A MANAGEMENT INFORMATION SYSTEM

FOR

AMERICA'S WASTEWATER TREATMENT PLANTS

A Thesis

Presented to

the Graduate Faculty

California State College, Hayward

In Partial Fulfillment

of the Requirements for the Degree

Master of Business Administration

by

Michael M. Williamsen

February 1972

A MANAGEMENT INFORMATION SYSTEM

FOR

AMERICA'S WASTEWATER TREATMENT PLANTS

by

Michael M. Williamsen

Approved:	Date:
Walter B. McFarland	February 25, 1972
Frank Jackson	February 28, 1972
Bill Mitchell	1 March 1972

Committee in Charge

Table of Contents

Introduction

Until very recently, there has been little concern with the effects of sewage treatment on our surroundings. As long as there have been no odor problems, little attention has been paid to the operation. This lack of concern has affected both the operation and management of wastewater treatment plants. Without strictly enforced effluent requirements, there has been little impetus to improve the operation or its management techniques. This situation is changing now that the U. S. government is setting and enforcing pollution control standards. Engineering technology has made great strides in solving the process problems associated with wastewater treatment. So far, however, no business management technological advancements have been utilized to help wastewater managers keep their facilities functioning correctly.

In the past ten years industries have had to find new ways to solve their production/operation problems. A major development in this area has been the introduction of management information systems (MIS). With these systems production facilities have become better integrated and structured to meet corporation objectives. Typically, separate information flows have been designed to tie together equipment operation, personnel performance, budget restrictions, and production output. Production operations not utilizing these modern information systems concepts experience relatively more difficulties in maintaining efficiency, economy, and quality control.

The wastewater treatment field has many parallels to private production operations. Though they do not work on a profit and loss basis, wastewater managers do have the responsibility to work within a budget. Because of this budgetary constraint, they have the problem of effective, economic, and efficient utilization of their production resources, i.e., equipment costing millions of dollars, and many people. Their objective is to produce large quantities, millions of gallons per day (mgd), of high quality water.

To date, however, wastewater managers have lacked modern management information systems techniques currently relied upon by their private enterprise counterparts. Though they work diligently, the wastewater managers are handicapped without an effective MIS to help them in the enormous task of effectively coordinating their diverse resources. As both budget constraints and pollution standards become tighter, a MIS for wastewater managers will become essential to coordinate the people, equipment, and budget effectively enough to achieve effective, low cost pollution control.

This paper describes a computerized MIS that can effectively, efficiently, and inexpensively close the wastewater manager's critical information gap.

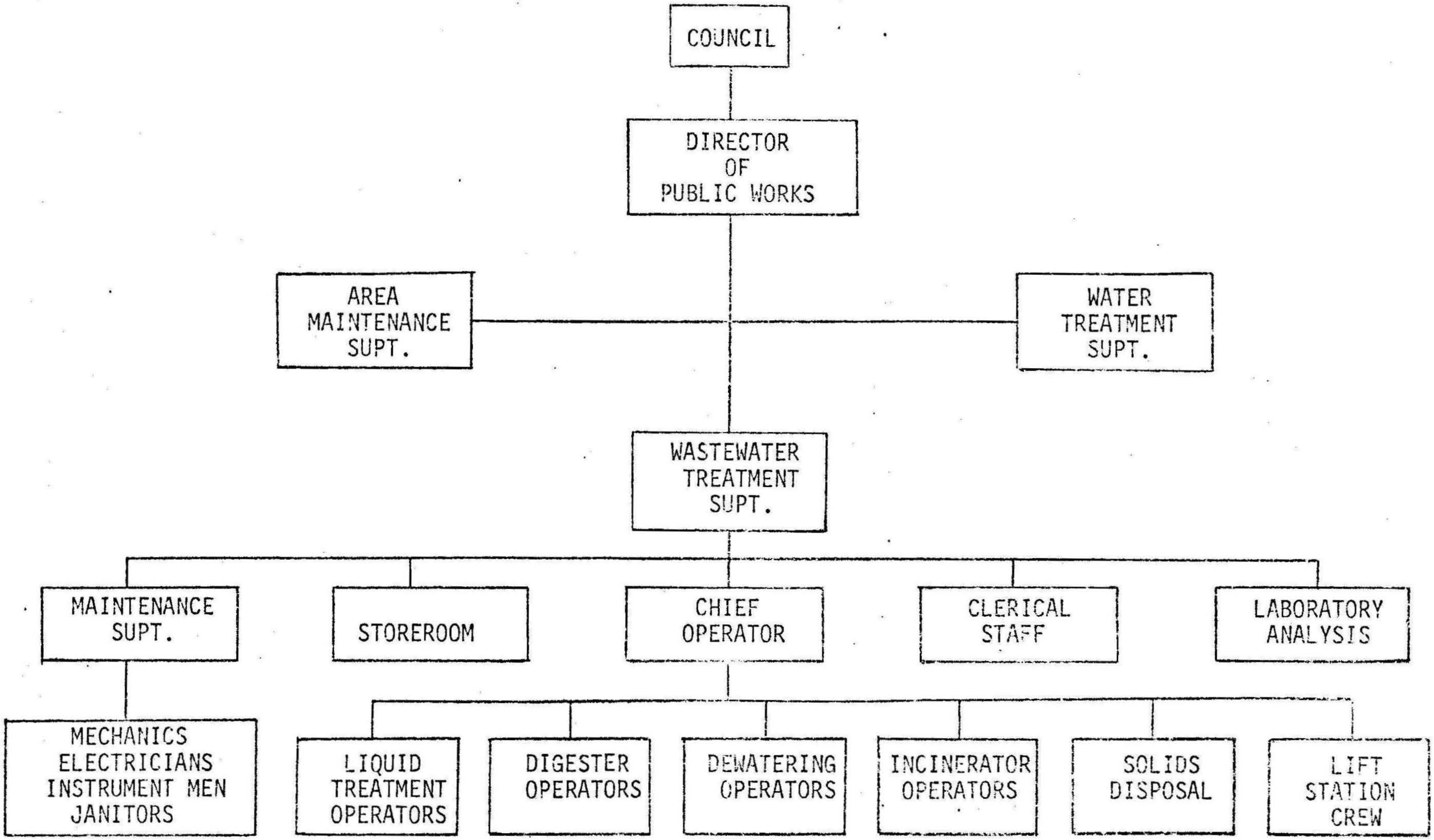
Organization of a Typical Plant

In general, the organization of a treatment plant has a superintendent in charge of day-to-day operations and directly responsible for the millions of dollars of assets tied up in the plant's equipment. (Fig. 1) Mechanics, operators and laboratory personnel all report to him. The superintendent in turn reports to a Director of Public Works who is responsible to the municipality's board of directors or council.

The information system that has been developed is at the level of the typical production information system. That is, it is a semi-open system that provides for information flows necessary to run the operation. External influences usually come from three areas: budgetary requirements, union contracts, and governmental standards for effluent quality. At present these three outside influences are correctly ranked by importance. The immediate future, however, points towards effluent quality considerations as becoming the most important.

In looking at the overall operation and the necessity to produce large quantities, millions of gallons per day (mgd), of high quality effluent, the production information system has to be capable of monitoring, controlling and evaluating the facility's equipment, people, budget

ORGANIZATION CHART



and product (stream) quality.

The normal structure has the superintendent performing all of these management functions as well as working on improving operational methods, planning necessary expansions and dealing with suppliers in an effort to get their equipment to function correctly. He is left with little time and has little, if any, of the formal business management background necessary to solve the long range problems that a production information system can help him handle so effectively.

Repair Section

The heart of a sewage treatment plant is the operating equipment. The normal data for a treatment plant's equipment consists of a file of equipment suppliers' brochures. The brochures give drawings, lubrication, and parts requirements and, in some cases, operational instructions. A more advanced plant system would have a card file for repair frequency records.

The usual repair sequence is as follows:

1. Equipment breakdown
2. Disassembly to determine the problem
3. Search for equipment supplier's brochure to locate part numbers
4. Search for part suppliers with parts in stock
5. Wait for parts
6. Repair equipment
7. Update equipment history card

Other breakdowns may occur during the "normal" repair time span. The effluent quality during this span depends on the plant flow, amount of equipment, labor force, critical nature of the breakdown and, of course, the length of time necessary to complete the repair sequence.

A computerized production information system must be able to provide timely, adequate, low cost repair information if the plant is to function effectively. The necessary information flows for every piece of equipment are outlined below and then explained in detail.

1. Commonly required repair parts
2. Stock and location of these parts
3. Supplier information for each part
   a. Acceptable suppliers
   b. How to contact them
   c. What to order
   d. How to order
   e. How much to order
   f. How much it will cost
   g. What is already on order
4. What lubrication is necessary
5. Alternate sources of parts supply
   a. Machine shop capabilities
   b. Other equipment containing identical parts
6. Instructions peculiar to the equipment in question, e.g., other things to do while the equipment is down, like, perhaps, inspection or repair of ancillary equipment
7. Location of detailed repair instructions

A detailed explanation of each of these information flows now follows.

1. Commonly required repair parts

This file will initially contain the manufacturer's recommended list of spare parts as modified by the budgetary limitations and the superintendent's judgment. As each piece of equipment builds up a repair history, the file can be modified to reflect the anticipated needs for each piece of equipment.

2. Stock and location of these parts

One of the goals of this wastewater treatment MIS is to reduce inefficient use of time. This information flow tells the mechanic what is required to fix a piece of equipment, if the required materials are on hand, and where they can be received. With this information and a field estimate of the repair problems, a decision can immediately be made to repair now or postpone repair until proper parts are on hand. If the decision is to repair now, the mechanic(s) can check out all of the necessary repair materials in one operation. They will not have to go back and forth from storeroom to job site as the repair takes place.

3. Supplier information for each part

   a. Acceptable suppliers

   b. How to contact them

   c. What to order

   d. How to order

e. How much to order

f. How much it will cost

g. What is already on order

If the parts are not in stock, all of a-g must be immediately available to the maintenance force. The information system is designed to print out purchase orders automatically when stock drawdowns reach an automatic reorder point. (This system is described in detail in the Purchase Order Section, page 19.) The reorder point is set by management and preprogrammed for each inventoried part. If a piece of equipment fails and the necessary repair parts aren't on hand because of long delivery or ordering neglect, the ordering information is still available. As the work order form is printed out, the computer checks the parts data file. If it turns up any insufficiently stocked parts, the computer will automatically ask if purchasing information is desired. If so, it prints out stock numbers and descriptions of understocked items.

4. Necessary lubrication

The type and amount of lubrication for each piece of equipment is also stored for retrieval. More maintenance effort can be saved by insuring that all of the material necessary for a repair is on hand when the repair starts. Just as with spare parts, lubricants can be automatically ordered as their stocks are used up.

5. Alternate sources of part supply

No system is infallible. When the necessary repair parts are not on hand, the critical equipment must still be repaired. Two parts sources other than parts on hand and suppliers' inventories are available: machine shop capabilities and other equipment containing identical parts.

Depending on the size of the plant and its management, various machining capabilities are available. Though bearings couldn't be repaired, it may be possible to rework pump shafts, repair valves, etc. This type of emergency repair capability can be a lifesaver to continued smooth plant operations and therefore must be made available in the information system. As envisioned, this information would be printed out only for insufficient stock situations. Typically, only a "no" or a drawing number (signifying "yes") would be printed out when needed.

When all else fails, it is often possible to cannibalize needed parts from non-critical equipment. When replacement parts arrive, the "cannibalized" equipment can be repaired; but in the meantime, the plant can function more or less as designed. This particular information flow would be built up as equipment was repaired and interchangeable items are noted.

6. Instructions peculiar to the equipment in question

These unique instructions are stored in the computer memory and automatically retrieved when information on the piece of equipment is asked for. Typical instructions could be special repair instructions or other things to do while the equipment is off line, e.g., inspection or repair of auxiliary equipment.

7. Location of detailed repair instructions

Seldom, if ever, will detailed repair instructions be printed out. The backup is a filing system of equipment suppliers' repair instructions. These files are to be kept in a single location, e.g., the maintenance shop. The location code stored in the computer references the file location of the particular repair instructions. To make this part of the system function, management will have to emphasize the importance of prompt, correct refiling and perhaps assign one man to do the refiling at the end of each day.

In order to achieve a useful system, the Repair Section (above) must be integrated with a Work Order Section. The proposed Work Order Section is explained below.

Work Order Section

Items 1 through 7 in the Repair Section give necessary repair information. However, there must be a workable arrangement for printing out, using, and updating this information. A well thought out work order system can do this. The first constraint is to consolidate the necessary information into a functional form. For most plants, a convenient size one page report would greatly reduce and simplify the paper flow. Repairs should also proceed more smoothly with all of (and only) the pertinent information available on one sheet of paper. All of the following information should be contained in the one page work order:

1. Work order number

    This number is also stored in the computer to keep work order and updating straight. A more sophisticated system could allow for retrieval of the final completed work order, if it is justifiable to save this information.

2. Equipment number and physical location

    An equipment number is necessary in order to retrieve any of the information contained in the Work Order Section. This is because people can make mistakes in copying and typing. The code number acts as a double check.

3. Pertinent general information

This information flow is also included to act as a double check. However, here the intent is to check the equipment at the work site. Typical information in this area would be: RPM, horsepower, head, etc. This is printed on a different line than item 2--to set it off from shop area data and because of line length limitations.

4. Special instructions (as discussed above)

5. Necessary parts to accomplish normal repairs

This was also discussed above. The information flows would be arranged in a matrix by part. For each part, the following information is listed: description, stock number, stock location code, amount in stock, amount required to repair the equipment, part lubrication code and amount of lubrication required. If there is insufficient stock of a part, the matrix expands to include supplier codes, machine shop production drawing numbers and other equipment numbers with the same part. If more information is desired in these last three areas, e.g., service and location description of equipment with common parts, this too can be generated.

6. Location of additional information

This information flow gives the file location of equipment repair manuals.

7. Lubrication requirements

A verbal description is given for the required lube codes printed out in section 5. A typical description would be:

Lube No. 6 = Molybaloy 30A SAE 90W, gear lube part no. 1175

The rest of the work order system consists of standard format sections (forms) for field data input. When a job is finished, the completed work order form is turned in and used to update the computer files. When manipulated, this data is transformed into a large portion of the information required for the management reporting system.

8. Repair history report

When filled out, this form gives a capsule history of each job. The following data is required:

a. Who worked on the job. Each worker who charges time to the job fills in his employee number.

b. Employee hour distribution by date and time for each worker.

c. Permit to remove the equipment from operation for repairs. This data is not inputted to the computer, rather it acts as a safety check to insure that the operations division has prepared the equipment for repair and knows that it will be out of service.

d. Effect of the repair on the total operation. A one letter designation by operations tells whether a unit operation had to be shut down (S) or not (N) to repair the equipment in question.

e. Length of downtime. When combined with "d" above, an evaluation is possible of the critical nature of any repair. This information will be useful in evaluating equipment performance in the management reporting section of the MIS.

9. Parts used

Parts are listed whether from stock or not. This data allows for computer update of inventory, purchase orders and costs. Because work orders may be oustanding for a number of days, provision must be made to update inventory in the interim. This is accomplished by an additional (non-computer generated) stock drawn down form in the stockroom. This form would give the following information for each part checked out: how many checked out, part number, who checked it out, the date and which work order it was charged to.

10. Supplier information

This is printed out for understocked parts only when requested. The format and content is similar to the automatic purchase order capabilities that are described in the next section.

Purchase Order Section

As was mentioned in the Repair and Work Order Sections, parts purchasing data is necessary to keep a plant functioning correctly. This data is contained in the Purchase Order Section. When draw downs are inputted, the computer automatically checks to see if the reorder point has been passed. If the part is now understocked, the computer outputs this fact and asks if purchasing information is desired. If it is desired, entering the part number automatically causes the following information to be printed:

a. A list of acceptable suppliers (usually three) ranked in order of preference--either cost or delivery is the usual ranking criteria.

b. Their phone numbers and addresses

c. The plant stock numbers and the supplier stock number. Since these stock numbers will not be the same, it is necessary to store and retrieve both.

d. A literal description of the part to aid in ordering

e. The suggested order quantity. Because the waste treatment plant inventories in general aren't large enough to justify E.O.Q. type inventory modeling, this order quantity will be based on judgment, experience, and price breaks.

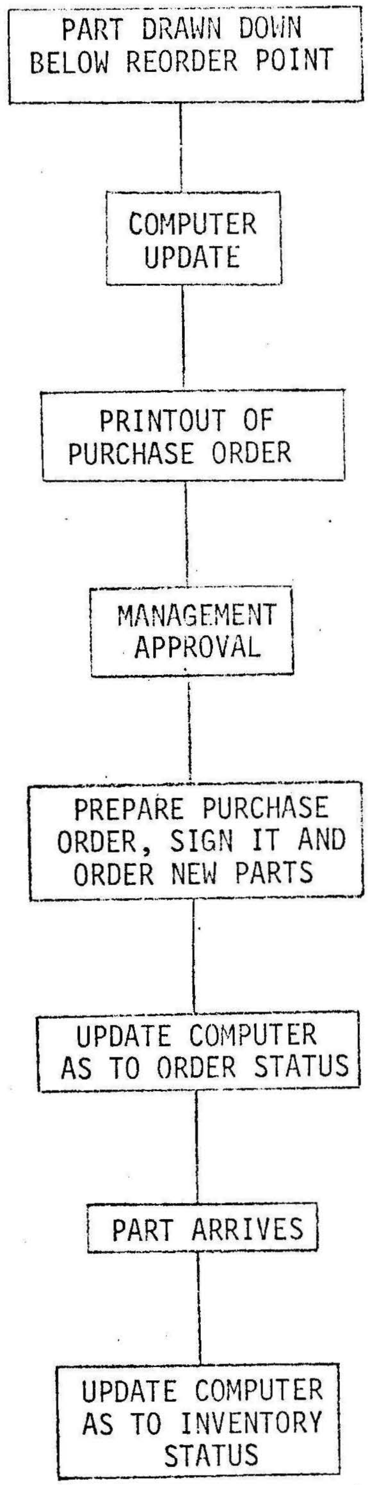
f. The cost of the order is printed out to insure that proper justification is obtained prior to actual ordering.

This "automatic" purchase order is not meant to be the final copy. Rather it is a facsimile of the plant's normal purchase order. The expected sequence of events is as follows: (Fig. 2)

1. Inventory drawdown below reorder point
2. Update of computer file for drawdown
3. Computer checks file and finds reorder point is passed
4. Computer prints out facsimile
5. Authorized person signs facsimile
6. Part is ordered and actual purchase order is filled out and authorized.
7. Computer files updated to show part on order
8. Part arrives
9. Computer files updated to show increase in stock

The last informational item needed before an ordering decision is made is: how much of the item is already on order. This information helps to reduce order duplication. It can also be used to order suppliers. As the amount on order at a supplier is outputted, so is the promised delivery date. Prompt delivery can be rewarded by increasing the

PURCHASING FLOW CHART



number of orders from that supplier. In any case, the supplier of on-order parts can be quickly and easily checked before another order is placed. The information system gives this flexibility by printing out a section titled "parts on order" for each piece of equipment in question. The information that is printed out is: supplier--

a. name, address, and phone number

b. part description, plant code, and supplier code

c. plant purchase order number

This completes the equipment maintenance portion of the information system. The sections that follow deal with the surveilance and management of the plant's people, equipment, budget and operation.

Operator Reporting Section

The work order system provides for repairs and, as explained later, process, budget and personnel evaluation. This flexibility is also necessary for operations and laboratory functions. The subsystems in these areas are simpler than the equipment area, because there is less information to be filled out and reported on. Each operator has his normal rounds and measurements to be recorded. To save computer connect time, only out-of-the-ordinary equipment problems are inputted on each shift. Other pertinent operational data is kept for input all at once.

The non-shutdown equipment problems are inputted as noticed and retrieved by the day shift maintenance foreman for his action. With the current method of reporting, many times minor problems go unsolved until they become a major problem. A typical example of a "trouble report" is a motor that "trips out" intermittently, but always resets--that is, until the last critical time. By accessing the computer and entering the equipment number, problem, operator and date, this data is available to field repair forces. This method is better than a log book, because only problems are noted and the information can be automatically sorted, stored and retrieved by equipment number.

To a large extent, the effectiveness of the operators determines the success of the operation. The next section is designed to give the informational reports necessary to evaluate plant performance.

<u>Laboratory Reporting Section</u>

The laboratory data system is a little more complex than the one for operators. As regulatory agencies become more stringent, laboratory reporting becomes more demanding and voluminous. At present it is not uncommon for these agencies to require a number of different reports anywhere from weekly to annually. Often more than 45 parameters must be reported on in air or water streams. Examples include CO, NO_x and reactive hydrocarbons in air streams; 5 day biological oxygen demand (BOD), suspended solids (SS), any number of heavy metals and phosphorus concentrations in the liquid streams. A typical plant will increase this value manyfold by "following" and reporting on the process from unit operation to unit operation. Influent, primary treatment, secondary treatment, digestion, dewatering, incineration, effluent polishing and final effluent may all have to be monitored, depending on the plant. Though not all of these 45 or so parameters are "followed", some must be to evaluate and control the operation.

As physical-chemical operations become more common, more and different data will be needed. Even now, it is not uncommon for plants to have a staff whose sole duty is data calculation and compilation. This is in addition to the laboratory staff that determines the values in the first place. The plant manager cannot hope to adequately evaluate this mountain of data. The computerized MIS, however, is able to rapidly and economically make calculations with raw data, arrange, store and output the results in meaningful formats.

In addition, management by exception flags can be built in to draw the manager's attention to areas of concern. A special reporting system that outputs only exceptional data can be utilized to reduce the mountain of data to a meaningful molehill. When tied in with the other managerial reporting systems described below, sorting routines can find potential answers for exceptional data points. An example would be low BOD removal for a period during which a clarifier was out of service for repairs. In this instance, the computer could match equipment down data with poor operational results data.

Because regulating agencies are continually changing requirements, this type of exception reporting becomes a more important additional tool for the manager.

The necessity of interfacing plant performance with equipment performance dictates the establishment of an equipment evaluation subsystem. This system is described in the next section.

Equipment Reporting Section

The utilization of the MIS concept in wastewater treatment allows the manager to get many more meaningful reports with which he can more effectively manage his operation. Operations reporting has just been covered. Equipment, people and budget reports are also necessary.

In the equipment area, a number of reports are useful. By sorting and otherwise manipulating the data from the work order and operator input sections, it is possible to evaluate the performance of: parts, equipment pieces and unit operations. When evaluating any of these areas, the manager will want to know the following information:

1. Amount of critical downtime
2. Frequency of parts replacement
3. Cost of repairs
4. Cost of operation
5. Expected future repair and operations costs

The information requirements for these five areas are explained in detail below.

1. Amount of critical downtime

   How much of the time is the item in question off-line for repairs? This is an important informational item for a piece of equipment that is critical to the process operation. Without the computer's rapid sorting ability, the plant manager at best could have only a "feel" for equipment reliability. If a continually malfunctioning part is the problem, it is doubtful that he will ever realize where the operational problem lies without this portion of the computerized MIS.

The first step to keying in on equipment problem areas is to set up decision rules and then program management by exception routines. The systems analyst, together with the manager, can decide tolerable repair downtime limits for equipment. When this level is reached, the computer automatically prints out an exception report. A typical report would include date, unit operation, equipment description, hours lost, parts replaced and labor and parts costs, e.g.:

10-7-72 filtration operation

PC-21, filtration supernatant pump, second floor filter building

Total downtime from 10-8-71 to 10-7-72 - 2.5%

Total labor cost during period - $1,708.25

Total supply cost during period - $97.50

<u>Repair history</u>

Date	Parts Replaced	Downtime
10/25/71	112	2.5 hrs.
11/17/71	112-175	3.2 hrs.
1/5/72	118	1.0 hrs.

As these reports are operated, the manager becomes aware of important problem areas. In the example, a particular pump is causing considerable downtime and repair expense. The repair history may show that a certain part causes most of the repairs, e.g., part no. 112. The manager can access the computer and find out that this part is a low cost bearing. By contacting the bearing supplier, he may be able to substitute a higher quality bearing and so solve the original problem.

Not all solutions are this easy, but the computer can readily draw attention to problem areas before they become serious. This management by exception tool allows the manager to concentrate on problems while letting the rest of the plant run by itself.

2. Frequency of parts replacement

Once again, preprogrammed management by exception routines can help the manager. As in the excess downtime example, constant replacement of certain parts can be emphasized. Once aware of the malfunctioning part, remedies can be instituted.

3. Cost of repairs

This also is an area ideally suited for management by exception programming. Perhaps critical downtime and frequent parts replacement are not so much of a problem as total labor and supplies costs. An example is a poorly built gear drive or one that was designed for a different service than it performs. In both instances, continuous, costly repairs that neither require excessive process downtime nor the same parts could result. This type of routine pinpoints the problem.

4. Cost of operation

As equipment wears out, the cost of operation will often come not only from repairs, but also from utilities and chemicals. This can be noticed especially in the case of vacuum filtration of sludges. As the filter cloth wears and becomes more porous, larger quantities of chemicals must be used to effectively remove the solids. In this instance, the chemicals are used as a body aid rather than a coagulant. An example of increased operational costs from a utilities standpoint is frequently noted in pump operation. As the pump wears or otherwise gets out of adjustment, it has to run an ever increasing number of hours to pump the same volume of material. There are many pumps in a typical operation. Without the use of a computer, effective evaluation of this type of data is nearly impossible.

All four of the above items lend themselves readily to management by exception programming. With this approach, no reports are generated unless the operation becomes noticeably different from a present guideline, or the management desires to evaluate the operation. It is anticipated that management would periodically want to look at equipment operation if for no other reason than to reconsider the automatic set points for the management by exception routines. Budget preparation, of course, would dictate equipment review. This type of budgeting and others will be considered after personnel evaluation is discussed.

Another important point is that all of the necessary data for the above evaluations comes from items filled in on the work order system. With the exception of the cost of operation (which comes from operator data logging), this information is routinely fed into the computer anyway. The computer, instead of the manager, then does the sorting, evaluating, and filing.

This routine data is also used in the areas of personnel evaluation as explained in the next section.

Personnel Reporting Section

The repair data can also be used for personnel evaluation. With the many day-to-day operation problems, the superintendent has had little time for employee evaluation. Usually he has had to rely on "gut feeling" or hearsay in these evaluations. With the computer-assisted production information system, a work history can automatically be compiled. Pertinent facts can be obtained for both a class of workers, e.g., mechanics, and individuals. Items of concern include.

1. Hours worked on specific jobs
2. Equipment worked on
3. Parts replaced
4. Time distribution, e.g., normal and overtime
5. Dollar value of parts replaced
6. Dollar value of labor used

Details of these informational items are explained below.

1. Hours worked on specific jobs

   Though all time is accountable for payroll purposes, not all of a worker's time is spent doing accountable repairs. By keeping track of "repair hours" a history can be built up for personnel and budgeting evaluations. Ratio analysis lends itself very well to this area. A particular man's hour distribution can be compared to that characteristic of his general group, i.e., the ratio of the work hours of mechanic "A" to the average for all mechanics.

2. Equipment worked on

This information would be used to pinpoint weak workers. For example, a computer history of jobs done by a mechanic and another listing of the maintenance histories of the equipment he worked on could show that a man is poor at repairing pumps. This is noted by the fact that he often re-repairs pumps and/or the pumps are worked on again shortly after his repair. This type of personnel evaluation would normally be done once a year at review time. There would be no automatic management by exception routine to pinpoint poor workmanship.

3. Parts replaced

This type of report can be used in two ways. The first use would be to compare the dollar volume of parts replaced per man to the average value for his trade. This type of ratio analysis is similar to that used in hour distribution evaluations. The second method is the one used in the equipment evaluation just described. If a man is continually replacing the same parts, he is either a specialist or he is improperly installing the part. The evaluation routine is also meant to be used in periodic evaluations. Because of the commonness of data, personnel problems may very well come to light automatically under the equipment evaluation section or under the budget section that is discussed later in this paper.

4. Time distribution

Every operation has some overtime. This overtime is usually divided rather evenly among the workers. However, a man's overtime to normal time distribution can still be used as a basis for evaluation because jobs often repeat themselves. This evaluation is accomplished by comparing a man's performance on a particular job when done on regular time to when the same job or type of job is done on overtime. This is a long term (1-2 years) evaluation tool because a considerable work history must be built up before it can be used fairly.

5. Dollar value of parts replaced

This type of report also lends itself to a ratio analysis. Once an adequate work history has been established, an individual's work performance in dollar value of equipment installed can be compared to the average for his trade.

6. Dollar value of labor used

This evaluation method is actually the dollar value of the hours worked on repairs. If management prefers this type of report, the computer can quickly convert hours to dollars.

Personnel evaluation is attainable for operators as well. By having the operators input data each shift and by keeping track of the shift staffing history, this previously unattainable information becomes a matter of course. Some potential evaluation parameters are:

Operation cost per man or per shift

Effluent quality per man or per shift

Data logged per man or per shift

Sick time per man

Number of late arrivals per man

Overtime per man

Operational problems per man or per shift

All of the above parameters are compared to acceptable standards or the average for all men. The operational problems evaluation is another use of the problem reporting routine that was previously discussed. The commonness of data makes possible both improved operation and rapid, equitable personnel evaluation.

Of course, the people, equipment and process performances are all a function of budgetary limitations. The Budget Reporting Section, explained next, essentially completes the basic production information system.

Budget Reporting Section

The budgetary area has also been a big problem for the plant superintendent. As each fiscal year end approaches, the manager burns the midnight oil trying to find out what his costs have been for running the operation. Some areas are easier than others. Receipts can be totalled for: utilities, process chemicals, laboratory supplies, etc. Difficulties arise when these figures have to be projected as a function of plant flow rate (MGD) and population increases. At best a total can be made of the flow rate by season and a guess factor applied for expected increases.

More problems arise in the maintenance area. Because of insufficient repair records and inadequate retrieval, the superintendent must usually add up his labor charges and guess at the dollar volume of repair parts. With the application of another factor to both this and the operating labor total, the new "budget" is complete.

A computerized production information system easily solves these problems. The computer automatically tallies, stores and retrieves pertinent cost data. In addition a graphing routine and regression analyses can establish any trends to aid in forecasting future demands. Extraordinary occurrences can be keyed on and justifications for remedies more easily budgeted in the coming year.

Overtime and repair costs are two areas where this justification scheme is acute. If a piece(s) of equipment is adding up repair bills that amount to a significant, e.g., 10%, portion of its repair costs or is causing excessive downtime, a management by exception routine will bring this to the attention of the manager. It is then his decision whether or not to budget for replacement.

The management by exception technique is also applied to manpower budgeting. Both the total of overtime costs and its percentage of another regular time salary provide good justification for increased staffing. Application of historical manpower relationships to: flow rate, equipment dollar value, pounds of sludge dewatered, laboratory data points run, etc., can anticipate additional manpower requirements for any projected increases in these values.

All of these data and projections are readily available from the computer in minutes. A production information system with this flexibility can go a long way toward reducing the midnight oil burning for a plant superintendent. For the first time, midyear corrections and adjustments are just as easily made and the manager can be ready at a moment's notice to discuss his budget with his governing body.

This new budgetary system is also invaluable in labor negotiations. The effect of proposed wage increases can be quickly determined. For the first time, fringe benefits can be truly evaluated by investigating the operation's historical fringe expenses. The net present value of any increases and other contract changes are also immediately available.

The manager also needs budget expenditure reports, and a cost per MGD analysis. By expanding these reports to cover costs by each unit operation the manager will have much better control and evaluation of the total process. Again, management by exception can be an important tool, e.g., dewatering chemical costs per pound of solids removed, fuel costs per pound of solids burned, power costs per million gallons pumped.

The Budget Reporting Section completes the basic information system. This basic system can, of course, be improved. One area of major importance to good plant operations is operator training. A brief introduction to this area is given in the next section.

Operator Training Section

Expansion of the production information system into manpower training can help make the manager's job easier. Most plants train operators at the site. Usually the new man reads lengthy operations manuals and gets some on-the-job training from other operators. At best the man has attended a government training program. There is little, if any, continuing training.

A computer training program can improve this situation in the two major areas of initial training and retraining. In the initial training phase the computer can be programmed to give detailed instructions on unit operations each time a new man takes over that operation. Training is accomplished by requiring the man to periodically log in data, and then evaluate this data against acceptable criteria, e.g., incinerator hearth temperature and feed rate. Instruction detail is reduced as the operator becomes more proficient. In retraining, on the spot questions and operation situation problems are given. By getting operators to play "games" with the computer, operator reliability and awareness can be increased.

The Operator Training Section complements the other areas of the information system. General comments on the operation of the total system and an analysis of future work needing to be done in this area are the subject of the final section.

Analysis and Conclusions

All of the above computer operations for this production information system must have one special condition: The computer program accessing must be extremely simple and the reports entirely understandable to people of high school education or less. This is often the level of education for wastewater treatment plant personnel. The problem is not a difficult one to solve, however. Simple typed instructions can get the operator on line. With the correct code, a numbered list of possible reports is printed. Typing the number desired will automatically cause the computer to have the report printed out. Additional reports can then be requested and printed if within the particular person's "need to know" area. "Executive" control by employee numbers segregates the information available to employees. Updating the data banks is made just as easy. The computer "asks" what files (routines) are to be updated and then "asks" for specific changeable items in that routine. The computer also automatically checks the inputted data and prints out error messages and additional instructions as necessary.

Cost is an important consideration for this or any other computer system. Wastewater plants are run by municipalities spread throughout the nation. Unlike a large corporation, these separate entities cannot afford to purchase the computer facilities necessary for this MIS. Fortunately, time shared facilities offer a solution to this problem. By using remote phone connected terminals, the plant can inexpensively use (share) large computer facilities. In addition, the time shared facilities offer 24 hour on-line operation not available through the normal municipal batch billing and payroll computer. Another advantage of the time share approach is that a number of plants can utilize a common data base. This reduces computer costs, but more importantly can greatly reduce inventory costs. By tying all plants together, storehouses and ordering can be consolidated, and maintenance efforts coordinated.

The sophistication of this MIS can be increased by adding automatic data input and evaluation and control routines. These additions are what is necessary to achieve automatic operation of a wastewater plant. The discussion of this type of system is out of the scope of this paper, but could be the subject of a future paper. The major road-block for this advanced system is an equipment technology gap. At present, adequate process instrumentation is not available.

In general, the production information system that has been presented in this paper satisfies the needs of wastewater treatment plants. All of the main areas of concern--people, equipment, budget and quality control--have been dealt with. With time shared computer facilities, adequate, low cost information can be made available to management in these areas. An added benefit is the ability to split out sections of the total system to solve the most pressing needs of plants that cannot afford the total system.

This paper has demonstrated that information systems' capabilities are available now for water pollution control plants. Though the system as presented may never be instituted in its entirety, some sort of MIS will be necessary if adequate pollution control is to be achieved in the area of wastewater treatment. That the technology is available for implementation is an important step in solving the management problems involved.

BIBLIOGRAPHY

Pierce, John F. Operations research and the design of management information systems. New York: Technical Association of the Pulp and Paper Industry, 1967.

Rappaport, Alfred. Information for decision making; quantitative and behavioral dimensions. Englewood Cliffs, New Jersey: Prentice-Hall, 1970.

Blumenthal, Sherman C. Management information systems; a framework for planning and development. Englewood Cliffs, New Jersey: Prentice-Hall, 1969.

Gallagher, James D. Management information systems and the computer. New York: American Management Association, 1961.

Enger, Norman L. Putting MIS to work; managing the management information system. New York: American Management Association, 1969.

Prince, Thomas R. Information systems for management planning and control. Homewood, Ill.: R. D. Irwin, 1970.

Cohen, Burton J. Cost-effective information systems. New York: American Management Association, 1971.