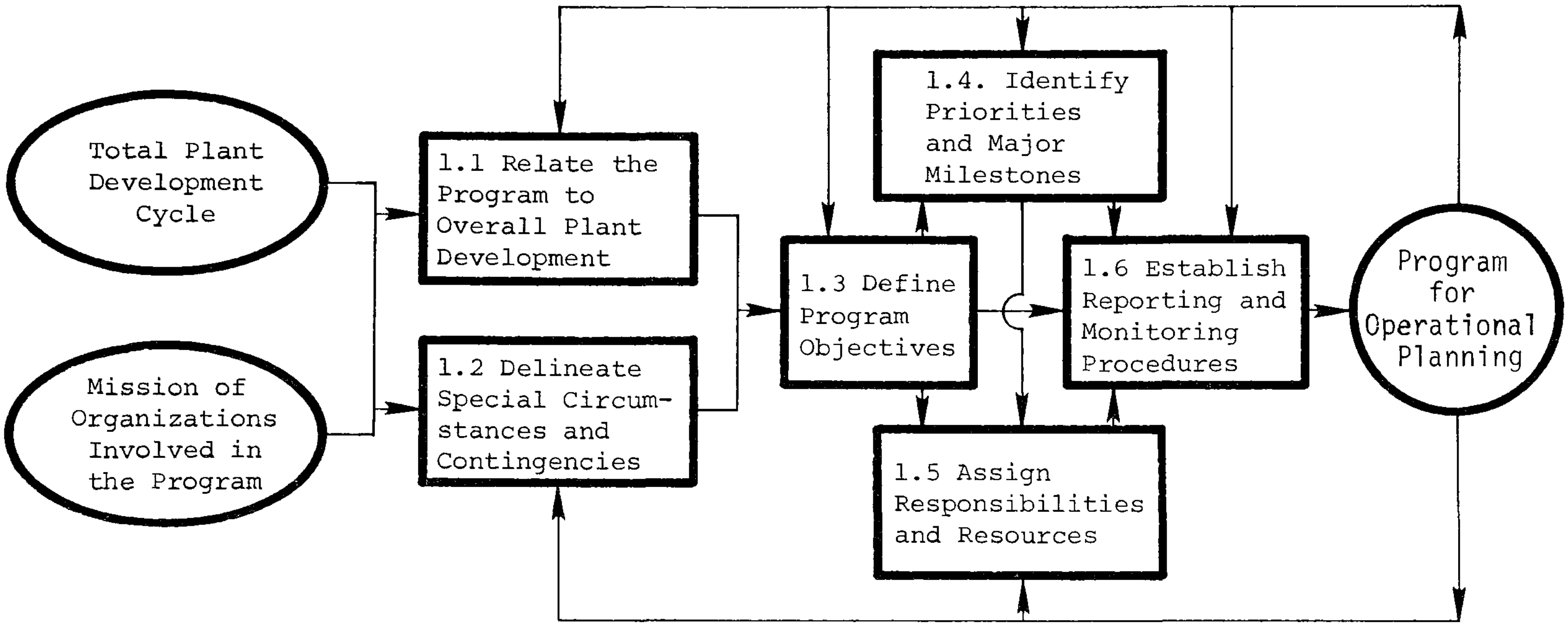


Figure 2. Schematic Overview of Steps in Defining and Managing the Operational Planning Program

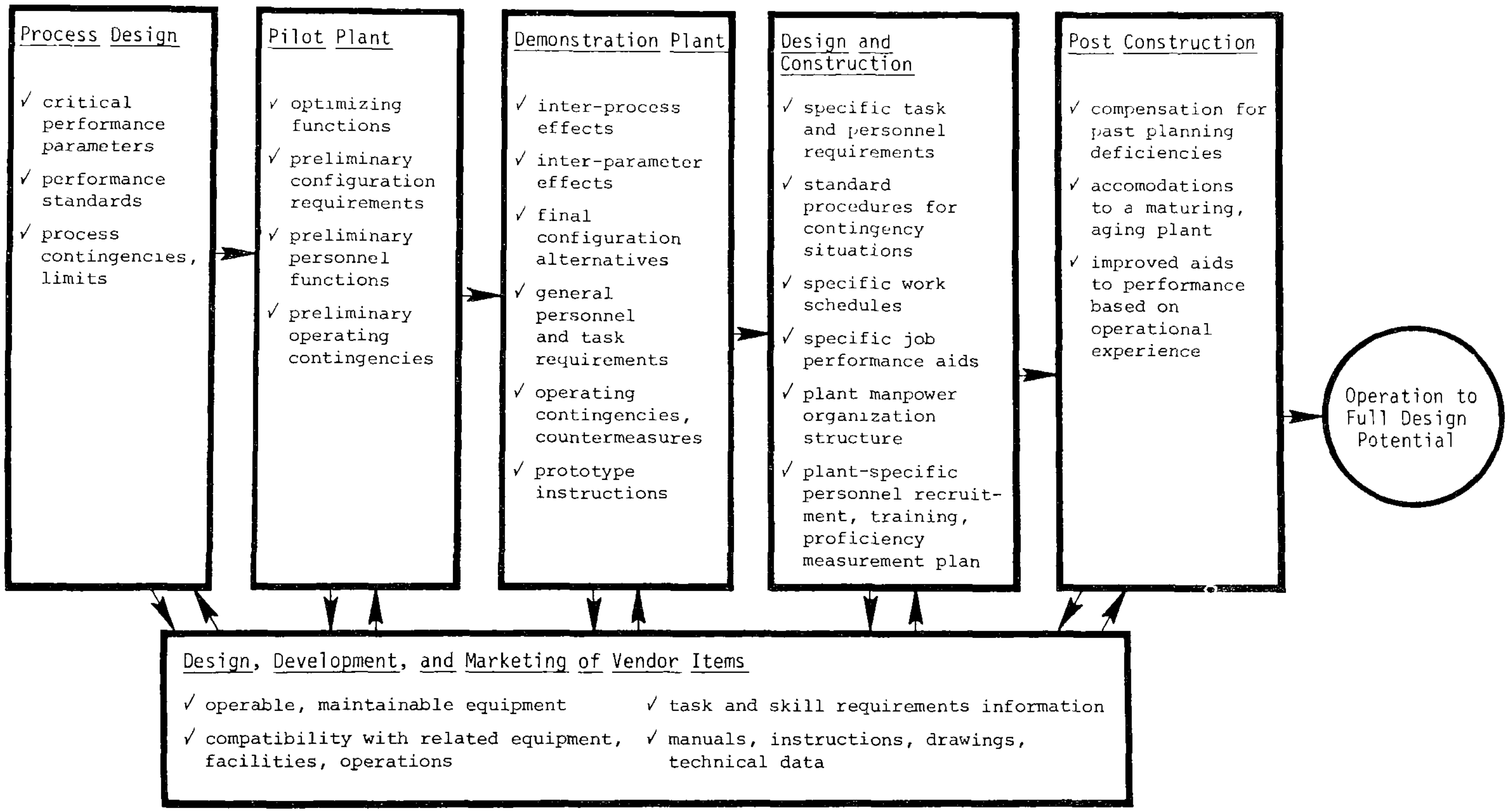


Figure 3. Idealized Model of Plant Development Phases, With Principal Operational Planning Products

3. The organizational roles and responsibilities for operation planning are not uniformly defined, making it necessary for each operational planning effort to take account of the particular mission (roles and responsibilities) of each organization involved.

The initial relating of a planning program to overall plant development will require that you:

1.1.1 Define the past history and expected future course of events for the particular development.

1.1.2 Delineate the state of planning information from past relevant development.

1.1.3 Identify major opportunities for operational planning output from anticipated future development.

1.2 Delineate Special Circumstances and Contingencies

Operational planning activities and their related end-products do not always unfold in optimum fashion. When operational planning does not follow along the idealized model presented in Figure 3, an extra burden is imposed on one or more of the potential beneficiaries of operational planning. That is, the products which should serve as input to succeeding steps may not be available, forcing earlier responsibilities upon the shoulders of those involved with later stages of development. Three undesirable results which may occur are:

1. District sanitary engineers and others responsible for the procurement of wastewater treatment facilities and the operation of multiple plants may have to divert resources to the preparation of manuals and other operational-support products. Such diversion can delay schedules; result in unnecessary inefficiency and error in translating research and development

experience into operational implications; and involve wastefully redundant planning activity across a number of locales in which the same processes, facility, or equipment may be used.

2. Design, consulting, and architectural engineers may have to spend excessive amounts of time seeking to obtain and derive implications from raw data generated by the research and development cycle.

3. Managers of individual treatment plants may be faced with extended periods of less than optimum performance while seeking to compensate for the lack of operational support information which should have been available from the developmental cycle.

The delineation of special circumstances and contingencies involves the following four activities:

1.2.1 Define the most advanced stage of development (i.e., pilot plant, demonstration plant, etc.) applicable to each functional component of the subject plant.

1.2.2 Compare the stage of development for the current effort in each case with the most advanced precedential effort in operational planning.

1.2.3 For each planning gap detected, determine the extent of the additional burden imposed and the most practical means for building it into the planning effort.

1.2.4 Incorporate the need for time and resources required by special circumstances and contingencies into the overall operational planning effort.

1.3 Define Program Objectives

The definition of program objectives involves the identification of two major kinds of "givens" that are imposed upon the operational planning effort. First, there are the givens that are imposed on the output side of the program--that is, the operational planning information and products to be implemented and the level of plant performance to be achieved through their implementation. Second, there are the givens imposed by the resources and constraints of the operational planning program. The two classes of givens must be identified and rationally synthesized to assure compatibility with the realities which influence the success or failure of resulting program objectives. Some of the relationships among major elements involved in defining program objectives are suggested in Figure 4.

1.3.1 Translate Required Outputs into Tentative Objectives

Estimates of output characteristics represent the principal set of output specifications. As shown in the idealized model of Figure 3, the level of specificity and expected accuracy increase with each successive stage of development. The setting of objectives must take into account these increasingly more stringent output requirements. The primary output characteristics to be translated into planning program objectives are:

1. The physical form of the outputs.
2. The informational content of the outputs. (At early stages of planning it will probably be possible to identify only classes of information rather than any detail within a class.) Appendixes A through D suggest classes of informational content which will assist with delineation of the content characteristics.
3. Dimensions of accuracy to which the outputs must adhere so that desired reliability for the planning user is attained.

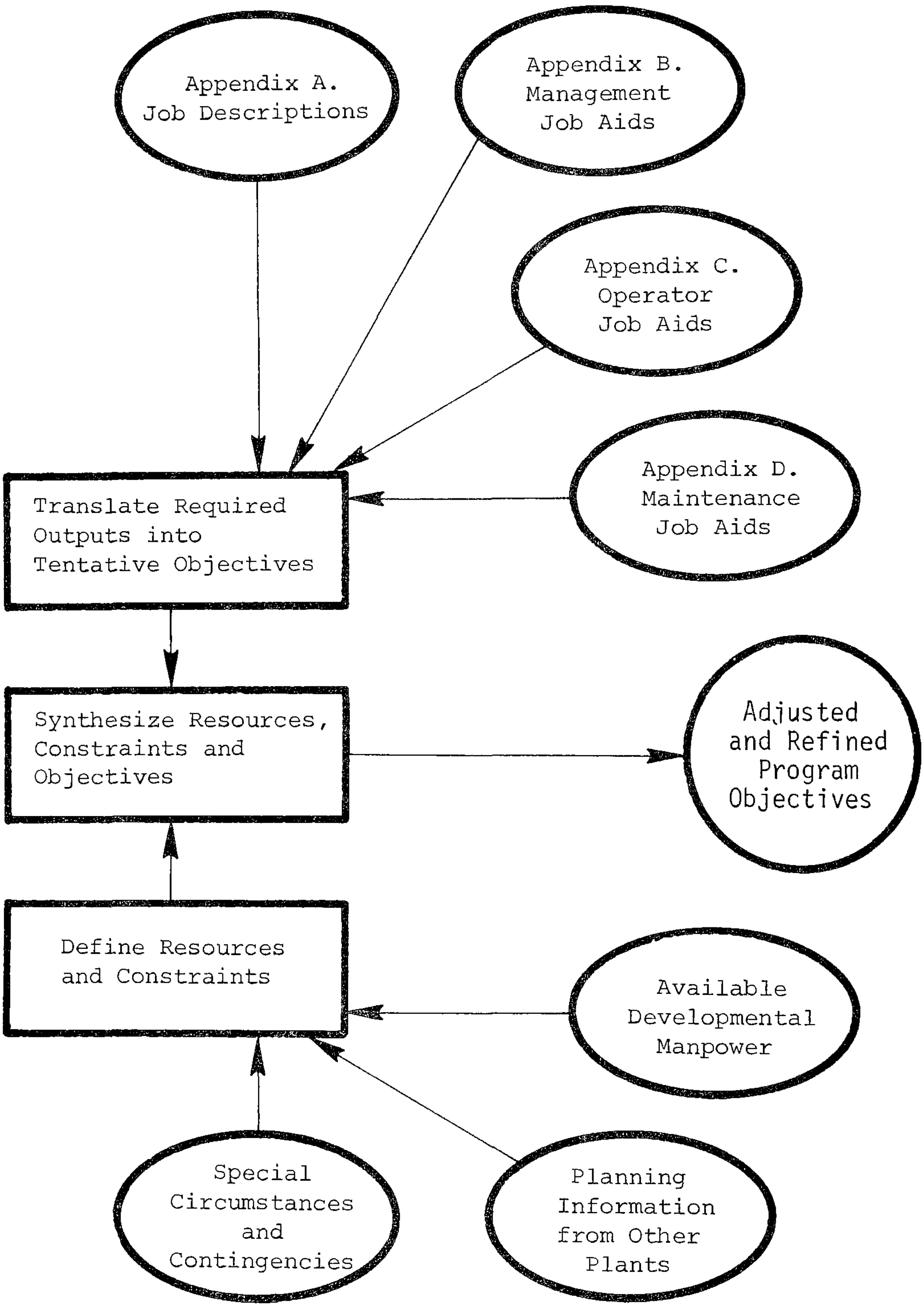


Figure 4. Schematic Overview of Major Elements Involved with the Definition of Program Objectives

4. Descriptions of output comprehensiveness when the output must completely describe a particular treatment parameter or personnel activity.

5. Reaction time or lead-time relevant to the reporting of planning information so that it will not lose its utility as a plant product or as input to successive stages of plant development.

1.3.2 Define Resources and Constraints

No program has unlimited resources of manpower, money, materials, facility, or time. Each resource has some limit placed on it. Additionally, each resource has organizational, technological, staff, policy, and administrative limits. All available resources must be identified and the limits which constrain them defined. All of the output requirements previously identified must be weighed against the probability of achieving them within the resources available to the program.

Some of the important resources and constraints to be considered, in addition to the obvious ones of time and money, are:

1. Previous treatment plants and processes. Planning information from other plants is a particularly rich resource if the plant of concern is sufficiently similar in all important aspects. The degree of dissimilarity is an important constraint.

2. Developmental manpower. Some assumptions and estimates must be made with respect to the knowledges and skills required to develop operational plans, who will provide them, and the level of effort required. A lack of personnel, or the money to purchase the services, is a significant constraint.

3. Management policy. Management policy or goals at the national, state, and local level provide guidelines of resources and constraints. Management policy can be interpreted as either a sound measure of resources and motivation or as a strong set of constraints or deterrents. In any case, most agencies operate under a complex of specific regulations and fiscal budgeting which must be recognized.

4. Special circumstances and contingencies. Special circumstances and contingencies affecting the development program, as discussed earlier, can serve either as a significant resource or as a constraint.

1.3.3 Synthesize Resources, Constraints, and Objectives

Resources and constraints may pose problems with respect to achieving what were initially realistic program objectives, making necessary the adjustment of program objectives. Any adjustments should adhere as closely as possible to the original output requirements and objectives configuration.

1.4 Identify Priorities and Major Milestones

The achievement of program objectives is never a simple matter of defining what has to be done and then sitting back to wait for the desired results to pour forth at the appointed time. Rather, there is generally so much to be accomplished by the program that one must set priorities on which objectives are to be attacked first and then be constantly alert to the direction and speed of program progress so that the program can be modified, as required, to attain its essential purposes.

Priorities assist with focusing in on those program activities which will yield the most immediate and significant payoff. Milestones represent significant points along the program development path, serving to pace the effort, provide a basis for assessment of progress, and as a framework for the assignment or resources and responsibilities. The following five steps will assist with the establishment of priorities and the identification of major milestones.

1.4.1 Establish Priorities

There are not clear-cut differentials between the application of a planning approach to different treatment processes or treatment systems. Where differentials do appear, however, it is with respect to the ultimate payoff to be derived from the application of a planning approach to treatment processes.

In general, the utility to be derived from effective operational planning is a function of the degrees of freedom inherent to operations, maintenance, and management of the individual treatment processes. The fewer the degrees of freedom, the lower the potential for achieving increased cost-effectiveness through operational planning. Additional factors are, of course, the cost of the planning process and the impact of a treatment process on effluent quality.

This really translates into priority differentials between treatment processes according to the utility potential of operational planning. Some treatment processes have a high potential for performance improvement while others are so inflexible as to provide little potential for performance improvement. Chlorination, for example, would obviously have less potential for performance improvement than would an activated sludge process.

It will be beneficial to set some priorities on which treatments or portions of the plant configuration should be attacked first. The following comments will assist in setting priorities:

1. Primary treatment processes are generally less amenable to performance improvements than are secondary treatments,

largely as a result of the comparatively few control parameters relating to process efficiency. Solids removal objectives of primary treatment can generally be met with relative ease because influent variability and other contingencies have a less dramatic effect on primary outflow and costs than would be the case with secondary or advanced treatment. Control of processes is relatively straightforward, and the level of skill and knowledge required for control is not as great as with biological systems. The principal benefits to be derived from operational planning are likely to be in the form of reduced operations and maintenance costs rather than significant improvements to primary effluent.

2. Secondary processes, due largely to their biological characteristics, are rather complex and have many variables impacting on process efficiency. While process control is critical to effluent quality, there are large segments of control technology which remain primarily a nondescript art form rather than a systematic application of reproducible and effective responses to given control situations. It is felt that operational guidance and planning can achieve the most significant improvements to cost-effectiveness through secondary treatments (where less-than-optimum control can have more of a degrading effect on effluent than would a lack of control over the primary treatments which precede it).

   Maintenance aspects of secondary treatment processes also deserve a high level of priority within operational planning. There is generally a much more diverse array of equipment required for secondary treatments than for primary treatments, requiring both maintenance specialists and/or personnel with diverse technical skills.

3. Advanced treatments are comparable to secondary treatments in terms of the complexity of operational control and the level of skill which must be developed for maintaining an optimally efficient process. In terms of the possible improvement to effluent quality, however, the range of improvement between ineffective and optimally effective operational control is small on a percentage basis for most advanced treatments. From the standpoint of effluent quality, it would be unwise to place too much emphasis on operational planning for advanced treatments until optimal control has been gained over primary and secondary treatments. On the other hand, advanced treatments cannot be neglected to the extent that a high risk situation occurs with respect to damage to costly and sensitive equipment or extreme operating costs.

   Maintenance aspects of advanced treatments are estimated to be comparable to the diverse requirements of secondary treatments. That initial operational planning devoted to maintenance should probably be limited to minimizing the risk of equipment damage through faulty maintenance rather than being concerned with more sophisticated elements of the maintenance environment. Attention must, of course, be turned back to advanced treatments when planning goals have been reached for primary and secondary treatments.

4. Sludge handling and disposal is rather different from all other treatments in that plant effluent is relatively independent of sludge handling. Based on the premise that operational planning should be geared to optimizing effluent quality at minimum cost, sludge handling and disposal fall out of the picture. On a cost basis alone, however, sludge handling and disposal can rank high in priority

because of the high capital investment and operating costs of some processes and the potential savings to be realized through effective operational planning. A cursory examination of control parameters and total costs will generally be sufficient to set priorities. The farmer who hauls away sludge lies at one end of the scale and incineration lies at the other end.

1.4.2 Identify Program Activities

Begin the identification of milestones by listing the major activities required by the planning development program. An "activity" is a unit of program work, with the size of the unit depending on the needs of the particular program. Generally speaking, an activity will represent a subobjective and will culminate with the production of information or products which serve as input to other, discernably different activities.

1.4.3 Order Activities

Determine the logical order for accomplishing each activity, paying particular attention to serial and parallel phasing of activities within the total chain.

1.4.4 Estimate Time Requirements

Estimate the time requirements for each activity and otherwise apportion time across activities so that their sum will result in objectives being met on time.

1.4.5 Key Milestones to Critical Activities

Critical activities are characterized by their ability to halt or slow down succeeding activities which are dependent upon them. Failure of an activity to achieve an acceptable subobjective within an allotted time frame will jeopardize program objectives unless some form of compensation is made. Critical activities, or combinations of activities, should be considered milestones along the time dimension, with each milestone representing a point where certain activities, events, and products must be accomplished.

1.5 Assign Responsibilities and Resources

Management of the operational planning program will invariably require the assignment of responsibilities to personnel and the allocation of other resources to ensure achievement of program objectives. Time, dollars, and personnel will be the principal parameters of concern, each of which is treated separately below.

1.5.1 Assign Personnel Responsibilities

The specification of program objectives, and the activities required for meeting these objectives, will fairly well dictate what must be done. The immediate problem to be faced is determining who, out of the available pool of personnel resources, can best carry out required activities in the operational planning program. The selection problem may, in fact, also include problems related to the training and experience of personnel in developing operational plans. The selection and training problems may be distinguished from each other in part by the following:

1. Selection introduces into the program personnel who have either:
    a. Requisite skills or knowledge of operational planning activities, or
    b. Aptitude for required skills or knowledge.
2. Training issues are introduced through the need to create requisite skills and knowledge within the personnel selected for the planning development program. This Guide is intended

to serve at least a part of the training and skill and knowledge development required for the planning program.

In general, motivation of the development team members will be at least as important a selection factor as technical skills in pollution control technology and operational planning. A firm belief in the improvements which can accrue to the operational effectiveness of plants through proper planning, and a willingness to relentlessly pursue elements of planning, should be a prime criterion for selecting members of the development team. The assignment of specific activities should, of course, consider the best possible matching of required skill and knowledge.

1.5.2 Allocate Time and Establish Schedules

There are many popular and useful techniques for scheduling the conduct of a program (COST/PERT, etc.). It is important, however, to realize that no scheduling system is infallible and that the monitoring and updating of schedules will be necessary to prevent overexpenditures of resources and to meet deadline commitments. One must also take cognizance of the fact that the milestones previously identified form a hierarchy of milestones within any schedule, some of which can be slipped without penalty and others which cannot. Generally speaking, it is advisable to distinguish between informal goals for your own use (which can be relaxed, if necessary) and formally assigned goals, which are rigid.

Since it is known that design and development efforts tend to expand to fill available time, avoid setting long-term deadlines in the allocation of time and responsibilities without setting intermediate goals. Make certain that program personnel understand intermediate goals and their individual responsibilities for reaching them. Establish a formal schedule for reaching each milestone and intermediate goal.

1.5.3 Allocate Money

Every program and project manager is faced with a shortage of money resources to carry out the kind of effort he feels is necessary. Funds for operational planning are no exception. First, there will be the inevitable struggle for operational planning funds versus hardware and process technology. Second, there is the difficulty of allocating funds among the various elements of the planning program, which really translates into the difficulty of putting money where it is most urgently needed without disrupting a balanced program to meet all operational planning objectives.

There will often be a strong temptation to fund most heavily those activities where the state-of-the-art can be pushed even though the assigned mission is to develop operational information and products to be applied to specific treatment technology rather than to push the state-of-the-art.

Because the operational planning program does not depend heavily on hardware or facility expenditures, money resources are expended almost exclusively for salaries and overhead burden. This means that there is a rather direct link between the time personnel spend in planning and operational planning costs.

1.6 Establish Reporting and Monitoring Procedures

The program manager, as the principal channel for the exchange of information between the planning program and key individuals, and as the person responsible for reviewing and evaluating program status on a continuing basis, must establish effective reporting and monitoring procedures. Perhaps the most difficult aspects of establishing these procedures are the timing, frequency, and form of review appropriate to the specific program. On the one hand, the development team can be impeded by a monitoring and reporting process that diverts time and attention from essential developmental activities. On the other hand, too little information too late into the program fails to serve as a check on program status and eliminates the opportunity to make any necessary midcourse corrections.

The establishment of reporting and monitoring procedures for operational planning should involve the following four activities:

1.6.1 Determine the key points for operational planning decisions, the nature of decisions to be made at each point, the alternatives available to the decision maker, and the kinds of information required to make a rational choice.

1.6.2 Determine who should be involved in making and implementing decisions, what information each should have to carry out his appropriate role.

1.6.3 Determine what legacy there might be from the information implied by 1.6.1 and 1.6.2 for the preparation of operational support products such as job performance aids.

1.6.4 Select the most effective mode (e.g., written, verbal), format, content, and timing for each report. Assign responsibilities.

2. DELINEATE PLANT PERFORMANCE CHARACTERISTICS

Plant performance characteristics here refer to those fixed and variable parameters of a wastewater treatment plant which bear upon the costs and quality of treatment. Since it is the general objective of operations, as well as design, to achieve quality treatment at minimum cost, it is essential that consideration of performance characteristics be a fundamental aspect of operational planning. However, treatment plants differ markedly in design, treat wastewater of different hydraulic and concentration loadings, and must meet effluent standards which may vary to a considerable extent. No fixed set of performance data is available, nor can be expected in the near future, which will suffice to guide the cost-effective management, operations, and maintenance activities of individual plants. This chapter describes how to:

1. Exploit and tailor available performance data.
2. Most effectively derive needed unique data and assumptions.

Figure 5 shows the five major steps in delineation of plant performance characteristics. These steps are complex and highly interactive. Figure 6 illustrates a single-thread sequence of substeps which cuts across the five major steps. The actual delineation of plant performance characteristics and derivation of their operational planning implications will involve a much more complex (simultaneous, contingent, and recurrent) derivation and use of data than are implied in Figure 6. However, Figure 6 suggests the main sequence--a skeleton around which the full body of an actual derivation of performance characteristic implications can be molded.

2.1 Define the Plant/Process Design Configuration

The performance of a treatment plant is largely dictated by the characteristics of the individual equipment and facility components of the plant

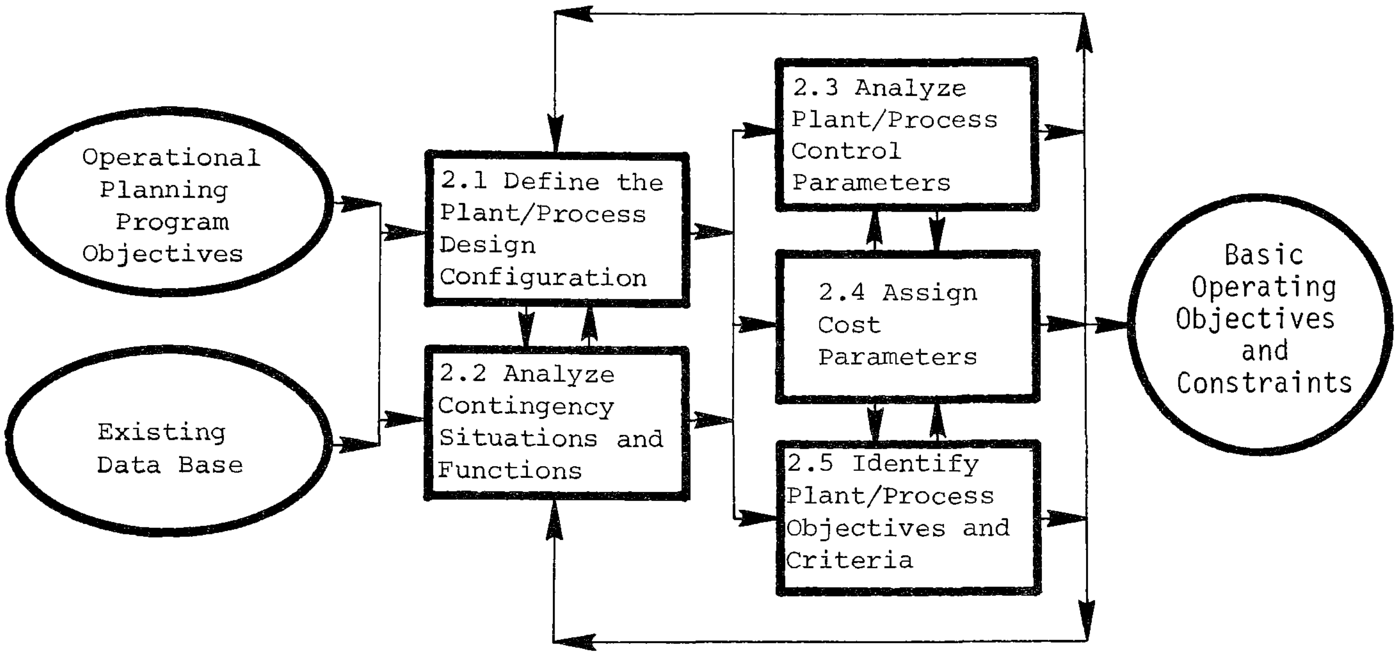
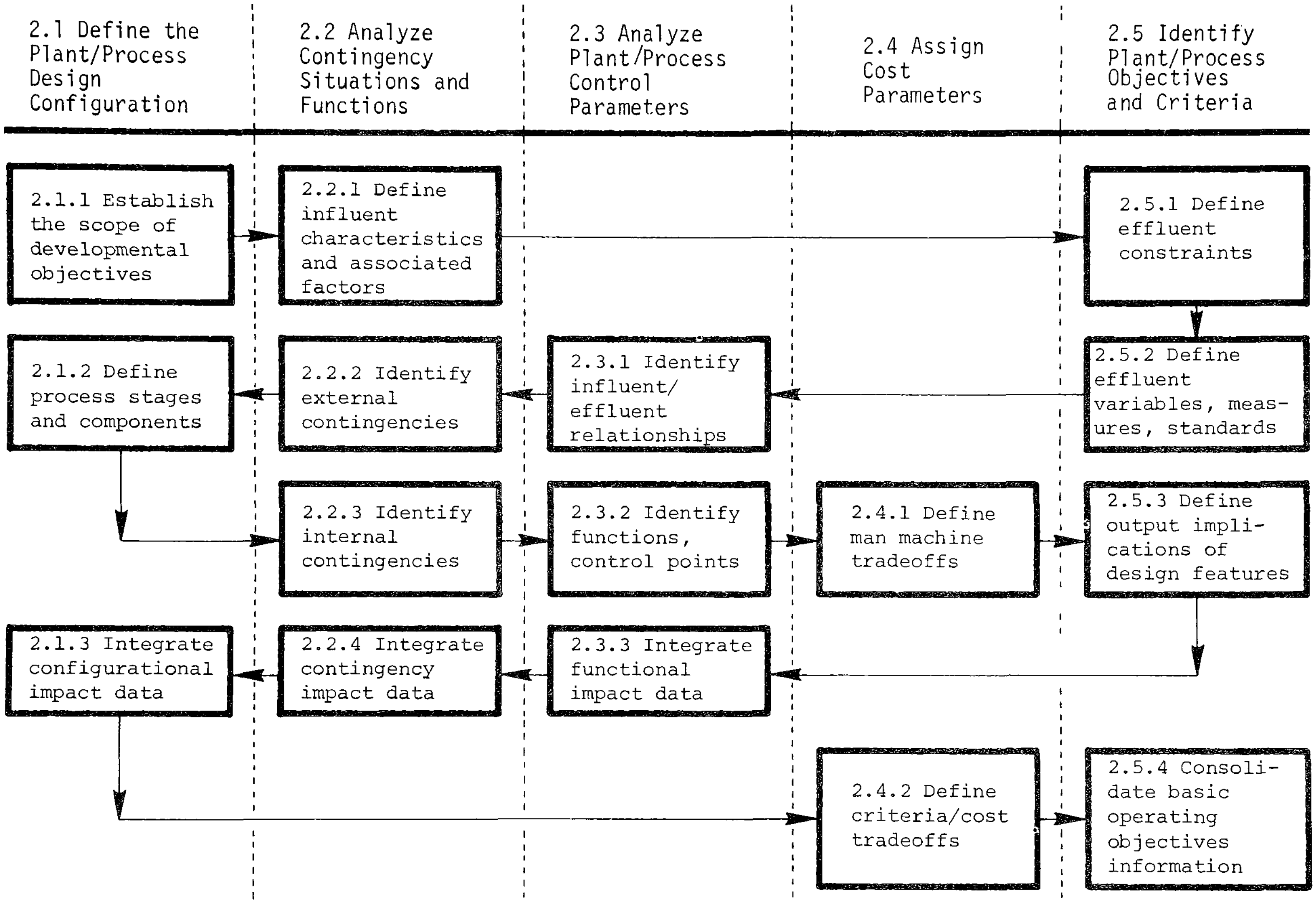


Figure 5. Major Steps in Delineation of Plant Performance Characteristics



2.1 Define the Plant/Process Design Configuration
2.2 Analyze Contingency Situations and Functions
2.3 Analyze Plant/Process Control Parameters
2.4 Assign Cost Parameters
2.5 Identify Plant/Process Objectives and Criteria
2.1.1 Establish the scope of developmental objectives
2.2.1 Define influent characteristics and associated factors
2.5.1 Define effluent constraints
2.1.2 Define process stages and components
2.2.2 Identify external contingencies
2.3.1 Identify influent/ effluent relationships
2.5.2 Define effluent variables, meas- ures, standards
2.2.3 Identify internal contingencies
2.3.2 Identify functions, control points
2.4.1 Define man machine tradeoffs
2.5.3 Define output impli- cations of design features
2.1.3 Integrate configurational impact data
2.2.4 Integrate contingency impact data
2.3.3 Integrate functional impact data
2.4.2 Define criteria/cost tradeoffs
2.5.4 Consoli- date basic operating objectives information

and the manner in which they are physically and functionally arranged to form a treatment system. Knowledge of the physical plant is a prerequisite to determining personnel requirements. Information about physical plant and personnel jointly provide the principal basis for operational planning.

2.1.1 Establish the Scope of Developmental Objectives

Establishing the scope of developmental objectives within the context of delineating plant performance characteristics, in a sense, involves simply the use of analyses carried out under Step 1, Define and Manage the Operational Planning Program. However, this articulation between developmental management and delineation of plant performance characteristics is essential since appropriate delineation will be very importantly defined by the developmental objectives toward which management is directed. More specifically, developmental objectives are major determinants of the relative importance to be placed on different elements and aspects of plant design, the level of configuration analysis to be undertaken, and the approach to be taken in deriving planning implications from configuration data. For example:

1. Research, development, pilot plant operations, and full-scale demonstrations may have implications across a spectrum of specific plant configurations. Rather than focus upon the implications of a discrete configuration for operational planning, persons involved in research, development, pilot plant operations, and full-scale demonstrations should emphasize:

    a. Performance characteristics and operational implications which generalize across a range of configurations, and the limits within which these limits are applicable.

    b. More specific analyses of performance characteristics required as development moves from these advanced stages toward specific plant design and construction.

2. Manufacturers and vendors of wastewater treatment equipment may have operational planning impacts across a spectrum of specific plant configurations. As with research and development, manufacturers and vendors should strive to emphasize:

   a. Performance characteristics and planning factors applicable to a specific treatment plant situation, the interactive effects with other treatment equipment, and the special situations and contingencies which may arise at a particular treatment plant installation.

   b. Performance characteristics and related operational planning factors which will generalize across a range of treatment equipment applications and installations. For example, the performance characteristics and operational implications of a particular chemical feeding unit will vary according to the nature of the chemicals used, the treatment to which chemical addition is applied, and the overall environment under which the unit must perform.

3. District sanitary engineers, and others responsible for the procurement of facilities and equipment, must set their developmental objectives in accord with the specific needs of individual plants and also in accord with generalizable aspects which can contribute to improvements across the range of treatment plants within their jurisdiction.

4. Consultants, design engineers, and architects, who are heavily involved with demonstration plants and the construction stages of treatment plants, will find their developmental objectives being confined rather closely to specific plant configurations. However, their efforts in operational planning for a specific

plant will be considerably stifled unless they are able to capitalize on other efforts of a more generalizable form.

5. Operating personnel will find primary interest in the discrete configuration of their own plant. The relative importance to be placed on different elements and aspects of the plant design, and the level of configuration analysis to be undertaken at the plant, will be a function of the effectiveness of previous operational planning for the plant and the availability of generalizable data and concepts for the planning process. While generalizable implications for planning may emerge from the planning efforts of operating personnel, developmental objectives will be most often concentrated on the problems of the specific plant configuration rather than on generalizable data and concepts.

2.1.2 Define Process Stages and Components

Not all plant design and configuration characteristics are likely to bear fruit in the operational planning effort. There are some stages and components of treatment plants that are not worth pursuing in terms of ultimate payoff. The general priorities set in Step 1.4 should have narrowed the field somewhat. It is now desirable to focus-in a little closer on the treatment components and operational needs of the plant to set more specific planning objectives.

Don't hesitate to exercise judgment in deciding what part(s) of the plant or system configuration is in greatest need of operational planning attention. Set your developmental objectives on those elements of the design configuration where operational gains are most needed and where the probable yield to performance improvement is maximized.

Table 1 reflects a sample of treatment technology areas having known impact on treatment but which lack adequate control procedures and practices. While the table is by no means comprehensive, it will provide at least some insight into the elements and characteristics of treatment where significant operational gains can be made.

2.1.3 Integrate Configurational Impact Data

Integration of configurational impact data provides a skeletal framework upon which other performance characteristics of the plant can be hung. Thus, hardware and facility become the common denominator for operational planning information and communicating information between stages of treatment development.

For each relevant process stage and component there is some number of physical dimensions and specifications essential to the planning effort. The dimensions and specifications required are a function of developmental objectives and the process stages and components deemed of primary importance to operational planning. Integration of data must take place across all those plant and process components having some bearing on how the plant will be managed, operated, and maintained, which reduces to integration across some number of the following specificational elements:

1. Specification of the size and other dimensional values related to the loading capabilities for each unit of equipment having configurational impact.

2. Measures for determining that equipment and components are operating as they were designed.

3. Conditions beyond equipment capabilities and which would lead to equipment failure.

4. Measures of equipment criticality with respect to normal treatment functioning (i.e., where equipment failure would result in plant down time).

Table 1

Sample Treatment Process Elements
Likely to Impact on Operational Planning

Treatment Process	Area of Technology Likely to Have Impact on Operational Planning
Grit Removal	Automatic controls and instrumentation for varying grit chamber utilization as a function of flow and concentration loading (i.e., achieving some degree of equalization).
Pre-aeration	Automatic controls and instrumentation for pre-aeration as a function of plant loading.
	Interactive effects of pre-aeration on other processes (i.e., oil and grease skimmer, activated sludge, etc.)
Prechlorination	Chlorine dosage rates and frequency of application as a function of influent concentration parameters and treatment situations (i.e., septic conditions during hot weather, etc.).
Primary Sedimentation	Interactive effects of primary sedimentation on other processes (flow velocity/retention time/overflow rate versus digester efficiency, activated sludge parameters, etc.).
	Utilization of multiple tanks as a function of loading.
	Relationships between test results and control parameters (i.e., turbidity versus loading and retention time, etc.).
	Sludge characteristics as a function of loading and scraper control parameters (i.e., length of time operated and frequency of operation).
	Sludge characteristics versus pre-aeration of prechlorination parameters.
	Tank surging versus pumping rates and tank baffling.
	Coagulant dosage rates as a function of loading characteristics and the type of coagulant used.
	Preparation, conditioning, and chemical feed techniques versus primary and secondary treatment performance characteristics (i.e., relative sludge volumes and densities, etc.).
	Process degradation as a function if improper preparation, conditioning, or feeding of chemicals.

Table 1 (Continued)

Treatment Process	Area of Technology Likely to Have Impact on Operational Planning
Imhoff Tanks	Flow control versus concentration and treatment performance.
	Control parameters versus sludge viscosity and foaming.
Trickling Filter	Influent loading and environmental factors (such as ambient temperature) versus standards of performance.
	Influent pumping rates versus filter loading and detention time in settling tanks.
	Recirculation rates versus filter loading and detention time in settling tanks.
	Laboratory analyses versus control parameters and optimal settings (such as recirculation rate).
	Observable symptoms of operational problems, troubleshooting procedures, and corrective control actions.
	Causes, cures, and preventive practices for such problems as ponding, odors, filter flies, and icing.
Activated Sludge	Standards of performance as a function of influent loading.
	Relationships between laboratory tests, loading, and control settings.
	Observable symptoms of process malfunction versus corrective control actions and preventive measures (i.e., sludge bulking, frothing, loss of sludge activity, etc.).
	Control procedures for air, oxygen, and combined aeration systems as a function of loading and process performance parameters.
	Sludge return rates versus loading and performance parameters.
	Waste sludge parameters versus biomass characteristics and loading parameters.
	Sludge volume index and sludge age as a function of loading and process control parameters.

Table 1 (Continued)

Treatment Process	Area of Technology Likely to Have Impact on Operational Planning
Activated Sludge (Continued)	Aeration control parameters versus mixed liquor solids concentration.
Intermittant Sand Filters	Dosage rates and interval between doses of influent as a function of loading parameters and filter condition.
Lime Clarification	Lime dosage rates versus operating pH and water concentration characterististics.
	Automatic controls and instrumentation for lime feed as a function of pH and hydraulic loading.
Microscreening	Solids loading versus filter efficiency and backwash requirements.
	Failure symptoms, corrective actions, and preventive measures for known problem areas (i.e., manganese buildup on metal screens, oil and grease clogging, slime clogging, etc.).
	Control parameters as a function of hydraulic and concentration loading (i.e., drum speed, backwash pressure, bypass wire adjustment, screen blanking, etc.).
Carbon Absorption	Minimum contact time as a function of inflow parameters and the design characteristics of the particular carbon absorption system.
	Carbon reactivation and makeup requirements as a function of influent loading.
	Interactive effects of primary and secondary treatments on the carbon absorption process.
	Automatic controls and instrumentation for the process as a function of plant loading and effluent standards.
Sludge Digestion	Near real-time tests and observable characteristics of digested sludge as control input for digester performance.
	Digester temperature versus digestion time, sludge characteristics, rate of sludge pumping, and sludge/supernatant withdrawal rates.

Table 1 (Continued)

Treatment Process	Area of Technology Likely to Have Impact on Operational Planning
Sludge Digestion (Continued)	pH, volatile acid content, and gas production versus stages of digestion and digester performance.
	Interactive effects of supernatant liquor with primary and secondary treatment processes.
	Interactive effects of digestion of vacuum filtration or centrifugation.
	Digested sludge feeding versus digester performance.
Sludge Conditioning	Near real-time test or observable sludge characteristics indicative of sludge condition.
	Chemical conditioner types and dosage rates as a function of sludge condition.
Vacuum Filtration and Centrifugation	Sludge conditioning parameters versus filter or centrifuge efficiencies.
	Solids content of sludge versus filter/centrifuge efficiency.
Chlorination	Correlation of diurnal chlorine demand and automatic control setpoints.
	Dosage rates and points of application as a function of odor control problems.
	Dosage rates and frequency of application as a function of sludge volume index when used to control sludge bulking in activated sludge processes or as foam control in Imhoff Tanks.
	Dosage rates and points of application for chlorine as a means of offsetting the corrosive effects of hydrogen sulfide.

5. Failure symptoms and probable causes of failure for each symptom.

6. Preventive maintenance recommendations and the interval between tasks for each equipment component.

7. Projections of mean time between failures for each equipment component.

8. Projection of mean time to correct equipment failures.

9. Estimates of preventive maintenance task time requirements.

10. Critical path flow diagrams to highlight serial and parallel sewage flows and the probable effects of a failure along each path.

2.2 Analyze Contingency Situations and Functions

Treatment plants are subject to a wide variety of contingency situations, ranging from influent loadings which exceed the design specifications of the plant to internal failures which can result in a loss of adequate treatment. Of the nonstandard situations which can develop during the lifetime of any treatment plant, some are totally unpredictable and impossible to foresee while others occur frequently enough to be acknowledged as distinct possibilities and plans made for dealing with them should they occur.

Defining and analyzing contingency situations serves to provide a foundation for the ultimate development of information to:

1. Alert plant personnel to sensitive situations which might occur.

2. Identify the treatment functions which would be affected by specific nonstandard situations and the nature of the impact.

3. Provide cues for the early detection of contingency situations.

4. Provide a plan of action for dealing with each contingency situation and thus minimize loss of treatment, danger to personnel, and cost.

The development of operational planning products for dealing with contingency situations will be dependent on the initial ability to:

1. Acknowledge situations to which treatments are susceptable.

2. Determine the probability of each contingency situation occurring within the context of a specific plant.

3. Formulate rational plans for dealing with each contingency situation.

4. Implement a contingency plan for each situation consistent with the level of threat posed by nonresponsiveness.

The individual planning activities attended to during any given planning effort will be governed by the stage of development for which the planning is being directed.

2.2.1 Define Influent Characteristics and Associated Factors

Influent characteristics represent a special form of contingency situation facing wastewater treatment plants; neither the hydraulic nor concentration loading can be expected to be steady-state. Diurnal fluctuations, shock loading by concentrated wastes, flooding, and other influent contingencies pose a potential threat to treatment capabilities.

Some variation in influent is expected; indeed, it is this variation that poses one of the essential needs for control over treatment processes. However, variations in loading beyond the controllable design features of treatment pose serious problems, possibly resulting in the loss of biological treatments and/or the discharge of an unacceptable effluent. In both cases, the characteristics of the influent represent essential information for developing effective operational plans.

The influent loading information of greatest value concerns the extreme situations which might occur rather than the average values to which this information is so often reduced as part of initial design requirements for a plant. Be rigorous in considering all influent parameters and pay particular attention to those parameters which, either individually or in combination, could have a significant impact on the plant and its optimal operation.

2.2.2 Identify External Contingencies

There are a number of external contingencies to which plants are susceptible and over which there is little direct control. Ambient temperature, humidity, rain, snow, and power failures are but a few examples. Compensation for the effects of these contingencies must be provided through the design of the plant and, more importantly with respect to operational planning, operational control of the plant.

Consider each external parameter of the plant environment with respect to the influence each may have on the treatment plant generally and on effluent quality specifically. Pay particular attention to noting sensitive parameters which could result in:

1. Danger to plant personnel.
2. Total or partial loss of treatment effectiveness.
3. Damage to treatment equipment or facility.

2.2.3 Identify Internal Contingencies

Within the confines of the treatment plant, there are many contingency situations which can impact on treatment effectiveness and costs. Perhaps the most easily recognized are those dealing with equipment and facility failures; pumps become clogged, automatic controls get out of calibration, instruments refuse to function properly, motors fail, and so forth. This general class of contingencies has to do with equipment reliability and the impact on treatment brought about by equipment failures. The other principal class of internal contingency situation has to do with operational control over the plant by its human operators who, like every human, are not infallible; sludge return rates get set too high or too low, settling tanks short circuit, sludge bulking occurs, and so forth. This class of contingency situations has to do with incorrect control of treatment processes but is heavily interactive with influent characteristics, external contingencies, and equipment malfunctions.

The identification and impact assessment for equipment and facility contingencies is relatively straightforward if one assumes that every unit of equipment is subject to failure and then, assuming that failure has occurred, assesses the impact of that failure on treatment. Estimates of equipment reliability (such as mean time between failure) will help in tempering what is or is not an important internal equipment contingency. Equipment manufacturers may have reliability information for their products or might be requested to prepare such information. Lacking valid reliability information, one is forced to make educated judgments.

Identification of control contingencies is best handled through an examination of the plant and process control parameters, a subject dealt with in Substep 2.3, Analyze Plant/Process Control Parameters. Here, however, it should be at least noted that each and every control parameter has some optimal set point based on the design of the treatment equipment and the influent and other characteristics at a given point in time. Control settings or actions on either side of the optimal represent control contingencies that, depending on the degree of divergence, will have a significant impact on the treatment plant.

2.2.4 Integrate Contingency Impact Data

As is probably obvious, each class of contingency situation (i.e., influent, internal, etc.) not only has independent impact on treatment but they might also interact with each other in such a way as to multiply impact significantly. By the same token, there might be some interactions which would tend to nullify each other. Integration of impact data should serve to:

1. Assess the interactive effects of all contingency situations and summarize their impact (or performance characteristics) on the total of the plant.
2. Provide a consolidated pool of contingency information which will serve as a check on the adequacy of the plant and process design configuration.
3. Provide a basis for ensuring that all control parameters and procedures for contingency situations are fully considered as part of operational plans.

Integration of data may be simplified in some cases through development of decision tables which embody contingency situations along one dimension and appropriate impact conditions and related control actions along another dimension.

2.3 Analyze Plant/Process Control Parameters

Treatment plants, regardless of how rudimentary they may be, will have at least some capability to adjust treatment parameters and thus compensate for variations in loading and other factors bearing on treatment effectiveness. The modern treatment plant involves a large number of controllable parameters, some of which are controlled through automatic devices and instrumentation and others which must depend on human sensing and manipulation for proper control.

The design objectives of treatment plants are based on the assumption that optimal control is exercised over the controllable features of the plant. Yet, if these objectives are to be met, there must be some method for identifying appropriate control responses and defining the method for executing control. There are three essential control characteristics which will assist with identifying and defining control parameters. They are characterized by the following:

1. The source of input data. What is the source of input information for making a control adjustment? Is information acquired through human senses or through automatic indicating and recording devices?

2. The mode of control utilized. Is control adjustment manually or automatically carried out?

3. The decision-making process. What is the method or procedure for comparing sensed data against standards to detect a need for control change, the direction of required control action, and the magnitude of control change to be made?

A relatively standard method of describing this basic information about the control process is through the use of control loops. In brief, a control loop defines how a control function is executed. There are at least three alternative forms of control loops, ranging from those of completely manual control to those of totally automatic control. There must be at least one control loop specified for each control function of the plant, with a control function being defined as the requirement to modify some variable of treatment to accommodate a change in influent loading, internal contingencies, or external contingencies bearing on treatment performance. Figures 7 through 9 illustrate the control loop concept for some typical combinations of manual and automatic control.

Control loops are central to the entire effort directed to operations aspects of treatment plants. What the operator must do, how he knows when to do it, and how he knows when it has been done correctly are all important elements of the control loop definition.

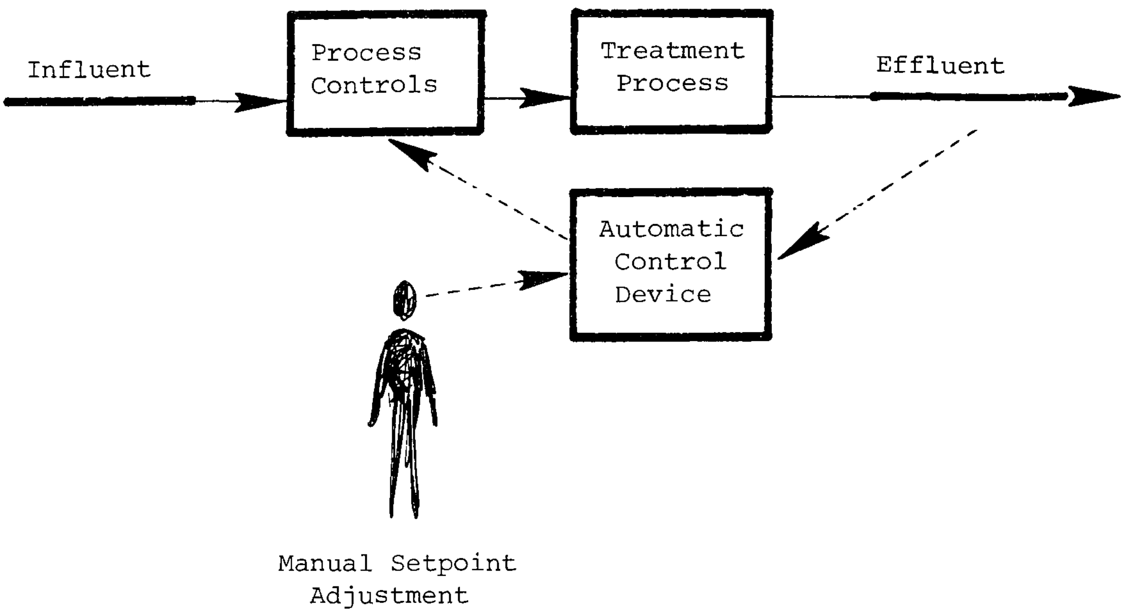


Figure 7. Automatic Control with Manual Setpoint Adjustment

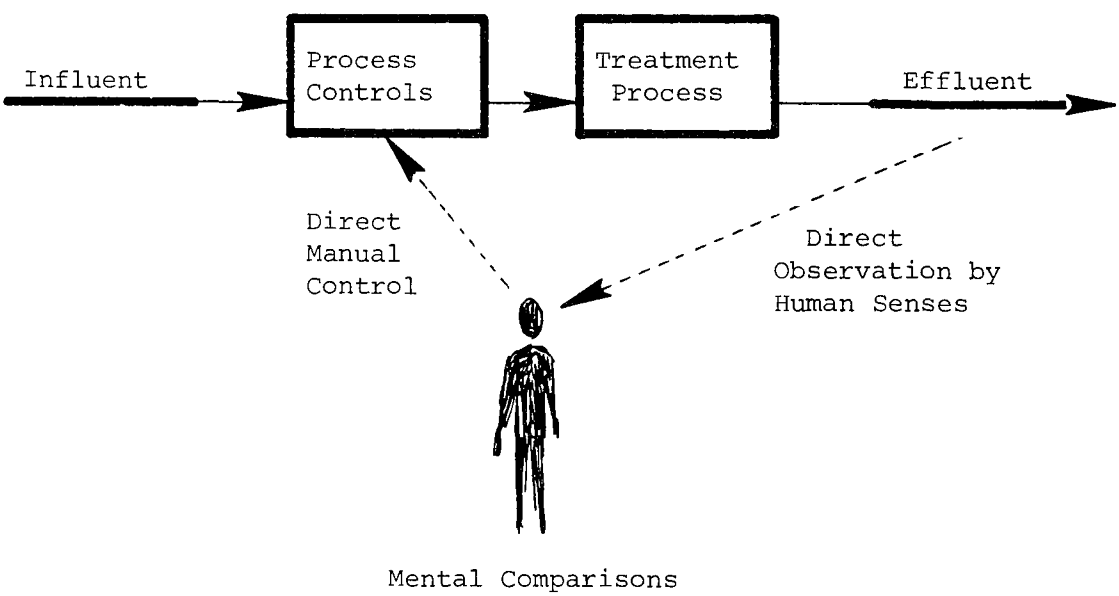


Figure 8. Manual Process Control

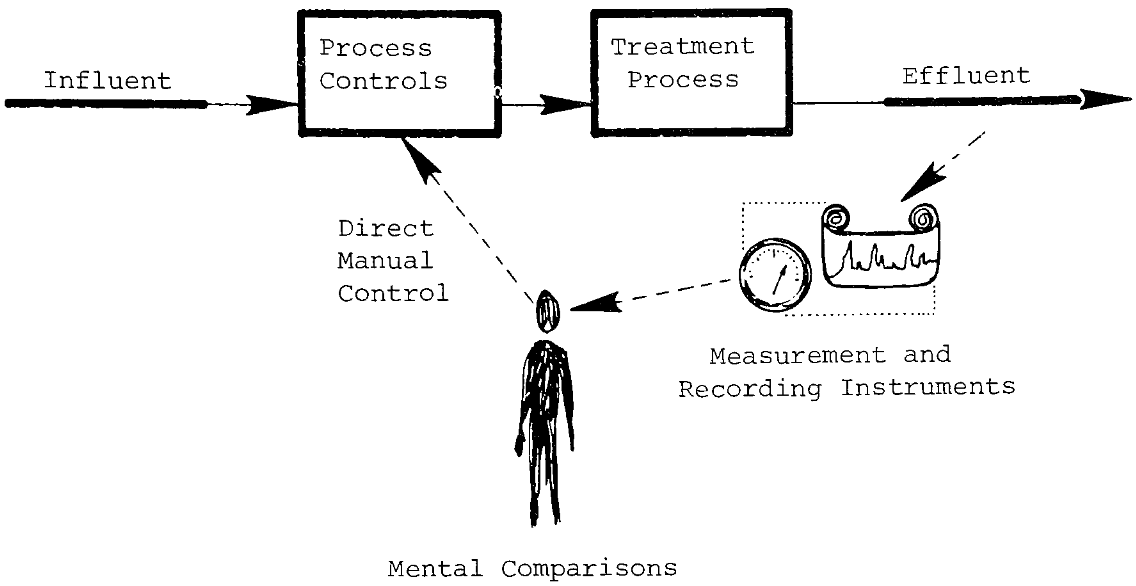


Figure 9. Sensing and Recording Instruments with Direct Manual Control

2.3.1 Identify Influent/Effluent Relationships

Influent and effluent relationships provide a major source of input and feedback data to the control of a plant. A large percentage of the control parameters for a plant are a function of these relationships; for a given influent loading to a specified design configuration, the effluent quality should be predictable. If the effluent quality achieved by the plant does not reach expectations for a given value of loading, then there is reason to believe that something is amiss with operation of the plant. The influent and effluent relationships of principal concern to the operator, however, are those which serve to trigger the need for control activities, provide guidance on the direction and magnitude of required control change, and provide positive and timely feedback on the adequacy of the control activities carried out.

Not all influent and effluent relationships will impact on plant or process control. Attention should be concentrated on those relationships which do impact on control of the plant. At least one means for identifying relevant relationships is to establish a range of influent loadings (guided by influent contingency information) and test each of these values against the design configuration to determine if a control change is dictated by the change from one value to another.

The results of this effort should be an enumeration of those relationships which will define control loops in terms of influent (as sensed information for making a control change) and effluent (as both the cuing information for control and as feedback on the results of control change).

2.3.2 Identify Functions and Control Points

Influent and effluent relationships will not account for all control parameters of the plant, and so a functional approach becomes appropriate to ensure that all parameters will be included in the planning effort. Control functions and control points provide meaningful information without requiring detailed levels of specification on <u>how</u> (i.e., automatically, manually, etc.) the control will ultimately be carried out in the plant, thus leaving a degree of flexibility in the design process without hampering either the plant design effort or the planning effort. The important issue at this time is to determine <u>what</u> control is necessary.

Identification of functions and control points can be effectively accomplished through either one or both of the following approaches:

1. Identify controllable features of unit treatments and other equipment components through examination of those detailed hardware specifications which are available. For each controllable feature included in the plant design (such as varying blower speed or the number of blowers utilized in the aeration of activated sludge), there is a control loop to be identified. If there is a control feature, then there must be some control function to be satisfied by that feature. Detailed plant design requirements or manufacturer's specifications will generally set forth all such control features.

2. Identify the functional control requirements of the plant or process to change with respect to influent loading, internal, or external contingencies. While this approach will not permit the level of specificity possible through an analysis of hardware, it is well suited to early stages of plant and process design (where hardware details are unavailable) and as an overall check on the capabilities of hardware to satisfy all control requirements.

Functional control data will require "fleshing out" in terms of sensing, comparative, and control mode information as it becomes solidified through the process of detailed plant design. These factors will be considered as part of Step 2.5, Identify Plant/Process Objectives and Criteria. Additionally, functional control requirements serve as primary input to the definition of man-machine tradeoffs, covered in Step 2.4, Assign Cost Parameters.

2.3.3 Integrate Functional Impact Data

The integration of functional impact data directs itself to the overall assessment and further analysis of operational control as it impacts on treatment plants and processes. All elements of the control environment should be considered together at this time so that interactive effects, as well as individual effects, become embodied into planning for operational aspects of treatment. The end result of this effort should be a more comprehensive understanding and definition of:

1. The criticality of each control parameter in terms of its impact on plant effectiveness, costs of treatment, danger to personnel, and damage to plant equipment and facility.

2. Relationships between control status, influent/effluent status, internal contingencies, external contingencies, and desired operational performance of the plant.

3. Thresholds for determining that sensed data is "in" or "out" of tolerance.

4. How control functions will be carried out (i.e., manually, automatically, or a combination thereof).

5. Support information applicable to control parameters and alternate modes of control.

2.4 Assign Cost Parameters

A primary objective of wastewater treatment plants is to achieve highly cost-effective treatment, an objective that cannot be reached without knowledge of cost factors and how these factors relate to treatment effectiveness. Although there is an almost infinite variety of cost parameters of potential use in operational planning, the breakdown of parameters and variables shown in Table 2 provides at least the obviously required data for planning and decision-making purposes.

With the exception of capital costs, which can be expected to remain relatively fixed once a plant is constructed, costs are largely dependent on influent loading, the level of effluent quality strived for by the plant, and the operational control and maintenance philosophy adopted. If a viable cost-effectiveness ratio is to be established for a plant, or if the minimum cost is to be achieved for given levels of treatment, it is imperative that all variables related to treatment performance be identified and defined in terms of whatever "sensitive" relationships exist.

As a general rule, one will gain maximum utility from cost information as a tool only through a breakdown of costs which go at least to the unit treatment level or, preferably, to the major components of each treatment and plant appurtenance. A cost accounting should always be employed rather than a general accounting so that the elements entering into the cost of treatment can be analyzed and applied on a unit basis (where plant management, operations, and maintenance staffs will have an opportunity to exercise cost controls).

Table 2

Breakdown of Cost Parameters and Variables

Parameter	Variables
Capital Cost	Design and construction costs plus interest on monies borrowed. This total cost is generally amortized over the expected life of the facility or equipment.
Labor Cost	Management personnel Administrative personnel Operator personnel Maintenance personnel Technical support personnel Clerical personnel Etc.
Cost of Consumables (treatment)	Coagulants Chlorine Lime Ferric chloride Etc.
Power Costs	Electricity Natural gas Other power costs
Maintenance Supplies	Replacement parts Lubricants Packing and other consumables Paint Pipe Replacement tools Etc.
Service Costs (nonplant personnel)	Consultants, design engineers, etc. Laboratory analysis Maintenance Data processing Customer billing Etc.
General	Water and other utilities for the plant Office supplies Insurance, etc. Legal costs

2.4.1 Define Man-Machine Tradeoffs

One of the most significant degrees of freedom in the design of treatment plants and the related costs of treatment has to do with the tradeoffs which can be made between people and equipment to perform plant functions. With respect to the preceding substep dealing with control parameters, for example, certain functions can be performed either through the use of personnel or through the installation of automatic control devices. The final decision for the plant configuration must certainly take into consideration the costs for each of the alternative control modes. Man versus machine decisions based solely on engineering state-of-the-art or capital investment costs will surely lead to an unhappy compromise.

Identify all of those plant functions which legitimately have alternatives for accomplishment. Be realistic though. Refrain, for example from stretching the technological state-of-the-art to include instrumentation and controls which are insufficiently developed for the specific treatment application. By the same token, do not arbitrarily exclude available instrumentation and controls simply because they have never been applied to a treatment situation before.

For each function having man-machine alternatives, define those characteristics of each alternative which will bear on the decision to choose one over the other. Perhaps the best way to do this is to consider, first of all, the treatment performance advantage or decrement attributable to each of the alternatives. Then, consider other factors bearing on the tradeoff decision and which, ultimately, will affect treatment costs. Some of the factors to be considered for each alternative include:

1. Capital costs. The initial cost of equipment, especially sophisticated control equipment, might easily outweigh the additional skilled manpower required by a largely manual control function.

2. Labor costs. While designs favoring automation might substantially reduce operations costs, increased maintenance labor costs might more than compensate for the savings.

3. Availability of skilled labor. The availability of skilled operators versus the availability of skilled maintenance personnel in the local labor market for a treatment plant is an important tradeoff consideration.

4. Skill diversity. The degree of special skills required for operating or maintaining treatment control can diverge radically. Part of the tradeoff decision pertains to limiting the number of special skills required. Otherwise, design might dictate need for electronic technicians, pneumatic technicians, hydraulic technicians, and so forth, when some degree of standardization might result in the need for only one skill area.

2.4.2 Define Criteria/Cost Tradeoff

Each of the tradeoff considerations which apply to man-machine decisions will have some point along a continuum where it becomes advantageous to either accept it or reject it in favor of another alternative. Cost-to-performance effectiveness ratios are obviously the single, most important criteria for structuring the configuration of a treatment plant, yet it is quite difficult to quantify the performance dimension of treatment and link it to treatment cost.

In spite of the need to induce a certain element of nonscientific judgment into the assessment of cost-effectiveness, a conscientious effort will generally produce information of sufficient validity to more than offset the risk inherent to the procedure. In the majority of cases, there will be some specified level of effluent quality which must be achieved by the plant; the issue thus becomes one of determining the cost of the alternatives capable of producing that quality, subject to contingency situations and functions. In other cases, there will be a desire to exceed prescribed standards; the issue reduces to quantifying the marginal treatment effectiveness which can be realized by incremental changes in the cost of treatment. In both instances, one should strive to correlate cost and treatment variables which will help to answer such questions as:

1. To what extent do dependent and independent variables of the specific treatment configuration account for variations in treatment costs?

2. What conceptual relationships exist to provide a realistic model for predicting the positive or negative cost increment when either the level of treatment or the alternative control procedures for the plant/process are changed?

3. What mathematical relationships exist between cost and treatment effectiveness and how can these relationships be exploited for gaining optimal control over individual processes and the plant as a whole?

4. What are the cost-sensitive factors for a given function and at what point of loading or level of treatment does it become advantageous to turn to some other alternative?

2.5 Identify Plant/Performance Objectives and Criteria

There are, invariably, standards placed on the quality of treated wastewaters discharged to the nation's water basins. The standards imposed by Federal, state, and local government represent the minimum level of treatment to be achieved by a plant; hence, they represent a minimal level of treatment objective. Plant performance objectives at a higher level of treatment may be set by the local plant authority out of a concern with the nation's natural resources and environmental problems.

2.5.1 Define Effluent Constraints

The requirements imposed on effluent discharges significantly constrain both the design of treatment plants and all operational characteristics which bear on effluent quality. For example, bypassing raw sewage during periods of high hydraulic loading, once a common practice, has been constrained in recent years by legislative requirements placed on discharges. Holding tanks, separation of storm and sewage waters, and other facets of plant design are constrained by effluent requirements as are operational control procedures and practices of the plant.

Identify and define those constraints imposed on the design and operation of the plant by effluent requirements. First, define the nature of requirements and standards placed on discharges by governmental agencies at the location of the plant. As appropriate, increase the stringency of requirements according to whatever other goals and desires may apply. Then, compare and test these objectives against the design configuration of the plant to ascertain those features of the design configuration which will be sensitive to maintaining objective levels of effluent quality at all times.

Sensitive design and operation features represent constraining factors with respect to meeting or surpassing effluent objectives. The size of sedimentation tanks is, for example, a sensitive design feature when hydraulic loading reaches that point where reduced retention time prohibits meeting effluent objectives. Thus, to ensure meeting or surpassing effluent objectives, each sensitive feature should be incorporated into a checklist for the design and development process and a thorough assessment made of the impact brought to bear by:

1. Influent characteristics and contingencies.
2. Internal plant characteristics and contingencies.
3. External plant characteristics and contingencies.
4. Plant and process control functions and control points.
5. Man-machine tradeoffs.

6. Resources for design and construction and cost-effectiveness tradeoffs.

2.5.2 Define Effluent Variables, Standards, and Measures

Effluent quality must be expressed in quantitative terms which will positively define effluent objectives. Variables represent the elements of the discharge measurable for quality; standards represent the specific value to be achieved for each variable in order to meet treatment objectives; and measures define the specific technique(s) to be employed in assessing the achievement of standards for each variable. The purposes of these more specific elements of effluent quality are twofold:

1. To delineate more specifically the constraints imposed on design and development.

2. To provide a normative basis for evaluation and control of the plant.

With perhaps a few exceptions, effluent quality will vary as a function of the hydraulic and concentration loading of the influent to a plant. Effluent objectives are thus set for the design of the plant according to some value of estimated loading for the population to be served by the plant. While effluent objectives are an important parcel of information, the loading values on which objectives are based do not very often coincide with the actual loadings experienced by the plant (particularly during the early years of a plant's life). Moreover, objectives are normally stated in such a way as to imply steady-state conditions while plants actually operate under conditions that are quite dynamic.

Effluent criteria provide more meaningful measures of plant capability by defining effluent quality in conjunction with loading conditions more representative of the dynamics to which the plant will be subjected during its life. Adequate definition of effluent criteria will require multidimensional testing of at least the following against the design configuration of the plant:

1. Influent characteristics, both hydraulic and concentration, representative of anticipated loading as it passes from the "best case" to the "worst case" situation.

2. External contingencies bearing upon treatment effectiveness.

The results of this effort should be a series of criterion values to express the optimal performance expectations of the plant with respect to contingency situations and functions, plant and process control parameters, and cost parameters. In addition to criterion values, it is important to express:

1. Time lag and other factors associated with diurnal loading fluctuations and effluent criteria.

2. Critical influent loadings to which the plant is either sensitive or vulnerable.

3. The range of influent and other variables impacting on treatment, and selected values within the range, to provide a useful model for plant control functions.

4. Internal and external contingency situations to which effluent criteria are sensitive.

An initial starting point in the identification of criterion values is to make a list of the parameters which are likely to vary over the life of the plant. A select set of variables for each parameter is then tested against the design configuration. The following list is representative of some relevant parameters and variables.

1. Hydraulic loading.

   a. Average daily flow.

   b. Maximum flow rate within a day.

   c. Minimum flow rate within a day.

   d. Average hourly flow.

   e. Population equivalent for area served by the plant.

   f. Etc.

2. Concentration loading.

   a. BOD.
   b. pH.
   c. COD
   d. Suspended solids.
   e. Dissolved solids.
   f. Organic solids.
   g. Settleable solids.
   h. Colloidal suspended solids.
   i. Total solids.
   j. Volatile liquids.
   k. Dissolved gases.
   l. Pathogenic bacteria.
   m. Saprophytic bacteria.
   n. Aerobic bacteria.
   o. Faculative aerobic bacteria.
   p. Faculative anaerobic bacteria.
   q. Macroscopic organisms.
   r. Nitrogen.
   s. Phosphorus.
   t. Insecticides.
   u. Heavy metals.

3. External contingencies.

   a. Influent temperature.
   b. Ambient temperature.
   c. Street washings and storm flows.
   d. Ground water infiltration.
   e. Toxic industrial spills to sanitary sewer.
   f. Etc.

2.5.3 Define Output Implications of Design Features

Insofar as plant operator personnel are concerned, effluent variables, standards, and measures come most importantly into play with respect to the individual unit treatments which comprise the plant. Individual and serial or parallel combinations of unit treatments must each contribute some functional role in the achievement of effluent criteria. Thus, each design feature of the plant has some implication(s) for reaching effluent criteria and should have its own set of outflow specifications, derived from effluent criteria and the plant design configuration, to serve operating needs.

Using plant effluent criteria as independent variables, it becomes possible to derive outflow criteria for unit treatments under the conditions specified for each plant criterion value. The unit treatment outflow criterion values thus derived characterize the effectiveness which must be achieved by each unit treatment if plant effluent criteria are to be met.

Because of the dynamics upon which both effluent and process outflow criteria are based, the achievement of criteria will cause important design and control implications to emerge. By alternatively analyzing different contingency situations and functions, plant and process control parameters, and cost parameters with respect to criterion values, output implications of the following types can be noted as input to a host of operational planning activities.

1. Outflow variables and criterion values for each unit treatment.
2. Effects of influent and contingency variables upon the function performed by treatment processes.
3. Influent, effluent, or other control data requirements.
4. Methods for sensing or measuring control data requirements.
5. Thresholds for determining that sensed information is "in" or "out" of tolerance.

6. Relationships between control status, influent/effluent status, and threshold values in determining appropriate control actions.

7. Effectiveness of alternative control modes (i.e., automatic, manual, etc.) in keeping pace with the synamics of the plant environment.

8. Required setpoint adjustments for automatic controls and the basis for making each adjustment.

9. Manual control loops applicable to situations where it becomes necessary to override an automatic control.

10. Support information for achieving and maintaining criterion levels of performance through operational control.

11. Variable costs associated with reaching criterion performance in view of contingency situations, alternative control modes, and design feature tradeoffs.

2.5.4 Consolidate Basic Operating Objectives Information

The objectives and criteria for the plant and its processes are inevitably subjected to some shifting during the design and development process as design features and resources and constraints are weighed against each other. Just as the design configuration of a plant must finally come to a point of solidification, the objectives and criteria must also come to a point of stabilization prior to the day when construction makes design irrevocable.

When some degree of stabilization has occurred it is time to consolidate all basic operational objectives and criteria into a compact and useful definition of plant performance characteristics. The consolidated performance characteristics of the plant serve as the final guide and specifications for operational planning materials development. To gain maximum utility the consolidation process should:

1. Weed out those alternative performance characteristics which do not apply to the final design configuration.

2. Identify and correct errors which may be present in design or operational information.

3. Ensure completeness in the delineation of all performance characteristics.

4. Integrate performance characteristics into meaningful information clusters as input to plant management, operations, and maintenance planning activities.

3. DEFINE TASK AND JOB REQUIREMENTS

This chapter describes activities directed toward the identification of personnel requirements for municipal wastewater treatment plants. These activities are organized around the following five basic steps, each of which results in products as defined briefly below:

3.1 Describe personnel functions results in a delineation of the activities to be performed by personnel in relation to and contrasted with functions to be carried out by the physical plant. Such delineation is made, implicitly or explicitly, early in the design of a process, equipment, or facility. The rigorous recording and communication of decisions about the allocation of personnel functions not only provides the basis for more refined definition of personnel requirements, it also can provide valuable orientation materials for personnel concerning operation and maintenance of the plant.

3.2 Describe tasks translates general personnel functions into a detailed definition of worker activities and skills required to accomplish these activities. Preliminary estimates of task requirements can be made early in the development process--as soon as an allocation of functional responsibility is made between equipment and personnel. Skeletal task identification must be rounded out and corrected as further information becomes available from the ongoing development. Task information is central to much of operational planning. It is basic to position, job, and staff development. It provides a rationale for personnel selection and classification, wage and salary administration, training, and the design of job-oriented manuals and other job aids. Task information also can help to focus on the important human engineering design features required in a wastewater treatment environment.

3.3 Describe positions defines the clusters of tasks which should be carried out by a single individual. It provides an efficient, but flexible, basis for operational management to use in making job assignments and work schedules. Positions can be defined as soon as task information becomes relatively definite and stable.

3.4 Describe jobs defines the clustering of positions into the jobs that will make up actual staffing for a plant. Although much can be accomplished toward defining job requirements as part of early design and development, the final determination of job boundaries will be made by operational management.

3.5 Describe staffing quantifies task and job requirements in terms of numbers of workers who should be employed in each job. During design and development, it is possible to combine general staffing criteria with functional and task information in order to establish relatively precise criteria for staffing a given plant. Ultimately, of course, operational management must verify or modify such criteria for staffing their plants.

3.1 Describe Personnel Functions

Effective wastewater treatment plant functioning requires a variety of supporting functions on the part of personnel. Delineation of personnel functions is a basic step in defining the operational planning problem. It includes the following three principal substeps:

3.1.1 Identify plant information.

3.1.2 Organize plant information.

3.1.3 Derive personnel functions.

3.1.1 Identify Plant Information

The informational products resulting from the Delineation of Plant Performance Characteristics (Chapter 2) should fulfill all essential information needs about the specific plant. However, additional or supplementary information may be found through any of the following sources:

1. Documentation for other similar plants can suggest functions which have not yet been formally delineated for a new plant in its early planning stages.

2. Policy, planning, and legal documentation relating to wastewater treatment requirements for the community to be served by the plant may help to clarify functional imperatives for the plant.

3. Objectives, criteria, and control parameter (per Chapter 2) descriptions as they may be presented in procurement and design documentation.

4. Research, development, pilot plant, and full-scale demonstration reports relating to processes and components intended for incorporation in the plant of concern.

5. Equipment specifications and descriptions for intended components of the plant of concern. Such specifications and descriptions may define:

   a. Techniques and procedures for operating equipment.

   b. Measures for determining whether equipment is operating according to design standards.

   c. Failure symptoms and likely causes of failure.

d. Preventive and corrective maintenance recommendations, including spare parts and other maintenance support materials.

e. Procedures for carrying out maintenance tasks.

6. Engineering, architectural, functional flow, and block diagrams and text generated as a product of designing the plant of concern.

3.1.2 Organize Plant Information

Background materials relating to plant design and its functioning can only be effectively exploited if they are processed in some organized fashion. Four steps help to organize plant information for purposes of functional analysis:

1. Emphasize unit treatment. Unit process treatments such as degritting, primary clarification, and anaerobic digestion, form the most natural and convenient basis for organizing plant functions.

2. Prepare functional flow diagrams. Such diagrams are a convenient way of summarizing the principal plant functions and their interrelationships.

3. Use consistent nomenclature and codes. Analysis and description of plant functions can be impeded by failure to establish and use a consistent scheme for easy reference to functions. It is even more important to have an effective way of indexing personnel functions to the plant functions which they support.

4. Be aware of functional levels. The purpose here is not to do an exhaustive analysis of the plant and its component equipment. Rather, the purpose is to look at functional characteristics of the plant down to a level of specificity

which is useful in helping to identify required personnel functions. Excessive detail is a detriment rather than a virtue.

3.1.3 Derive Personnel Functions

Once plant functional information and supporting documentation are organized, personnel functions can be derived by systematic review of each plant function. In general, this derivation is most effectively accomplished in the following sequence:

1. Derive operator functions. Operator functions tend to emphasize treatment process monitoring and control. They are closely linked to the central process functions (control loops) of the plant. The required operator functions will be most immediately and obviously available from a review of plant control functions. These operator functions can, in turn, provide a useful frame of reference in deriving personnel functions less directly and obviously supportive of major on-line treatment processes.

2. Derive maintenance functions. Maintenance functions for personnel are derivable largely from the design and operating characteristics of equipment. Both preventive and corrective aspects of maintenance must be considered. Broad categories of maintenance functions are periodic checking, adjusting, troubleshooting, repairing, replacing, and servicing (e.g., cleaning, lubricating, replenishing).

3. Derive support functions. Technical support such as engineering and laboratory analysis, storekeeping, and custodial services, are best derived from a joint consideration of the plant performance characteristics and the previously identified operator and maintenance functions.

4. Derive management (administration and supervision) functions. Though management functions are ultimately aimed at optimizing plant performance, they are importantly conditioned by the operator, maintenance, and support functions through which management must have its effect.

A worksheet for recording operator and maintenance functions derived from plant functions is illustrated in Figure 10. As shown in Figure 10, it is frequently useful to distinguish explicitly between personnel and equipment functions--particularly for operator functions.

3.2 Describe Tasks

Personnel functions represent relatively broad functional requirements which must be fulfilled by humans, but they do not provide details of required worker activities and skills. Tasks are component parts of personnel functions and, through their description, a detailed definition of worker requirements for meeting system functions is derived. Figure 11 reflects the place of task information in a hierarchy of work specificity where system requirements are steadily branched into successively more detailed human involvement.

The accomplishment of this step is centered around the following individual substeps, normally approached in serial fashion:

3.2.1 Identify tasks.

3.2.2 Describe activity requirements.

3.2.3 Describe critical activity characteristics.

3.2.1 Identify Tasks

The identification and enumeration of tasks is aimed at identifying discrete groups of behaviors directed toward the outcomes specified by personnel functions which are themselves a specifiable outcome required to

Plant Function/Subfunction	Personnel Function	Equipment Function
1. Monitoring quality of discharge water.		
1.a. Monitoring pH of discharge water.	Collection of samples from discharge water. Operation of pH instrumentation. Recording pH values in log. Preventive maintenance of pH instrumentation. Corrective maintenance of pH instrumentation.	Automatic pH analysis with direct reading scale.
1.b. Monitoring of BOD in discharge water.	Collection of samples from discharge water. BOD analysis on discharge samples. Recording analysis results in log.	
1.c. Etc.		
2. Suspended solids removal.		
2.a. Grit removal.	Preventive maintenance of grit chamber. Corrective maintenance of grit chamber. Operation of flow control valving. Operation of emergency bypass valving. Disposal of grit.	Separation of grit from input flow.
2.b. Etc.		

Figure 10. Worksheet for Allocating Plant Functions and Subfunctions to Personnel Functions and Equipment Functions.

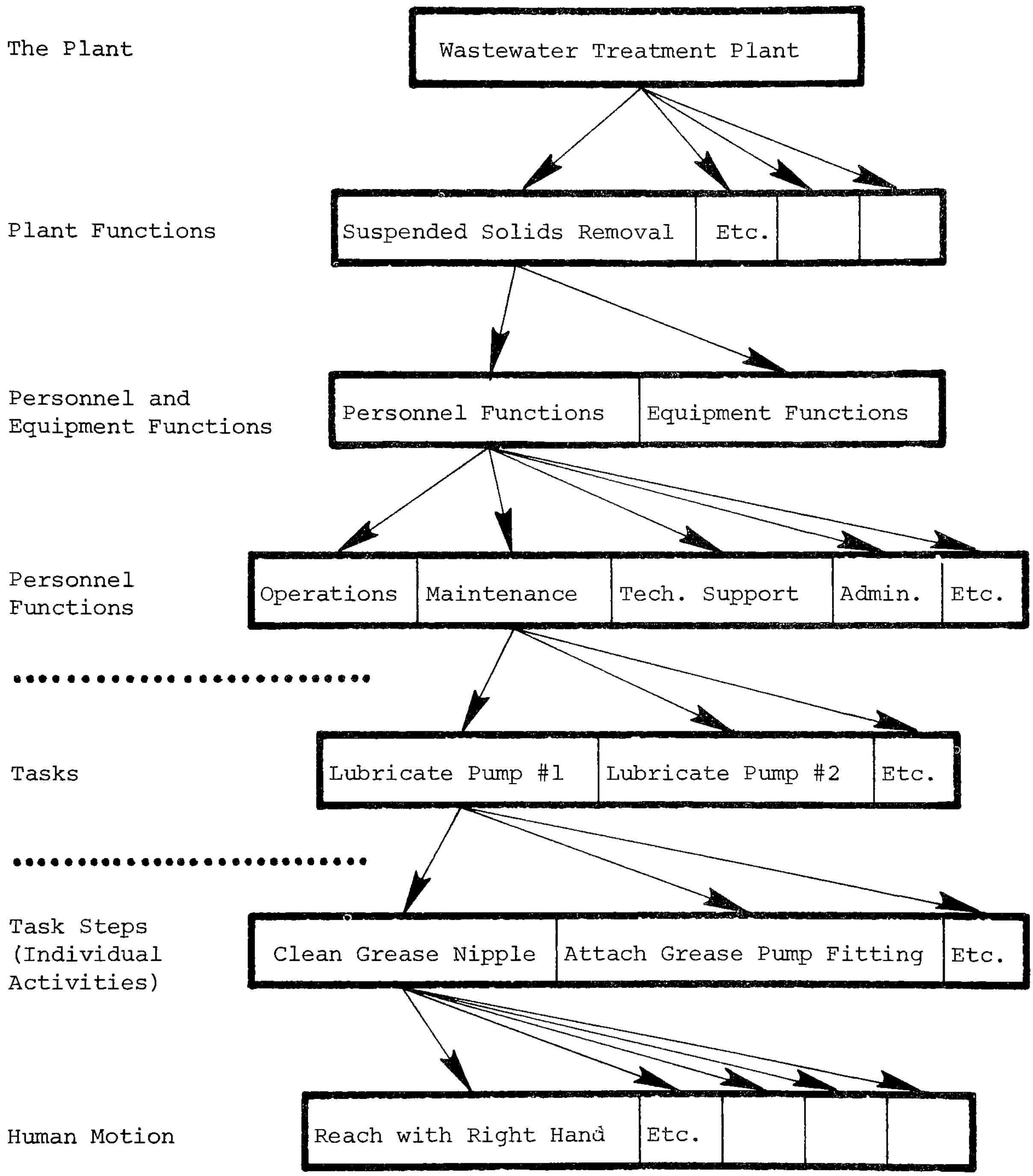


Figure 11. Relationship of Tasks to a Hierarchy of Work Requirements in a Wastewater Treatment Plant.

meet plant treatment objectives and criteria. In identifying the required tasks, emphasis is placed on relating personnel functions to the units of equipment or operations with which functions are to be performed.

As an aid to the enumeration of tasks, it is recommended that a matrix task inventory be prepared for each personnel function involving direct interaction with equipment or other tangible features of the plant. The matrix task inventory helps in the identification of tasks by testing the appropriateness of potential action verbs against a listing of the known hardware objects associated with a personnel function. A list of task-related action verbs is arranged along one axis of the matrix and the tangible objects along the other. The object list, which should be readily available from the equipment listing and detailed specifications of the previous step, should include every object to be acted upon in some way by a person. The list of objects would thus encompass forms, supplies, instruments, tools, and any other objects associated with a personnel function in addition to the primary plant equipment around which the personnel function is centered.

Some examples of action verbs which might be appropriate to a preventive maintenance personnel function are: check, adjust, lubricate, replace, clean, align, calibrate, and disassemble. The complete list of action verbs can be expected to vary considerably for each personnel function, although there will also be a tendency for some actions to be applicable to a great many personnel functions. For an administrative function, some appropriate action verbs might be: evaluate, compute, compose, edit, review, and inventory. For an operations function, they might be: observe, measure, regulate, adjust, activate, compare, etc. Because both the actions and objects will be different for each personnel function, it will be necessary to develop a separate matrix for each personnel function.

After entering the object and action verbs along their respective axes of the matrix, examine each object and action verb possibility to determine if someone does, or might have to, perform this action for this object.

It is recommended that the following three operations be carried out with the matrix:

1. Consider each object in turn and step through the action verbs listed along one axis of the matrix, making decisions as to whether someone will have to perform the indicated action for that object. Place an "X" in the cell if a particular object requires that action or a dash (-) if the object does not require that action. In case of doubt, leave the cell blank until it can be definitely determined.
2. After testing all of the actions against the first object, determine if additional actions are appropriate, and if so, enter them. Consider the next object against all the actions and again add any new actions to the matrix, but be sure to consider the new actions against the previous object(s). Continue the process through all of the objects.
3. After completing the testing of actions against objects, check the overall matrix to ensure that certain actions have not been repeated in slightly different forms. For example, installing a filter would involve removing the old one and replacing it with a new one. It would be misleading to have all three of these actions "checked" in the matrix when the removing and installing actions might better be considered parts of the replacement process. Choose that action verb that best describes the actual activity and refrain from including subordinate or repetitive entries.

These same operations are carried out for each personnel function. The final result of the effort should be a comprehensive listing of tasks (actions and objects) for the entire plant. Figure 12 provides an example matrix task inventory of an operations and maintenance personnel function.

	Check	Adjust	Align	Disassemble	Assemble	Lubricate	Clean	Paint	Test	Fill/Drain	Remove	Install	Replace	Complete	Hose Down
Function: Maintenance of Lift Station															
Dry Wells 1 & 3	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Centrifugal Pump	X	-	-	X	X	X	X	X	X	-	X	X	X	-	-
Ejectors	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Controls	X	X	-	-	-	-	-	-	X	-	-	-	-	-	-
Check Valves	X	-	-	X	X	-	X	-	X	-	X	X	-	-	-
Trash Racks	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Bar Screens	X	-	X	[illegible]	-	-	-								
PM Re															

	Check	Stir	Flush Out	Adjust	Record	
Function: Operation of Standard Rate Filter						
Dosing Tanks	X	X	X	-	-	-
Distributors	X	-	X	X	-	-
Drain Valve	X	-	-	X	-	X
Air Relief Pipes	X	-	X	-	-	
Recirculation Control	X	-	-	X	-	

Figure 12. Examples of the Task Inventory Matrix for a Maintenance and Operations Function.

3.2.2 Describe Activity Requirements

Task activity requirements represent "what" a worker must do to perform a task in terms of the individual activities, or steps, required. Further, activity requirements are intended to reflect "how" a worker knows when to initiate a task and detect that the task has been successfully completed. In brief, the activity descriptions specify, along an operational time scale, the cues that personnel should perceive and the related responses they should make. A task activity description must be developed for each task and must include the following information in detail.

1. Task title. Each activity description must be identified by an unambiguous task title. Where there are redundant tasks (for example with duplicate units of equipment), there is no need to repeat descriptions, but inconsistent task titles could easily lead to unnecessary effort and confusion. If a matrix task inventory was used, the combination of verb and object derived through this process is generally sufficient. Examples might be "lubricate centrifugal pump #14" or "clean trash rack."

2. Start cue. The start cue is the information or signal which initiates the activities performed by the task. For a task which is part of an operations function, for example, the start cue may be an observed condition of wastewater passing through a treatment process, a meter reading of particular value, a laboratory report, or an oral message. Control parameters and control loops (Chapter 2) represent a valuable source of such information, as do detailed equipment specifications which provide maintenance information such as failure symptoms and preventive maintenance schedules.

3. Action statements. Action statements convey the human activities, or steps, required for task performance. Individual action statements are much like task titles in that they

convey action through a verb and the objects acted upon. Here though, the verb describes a unitary behavioral activity and not a collection of activities. The choice of verb must be behaviorally oriented. Behavioral verbs are distinguished from movement verbs in that they more clearly denote the intellectual process rather than the physical action. Behaviorally oriented verbs are exemplified by detect, identify, align, recognize, interpret, compute, and classify. The use of movement verbs should be avoided; they tend to result in extremely detailed descriptions which later require systematic "synthesis" in order to derive useful information for operational planning.

4. End cue. The purpose of the end cue is to indicate that the task has been properly completed. Here, the emphasis is upon effects of the task behavioral actions, rather than the behavioral actions themselves. If the task is to lubricate a pump, the end cue refers to the conditions that indicate that the pump has been properly lubricated. If the task is to adjust a flow control valve, the end cue may be that a flow instrument reads a particular value, or that water reaches a certain level in a tank or sump. The end cue is, in many respects, a standard of qualitative performance, a goal for task performance, and required knowledge for performance of the task.

5. Required tools. A listing of tools and auxiliary equipment necessary for performing task activities is important to the description. In particular, special tools and equipment with which personnel may not be familiar must be noted. Electronic test equipment and water analysis instruments, for example, can place significant additional activity requirements within the context of task performance.

6. Task location. Note where the task is performed. For maintenance tasks especially, there is the possibility that task activities can be performed either on-line or off-line (in a central shop facility), which would undoubtedly have some impact on the conditions under which activities are performed.

3.2.3 Describe Critical Activity Characteristics

Another class of task activity requirements, which support and complement the preceding, pertains to more purely qualitative aspects of task performance and levels of skill and knowledge. The description of this class of activity requirements is aimed at defining critical dimensions and values which must be achieved by a worker if his performance of a task is to be considered acceptable. While activity descriptions state what the worker must do, the critical characteristics of activities define "how well" the task must be performed, provide insight to required skill and knowledge, and provide quantitative dimensions to task performance. The following represent critical aspects of task performance to be included in task descriptions.

1. Decisions or diagnoses. It must be determined if there are decisions or diagnoses which must be made as a part of the task performance. Are there alternatives based on the same start cue? If there are decisions to be made, what is the basis for the decisions? Brief statements should be supplied as part of each task description to reflect what options are available and the basis for making the decision or diagnosis.

2. Task frequency. Task frequency is a measure of how often the task must be performed per unit of time. Scheduled tasks, such as the submission of monthly reports to state and local health departments, are easily identified and pose no real problem. Unscheduled tasks, such as with the

corrective maintenance of equipment, are more difficult to accurately specify. In such cases, an estimate of frequency will have to be made on the basis of data from similar system equipment, expert judgments, and knowledge of equipment reliability. In all cases, however, it is important to note whether the task is scheduled or unscheduled. This information has important implications for deriving quantitative personnel requirements and for training.

3. Task time. Task time represents a measure of the time necessary to perform the task. There are two important time parameters which must be derived as part of the task description. One parameter of task time reflects the task requirements necessary for meeting system objectives; that is, the system may be degraded if the task cannot be performed within some time limit. The other parameter pertains to the average amount of time required for performance of the task by a properly qualified person. Obviously, the average actual time must always be less than the "system-imposed" time if system objectives are to be achieved. The system-imposed time provides a check on system design while the actual average time represents valuable information for job design, staffing guides, and other planning activities.

   Average actual time should be based on the length of time between a task start cue and that point at which the person, or team of persons, would be available to begin another task. That is, the time required to pick up tools, clean up the work area, return tools, and so forth should be included in the time measure.

   Average task time, to be even reasonably accurate, should be based on the "time-study" and "work-sampling" techniques employed extensively in the fields of psychology and industrial engineering. The United States Department of the Navy (1967) has outlined many appropriate techniques for such measures, as have many other institutions and authors. Therefore, detailed procedures are not incorporated here.

During some stages of plant development, there will be no opportunity for measuring task time since the tasks are not being performed. In such cases, it is appropriate to utilize time measures which might be available for similar tasks in operating systems. Inquiries for such data should be made to EPA's Division of Manpower and Training. If data from other systems are not available, it will be necessary to estimate task performance times. Estimated times should be later reexamined and revised until sufficient operational status has been developed to permit measurement of standard times.

Caution is in order for the measurement of task performance times in Demonstration Plant situations because the personnel involved at this level are often more qualified and experienced than can be expected at a typical treatment plant. Because an engineer can perform a task in a certain period of time does not mean that the expected treatment plant population will be able to perform in that time, even with adequate training and experience.

4. Memory requirements. Must the task be performed from memory or is there some built-in provision for guiding the activities of a worker?

5. Special behaviors. Are there special behaviors required for performing the task? These represent critical behaviors for task performance and are of such a type that not everyone in the population could be expected to perform them adequately.

Examples might be "mentally adding a series of ten, two-digit numbers" or "lifting a 100-pound bag of chemicals above the shoulder."

6. Coordination requirements. Are there physical coordination requirements that not everyone in the population could be expected to perform adequately?

7. Special environments. Are there environmental conditions associated with task activities which might have a significant impact on task performance? Cold outdoor weather is an example.

8. Likely errors. Are there situations within the structure of task activities where errors are likely, and if so, what are they and what is their impact on system functioning?

9. Task criticality. Would failure to perform this task at the appropriate time and within stated tolerances of time, or quality, result in failure to meet system objectives? Also, would an error in task performance jeopardize achievement of system objectives? A three-point numeric scale is frequently used to indicate the level of task criticality.

10. Hazards involved. Are there any hazardous situations which might be encountered through performance of task activities, such as toxic fumes, falls, fire, electricity, etc.?

11. Number of personnel. Can the task activities be performed by one man or is a team effort and coordination between team members required?

There are three commonly used formats for recording task data. In brief, they are: verbal descriptions, tabular formats, and flow charts with supporting information. Verbal descriptions are seldom used because data extraction is difficult, and, for large systems, the approach is bulky and unwieldy. Tabular approaches offer the advantages of relative compactness and easy extraction of data; they are also quite adaptable to a variety of situations. The flow chart method of description can be bulky and awkward as a working document, but offers advantages for the analysis of critical human performance requirements. It is recommended that the tabular format be used, but a verbal or flow chart format might well be used in support of particularly complex or critical tasks. Figure 13 represents a starting point for the recording of task descriptions intended for use in operational planning.

There will be a considerable amount of personnel data available when these facets of task description are completed. Adequate description of personnel requirements dictates the need to present task data in a manner which will facilitate the conversion of "what has to be done" to "what kinds of people are required and how many." The final task-personnel requirements must, therefore, be developed into formats which will permit easy extraction of personnel information as input to other activities, serve as an overall vehicle for communicating task information, and form a permanent record for possible future use in other system efforts.

Subsequent analysis of task information is heavily dependent on being able to pull task information together according to commonalities of one type or another. A classification code should be assigned to each task description which will permit all tasks to be cross tabulated along as many dimensions as possible. At a minimum, it should be possible to compile tasks according to system and personnel functions.

3.3 Describe Positions

Positions represent units of work comprised of one or more tasks which must for practical purposes, be performed by a single person at a given location within the plant. The design and description of positions is the initial stage of job design, which has as its goal the differentiation and aggregation of tasks in such a way as to optimize the ultimate efficiency, effectiveness, and economy of the plant staff.

WORKSHEET FOR TASK DESCRIPTION

Function Preventive Maintenance - Lift Station #2 Function No. 14-3

Task Title Lubricate Centrifugal Pump Task No. 17

Task Criticality Noncritical / 3 System-required Time —

Frequency 1/10 Days Average Time 0.15hr.

Start Cue(s) PM Schedule, high pitch noise

End Cue(s) Small amount of grease squeezed from cups

Occupational Area ______ Skill Level ______

Code	Action Description	Remarks (contingencies, decisions, cautions, references)
1	Locate manual grease pump	
2	Inspect grease nipple	If dirty, wipe clean with cloth.
3	Attach grease pump	Normally done with pump in operation--rotating shaft is a dangerous hazard.
4	Operate grease pump	Continue until small amount of grease "oozes" from bearing cup. If grease won't enter nipple, branch to task 12-04 REPAIR CENT. PUMP.
5	Clean excess grease from bearing cup	
6	Record date of lubrication on PM schedule	
7	Initial PM schedule	
8	Replace grease pump	
9	Report any symptoms of pump failure to supervisor	Requires ability to discriminate between normal and abnormal pump noises.

Figure 13. Sample Format for Task Description.

3.3.1 Identify Linkages

Tasks are combined into positions largely on the basis of inter-task linkages which serve to enhance overall work performance. Important task linkages to be identified include the following:

1. Equipment linkages. The nature of equipment (the object[s] acted upon) forms a primary relationship between tasks. Commonalities in equipment and tools are generally indicative of heavy transfer of skill and knowledge from one task to another, thereby fostering the development of worker capabilities. Equipment linkages should consider not only the tasks performed on identical units of equipment, but also equipment with similarities of design and operating principles.

2. Facility linkages. The design of the physical plant facility and the location at which tasks are performed have a direct bearing on work efficiency. The physical separation of tasks poses travel and logistics problems, resulting in a loss of productive time, when tasks cannot be ordered into a short, closed loop of travel activity.

3. Communications linkages. The communication of required task information, both input and feedback, has significant impact on how tasks might best be combined. Increased efficiency and reliability can generally be achieved by eliminating or reducing redundant information transfer to more people (positions) than is necessary. Task start- and end-cues, as well as all required support information, should be carefully examined for inter-task commonality.

4. Time-sequence relationships. Tasks having simultaneous or sequential performance relationships to each other are a strong influence on how tasks can or cannot be combined.

Obviously, two tasks cannot be performed simultaneously by the same person, and therefore cannot be parts of the same position. Where sequential task performance is dictated, there is the possibility of gain through assignment to a single position.

5. Homogeneity of skill and knowledge. The type and level of skill and knowledge required for tasks is important to ensuring satisfactory performance and to motivation and training factors of the personnel organization. In general, tasks within a position should represent a high level of skill and knowledge homogeneity. Task criticality, level of training required, limits on task performance time, error consequences, memory requirements, and physical skills are some of the task characteristics which, in combination, assist with making judgments about inter-task commonalities of required skill and knowledge.

3.3.2 Cluster Tasks

Positions are structured by aggregating tasks into operationally meaningful combinations. The term applied to this process is "task clustering," which seeks to capitalize on task linkages as a means for developing meaningful combinations.

Task clustering requires considerable manipulation of task and task linkage information. Reiterative sorting of tasks into tentative clusters, and the testing of clusters against appropriate criteria, is carried out until the maximum number of criteria are satisfied both qualitatively and quantitatively. In general, the criteria for clustering tasks into positions should include:

1. Common functions or objectives.
2. Location of task performance.
3. Timing sequence of task performance.

4. Equipment utilization.
5. Common skill and knowledge requirements.
6. Common capability requirements.
7. Task time requirements.
8. Nature of the task in terms of its frequency of performance, priority, and criticality.

3.3.3 Define Performance Implications

The performance implications of positions are carried, in the main, by the component tasks of that position. However, within a particular position configuration, there is the possibility that the combination of tasks will have an effect on required and/or expected performance. Each tentative position should be carefully examined for interactive performance implications of tasks and, where necessary, adjustments made to enhance position performance. Adjustments can be made either to the assignment of tasks to a position or to the specific situations which induce the performance decrement.

Some of the questions to be answered in defining performance implications include the following:

1. Does the position provide for performance of all emergency situations which can be feasibly anticipated without conflict? That is, is there a task scheduling conflict which might hamper position performance under specific conditions?

2. Do tasks within a position violate any imposed standards or union jurisdictions?

3. Does the distribution of tasks to positions provide for the standby or take-over of positions without serious deterioration of performance? Sickness, accidents, and normal leave time may necessitate the transfer of position responsibility to another person.

4. Is there sufficient variability in the performance times of tasks within the position that position performance might be degraded through overloading?

3.3.4 Define Affective and Motivational Factors

It is expected that the first approximations to job positions will be based primarily on strict performance considerations. However, once preliminary positions have been defined, motivational and morale factors can no longer be ignored. Define motivational and morale factors for each position and, if necessary, restructure positions to yield improved worker motivation and morale.

While the principles of task clustering previously described were aimed primarily at optimizing position functioning, another set of principles can be effectively used as a test for motivational factors. Four principles which will assist in identifying worker motivational factors with respect to positions are:

1. Tasks requiring responsibility or authority for assigning personnel, for distributing work, for evaluating work, for making decisions, for handling emergency situations, and for generally taking charge of a situation, should be assigned to several positions of increasing responsibility rather than to only one position (principle of supervisory structure).

2. Tasks assigned to a given position should keep the man busy (principle of time utilization).

3. Tasks assigned to a given position should avoid excessive repetition (principle of self-esteem).

4. Positions should be related to other similar positions where the primary difference is the level of skill and knowledge required, so that progression is possible (and

obvious) from relatively routine positions to positions of substantial responsibility and authority involving similar tasks (principle of worker progression).

3.3.5 Prepare Position Descriptions

Since a job is comprised of one or more positions, position descriptions represent the principal tool through which jobs will ultimately be structured. As such, the position descriptions must contain the qualitative and quantitative information to permit the rational development of jobs. The position description is a summary of the task information encompassed by the position, characterized by the following four essential elements:

1. Task enumeration. The tasks included within the position should be enumerated by task code number and task title. List the tasks, to the maximum extent possible, in the order in which they are performed.

2. Time dimension. Itemize the task performance times and the frequency of performance for each entry. Multiply frequency by performance time for each task and then sum to derive a total time requirement for the position. The time requirement should be expressed in man-hours per week, which will require the reduction of task frequencies to a common denominator prior to the summation process.

3. Skill level estimate. To assist with the combining of positions into jobs, a skill level estimate should be assigned to each position description. A three-level numeric scale is generally sufficient to cover the range of required skill. The scale should be indicative of the levels of skill one might develop through: (a) on-the-job familiarization, (b) limited formal training, or (c) considerable formal training.

4. Occupational area. An early estimate of the occupational area of which the position would be considered a part should be entered on each position description. This can be facilitated by entering the personnel functions to which each position applies.

3.4 Describe Jobs

Jobs represent one or more job positions which, for practical purposes, are carried out by a single individual. Job responsibility is centered around the sum of the tasks encompassed by each job position. The purpose of job description is to present a concise picture of the qualitative personnel requirements to be fulfilled through the hiring and training of a plant staff.

3.4.1 Cluster Positions

Just as tasks are rationally organized into job positions, job positions are clustered into units of work to represent that which must be performed by a given individual within the plant. The total work assigned to an individual is called a job. The clustering of job positions into jobs is carried out through much the same process as was used for the clustering of tasks.

The linkages which apply to the clustering of tasks also apply to the clustering of positions. In addition, the clustering of positions into jobs should seek to structure required work into efficient and least-cost personnel assignments. Toward this end, the clustering of positions should:

1. Maximize utilization of existing personnel classifications and job organizations, but not to the point of forcing unique requirements on a person or jeopardizing system efficiency and cost-effectiveness.

2. Minimize initial and update training requirements.

3. Minimize the spread of complex skill, knowledge, and proficiency requirements across personnel except as might be necessary to create an effective career hierarchy.

The clustering of positions must take careful consideration of quantitative aspects to prevent the overloading or underloading of work assignments.

3.4.2 Prepare Job Descriptions

Job descriptions are the principal means for expressing the qualitative dimension of required personnel. A separate job description must be prepared for each unique combination of job positions. The descriptions serve to present the conclusions and recommendations of the job design effort and as a product to guide the hiring, training, and career structure of the plant personnel organization. Because of widespread applications for job descriptions in specific plants, and the overall developmental cycle of treatment plants generally, it is important that the descriptions follow standard formats and principles of development.

A complete and meaningful description of required jobs is dependent on definition of at least the following job elements:

1. Job title.
2. Functions performed by the worker.
3. Indications of required training.
4. Significant aptitudes required by the job.
5. Significant interest associated with the job.
6. Significant temperaments associated with the job.
7. Critical physical demands of the job.
8. Working conditions of the job.
9. Enumeration of the positions and tasks of the job.

The desired format for job description must necessarily be closely aligned with the specifications adopted by the United States Department of Labor, which are the most widely recognized and used form of definition for planning and development purposes. The *Dictionary of Occupational Titles* (DOT), produced by the Department of Labor, serves as a standard reference for development of job descriptions in operational planning. The only exception to DOT format is the additional requirement for enumerating positions and tasks.

The procedural technology and development of job descriptions, as well as required formatting, is significantly detailed and has therefore been relegated to a separate section of this Guide. Appendix A provides comprehensive guidance to the development of job descriptions.

3.5 Describe Staffing

Staffing denotes how many people are required to adequately man the treatment plant. The conventional means for expressing this quantitative dimension is through staffing plans, which account for the number of people required to serve in each job title. The quantitative dimensions of tasks, positions, and jobs are translated into "real people" by the staffing plan.

3.5.1 Identify General Criteria

Staffing of a given plant will be influenced by prescribed general criteria. These criteria must be identified and their impact assessed prior to the development of a staffing plan. Some representative general criteria are as follows:

1. Shifts. The number of shifts will influence the total number of personnel required in each job. It can be assumed that municipal treatment plants will operate 24 hours a day, but there is a great deal of latitude in what personnel functions can be fulfilled within a single 8-hour shift and those which require more or less around-the-clock personnel inputs. The degree of automation, the size of the plant, and local practices with respect to "on-call" personnel are but a few of the possible factors bearing on required job shifts.

2. Days per week. Some personnel functions must be fulfilled 7 days per week while others can normally be fulfilled within a normal 5-day work week. Operations functions, for example, generally dictate 7-day requirements while administrative functions can most often be served in a 5-day week.

3. Minimum personnel. Federal, state, and other regulatory agencies have set forth minimum personnel recommendations for certain sizes and types of treatment plants. These recommendations should serve to guide the staffing for individual plants. The Federal funding of plant construction, for example, is contingent upon certain minimum personnel staffing criteria.

3.5.2 Estimate Worker-Hour Requirements

Estimate the total man-hours required for each job title during each applicable shift. This can be facilitated by summation of the quantitative values assigned to each position incorporated into the jobs. Temper these estimates with other performance time estimates which may be available, including:

1. Utilization of data accumulated from other similar jobs and job positions.
2. Time measures of simulated or actual work performance.
3. Best judgments by job analysts, technical experts, and/or experienced workers in jobs with similar requirements.

3.5.3 Estimate Worker Requirements

Estimate the number of persons required in each job by dividing the shift man-hour requirements by the number of hours in a shift (rounded upward to the nearest whole number) and summing across the required number of shifts. This first estimate must then be increased to compensate for vacations, sickness, and other "shift implications" such as 7-day functional requirements. On the other hand, the first approximation might be decreased somewhat through the redistribution of task and position assignments. For example, initial staffing estimates may indicate one job is slightly overloaded for one person while another is significantly underburdened and, through minor task redistributions, acceptable loading is found possible without the additional staff member originally indicated.

3.5.4 Derive Dual Values

It is characteristic of wastewater treatment plants that not all personnel required for their effective, sustained operation are engaged full time in their functioning. This, combined with the added complexity that some jobs are required on multiple shifts and others on only one shift, makes it desirable to present two related but separate quantitative estimates for each job:

1. The total number of personnel to be involved.
2. The total number of man-hours for a specified unit of time (most typically a week).

It is not uncommon for municipal treatment plants to borrow required manpower from other municipal services, particularly when the requirements are minimal or there is only an occasional need. Similarly, it may be more economical to contract certain services than to have in-house capabilities. Note any such instances so that they may be incorporated into the staffing plan.

3.5.5 Prepare Staffing Plan

The staffing plan should consolidate the total staffing requirements of the individual plant into a brief but concise summary description. The recommended regular plant staff, as well as any part-time or contracted resources, are listed by job title and the number of persons required in each job. A sample staffing plan format is presented as Figure 14.

Staffing Plan for Plant Number --,

---------- Sanitary District,

--------------, Pennsylvania

Functional Area	Job Title	Number Persons/Man-Hours Per Week: At estimated flow of 20 mgd at Plant Startup	Number Persons/Man-Hours Per Week: At design flow of 35 mgd
Supervisory/ Administrative	Superintendent	1/40	1/40
	Asst. Superintendent	1/20	1/30
	Operations Supervisor	a/13	a/20
	Shift Foreman	1/20	1/20
	Maint. Supervisor	a/13	a/20
	Maintenance Foreman	a/13	a/20
	Clerk Typist	1/40	1/40
Operations	Operator I	4/140	5/160
	Operator II	6/168	8/200
Maintenance	Auto. Equip. Operator	1/30	1/40
	Mechanic I	1/40	2/60
	Mechanic II	1/20	1/30
	Electrician I	1/20	1/40
	Electrician II	1/40	1/40
	Maint. Helper	2/80	3/100
	Painter	a/10	a/10
Technical Support	Chemist	a/30	1/40
	Laboratory Technician	1/40	1/40
Other Support	Storekeeper	a/20	a/20
	Custodian	1/40	1/40
	Laborer	3/100	3/120
	TOTAL STAFF	26	32

Note: Staffing indicated in terms of the number of men assigned; the second value indicates the number of man-hours per week. The letter "a" represents personnel functions fulfilled by drawing upon other municipal employees, contracted services, or other "outside" resources.

Figure 14. Sample Format for Staffing Plan.

3.5.6 Cross-Check Values

As a check on the quantitative values presented in staffing plans, it is recommended that staffing guides be consulted. These documents are available through EPA's Division of Manpower and Training for many conventional treatment processes and a variety of general treatment plant types and sizes. The staffing guides can be used to help structure the staffing plan and as a means for comparing values specified for a particular plant with those which represent an average of various plant design configurations.

Do not bend the values obtained through your job and task analysis to fit those of the staffing guide; the staffing plan is tailored to fit the requirements of the specific plant, and it can be expected that values are going to differ. Become suspicious of the values you have generated only if they appear unreasonably divergent from staffing guide values. In other words, use the staffing guides as a check, not as a set of specifications. Request copies of staffing guides through:

Manpower Development Staff
Office of Water Program Operations
Environmental Protection Agency
Washington, D. C. 20460

Table 3 reflects at least a sample of the quantitative data currently available in the form of staffing guide information. The information presented in staffing guides represents the minimum, or criterion, number of personnel required to manage, operate, and maintain particular types of plants in an effective manner. As can be seen in Table 4, there is considerable latitude in personnel requirements as a function of both plant type and hydraulic loading.

At least for conventional forms of primary and secondary treatment, the total staffing should fall within the boundaries described by the two curves of Figure 15. Primary plants with low-labor forms of sludge disposal represent the low end of the scale and activated sludge plants with incinerators for sludge disposal represent the high end. Plants with

Table 3

Illustrative Staffing Guide Information for Conventional Treatment Plant Types and a Range of Hydraulic Loadings

Total Manpower Requirements per Plant as Function of Flow										
	Flow (mgd)									
Plant Type	1	3	5	10	20	35	50	65	80	100
PRIMARY with:										
Digesters and Lagoons or Drying Beds	4.0	5.5	7.5	9.5	14.5	22.0	29.0	34.5	41.5	48.0
Digesters and Vacuum Filters	4.0	6.0	7.5	11.5	17.5	26.0	35.0	41.5	49.0	57.0
Vacuum Filters and Incinerators	4.0	6.0	8.0	11.0	17.5	26.0	33.0	41.0	49.0	57.0
TRICKLING FILTER with:										
Digesters and Lagoons or Drying Beds	5.0	7.5	10.0	12.0	19.5	29.0	37.0	46.0	54.0	63.5
Digesters and Vacuum Filters	5.0	8.0	10.0	15.0	24.0	36.0	45.0	55.5	65.5	77.5
Vacuum Filters and Incinerators	5.5	8.0	10.5	15.0	24.0	36.0	48.0	55.5	68.5	81.5
ACTIVATED SLUDGE with:										
Digesters and Lagoons or Drying Beds	6.5	9.5	12.5	16.0	24.0	35.0	45.0	54.5	63.5	73.0
Digesters and Vacuum Filters	7.0	10.0	12.5	19.0	29.0	42.0	53.0	66.5	75.5	88.0
Vacuum Filters and Incinerators	7.0	10.0	12.5	18.0	27.0	41.0	53.0	64.5	74.5	90.0

Adapted from data produced by Black and Veatch Engineers, Kansas City, Missouri.

Table 4

Sample Staffing Guide with Distribution of Staffing
Across Representative Occupation Titles

Staffing Criteria for Activated Sludge Treatment Plants with Vacuum Filters and Incinerators (Based on 3 shifts and 7 day/week)*										
	Plant Average Day Capacity in mgd									
Occupation Title	1	3	5	10	20	35	50	65	80	100
Superintendent		.5	.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Assistant Superintendent						1.0	1.0	1.0	1.0	1.0
Clerk Typist					1.0	1.0	2.0	2.0	3.0	4.0
Operations Supervisor							1.0	1.0	1.0	1.0
Shift Foreman						1.0	2.0	3.0	3.0	5.0
Operator II	2.0	3.0	4.0	4.0	5.0	8.0	11.0	12.0	15.0	17.0
Operator I	4.0	5.0	6.0	6.0	9.0	12.0	14.0	17.0	19.0	25.0
Automatic Equipment Operator						1.0	1.0	2.0	2.0	2.0
Maintenance Supervisor								1.0	1.0	1.0
Mechanical Maintenance Foreman						1.0	1.0	2.0	3.0	3.0
Maintenance Mechanic II				1.0	2.0	2.0	2.0	2.0	2.0	3.0
Maintenance Mechanic I				1.0	1.0	2.0	2.0	2.0	2.0	2.0
Electrician II				.5	1.0	1.0	1.0	2.0	2.0	2.0
Electrician I						1.0	1.0	1.0	1.0	2.0
Maintenance Helper				1.0	2.0	3.0	4.0	4.0	5.0	6.0
Laborer		.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Painter								.5	1.0	1.0
Storekeeper								1.0	1.0	1.0
Custodian							1.0	1.0	1.0	1.0
Chemist									.5	1.0
Laboratory Technician	1.0	1.0	1.0	1.5	2.0	2.0	3.0	3.0	3.0	3.0
Total Staff	7.0	10.0	12.5	18.0	27.0	41.0	53.0	64.5	74.5	90.0

*Source: Black and Veatch Engineers, Kansas City, Missouri.

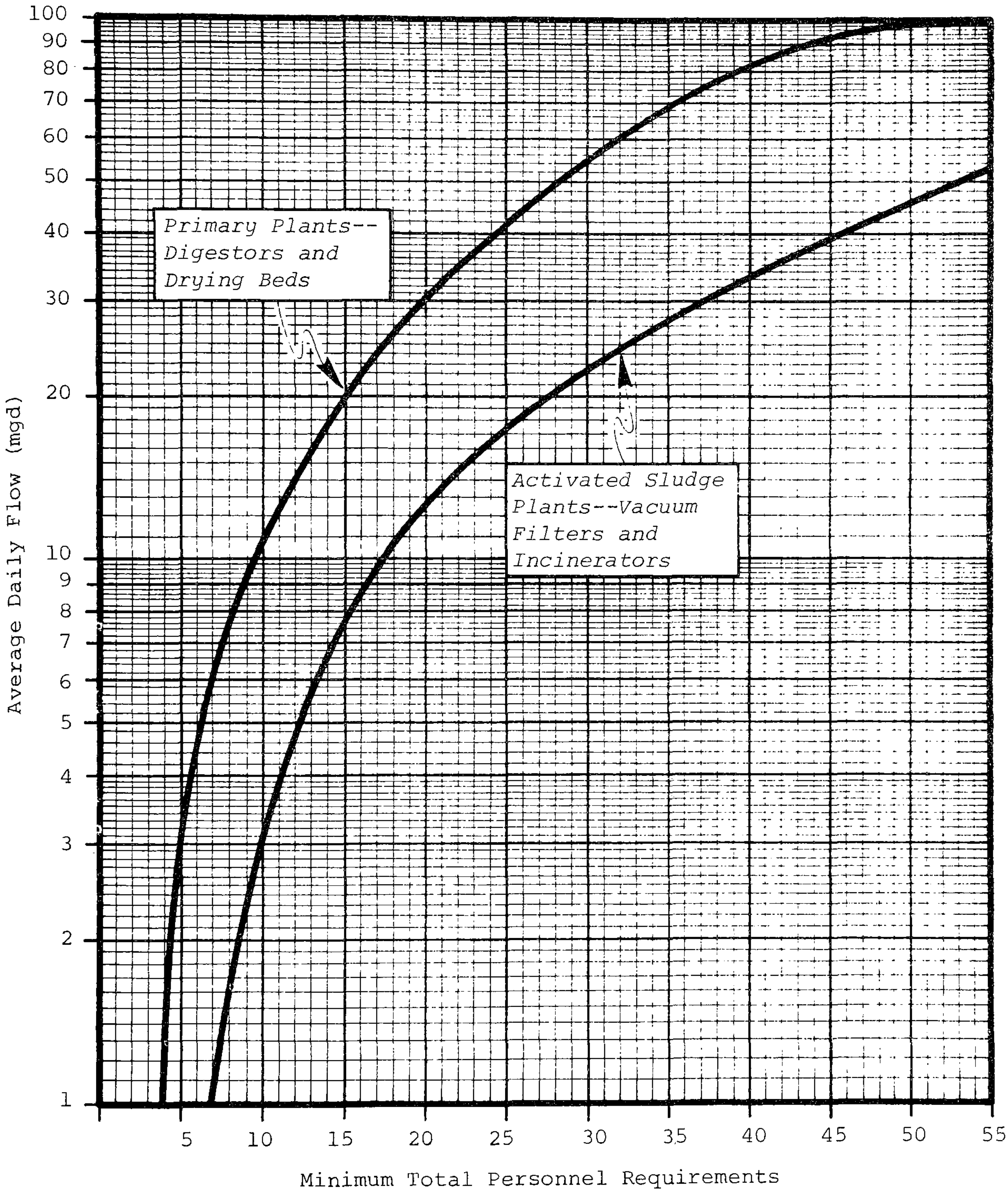


Figure 15. Relative Range of Required Personnel for Conventional Forms of Primary and Secondary Treatment Plants

advanced treatments, as well as plants with an unusually low degree of automation and mechanization, would likely fall somewhat out of the described range and into the area of higher manpower requirements per unit wastewater treated.

4. PREPARE JOB AIDS

This chapter presents general procedures and principles concerned with the development of job aids. A job aid is a device or document which stores information necessary for work performance in such a way that it is readily available and useful to workers as required on the job.

Job aids are aimed at extending worker capabilities through a reduction in the need to mentally store and then recall job information. Appropriate means for storing job information range from manuals of job information and instructions to terse reminders of information elements to "cue" the worker at the task location. Some examples of job aids include checklists, tables, arrows showing direction of flow in pipes, and labels indicating tolerances for control settings and status indicators.

The preparation of job aids, as described here, involves the following seven major steps:

4.1 Verify the data base.

4.2 Assess the need for information support.

4.3 Structure information needs by positions/jobs.

4.4 Sequence information needs.

4.5 Determine functions served by information.

4.6 Determine units and formats for information support.

4.7 Design and test aids.

Some of the relationships of these steps to each other and to sources of information are suggested in Figure 16.

4.1 Verify the Data Base

Plant information and data help to define needs for aids, structure aids, and provide content for aids. The job and task information (whose organization and preparation is described in the previous chapter) is central to

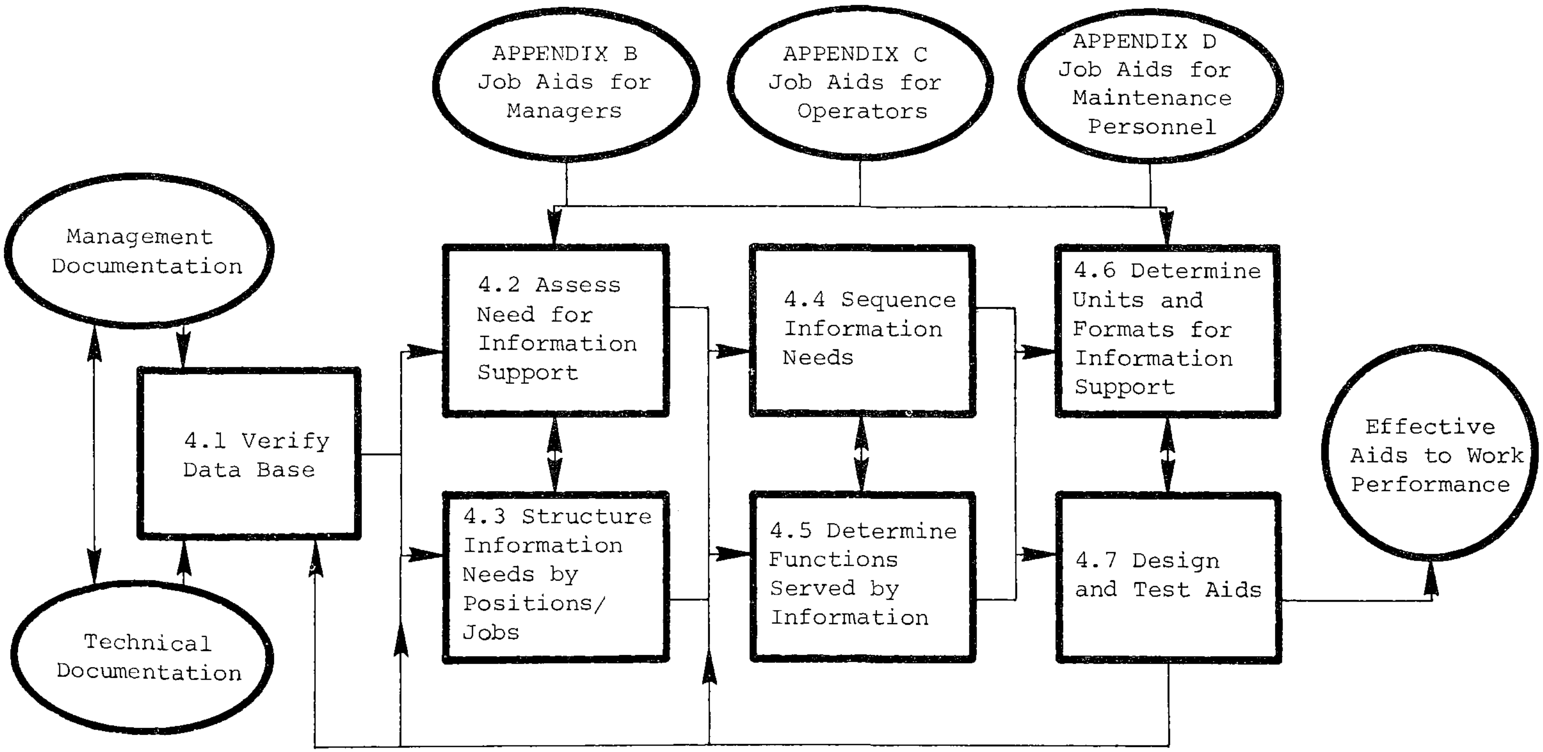


Figure 16. Principal Steps in the Preparation of Job Aids

the design of job performance aids--both directly and indirectly through its organization and focusing of other plant data. As a first step in preparing job aids, review job and task information to ensure that:

1. Job and position descriptions have a complete delineation of required tasks; that is, all significant areas of required performance have been covered.

2. All tasks are accurately and completely described. It may not be practical to describe in detail all of the varieties of performance that can be exhibited by personnel faced with varied contingencies--such as a manager involved in negotiations with suppliers or a manintenance technician involved in troubleshooting. The variety of conditions with which a task is to cope and the nature of the effect of variation in these conditions on task requirements can and should be described, however.

3. All task steps are clearly within the capabilities of the worker. Informational aids cannot, for example, compensate for requirements which demand excessive reach or visual acuity. The requirements must be made less stringent through appropriate human engineering.

4. The intellectual (information processing) and memory requirements of all tasks can readily be inferred from their descriptions.

5. The job and task information can readily be related to known characteristics of the prospective work force such as formal education, demonstrated mathematical abilities, and prior experience in wastewater treatment.

It is entirely appropriate that job and task descriptions include a great deal of backup information about facilities, equipment, treatment processes, and organization of the work force only by reference to documentation prepared for other purposes. Review such documentation to assure that it does clearly support job and task descriptions fully and adequately. Also, assure that the impact of described tasks on plant performance characteristics (whose description is discussed in Chapter 2) is clear. Such clarity is important for at least two reasons:

1. Selection of tasks to be supported by informational aids can be guided by the probable impact on plant performance.
2. Design of individual aids should be oriented toward enhancement of effective plant performance.

4.2 Assess the Need for Information Support

Not all worker activities will require job aids. An early step in preparing job aids should be to identify the specific worker activities (tasks and task steps) whose performance can be improved through the use of job aids. Review of each task, to identify job aid requirements, should include the following:

4.2.1 Assess the possible kinds of error.
4.2.2 Assess the probability of error.
4.2.3 Assess the maximum consequences of error.
4.2.4 Assess the probabilities of error detection.
4.2.5 Assess the distribution of consequences.
4.2.6 Assess the probable payoff from job aids.
4.2.7 Assess tradeoffs with job aids.
4.2.8 Define job aid objectives and specifications.

4.2.1 Assess the Possible Kinds of Error

Each significant job activity involves at least three aspects:

1. Perception--drawing information from the work environment.
2. Cognition--mentally processing perceived information to guide work activities.

3. Response--carrying out the overt biomechanical work requirements.

Consider perceptual, cognitive, and response errors separately. It may also be useful to consider different kinds of error within each of these classes. Perceptual errors include the following:

1. Attention errors include:

   a. Inattention errors such as may be revealed by a failure to monitor some important aspect of the changing environment. For example, an operator may fail to keep an adequate check on the quality of sludge.

   b. Misdirected attention errors such as may be revealed by concentration on one aspect of the job to the exclusion of other important aspects. For example, a plant manager may be concerned with operating costs to such a degree that he fails to see substandard worker performance which is having a detrimental impact on plant effectiveness.

2. Detection errors involve incorrect perceptions of the environment, even though the worker may be attending to the appropriate parts of that environment. Detection errors may be in any sensory mode (sight, sound, smell, feel). They can involve both perceptions of current status and of change characteristics. Detection errors include two principal types:

   a. False detection which involves the perception of significant states or characteristics of the environment which are, in fact, not present. For example, a maintenance worker may read a test instrument during a routine check to indicate an equipment malfunction when the equipment is actually operating properly.

b. Detection failure which involves a failure on the part of the worker to identify significant states or characteristics of the environment. For example, a plant manager may fail to perceive that a daily plant performance report indicates that one or more effluent measures indicates a below-standard condition.

Cognitive errors include the following:

1. Evaluation errors which involve an incorrect interpretation of input data with respect to one or more of the following:

   a. Relevance, such that relevant data are judged not to bear on a given issue or irrelevant data are judged to bear. For example, a plant operator may fail to see the relevance of high toxic metal content for performance of biological treatment processes.

   b. Sufficiency, such that the worker judges information which is adequate for selecting a course of action, as inadequate; or, judges information which is inadequate to suffice for guiding a choice, as adequate. For example, a maintenance worker may have enough information available to diagnose an equipment failure exactly, but continue to make redundant checks. Conversely, he may replace a properly functioning component because he fails to recognize that he has not eliminated all of the other possible sources of malfunction, even though this might be done with additional simple checks.

c. Content errors are of two main types:

(1) Discrimination errors involve use of classification schemes or measures which are either too broad or too specific. For example, a plant manager may demand such specific performance data that he is unable to assimilate it. In contrast, he might be satisfied with information that is so broadly summarized that he is unable to use it to support effective decision making.

(2) Classification errors involve the assignment of data to the wrong class, within whatever classification scheme the worker is using. For example, an operator may confuse a reading of one parameter for another.

2. Memory errors can be in both long-term and short-term memory Long-term memory tends to involve knowledge about the theory underlying treatment and support processes, functional and physical design of the plant, and work procedures. Short-term memory tends to involve recall of information just recently acquired from the work environment. Memory errors take three main forms:

a. Omission errors involve a failure to remember needed job information. For example, an operator may forget a step in an equipment shutdown procedure.

b. Interpolation errors involve the intrusion of extraneous information. For example, a plant manager may unnecessarily complete a report because he wrongly remembers that it is required by the district sanitary engineer.

c. Falsification errors involve distortion of remembered information. For example, a worker may correctly read a meter, but then remember a wrong reading.

3. Transformation errors involve faulty translation of information from one form into another. It is sometimes useful to distinguish at least two kinds of transformational error:

   a. Procedural, which in turn includes two finer classes:

      (1) Rule selection in which the worker chooses the wrong rule. For example, a worker may use a linear transformation of his data when a log transformation is appropriate.

      (2) Rule following in which the worker does not correctly follow the established rule. For example, he makes a simple mistake in calculation.

   b. Logical, which includes two finer classes analogous to those for procedural errors:

      (1) Model selection in which the worker chooses a faulty or inappropriate frame of reference to guide his approach. For example, a plant manager may use an inappropriate biochemical theory in estimating the probable impact of a new industrial hookup to the system.

      (2) Reasoning in which the worker is not consistent with whatever logical system he has chosen to

follow. For example, a maintenance worker may be inefficient in troubleshooting equipment failures because he fails to eliminate all of the alternatives which are possible from a given series of checks.

Response errors include the following:

1. Selection errors involve choice of the wrong response. For example, an operator may bypass a portion of influent during an overload period even though he has more effective options available to him.

2. Initiation errors involve some failure to start a response as intended. They may include:

   a. Timing, where the response is initiated either sooner or later than is appropriate. For example, an operator may switch off a pump before a tank is fully purged.

   b. Sequence, where two or more responses are out of order with respect to each other. For example, a maintenance worker may remove an electrical safing wire before activating equipment even though standard procedures call for a reverse sequence.

   c. Deletion, where an intended response is not actually initiated. For example, a manager may intend to tell an operator about a change in work procedures but fail to do so.

   d. Insertion, where an unintended response is initiated. For example, an operator may introduce a control action which is irrelevant to the task at hand.

3. Execution errors involve inadequate consummation of an initiated response. They may include:

a. Position, where some aspect of spatial location is not properly handled in the response. For example, an operator may set a control to an incorrect setting.

b. Direction, where some aspect of the response movement does not follow a desirable path. For example, an operator may turn a valve control in the opposite direction from that intended.

c. Magnitude, where some aspect of response amplitude is not within allowable limits. For example, an operator may not depress a pushbutton far enough to activate a circuit.

d. Duration, where a response is ended too early or terminated prematurely. For example, a maintenance worker may stop adjustment on a piece of electromechanical equipment before it is fully aligned.

4.2.2 Assess the Probability of Error

An important factor in determining error probability is the frequency of performance. Naturally, the more frequently a given activity is performed, the greater the opportunity for errors in connection with that activity. However, frequent performance of a given activity usually leads to an increased familiarity with the information inputs and responses involved in the activity. This familiarity can enhance reliable error-free performance. There is one way in which familiarity can lead to increased potential for error. Such increased error potential can result from linkage of familiar information inputs with unfamiliar response requirements, familiar responses with unfamiliar information, or (worst of all) familiar information with familiar responses but in unfamiliar ways. For example, an operator may have especially high error potential on a task where he is required to increase biological activity by flow reduction if he usually accomplishes this by increasing the supply of air.

ıch aspect of a job activity is subject to different error-inducing ıctors. Human engineering and some industrial design manuals are largely ɛvoted to a description of design features which impact on quality of ɛrformance. In very general terms:

1. Perceptual error is increased by:

   a. Weak intensity of the signal carrying needed information. For example, a warning light may not be sufficiently bright to alert the operator.

   b. Inadequate contrast between the signal carrying needed information and background "noise." For example, a meter dial may be too close in color to the instrument face plate.

   c. Excessive rate of information change. For example, the sensor on a particular process parameter may be so sensitive as to set up a frequency of oscillation that cannot be tracked by the observer.

   d. Excessive complexity of information. For example, information about multiple process parameters may all converge on an operator at one time and without a simple indication of which parameters are close to a tolerance limit, making "state-of-the-plant" decisions difficult.

   e. Partial information. For example, a maintenance worker who receives an incomplete report of malfunction symptoms is more likely to misdiagnose equipment troubles than if he receives a full report.

2. Cognitive error is increased by:

   a. Ambiguous relationships between input information and response requirements. For example, a manager is much more likely to take appropriate corrective action when his plant is not performing up to design capability if he has a clear indication of the relevant alternatives available to him than he is otherwise.

b. Ambiguous rules for translating information input into appropriate responses, especially if the worker is to achieve multiple criteria. For example, a manager who is expected to achieve maximum plant performance and minimize cost must have clear trade-off rules if he is expected to maintain a reasonable balance.

c. Complex relationships between input information and required responses. For example, an operator is much more likely to make a mistake in choosing the right response if it is conditional upon a number of possible contingencies in the external environment than if he always makes the same response to a given process status.

d. Memory demands, especially if they are specific and do not include convenient cross-checking. For example, an operator decision which is based on a remembered series of instrument readings is very likely to be based on at least partially incorrect information.

3. Response error is increased by:

a. Similarity of response alternatives, especially if the number of alternatives is large and/or the options are not well defined. For example, a worker is most likely to flip the wrong switch when he is faced with a panel of similar-appearing switches.

b. Stringent physical requirements. For example, a worker is generally more likely to mishandle a load near the upper limit of his carrying capacity than he is a lighter one.

c. Required precision. For example, a worker is much more likely to make one or more errors in precisely setting a continuous fine-tuning knob than he is a discrete position switch with positive detents.

d. Complex response requirements. For example, a manager faced with a need to justify his plant's performance to a whole complex of concerned agencies is much more likely to become involved in communication difficulties than if he has only a single-point responsibility.

e. Ambiguous feedback. For example, an operator is more likely to miss the need for further process control actions when there is a significant delay in feedback of information about the effects of control measures which he has previously taken.

There are also a number of general factors which can increase the probability of error on any or all aspects of performance, including:

1. An unfavorable physical environment, including such factors as extreme temperature, crowded work space, poor lighting, noise, and wetness or ice.

2. Either an overload (too much work for the time available) or so little in the way of active work requirements that attention wanders.

3. Poor motivation or morale on the part of the plant staff.

4.2.3 Assess the Maximum Consequences of Error

Determine the likely worst consequences of each error if it is not detected, or is detected only after its worst consequences have occurred. Consider at least the following kinds of consequences:

1. Time loss.
2. Degraded process control, including possible effects on each of the parameters identified in Chapter 2.
3. Equipment damage.
4. Wastage of materials and/or purchased services.
5. Personnel injury.
6. Increasing the opportunity for other, possibly more serious, errors.

4.2.4 Assess the Probabilities of Error Detection

Assessment of the probabilities of error detection should include at least the following steps:

4.2.4.1 Identify the significant opportunities for detection. For example, detection may be almost inevitable on the next operation if an error is made on a setup step which is essential to performance of the following operation.

4.2.4.2 Identify who may be involved in the detection. For example, the perpetrator of the error, a fellow worker, an inspector, the plant manager or other supervisor may all have an opportunity to detect an error.

4.2.4.3 Estimate the probability of detection at each significant opportunity.

4.2.4.4 Estimate the elapse of time and relevant changes in system status likely to occur between error event and detection.

4.2.5 Assess the Distribution of Consequences

Assessment of the distribution of error consequences should involve at least the following steps:

4.2.5.1 Cross-compare (for each possible error) the probability, maximum consequences, and likelihood of detection.

4.2.5.2 Eliminate from further prime consideration those activities lacking any significant potential for error consequences.

4.2.5.3 Estimate (for the remainder of activities and errors) the frequency of different kinds and levels of error consequence.

4.2.6. Assess the Probable Payoff from Job Aids

Assessment of payoff from job aids should include the following steps:

4.2.6.1 Identify the types of aids appropriate to each activity with potential for significant error (including too slow performance). The classifications and descriptions of job aids in appendixes B and C should be useful in suggesting possible job aids.

4.2.6.2 Make tentative choices of the preferred type or combination of types of aids.

4.2.6.3 Estimate the impact of proposed aids under conditions of optimum use.

4.2.6.4 Modify estimates of job aid payoff by estimates of their probable use. For example, it is typically the case that the usual operating and maintenance manuals are infrequently referred to except by very inexperienced workers or when unusual circumstances are encountered.

4.2.7 Assess Tradeoffs with Job Aids

Consider job aids in conjunction with and as alternatives to other design features of the operating environment. Principal among the factors to be traded off against job aids are:

1. Personnel selection. The requirements for job aids become less stringent as increasingly higher levels of worker knowledge and skill can be assumed. At least three factors constrain use of personnel selection as a means of minimizing operational difficulties:

   a. With increasingly complex designs for municipal wastewater treatment plants, even the most outstanding staffs require assistance if they are early to achieve full performance potential on new operations.

   b. It is not only costly, it may literally be impossible to recruit the most knowledgeable, skilled, and experienced personnel.

   c. Beyond a certain point, selection of excessively skilled personnel can have its own negative impact. Workers who are over-qualified can become bored, inattentive, prone to absenteeism, a source of errors, a detrimental influence on the morale of other workers, and a turnover problem.

2. Training. Personnel who are highly trained on a new set of operations generally require a lesser set of informational job performance aids than untrained personnel. However, the performance of even the most highly trained workers may benefit from job aids, especially where:

   a. A great deal of specific, detailed information is involved.

b. Standardized written records are desired of the worker.

c. Tasks are infrequently performed and/or must be responsive to unusual circumstances.

d. The worker must make relatively complex judgments according to specified criteria.

3. Human engineering. Design of equipment to facilitate performance of required tasks can substantially lessen the requirement for separate job performance aids. Indeed, in a sense, the design of informational job performance aids is simply an extension of equipment and facility human engineering. However, cost considerations can lead to definite limits on the extent to which required job information can be built into the equipment and facilities with which workers interact.

4. Automation. Instrumentation and automatic control are ways of eliminating many traditional operating tasks. However, not only are these means constrained by technical state-of-the-art, they will commonly increase requirements for:

   a. Operator monitoring of machine performance.

   b. Maintenance of increasingly complex equipment.

   c. Management of a technologically sophisticated and malfunction-vulnerable system.

4.2.8 Define Job Aid Objectives and Specifications

Summarize the assessment of needs for informational job performance aids in terms of at least the following areas of tentative conclusions:

1. The activities to be supported with job aids and the error potential to be reduced thereby.

2. The types of aids to be used in support of each activity including an indication of the content and means of presenting the content.

3. Special features required of an aid to meet unusual needs such as accessibility of visual information without interruption of a primary task which requires both hands to be fully occupied.

4. Critical assumptions about other characteristics of the operating environment required if tentative conclusions about job aids are to be valid. For example, these assumptions might include reference to the particular task analysis documents which define activities and likely errors, characteristics of workers, and environmental conditions (such as lighting, humidity) under which aids will be used.

5. Sources of data that should be drawn up in the construction of each aid.

4.3 Structure Information Needs by Positions/Jobs

Relate the job aid requirements identified under 4.2 to the position and job information developed per Chapter 3. This is a preliminary step toward the effective organization of job aids. If each requirement is translated into an independent aid, the worker may be hampered by a welter of information which will impede rather than enhance his performance. Thus, it is essential that requirements be translated into an articulated set of aids which are conveniently available. But, it is all too easy to organize and cluster aids in ways which are not compatible with the broader requirements of positions and jobs, even if individual needs for aids are derived in relatively microscopic detail from task data per Step 4.2. In order to avoid the twin dangers of disarticulated and wrongly clustered aids, the following steps should be followed in structuring information needs by positions/jobs:

4.3.1 Identify job aids that can satisfy multiple information needs. These needs can be across activities within tasks, work positions, or jobs. For example, a basic process flow diagram might be used both by operators and maintenance workers.

4.3.2 Assure the convenience of each job. Organize plans for aids such that the set of aids for each defined job represents an accessible and orderly whole. Avoid having persons with one job search through information, most of which is relevant only to other jobs.

4.3.3 Allow for flexibility in the definition of jobs at the local plant. Each plant is likely to demand some unique variation in the way duties and work positions are clustered into total jobs. This variation may stem from:

a. Special local circumstances, such as labor agreements, which constrain work assignments.

b. Optional areas of work assignment where duties can be shifted across jobs on a day-to-day or week-to-week basis.

c. Evolution of improved procedures and assignment as a plant and its organization mature.

This means that job aids should be organized primarily around clusters of tasks (duties, work positions, and functions) always likely to be performed by a single worker during any given assignment--even if the cluster of tasks may be assigned to persons with different job titles from time to time. Though job aids are primarily organized around such unitary assignment units, this should not be construed to violate 4.3.2, above. Convenient access should be provided to a job aid for all jobs that may have occasion to use it. For example, there may be a central file of procedural checklists and/or they may be posted at the physical work station. Each job may have its own manual which references the relevant checklist and indicates its location.

4.4 Sequence Information Needs

The structuring of information needs by positions/jobs (Step 4.3) provides a first basis for organizing job aids. Further organization of aids can be achieved by systematic concern for the sequence in which information is presented. Such concern can be reflected in the following steps:

4.4.1 Determine invariant order.

4.4.2 Determine contingent order.

4.4.3 Determine temporal imperatives.

4.4.4 Determine frequency implications.

4.4.5 Determine criticality implications.

All of these steps depend heavily upon the results of task description and analysis as described in Chapter 3 and of assessment of the need for information support (Step 4.2).

4.4.1 Determine Invariant Order

Determine which activity sequences are always to be carried out in the same order. This will guide the structuring of job aids in a compatible arrangement. The determination of invariant sequences will depend in substantial measure upon knowledge of the processes, equipment, and facilities of the plant. For example, a determination of the exact order for re-assembly of a pump may depend upon rather intimate familiarity with the design of that particular component.

Activity sets whose order is not clearly imperative pose an added problem. Even though it may not, strictly speaking, make any significant difference to plant performance in what order a set of activities is carried out--it may be a matter of convenience to have some order specified. It is desirable, then, to distinguish:

1. Invariant sequences of activities where the order is essential.
2. Activity sequences that are probably better described as invariant, even though the order is essentially arbitrary.
3. Activity sets that have to be performed within prescribed limits, but whose order of performance is at the discretion of the plant manager or individual worker.
4. Contingent sequences, which represent an added set of considerations as outlined below.

4.4.2 Determine Contingent Order

Contingent sequences of activities impose a special burden upon job aids in that the requirements for information to guide the order of activity may equal or be greater than requirements for describing or otherwise supporting individual activities. This is in contrast to invariant activity sequences since an indication of order for such sequences can be handled by such obvious techniques as sequential numbering.

As with invariant orders of activity, the determination of contingent sequences involves use of substantial knowledge about plant facilities, processes, and equipment. For example, it takes considerable knowledge of plant processes and trouble symptom relationships to prescribe a trouble-shooting procedure by which an operator can diagnose effluent quality problems through an efficient series of checks, with each subsequent determination based on the results of his previous reading.

The most difficult contingent series to identify, delimit, and support with useful information, however, are those in which the contingent actions can only be determined on the basis of probabilities rather than on the basis of deterministic factors such as equipment design. For example, a plant manager's strategy for purchasing supplies may be based on predictions about behavior of the market over time. One factor making a determination of such contingent action series difficult is the freedom the designer has in specifying the degree of contingent action to be taken. In the purchasing example, it is possible to define relatively invariant procedures which ignore market dynamics or to define sophisticated algorithms which seek to minimize costs over time. Similarly, there will typically be considerable freedom in specifying the rigidity of response in dealing with factors disruptive to process control.

In determining contingent sequences, particularly where they involve probability estimates or complex problem solving, it is essential that the prescribed procedures be defined. Hopefully, this prescription will be reflected in the task descriptions and analyses covered under Chapter 3. If any ambiguity remains, however, it must be resolved at this point in designing job aids.

4.4.3 Time Frame Implications

Certain actions may be constrained not only as to sequence relative to other actions, but may also have to be performed within some time frame determined by conditions, events, or other actions. Such temporal requirements may also have implications for the availability and design of job aids which support the relevant action. Review, therefore, task information against previously identified job aid requirements to determine any additional requirements which are imposed by time contraints.

4.4.4 Determine Frequency Implications

A great deal of the structuring of job aids will be determined by considerations derived from previous steps. However, frequency considerations may still be a factor in determining the final structure of aids. Note, however, that the important concern here is not simply a repetition of the concern for performance frequency in assessing the probability of error (Step 4.2.2). Rather, the crux of the concern here is with an estimate of the frequency with which an aid will be used since this may have implications for the relative accessibility of the aid.

4.4.5 Determine Criticality Implications

The assessment of need for information support (Step 4.2) should reflect substantial concern for the criticality of job aids. However, as a last step in determining sequence considerations, it is important to review the evolving structure of aids to assure that the most critical performance is given appropriate precedence.

4.5 Determine Functions Served by Information

Review job aid analyses evolved to this point, in conjunction with related job/task data, as a basis for deciding upon functions to be served by informational job performance aids. Each function is defined by at least three main characteristics:

1. Purpose.
2. Extent of memory support.
3. Amount of discretion left to the worker.

There are six main purposes to be served by a job aid. They are to:

1. Alert the worker that his action is required and what aspect of his job responsibility is involved.

2. Sequence the worker's actions, with respect to each other and with respect to events in his environment.

3. Orient the worker to where (for example, with what components of the system) his action is required.

4. Instruct the worker how to carry out his required actions.

5. Inform the worker about standards to be met, cautions to be observed, exceptions to be made, etc., in carrying out his work.

6. Exemplify, with pictured and/or descriptive samples of specific work performances, satisfactory ways of carrying out instructions.

The extent of memory support can vary from no aid (leaving the worker on his own to cope with the dynamics of his work environment) to a full description of the context and performance requirements that would suffice to support a novice worker. If an informational aid of some kind is provided, minimum description is aimed at providing the worker with cues rather than providing full substantive description. Three types of cues must be considered:

1. Memory cues are aimed at jogging the worker's memory. For example, a checklist may present only the barest outline of work steps, depending upon the worker's memory for the specifics of procedures to be followed.

2. Highlight cues are aimed at helping the worker to select (out of a larger informational context) that information which he feels he needs. For example, sections of an operating manual may be arranged so as to present general prescriptions initially with more detailed supportive information later--somewhat in the form of a classic news article.

3. Index cues are aimed at helping the worker gain access to information which will aid his job performance. Subject indexes, tables of contents, and diagrammatic indicators of source materials are examples of index cues.

A given job aid element may, of course, support multiple kinds of cuing.

The amount of discretion left to the worker can vary, at least in theory, from complete freedom on the part of the worker to total prescription of his actions.

4.6 Determine Units and Formats for Information Support

4.6.1 Determine Units of Information Support

Structure the content of job aids to:

1. Cover as many work steps as possible, commensurate with clear and effective presentation of information for each step.
2. Encourage straightforward series of work steps, handling contingency situations as simply as possible.
3. Minimize the irrelevant information facing the worker during any given use of the aid. Where the bulk of information potentially needed by the worker for a given task is relatively large:
    a. Cluster the information into units which the worker can use in sequence and/or at his discretion.
    b. Provide cuing aids that will help the worker to conveniently select only that information which he needs.
4. Parallel the way in which the worker will normally perform his job. In particular, this means:
    a. Assure easy access to job aid information in the order of usual performance.
    b. Make the job aid units consistent with the start and end points of work tasks and major duty cycles.

5. Serve the varied requirements of different work locations, which include:

   a. Keep the size of any one aid commensurate with the most restrictive conditions under which it is likely to be used.

   b. Allow for easy portability of aids likely to be used in multiple locations.

   c. Minimize the likelihood of conflicting demands for a given aid by different workers.

4.6.2 Determine Formats for Information Support

Decide on the appropriate format for each independent unit of job aid information. Recognize that there is an interaction between the media of presentation and formats of presentation. Principal among the media which might be considered for the presentation of job aid information are:

1. Audio is essentially limited to narrative job instructions, although it may be possible (but unlikely) that it will be cost/effective to provide reference audio signals that will help the worker to analyze aural cues (such as sounds of equipment operation) heard on the job. The main advantages of audio presentation are:

   a. Use of an alternative channel of information input when the worker's visual channel is fully occupied with tracking signals in his environment.

   b. Convenient pacing of work activities.

2. Video and movie projection permit speeded, slowed, and real-time presentation of change information such as the lag characteristics of instruments following different control manipulations. They can readily be combined with an audio presentation.

3. Microform (roll film, microfiche, cartridge or cassette, aperature card) provides copy which is economical in terms of cost and storage space. Microform applications can range from programmed filmstrips with audio support to a film analog of a document library. Combined with an effective indexing scheme, and even a modest computerized retrieval system, microform systems can provide the worker with easy access to a large base of job information.

4. Computer programs can assist workers in data processing and, through the implementation of formal models, forecasting of results from contemplated actions. With increasing sophistication of municipal waste treatment plants, it is likely that computers will be increasingly used in automated process control. They may well become such an integral part of the plant environment that it will be difficult to determine if they are part of the on-line system or used as separate informational job performance aids.

5. Hard copy (manuals, checklists, drawings) has been overwhelmingly the dominant medium for informational jobs performance aids. The format considerations presented below have most immediate reference to hard copy, although they can equally be applied to video and microform. Some of these format considerations can selectively be applied to audio and computer program design as well.

In the selection, and later detail design, of formats for each unit of job aid information, consider at least the following general kinds:

1. Narrative text.
2. Tabular text.
3. Tables.
4. Diagrams.
5. Pictorials.

6. Formulas and algorithms.
7. Graphs.

Each of these types of format is described below.

Narrative text. In general, minimize the use of open-format narrative. It may, however, still prove to be the most effective format for some purposes--especially as a stage-setter for the application of more highly formatted aids. Use cuing devices liberally in such text, including:

1. Frequent paragraphing.
2. Numerous short titles.
3. Underlining, different type, arrows, color, geometric forms, shaded areas, boxed materials, and other devices to draw the worker's attention.
4. Concise examples.

Tabular text. As narrative text is increasingly cued and formatted, the line between it and tabular text becomes tenuous. The distinguishing characteristic of tabular text is presentation of discrete units of information as ordered sets. Well-designed tabular text is much more effective for presenting job procedures than equally well-written free-narrative text. Tabular text lends itself to quite abbreviated statements in the form of checklists.

Fundamental textual units are usually presented as a vertical series, from top to bottom of the page. If the nature of the actions described by the text are highly varied from one unit to another, it may be best to leave the order of presentation within each unit open. More typically, however, there will be sufficient homogeneity from one action to another that communication will be simplified by following a uniform order for presenting information within each vertical unit. If the individual vertically sequenced information units are relatively simple, uniform order of presenting classes of information within each unit will probably provide sufficient format structure. If the vertically defined information units tend to be lengthy or complex, horizontal structuring of text through the use of designated columns will help to simplify the worker's use of tabular text.

Simple serial procedures most obviously lend themselves to support by tabular text. However, it is also possible to develop tabular text to support complex tasks with a large number of contingencies. For example, fault diagnosis and troubleshooting tend to be the most complex tasks in plant maintenance. In Figure 17 is presented sample tabular text in support of a sample fault diagnosis and troubleshooting task. Note the vertical sequence of information units and horizontal format for each unit.

Tables. Highly formatted tabular text such as that illustrated in Figure 17 comes very close to being a table with high textual content. Indeed, the line between the two is arbitrary. Tables are especially used for the presentation of highly abbreviated, coded, and quantitative information. One kind of table having particular relevance to the design of informational job aids is a decision table, which is intended to assist the worker in choosing the proper course of action in the face of a large number of contingent conditions. One of many possible formats for such a table is illustrated in Figure 18.

Diagrams. Construction blueprints, engineering schematics, installation diagrams, wiring diagrams, and process flow charts all contribute to the body of information available for potential use in job performance aids. Such diagrammatic materials may well be required as part of the plant documentation regardless of their relevance to job aids. Their availability, however, is not sufficient justification for their inclusion in job aids. They should be used only so far as they are judged to have significant potential for enhancing worker performance. Also, diagrammatic materials prepared for design and construction are not necessarily unitized, at the level of detail, in the format, or associated with the collateral information that would make them most useful as job performance aids.

Step #	Action	If this, go to→→	Step #	If this, go to→→	Step #
T.11.1	Check power lamp K3	OFF	T.11.2	ON	T.11.6
T.11.2	Check circuit breaker X7	OFF	T.11.3	ON	T.11.6
T.11.3	Depress circuit breaker X7	Goes OFF	T.11.4	Stays ON	T.11.6
T.11.4	Manually rotate motor shaft	Bound	T.11.5	Free	T.11.9
T.11.5	Replace motor bearings→→→→→→	→→→→→→→→→→→→→→→→→→	→T.11.3	--	--
T.11.6	Check flow rate gauge I12	LOW	T.11.7	NORMAL	T.11.45
T.11.7	Turn power off; remove gear housing; inspect	No Damage	T.11.8	Damage	T.11.20

Figure 17. Sample Tabular Text to Support Diagnosis and Troubleshooting

Variable	Condition	*Condition Set								
Influent BOD	less than	√	√	√						
	to				√	√	√			
	more than							√	√	√
Effluent BOD	less than	√			√			√		
	to		√			√			√	
	more than			√			√			√
Action										
Shut valve k, shut valve M		X	X							
Open valve K, shut valve M				X	X					
Shut valve K, open valve M						X	X	X		
Open valve K, open valve M									X	X

*Since alternative conditions for a given variable cannot be present simultaneously, the possible combinations are the geometric sum of all conditions across variables (in this case, 3 x 3 = 9).

Figure 18. Sample Decision Table to Assist Worker in Choosing Proper Control Action

Diagrams of two types are generally most useful as job aids:

1. Functional flow diagrams which show (either directly or by reference to other aids):

   a. Where the worker intersects with functioning of the system.

   b. The kinds of information about functioning he should attend to at each point of intersect.

   c. How worker activities will impact on system functioning.

   d. What the proper procedures are for worker interaction with the system at each point of intersection.

   e. In minimum detail, what the nature of system continuity is between points of worker intersect and interaction.

2. Decision diagrams which show, in the form of action trees, the appropriate course of worker response to contingent situations. Decision diagrams can take on a variety of useful formats, one of which is illustrated in Figure 19 using the material from Figure 17 (for fault diagnosis and troubleshooting) and in Figure 20 the material from Figure 18 (choosing proper control action) in decision diagram form.

Pictorials. In contrast to diagrams, which typically represent the wastewater treatment system or component parts in highly symbolic and functional terms, pictorials represent the system or its components in realistic physical terms. Pictorials can be a great help to the worker in assigning proper nomenclature to objects and in locating specific items, but the following steps should be taken to avoid common mistakes in the design of pictorials as job aids:

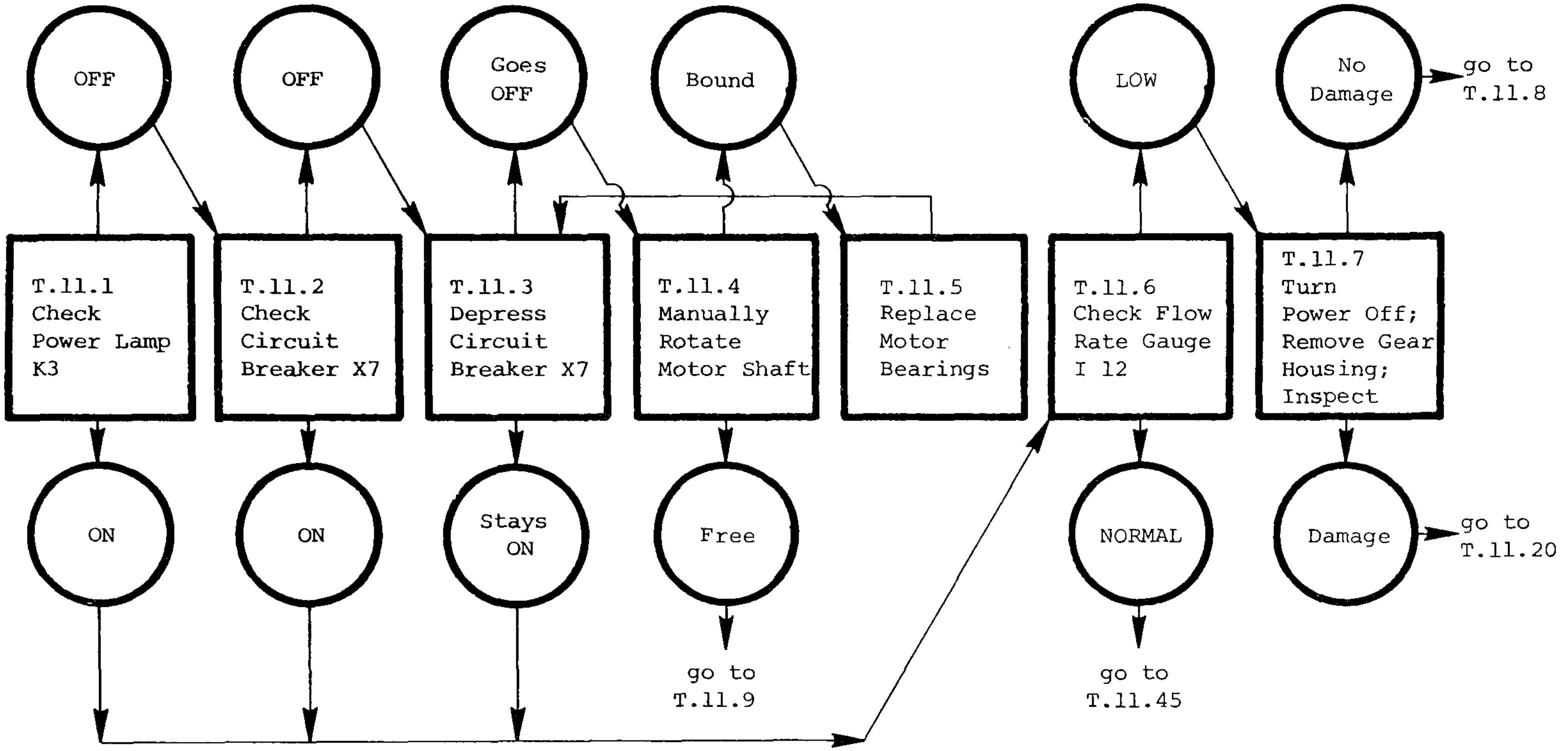


Figure 19. Sample Decision Diagram to Support Diagnosis and Troubleshooting

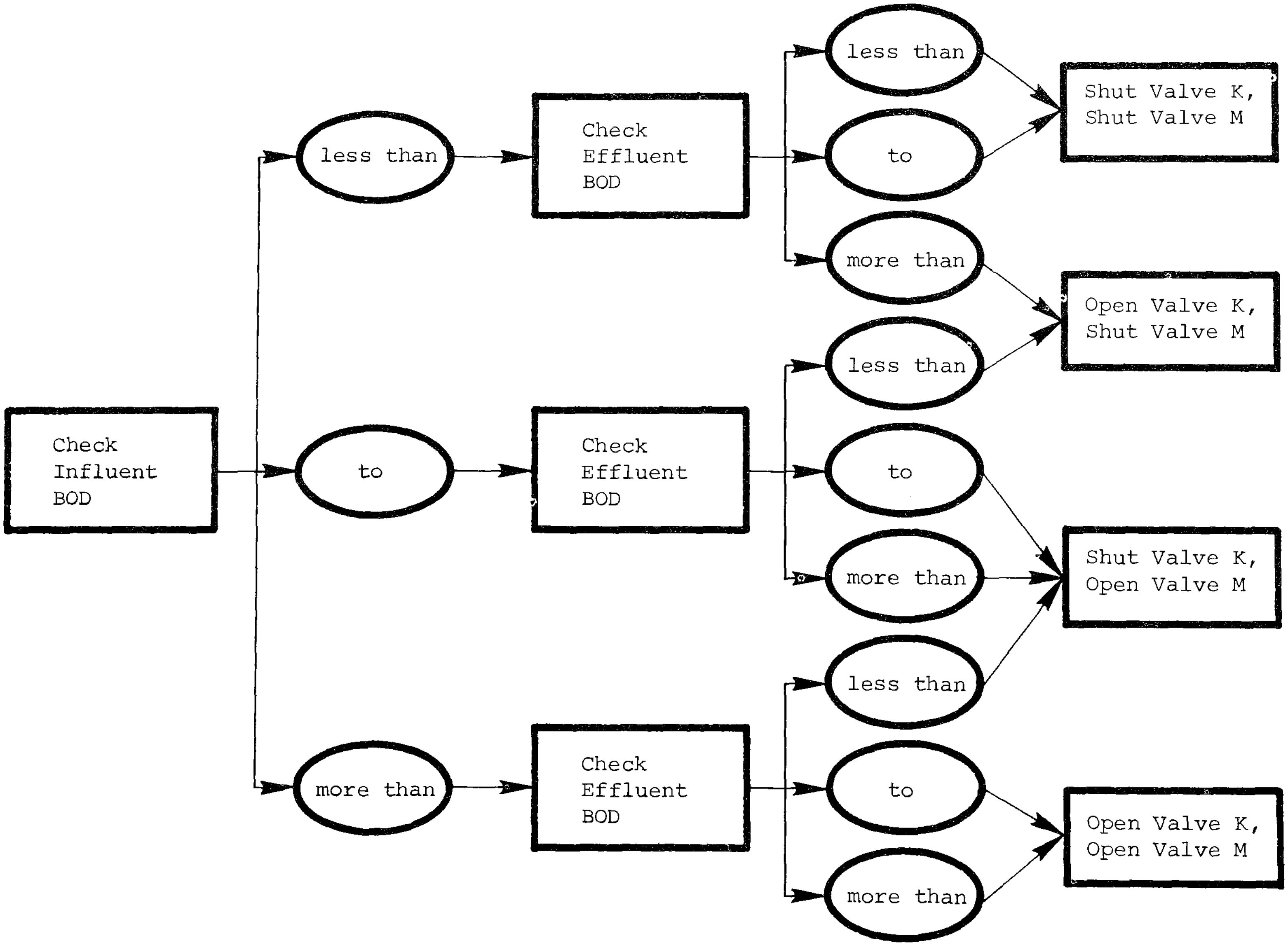


Figure 20. Sample Decision Diagram to Assist Worker in Choosing Proper Control Action

1. Assure that all pictorials have an explicit function. If aids are intended exclusively for use in the work environment (they are not also to be used as off-site training aids), there is no point to including pictorials of items that can easily be located directly.

2. Include only necessary detail. One of the principal reasons for pictorials is to provide simplified representations that help the worker locate essential items and features. This purpose will be defeated if pictorials are not highly selective in the detail presented.

3. Insure sharp focus of critical cues. If photographs are used, consider touch-up of raw photography to enhance essential reference cues.

4. Present procedural information on the same frame as the relevant pictorials or explicitly key pictorials to separate job procedures.

Formulas and algorithms. Mathematical calculations and other data conversions are prone to human error, especially where the worker is under speed stress. Provide the worker with aid by:

1. Supplying electronic calculating equipment or other devices which are compatible with data processing demands.

2. Making the form of required data processing operations consistent with the available aids.

3. Breaking operations into a series of simple steps.

4. Using familiar symbols and operations insofar as possible.

5. Maintaining consistency of symbology and approach across data processing tasks, insofar as this is possible.

6. Providing especially preformatted worksheets that will encourage an orderly progression of data processing operations.

7. Providing a means of cross-checking interim results to prevent long strings of operations from being in error due to previous mistakes.

Graphs. Numeric tables have already been pointed out as being one aid to data processing. Graphs provide an alternative which usually is more compact but less precise than a table. Of special potential as an aid to interpreting process control relationships are graphs which permit conversion from one or more variables to another where the relationships are nonlinear.

4.7 Design and Test Aids

The design and testing of informational job performance aids includes the following steps:

4.7.1 Organize and review job aid specifications and task/performance data.

4.7.2 Define variables to be monitored, controlled.

4.7.3 Define indicators, indications of deviation from standard control.

4.7.4 Identify possible sources of deviation.

4.7.5 Analyze the dynamics of deviation.

4.7.6 Prepare action strategies.

4.7.7 Draft scheduled aids.

4.7.8 Draft contingency aids.

4.7.9 Review and revise aids.

4.7.10 Format and reproduce aids.

Each of these steps is described below.

4.7.1 Organize and Review Job Aid Specifications and Task/Performance Data

Review and exploitation of task data have been both explicit and implicit throughout the description of Steps 4.1 through 4.6. Here, in the final design of job aids, task and related plant performance data will be used continually. Use the insights gained from Steps 4.1 through 4.6 to organize task and performance data in ways that will make them amenable to use in this job aid design and testing process.

Results of the analyses described in Steps 4.1 through 4.6 can be recorded in a variety of ways and degrees of detail. It will usually be desirable, however, to prepare a brief written summary of conclusions from all reviews and analyses to guide the design of each aid. The summary for each aid should include:

1. Reference to backup plant design and performance data, job, position, and task descriptions.
2. The key characteristics of worker performance to be enhanced by the aid, and functions served by the aid.
3. The principal sequence and dependency relationships among actions covered by the aid.
4. Principal sequence and dependency relationships of the subject aid to other designated aids.
5. Media and formats to be used for the aid.

A sample summary is illustrated in Figure 21.

4.7.2 Define Variables to be Monitored, Controlled

Review relevant plant performance and task descriptions to determine the system variables to be assured or influenced by worker actions covered by the aid. If these variables and relationships to worker actions are sufficiently clear to support aid development, move to Step 4.7.3. If the

JOB AID: OG 17 Secondary Tank Shutdown Checklist.

REFERENCE: System Diagram 12, Detail Schematic 1147, Operator Job Description 7, Position 7.3, Task 7.3.4.

PERFORMANCE ENHANCEMENT: Primarily to assure no steps left out and proper sequence of steps, not to present detailed instructions or backup information except by reference to manuals. Initiation of procedure at option of plant manager.

INTERNAL RELATIONSHIPS: Steps invariant and order important; order of valve closing especially critical.

RELATIONSHIPS TO OTHER AIDS: Summarizes detailed instructions O-17.7.3.4 of the operations manual. Manager's handbook section M-17.7.3.4 describes conditions for electing to shutdown.

MEDIA AND FORMAT: Plastic-coated checklist with numbered steps, e.g., "Turn Value 12 full OFF."

Figure 21. Sample Job Aid Summary Description

available descriptions are incomplete or lacking in clarity, revise and/or supplement them to clarify precisely what about the system is to be monitored and/or controlled.

4.7.3 Define Indicators, Indications of Deviation from Standard Control

Review plant performance descriptions, task descriptions, and any supplementary descriptions developed under Step 4.7.2 to determine if the worker may encounter indications with which he must cope by special contingent means. Recognize that much hinges on the definition of what are standard control means and what are special contingent means of system control, and that the judgments involved in making this distinction are rather subtle.

From the point of view of the job-aid designer, the crucial question is whether a control procedure requires specialized analyses beyond those already outlined or can be supported adequately with job-aid designs based exclusively on analyses prescribed to this point. If further depth of analysis is required, carry out Steps 4.7.4, 4.7.5, and 4.7.6. If such analysis is not required, go directly to Steps 4.7.7 and/or 4.7.8--both of which involve the initial drafting of aids.

Note also that there may be a difference between what is routine to the job-aid designer and what is routine to the worker. The designer may choose to break an aid at the point of any contingency and define additional aids as prescribing special contingent procedures. That is, the designer has a great deal of latitude in prescribing what are scheduled or normal procedures and what are special or contingency procedures. Which aids are defined as scheduled and which are defined as contingency--from the point of view of the worker--may not entirely parallel the designer's need or lack of need for special analyses.

Finally, also note that the definition of scheduled or routine aids versus contingency aids is very much affected by the distribution of responsibilities among workers. For example, an operator may be instructed to call upon the maintenance department routinely when specified indications are observed. The job-aid designer may have to carry out no specialized analyses to determine what conditions should be specified for initiation of a maintenance call. The maintenance worker's routine for verifying and amplifying observed malfunction indications may, however, require specialized analyses in addition to those prescribed to this point--even though these checkout procedures will be scheduled (in the sense of always being a first-order of business when receiving a trouble report) and routine from the point of view of the maintenance worker. If the maintenance worker is to be further provided with specific instructions for carrying out troubleshooting procedures, the job-aid designer may have to carry out additional analyses to support the design of troubleshooting procedures which are contingent upon the results of checkout routines.

4.7.4 Identify Possible Sources of Deviation

Remember that this step depends upon necessity. That is, it should be performed as a separate step only if previously developed information does not support direct design of aids. If additional depth of analysis is required, begin with an identification of the possible sources of deviation from desired system status or performance. This involves identifying the system components and modes of deviation associated with each indication for each indicator identified under 4.7.3.

For example, a manager may be faced with a series of periodic reports (indicators) which show frequent occasions when effluent quality falls below plant goals in one or more measured parameters (indications). Possible sources to be considered might include components and modes or causes of deviation as suggested in Figure 22.

4.7.5 Analyze the Dynamics of Deviation

Develop a model of the system or that part of the system directly involved in the tasks of interest. Essentially, this means defining relationships among the relevant components of the system in such a way that it

Components	Failure Models
Inherent Design Defect	Systematic failure when capacity is exceeded. Influent characteristics which violate design assumptions.
Operator Performance	Monitoring deficiency. Defective control procedures.
Equipment Defect	Inadequate periodic maintenance. Inadequate corrective procedures. Hidden chronic faults.

Figure 22. Sample Sources of Deviation from Plant Effluent Quality Goals

becomes possible to identify the information required to distinguish among possible sources of deviation from desired status or performance. For example, if the relevant segment of the plant can be represented as the simple series chain shown in Figure 23, distinguishing among the components (boxes) as a source of deviation from desired performance demands that a determination be made of whether the process is in-tolerance at each of the checkpoints (circles) intermediate between known influent and effluent points (ellipses).

4.7.6 Prepare Action Strategies

Derive, from the appropriate model(s) of plant and processes:

1. A sequence of steps for determining causes of deviation from desired status or performance goals.
2. A sequence of steps for achieving desired status or performance.

Determination of the observed indications which should lead to selected contingent diagnostic checks and corrective action will be the crux of preparing action strategies. That is, it is both critically important and difficult to judge what the worker should do and not do when faced with designated information. Most difficult of all will be to balance efforts to:

1. Minimize worker performance time.
2. Minimize likelihood of worker error.
3. Keep worker skill requirements within reasonable limits.
4. Minimize plant operating costs.
5. Maximize plant performance.

4.7.7 Draft Scheduled Aids

Determine which aids will support scheduled tasks. Develop a schedule for such tasks and their supporting aids for each job. Assure that the schedule

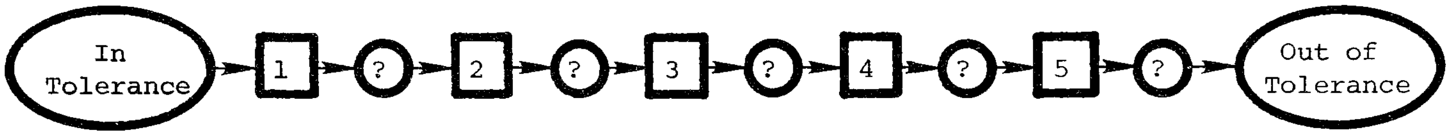


Figure 23. Model of Portion of the Plant to Help Analyze Information Needs for Aids

of tasks is articulated across jobs. Reflect all of the previous analyses in drafting each scheduled aid. Key scheduled (routine) aids to contingent aids that will be used in the event specified indications of deviation from desired status or performance are encountered during and cannot be dealt with as part of routine tasks.

4.7.8 Draft Contingency Aids

Determine which aids will be required to support tasks that will be initiated only upon encountering nonroutine circumstances (e.g., a manager who feels he is not getting full performance potential out of his staff, an operator faced with a flash flood, a maintenance worker faced with a major equipment failure of unknown cause). Draft these aids, keying them to routine aids that may be involved in initiation of or follow-up to contingent tasks. Also cross-key contingent aids where, depending upon circumstance, the use of one may lead to another.

4.7.9 Review and Revise Aids

The general concepts and procedures involved in the assessment of all operational planning, including the preparation of job performance aids, are described in Chapter 5. No effort is made here to summarize those concepts and procedures. It should be pointed out here, however, that at least three steps should be carried out after aids are drafted and before their final reproduction:

4.7.9.1 Review each aid.

4.7.9.2 Test each aid, by having individuals, similar to those who will ultimately be using it on the job, actually perform or simulate performance of the relevant tasks.

4.7.9.3 Revise each aid, if necessary, on the basis of results from 4.7.9.1 and 4.7.9.2.

Review, test, and revision (as well as the initial design of aids) should include a concern for the following:

1. Completeness. The set of aids should provide consistent support across all tasks for each worker.

2. Accuracy. Inaccurate information will cause erroneous job behavior and/or erode faith in aids.

3. Modifiability. One kind of especially likely inaccruacy is failure to keep up with evolving plant design, both planning and post-operational modifications. Provisions must be made for the update of aids.

4. Clarity. No matter how complete and accurate a job aid is in a technical sense, it will not have the desired effect on performance unless it communicates, e.g.:

   a. Avoid engineering and technical terms that might be beyond the educational and experience level of the intended user.

   b. Separate numerical values from verbal text in most instances; highlight quantitative values where they must be included in textual material.

   c. Present only information which the user may not know or might forget; use cues rather than narrative text where possible.

   d. Present information and data in its most useable form rather than in a form requiring translation for its application.

   e. Only present variables which are likely to influence the worker's actions; avoid a discussion of variables or issues which are of theoretical value only.

   f. Present all material in size and contrast so as to be perceived easily by the worker.

5. Accessibility. Package and index aids for easy access to needed information.

6. Convenience. Consider the conditions under which the aid is to be used, e.g.:

   a. Bind booklets and manuals to permit pages to lie flat when open.

   b. Avoid foldout pages which become unmanageable where large flat surfaces are not available; avoid pages which fold out vertically into the worker's lap.

   c. Use work cards or other abbreviated units where aids must be used without benefit of a convenient working surface.

   d. Use extra-sized print and graphics or use auditory aids where illumination may be poor.

   e. Where information is site specific and needed away from a central work station, mount aids on equipment or walls.

7. Durability. Provide plastic coating or other protection where dirt, water, chemicals, or frequent handling may be a problem.

4.7.10 Format and Reproduce Aids

An essential point to remember about the preparation of final formats and reproduction of aids is that desirable characteristics may be lost in the process. For example, wide spacing may be compressed; individual draft items may be bound together with bindings becoming more restrictive and permanent. The job aid designer must be alert to all such possible sources of degradation to job aid utility.

5. ASSESS OPERATIONAL PLANNING INFORMATION

The need for assessing operational planning information is basically two-fold. First, there is the need to identify and correct inadequacies of planning which do not become apparent until assessed in the proper context. Second, there is a need to receive feedback on operational planning concepts and practices so that future planning activities can build on a solid foundation of proven planning technology. Thus, assessment provides a guiding influence throughout operational planning and serves as a check on the results of planning which, hopefully, will lead to new generalizable concepts and improved planning technology for the future.

Specific needs for assessment are primarily a function of "newness" and, hence, the lack of relevant precedents associated with:

1. Data acquisition.
2. Data reduction and analysis.
3. Operational planning concept formulation.
4. Experience of the development team with system analytic and operational planning activities.
5. Translation of plant information into operational planning activities and products.

While the level of emphasis placed on assessment can be legitimately decreased as experience and expertise is gained in required activities of planning, there will always be a need to make that final evaluation of the man, as a plant component, and the extent to which his performance is optimized through the products of planning. The essential attitude one must adopt is that the input-output characteristics of the man must be evaluated and optimized along with the machine components of the plant.

An approach to the assessment of operational planning is provided through the following basic steps, each of which is briefly defined:

5.1 Define assessment objectives and criteria results in the identification of appropriate goals and criteria for measuring the achievement of operational planning objectives.

5.2 Define data gathering, measurement, and testing procedures leads to the selection of assessment tools for measuring the degree of achievement reached for each operational planning objective.

5.3 Carry out tests results in the application of assessment tools to provide evaluative data.

5.4 Analyze and interpret results leads to conclusions and recommendations concerning the optimization of those operational planning factors which were assessed.

5.5 Translate assessment results into planning action establishes a framework for applying the results of assessment to the correction of deficiencies and the overall optimization of operational planning effectiveness.

5.1 Define Assessment Objectives and Criteria

The principal motive of assessment is, of course, concerned with gaining feedback on how well operational planning will or has served to maximize plant operational effectiveness. "How well" immediately implies that there are objectives to be achieved and that there are measurable criterion values which will permit their assessment.

There are, in fact, two major types of objectives which must be appropriately defined as part of any meaningful assessment. They are:

1. Operational planning objectives, which are concerned with some aspect of operational planning.
2. Assessment objectives, which are concerned with goals and criteria for determining the achievement of operational planning objectives.

5.1.1 Redefine Operational Planning Objectives

Operational planning objectives were established earlier (Chapter 1) as one of the initial steps in defining an operational planning program. The essential characteristics of those objectives were expressed in terms of:

1. The physical form of program outputs.
2. The informational content of program outputs.
3. Dimensions of accuracy and completeness to which the outputs must adhere.

The redefinition of planning objectives is aimed at culling forth those detailed elements which define outputs (informational products, activities, etc.) to be achieved through the planning program and the expressed quantitative/qualitative expectations of the effort (level of completeness, accuracy, etc.). The resulting enumeration of outputs and expectations serve two major assessment functions:

1. A check is provided on the clear, concise, and comprehensive statement of program objectives, providing an opportunity to further assure program direction and resource allocation. This check must, of course, be made early in the program if it is to clarify and enhance efforts of the development team.
2. A consolidated set of program outputs and qualitative/quantitative expectations are established as the main framework for assessment.

5.1.2 Translate Objectives into Operational Criteria

While planning objectives define what is to be accomplished through specific outputs (thereby defining what is to be assessed), the quality expectations of these outputs must be translated into a form which will permit measurement of adequacy. Each output resulting from 5.1.1 must have a criterion value associated with it to express qualitative and/or quantitative expectations. If the original statement of objectives did not provide adequate criteria, or if additional or more specific outputs have evolved through the process of redefinition, it becomes necessary to translate expectations into explicit criterion values.

In order to constitute a sufficient basis for judging adequacy, the criterion portion of an objective must define:

1. The variable(s) on which or according to which judgments are to be made.

2. The point(s) or region(s) on the criterion variable(s) at which judgments of adequacy will change to judgments of inadequacy--the term "standard" is applied to such points and/or regions.

As you will recall from Chapter 1, operational planning objectives will necessarily vary from one plant to another, from one planning product area to another, and from one developmental stage to another. In particular, the stage of development will impact on the level of specificity with which it is possible to define outputs and criteria. During early stages of development it is most likely that outputs and criteria will be closely oriented to planning materials and products. Ultimately, however, the outputs and criteria must be extended to the specific human behavior expected of the plant staff through implementation of planning materials and products.

The objective for staffing information at an early stage of development, for example, might reasonably be limited to an approximation of the number of people required in each of whatever job titles are most appropriate; outputs and criteria would be primarily centered around early task and job description products. An objective such as this becomes increasingly more comprehensive and stringent as the final stages of design for a plant become finalized, while at the same time, a transition toward people and behavioral outputs takes place. The final objectives in the staffing example, and the major concern of assessment at the final stage, must be sufficiently detailed and explicit to foster the hiring and training of a qualified staff, in the right numbers, prepared to effectively and efficiently perform their jobs when required. Thus, criterion variables must shift from the earlier physical and content characteristics of planning products to the results produced by these products in the context of the plant. Were people with the right qualifications hired? Were members of the staff adequately trained to perform each and every assigned task? Were there too many or not enough people hired in each job category?

5.1.3 Define Assessment Objectives and Criteria

There are obviously varying levels of effort which should be devoted to the assessment of operational planning objectives. Assessment results in information which is evaluated in terms of applicable operational criteria, which are concerned with how adequate individual operational planning efforts have been. But, these operational judgments must be conditioned with criteria for the assessment itself--how adequately has it reflected the true state and how accurate are the expectations which the assessment has established for operational performance. The following classes of criterion variables must be recognized and their impact appraised as a factor in defining assessment objectives and criteria.

Validity is the class of criterion variables by which one judges how assessment results reflect events in the real world. Some significant aspects of validity are:

1. Relevance--whether assessment results relate to operational and assessment objectives.
2. Predictiveness--how well assessment results forecast status at some future time.
3. Bias--the extent to which results are representative of the population of entities and events to which they manifestly refer.

4. Sensitivity--ability of the assessment to detect evaluation dimensions which may not be obvious.

5. Comprehensiveness--extent to which assessment deals with the full range of significant entities and events.

6. Timeliness--extent to which assessment results are available while they are still of use to planning and design activities.

7. Importance--practical implications of assessment results.

Reliability refers to the degree to which consistent results are obtained in two or more presumably comparable situations. Sources of unreliability include:

1. Measuring instruments which do not always record identical phenomena in an identical way.

2. Respondents or subjects or materials with a seemingly random component.

3. Small samples of individuals or events which result in unstable estimates of population parameters.

Efficiency is concerned with the extent to which assessment is responsive to cost and time constraints and accomplishes its useful purpose without waste.

Figure 24 reflects some broad sample objectives for the five major product areas of operational planning. Such broad objectives must become more explicitly detailed with each successive stage of plant design and development.

Product Area	Operational Planning Objective	Assessment Objective
Delineation of Plant Performance Characteristics	Provide descriptions of plant-specific characteristics necessary to support and structure the total of operational planning activities and products.	Determine the accuracy and adequacy of the data base as a tool for developing operational planning materials.
Analysis of Task and Job Requirements	Provide written descriptions of the types and numbers of personnel required for effective functioning of the treatment plant.	Compare qualitative and quantitative staffing recommendations with manpower utilization of the plant after installation is complete.
Preparation of Management Information	Provide information of immediate and long-term value to management in properly staffing, training, and controlling the plant for cost-effective treatment.	Compare information provided with that which is, or was, utilized and determine inadequacies of information presented to management.
Preparation of Operator Information	Provide information to plant operators to guide the control of treatment with maximum effectiveness and efficiency.	Compare operations information provided with that which is utilized and determine need for changing performance aid applications, content, or methods of presentation.
Preparation of Maintenance Information	Provide information to guide the effectiveness and efficiency of both preventive and corrective maintenance of the plant.	Compare maintenance information presented with that which is utilized; determine the accuracy of the information and the need for changing performance aid applications, content, or methods of presentation.

Figure 24. Illustrative Assessment Objectives for Some Operational Planning Objectives

5.2 Define Data Gathering, Measurement, and Testing Procedures

This step leads to the selection of appropriate testing and/or other data collection strategies to reflect if criterion performance for operational planning objectives is being reached. The measures and data collection strategies selected must be tailored to the criterion set for each planning objective.

5.2.1 Analyze Objectives and Principal Dimensions

There are three principal dimensions which serve to characterize the many possible approaches to collecting assessment data. The analysis of assessment objectives in terms of these dimensions will assist in setting the stage for a viable assessment strategy. The three dimensions, in brief, are:

1. Static-dynamic. On the relatively static end of the scale lie retrospection, expert opinion, paper-and-pencil tests, and utilization of facts in hand or derivable from information already available. On the dynamic end of the scale lie the manipulation of plant components under anticipated conditions of operation and the collection of findings of interest through the systematic observation of plant performance. An intermediate alternative is simulation of some plant components and functions according to principles known, or assumed, to underlie the performance of interest.

2. Experiment-demonstrate. Assessment may vary from carefully designed and closely controlled experimentation to open-ended loosely controlled demonstration. The difference in orientation is largely dependent on the purpose. Experimentation is appropriate for selecting, refining, or modifying a particular aspect of operational planning. Demonstration is suitable for showing that operational planning designs or products suffice for specified situations.

3. Intensive-comprehensive. There are practical limits on the amount of time and/or effort which can or should be allocated to the accomplishment of a given assessment objective. Strike a balance between an intensive narrow look and a less intense but more comprehensive look across all aspects of objectives.

5.2.2 Evaluate Alternative Approaches

The acquisition of assessment data may draw upon any one, or a combination of many, of the available collection techniques. The following data collection approaches, each of which is described in terms of positive and negative attributes, appear relevant to treatment plant contexts and will serve as a starting point for the selection of a suitable approach to assessment.

Discussion and Interview. A principal means for gathering a broad source of assessment data is through carefully recorded discussions and interviews with plant personnel to clarify the effectiveness of the operational planning effort in reducing operational problems, particularly those problems which were, or should have been, included in operational planning objectives. Note all problems not attacked in operational planning so that they may be included in future planning activities.

It is good practice to have a set of carefully thought-out questions to structure the interview even though it is quite fruitful to encourage interviews to go beyond the scope of specific questions.

The most comparable form of information is obtained through use of multiple choice or rating-type questions. It is generally undesirable to place exclusive, or even major, reliance on close-ended questions. Extracting insight from knowledgeable persons (particularly those with experience at plants with and without significant operational planning) can be much more rewarding than a scientific survey.

Direct Operating Data. The very nature of wastewater treatment dictates that large amounts of data will, or should, be collected to reflect the operational readiness, loading, level of treatment provided, and other relevant aspects of the operating plant along a time dimension. Many of these measures are automatically monitored and recorded on a continuing basis while others are dependent on human observation and perception. In any case, there is a substantial number of data collection means available which--because the data are a routine part of equipment status, control, or cost information--can be an inexpensive and important part of evaluating the achievement of operational planning objectives.

Extreme caution is the byword for accepting data from another operating plant for comparison with the plant of concern when little is known about the other plant. "Pencil titration" is a trick that is probably more prevalent than one would like to believe. Make sure that instrumented data collection is carefully calibrated and maintained and that laboratory tests are validly performed. Bad data is frequently worse than none at all.

Incident Reporting. Factual information is best obtained from specific identified incidents or events pertaining to treatment management, operations, and maintenance. Asking individuals to discuss their impressions of, or reactions to, reported operational problems is also useful. If incident reporting covers a broad range of operational characteristics, a relatively large number of incidents is required to provide comprehensive coverage of the situation. This would mean that discussion with many individuals is necessary since most individuals can only reliably report a handful of incidents on a given topic. Incident reporting is best combined with other techniques because of the limitations on the number of individuals available in most wastewater treatment applications.

Observation of Operations. Direct observation of the operational setting provides a convenient means for verifying verbal and written treatment information and filling in information gaps. It is often desirable, for at least the purposes of orientation, to observe operations in an unguided way. For recurrent or prolonged periods of observation it becomes necessary to establish specific purposes, sampling procedures, and routines to prevent gross inefficiencies.

Survey or Questionnaire. Surveys and questionnaires generally appear to be an easy way to collect a lot of data cheaply and quickly. There are, however, a number of factors which serve to limit the appearent usefulness and advantages of this form of data collection. To be carefully designed, they take a long time to prepare; they should be pretested with a small representative sample; the time of respondents must be counted as part of the cost; there are usually a significant proportion of nonrespondents; and busy design personnel and plant staffs take a dim view of surveys unless their purpose is immediately relevant and important. In general, the use of surveys should be highly selective and severely limited.

Document Review. Basic treatment plant design and operating information is often available and can be used for drawing rough comparisons between the subject plant and other plants of similar design and size. As an assessment tool for evaluating operational plans, however, care must be exercised with respect to extrapolation of data when plant loading, treatment objectives, criteria, and design configuration do not match the subject plant. It is anticipated that operational planning information will become an increasingly valuable part of wastewater treatment plant documentation and that its contribution as an assessment tool will likewise increase.

5.2.3 Match Objectives to Best Approaches

From the alternatives outlined in 5.2.2, it is likely that one or two approaches will appear to have clear advantages over all others with respect to each assessment objective. It is also probable that some number of objectives is amenable to the same approach and hold potential for being carried out through a singular and coordinated effort that will satisfy each objective.

Match each objective with its most favorable data collection approach, compromising only where increased efficiency largely offsets any disadvantages which might accrue.

5.3 Carry Out Tests

This step centers around the implementation of the data gathering strategies formulated in the previous step. This step should be one of routine procedure if the proper attention was devoted to defining the previous step. There are, however, a number of important substeps which will help ensure efficient and effective data gathering.

5.3.1 Define a Testing Plan

A guide or blueprint is necessary to inform those who will be involved or concerned with assessment tasks. The plan should cover at least the purpose, objectives, test methods (procedures, criterion variables, measures, data analysis, test instruments, etc.), facility requirements, report intentions, and possible benefits to be derived through assessment. Every assessment effort will certainly not require a fully documented plan, but every plan should be based on a consideration of the above factors. Assignments and responsibilities for the collection of data must, of course, be a part of the plan, and it is through the plan that an efficient and effective data collection effort is directed.

5.3.2 Define Probable Contingencies

Contingencies almost invariably arise and cause the conditions for gathering assessment data to differ from those that were assumed in the plan. It is necessary to react to these contingencies without compromise to the entire effort. Unfortunately, operational (field) settings which normally yield the most realistic conditions for assessment also present the greatest risk of compromise since establishing and maintaining necessary controls is most difficult under these conditions. For this reason, in particular, it is desirable to try out data collection procedures and provide specific practice in anticipation of the test and data collection effort, even when trained and experienced personnel are involved in the assessment effort.

5.3.3 Implement Pretesting

The tryout of planning information on a small scale is essential to overall accuracy and utility. Likewise, the assessment process itself benefits from pretesting of data collection strategies. While the ideal tryout situation would involve a representative sample of the intended population, a great deal can be learned about the adequacy of the assessment plan with tryouts using in-house personnel or other members of the design or development team.

5.4 Analyze and Interpret Results

The design for analysis and interpretation of assessment information is an inherent part of assessment planning. Steps 5.1 through 5.3 should lead to formulation and implementation of an assessment approach which will enable the treatment of results in such a way as to permit an adequate test of the criterion set for each operational planning objective. This step involves execution of a prearranged plan and is not a process of deciding what to do with data after they have been collected. No amount of data juggling can compensate for a faulty assessment approach.

The following substeps will assist with carrying out an orderly data analysis and interpretation effort.

5.4.1 Reduce Data to Manipulable Forms

A difficult aspect of assessment is that many of the data will have significant utility only at the time they are collected. Other data are of recurrent use across a long time span and variety of purposes. Deciding ahead of time which data will and will not be of continuing value is difficult if not impossible. It is, therefore, important from the earliest stages of assessment to hammer incoming data into a compact, consistent, manipulable form.

5.4.2 Implement a Coding and Classification System

The principal way of reducing incoming data to manipulable form is to categorize incoming data and code them on a real-time basis. Even roughly precoded data are more useful than raw data that "someone should get around to doing something with sometime." Early and informed attention to rough coding and classification procedures will have a beneficial impact throughout assessment of the evolving treatment plant.

5.4.3 Draw Upon Inferential Techniques

Even after the mechanics of processing data are established, interpretation of assessment data still remains. Mathematical or statistical models seldom apply to the kinds of data generally available. As an "operational planner," you are in essence a creative artist and decision maker faced with a great deal of ambiguity and uncertainty. Careful use of the best obtainable data prevents many false starts and erroneous conclusions. In the final analysis, however, data only provide a platform from which you can spring to the broad inferential leaps required to accomplish effective operational plans.

5.5 Translate Assessment Results into Planning Action

The significant contributions of assessment to operational planning can only be realized if the results are translated into activities directed to optimization of the planning process, the products generated through the planning process, and the utility of the products with respect to achieving plant cost-effectiveness. That is, assessment is directed toward determing how closely actual performance approaches the most advantageous region of performance for the plant. Where disparities occur, there is need for planning actions to bring actual and desirable performance into alignment.

5.5.1 Apply Cost-Effectiveness to Planning Actions

Concern with optimization actions will occur at two levels. First, there is the matter of optimizing input/output objectives and requirements as well as plant performance characteristics in relation to the overall pollution control efforts of the nation. Second, there is the matter of optimizing operational planning characteristics to meet specific plant objectives. At both levels, however, resolution is acheived through the application of cost-effectiveness models for comparing the alternative objectives or operational planning approaches and selecting that alternative which will most nearly satisfy pre-established criteria. The constructive use of assessment results is, therefore, largely dependent upon one's ability to progressively optimize that which was assessed.

5.5.2 Document Results and Planning Actions

Much of the potential benefit from assessment can be lost if the results and intended planning actions produced by assessment are not documented. Regardless of the formality or informality of the documentation, there must be at least some manner of recording and communicating assessment results of significance and any proposed actions for further enhancing operational planning. Documentation must be sufficient to serve as a plan for carrying out planning actions and as a historical reference to guide additional iterations of the operational planning process at the specific plant or permit generalization to other treatment plants.

OVERVIEW OF APPENDIXES

The four appendixes which follow are in support of general principles and procedures provided in the main body of this Guide.

Appendix A--Job Description Format and Development Recommendations

This Appendix provides specific job description format recommendations and development procedures in support of the task and job description guidance provided in Chapter 3.

Appendix B--Classification and Description of Informational Job Aids for Managers

The general nature of planning information appropriate to plant management personnel is briefly described, and suggestions are made for presenting information in the form of job aids. The development of job aids is not considered as part of the appendix; considerable interaction will be required between Chapter 4 (Prepare Job Aids) and the material presented.

Appendix C--Classification and Description of Informational Job Aids for Operators

The nature of planning information appropriate to plant operations personnel is provided and suggestions made for the presentation of each information type through various job aids. Again, close linkages between the information presented and Chapter 4 are required.

Appendix D--Classification and Description of Informational Job Aids for Maintenance Personnel

Types of operational planning information and related practical job aids are presented for plant maintenance personnel. As with the previous two appendixes, Chapter 4 provides the specific procedural guidance for development of each information type into practical job aids.

APPENDIX A

JOB DESCRIPTION FORMAT AND DEVELOPMENT RECOMMENDATIONS

The essential components of job description were outlined as part of Chapter 3. This appendix, patterned after the Department of Labor's *Dictionary of Occupational Titles* (DOT), is intended to support the development of uniform, accurate, and comprehensive job descriptions for use in operational planning activities for wastewater treatment.

Assign Job Title

A job title is the name by which an occupation is commonly known. The extent of common usage determines the wording and acceptance of the job title for identifying an occupation. Other names by which an occupation is known in various parts of the country or in specific employment situations are known as alternate titles. Complete identification of an occupation must include both the accepted job title (those listed in the DOT) and alternate titles which are found to exist. The use of an alternate title by itself is not an acceptable method for identifying an occupation; such use leads to confusion.

Invert or Modify Job Titles

Titles of jobs in a specific craft or industry should be inverted or modified to permit formation of an alphabetic guide, thus keeping the related jobs clustered together. Examples of inverted job titles are: Carpenter, Maintenance; and Carpenter, Rough. Examples of job titles modified by rank would be: Carpenter Foreman, Carpenter Apprentice, and Carpenter Helper. Job titles to which arbitrary modifiers have been added to distinguish one job from the other are: Carpenter, Bridge; and Carpenter, Wooden Tank Erecting. Again, the use of accepted job titles is mandatory, but the inclusion of alternate titles with appropriate modifiers is encouraged.

Assign Six-Digit Occupation Code

A six-digit code number must accompany each occupational definition. The purposes of this code are to (1) provide a method for grouping jobs with the same basic occupation or worker trait characteristics, and thus aid in discerning various occupational relationships; and (2) provide a standard method for classifying the abilities, vocational experiences, and potentials of workers. The first three digits of the code indicate specific occupational categories, divisions, and groups. The second three digits of the code express worker relationships to data, people, and things.

Assign Occupation Category Code

The first digit of the code represents nine occupational categories. All occupations can be conveniently grouped into one of these broad occupational categories.

0, 1	Professional, technical, and managerial occupations
2	Clerical and sales occupations
3	Service occupations
4	Farming, fishery, forestry, and related occupations
5	Processing occupations
6	Machine trade occupations
7	Bench work occupations
8	Structural work occupations
9	Miscellaneous occupations

Assign Division and Group Code

Through addition of the second digit of the DOT code, 84 two-digit divisions of the nine broad occupational categories are represented. The 84 divisions are, in turn, subdivided into 603 distinctive three-digit occupational groups represented by the third digit of the code.

Assign Functional Relationship Code

The fourth, fifth, and sixth digits of the code, which fall to the right of a decimal point, represent relationships specific to data (fourth digit), people (fifth digit), and things (sixth digit). Each coded digit permits the expression of eight levels of complexity, in the form of a hierarchy, such that each successive function can include the simpler ones and exclude the more complex functions. The premise upon which the code is based is that every job requires the worker to function in relation to data, people, and things in significant but varying degrees. The functional hierarchies for the last three digits follow. Each level of the functional hierarchies is defined in the DOT.

Data (forth digit)	People (fifth digit)	Things (sixth digit)
0 Synthesizing	0 Mentoring	0 Setting-Up
1 Coordinating	1 Negotiating	1 Precision Working
2 Analyzing	2 Instructing	2 Operating-Controlling
3 Compiling	3 Supervising	3 Driving-Operating
4 Computing	4 Diverting	4 Manipulating
5 Copying	5 Persuading	5 Tending
6 Comparing	6 Speaking-Signaling	6 Feeding-Offbearing
7 } No significant	7 Serving	7 Handling
8 } relationship	8 No significant relationship	8 No significant relationship

As much care as possible should be exercised to insure that the six-digit code accurately describes the group arrangement and worker traits arrangement for each occupational definition input to the Manpower Planning Program. Each occupation must be carefully assessed, particularly with respect to the data-people-things hierarchies, to identify the performance requirements of the job. Task description materials should be the basis for developing the six-digit code.

Prepare Verbal Descriptions

A brief verbal description is a required part of the occupational definition. The purpose of the verbal description is to identify what gets done, how it gets done, and why it gets done. Additionally, the verbal description may provide, indicate, or imply other information such as functions performed by the worker, significant aptitudes, interests, temperaments, and critical physical demands required by the job.

Although the verbal description should be as short as possible, the guiding principle in description development is that the final product relates a concise and concrete occupational picture which will also convey some indication of the level of complexity involved. The verbal description should be prepared from factual data concerned with what, how, and why the job is performed; task description materials are the best source of such data.

Define Worker Trait Profile

Worker traits are those abilities, personal traits, and experience characteristics required of a worker in order for him to achieve an average level of success in performing his job responsibilities.

Six distinct components are used to project a profile of the worker traits required by an occupation. These worker trait components are:

1. Training time. The amount of general educational development and specific vocational preparation a worker must normally have to qualify for the job.

2. Aptitudes. The specific capacities and abilities required in order to learn or perform the tasks and duties of the job.

3. Interests. The preferences for certain types of work activities and experiences considered necessary for job success.

4. Temperaments. The types of occupational situations to which a worker must adjust.

5. Physical demands. The physical activities required of a worker in the job situation.

6. Working conditions. The physical environment and surroundings associated with the job.

While it is true that significant worker trait requirements are reflected in the verbal description of the job, either explicitly or through implication, the worker trait profile is meant to provide a more definitive and comprehensive source of worker trait information. The worker trait profile provides a numeric scale which reflects the range of required traits and/or levels of traits for each of the components. Alphabetic and numeric codes are used to identify the ranges and levels for the profile components, thus saving space and facilitating the comparison of traits across different occupations. The following paragraphs discuss in greater detail the worker trait components.

Define Training Time

The training time component consists of defined levels of training in the areas of General Educational Development (GED) and Specific Vocational Preparation (SVP).

General Educational Development refers to those aspects of education (formal and informal) which contribute to a worker's (a) reasoning development and ability to follow job instructions, and (b) acquisition of "tool" knowledges such as language and mathematical skills. GED describes education of a general type which does not relate directly to recognized occupational objectives. Such education is ordinarily obtained through elementary schools, high schools, or college; it is in contrast to schooling directed primarily toward a specific occupation.

A numeric code is used to identify the six levels of educational development defined in the DOT, with "1" representing the lowest level, and "6" representing the highest level of development. The lowest level of development is exemplified by "Applying common-sense understanding to carry out simple one- or two-step instructions," and the opposite end of the scale by "Applying principles of logical or scientific thinking to a wide range of intellectual and practical problems." The complete definitions will not be presented in this manual since they are quite lengthy; Volume II of the DOT may be consulted for complete definitions of each level of GED.

Specific Vocational Preparation is defined as training required to learn the techniques, acquire the information, and develop the mental and physical skills required for average performance in a specific job-worker situation. It includes training given through any of the following modes of instruction: vocational education, apprentice training, in-plant training, on-the-job training, and essential experience acquired on other jobs. The appropriate amount of SVP for a job is reflected through a numeric code; "1" is the lowest level and corresponds to "short demonstration only," while "9" is the highest level and corresponds to "over 10 years" of SVP. A complete listing of the definitions is not presented in this manual; Volume II of the DOT may be consulted for complete information on the nine levels of SVP.

It is sometimes necessary to show a range of Specific Vocational Preparation since requirements vary. The normal range can be shown by listing both the high and low levels which bound the interval.

Define Aptitudes

Aptitudes are defined as specific capabilities and abilities required of a person in order to learn or adequately perform a task or job. There are

11 distinct aptitude areas to be considered as part of the worker trait profile. The areas, and the letter symbol code for identifying each, are:

G	Intelligence	K	Motor Coordination
V	Verbal	F	Finger Dexterity
N	Numerical	M	Manual Dexterity
S	Spatial	E	Eye-Hand-Foot Coordination
P	Form Perception	C	Color Discrimination
Q	Clerical Perception		

A numeric code is used to indicate how much, or what level, of aptitude is required for satisfactory (average) performance of job tasks and duties. The average requirements, rather than maximum or minimum, should be cited. The level of aptitude appropriate for each area is designated by using the following scale, which is expressed in terms of equivalent amounts of aptitude possessed by segments of the general working population.

Level 1.	The top ten percent of the population.
Level 2.	The highest third, exclusive of the top ten percent of the population.
Level 3.	The middle third of the population.
Level 4.	The lowest third, exclusive of the bottom ten percent of the population.
Level 5.	The lowest ten percent of the population.

This numeric scale is applied to each aptitude area. The resulting expressions should be presented in tabular form as shown below for a hypothetical case.

		*	*								
Apt:	G	V	N	S	P	Q	K	F	M	E	C
	1	1	1	2	2	3	4	4	4	5	5
	2	2	2	3	3						

*Significant Aptitude

As shown in the above example, more than one level can be used for an aptitude area when job circumstances dictate a rather broad range of aptitude. The range must never exceed two levels, and it is desirable to discriminate to a single level.

Significant aptitudes should be identified as such by the use of bold face type for the area code or through the use of an asterisk above the code. Significant aptitudes are those considered essential for average successful job performance.

Define Interests

Interests are defined as the preferences an individual may have for certain types of work activities or experiences. As part of the worker traits profile, interests are expressed in terms of positive preferences for one factor of a mutually exclusive pair of factors which define certain activities. Five pairs of factors are provided so that a strong preference for one factor implies rejection of the other factor of the pair. Examples of factor pairs are:

Code 1.	Situations involving a preference for activities dealing with things and objects.	vs.	Code 6.	Situations involving a preference for activities concerned with people and the communication of ideas.

The expression of interests in the worker traits profile is accomplished by listing the numeral designations for the most applicable activity factors. It is unlikely that the activities of most jobs will result in strong associations with more than two or three interest factors. It is not desirable to "force" a factor from each of the five pairs into the interest portion of the profile; attention should be given to those which are consistent with the tasks and general requirements of the job.

Define Temperaments

Temperament refers to the nature or disposition characteristic of personnel in specific occupational situations who satisfactorily adjust to the performance demands of the job. For the purpose of the worker traits profile 12 rather broad situational contexts have been developed to represent the entire domain of occupational situations. A number or letter is used to represent any of the 12 defined situations in the profile. Examples of the situation definitions to be used are:

> Code 1. Situations involving a variety of duties often characterized by frequent change.
>
> Code 4. Situations involving the direction, control, and planning of an entire activity or the activities of others.

All activities of the job which closely match defined situations should be represented in the worker traits profile by entering the appropriate number or letter code. There will generally be more than one situation which applies, but rarely will there be more than five or six.

Define Physical Demands

Physical demands are defined as those physical requirements of the job and physical capacities (specific physical traits) of personnel necessary to meet the job requirements. In all cases, the worker must have physical capacities equal to or in excess of the physical demands of the job. There are six major physical demand factors which will be used to define the physical capacities of workers in the traits profile. Only those factors which are essential to job activities should be entered in the physical demands portion of the worker traits profile. A close comparison must be made between the task requirements of the job, as reflected in the task description materials, job data banks of environmental protection agencies, and DOT definitions before entering the profile information. These factors are:

1. Lifting, carrying, pushing, and/or pulling (strength). This factor is expressed in the profile by entering the letter code for those strength definitions which typify normal work activities for the job. The five strength categories, which are completely defined in the DOT, are:

S	Sedentary Work
L	Light Work
M	Medium Work
H	Heavy Work
V	Very Hard Work

2. Climbing and/or balancing. The number "2" is entered if any part of the definition for this factor is an element of job activities.

3. Stooping, kneeling, crouching, and/or crawling. The number "3" is entered if any job activities match the definition for this physical demand factor.

4. Reaching, handling, fingering, and/or feeling. The number "4" is entered if the definition for this factor applies to job activities.

5. Talking and/or hearing. The number "5" is entered if the definition for this factor applies.

6. Seeing. The number "6" is entered if the definition for this factor corresponds to a required activity of the job.

Define Working Conditions

Working conditions are defined as the physical surroundings of a worker in a specific job situation. Working conditions are meant to describe the physical environment factors which a worker must be physically and mentally prepared to withstand as a normal part of the job.

There are seven broad factors of physical surrounding which must be considered in defining the working conditions applicable to a job. These factors are:

Code 1. Inside, outside, or both.
Code 2. Extremes of cold plus temperature change.
Code 3. Extremes of heat plus temperature change.
Code 4. Wetness and humidity.
Code 5. Noise and vibration.
Code 6. Hazards.
Code 7. Fumes, odors, toxic conditions, dust, and poor ventilation.

Coded entries to the working conditions portion of the worker traits profile should only be made for those instances where job activities meet or exceed the criteria defined in Volume II of the DOT.

APPENDIX B

CLASSIFICATION AND DESCRIPTION OF INFORMATIONAL JOB AIDS FOR MANAGERS

The operational planning effort should result in certain information designed to assist managers with their functional role in the treatment plant. This information, tailored to the characteristics and operational setting of the individual plant, provides managers with the necessary tools and resource materials to smoothly and effectively phase new or modified treatment plants into operation. Longer-range utility of the information provided to management is derived through their ability to adapt and modify the initial framework to meet future requirements.

Operational planning products for managers are described in terms of appropriate job aids and job aid content. Development of the job aids should be carried out through use of the principles and procedures provided in Chapter 4. The following classification of essential management job aids is provided in this appendix:

1. Planning aids--outline important areas of personnel and training which must be attended to prior to operational status of a plant.
2. Aids to external relations--provide management with guidelines and suggestions for interacting with other agencies and the public.
3. Scheduling aids--provide management with milestone data to assist with effective planning of the transition to operational status.
4. Budgeting aids--assist management with the preparation of meaningful funding and budgeting information.
5. Aids to operational management--provide a basis from which managers can assess performance of the plant.

6. Aids to maintenance management--provide a basis from which management can evaluate maintenance aspects of the plant.

7. Aids to management of purchased services--provide guidance for decision-making with respect to in-house versus contracted plant services.

8. Aids to personnel management--provide guidance for developing and maintaining a properly motivated work force.

9. Aids to data management--provide guidance for establishing and maintaining a data system to assist with management decisions.

Provide Planning Aids

Provide Training Specifications

Provide management with training specifications to guide the professional and technical development of required plant personnel. The specifications should provide a recommended curriculum of instruction for all jobs having task requirements beyond the normal repertoire of skill and knowledge for the intended population of new-hire or other job enrollees. The recommended curriculum for each job title should be expressed in terms of:

1. Subject or topic areas.
2. Training time (hours) estimate.
3. Training aids and other required materials.
4. Training objectives.

It is important that the training objectives properly define the performance parameters the trainee is to meet in order to fulfill job responsibilities. For most jobs, the inexperienced employee is not expected to perform assigned tasks at the same proficiency level as would be expected from experienced workers. In other cases, particularly with respect to hazardous or critical tasks, the trainee must achieve a level of skill equal to or surpassing job requirements to insure initial task success. The guiding principle for training objectives should be that they inform management and subsequent training developers what must be expected of the trainee in order to "pass" each portion of the training curriculum.

Curriculum and training specifications, which may be available for certain treatment plant jobs through the Division of Manpower and Training of EPA, can serve as the heart of plant-specific training and/or as models for other jobs. Figure 25 reflects a sample format for curriculum and training specifications.

Recommend Training Sources

Provide management with recommendations concerning how and where required training can be best accomplished, particularly with respect to formal classroom training in specific pollution control subject matter. Regularly scheduled sources for formal training are relatively limited in terms of the curriculums offered, the proximity of training institutions to plant locations, and the time phasing of enrollment opportunities and courses of instruction offered. A general search for sources of job training should include the following:

1. Contact the Training Division of EPA as early as possible to determine the dates, locations, course outlines, and other pertinent information about short courses offered through the auspices of EPA and to determine their recommendations for your specific training needs.
2. Contact nearby vocational/technical schools, colleges, and universities to determine what courses they offer that might fit specific training needs for the subject plant.
3. Contact equipment manufacturers and vendors of installed equipment to determine if they offer formal training in the operation and maintenance of their equipment, time

Curriculum and Training Specifications for (Job Title): Laboratory Assistant

System Class: Wastewater Treatment, Municipal

Generic System Type: Primary Treatment (Digestion and Sludge Beds)

CURRICULUM	TRAINING AIDS AND MATERIALS	TRAINING OBJECTIVES
Laboratory/Plant Safety (6 hours) √ Chemical Handling √ Treatment of Chemical Burns √ Basic First Aid √ Laboratory Fire Fighting √ Etc.	Plant Laboratory Facilities MSA First Aid Kit #--- First Aid Handbook, Amer. Red Cross; 19-- Edition, Chap 1, 4, 11, and 12 WPCF Manual #1, Safety in Waste Water Works; WPCF, 19-- Chaps. 4 & 5 unless better emphasis on laboratory work can be found elsewhere Chart showing fire and emergency evacuation plan for the plant; a floorplan with exit routes will have to be developed 5 pound CO_2 and dry chemical fire extinguishers Etc.	Trainee must be able to: √ Explain and demonstrate proper way to mix acids and alkalies. √ Describe procedures and point out materials for treating a chemical burn. √ Describe symptoms for chlorine poisoning and immediate treatment to be provided. √ Point out location of fire extinguishers in the plant. √ Describe procedure for extinguishing chemical, electrical, and other fires using either dry chemical or CO_2 extinguishers. √ Describe appropriate first aid technique for injuries listed in Appendix II of First Aid Handbook. √ Etc.
Correspondence Course in Water Analysis Techniques (30 hours over a 6-week period) √ Tests for BOD √ Tests for COD √ Tests of suspended solids √ Etc.	EPA Correspondence Course, Series IV, Booklets 1 thru 6 Plant Laboratory Facility Handbook of Chemistry and Physics, any of the reputable publishers Etc.	√ Set up and conduct required tests to prescribed scientific standards. √ Prepare standard data sheets to show results of tests conducted. √ Etc.
Water Sampling Techniques √ Etc.	Etc.	√ Etc.

Figure 25. Sample Format for Curriculum and Training Specifications

requirements for such training, and the nature of any costs involved.

4. Contact state and local regulatory agencies for courses they may offer with respect to the training and licensing of operators, laboratory personnel, and maintenance personnel.

Recommend Training Aids and Materials

Provide management with a list of specific training aids and materials useful for the training environment. Recommended training aids and materials should accompany each course of instruction in the recommended curriculum to enhance and support the instruction. Training aids and materials are characterized by:

1. Text books, instruction manuals and reference manuals.
2. Films, slides, flip charts, and other graphic media.
3. Models and simulations of the plant or its components.
4. Self-instructional texts.
5. Operations and maintenance manuals.
6. Operational system or plant components and facility used for training purposes.

Consider an Interactive Training Proposal

A proposal might be made to management for the utilization of plant design personnel to teach and/or work closely with other instructor staffs during the initial training period. Such an arrangement will help ensure the specificity and accuracy of training for the subject plant.

Suggest a Training and Reference Library

Texts, reference manuals, and other materials deemed appropriate to immediate and long-range training should be identified and presented to management so that an in-house library may be established. Other elements of the library will, of course, be operations and maintenance manuals, plant design information, and other information of long-term value.

There are, of course, many materials directed to the management, operations, and maintenance activities of specific types and configurations of plants. Be selective, limiting training and reference materials to those which are highly relevant to the specific plant, the nature of training to be carried out, and the anticipated needs of the plant staff.

Examples of training and reference materials which might be appropriate are:

1. *Manual of Treatment Processes*, Water Quality Management Series, Vol. I, Eckenfelder, Wesley W. (Ed.).

2. *Standard Methods for the Examination of Water and Wastewater*. Available from the American Public Health Association, American Water Works Association, or the Water Pollution Control Federation.

3. *Simplified Laboratory Procedures for Wastewater Examination*. Available from the Water Pollution Control Federation.

4. *Operation of Wastewater Treatment Plants*. Available from the Water Pollution Control Federation.

5. *Manual of Wastewater Operations*. Published by the Texas Water Utilities Association.

6. *Environmental Wastes Control Manual*. Published annually by Public Works Magazine.

7. *Journal of the Water Pollution Control Federation*.

Provide Aids to External Relations

Treatment plant managers must interact with the general public and interested technical representatives. They must, therefore, be prepared to provide information with respect to the technical capabilities and overall operation of the plant. Activities which will assist management with external relations of both technical and general interest classes are described below.

Suggest Publicity Charts and Similar Media

Visitors to treatment plants have an interest in how well wastewater is treated before discharge; as taxpayers they have a right to know. By the same token, plant personnel can take a certain amount of pride in being a part of a smoothly functioning plant, and there is much to be gained by dissemination of information to the public. One excellent way of providing plant performance feedback to the public and the plant staff is through the use of graphs and charts posted in a conspicuous location. Performance milestones, such as treatment standards, should be incorporated so that a glance will tell if treatment objectives are being met or surpassed. Much can be gained from taking a hard look at the accident prevention statistics so often conspicuously displayed at industrial locations.

In addition to their publicity usefulness, graphs and charts are beneficial to management, operations, and maintenance personnel in the detection of trends and the spotting of trouble before a situation becomes critical.

Provide External Coordination Requirements

Changes in the residential and industrial growth patterns of a treatment plant service area can have a dramatic influence on the treatment effectiveness achieved by the plant. Management staffs must keep abreast of these patterns so that any corrective actions can be initiated with enough lead time to prevent treatment degradation. A valuable management aid is the transformation of service area studies into a brief technical note to summarize the important characteristics to be carefully watched during future years. The aid should account for the impact of such factors as:

1. Wastewater discharge ordinances.
2. Land use planning studies.
3. Zoning regulations.

The aid should provide guidance for establishing effective coordination with industrial and residential agencies as a means for assessing the impact of service area dynamics on treatment. For example, coordination might be particularly important between management and the local agency charged with responsibility for issuing building permits. Prior to issuing an industrial building permit, the agency might refer the applicant to treatment plant management for an assessment of potential waste discharges and to be made aware of any pretreatment that might be required.

Provide Scheduling Aids

Scheduling is a key element of management responsibility, particularly with respect to gaining the lead time required for new or updated treatment plants.

Provide Work Schedules and Schedule Implications

Identify the tentative scheduling of all staff jobs to reflect the implications of shifts, seven-day operations, and any other factors bearing upon the availability of adequate manpower resources. Provide management with a rationale for how schedule modifications affect the availability of resources. For example, assuming that maintenance and some other functions are normally carried out during a regular daylight shift, some provision must be made for the scheduling of "on-call" work responsibility to take care of emergency situations developing on other shifts.

Provide Hiring Dates

Provide management with projected hiring dates to correspond with the plant construction schedule. This information should tell management when various members of the new staff should be "on-board" to undergo training, become familiar with new equipment, or to release members of an existing staff to attend training or take on new job responsibilities.

Provide Program Scheduling Aids

Critical path scheduling methods, such as the PERT technique, are an invaluable aid to management. In essence, the work activities which must be performed to complete a program are identified and the length of time to complete them is estimated. The sequence in which the activities must be completed will form a serial path, with generally some number of parallel paths leading to the completed work effort. The longest path determines the time required to complete the effort and is referred to as the critical path. Activities, and the products resulting from each activity, are normally shown in the form of a diagram keyed to a time dimension.

Provide Budgeting Aids

Management cannot strive for cost-effectiveness without accounting for two of the principal cost factors involved in fiscal planning: labor costs and cost estimating for treatment as a function of loading and level of treatment.

Project Labor Costs

Provide management with a general guide to the salary range for each of the job titles provided in staffing information. The salary scales should be based on supply and demand relationships in the local labor market from which the staff will be acquired. The local offices of state employment services and other municipal plants in the area can probably provide the necessary information. The objective must be to accurately judge what monetary resources will be required for staffing so that a reasonable estimate is provided for budgeting purposes in the municipal government. If realistic amounts of salary monies are not initially appropriated, it is unlikely that a properly trained, experienced, and motivated work force can be acquired. Surveys of plant operations personnel have indicated that salary aspects of pollution control work are in the greatest need of improvement if good people are to be recruited and retained.

Provide Correlations of Treatment Level and Cost

Provide management with a basis for assessing the marginal cost for increasing or decreasing the level of treatment provided by the plant. The area of interest is, of course, centered around those operations, maintenance, power consumption, and chemical costs which can quickly lead to diminishing returns in treatment per unit of cost. Levels of treatment below required standards are not within the region of concern. Limit cost analysis to levels at or above required standards. The development of this information will require answers to at least the following questions:

1. To what extent do dependent and independent variables of treatment account for variations in treatment cost?
2. What conceptual relationships exist to provide a realistic and dependable model for predicting the positive or negtive cost increment when either the level of treatment or the alternative control procedures for a process (and the plant) are changed?
3. What mathematical relationships exist between cost and treatment variables and how can these quantitative relationships be capitalized upon for management control of the plant?

Answers to these questions are derived through testing the impact of various levels of effluent quality upon sensitive performance characteristics and then associating incremental costs for each viable option (see Step 2, Delineate Plant Performance Characteristics).

Provide Aids to Operational Management

Management must be provided with a normative basis against which it can assess plant and process performance. In general, this body of information represents a management summary of the treatment criteria dealt with in Chapter 2. Management should be able to use the information to determine if the plant is doing the job it was designed to do; and if the plant is not meeting design objectives, the information should assist with localizing treatment problems.

Influent and Effluent Data

Management must be provided with a means for assessing the level of treatment the plant is achieving with respect to influent loading. At least the following factors must be incorporated into such a management tool:

1. Effluent concentration values--representing criterion levels of treatment corresponding to a representative set of influent hydraulic and concentration loading values.

2. Unit treatment outflow values--representing criterion treatment levels for each plant process with respect to a representative set of inflow hydraulic and concentration loadings.

3. Verification procedures--a listing of the procedures and techniques for assessing observed versus theoretical influent and effluent values.

Relationships between influent and effluent characteristics should be expressed along the influent, external, and internal contingency dimensions identified in Chapter 3. The tabular format illustrated in Figure 26 is one possible means for expressing this information to management in summary form.

DESIGN OBJECTIVES AND CRITERIA FOR PRIMARY SEDIMENTATION PROCESS

Plant Influent Loading	Expected Outflow Quality						
	BOD	COD	SS	DS	Total Solids	Etc.	
Design Loading: Hydraulic: 2.5 mgd Concentration: BOD-560 ppm COD-380 ppm SS-25 mg/l Phos. pH-6.8 Etc.							Process Design Objectives
Selected Loadings: A. Hydraulic: .5 mgd at design concentration shown above. B. Hydraulic: 1.0 mgd at design concentration shown above. C. Etc. to include all loadings and contingency parameters identified for the plant design objectives and criteria.							Process Performance Criteria (assuming optimal control)

Figure 26. Tabular Format for Expressing Objective and Criterion Outflow Values According to Influent Loading

Define Important Dynamic Relationships

As evaluative tools for management, steady-state relationships between variables do not very often reflect reality. Time-based relationships (or any other dynamic relationship), on the other hand, provide a realistic tool for operational management and the assessment of plant performance.

The expression of dyanmic relationships can range from sophisticated computer-based models to relatively simple, and yet meaningful and useful, graphic means. Choose whatever means of expression will adequately serve management needs without imposing unusual skill requirements or otherwise exceeding in-house capabilities of the plant (such as might be the case with a computer-based model). Figures 27 and 28 illustrate a simple graphic means of expressing dynamic influent and effluent relationships according to diurnal fluctuations in loading.

Other representative dynamic relationships include:

1. Day-to-day fluctuations in plant loading versus effluent quality.
2. Seasonal fluctuations in plant loading versus effluent quality.
3. Ambient temperature fluctuations versus effluent quality for given levels of plant loading.

Provide Operations/Cost Relationships

Identify the cost relationships associated with the control variables of major plant units in such a way as to make clear what operations options are available and the cost increments (at least in rough measures) incurred with each option. Combined power costs and maintenance labor costs might reflect, for example, that it is more cost-effective to operate two pumps intermittently than to run a single pump continuously.

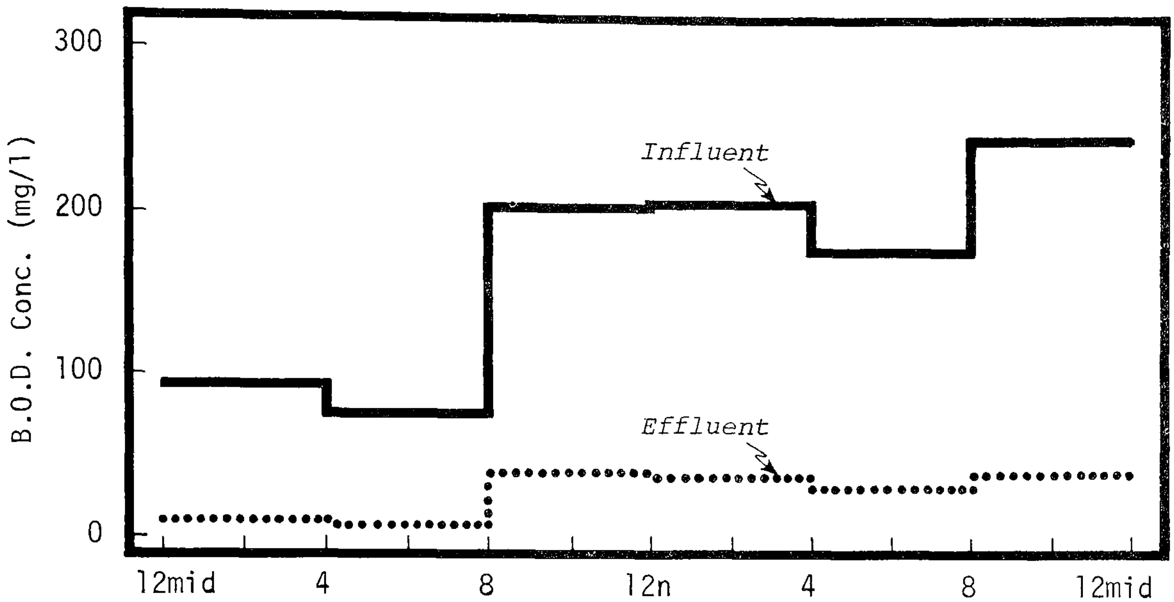


Figure 27. Sample Graphic Expression of B.O.D. Variations by Time of Day

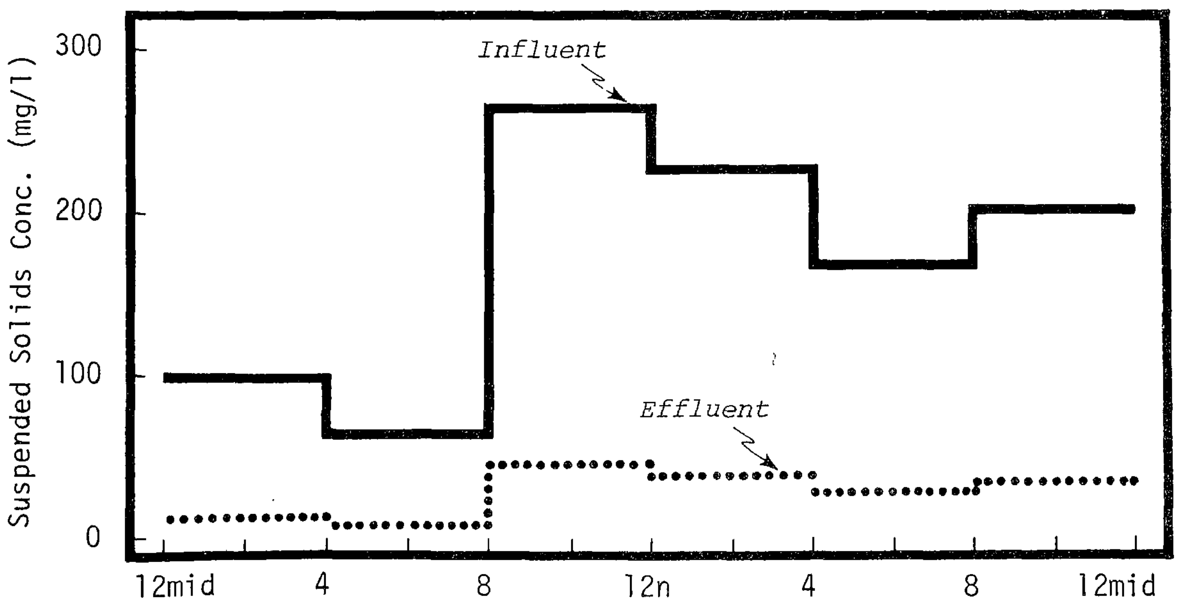


Figure 28. Sample Graphic Expression of Suspended Solids Variation by Time of Day

Recommend Operating Records

Treatment plant operating records are required to serve two primary functions: to provide information for operational control, and to provide historical records of plant performance for possible future needs. Historical data, in addition to being required by most regulatory agencies, forms a base of data with wide applications in management decision making. Important operating information to be provided to management includes:

1. Hydraulic loading.
2. Concentration loading.
3. Effluent quality.
4. Process status.

The specific variables to be measured, the measurement technique, frequency of measurement, and other factors bearing on the data must also be provided. Sample data forms provide a convenient means for conveying appropriate operating data requirements.

Plant/Process Performance Models

Process and plant performance models should be developed which can be directly applied to the operational status of the plant by management. The desired models represent tools which are tailored for direct application to management problems such as interpretation of how well the plant is functioning, assisting with the isolation of treatment deficiencies, and generally facilitating the decision-making role of management. Two general objectives should always be to:

1. Present a model, or number of models, to describe the individual operating characteristics of the plant.
2. Solve specific problems or test hypotheses about processes and treatment characteristics based on models of operational characteristics.

Provide Architectural and Engineering Drawings

A complete set of the architectural and engineering drawings for the treatment plant should be furnished to management for use as a functional tool and as a permanent reference. The drawings should be keyed so that a clear path is specified for relating one drawing to another and for matching with comparable functional flow diagrams.

Provide Schematic Flow Diagrams

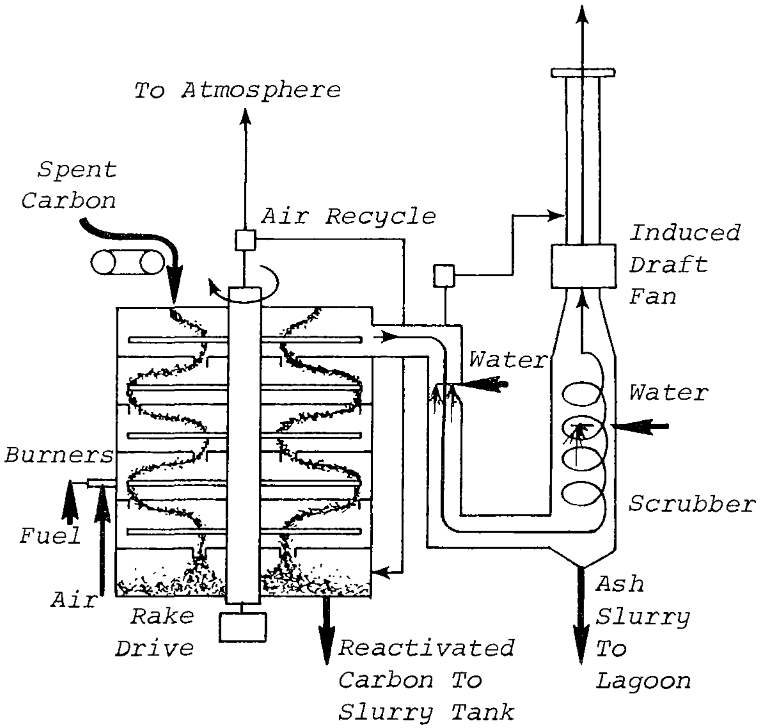
Functional schematics must be provided to supplement and clarify general plan drawings. Separate schematics should be provided for each unit treatment or other major treatment component as well as for the plant as a whole. General plan drawings and functional schematics should be keyed so that a hierarchy emerges wherein any element of the physical plant can be traced to either engineering or functional descriptions.

Provide Verbal Descriptions of Plant Functions

Each functional component of the plant should be briefly and concisely defined so that management will have a firm conceptual understanding of how the plant operates. Both the positive and negative features of the plant should be included in the verbal descriptions. Figure 29 illustrates how the verbal and functional descriptions might be combined.

Provide Aids to Maintenance Management

Maintenance aspects of treatment plants represent a very significant portion of total monetary and human resource expenditures. Maintenance of the plant, therefore, places a certain burden on management for constant evaluation and optimization of maintenance programs, a function which can be eased through the provision of appropriate management information. The following activities and products are intended to serve at least some of the essential needs for maintenance management:



MULTIPLE-HEARTH REACTIVATION FURNACE

Spent carbon enters the top of the furnace. An air-cooled rotating shaft, with rakes at each hearth level, extends vertically through the unit. The carbon is raked in a spiral path moving in and out of each successive hearth through alternate drop holes. Activated carbon discharged from the bottom hearth at 500° F is completely reactivated since all the organic matter has been burned away. Combustion gases pass through a high-efficiency wet scrubber.

Figure 29. Illustrative Schematic Flow Diagram and Corresponding Verbal Description

Recommend Maintenance Records

Maintenance records must be developed which will serve as an effective management tool for the overall evaluation, control, and direction of plant maintenance. A plan for recording pertinent maintenance information should be directed to at least the following elements of each unit of plant facility and equipment requiring maintenance services:

1. Labor time devoted to routine preventive maintenance.
2. Labor time devoted to corrective maintenance.
3. Dates on which preventive and corrective maintenance took place.
4. Hours the unit was available for use.
5. Hours the unit was unavailable for use, by major class of failure.
6. Name of person performing maintenance.
7. Cost of maintenance materials and parts consumed.
8. Observed symptoms indicating potential future maintenance needs.

Provide a Maintenance Evaluation Plan

An evaluation plan should be provided, utilizing data from maintenance records, to guide the overall analysis activities of management. The plan should include methods and techniques which will allow:

1. Isolation of equipment with high failure rates.
2. Identification of major causes of failure.
3. Establishment of relationships and trends between preventive maintenance schedules and equipment failure rates.
4. Formulation of equipment specifications which will alleviate certain maintenance problems in any future purchases.

Provide Aids to Management of Purchased Services

It is generally impossible to acquire an in-house capability in all required skills without creating grossly excessive labor costs. The following types of activities can provide management with information to assist with outside-service decision making.

Identify Alternatives to Hiring

Identify any alternatives that may exist with respect to the acquisition of manpower resources. For example, there may be advantages to having contracted services until such time as an in-house capability can be developed. Or, it may be possible to "borrow" resources from other municipal manpower pools to assist during the period of acquiring a fully trained and experienced plant personnel complement. Electricians, mechanics, and other journeyman-level personnel are frequently available to perform work in departments of the municipality other than that to which they are assigned--if arrangements to this effect can be made in advance. Municipal water supply departments, where they exist, provide particularly good opportunities for sharing the utilization and expense of maintenance specialists because of the similarities in process equipment.

Identify In-House Versus Contractor Tradeoffs

On the basis of estimated manpower utilization (from staffing requirements of Chapter 3), there is a possibility that some plant functions will result in such low task loading that it is not prudent to employ a person (or additional person). Describe the circumstances of each case, make recommendations for either hiring or contracting for the services, and make clear the tradeoffs involved in the decision to hire or contract. Three of the important tradeoff considerations are:

1. Availability of personnel when required.
2. Cost of the two service options.

3. Supply and spare parts inventories required for in-house capability.

Assess each cost variable with respect to available alternatives and identify the conditions under which each alternative becomes a preferred choice. For example, the overhauling of certain equipment might best be handled through the manufacturer up to a certain number of units per month, but if the number of overhauled units per month exceeds that number, it becomes more cost-effective to develop an in-house capability. With respect to another variable, such as replacement parts, there may be such alternatives as: keeping no inventory; a small inventory with replacement as use occurs; or, a large inventory to take advantage of discounts, with the changeover point a function of failure rates, equipment criticality, discount possibilities, and storage space for an inventory.

Provide Aids to Personnel Management

One of management's initial information needs is concerned with development of a competent and properly motivated work force. Information useful for this purpose must be provided to management early enough so that it may be effectively applied to the acquisition and training of the proper numbers and types of people prior to the time they are to assume their assignments in the treatment plant. The following forms of information are essential to the personnel and training activities of management.

Provide Job Descriptions

Provide complete job descriptions for each element of the required work force. Appendix A provides the essential information to be included in the job descriptions. In cases where there is an existing waste treatment plant staff, such as with the updating of a plant or the addition of a new plant to a multiple plant system, make comparisons between the new jobs and those which currently exist in terms of numbers and the general skill requirements.

Provide a Staffing Plan

As described and illustrated in Chapter 3, provide a staffing plan to summarize the required work force. Where there is an existing work force, draw comparisons between what will be required and what already exists. For example, indicate what "old" jobs can be retained in the new manpower structure with minimal additional training, what jobs will almost certainly require the hiring of a new person, and so forth. An assessment of the duties performed by the existing staff will, of course, have to be made.

Suggest an Organizational Structure

Recommend an organizational structure commensurate with the overall size and general type of plant under consideration. The recommendations should take into account the differences in staffing which may occur as the result of the plant's gradually progressing from initial loading to conditions of design loading, and any implications such changes may have on an initial organizational structure. The recommended structure should be presented in the form of an organizational flow chart to reflect lines of authority as well as functional requirements within the treatment plant or system.

Suggest a Career Development Ladder

Provide some indication of how a career development hierarchy might be established within the context of the plant or system which would allow for monetary as well as technical, social, and self-esteem advancements. Levels of certification, experience, formal training, job titles, and other factors of the jobs should be examined for possible use as an advancement vehicle. Turn to demonstrated examples of effective personnel policies in other waste treatment plants for ideas.

Specify Certification Requirements

Regardless of whether local or state operator certification is mandatory, specify appropriate levels of certification for all applicable job titles according to whatever classification system prevails for the jurisdictional area of the plant.

Provide Guidance for Hiring Personnel

Provide management with general guidelines for hiring personnel in terms of where the appropriate skills may be found. This information should include recommendations for a recruiting effort, where the effort should be directed, and some of the known media for reaching potential staff members. The following should be considered:

Identify Schools. A listing of local public and private schools should be provided for possible use in recruiting personnel, particularly entry level personnel where prior waste treatment experience is relatively unimportant. The same list of schools can also serve a useful function for training purposes. A good starting place is the local high school, where there is most often a guidance counselor knowledgeable about other schools, vocational/technical courses available locally, and so forth.

Suggest Journals. There are many journals devoted to the field of wastewater treatment which include an employment section for job openings and people searching for jobs. The usefulness of journal advertising is limited primarily to professional level jobs, but there may be recruiting efforts where use of this media is warranted.

Interact with Unions. Where unionization of treatment plant personnel has taken place, coordination of recruiting with the appropriate union(s) can be beneficial to both the union and management.

Provide Aids to Data Management

Plant managers are heavily dependent on data of all types to make decisions and to assess plant performance resulting from those decisions. There is, of course, the need to assess the status of the plant at timely intervals and to determine the most cost-effective manner of treatment for given conditions, both of these functions being partially served through appropriate operations and maintenance records. There may also be a need for data to permit the exercise of plant models or to test specific hypotheses with respect to a new or updated treatment plant.

Specify Data Collection Objectives

Provide management with a set of data collection objectives aimed at creating a total picture of plant operational status. The data objectives should be aimed at revealing as many alternative views about management, operations, and maintenance as possible. In all cases, the data collection objectives must be stated in such a way that collected data are referenced to real or suspected treatment problems. That is, each data element to be collected must be cross-referenced to the specific problem-solving applications to which it can be applied.

Estimate Data Costs

Cost is an important consideration in setting data collection objectives for management. In general the greater the amount of data collected, and the accuracy with which it is collected, the greater the cost. Technical considerations of data collection should be carefully evolved to avoid a level of precision beyond management's needs and which would translate into higher, and possibly unnecessary, data costs.

Identify Technical Considerations of the Data

There are several technical considerations which should be carefully considered in setting data collection objectives as well as management's ability to apply the data. The following are some of the more important technical considerations:

1. Bias is an important factor in sampling the population of data relevant to treatment plant applications. Biases

usually develop in connection with the judgments about the range of variations in treatment practices, the consequences of alternative practices, and the relative utility of one treatment concept over another.

2. Precision of data may be increased or decreased by changing the number of measurements with a given data method or by alteration of the data method. Evaluate tradeoffs between the two in terms of specific treatment system factors and the cost of data collection.

3. Level of confidence should be established according to an overall assessment of relevant factors, including the stage of development, rather than some arbitrary value. The major factor is the risk (or cost) of falsely accepting or rejecting data.

Limit the Range

Surprising amounts of data collection can be realized for alternatives that are not feasible or for a range of variation beyond what is necessary. Weed out nonfeasible alternatives and limit the range of variables to a realistic and necessary base.

Recommend In-House Research

Describe to management the nature of potential or real operational problems which might be solved through in-house research. Certain forms of research can be carried out through the exclusive use of plant staff and resources as long as sophisticated apparatus is not required and if a research plan is sufficiently defined that advanced levels of skill are not required for implementing or interpreting the results of the research. Research plans presented to management should:

1. Briefly describe the problem.
2. Provide an approach for collecting required data.

3. Provide a strategy for analyzing and interpreting the data.
4. Provide a summary of the benefits which could accrue from the research findings.

Outline the Potential for Automatic Data Processing

Opportunities for automatic data processing should be investigated and recommendations made to management. There is a considerable number of computer programs available to reduce the clerical chores of maintaining up-to-date management information. There is also a number of firms in the business of taking more or less raw data from treatment plants, processing it to produce incremental and historical comparisons along many variables, and providing management summaries on a contract basis. A listing of some of the currently available computer programs can be obtained through:

Environmental Protection Agency
National Environmental Research Center
Treatment Optimization Research Program
Cincinnati, Ohio 45268

Figure 30 illustrates a consolidated summary of digester performance produced through a typical application of automatic data processing to standard elements of operating data.

FINAL TABULATION MAR 31, 1967 PAGE 17
TREATMENT PLANT-SLUDGE SAMPLING AND TESTING PROGRAM 2 STATION 5 NO 4 RECIRC

DATE	HOUR	LAB SAMPLE NO	PH	TOTAL SOLIDS %	VOLATILE SOLIDS %	TOTAL VOLATILE %	VOLATILE ACIDS MG-L AS HOAC	B.O.D. MG-L	TOTAL ALKALINITY MG-L AS CACO3	SAND %	OIL & GREASE %	ACCURAY % SOLIDS %
3/01/67		30018	6.9	2.8	1.4	47.9	223	8,400	2,900			
3/02/67		30068	7.0				240		3,060			
3/03/67		30116	6.9	3.2	1.5	46.6	189	3,780	3,150			
3/04/67		30154	6.9				206		2,850			
3/05/67		30173	7.0				223		3,000			
3/06/67		30189	7.0	3.2	1.4	44.0	172	5,100	2,950			
3/07/67		30260	7.0				206		3,000			
3/08/67		30328	6.9	2.8	1.4	49.3	309	4,200	3,000			
3/09/67		30362	7.0				223		3,200			
3/10/67		30397	7.1	3.0	1.4	47.2	274	4,200	3,250			
3/12/67		30447	7.0				172		3,150			
3/13/67		30466	7.1	3.3	1.5	45.3	154	6,000	3,100			
3/14/67		30529	7.0				172		3,400			
3/15/67		30681	7.0	3.2	1.4	43.5	206	4,200	3,050			
3/16/67		30727	7.0				172		2,950			
3/17/67		30769	7.0	3.0	1.3	44.4	120	3,660	2.950			
3/20/67		30834	6.9	1.9	.9	46.9	137	5,100	2,650			
3/21/67		30865	6.9				240		2,700			
3/22/67		30945	7.0	2.9	1.3	44.2	378	4,140	2,750			
3/23/67		31000	6.8				463		2,500			
3/24/67		31037	7.0	2.6	1.2	45.6	618	5,700	2,800			
3/25/67		31065	6.9				635		2,500			
3/26/67		31081	6.7				755		2,900			
3/27/67		31098	7.1	2.6	1.3	50.0	806	4,680	2,950			
3/28/67		31129	7.2				806		3,200			
3/29/67		31164	7.0	2.6	1.4	53.7	858	4,380	2,900			
3/30/67		31203	6.9				909		2,850			
3/31/67		31240	6.9	2.5	1.3	51.9	858	7,500	2,900			
AVERAGE			7.0	2.8	1.3	47.2	383	5,074	2,948	.0	.0	.0
MAXIMUM			7.2	3.3	1.5	53.7	909	8,400	3,400	.0	.0	.0
MINIMUM			6.7	1.9	.9	43.5	120	3,660	2,500	.0	.0	.0
TOTALS								71,040				

MONTHLY SUMMARY OF TESTING DATA

% REDUCTION OF VOLATILE SOLIDS IN DIGESTER 1 = 62.26
% REDUCTION OF VOLATILE SOLIDS IN DIGESTER 2 = .00
% REDUCTION OF VOLATILE SOLIDS IN DIGESTER 3 = 49.05
% REDUCTION OF VOLATILE SOLIDS IN DIGESTER 4 = 70.68

Figure 30. Sample Printout of Digester Performance Produced Through Automatic Data Processing

APPENDIX C

CLASSIFICATION AND DESCRIPTION OF INFORMATIONAL JOB AIDS FOR OPERATORS

This appendix provides recommendations for job aids to assist operators with their functional role and responsibilities within the treatment plant The appendix is structured through a classification of major information content areas deemed appropriate to operational activities. Within each content area, a finer level of detail is provided for classes of information to be presented to operator personnel along with corresponding recommendations for appropriate job aid(s) for presenting the information effectively. The classes of information are intended to be self-explanato1 The mode(s) of job aid presentation, keyed to information classes in the form of matrices, is defined in Chapter 4, along with principles and procedures for development.

The intent is not to dictate information needs of operators nor to specify what form of job aid must be used for its presentation. Rather, the intent is to suggest what is likely to be appropriate in terms of both content and alternative job aid formats. The final selection must be guided by specific plant circumstances.

Major content areas considered are:

1. Aids to process startup.
2. Process control aids.
3. Aids to process stabilization.
4. Aids to servicing procedures.
5. Aids to maintenance coordination.
6. Reporting aids.

Aids to Process Startup

The "startup" of biological forms of wastewater treatment represent special cases for treatment operations; special control procedures are required to foster development of the proper numbers and types of biological growths prior to the introduction of full-scale loading. The need for special startup information will exist at the time the plant initially goes into operation and thereafter as determined by process failures.

Table 5 presents some representative types of "startup" information of value to operators and some suggested formats for presentation through job aids.

Figure 31 illustrates a possible job aid format for the presentation of conditions and criteria necessary for startup of an activated sludge process. Individual aids, as well as combinations of aids, must be utilized to effectively communicate startup information to plant operators.

Process Control Aids

Process control aids present information, tailored to the specific size and configuration of the concerned plant, to assist with the monitoring and effective control of treatment processes. The control information to be presented is based on treatment plant objectives and criteria for the range of loading and other parameters to which the plant is subjected. Control loops for each controllable treatment parameter, in conjunction with objectives and criteria, represent the principal framework for deriving the information needs of operators with respect to controlling treatment processes.

Table 6 reflects at least some of the important units of process control information to be presented to operators and some suggested forms of job aids appropriate to each type of information. Nearly all of the information

Table 5

Elements of Startup Information for Biological Treatments and Some Appropriate Forms of Presentation Through Job Aids

Class of Startup Information to be Presented to Operators / Suggested Mode(s) of Job Aid Presentation	Manual(s)	Detailed Task Procedure Information	Reference Material (special purpose)	Model/Simulation/ Example	Checklist(s)	Troubleshooting Action Trees/Decision Tables	Function Flow Logic Diagrams
Facility and equipment conditions for startup	X				X		
Loading parameters and values for startup (waste to micro-organism ratio)	X				X		
Recommended method(s) for starting biological growth	X	X					
Types and ratio or preferred micro-organisms	X		X		X		
Instructions for controlling the growth and predominance of preferred micro-organisms	X	X				X	X
Instructions for controlling the metalobic rate in early stages of growth	X	X		X			
Recommended types of food matter	X		X		X		
Effects of temperature on growth characteristics	X			X			
Effects of oxygen on growth characteristics	X			X			
Methods of inhibiting the growth of undesirable micro-organisms	X	X					X
Values and conditions for transfer to full-scale treatment	X		X			X	
Instructions for converting to full-scale treatment	X	X		X			

STARTUP CONDITIONS AND CRITERIA FOR ACTIVATED SLUDGE

Item or Condition	Startup Criteria
Micro-organisms	A varied culture of different types of bacteria with zooglea ramigara and/or other gel formers present; stalked, ciliate protozoa and free swimming ciliates present without the smaller flagellate protozoa; absence of the fungus, sphaerotilus natans.
Feed characteristics	The raw sewage to be predominantly composed of a mixture of soluable, colloidal, and suspended materials; soluable BOD being more difficult to process especially at lower temperatures. For average domestic sewage, the feed should contain between 8 and 18 ppm free amonia as N and between 1.7 and 218 ppm phosphorus as P; the raw sewage must be free of toxic materials.
Temperature	Optimum temperature of 82 degrees F.
pH	Between 7.0 and 7.5.
Air requirements	a. 0.5 to 1.5 cu. ft. of free air per gallon of sewage. b. 500 to 700 cu. ft. per lb. of BOD removed when BOD loading 25 to 30 lb. per 100 lb. aerator solids. c. 700 to 1750 cu. ft. per lb. of BOD removed when BOD loading 25 to 12 lb. per 100 lb of aerator suspended solids.
Aeration period	5 to 7 hours with diffused air.
Sludge age	3 to 4 days.
BOD loading	a. 25 to 30 lbs of BOD per 1000 cu. ft. of aeration tank. b. 30 to 40 lb of BOD per 100 lb. of aerator suspended solids. c. 20 to 30 lb. of BOD per 100 lb. of aerator suspended solids at reduced flows.
Sludge quantity	1500 to 3000 ppm aerator suspended solids.
Sludge quality	Volatile matter--60 to 85% of total aerator solids. Alkalinity--100 to 200 ppm. Dissolved oxygen content at outlet--2.0 to 5.0 ppm. 30 minute settling test--15 to 25%. Sludge volume index--near 100.

Figure 31. Illustrative Tabular Job Aid Presenting Startup Criteria for an Activated Sludge Process

Table 6

Elements of Process Control Information and Some Appropriate Job Aid Forms of Presentation

Class of Process Information to be Presented to Operators \ Suggested Mode(s) of Job Aid Presentation	Detailed Task Procedural Information	Manual(s)	Reference Material (special purpose)	Model/Simulation/ Example	Task Performance Schedule(s)	Process Equipment and Control Labels	Cue Materials	Checklist(s)	Troubleshooting Action Trees/Decision Tables	Function Flow Logic Diagrams
Process performance parameters to be checked		X								
Suggested intervals for performance checks		X			X					
Standard values or conditions indicative of acceptable process/ plant performance		X	X				X			
Values or conditions indicative of unacceptable performance		X	X				X			
Relationship between observed status and required control changes		X		X						X
Identifying proper control change for given process/plant conditions	X	X	X	X		X	X		X	X
Instructions for carrying out control changes	X	X					X	X		
Symptoms of control problems and the nature of associated problems		X	X	X					X	
Techniques for isolating control problems		X						X	X	X
Contingency situations and appropriate emergency procedures	X	X	X							
Interprocess relationships on treatment control		X		X						X
Tradeoff factors in optimizing treatment cost effectiveness		X	X							

should, of course, be presented in a consolidated manual, but individual aids also need to be designed for use at control task locations.

Figure 32 illustrates a possible job aid format for presenting symptoms of digester control problems and related alternatives which could cause the problems.

Code Labels. Operator access to information can be enhanced through the labeling of operational components of the plant which correspond with keys, indexes, sections of manuals, and other information storage sources.

Control Relationships. Control relationships should be posted at controls to the maximum extent possible. For example, if flow rate has an effect on the optimal on/off ratio of an equipment unit, the optimal ratio might be posted in the form of a graph as illustrated in Figure 33.

In other control situations, as depicted in Figure 34, it may only be necessary to provide a checklist of alternative control factors.

Aids to Process Stabilization

Process stabilization refers to the relatively steady-state level of treatment effectiveness desirable for a plant in spite of nonsteady-state loading and other factors impacting on treatment effectiveness. Process stabilization implies operational control of processes in such a manner that loading and other factors are anticipated and control adjustments made so that process and plant effluents meet criterion on a continuing basis.

Table 7 reflects some important categories of information to assist with achieving process stabilization and some corresponding job aid types for the presentation of information to plant operations personnel.

Figure 35 is a sample job aid format for presenting information concerned with toxic elements.

Digester Failure Symptom \ Possible Failure Cause	Overloading	Excessive Sludge Withdrawal	Feeding Sludges Above Normal Concentration	Feeding Voluminous Sludges Below Normal Concentration
Decreased methane production		X		
Immediate increase in carbon dioxide with decrease in methane	X			
Increased carbon dioxide with decreased methane production			X	
Increased volatile acids			X	
Rapid increase in volatile acids with decrease in alkalinity	X			
Decreasing alkalinity		X		
Increased ammonia alkalinity			X	X
Increased percentage of carbon dioxide				X
Decrease in digester temperature				X
pH drop	X	X	X	X
Foul smelling supernatant	X		X	

Figure 32. Illustrative Operations Job Aid for Identifying Digester Failure Possibilities According to Observable Symptoms

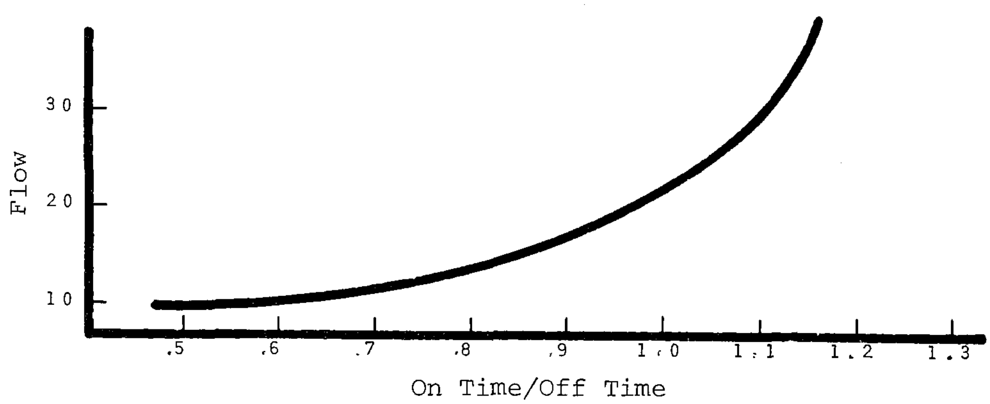


Figure 33. Sample Aid for Checking and Setting Control Point

OXYGEN CONTROL FACTORS FOR AERATION TANK

Increase Dissolved Oxygen by:	Increasing blower speed Starting additional blower Decreasing food supply/sewage flow Placing more aeration tanks into operation Bypassing part of aeration tank influent (ONLY AS A LAST RESORT)
Decrease Dissolved Oxygen by:	Decreasing blower speed Shutting off a blower Wasting air to the atmosphere Increasing sewage rate of flow Taking aeration tanks out of operation. Bypassing all or part of raw sewage directly to the aeration tanks

Figure 34. Sample Job Aid for the Control of Dissolved Oxygen in an Aeration Tank

SAFE LIMITS FOR TOXIC ELEMENTS

Waste Element	Maximum Safe Limit in Raw Sewage
Chromium as Cr (hexavalent)	3 ppm
Copper	1 ppm
Cyanides	2 ppm
Acids or alkalies	pH range of 6.0 to 9.5
Phenol or equivalent	50 ppm
Formaldehyde	Undesirable in any quantity
Oils and greases	100 ppm
Zinc, Nickel, Mercury, Lead, Arsenic	Undesirable; safe limits not established

Figure 35. Illustrative Checklist for Use in Reviewing the Results of Laboratory Analysis

Table 7

Elements of Process Stabilization and Some Appropriate Forms of Job Aid Presentation

Class of Process Stabilization Information to be Presented to Operators \ Suggested Mode(s) of Job Aid Presentation	Manual(s)	Detailed Task Procedure Information	Reference Material (special purpose)	Model/Simulation/ Example	Task Performance Schedule	Checklist(s)	Troubleshooting Action Trees/Decision Tables	Function Flow Logic Diagrams	Graphs and Nomographs
Treatment process objectives and criteria	X		X			X			
Cost and level of treatment as function of hydraulic and concentration loading	X			X					X
Cost and level of treatment compromise points	X					X			
Methods for establishing cost/level of treatment stabilization points	X	X		X				X	
Control adjustments for maintaining stability through diurnal and other normal fluctuations in loading	X	X			X			X	
Shock loading conditions which can destroy treatment stabilization	X		X						
Symptoms and warning signs of shock loading	X					X	X		
Preventive measures for shock loading	X				X				
Contingency situations and effects upon reaching and maintaining treatment criteria	X		X				X		
Procedures for dealing with contingency situations	X	X				X		X	
Toxic elements and safe limits for maintaining stabilization	X		X			X			
Procedures for dealing with process instability	X	X							
Evaluation plan for assessing process performance	X	X		X		X			

Aids to Servicing Procedures

There is almost always a number of relatively unsophisticated maintenance tasks, primarily in the areas of simple "servicing" procedures, which can be efficiently performed by operators rather than complicating the issue by having to call upon maintenance personnel. A common example is the refilling of pens on chart recorders.

The responsibility for servicing tasks, or perhaps even dual responsibility with maintenance personnel in some cases, must, of course, be designated as part of job description.

Job aids for servicing tasks assigned to operations personnel should be developed according to the recommendations provided in Appendix D under the heading of "Aids to Preventive Maintenance." Any other "maintenance-oriented" tasks assigned to operator personnel can also benefit from the overall recommendations provided in Appendix D.

Aids to Maintenance Coordination

Operations personnel are in almost continuous contact with plant facility and equipment. They are, therefore, in a position where they are likely to identify maintenance needs before they might normally be detected by the maintenance staff. The means for detecting and reporting maintenance problems requiring immediate or near-future attention must be provided to the operations staff. In addition, procedures for controlling treatment during periods of equipment malfunction or "outage" must be provided as part of overall plant contingency planning.

Table 8 indicates some of the maintenance coordination information and products which should be developed to assist operators with their role in effective maintenance. The suggested job aid formats are intended to provide starting points for information presentation.

Table 8

Elements of Maintenance Coordination
and Related Recommendations for Job Aids

Types of Maintenance Coordination Information to be Presented to Operators / Suggested Mode(s) of Job Aid Presentation	Manual(s)	Detailed Procedural Information	Reference Material (special purpose)	Model/Simulation/ Example	Cue Materials	Checklist(s)	Troubleshooting Action Trees/Decision Tables	Function Flow Logic Diagrams	Form for Recording and Transmitting Maint. Info.
Symptoms of equipment malfunctions which should be regularly checked by operations personnel	X		X			X		X	
Procedures for communicating maintenance needs to maintenance/management personnel	X								
Recommended maintenance request form:									
Description of observed malfunction									X
Equipment unit malfunctioning									X
Location/serial number as required									X
Criticality of malfunction to operational effectiveness of treatment									X
Date and time malfunction observed									X
Name of person reporting malfunction									X
Instructions for minimizing the effects of malfunctioning equipment on treatment	X	X		X	X	X	X		
Instructions for operating treatment processes during periods of specific equipment outage for maintenance	X	X		X		X	X	X	

Figure 36 provides a sample format for one possible type of maintenance request form.

Reporting Aids

Documents concerned with the operational status of a treatment plant are essential to operational control, assessment of plant effectiveness, plant management, and the detection and analysis of trends for the treatment of wastewater. Specifications of appropriate information to be collected and reported by operators represent a major first step in what should be a continuing program of plant evaluation, and subsequent modifications, leading to maximal cost-effectiveness.

Table 9 reflects some informational elements to assist operators with the collection and reporting of appropriate information. The table also provides suggested aids to assist with the collection and reporting of each information type.

MAINTENANCE REQUEST FORM

Date 7/30/72

Time 8:46 PM

Equipment Description:

Return sludge pump control for #1 pump

Location:

Blower building

Problem:

Pump will not always go on. ~~Have~~ to keep turning with on-off until pump finally ~~starts~~. Once started, pump seems OK.

Criticality:

If pump quits, #2 pump can handle job for one or two shifts. After that, we run the risk of losing activated sludge.

Signature: John Q. Doe

Figure 36. Sample Maintenance Request Form

Table 9

Elements of Operational Data to be Documented and Some Related Job Aids and Documentation Methods

Types of Reporting Information to be Presented to Operators / Suggested Mode(s) of Job Aid Presentation	Manual(s)	Operator Log	Preformatted Special Report Forms	Management Summary Report	Preformatted Cost Accounting Records
Techniques for processing and drawing conclusions from operations data	X				
Procedures for collecting and reporting operations data	X				
Guidelines for collection and reporting of specific data elements:					
Raw waste volumes and characteristics	X		X		
Treatment quality as function of loading	X		X		
Unusual loading or treatment situations	X	X		X	
Major accomplishments and/or setbacks encountered	X	X		X	
Documentation of treatment failures and/or inability to meet criteria	X	X		X	
Data which may help in isolating the cause of failures; i.e., symptoms, conditions, etc.	X			X	
Labor time charged by operators against unit treatments (or more detailed functional elements)	X		X		X
Consumables and other nonlabor treatment cost elements	X				X
Information to be transferred from shift to shift, operator to operator, and of historical value	X	X			

APPENDIX D

CLASSIFICATION AND DESCRIPTION OF INFORMATIONAL JOB AIDS FOR MAINTENANCE PERSONNEL

This appendix provides recommendations for job aids to assist maintenance personnel with their responsibilities in the treatment plant. A classification of major content areas forms the primary structure for the appendix, with a finer level of detail provided within each content area. Classes of pertinent maintenance information are keyed to recommended job aid presentation modes through the use of matrices. As with the previous appendix, more complete definition of the various job aids and procedures for their development will require reference back to Chapter 4.

The major content areas considered are:

1. Aids to preventive maintenance.
2. Alignment and adjustment aids.
3. Diagnostic and troubleshooting aids.
4. Repair and overhaul aids.
5. Reporting aids.

Aids to Preventive Maintenance

Preventive maintenance, in the context of this appendix, refers to all maintenance activities directed to the routine servicing and preservation of equipment and facility to reduce the probability of unexpected failure and increase life expectancy. For the purposes of this Guide, all maintenance activities not performed for the express purpose of correcting a failure are arbitrarily considered preventive maintenance and include such tasks as lubrication, cleaning, and painting.

Table 10 lists some of the essential types of preventive maintenance information to be presented to maintenance personnel as well as some job aid formats applicable to each information types.

Table 10

Essential Elements of Preventive Maintenance Information and Related Recommendations for Job Aids

Types of Preventive Maintenance Information to be Presented to Maintenance Personnel \ Suggested Mode(s) of Job Aid Presentation	Manual(s)	Task Procedural Information	Checklist(s)	Coding/Labeling/Numbering of Equipment Components	Central and Equipment-Located PM Schedules	Equipment Data Cards
Enumeration of equipment and facility requiring scheduled checks or inspections	X			X		X
Enumeration of equipment and facility having service requirements (i.e., lubrication, etc.)	X			X		X
Recommended frequency for check, inspection, service tasks	X				X	X
Enumeration of equipment, tools, or materials for each preventive maintenance task	X		X			
Procedures for performing check, inspection, service tasks	X	X	X	X		
Control settings and conditions required for performing checks and inspections	X		X			
Tolerances or conditions indicative of proper or inadequate equipment functioning (malfunction symptoms)	X		X			
Procedures for measuring tolerances or perceiving need for maintenance actions	X	X				
Method for recording when last equipment service was provided	X				X	
Method for noting when next equipment service will be required	X				X	

Figure 37 is an example of a preventive maintenance schedule designed for use at the equipment location. The example combines some of the features of a checklist with a convenient means for determining when lubrication was last performed and when it is again due, as well as who performed the lubrication.

Alignment and Adjustment Aids

Alignment and adjustment activities refer to those aspects of maintenance designed to compensate for wear and "drifting" of equipment through normal use. The objective of alignment and adjustment activities is to keep equipment "peaked" at the most desirable level of performance and prevent out-of-tolerance conditions which could bear upon treatment effectiveness, treatment costs, or a reduction in equipment life.

Table 11 identifies some information types deemed essential to alignment and adjustment activities of maintenance personnel and a number of possible forms of presentation of the information as job aids.

Diagnostic and Troubleshooting Aids

The ability of maintenance personnel to correct equipment failures is, in many cases, a function of their ability to focus-in on the cause of the failure. Once the problem is properly diagnosed, the repair or replacement of faulty components is relatively routine. This particular section is intended to enhance the ability of maintenance personnel to quickly and accurately diagnose the corrective action necessary to put faulty equipment back into service.

The types of information which can effectively enhance and support the troubleshooting of plant equipment are presented in Table 12. Suggested formats for presenting the information to maintenance personnel as job aids is also presented.

LUBRICATION SCHEDULE

(Keep Posted at Primary Tank #2)

TRANSFER CASE--Drain and refill every 6 months; 90 weight hypoid oil

Date of Change	Changed By	Change Due On

UNIVERSAL JOINTS--Grease weekly; high-pressure lithium grease

Date	Lubricated By	Date	Lubricated By

Figure 37. Example of a Service Schedule Designed for Posting at Task Site

Table 11

Elements of Alignment and Adjustment Information and Some Appropriate Forms of Job Aid Presentation

Types of Alignment and Adjustment Information to be Presented to Maintenance Personnel / Suggested Mode(s) of Job Aid Presentation	Manual(s)	Task Procedural Information (special purpose)	Checklist(s)	Detailed Equipment Specifications	Pictorial Drawings and Blueprints	Coding/Labeling/Numbering of Parts and Components	Function Flow Logic Diagrams	Troubleshooting Action Trees/Decision Tables	Equipment Data Cards
Enumeration of alignment and adjustment tasks which can be performed in-plant	X								X
Recommended interval for performing alignment and adjustment checks	X		X						X
Symptoms and characteristics of equipment in need of alignment or adjustment	X						X		X
Procedures for aligning or adjusting	X	X		X	X	X		X	
Tolerances for the alignment or adjustment of equipment and equipment controls	X			X					X
Test equipment or standards required for alignment or adjustment tasks	X		X						X

Table 12

Categories of Troubleshooting Information and Some Related Job Aid Forms of Presentation

Types of Troubleshooting Information to be Presented to Maintenance Personnel / Suggested Mode(s) of Job Aid Presentation	Manual(s)	Task Procedural Information (special purpose)	Checklist(s)	Coding/Labeling/Numbering of Parts and Components	Equipment Data Cards	Detailed Equipment Specifications	Pictorial Drawings and Blueprints	Schematic Diagrams	Model/Simulation/Example	Troubleshooting Action Trees/Decision Tables	Function Flow Logic Diagrams
Instructions for diagnostic tests and checks	X	X	X	X			X		X	X	X
Enumeration of failure modes for each unit of equipment subject to a failure	X	X	X							X	X
Reliability information and failure probabilities for equipment	X				X	X			X		
Failure symptoms and characteristics for failure modes	X		X							X	X
Control settings and conditions required for diagnostic tests	X	X	X					X			
Tools/instruments required for troubleshooting	X				X	X					
Procedures for removing or disassembling equipment for the purpose of diagnosis	X	X		X			X				
Procedures for measuring or assessing components for failures or defects	X	X	X				X				
Reference information keyed to appropriate repair or replace tasks	X				X	X	X				

Repair and Overhaul Aids

The repair or overhaul of treatment equipment is designed to correct equipment which has malfunctioned or has worn to the extent of being non-serviceable.

Table 13 identifies some of the essential forms of information required for repairing and overhauling equipment. The table also reflects some job aids appropriate to each type of repair and overhaul information.

It should be noted that, while many major repairs and overhauls are carried out under maintenance contracts rather than through in-house resources, it is, nevertheless, desirable to develop informational job aids for all equipment units. Otherwise, the lack of appropriate job aids for some equipment units will significantly dampen future options to develop an in-house capability for their repair and overhaul.

Reporting Aids

The operational availability and reliability of treatment plant equipment, the nature of current and anticipated maintenance problems, and the costs of maintenance represent important decision-making information for both maintenance and management personnel. Maintenance data are essential to a workable maintenance philosophy, the detection and analysis of maintenance trends, and the assessment of equipment reliability and maintainability as input to cost-effective future purchases.

Table 14 presents a number of essential information types to be presented to maintenance personnel to assist them in the reporting of relevant maintenance data. Some job aid techniques are suggested for presenting the information to maintenance personnel and to assist with their reporting function.

Figures 38 and 39 illustrate some of the possible job aids for recording and reporting maintenance information.

Table 13

Categories of Overhaul and Repair Information and Some Related Forms of Job Aid Presentation

Types of Overhaul and Repair Information to be Presented to Maintenance Personnel \ Suggested Mode(s) of Job Aid Presentation	Manual(s)	Task Procedural Information (special purpose)	Checklist(s)	Pictorial Drawings and Blueprints	Schematic Diagrams	Troubleshooting Action Trees/Decision Tables	Function Flow Logic Diagrams	Equipment Data Cards
Design information for each unit of equipment	X			X	X		X	X
Corrective maintenance information for each unit of equipment	X	X		X	X	X	X	X
Method for providing rapid access to essential equipment information	X							
Tools and facility required for removal/replacement of component parts and/or overhaul	X		X					
Enumeration of tasks to be performed in-plant and those requiring outside services	X							
Enumeration of tasks for repairing specific equipment functions	X	X	X			X	X	
Enumeration and sequencing of tasks for complete overhaul of equipment units	X	X	X					
Tolerances for repair/replace decision making	X		X				X	
Instructions for measuring tolerances	X	X						
Procedures for repairing or refinishing component parts	X	X		X				
Information for ordering and stocking spare parts (local sales outlet, local service representatives, etc.)	X							X
Recommended inventory of spare parts and supplies	X							X

Table 14

Essential Elements of Maintenance Data and Some Related Job Aids and Methods of Reporting

Types of Data Recording and Reporting Information to be Presented to Maintenance Personnel \ Suggested Mode(s) of Job Aid Presentation	Manual(s)	Maintenance Log	Management Summary Reports	Equipment Data Cards	Preformatted Special Report Forms	Preformatted Cost Accounting Records
Procedures for recording and reporting equipment problems and recommendations for future overhaul/purchases	X		X			
Procedures for recording and reporting pertinent information about the status of plant equipment and facility	X	X	X		X	
Procedures for recording and reporting cost data:						
Labor costs for corrective maintenance	X					X
Parts and materials for corrective maintenance	X					X
Labor costs for preventive maintenance	X					X
Materials consumed for preventive maintenance	X					X
Cost of contracted maintenance services	X					X
Procedures for compiling and utilizing reliability information	X			X		
Procedures for assessing impact of maintenance task scheduling	X					
Guidelines for an equipment data file to record maintenance history of equipment units	X			X	X	

INSPECTION SHEET--SETTLING TANKS

Date______________

Inspected by______________

Tank Number	#1	#2	#3
Gear Box and Sprocket			
Bull Sprocket			
Drive Chain			
Driven Sprockets			
Flight Chain			
Flights and Shoes			
Rails			
Service or Adjustments Made:			
Description of Repairs to be Made: (requiring down time)			

Remarks:

Figure 38. Combination Checklist and Inspection Report Form

EQUIPMENT DATA CARD

Equip. Nomenclature	Location in Plant
Equip. #	Mfg.
Type	Address
Model	
Serial #	Serv. Rep. / Phone
RPM	Vari-Drive Type
Capacity	Vari-Drive Serial #

Bearings	Mfg. & Part #	Shaft Size	Coupling	Belts
Ball			Type	Type
Roller			Mfg.	Size
Sleeve			Serial #	Cat. #

Packing	References
Type	Dwgs #s
Size	Maintenance Manual #s
Number Rings	Operations Manual #s
Recommended Brand	

Date Installed:	Location:	Application:

Date Repaired	Repairs or Parts Replaced	Cause	Total Repair Cost

(Service Record Continued on Reverse Side of Form)

Figure 39. Illustrative Form for Recording Pertinent Equipment Data and Service Information

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SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No. *2.*

W

5. Report Date

6.

8. Performing Organization Report No.

GUIDE TO THE PREPARATION OF OPERATIONAL PLANS FOR SEWAGE TREATMENT FACILITIES

Seiler, E. L. and Altman, J. W.

Project No.

17090FWA

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Synectics Corporation
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Allison Park, Pennsylvania 15101

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13. Type of Report and Period Covered

12. Sponsoring Organization

Environmental Protection Agency report number, EPA-R2-73-263, July 1973.

A proceduralized methodology is provided to guide the initial and ongoing planning necessary for extracting maximum potential from wastewater treatment plants. The objective of the planning activities is the development of conceptual and applied tools for direct use by plant personnel in optimizing the cost-effectiveness of their plant, complementing the design engineering of the physical plant.

The main body of the Guide is divided into five major steps, representing a proceduralized methodology for developing operational planning materials. The contents and sequencing of these steps are designed to rationally combine operational planning and design engineering. Heavy emphasis is placed on general methods and principles which can be applied to a wide variety of specific treatment plant designs and situations.

The four appendixes of the Guide provide a detailed classification and description of planning materials deemed essential to plant functions of management, operations, and maintenance. Job descriptions, plant manuals, checklists, reference materials, task schedules, decision tables, and operating records are among the specific materials designed to support the above personnel functions. Thus, the appendixes serve to define the nature of the planning outputs while the five procedural steps of the main body provide a framework for their development.

17a. Descriptors

*Management planning, *Operations research, *Operation and maintenance, *Optimization, *Human engineering, job analysis, manpower, systems engineering, human resources, operations, operating criteria, information systems, manuals, plant records

17b. Identifiers

Job aids, performance standards, performance aids, management data, operator data, maintenance data

17c. COWRR Field & Group 06A, 05D

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