

**PROCEEDINGS:
FIFTH WORKSHOP ON
HOME-SEWAGE DISPOSAL IN COLORADO
OPERATION AND MAINTENANCE
OF
ON-SITE WASTEWATER TREATMENT SYSTEMS**

**Edited by
Robert C. Ward**

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PROCEEDINGS
FIFTH WORKSHOP ON HOME SEWAGE DISPOSAL
IN COLORADO

Emphasizing

OPERATION AND MAINTENANCE
OF
ON-SITE WASTEWATER TREATMENT SYSTEMS

Edited by

Robert C. Ward
Department of Agricultural and Chemical Engineering
Colorado State University

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Norman A. Evans, Director

INTRODUCTION TO PROCEEDINGS

These proceedings record the presentations made during a one-day Workshop on Home Sewage Disposal on February 24, 1983. The workshop was supported by the National Science Foundation (through a research grant on operation and maintenance of small wastewater treatment systems), the Water Resources Research Institute and the Cooperative Extension Service (both at Colorado State University), and the Colorado Department of Health.

The workshop emphasized the operation and maintenance of on-site wastewater treatment systems. The workshop consisted of three sessions. The first session consisted of four papers that discussed the need for stronger operation and maintenance for wastewater treatment facilities and presented several ways this need could be addressed. The second session also consisted of four papers which, in total, described the results of an operation and maintenance (O&M) study of small wastewater treatment systems funded by the National Science Foundation over the past two years.

The third session involved the workshop participants and seven Apple computers. The computer disks necessary to evaluate O&M requirements were provided to each attendee, who then had the opportunity of performing an O&M evaluation of their own or use data supplied by the workshop instructors. The proceedings contains no information on this hands-on session. It should be pointed out, however, that the participants found the computer-aided O&M evaluation very user-friendly. The computer O&M evaluation is described in the last four papers in the proceedings. People interested in obtaining copies of the computer disks should forward \$12 to the Agricultural and Chemical Engineering Department, Colorado State University, Fort Collins, Colorado, 80523 (Attention: Robert Ward). These disks contain all the O&M data and the programs for the evaluation. The paper by Nettles is the user manual for the program.

TABLE OF CONTENTS

	<u>Page</u>
Introduction to Proceedings	i
Welcome Evan Vlachos	1
Opening Remarks Robert C. Ward	3
The Role of Operation and Maintenance in the Success of a Wastewater Treatment Facility	7
Thomas G. Sanders	
Boulder County's Development of an Operation and Maintenance Program for Onsite Systems	16
Mike Whitmore	
Contracting the Operation and Maintenance of Small Wastewater Treatment Systems	27
David Shupe	
Expanding On-Site Management Responsibilities	34
Steve Dix	
Procedures Used to Determine Operation and Maintenance Requirements	41
Robert C. Ward	
O&M Requirements for Small Flow Technology	48
James D. Englehardt	
Computer Storage and Retrieval of O&M Requirements111
Stewart Noyce	
User Documentation of Computer Program for On-Site Wastewater Treatment Operation and Maintenance Requirements116
Appendix A. Computer-Generated Report for Boulder County, Colorado124
Appendix B. Listing of Main Program129
Appendix C. List of Workshop Participants145

WELCOME
by
Dr. Evan Vlachos
Director, Environmental Resources Center
Colorado State University

Beyond the standard obligatory welcome of the University, I would like to express my personal interest for the topic you will discuss. In this few minutes of greeting I would like to share with you two major underlying themes that I detect in your meeting. These are preoccupations not only with home sewage disposal and on-site wastewater treatment, but also major questions of infrastructure that are being seriously discussed nationally and internationally.

The first has to do with the question of what is called "the consequences of metabolism." Under this polite term is the fact that the nation and its systems, its infrastructure in a sense, is aging. Clogging arteries of highways, of sewers, of water, are the natural consequences of growth, demanding that something must be done to "maintain the infrastructure." Infrastructure maintenance has now become the banner word, the fighting of aging systems - like an individual whose battle is to avoid the increasing girth and the natural problems of decay.

The second question that I believe underlines your discussions is that of "appropriate technology." As we have been changing over the years, the major realization of the past decade is not only the obvious preoccupation with environmental despoliation, noxious waste, aspects of water quality and quantity, but also the larger issue as to the scale of intervention in the surrounding environment. There has been a significant shift from centralized macro-engineering structures to more on-site, smaller-scale projects.

Thus, the two terms, "infrastructure maintenance" and "appropriate technology," are becoming part of a different approach to societal problems

encompassing a different scale, different resource mobilization, different organizational requirements, etc. In essence, they are becoming part of the coming post-industrial society, whose major characteristics are decentralization, information, and cybernetics. In other words, the wide utilization of the computer, the exchange of information through electronic means, remote sensing, etc., allows us to do something that we could not easily do in the past, i.e., deconcentration, local autonomy, and appropriate scale. I may be expanding more than you perhaps intend to, but I wanted to read in your meeting the preoccupation with how in the '80s and '90s and throughout the coming years American society, the West, Colorado, or any particular locality can manage the major dilemma of maintaining growth and at the same time stability, all in trying to accommodate a dynamic and expanding system of resource utilization with sensitivity to local conditions and traditions. I truly believe that the challenge of scale, of mobilization of resources, and of stability and change should be addressed in your meeting as important ingredients of the necessary task of infrastructure maintenance with appropriate technology.

OPENING REMARKS

by

Robert C. Ward

Agricultural and Chemical Engineering Department
Colorado State University

Colorado State University (CSU) has conducted a teaching, research and extension effort in the area of on-site or small flow wastewater treatment technology for the past 12 years. During this time four research projects have been performed; four workshops, prior to this one, have been held; many seminars have been held around the state; many students have been trained in this area; and a number of publications have been prepared on the subject.

This work has involved the support and cooperation of a number of organizations, both within CSU and outside. The Water Quality Control Division of the Colorado Department of Health, the National Science Foundation, the Cooperative Extension Service, and the Colorado Agricultural Experiment Station have been actively involved in this work and their support has made it all possible.

The workshop today is an outgrowth of an Experiment Station and National Science Foundation-supported research effort to define detailed operation and maintenance requirements of on-site or small flow wastewater treatment technology. The Experiment Station project is entitled "Environmental Management in Rural Colorado Communities," and the National Science Foundation project is entitled "Management of Decentralized, On-Site Systems for Treatment of Domestic Water." Both these projects end this spring, and now is an excellent time to summarize their results.

Before, however, presenting results of our detailed research, it is necessary to examine the role of operation and maintenance of wastewater treatment technology in a broader context. To assist us in this task, we have invited a number of speakers to describe their efforts in this area.

Session 1 is organized around trying to provide information on the need and also on some of the trends that are developing in the area of operation and maintenance today. The first speaker is Dr. Tom Sanders, Professor of Civil Engineering at CSU, and Program Leader of the Environmental Engineering Program. He will be keynoting the idea of operation and maintenance and its role in wastewater treatment in general. There has been a lot of emphasis in the past few years to begin to look at the O&M situation in wastewater treatment, and he will address some of the trends and concerns.

As the importance of operation and maintenance is being recognized, a number of efforts are being undertaken to improve the operation and maintenance of small systems. These efforts have very little precedence. There's not too much background in this area and the people involved, in providing a central form of operation and maintenance for small systems, are exploring new territory. There is very little support for such coordinated O&M and, consequently, there's a lot of resistance to it on the part of many people who don't understand exactly what's going on. These coordinated O&M efforts are being made in government and in private enterprise. To report on the government efforts, Mike Whitmore will describe programs underway in Boulder County to deal with operation and maintenance problems of small systems. David Shoup, representing private consulting, will describe programs his company is currently operating to provide operation and maintenance services for small systems. The type of efforts these two gentlemen will be describing are what I would refer to as "the state of management" or the "state-of-the-art of management," because such management is an evolving concept and there are pioneering efforts across the country very similar to what each of these gentlemen will be describing. Once these gentlemen complete their descriptions of what they are doing in terms of government

and private enterprise, Steve Dix will provide a national perspective of what is happening with such management efforts. Steve is the technical director of the National Small Flows Clearinghouse at West Virginia University, Morgantown.

Following our break, several of us from CSU who have been conducting the National Science Foundation project will describe the project's procedures and results. I will provide a little background on the project itself and some of the procedures used. Jim Englehardt, who has recently completed his Master's degree, will present the operation and maintenance details. Stewart Noyce will describe the computer program developed to store and retrieve the operation and maintenance data. David Nettles, a graduate student in the Agricultural and Chemical Engineering Department, will describe user documentation for the program. The program has been written to be very user-friendly.

I'd like to point out that while the operation and maintenance data were collected more with the idea of a community-wide type of evaluation (a central management of individual systems, if you will), the specific requirements that are given as part of our results are relevant to individual situations. The computer program is not needed if you simply want to take the procedures that we have analyzed and use them in an individual situation. The problem comes when you have a community of 50 systems, and you have ten of one type, five of another type, etc. How, collectively, do all the O&M requirements sum together? This is where the computer program greatly facilitates the evaluation. If you didn't have the evaluation computerized, it would be a matter of flipping pages back and forth for a considerable amount of time trying to do the summations and make sure that all the assumptions you are using are uniformly applied. The computer program has taken

care of these problems for you.

With this brief background, let's proceed.

THE ROLE OF OPERATION AND MAINTENANCE IN THE
SUCCESS OF A WASTEWATER TREATMENT FACILITY

by

Thomas G. Sanders
Civil Engineering Department
Colorado State University

I want to thank you for being here. Robert took a real chance. I've known Robert for about nine years now, and we disagree immensely on the role of small-scale on-site treatment systems vs. large-scale central treatment systems. It has always been a problem. Robert and I are amicable on everything else but this; however, I do see the need and I want to discuss some of my ideas from the conventional, outdated, old-line sanitary engineering mentality. There is some creditability in that, and we cannot forget it.

What if we converted this town to all septic tanks and operation and maintenance were performed by the city? That means visiting 15,000 to 20,000 septic tanks, and if you just go once a year, what a tremendous job that is. That's the kind of thing that can be extrapolated up if we're not careful. But, I see, there is a definite need for small-scale on-site systems in rural areas. The topic of my talk is the Role of Operation and Maintenance in a Successful Wastewater Treatment Facility - large-scale, small-scale, we can think about each one in the same context. The major problem we have in large-scale, multimillion dollar treatment facilities is not so much the design, and not so much the money available to run it, but it is the operation and maintenance problems. We have systems that cost \$20 to \$60 million dollars that aren't run properly throughout the United States. A good percentage of our large-scale, big treatment processes are not meeting stream standards. They can meet standards, generally speaking, if they are properly operated and maintained.

Now, at large systems you have technical people with an O&M background.

They enjoy it, they're getting paid to run the plant, and yet it's still not properly operated and maintained. And I confront you with this. How can we expect a small-scale individual system operated by a housewife with three screaming kids and a backed-up washing machine to properly manage her system? It can't be done.

Very few of us have gotten inside our washing machines and oiled them - or gotten in the attic fan and oiled it. It has to be oiled - if it isn't, it will break down. And we wait until this happens and replace it. That's the kind of thinking that we have to change, and maybe it's a sociological problem vs. a technical problem.

The problem with operation and maintenance lies in two areas. First, in addressing the need for wastewater treatment, we begin with planning. We are very good at planning, and we teach this at the university. We're getting more and more planning; centralized planning which has been mandated by Congress for many years (only recently are we reversing the trend).

Next we will consider the design of treatment plants. This is what we have been taught. This is what I get paid for: teaching design - large-scale or small-scale. In Civil Engineering's Environmental Engineering Program this is what we teach. We teach planning; we teach design. We have gotten away from construction. This is a fatal error. Construction is no longer associated with civil engineering. We stepped back away from it, since we don't want to teach applied construction. We want to teach planning and theoretical design concepts. We have almost lost control of construction in civil engineering.

What about operation and maintenance? We have never addressed that in the universities. In fact, my biggest problem coming in here today was trying to discuss something about operation and maintenance because I don't teach it. I don't know much about it. I've visited many sites, and my

experience has come from talking with plant operators and seeing what their problems are on the large-scale. Small-scale, I just have to speak to my office mate, or speak to my cousins, etc. who have septic tanks and cesspools and all the conventional on-site disposal practices which have proliferated since 1912. So, there's the first reason we have trouble with O&M; we don't even address it in the universities.

As soon as engineers get paid for the design of a sewage treatment plant (we plan it, we design it, and we might even help build it), we leave. It is only recently that the consulting firms and the designers are staying and providing input to get the sewage treatment plant operational. Many are not being retained on a long-term basis to keep it operational. It is very complicated and very difficult to run a sewage treatment plant correctly, and I perceive that it's not the problem that we don't know; it's just that we haven't put any emphasis on operation and maintenance. The whole structure of payment for a wastewater treatment plant (from an engineer's point of view) was associated with capital construction. Why throw away a system because it hasn't been operated properly? This is the conventional way we have looked at it in the past.

Many times the apparent lack of proper operation and maintenance of large-scale sewage treatment plants (and you'll see it even more so with small-scale sewage treatment plants because there will be a lot of interests that want to see them fail) is in fact bad design. There is a lot of bad design around today. Now, in the past when we've had problems with operating large-scale wastewater treatment plants, whether it's bad design or operation and maintenance or a combination of both, all we had to do was raise our hand and ask for federal bucks and they would come streaming down. The age of federal largesse is over. No longer can we address the sewage treatment problems in this town or other towns by saying, "Hey, let's build a

bigger and better plant." That kind of mentality is over. What we're going to have to do on the large-scale and the small-scale is start planning for proper operation and maintenance.

The Fort Collins Sewage Treatment Plant is one of the best I've ever seen in the country because it is properly operated and maintained most of the time. Most of those I have visited throughout the country are not. In fact, we are lucky if the guy who is running the sewage treatment plant in most cities in the United States wasn't working on the highway department at one time and, by moving up, becomes supervisor of a wastewater treatment plant. That happens more times than not. You cannot blame someone who doesn't have the background and understanding of the system if it is not properly operated and maintained. It's very difficult. We have to put more expertise in this area.

There's the problem as I see it. We don't teach operation and maintenance (O&M) in school. We don't emphasize it, as the federal largesse used to bail us out when the O&M failed. Let's build a sewage treatment plant - that was federal policy. No longer will it be.

For proper operation of the system, then, what must we do? Well, let's just take a look at a septic system and any other small systems that are available. What do we know about a septic system in order to operate it properly? Extrapolate this with your experiences, and I'm sure that most of you can list many reasons why septic systems fail. For one thing, wastes have to be decomposable. We can handle some nondecomposables - eggshells, fiber, and toilet paper. Septic tanks, historically, were not designed to handle garbage-grinder wastes. How do you tell a housewife she can't have a garbage grinder because her house is on a septic tank?

What about toxic chemicals? You know, this country is, if it isn't anything else, prone to solve every problem we've got with more chemicals.

In fact, our biggest problem is too many chemicals in the environment. For a biologically active system to work and decompose biological decomposables, we've got to keep the toxic chemicals out of the system.

We're the country that oils the squeaky wheel, which demonstrates that we have no idea about operation and maintenance - because when its squeaking, it's too late. When you have a "squeaky wheel" with a septic tank, what is it? It backs up. By then it's damaged or pretty well destroyed. You can clean it out and maybe it will continue to work. So the whole "squeaky wheel" mentality has got to be eliminated. You've got to have regular, routine maintenance and operation of wastewater treatment systems.

What about hydraulic overloading? This is a nice one. No problem, right? But now everybody has a dishwasher. You have a couple of teenaged girls. They take two showers a day - if you don't stop them. So you have more kids. And every time you have a kid, do you add more leach field? Do you add another septic tank? No. What about putting in hot tubs? Is the septic tank improved and updated with each new flow? No. If you put 10,000 septic tanks in a town and keep expanding water use, the treatment system must expand also. With septic tank systems we are fixed with that size. With a central system we can add another sedimentation tank and activate it. With small-scale systems you can't, or normally don't. That's a problem, and it's going to have to be addressed.

The profession, in general, ignores the problem with sludge. Sometimes 65 percent of the total annual operating cost of a plant is the collection and disposal of sludges. It's almost always ignored. You know your unit processes and designs. The kinetics is what we're interested in. Getting rid of the sludge is not a very interesting topic, so it's ignored. The same thing with small systems. What do you do with all the septage if you

do have an annual pickup of sludges?

Maintenance of a septic system - you have to periodically measure the sludge depth and remove the sludge. How many homeowners go out in the backyard with a spade, dig up to the manhole, lift the manhole, get a stick and measure the depth? In general, they won't. What we need, and I'm not pushing any kind of electronic system, is a way to easily find the depth of that sludge without having to dig it up. That might improve the situation a bit, but it won't solve the problem, because we still have the "squeaky wheel" mentality.

The major argument against on-site systems is the idea that we're sliding back to the pre-nineteenth century. You get blamed for being an old-time conservative, and you can't change your ideas. This isn't a change of ideas! Small-scale, on-site systems were what we had for a long time, and during this time we had large-scale off-site cholera and typhoid problems. We're again going to have large-scale, off-site problems - not with cholera and typhoid, because there are shots for these now. But, Giardia lamblia is a thing that is raising its ugly head along the Front Range. How are you going to deal with Giardia lamblia when your septic tank backs up and starts ponding in the yard? That's why this conference is so absolutely important. If you want to utilize these systems, they cannot fail. If they do fail, you've got to have some remedies immediately.

When a large-scale sewage treatment plant fails, the town that has the failure doesn't suffer. It's the town downstream that might suffer, and that's why we've gotten away with it for so long. We don't worry about overloading problems at Fort Collins, or if the plant doesn't treat one day or so. It doesn't affect us. We don't have to wallow in it. We don't have to drink it. We have our water system inflow upstream from the wastewater discharge. But the key item, if you don't remember anything else about

this symposium, is that if we want to prevent diseases and keep our health as well as it's been and prevent communicable diseases and wide-scale gastroenteritis or Giardia or anything else, we must physically keep man away from his wastes - physically prevent him absolutely from coming in contact with his wastes. If you do that you don't have health problems, and that's why on-site systems are dangerous. You've increased the probability of more and more people coming in physical contact with their wastes. It just happens, and I don't know if the City can afford 200 people a year coming in direct contact with their wastes because of faulty systems. If you have 10,000 septic tanks in a county, how many of them are not going to be working? Five percent? Such a reliability is higher than anything we have now in engineering. This is the problem. It has to be addressed. And the only way I see addressing it is sound operation and management protocol and procedures.

How will better O&M be obtained? Recall the homeowner who knows absolutely nothing about sewage treatment plants nor cares. He was probably raised where everything goes down the toilet. He never worried nor thought about the wastewater treatment system. Now he has a system that has to use biodegradable toilet paper. He cannot install a garbage disposal. He has to watch and make sure nothing gets down the toilet that doesn't belong there. Drano cannot be used. They have to change culturally, and that's going to be tough. So, proper operation will come from better education and reading the O&M manual. Of course, nobody ever reads their manuals for the microwave, the washing machine, the garbage disposal, or anything else, but it's going to have to be done. The way to beat this situation is to charge them \$300 to fix it. Very quickly, if they get charged money for something that's being upset, they'll start figuring out how to solve the problem. Proper operation is just better knowledge of the system.

You don't want everybody to have an undergraduate degree in sanitary engineering or environmental science to understand it.

The second problem is the development of a maintenance program. I have been vehemently opposed to the small-scale, on-site systems because the major problem is the maintenance. You solve the maintenance problem, and I agree it will work. There's no problem with that - I think it will work. I know if I had one and I had to depend on it I could make it work, but I don't think there is incentive for other people to do so.

The maintenance part - you have to define who owns it; who has responsibility; who is liable for it? Then the procedure - what kind of inspection routine do you have? Who does it, and when? How frequently do you inspect the system? You know better than I that if you just do nothing for a septic tank and it's designed properly (you assume it's designed properly) you can ignore it for 2 months, 6 months, one year? I don't know - you can't depend on the "squeaky wheel." You're going to need a routine where it is such that they catch the problem before it arises.

The labor - the labor problem is immense. I saw a survey that was made in 1979 regarding inspections of water treatment plants. The national survey showed something like 55 percent of municipal water treatment plants were never visited by a federal, state, or county person inspecting the facility to see if it was operating properly. And now you tell me that you're going to have a system in a county where you have 10,000 septic tanks or 10,000 ET ponds or mounds and things like that and you're going to periodically check whether they are operating properly. I'm skeptical. I can be convinced; I can have my mind changed. Ten thousand - the only people who go regularly to houses are postmen, and that's even becoming irregular.

So, my conclusion is that in order for small-scale, on-site systems

to work on any kind of reasonable scale, and that's what we're talking about today, you have to have an effective operation program. Mainly, you control that by good design and knowledge of the system. And, you have to have penalties associated if the system fails and the city has to come in and straighten it out. The second aspect is a maintenance program. It's labor-intensive. It provides jobs, which is fine. We're replacing capital-intensive systems with labor-intensive systems, so the cost of the system is going to increase because the community will take care of all the labor. The capital-intensive, of course, is subsidized by the federal government. If you have a failure of a septic system or a cesspool system or whatever the on-site system is, it is not the same thing as the failure of a washing machine in a house. It has to be separated. When you have a failure of any kind of human waste disposal system, the entire community has a problem, not that individual person. So, I think this is very important, and I think eventually you have to move into a local - either city, county, or even state management program, and have control over the operation and maintenance of all home-site systems. Thank you.

BOULDER COUNTY'S DEVELOPMENT OF AN OPERATION
AND MAINTENANCE PROGRAM FOR ONSITE SYSTEMS

by

Mike Whitmore
Boulder County Health Department

Like many local health agencies, Boulder County Health Department is responsible for regulating the installation of individual sewage disposal systems and has a very active role in the approval, inspection and monitoring of larger on-site systems.

In addition to a strong interest in the protection of ground and surface waters, we have long been concerned with improving the functioning and longevity of on-site systems.

Several years ago, we began to look more closely at the various management functions related to on-site systems in order to evaluate our effectiveness and to identify potential areas for program improvement.

Our listed management functions resemble those identified in most current literature. To be most successful, any on-site system program should include at least the functions of:

- planning
- site evaluation
- design
- installation
- inspection and monitoring
- operation and maintenance

When reviewing our involvement in each of these activities we have noted the following:

A. Planning - We have been satisfied with our ability to provide input towards the development of Land Use documents for Boulder County, such as the Zoning Resolution, Subdivision Regulations, Comprehensive Plan, and

similar policies related to development of new commercial and residential property.

We are fortunate to have a very knowledgeable, supportive Board of Health and a good working relationship with the County's Land Use and Public Works Departments. This enables certain basic on-site system policies to become integrated with other development criteria.

B. Site Evaluation - The Department has a very adequate program for evaluating the use of proposed on-site systems for both subdivisions and individual properties. We encourage the use of central sewer service, community systems, and the clustering of systems whenever feasible in order to improve the likelihood of regular maintenance.

We work closely with private consultants in many aspects of site evaluation, as certain soils testing is performed by, and geologic data gathered by engineering and geological consulting firms.

County regulations governing ISDS's, those under 2,000 gallons/day, are written and updated as needed to reflect current on-site system technology.

C. Design - For many years there was a scarcity of good literature about the design of small wastewater systems. This situation has changed markedly in the last few years with the introduction of many design-related manuals that detail specifications as well as basic, conceptual information for a wide variety of on-site systems. This literature enables local health agencies to adopt minimum standards for conventional systems and serves to provide the engineering profession with demonstrated design specs.

We can require, then, sufficient detail on designs to be confident that the on-site system installation is not only technically feasible, but is not likely to pose a threat to public health or the environment.

D. Installation - It has been a high priority to allocate sufficient staff time to be able to conduct thorough final inspections of on-site system installations. This includes scheduling additional followup inspections to insure that any deficiencies in the installation are corrected.

In the case of engineered systems, we require the final inspections be conducted by a representative of the engineering firm as well as our department to verify compliance with all plans and specifications.

As with most local health departments, we are responsible for the licensing of system contractors. Three years ago we added a written installers' exam to the licensing requirements in order to better familiarize the installers with our County ISDS regulations.

E. Inspection and Monitoring - Regular inspection and monitoring activities were, by comparison, quite limited. In cooperation with the District Engineer at the State Health Department, we inspect systems involving discharge permits on at least an annual basis. Monitoring for these facilities is accomplished quarterly, using laboratory capabilities of the Boulder County Health Department. This monitoring serves primarily to verify the adequacy and accuracy of routine tests performed by the facility management, and is not intended to satisfy permit monitoring requirements.

A few dozen of the larger, on-site systems are examined as part of other inspectional programs related to summer camps, recreational facilities, and public water supplies. Smaller on-site systems, however, are generally inspected only on complaint, during occasional sanitary surveys, or as part of the loan inspection program - a service provided to lending institutions, buyers, and sellers of property served by on-site systems. In all, less than 800 of the estimated 15,000 on-site systems in Boulder County are inspected in a given year. This does not constitute an effective inspection and monitoring program for existing systems and is not, given

the current funding outlook, anticipated as one best suited to the County's management in the near future. We have reason to be more optimistic about establishing programs for new systems, however, as will be explained in the following section.

F. Operation and Maintenance - In order to improve system functioning and prolong useful system life, we encourage regular pumping of septic tanks and treatment units. Other than circumstances associated with the abatement of nuisances due to failing systems, however, we have no mandatory pumping requirements, and have never attempted a renewable permit program whereby such maintenance must be demonstrated in order to obtain a current permit. Education materials, including a septic system care and maintenance brochure prepared by our department, are given to new system owners and other interested persons.

As mentioned previously, we have encouraged the use of community and clustered systems when feasible. This policy was prompted by an identified lack of maintenance for most small on-site systems and resulted in the collective use of large absorption fields in several recent subdivisions. This particular development, an addition to Gaynor Lakes Subdivision south of Longmont, is composed of 11 lots, with all sewage effluent diverted to a dosing system feeding four absorption beds.

This arrangement has several advantages, including:

- more uniform installation;
- separation of the absorption system area from potentially damaging uses such as livestock grazing, vehicular traffic, and excessive irrigation;
- improved system monitoring and maintenance capability;
- the establishment of additional, available land area in the event of a needed addition or repair to the system; and

- the location of the absorption beds out of potential high groundwater areas.

Foothills Ranch Subdivision north of Boulder is another example of the community system concept. In this case, two large absorption/ET beds serve seven lots in an area characterized by low permeability soils.

In addition to some of the advantages described in the previous example, this arrangement allowed selection of the best available soils and provided the best solar and wind exposure for improved ET effects.

To improve the changes for regular inspection of these new community systems, we have required the formation of a management entity, usually a homeowner's association, with specific responsibilities for providing (or contracting to provide) regular inspection and maintenance services. These activities may include inspecting and pumping tanks, cleaning lines, maintenance of pumps and other mechanical or electrical equipment, monitoring effluent or groundwater levels, switching diverter valves, correcting erosion or other surface drainage problems, maintaining vegetation and other landscaping, and so on.

We prefer to group the functions of operation, inspection, monitoring, and maintenance into the category of operation and maintenance for the purposes of simplification and evaluation of program effectiveness. We feel that significant improvements have been made in terms of incorporating these items into the review and approval process for new development, both residential and commercial. As such, a significant improvement in the implementation of operation and maintenance practices for new systems is anticipated. We are left, however, with thousands of existing on-site systems installed over many decades that could benefit from improved operation and maintenance.

Individual systems installed in isolated locations are least amenable to solutions involving a centralized management entity, and are probably best handled through the goal of better owner education about system use and maintenance. Fortunately, other groups of systems lend themselves more readily to management concepts. It is these existing, higher-density developments that have been the focus of our attention in developing better operation and maintenance programs.

The Boulder County Health Department submitted a grant proposal to EPA in 1979 for a trial O&M program. The scope of work was later modified, and a joint grant proposal with the Denver Regional Council of Governments (DRCOG) was submitted and awarded in July of 1981 through the continuing 208 Water Quality Management Program. Under contract with DRCOG we selected Shannon Estates Subdivision as the principal subject of our work.

Shannon Estates lies five miles east of Boulder in relatively flat terrain, surrounded largely by both irrigated and dry-land farming operations. The subdivision was originally approved in 1963 and consists of 159 single-family lots. Despite recommendations by our department for construction of both central water and sewer facilities, the developers were able to provide a central water system only. Water is obtained from three deep-drilled wells, treated, and piped to all homes. Despite having a central water system (considering the use of on-site sewage disposal systems), the density is very high, averaging 1/3 acre lots sized approximately 95 feet by 150 feet.

Soils are quite variable, comprised of sandy loam, sandy clay, and sandy silt. Percolation rates vary from 8 minutes/inch to over 60 minutes/inch, although generally soils are quite permeable. Hard sandstone bedrock underlies the subdivision at depths of 10-13 feet and serves to trap shallow groundwater, creating a perched water table in the area.

Groundwater was originally measured as high as 7 feet below ground

surface, although the majority of the subdivision had no evidence of groundwater in 8 foot and 10 foot deep soil profile holes. These groundwater levels have changed dramatically in the 20 years since the first homes were built in the subdivision.

A sanitary survey conducted in 1977 indicated that groundwater levels were steadily rising in the area. To better define this problem in our recent study, we drilled ten monitoring wells to measure depth and quality of the shallow groundwater. These monitoring pipes were installed to depths of approximately 13 feet, and were located at the most representative points in the subdivision.

The groundwater levels in these wells were measured every two weeks from May to September, 1982. Additionally, six sets of nitrate tests and two sets of MPN coliform tests were performed during this period. Nitrate results varied from .3 MG/L to over 19 MG/L, total coliform from 110 to <2 to 7,000/100 ML. (See Table 1). Groundwater levels measured as high as 3 feet 1 inch at one location and were found at depths of 7 feet or higher at all 10 wells at least sometime during the monitoring period. Flow in a large irrigation ditch, bisecting the southern portion of the development, was also recorded during irrigation season.

Not only were instances of groundwater contamination apparent, but it was obvious that the rising groundwater levels were posing a threat to the continued functioning of on-site systems. Many homeowners have installed sump pumps to dewater basement areas.

The discharge from these sumps generally ends up in roadways and drainages, creating nuisances, road maintenance difficulties, and (in the winter months) safety hazards due to ice accumulation. The saturated conditions of certain road surfaces at the north end of the subdivision encourages the formation of potholes and regular road maintenance is difficult, if not impossible.

Replacement of absorption beds in the high groundwater areas must usually be accomplished by mounds, in order to meet required separation from water table levels.

A written sewage disposal survey was prepared and distributed by representatives from the Boulder County Health Department, DRCOG, and Shannon Estates Homeowners' Association. Seventy surveys were returned, and the results compiled by DRCOG personnel.

These survey results, septic system permit records, groundwater and irrigation water monitoring data, public works data, and available geological information were pooled to establish a basis for planning any corrective actions and proposing an operation and maintenance program. Some key points that we felt needed to be considered before proceeding with O&M development are summarized as follows:

- (1) Groundwater levels have risen markedly since the development of the subdivision. This is probably due to the impermeable sandstone bedrock trapping all water percolating into the soil. The principal sources of this water are likely:
 - landscape irrigation;
 - natural precipitation;
 - on-site sewage disposal system effluent; and
 - seepage from irrigation ditches.
- (2) A project to lower the water table by installation of subsoil drains, dewatering wells, or other means is essential prior to implementing any O&M program.
- (3) Connection with even the nearest municipal or community sewer system is not considered economically feasible.
- (4) Additional groundwater monitoring on a year-round schedule has been implemented to better define the sources of the high-water table.

- (5) Approximately 12 percent of the on-site sewage disposal systems have required repair over the last 20 years.
- (6) The subdivision is fully developed and no additional development is anticipated at this time.
- (7) One-third of the survey respondents regularly or occasionally pump shallow groundwater to eliminate basement flooding, improve septic system performance or irrigate landscaping.
- (8) High-calcium hardness in the community water system has prompted many homeowners to install water softeners. Our experience has shown that the backwashed brine solutions frequently cause deterioration of septic system components if discharged to the system.
- (9) Most of the septic tanks are the older, one-compartment variety. Consequently, regular tank pumping and maintenance of baffles is extremely important to prolong system life. Tanks are currently being pumped on an average every 2.2 years.
- (10) The average household has three residents and spends \$25 annually for septic system maintenance.
- (11) Two-thirds of the survey respondents indicated a willingness to support an on-site system management entity.
- (12) The existing Shannon Estates Homeowners' Association or the Water Sanitation District would be logical choices to implement an O&M program.

This past Fall, the necessary information was sent to James Englehardt at CSU to prepare an evaluation of operation and maintenance costs for Shannon Estates Subdivision. I will not go into detail concerning the development or contents of this evaluation, as there will be adequate coverage of this material later today by Robert Ward and James Englehardt.

The results of this computerized evaluation are being used to prepare the final O&M proposal for the subdivision.

It is our desire that implementation of the operation and maintenance program will coincide with the completion of corrections to the high ground-water and drainage problems. Coupled with this drainage work, we strongly believe this O&M program will significantly improve the functioning and longevity of on-site systems.

TABLE 1. DATE, TYPE OF TEST, AND RESULTS

SAMPLE OR MONITORING LOCATION	5/4/82 WTD NO ₃	5/19/82 WTD NO ₃	5/26/82 WTD NO ₃	6/2/82 WTD NO ₃	6/24/82 WTD	7/13/82 WTD NO ₃	7/27/82 WTD MPN	8/4/82 WTD MPN	8/17/82 WTD NO ₃	9/2/82 WTD
Monitor Pipe #1 (Drilled Depth 13')	9'7" 1.4	8'8" 1.3	8'7" 0.93	7'10" 1.0	6'3"	6'6" 0.54	Dry (1)	Dry (1)	Dry (1)	Dry (1)
Monitor Pipe #2 (Drilled Depth 13')	Dry ---	9'9" 18.8	9'2" 19.6	8'2" 19.5	7'8"	7'0" 19.60	8'0" 24,000 <2		8'11" 9.38	Dry (2)
Monitor Pipe #3 (Drilled Depth 13')	7'5" 2.4	7'2" 2.7	7'2" 2.95	6'8" 3.33	7'4"	6'8" 3.80		7'0" ≥240,000 7,000	7'1" 0.20	7'9"
Monitor Pipe #4 (Drilled Depth 11')	3'11" 7.7	3'5" 6.8	3'9" 4.50	3'9" 3.85	3'10"	3'9" 8.60	4'0" 11,000 700		3'10" 6.75	4'2"
Monitor Pipe #5 (Drilled Depth 13')	7'0" 7.1	7'1" 6.0	6'7" 6.50	6'6" 6.70	5'1"	4'2" 6.05	4'6" ≥240,000 130		4'11" 6.05	5'10"
Monitor Pipe #6 (Drilled Depth 9')	4'4" 1.7	3'1" 0.5	3'5" 0.53	3'8" 0.50	3'10"	3'11" 0.98		3'10" 350 2	4'0" 1.37	4'4"
Monitor Pipe #7 (Drilled Depth 10')	Dry ---	Dry ---	Dry ---	8'9" 9.40	8'4"	7'8" 5.20	8'3" 110 2	8'0" 920 2	7'8" 5.90	8'0"
Monitor Pipe #8 (Drilled Depth 11')	5'6" 7.2	5'0" 7.3	5'5" 3.80	5'6" 4.50	4'10"	5'0" 0.85		5'3" 22,000 <2	5'4" 7.57	5'8"
Monitor Pipe #9 (Drilled Depth 14')	7'4" 3.1	6'9" 4.4	8'0" 4.40	4'7" 2.8	6'6"	5'7" 0.65		6'7" ≥240,000 <2	6'10" 1.45	7'2"
Monitor Pipe #10 (Drilled Depth 15')	8'7" 6.0	7'7" NS	7'2" 6.53	6'4" 7.70	7'1"	6'6" 2.40	7'8" ≥240,000 79		7'8" 0.30	8'3"
South Boulder Canyon Ditch @ Kilkenney	Dry ---	Dry ---	(Flow 1'10" Deep) NS	(Flow 2'0" Deep) NS			(Flow 4" Deep) NS	Dry ---	Dry ---	Dry ---
Sump Discharge at Kilkenny & Kerry	6.1		6.3							

NS = No Sample
WTD = Water Table Depth
NO₃ = Nitrate Analysis in mg/l

MPN = (Most Probable Number) Bacteriological Test - Total Coliform
Fecal Coliform

(1) Hole Filled with Sediment - 7'0" Deep
(2) Hole Filled with Sediment - 9'3" Deep

CONTRACTING THE OPERATION AND MAINTENANCE
OF SMALL WASTEWATER TREATMENT SYSTEMS

by

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Someone wiser than I once said, "A proper definition of the problem is half the solution." Here in America one of our national characteristics is to carry every good idea to its most illogical extreme. Witness, video games, hula hoops, cigarettes, rock-n-roll, and other children's playthings. In the business of waste management we have defined the problem very well, as we are more than capable of doing. It sometimes seems to me, however, that we have decided that since defining the problem is half the solution, more definition of the problem is the rest of the solution. Consequently, we have tons and tons of information about how to go about finding solutions to problems, and relatively few solutions to problems.

On the basis of some past experience, we have convinced ourselves that individuals or small groups are incapable of caring for the operation and maintenance of their own on-site sewage treatment systems. Actually I don't think that is a valid conclusion. I feel that people are capable of maintaining their systems. They are often, however, either unknowledgeable or unwilling to do so, or sometimes a little bit of each. For instance, frequently we are asked to inspect a house before a new owner takes possession. As a matter of course, out in the County one of the first questions that we try to track down is the condition of the septic system. Usually when you ask the previous owner how long it has been since he pumped the septic tank, the response is "Septic tank? - What's that?" Not only do they not know what it is, they don't know where it is and, of course, obviously have no idea how long it has been since it was cleaned.

In general, small wastewater treatment systems are found in rural or somewhat isolated areas. Often the subdivisions in that situation are primarily populated by people who have recently moved there from a more urban environment, have no experience with the use of septic systems, and their primary goal in sewage treatment is merely that when they push down the little silver handle it goes away. Again I say, people are not unable to learn, but altogether too often the ways of getting the proper information to them are sparse or unavailable, and so they not only don't know how to handle their systems, they also don't know where to go to find out how. Consequently, sometimes by default more than anything else, firms such as ours find ourselves endeavoring to furnish to homeowners' associations, small districts, groups of individual homeowners and the like, operation and maintenance service for small treatment facilities.

Normally, when we design such treatment facilities, we develop in the design process an O&M Manual for the care and management of the facility. In the design of an individual septic system we endeavor to provide the eventual owner with a manual which indicates the type of care the system should have. We endeavor to talk with the owner as a part of the design process and encourage him to learn all he can about the way to care for his system and use it properly. Nevertheless, there is obviously no way you can be sure of reaching everybody, and this service needs to be provided to those who either can't or won't maintain the facilities for themselves. Our firm operates several small treatment facilities for subdivisions, homeowners' associations, and districts. These are sand filters, aerated stabilization ponds, septic systems, either individual or clustered in some cases, or small treatment plants. Each one takes its own maintenance program, each one is administered on an individual basis, tailored to the specific situation. One problem that has arisen in our experience, however,

is that when you are providing service on a contractual basis, you and your maintenance program are subject to the whims and attitudes of the population of the subdivision. From time to time conditions arise out of which they decide that either someone else can provide better management, someone else can provide cheaper management, they don't need any help, or they can do their own, or any one of a number of other things. Then service is discontinued either for a time or indefinitely. This leads to the obvious kinds of problems that much of our current literature addresses almost without exception, based on the economics of the situation and the desires of the people for something less expensive than whatever it is they have.

In order to more actively systematize this kind of situation, our firm has been working with the Larimer County Health Department and the County Commissioners for a number of years. We have endeavored to develop an Operation and Maintenance District which would be able to provide the O&M functions, but which would not necessarily own the facilities which it maintains. Being a district or quasi-municipal entity, it could then essentially insure or guarantee the continuity of proper maintenance and operation functions without the gaps referred to previously. Of course, this would have also the taxing potential of any quasi-municipal entity. The concern of the County Commissioners has to this point been being sure that the district would limit itself to the O&M functions rather than seeking to expand itself. We have found in the study of recent literature such as the EPA Manual 600/8-82-009, "Management of On-Site and Small Community Wastewater Systems," that the idea of such a district is one being used in other places. Our first proposal to the commissioners was back in about 1974 or 1975. At that time it probably was a fairly new and untried idea. Currently the posture in the County appears to be one of acceptance of the

idea providing that the mechanics of the situation can be worked out. We are working on that at the present time.

Probably the most difficult problem in the contracting for operation and maintenance of wastewater systems is the concept of establishing financial reserves for ultimate replacement and repair of mechanical equipment if such is part of the system. Most homeowners' associations tend to want to keep the cost to only current operations. We, of course, do our best to convince them that this is not the only cost involved. Nevertheless, it is the hardest one for most homeowners to deal with, because it takes present cash out-of-pocket to meet some presumed future needs, which in their eyes is ill-defined; that is, they can't see it. In most cases, however, continued efforts in patience and understanding with the homeowners' associations do usually result in proper establishment of reserve funding for such repair and maintenance.

One thing that I tend to feel rather strongly about, probably because of the bias of my own position, is that this kind of function is one that can best be supplied through the private sector. You may think of the Utility District as a government function, but in fact it is really a collection of people banding together, under a legal banner, so to speak, to provide certain functions for themselves, rather than demanding them from the government. In general, particularly in the area of small wastewater facilities, I feel it can be provided more economically and just as well, if not better, by this means, as opposed to a County-wide sanitation district in which the commissioners are required to be the board of the sanitation district. Philosophically, at least, this kind of approach is, I believe, more compatible with our form of government, a democratic government where people can do for themselves. Obviously there are exceptions to that, but the concept of wanting to do for yourself rather than

requiring some benign "godfather" organization to do it for you is in many ways a valid one, and one which in the long run leads toward a more informed citizenry, and one that is responsive to the needs of the system. Obviously, they are very close to it, its failure hurts them directly, immediately, and very obviously. This seems to me to argue well for treatment close to the source of the problem, which is basically what small wastewater technology is all about. In tailoring an O&M program to the individual treatment facility, obviously cost depends on the type of facility, the kind of maintenance it needs, and so on. A septic tank at each individual household, an individual leach field, a community leach field, a waste stabilization pond, a lift station, each of these takes different approaches, requires different degrees of maintenance, each has its own pattern of need. The maintenance routine must be geared to that specific need. Obviously, then the fees charged to the homeowners are based on the intensity of the supervision program. In most such cases we bill our services to the homeowners' association and require them to handle their own billing internally within the association. Obviously it is very difficult for us to write a contract with each individual in the subdivision, although this can be done. Where this becomes somewhat unmanageable is when you have someone or a few in the subdivision who do not see themselves in relationship to the total group and feel that they can carry their own responsibilities by themselves. This, in our view, is a selfish attitude because it says, "It doesn't matter to me whether my system fails because of my negligence, or that somebody else is going to get hurt." This is not a very sound basis for a community. So, by and large we deal with the homeowners' association rather than with individuals whenever possible, in essence forcing some semblance of community feeling.

In design, it is our policy as a company to keep the type of system at the simplest possible level which provides adequate treatment. If individual septic systems are the most effective means, we see nothing wrong with using them. If, on the other hand, a clustered septic system makes sense, then that is what we design. I myself live on such a system, have for some nine years, and it is functioning very well both economically and physically. The maintenance program on such a system as that is really quite low. It requires checking of the sludge and scum levels in the tanks once a year and monitoring of the field on a semi-annual basis, and that's about all. In contrast to that, one of the systems we operate includes a lift station which needs checking on at least a weekly basis. The alarm system is visible and audible to the people in the subdivision. All of them know of its presence and are keyed into calling us if anything goes wrong. In general, we are seldom called by them because we stay on top of it ourselves. That particular system also involves an aerated lagoon, and from time to time things can go wrong with the aerator; simple things, for instance, such as high winds breaking mooring cable or mooring line. The line wraps around the motor shaft and stops the motor. This has happened a time or two. That kind of thing requires some degree of upkeep and staying on top of the system. All of these kinds of things have to be taken into account when the wastewater treatment rate is established for the homeowners' association.

In general, I think the best thing to remember in such a program is that you get what you pay for. If you pay for a low level of maintenance and supervision, that's about all you are going to get, which can in the long run, and sometimes even in the short run, lead to problems. I do not necessarily advocate the "cadillac" kind of approach, which means over-supervision. I simply mean that the contract for operation and maintenance

should be tailored to the specific system and to the needs of the homeowners, with the best interest of the total community uppermost in mind. I don't know whether my remarks have answered very many questions or whether they have raised any, but if they have in fact raised any questions in your mind I would like to discuss them with you, either individually or in the group.

EXPANDING ON-SITE MANAGEMENT RESPONSIBILITIES

by

Steve Dix
Small Flows Clearinghouse
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The National Small Flow Clearinghouse at West Virginia University provides a center for data collection and dissemination for on-site wastewater technology. One very important aspect of this rapidly expanding technology is management of on-site facilities, more specifically their operation and maintenance. Besides collecting information on this aspect, I am fortunate to have the opportunity to develop alternative technologies for rural areas of Monongalia County. The following information covers aspects of a management program which I have recently experienced as technical director for the Clearinghouse, and by working for Monongalia County.

PUBLIC EDUCATION

If one is going to manage anything, especially a system currently operated by an individual, the individual needs to become aware of why this new type of government activity is necessary. The need to educate the public on the required maintenance for on-site systems is therefore paramount. They must fully recognize the need to maintain the system, the advantages of doing so, and the cost when individuals fail to take this responsibility.

Public meetings play an essential part of transferring information. These meetings provide an opportunity to raise questions which force the individuals to think about maintenance of their on-site systems. A good way to begin the discussion is to ask the audience, "How do you know when it's time to pump the septic tank?" Their response usually demonstrates reluctance to inspect the septic tank and the difficulty in making the

inspection. First of all, there may be the problem of finding the system, and second, how does one actually inspect the tank. The excuse, "If it's not broken, don't fix it," may be used to avoid the unpleasant task of finding and inspecting the system. Given that they don't understand the consequences of not inspecting the system and the unpleasant nature of doing so, it's easy to see why the inspections are planned for tomorrow, which is always too late.

To illustrate the need for septic tank maintenance, a comparison of a septic tank to the oil system in a car is useful. The economics are similar, as are the procedures. What the individual needs to recognize is that what he has in his backyard is an engine without a dip stick, idiot light, or other means of inspection, and he is driving this machine until it blows up. If he can assume the same attitude toward care for his septic tank as he assumes for his car, he will support a program that will maintain his system.

Septic systems have taken on a special significance to many individuals in a community. Legal obstacles are often used to hinder any type of management program. What these individuals must recognize is that onsite systems require support just like other utilities. Programs established with other utilities, e.g., gas or water meters where public property is housed on private property and regularly inspected, may serve as an existing approach that may be transferred to management of on-site systems. What is so special about septic tank inspection as opposed to reading a gas or water meter? With some simple modifications, access to the septic tank and leachfield may be brought to the surface providing access for quick and easy inspection. With these types of simple modifications, the management program can be sold to the public as not much more than reading the gas meter.

Maintaining a good on-site wastewater system in a community may also be couched in terms of an investment in your own property. Homes in areas without adequate wastewater facilities cannot be financed except by the owner. Without the support of financial institutions sale is difficult, much more cumbersome, and the individual must assume the risk of owner financing. Besides the problem of sale, there is the added limitation (usually placed by the Health Department) on the development of land adjacent to residences with failing systems. It's quite common for a moratorium to be placed on future developments in these areas if the systems are failing. Thus, the use of one's land both through its sale or its future development may revolve around the status of the individual's wastewater system as well as the performance of neighboring systems.

Again, with this understanding, the impact of system failure, the idea of paying for a wastewater system - whether it be an on-site management program which guarantees the operation of the on-site systems or a small community system - one is protecting his investment and ability to use the land for its best use.

Besides recognizing the cost to repair an onsite system, the individual needs to realize the impact of an entire community which fails to maintain its systems. Aside from the possible health hazard, there is the high cost of replacing all of the on-site systems in the entire community. The costs go beyond the price of the physical system, they include the cost of planning the new system and the cost associated with financing and developing an O&M program. If the extent of the failure of on-site systems is not well defined, which is usually the case, it may take years and many dollars to develop the new wastewater system.

Education plays a key role in establishing an onsite maintenance program. With a good educational program a good maintenance program can be established,

hopefully, before the systems begin to fail and the problems and costs multiply.

Only with an understanding of the need for regular maintenance and the economic implications of the failure to establish maintenance responsibilities can an individual appreciate an on-site wastewater management program. Unfortunately, individuals and communities only go through this experience once and, therefore, do not have the experience to avoid unnecessary and costly practices.

UP FRONT INDIVIDUAL FINANCIAL SUPPORT

Given this type of educational experience, one community in Monongalia County asked what they could do now while the planning proceeded. They had signed petitions, done surveys, etc., in an attempt to get something going, but they had failed to see any new systems or programs develop. There was little question that a new system for these individuals would be established. Given this fact, the recommendation was made to individually save funds to help pay for some of the front-end costs of the new system.

Borrowing money in today's economic climate is expensive. Reduction in front-end costs translates into greater debt which, in turn, is reflected in higher monthly rates. Thus, if a community can invest a greater amount of its capital into the system initially, they will see lower monthly rates. So, it makes sense to set up a savings account similar to a Christmas Club account or, more appropriately, a "flush fund account." Early in the planning process, individuals need to sign up for a special account in which funds are automatically deposited. This flush fund will help pay for tap-on fees or other modifications to their individual system when the new management program is established. Given the time between the beginning of the planning period and the startup of the new system or management program,

a considerable amount of money can be reserved, thus lessening the impact and resistance to higher front-end charges.

PLANNING THE APPROPRIATE MIX OF ALTERNATIVE SYSTEMS

The presence of an on-site management program multiplies the type of technologies that must be addressed in the planning process. There are no longer the choices between any one technology or another. The question that must be addressed is what mix of technologies costs less. It is not so much a matter of what technologies are used but, rather, where they are applied. Where does one stop with effluent sewers and begin with managed, engineered on-site systems? Defining the boundaries of each technology becomes a major task, potentially requiring many trials with various mixes of technologies. Just two or three different technologies being applied to a small community may require evaluation of five or six configurations.

An extensive evaluation of potential alternatives requires a computer program that can define the cost of a given configuration. Electronic data sheet software such as VISICALC have the potential for this type of application. With components and their specific costs established on an electronic spread sheet, it's just a matter of inserting the number of components that will be required to serve a defined area. In this manner, the extent of the effluent sewer and the areas served by cluster mounds or on-site systems may be quickly defined on a least-cost, present worth basis.

Because various technology mixes require a different maintenance program, the cost of operating these alternative systems can also be defined by using a computer program. The interactive computer program developed at Colorado State University is thus very timely. Without such a program it would not be possible to accurately define the cost of a management program, which is an integral part of the cost-effective analysis.

PERMITS

Permits are a common mechanism used by health departments to regulate the installation of on-site systems. Operation of on-site systems may also follow this approach. Operating permits for automobiles serve as an analogous system currently in use in many states. By applying this familiar approach to alternative on-site wastewater systems, the final inspection of a new system would be replaced by a permit for its operation until another inspection of the system is required. The length of the permit could depend on the complexity of the system, the safety built into the system, individual care in using the system, its dependability, and the impact of its failure both economically and environmentally. The permit could be site-specific and sensitive to the potential cost of the system failing. For example, if a system is in a sensitive environment where its failure may have significant consequences and where it will be very costly to replace or repair, the system should be inspected more frequently. Likewise, the system should be as simple and reliable as possible. If, on the other hand, the system is in a low-density area with good soil and room to expand, a less stringent inspection frequency may be appropriate, especially if inspection is costly due to its location.

The role of the individual using the system cannot be underemphasized. How the individual cares for the system, the demand he places on the system, how he repairs leaky plumbing and what he dumps into the system must also be considered. Here again, education of the family using a specific system is important. It is not inconceivable and certainly should be a goal for the individual to assume complete responsibility for system inspection. However, some check and safeguard must be in place to insure proper operation. Stinson Beach, California, is one community that uses the permit approach. Following a study of system maintenance and system longevity,

the State of North Carolina is also giving serious consideration to a permit system in place of final inspections.

PARTING THOUGHTS

As we gain experience in on-site management, we gain a clearer understanding of the expansive nature of the subject. The systems and management programs require professional expertise. The care and operation of the systems require an effective working relationship between the managing entity and the individual. Education will continue to play a major role in establishing management programs, both to train the professional responsible for the system and to educate the public in its role and responsibilities. Workshops such as this will not likely fade in importance. They must become a regular part of a state on-site wastewater management program. Without this educational and management program on-site systems can only be expected to fail at an unnecessarily high rate, multiplying the problems and cost to individuals and local governments. It will be up to the state and local governments to decide whether they want to react to problems as they occur or develop a program which prevents the on-site system failure.

PROCEDURES USED TO DETERMINE
OPERATION AND MAINTENANCE REQUIREMENTS

by

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Colorado State University received a grant from the National Science Foundation in September, 1980, to evaluate the "Management of Decentralized, On-Site Systems for Treatment of Domestic Wastes." This grant permitted a large expansion of small wastewater systems work already underway and funded by the Colorado Agricultural Experiment Station.

The NSF grant supported a detailed and complete evaluation of specific operation and maintenance (O&M) requirements of on-site wastewater treatment technology. Prior to this work, O&M information was widely scattered, lacking much detail and, in many cases, simply did not exist. To develop accurate and complete O&M requirements for on-site technology required a well planned and comprehensive approach to data collection and information development. The project was organized into three phases: (1) literature survey; (2) field surveys; and (3) O&M data development.

Literature Survey

Published literature in the form of research reports, texts, and journal articles as well as manufacturers' specifications was reviewed. The published literature was rather limited when the specific topic of operation and maintenance (O&M) was sought. There are descriptions of the basic processes involved (U.S. Environmental Protection Agency, 1980c; and Laak, 1980) and these were used to develop theoretical O&M requirements.

Case studies for specific communities which emphasized on-site systems were reviewed. Many of these studies did not provide O&M details, but rather dealt primarily with institutional and design aspects. Thus, in order to use the case studies, it was necessary to carefully review and sort out O&M recommendations. Kriessl, et al. (1977), Ciotoli and Wiswell (1979) and Abney (1980) are case studies in which it was possible to obtain some O&M information.

Manufacturers' literature was obtained from a mailing to 125 companies. Over 60 responses were received providing information on a complete range of equipment from plastic liners to complete package plants.

Field Surveys

During the course of the study 18 sites were visited where an existing management program was operating, specific types of technology were being constructed, inspected, maintained, etc. and efforts were being made to assist communities in developing their own management capabilities. These site visits provided considerable information on manhours, equipment and costs of on-going operation and maintenance.

Equipment suppliers were contacted by mail and/or phone when additional information on specific types of equipment, parts and supplies was needed. Contractors supplied information on pumping and repair costs. Chemical laboratories supplied information on water analysis costs. Miscellaneous contacts were made to obtain data on hardware items, chlorine, filter sand, etc.

Operation and Maintenance Data Utilization

After the operation and maintenance (O&M) data was collected, it had to be organized and presented in a coherent fashion. The volume of data also required a more rapid means of access than simply publishing it would have permitted. To this end, the data was computerized to permit rapid access and utilization in a community wide analysis.

The data was organized by technology type or unit process and, further, by specific O&M requirement (e.g., supplies and personnel). A classification system, with the breakdown as shown below, was derived, such that O&M requirements and costs would be additive for any combination thereof.

- septic tank
- septic tank effluent pump
- individual aerobic plant (0.2000 gpd)
- extended aeration package plants (2000-1000 gpd)
- rotating disk package plants (0-10000 gpd)
- lagoons (0-10000 gpd)
- leachfields, mounds, and ET beds
- buried sand filters (single home, surface discharge)
- accessible sand filters
- tablet chlorinators

For example, a septic tank may service one or multiple homes. It is commonly used in line with any of the units listed and often with combinations of units. A small community utilizing both mounds and leachfields will generally incur the expense of only a single groundwater monitoring program, however, and will not generally require twice the number of landscaping tools. The O&M needs for the categories listed are complete without being duplicative.

O&M information within each category was then organized. A parallel format was derived, each category having the same classes of O&M

requirements. The structure which leads most directly to itemized cost calculations was adopted, as follows:

- procedures and schedules
- personnel and contracted work
- parts and supplies
- equipment
- power
- annual costs per home

The procedures and schedules (how often each procedure is performed) lead directly to required personnel qualifications, wage rates, manhours, and/or to expenses for work assumed to be contracted out. These are given under "Personnel and Contracted Work." These figures, along with the quantities and prices for parts and supplies, equipment, and power, all lead to equations for calculating the annual costs per home.

Assumptions

In order to derive equations which would calculate costs in many different situations, some assumptions had to be made. Often, but not always, a linear relationship was assumed to exist between O&M requirements and the number of homes (flow rate). The price for septic tank pumping, for example, was taken somewhere in between typical group rates and average rates for single homes. As mentioned above, tasks requiring expensive equipment, such as pumper trucks or chemical analysis instrumentation, were assumed to be contracted. This might give a more conservative estimate of labor, equipment maintenance, overhead, etc., involved for a larger community which could assume the task itself. Since wastewater flow must, by nature, be an estimate, 3.33 persons per home, 100 gallons per capita day gpcd design flow, and 45 gpcd average

daily flow are assumed. Systems treating a maximum of 10,000 gpd (30 homes) were considered. Thus, maintenance of sewer mains, either gravity or low pressure, are considered negligible. A 20-year planning period was assumed, with replacement of parts with an expected life of greater than 20 years considered a capital expense. Capital expense, system rehabilitation, initial start-up expense, insurance, taxes, licenses, and administrative expenses were not included. Finally, calculations were performed in first quarter, 1982 dollars, and updated with the EPA Operation, Maintenance, and Repair (OMR) index. The index is based on 5 mgd extended aeration plants, and is the most applicable index found. It is also readily available by telephone or in writing from the U.S. EPA as will noted in the user's manual (Dave Nettles' talk) for the computer program.

Computer Program

To make the results more accessible, a computer program was developed for use on an Apple II micro-computer. The program accepts input data as to the number and types of existing or proposed onsite systems and miscellaneous data specific to a small community. For each technology utilized, the information described above is printed. This becomes the appendix to a report evaluating the O&M costs to the community. Included in the report is a table summarizing the annual cost per home for each system or component (for comparison of systems), the number of homes using each system type, and total annual cost to the community. This information could be useful in determining user fees, as well as in cost effectiveness analyses. Also, provided is a list of costs not included in the report which might need to be considered (capital

expense, administrative costs, etc.)

To make the program more flexible and potentially site-specific, the option was provided to change any figures within the cost calculations. Individual costs may be modified to reflect local conditions, or deleted entirely to tailor the results to a specific type of analysis or to different situations.

Summary and Conclusions

The collection of operation and maintenance (O&M) data for on-site (small flow) wastewater treatment systems involved surveying a number of different sources of information. The O&M data came in many different forms and often from very specific types of systems. The data differences had to be reconciled, the information had to be condensed and it had to be generalized to meet the requirements of an overall evaluation scheme such as that developed. This latter data manipulation required a careful review of the unit processes themselves to insure that the O&M generalizations were around the average of that required for a given treatment technology.

The O&M information, for a specific type of technology, is complete as presented. However, to evaluate the O&M needs where a large number and variety of technologies are being used, the data as presented was far short of meeting the need. This led to the development of a computer program for the Apple II computer which can analyze all the data for a community quickly and conveniently.

The procedures used to develop O&M requirement information for on-site technology were thorough and accurate. The O&M data developed as a result of the project represents the "state-of-the-art" as of 1982.

Provisions have been made to update the cost data via an EPA index. These results represent the most thorough and complete evaluation of O&M requirements for on-site wastewater treatment technology published to date. Hopefully, such a study will emphasize the need to carefully consider and plan for the provision of a sound O&M program whenever on-site or small flow wastewater treatment technology is utilized.

O&M REQUIREMENTS FOR SMALL FLOW TECHNOLOGY

by

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The preceding paper described National Science Foundation-supported research, conducted at Colorado State University, which quantified and computerized the operation and maintenance (O&M) requirements and costs associated with on-site sewage disposal technology. A large body of information from manufacturers, suppliers, contractors, consulting engineers, management personnel, and operators was compiled along with previously published literature. Systems were then classified by similar O&M requirements to make computerization possible, as follows:

- septic tank
- septic tank effluent pump
- individual aerobic plant (0-2000 gpd)
- extended aeration package plants (2000-10,000 gpd)
- rotating disk package plants (0-10,000 gpd)
- lagoons (0-10,000 gpd)
- leachfields, mounds, and ET beds
- buried sand filters (single home, surface discharge)
- accessible sand filters
- tablet chlorinators

This information was analyzed, reconciled, and condensed considerably, yielding an outline of the most efficient O&M program for each technology. Certain necessary assumptions (discussed in the previous paper) were made, and the recommendations developed for each technology were organized as below, again to permit computerization:

- procedures and schedules

- personnel and contracted work
- parts and supplies
- equipment
- power
- annual costs per home

The resulting, concise body of O&M recommendations and cost formulas were embodied in a computer model, providing both data retrieval and cost estimation capabilities.

An existing or proposed inventory of on-site systems and certain community characteristics may be input to the program, which then lists O&M requirements along with site-specific annual costs.

Results

This paper presents the research results in the form of a computer printout, as they would be generated for each system as part of the total O&M analysis for a community.

The printout for each system is included as a figure within the appropriate section of this paper. Part A of each figure presents recommended procedures and schedules, derived from a review of all of the references listed for that system. Parts B, C, D and E give personnel and contracted work, parts and supplies, equipment, and power requirements, respectively. Part F in each figure shows the calculation of annual expenses per home, assuming a few typical community parameters (entries shown in capital letters) which are discussed in each case. Expenses in first quarter 1982 dollars are updated with the U.S. Environmental Protection Agency (EPA) operation, maintenance, and repair (OMR) index.

The discussion in each section first details the operational problems associated with each process, then documents numerical quantities and elaborates as necessary on the recommendations given. Prices for small hardware

supplies, chlorine, filter sand, power, septage pumping, disposal bed repairs, and chemical analysis were obtained from local suppliers. Service vehicle operating expense was calculated using government statistics for light trucks (General Services Administration (GSA), 1982) and the EPA OMR inflation index. All other specific time requirements, costs, and other quantities are referenced individually. Points which are sufficiently clear and complete in the printout are not repeated in the discussion.

Septic Tanks

The investigations outlined previously revealed the following problems associated with septic tank use and consequent recommendations for their operation, maintenance and repair. This section covers the tank itself and dosing siphons which may be employed in some tanks. Good descriptions of septic tanks and dosing siphons may be found in EPA (1981) and Laak (1980).

Operational Problems

Without adequate attention, a septic tank will not operate properly. Eventually, it will accumulate sludge and scum to a point where either one or both will be discharged, making expensive repairs to leachfields, effluent pumps, or other units necessary. Another common problem is that, due to the highly corrosive nature of the sewage, the inlet and outlet baffles will come loose and fall off, again allowing solids and/or scum to leave the tank. Even though the baffles (often PVC sanitary tees) are generally cemented in with corrosion resistant grout, the buildup of sulfuric acid and other reactants at the air-liquid interface often attacks the cement tank surrounding the grout. This will sometimes release the baffle within as little as six months after installation (Finley, 1982).

O&M Procedures

The procedures recommended to avoid these problems are given in Figure 1. They include (1) annual inspection, and (2) having the tank pumped when necessary to remove the sludge and scum. This inspection may require about 1.5 hours (Nelson, 1981b, Ciotoli and Wiswall, 1979, Dix, 1982). Allowance of \$6 per hour wage is made, although this may be increased if the inspection person also performs other more skilled duties. It should include checking the condition of the tank (for deterioration) and baffles, and repair when necessary. Where a dosing siphon is employed, it should be cleaned and the vent tube flushed to prevent the siphon from "dribbling", or discharging continuously. If the bottom of the scum layer is within three inches, or the sludge within eight inches of the bottom of the outlet baffle, the tank should be pumped (EPA, 1980c). A pumper truck is usually employed to remove and transport the septage slurry to a central disposal facility or land application site. Ward (1981) describes an experimental alternative to trucking septage-treatment and disposal on the homeowners' property. Costs for conventional trucking range from \$50 to \$100 depending on how far the truck must travel. Septage disposal alternatives such as these are presented and evaluated by Otis et al. (1977).

Another septic tank O&M program sometimes used is regular pumping of all tanks at three to five year intervals, with no inspections. This represents a widely accepted average time between pumpings. Generally, however, research has shown septage accumulation to be extremely variable (Bowne, 1982; Weibel et al., 1949; Brandes, 1978). Thus, even though the average tank may need pumping every fourth year, many may require it every year.

SEPTIC TANK

A. PROCEDURES AND SCHEDULES

1. Annual Inspection
 - a) Check condition of outlet and inlet baffles, key joints, and the tank itself. Repair as required.
 - b) Measure sludge level; if within 8 inches of outlet baffle, pumping is necessary
 - c) Measure scum level; if within 3 inches of outlet baffle, pumping is necessary
 - d) If dosing siphon is employed, observe operation, flush bell and bell vents
2. Pump tank as necessary (average once/4 yrs)
3. Educate homeowners: The following should not be introduced: disposable diapers, feminine napkins, paper towels, cigarette butts, excessive grease or toxic chemicals, coffee grounds, bones.

B. PERSONNEL AND CONTRACTED WORK

Inspection and record keeping: trained person
1.5 man-hr/home/year (including transportation), \$6/man-hr

Solids Pumping: 0.25 pumping/home/year, \$75/pumping

Non-routine repair: assume 6% baffle replacements
\$25/replacement
6% inspection lid replacement
\$12/replacement
Total: 6% of homes, \$37 charge

C. PARTS AND SUPPLIES

Disinfectant, gloves etc. - \$27/100 homes/yr (negligible)

D. EQUIPMENT

Sludge depth measuring device	\$126/3 yrs
Lid hoist	\$114/5 yrs
Garden hose	\$20/2 yrs
Total:	\$75/yr

E. POWER

none

Figure 1. Septic tank O&M requirements.

F. ANNUAL COSTS PER HOME

Inspection:

$$1.50 \text{ man-hr} * \frac{\$ 6.00}{\text{man-hr}} * 100.00 \text{ TANKS} * \frac{1}{100.00 \text{ HOMES}} = \$ 9.00$$

Solids Pumping:

$$0.25 \text{ pumpings} * \frac{\$ 75.00}{\text{pumping}} * 100.00 \text{ TANKS} * \frac{1}{100.00 \text{ HOMES}} = \$ 18.75$$

Repair:

$$0.06 \text{ repairs required rate} * 100.00 \text{ TANKS} * \$ 37.00 * \frac{1}{100.00 \text{ HOMES}} = \$ 2.22$$

Equipment:

$$\$ 75.00 * \frac{1}{100.00 \text{ HOMES}} = \$ 0.75$$

Vehicle:

$$4.00 \text{ AVERAGE MILES SERVICE} * \frac{\$ 0.38}{\text{mile}} * 1.00 \text{ service} * \frac{1}{100.00 \text{ TANKS}} = \$ 1.52$$

TOTAL: (FIRST QUARTER 1982) \$ 32.24

UPDATED TOTAL: \$ 32.71

TOTAL OMR 82 OMR
\$ 32.24 * 3.49 / 3.44 =

Figure 1 (continued).

Comparison of Pumping Strategies for Septic Tanks

To examine the costs of various pumping (O&M) strategies for a community, an analysis of the costs involved has been developed. Figure 2 shows the sludge accumulation rates found by three independent studies, given as time until pumping. These 109 tanks show an average time of 4.34 years, with a standard deviation of 6.71 years. These researchers have used somewhat differing criteria to indicate when pumping is required. However, their results provide a good cross-section of bias, with a very reasonable mean and characteristically large standard deviation. If the time until pumping is assumed to be normally distributed with this mean and standard deviation and, further, if a leachfield failure is assumed to occur one year after pumping is deemed necessary, the fraction of systems which might be expected to fail each year may be calculated as in Figure 3. Then the annual costs per 100 homes can be estimated for different O&M programs as in Figure 4 (assuming a cost of \$60 per solids pumping). The program which includes annual inspections is decidedly the least expensive.

In the above case, the inspection program is shown to be very well justified. This was done without consideration of baffle replacement. Finley (1982) has found that baffle replacement is a frequent necessity and that missing baffles do cause some degree of leachfield failure within a year. He states that this alone justifies annual inspections. The annual cost to a community or inspection of 100 tanks may be estimated as:

$$100 \text{ inspections} \times \frac{1.5 \text{ hr}}{\text{Inspection}} \times \frac{\$6.00}{\text{hr}} = \$900$$

Reference	Number of tanks	Years between pumpings (x)
Brandes, M., 1978	1	8.08
	1	2.89
	1	1.44
Pueblo Reg. P.C., 1981	22	1
	40	2
	29	3
Bowne, W. C., 1982	1	8
	3	13
	2	11
	1	17
	1	16
	2	33
	1	10
	1	38
	1	21
	1	6
1	29	
Total:	109	$\bar{x} = 4.34$ yrs $s = 6.71$ yrs

Figure 2. Septage accumulation data.

Regular pumping interval for all tanks	Normalized $z = (x - \bar{x})/s$	Fraction of tanks needing pumping	Fraction of systems failing*
one year	-0.4978	0.31	0.0
two years	-0.3487	0.36	0.31
three years	-0.1997	0.42	0.36
four years	-0.0507	0.48	0.42+0.31=0.73

*assume failure one year after pumping is needed.

Figure 3. Calculation of number of system failures for different O&M schemes (having no inspections) assuming normal distribution.

Pump once/year

100 pumpings x \$60/pumping =	\$6000
0 repairs x \$750/repair =	<u>0</u>
Total:	\$6000

Pumping once/two years

50 pumpings x \$60/pumping =	\$ 3000
31 repairs x \$750/repair =	<u>23750</u>
Total:	\$26250

Pump once/three years

33 pumpings x \$60/pumping =	\$ 2000
36 repairs x \$750/repair =	<u>27000</u>
Total:	\$29000

Pump once/four years

25 pumpings x \$60/pumping =	\$ 1500
73 repairs x \$750/repair =	<u>54750</u>
Total:	\$56250

Inspect annually and pump as needed

100 insp x 1.5 hr x \$6.00/hr =	\$ 900
100 tanks x $\frac{1 \text{ pumping}}{4.34 \text{ yr}}$ x \$60/pumping =	<u>1382</u>
Total:	\$ 2282

Inspect biannually (pump as needed)

50 insp x 1.5 hr x \$6.00/hr =	\$ 450
100 tanks x $\frac{1 \text{ pumping}}{4.34 \text{ yr}}$ x \$60/pumping =	1382
31 repairs x \$750/repair =	<u>23250</u>
Total:	\$25082

Figure 4. Annual cost per 100 homes using various pumping strategies.

If only one \$750 leachfield repair and three \$60 tank pumpings are avoided because of the inspection program, then its cost is justified.

The septic tank O&M program may also include homeowner education, the third procedure listed in Figure 1A. If slowly or nondecomposing materials (bones, feminine napkins, grease, etc.) are introduced, pumping frequency will be increased. Also, the discharge of water softener backwash to a septic tank/soil absorption system will not detrimentally affect the soil structure, but may cause hydraulic overloading (Sack, 1981). Leaflet distribution or personal communication during the inspection is often effective in avoiding these problems.

Personnel and Contracted Work

A trained (on-the-job training) person is required for inspection work. The time allowed in Figure 1B is 1.5 man-hours (Nelson, 1981b; Dix, 1982) at \$6.00 per man-hour (Nelson, 1981b). This should be sufficient time for transportation, inspection, and minor repair work when necessary. Time required for baffle or septic tank lid replacement is minimal (Glenn, 1982).

For cost estimation purposes, tank pumping is assumed to be contracted out, possibly at a group rate, since a pumper truck would be a large expense for a small community. This cost includes, then, vehicle expense, labor, septage disposal, etc. A conservative estimate of \$75 per pumping was arrived at after reviewing many individual and group rate prices (Ross, 1981; Day, 1981; Glenn, 1981; Nelson, 1981; Dix, 1982).

The miscellaneous repair costs given in Figure 6B are estimated from Finley (1982) and Glenn (1982).

Other Costs

Other expenses (supplies and equipment for inspection work) are shown in Figure 1C and 1D, taken from Finley (1982) and a local hardware supplier. Disinfectant (household bleach), gloves, and garden hose protect the inspection person from contamination. One sludge depth measuring device which has been effective (Nelson, 1981a) is illustrated in Figure 5.

Many tanks will require some type of winch or hoist for lid removal. No power is required for operation, nor are chemicals needed. Septic tank additives have not been shown to be beneficial to the functioning of the septic tank, and should not be used (EPA, 1980c).

Figure 1F presents the calculation of all of the above annual expenses as well as service vehicle expense for a group of 100 single-home septic tanks, on a per home basis. Vehicle expense (GSA, 1982) includes fuel, lubricant, labor, parts, etc. Service mileage must include trips to suppliers and other unscheduled travel as well as scheduled service calls. For illustration in Figure 1F, it is assumed that the service person travels six miles to inspect three closely grouped homes, then drives six miles back in a typical morning, thereby averaging four miles per service. All other expenses are direct results of the preceding discussion. The total is updated to second quarter, 1982 dollars using the EPA OMR index.

Septic Tank Effluent Pumps

These small (1/4 to 2 hp), submersible pumps are used in pressure dosing of subsurface disposal systems, in low pressure sewer systems, in

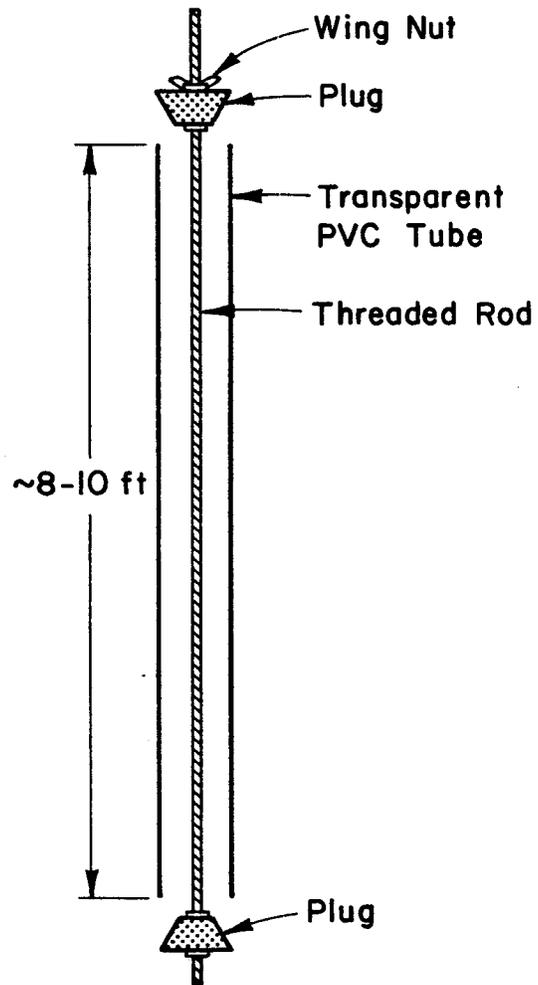


Figure 5. Sludge and scum depth measuring device (after Nelson, 1981a).

recirculating sand filters, and in other applications where the influent to the pump is free of solids and pumping is needed. EPA (1980c) provides a description of the units.

Operational Problems

Effluent pumps may become clogged or bound. Particularly during prolonged periods of inactivity (as in vacation homes), iron sulfide buildup can bind the impellor. Also, electrical problems can occur in the control system. Generally, though, these pumps are relatively reliable. The mean time between unscheduled service calls may be from four to six years if some preventative maintenance is performed (Overton, 1981; Bowne, 1982).

O&M Requirements

The annual inspection described in Figure 6A is recommended preventive maintenance. Pumps should be easily removable so that they may be repaired in a shop. If a low pressure sewer system is used, a small amount of routine attention, as shown, suffices (Florida Department of Environmental Regulation, 1981).

The time required for all service work is conservatively but reasonably five man-hrs per pumping unit per year (Overton, 1981a; Bowne, 1982). An analysis of the work by Bowne (1982) shows that a negligible fraction of that time (0.12 hrs) is attributed to maintenance of the sewer system, and that no allowance for materials expense is necessary for sewer system maintenance. However, this time does include septic tank maintenance. Thus 1.5 man-hrs, estimated previously, has been subtracted to give 3.5 man-hrs per pump per year, shown in Figure 6 B.

SEPTIC TANK EFFLUENT PUMP (STEP)

A. PROCEDURES AND SCHEDULES

1. Annual Inspection of Units
 - a) Remove pump from chamber, check intake for blockage, check suction plate and body for corrosion; clean entire pump (and chamber, if level controls are affected by accumulation)
 - b) Check all valves for proper operation
 - c) Refurbish brass disconnect fittings
 - d) Return pump to chamber and test
 - e) Test alarm system
2. Routine Sewer Maintenance
 - a) Exercise all shut-off, air release, and pressure sustaining valves once per month
 - b) Flush mains, particularly at end of lines
3. Non-routine Repair

B. PERSONNEL AND CONTRACTED WORK

Inspections, Service and Repair Work:

Qualifications:

- 1) specific training
- 2) knowledge of:
 - pump mechanics and operation
 - pipe handling and repair
 - mechanics of fittings, valves, and other components
 - customer relations
 - general operation of STEP system
 - system installation

3.5 additional man-hrs/pump/year (with or without sewer), \$10/man-hr

C. PARTS AND SUPPLIES

Maintain inventory of 1 or 2 spare pump/control units for every 20 homes

1 pumping unit/8 yrs, \$250/unit

D. EQUIPMENT

(Shop with maintenance tools)

E. POWER

1 hp	150 gpd	1 hr	0.746 kw	0.20 kwh/day
----- *	----- *	----- *	----- *	-----
home	10 gpm	60 min	hp	home

Figure 6. Effluent pump O&M requirements.

The service person qualifications listed are given by the Florida Department of Environmental Regulation (1981). Parts C, D, and E of Figure 6 show remaining O&M requirements. An inventory of spare pumps, impellers, and control units facilitates repair work. From 3 percent (for over 200 installed units) to 10 percent (for under 30 units) of the number of units in use are recommended (Florida Department of Environmental Regulation, 1981). Pumps are expected to last from five to ten years (Bowne, 1982 and Overton, 1981a). Typical cost is from \$200 to \$400 (Bowne, 1982; Scroggins, 1982; Kriessl et al., 1977; Overton, 1981b). The typical pump delivers 0.5 hp and from 10 to 50 gpm (Bowne, 1982; Overton, 1981a and 1981b; Kriessl et al., 1977). Power requirements depend upon the terrain, how many homes share a pump, etc., but may be conservatively estimated as shown.

The annual costs per home for 30 single home effluent pumps are calculated in Figure 6 F. Since the pumps are inspected along with the septic tank or other treatment unit, no additional mileage is incurred.

Individual Aerobic Units

These extended aeration units can be used in surface discharge applications and where other systems will not work. They are mechanically complex and very expensive to operate. Generally, they service a single home, and the discussion below focuses mainly on the single home units as described in EPA (1980c).

Very little data could be found for units in the 500 to 2,000 gpd range; however, it appears reasonable to assume that costs vary linearly with flow in this limited range (two to five homes). This is done here

in order to bridge the gap with the 2,000 to 10,000 gpd package plants treated later.

Operational Problems

Proper aeration and mixing is critical to the performance of these systems. Air diffusers sometimes clog. The mechanical parts demand regular attention to seals, lubrication, filters, and controls. Sludge and scum accumulate as in septic tanks. Table 1 (from EPA, 1980c) provides a list of common problems and remedies.

O&M Procedural Requirements

Often manufacturers recommendations for these systems are so much less conservative than those of other published sources as to be unreconcilable. Most sources of actual experience tend to be somewhat less conservative than the EPA Design Manual (1980c). Recommendations given in Figure 7A and 7B lean toward the conservative but practical. The inspections detailed there may be performed every one to two months, with 20 man-hours per year allowed for all inspection and service work (EPA, 1980c; Abney, 1980; Fancy, 1980; McEnterfer, 1982; Arizona Anti-septic Systems, 1981). The half hour cylinder settlement test consists of observing 1,000 ml of mixed liquor in a graduated cylinder for one half hour, and recording the level of settled sludge at specified times. This will indicate the quality of floc, aeration problems, etc. With a regular maintenance program, emergency serving should average less than one visit per home in five years (Fancy, 1980; Cruce, 1981). The service person qualifications listed are given by Fancy (1980).

Pumping of accumulated solids is necessary periodically although sometimes sludge may be wasted to a septic tank for storage. Here

Table 1. Operational problems—individual aerobic plants (EPA, 1980c).

Observation	Cause	Remedy
Excessive local turbulence in aeration tank	Diffuser plugging Pipe breakage Excessive aeration	Remove and clean Replace as required Throttle blower
White thick billowy foam on aeration tank	Insufficient MLSS*	Avoid wasting solids
Thick scummy dark tan foam on aeration tank	High MLSS*	Waste solids
Dark brown/black foam and mixed liquor in aeration tank	Anaerobic conditions Aerator failure	Check aeration system, aeration tank. D.O.
Billowing sludge washout in clarifier	Hydraulic or solids overload Bulking sludge	Waste sludge; check flow to unit See reference (37)
Clumps of rising sludge in clarifier	Denitrification	Increase sludge return rate to decrease sludge retention time in clarifier
	Septic conditions in clarifier	Increase return rate
Fine dispersed floc over weir, turbid effluent	Turbulence in aeration tank	Reduce power input
	Sludge age too high	Waste sludge

* Mixed liquor suspended solids.

INDIVIDUAL AEROBIC (0-2000 GPD)

A. PROCEDURES AND SCHEDULES

1. Inspection: every 1 to 2 months
 - a) Visually check aeration and mixing. Inspect diffusers, clean or replace as required. Record.
 - b) Perform half hour cylinder settlement test on mixed liquor. Record.
 - c) Observe motor-blower operation. Clean or replace air filter, oil if necessary. Clear air intake of weeds or other obstruction. Record.
 - d) Check sludge and scum levels. remove floating solids if necessary. Brush down tank. Record.
 - e) Check trash trap for accumulated solids.
 - f) Manually operate and check alarm. Record.
2. Unscheduled service calls (infrequent, average 1 per 5 years)
3. Pump sludge as required: assume every 12 months
4. Homeowner education
5. For surface discharge, monitor and record biochemical oxygen demand (BOD), suspended solids (SS), and fecal coliforms (FC) quarterly

B. PERSONNEL AND CONTRACTED WORK

Inspection and Service person: mechanical, chemical, or biological background; ability to work without supervision; will need specific training on the various units utilized.

20 man-hrs/home/year at \$10/man-hr

Solids Pumping: 1 pumping/home/year, \$60/pumping

Chemical analysis for surface discharge (BOD, SS, FC)
Contract 4 samples/yr, \$28/sample

C. PARTS AND SUPPLIES

air filter, compressor vanes, compressor, pump, lubricants, etc.
= \$75/plant/yr

D. EQUIPMENT

1000 ml graduated cylinder	\$14/2 yrs
garden hose	\$20/2 yrs
gloves	\$6/yr
thermometer	\$10/yr
grease gun	\$13/5 yrs
bucket	\$9/2 yrs
brushes	\$15/yr
skimmer net	\$15/yr

Total: \$70/yr

Figure 7. Individual aerobic plant O&M requirements.

E. POWER

8 kwh/day, \$0.07/kwh

F. ANNUAL COSTS PER HOME

Labor:

	\$ 10.00		
20.00 man-hrs * ----- =			\$ 200.00
man-hr			

Solids Pumping:

	\$ 60.00		
1.00 pumpings * ----- =			\$ 60.00
pumping			

Analysis:

	\$ 28.00			
4.00 samples * ----- *		0.00 SURFACE DISCHARGING * ----- =		\$ 0.00
sample		PLANTS 30.00 HOMES		

Supplies and Parts:

\$ 75.00 =			\$ 75.00
------------	--	--	----------

Equipment:

	1		
\$ 70.00 * ----- =			\$ 2.33
30.00 HOMES			

Power:

	kwh		\$ 0.07	
8.00 --- * 365.00 days * ----- =				\$ 204.40
day	kwh			

Figure 7. (continued).

Vehicle:

6.20 services *	4.00	AVERAGE MILES	\$ 0.38	
		-----	*	----- =
		SERVICE	mile	\$ 9.42

TOTAL: (FIRST QUARTER 1982) \$ 551.16

UPDATED TOTAL:	TOTAL	OMR	82 OMR	
	\$ 551.16 *	3.49 /	3.44 =	\$ 559.17

Figure 7. (continued).

again, sources varied widely, from one pumping in eight months, to five years, to never (EPA, 1980c, Abney, 1980; Boyle and Otis, 1979; Arizona Antiseptic Systems, 1981; Jet Inc., 1980; Environmental Dynamics Inc., 1981; McEnterfer, 1981).

If the unit discharges to surface water, effluent monitoring is legally required, though frequency may vary locally. Also, an education program promoting homeowner understanding of the systems would be a valuable management function. All of these functions are seen in Figure 7A and 7B.

Other O&M Requirements and Cost Calculations

Other requirements are given in Figure 7C, 7D, and 7E. Replacement parts commonly cost \$75 per year (McEnterfer, 1980; Fancy, 1980). Reported power consumption varies from 2 to 10 kwh per day (McEnterfer, 1981; EPA, 1980c; National Utility Contractors Assn., 1979; Boyle and Otis, 1979; Otis et al., 1977; Abney, 1980).

Annual expenses per home for a group of 30 homes are shown in Figure 7F. assuming four vehicle miles for the average service as was done for septic tanks.

Comparison to Past Work

Fancy (1980) has found an average annual cost per home of \$130 (to a maximum \$330) for labor and \$64 for parts (when updated with the OMR index). This was for an area with a high density of aerobic units. Using Figure 7, \$200 and \$75, respectively, are obtained. This margin of safety allows for cases where fewer homes utilize aerobic units, making labor less efficient.

0-10000 gpd Extended Aeration Package Plants

The extended aeration process is somewhat less expensive to operate in multiple home applications. Systems studied include those servicing up to 30 homes, or 10,000 gpd design flow. These systems sometimes include comminutors and/or sludge digesters. System descriptions are found in EPA (1977) and Laak (1980). Chlorinators are treated separately.

Operational Problems

These plants are mechanically complex and relatively labor intensive. Proper aeration, again, is critical to the process. These larger systems will generally provide more operational control, such as aerator timers and valves. Plugged air diffusers can be a problem, as can flow or chemical shocks, rising sludge, foaming, and mechanical failures. Solids accumulate as in other systems and must be removed periodically. These problems are briefly summarized in Table 2.

O&M Requirements

Figure 8 includes a brief summary of recommended O&M procedures compiled from many sources. These will vary somewhat from system to system. Manufacturers literature must be consulted for any particular system. Many of the manuals obtained for this work were very complete. This type of sewage plant requires a minimum of 400 man-hours per plant per year for effective operation and acceptable effluent quality (Gua et al., 1981; Environmental Dynamics, Inc., 1981; EPA, 1977; Gates, 1982; Centrox Corp., 1980). A licensed operator is legally required, as

Table 2. Summary of extended aeration operational problems.

Secondary Treatment Process Problems

- 1) Rising sludge due to denitrification
- 2) Bulking sludge due to various imbalance conditions between the three variables biological oxygen demand (BOD), suspended solids (SS) and the level of dissolved oxygen (DO) maintained.
- 3) Frothing, often due to the introduction of synthetic detergents.

Mechanical Problems

- 1) Blower failure due to wear, improper lubrication, improper belt tension, dirty oil or air filters, clogged or leaky air lines, scale build-up on impellers or casing, etc.
- 2) Pump failure due to damaged impeller, electrical problems, etc.
- 3) Electrical problems (numerous).

Miscellaneous

- 1) Clogged diffusers

2,000-10,000 GPD EXTENDED AERATION PACKAGE PLANTS

A. PROCEDURES AND SCHEDULES

1. Daily
 - a) Visually check color and appearance for proper aeration and mixing. Check for proper odor. Clean air diffusers if necessary. Record.
 - b) Remove scum with net and dispose of
 - c) If hand-raked influent screens, clean and dispose of screenings
 - d) If comminutor; clean and dispose of large objects
 - e) Chemical analysis (and record keeping):
 - mixed liquor and effluent settleable solids (half hour cylinder settlement test)
 - mixed liquor dissolved oxygen (DO)
 - f) Adjust aeration (and sludge return) as indicated by a) and e)
2. Weekly
 - a) Brush or hose down all parts of tanks
 - b) Inspect compressor/blower for proper lubrication, V-belt tension and wear. Fill with oil, grease bearings, clean or replace air filter
 - c) Check pH and temperature of influent, clarifier, and aeration chamber. Record.
 - d) If comminutor; lubricate
3. Monthly
 - a) Clean air diffusers
 - b) If comminutor; sharpen or replace teeth
4. Quarterly
 - a) Change oil in blower gear cases
 - b) If surface discharge, measure effluent biochemical oxygen demand suspended solids, fecal coliforms (FC), pH and flow. Record.
5. Other
 - a) Building and grounds maintenance; painting
 - b) Pump sludge and scum every 2-12 months as necessary
 - c) Non-routine service and repair

B. PERSONNEL AND CONTRACTED WORK

Operation: trained, licensed operator
400 man-hrs/plant/year, \$10/man-hr

Chemical analysis for surface discharging plants (BOD, SS, FC):
contract 4 samples/plant/year, \$31/sample

Solids Pumping for plants without digester or land disposal:
1 pumping/plant/year \$90/pumping

C. PARTS AND SUPPLIES

Lab supplies: (chemicals, equipment maintenance, pencils, paper)	\$20/yr
Lubricant:	\$25/yr
Replacement parts: blower, belts, valves, alternator	\$225/yr

Figure 8. Extended aeration package plant O&M requirements.

Touch up and paint

\$70/yr

Total:

\$340/plant/yr

D. EQUIPMENT

(Treatment plant enclosure if freezing climate)
 (Lab space with hot water, storage for chemicals)
 Test kits: DO, pH, settleable solids
 Garden hose
 Plastic garbage can
 Grease gun
 Stiff bristle push broom
 Small skimmer net
 Short handled brush
 Large skimmer net

\$119/4 yrs
 \$20/2 yrs
 \$20/2 yrs
 \$13/5 yrs
 \$13/yr
 \$8/yr
 \$3/yr
 \$15/yr

Total:

\$91/yr

E. POWER

2.5 hp	333 gpd	24 hr	0.746 kw	3.0 kwh/day	
-----	*	-----	*	-----	=
5000 gpd	home	day	hp	home	

F. ANNUAL COSTS PER HOME

Labor:

man-hrs	\$ 10.00			1	
400.00	-----	*	-----	*	1.00 PLANTS * ----- =
plant	man-hr			30.00 HOMES	\$ 133.33

Solids Pumping:

pumping	\$ 90.00			W/OUT	1
1.00	-----	*	-----	*	0.00 PLANTS SEPT. * ----- =
plant	pumping			DISP.	30.00 HOMES

Parts and Supplies:

\$ 340.00				1	
-----	*	1.00 PLANTS * -----			=
plant				30.00 HOMES	\$ 11.33

Figure 8. (continued).

Power:

$$3.00 \frac{\text{kwh/day}}{\text{home}} * 365.00 \text{ days} * \frac{\$ 0.07}{\text{kwh}} = \$ 76.65$$

Equipment:

$$\frac{\$ 91.00}{\text{plant}} * 1.00 \text{ PLANTS} * \frac{1}{30.00 \text{ HOMES}} = \$ 3.03$$

Vehicle:

$$365.00 \text{ services} * 4.00 \frac{\text{AVERAGE MILES}}{\text{SERVICE}} * \frac{\$ 0.38}{\text{mile}} * \frac{1}{30.00 \text{ HOMES}} = \$ 18.49$$

Chemical Analysis:

$$4.00 \frac{\text{samples}}{\text{plant}} * \frac{\$ 31.00}{\text{sample}} * 1.00 \frac{\text{SURFACE DISCHARGE}}{\text{PLANTS}} * \frac{1}{30.00 \text{ HOMES}} = \$ 4.13$$

TOTAL: (FIRST QUARTER 1982) \$ 246.98

UPDATED TOTAL: \$ 250.57

TOTAL OMR 82 OMR
\$ 246.98 * 3.49 / 3.44 =

Figure 8. (continued).

is effluent monitoring where the effluent is discharged to surface water. Accumulated solids must be removed periodically, varying from every two months to every five years (Environmental Dynamics, Inc., 1981; Gates, 1982; Olson, 1982). If a sludge digester is not provided, and land disposal is not available, septage pumping may be contracted for slightly more than the cost of septic tank pumping (Olson, 1982).

Necessary parts and supplies are also presented with costs in Figure 8 C (Centrox Corp., 1980; Olson, 1982), followed by a list of common operational tools (Ecodyne, 1981; EPA, 1977). Average power requirement for a typical plant of this size may be calculated as shown (Olson, 1982; Centrox Corp., 1980).

Cost calculations in Figure 8 F are for one subsurface discharging plant with septage disposal facilities, servicing 30 homes. Four average miles per daily service are assumed.

Comparison to Past Work

Guo et al. (1981) presents O&M costs for eight package plants of the size treated here. When updated with the EPA OMR index, the average annual costs per home would be \$78 for labor and \$35 for parts, supplies, power, and chemicals. These respective costs as estimated with Figure 8 for 20 homes are \$200 (based on the same author's minimum recommendation of 400 man-hrs per year per unit, which is more than has generally been allowed for), and \$97 (\$77 for power alone). Michel et al., 1969 and EPA, 1977, indicate total O&M costs of \$130 for 100 persons (30 homes). For 30 homes, a total cost of \$230 is obtained from Figure 8. Using a more typical 200 man-hrs per unit, \$164 would be obtained. The total costs obtained here, therefore, represent a maximum due to the accumulation of conservatively biased components.

This makes the results more applicable where only a few units are utilized. This would often be the case for a small community, since each of these units services multiple homes.

0-10000 gpd Rotating Disk Package Plants

Less experience with these systems has been accumulated than has been for the extended aeration plants; however, indications are that their performance is comparable if the proper temperature is maintained. The system is less complex and requires substantially less attention. EPA (1977) describes the system.

Operational Problems

This process is temperature sensitive. An enclosure is necessary to control temperature and prevent algae growth. Solids accumulate and must be removed periodically. Aside from these considerations, the process is very stable and the units are relatively reliable mechanically.

O&M Requirements

Figure 9 summarizes required O&M tasks, including monthly inspections, lubrication, and effluent monitoring for surface discharge. Solids must be pumped every 8 to 12 months (EPA, 1980; Croston, 1980). The costs for pumping and for paint touch-ups would be similar to those obtained for extended aeration plants from Olson (1980). Lubricants and belts may account for \$54 per year (Houp, 1982). Equipment and power are added to the plant enclosure to improve system performance, the required temperature varies (inversely) with the detention time. Since

0-10,000 GPD ROTATING DISK PACKAGE PLANTS

A. PROCEDURES AND SCHEDULES

1. Monthly
 - a) Visually inspect clarifiers. Observe and record color, odor, growth thicknesses on disks, and sludge and scum levels.
 - b) Check effluent settleable solids
 - c) Hose down sidewalls, weirs, etc.
 - d) Observe mechanical operation
2. Every 4 months
 - a) Check and maintain all lubricant levels
 - b) Grease shaft bearings
 - c) Inspect chain drive and if necessary;
 - clean chain in kerosene and lubricate
 - change oil
 - adjust chain tension
 - d) If surface discharge; monitor and record effluent biochemical oxygen demand (BOD), suspended solids (SS), fecal coliforms (FC), pH and flow
3. Annually
 - a) lubricate motor
 - b) change gear reducer oil
 - c) touch up paint
4. Pump sludge as required (assume 1.0 pumping/yr)

B. PERSONNEL AND CONTRACTED WORK

Operation: trained, licensed operator
15 man-hrs/plant/year, \$10/man-hr

Chemical analysis for surface discharge: contract 4 samples/plant/year,
@ \$31/sample

Solids Pumping: 1 pumping/plant/year, \$90/pumping

C. PARTS AND SUPPLIES

Touch up and paint:	\$70/yr
Lubricant: 45 quarts oil, 1 tube grease - total	\$50/yr
Belts: 4 belts, 5 year life, \$5/belt:	\$4/yr
Total:	\$124/yr

D. EQUIPMENT

(Facility enclosure to control temperature and prevent algae growth)	
1000 ml graduated cylinder	\$14/2 yrs
garden hose	\$20/2 yrs

Figure 9. Rotating disk package plant O&M requirements.

grease gun
long handled brush

\$13/5 yrs
\$13/yr
\$33/yr

Total:

E. POWER

1 hp 333 gpd 24 hr 0.746 kwh 1.2 kwh/day
----- * ----- * ----- * ----- = -----
5000 gpd home day hp home

F. ANNUAL COSTS PER HOME

Operator:

man-hrs \$ 10.00 1
15.00 ----- * ----- * 1.00 PLANTS * ----- = \$ 5.00
plant man-hr 30.00 HOMES

Analysis (surface discharge):

samples \$ 31.00 SURFACE 1
4.00 ----- * ----- * 0.00 DISCHARGE * ----- = \$ 0.00
plant sample PLANTS 30.00 HOMES

Solids Pumping:

pumping \$ 90.00 1
1.00 ----- * ----- * 1.00 PLANTS * ----- = \$ 3.00
plant pumping 30.00 HOMES

Parts and Supplies:

\$ 124.00 1
----- * 1.00 PLANTS * ----- = \$ 4.13
plant 30.00 HOMES

Equipment:

\$ 33.00 1
----- * 1.00 PLANTS * ----- = \$ 1.10
plant 30.00 HOMES

Figure 9. (continued).

Power:

	kwh/day		\$ 0.07	
1.20	-----	* 365.00 days *	-----	=
	home		kwh	\$ 30.66

Vehicle:

		AVE MILES	0.38\$	
12.00	services *	4.00	-----	* -----
		SERVICE	per mile	
			1	
	* 1.00 PLANTS *	-----	-----	=
		30.00 HOMES		\$ 0.61

TOTAL: (FIRST QUARTER 1982) \$ 44.50

	TOTAL	OMR	82 OMR	
UPDATED TOTAL:	\$ 44.50 *	3.49 /	3.44 =	\$ 45.15

Figure 9. (continued).

the required heat, if any was to be added, would vary with both system design and climate, it is not considered in Figure 9E .

Figure 9F shows the calculation of costs for one subsurface discharging plant servicing 20 homes. An average of 4 miles per service is assumed.

0-10000 gpd Lagoons

Lagoons are a popular form of wastewater treatment for small clusters of homes due to their minimal O&M requirements. Performance is good provided periodically higher suspended solids (SS), due to algae in the effluent, is acceptable. Facultative lagoons, both aerated and nonaerated, are the most common and are considered here. Descriptions are found in EPA (1977) and Laak (1980).

Operational Problems

The basic simplicity of lagoons makes them relatively problem free. Weeds, insects, and wildlife proliferate, however. Rodents may damage dikes. Hunting should be prohibited to avoid property damage, etc. Sludge accumulation is generally not significant (National Environmental Health Assoc., 1981; EPA, 1977).

O&M Requirements

The procedures shown in Figures 10A include weed control, dike and aerator maintenance, and effluent monitoring. Costs are explained in parts B through E of the same figure. These figures were arrived at through consideration of actual operating data from three lagoons (Vogel, 1982) and operators' recommendations (Vogel, 1982), as well as

0-10,000 CPD LAGOONS

A. PROCEDURES AND SCHEDULES

1. Weed control by spraying, mowing or propane torch. Weekly.
2. Occasional dike inspection and maintenance, rodent control.
3. For aerated lagoon; pull aerator out twice/year for inspection and cleaning.
4. For surface discharge; monitor effluent flow, pH, chlorine, biochemical oxygen demand, suspended solids, fecal coliforms as required by law. (assume quarterly)

B. PERSONNEL AND CONTRACTED WORK

Trained, licensed wastewater operator:

Weed control and dike maintenance: 26 man-hrs/year
\$10/man-hr

Aerator maintenance: 8 man-hrs/yr. \$10/man-hr

Chemical analysis for surface discharge: contract 4 samples/year,
\$31/sample

C. PARTS AND SUPPLIES

Non-aerated lagoon: weed spray, 5 gal \$75/yr
For aerated: 1 aerator/15 yrs \$1500/15 yrs
Total for aerated lagoon: \$175/yr

D. EQUIPMENT

Sprayer \$43/5 yrs
Total: \$9/yr

E. POWER

For aerated lagoon:

$$1.25 \text{ hp} * 0.746 \text{ kw/hp} * 15 \text{ hr/day} = 14 \text{ kwh/day} \\ @ \$0.07/\text{kwh}$$

Figure 10. Lagoon O&M requirements.

F. ANNUAL COSTS PER HOME

Labor:

$$26.00 \text{ man-hrs} * \frac{\$ 10.00}{\text{man-hr}} * 1.00 \text{ LAGOONS} * \frac{1}{30.00 \text{ HOMES}} = \$ 8.67$$

Labor (aerated):

$$8.00 \text{ man-hrs} * \frac{\$ 10.00}{\text{man-hr}} * 1.00 \text{ AERATED LAGOONS} * \frac{1}{30.00 \text{ HOMES}} = \$ 2.67$$

Supplies and Parts:

$$\$ 75.00 * 1.00 \text{ LAGOONS} * \frac{1}{30.00 \text{ HOMES}} = \$ 2.50$$

Supplies & Parts: (aerated)

$$\$ 100.00 * 1.00 \text{ AERATED LAGOONS} * \frac{1}{30.00 \text{ HOMES}} = \$ 3.33$$

Power:

$$14.00 \frac{\text{kwh}}{\text{day}} * 365.00 \text{ days} * \frac{\$ 0.07}{\text{kwh}} * 1.00 \text{ AERATED LAGOONS} * \frac{1}{30.00 \text{ HOMES}} = \$ 11.92$$

Vehicle:

$$52.00 \text{ services} * 4.00 \frac{\text{AVE MILES}}{\text{SERVICE mile}} * \frac{\$ 0.38}{\text{mile}} * 1.00 \text{ LAGOONS} * \frac{1}{30.00 \text{ HOMES}} = \$ 2.63$$

Figure 10. (continued).

through consideration of the processes and problems involved. Power requirements will vary depending on climate, degree of aeration desired, flow, etc. It is estimated here for a typical case (Vogel, 1982) to simplify computer calculation.

Figure 10F presents costs for one aerated lagoon servicing 30 homes, assuming four average miles per service trip.

Leachfield, Mound, Evapotranspiration (ET)

These systems all discharge to groundwater and have similar O&M requirements. Therefore they are treated together. The leachfield, though, is generally the least expensive to install, operate, and maintain, given proper design, siting, etc. Mound and ET beds can be used where siting limitations preclude a standard leachfield, but are prone to failure if not properly attended. Mounds are often preceded by a septic effluent pump, treated earlier. Descriptions of all beds are found in EPA (1980c). Laak (1980) describes leachfields.

Operational Problems

Properly managed leachfields are generally problem free. Improper siting may cause effluent to enter the groundwater. Solids in the influent will cause bed clogging, resulting in odors, ponding, and/or in sewage "backing up" into the house. Distribution boxes which are not level can cause surfacing of effluent on sloping sites (Sack, 1981). Mounds and ET beds are much more problem-prone and require very effective management. They are sensitive to hydraulic overloading, bed compaction inadequate stormwater drainage, and improper vegetation. Failure is generally characterized by surfacing effluent. Hoover

et al. (1981) calculated approximately a 50 percent mound failure rate for the state of Pennsylvania. McKluskey (1982) estimated a 50 percent ET failure rate and 10 percent leachfield failures in Mill Canyon, Colorado, an area of problem soils.

O&M Requirements

Figure 11 presents the O&M functions needed to help avoid problems, including inspections, homeowner education, and groundwater monitoring. The groundwater monitoring program specified (CFR 40, 265.91 and 265.92; Nelson, 1980; and Ward, 1982) is a relatively inexpensive way for a community to detect an otherwise unapparent type of system failure. Homeowner education is absolutely essential as preventative maintenance of ET systems, since any of the conditions mentioned above will cause system failure.

All system components are considered have an expected life of at least 20 years, and thus system rehabilitation may be considered a capital expense. However, provisions have been made here to include complete system repair in the economic evaluation, if desired, for areas which have an established failure rate for existing systems. Estimates of repair costs were obtained from contractors noted earlier. These were supplemented with new system construction costs (Hoover et al., 1981; Sack, 1981; Nat'l Envir. Health Assoc., 1981; Klink et al., 1982), considering that repairs often consist of adding to the old bed at about half the cost of a new system.

Figure 11F presents annual costs per home for a community with 100 leachfields, 10 mounds, and 10 ET beds. Thus the total is an average which most strongly reflects the costs for leachfields, which often

LEACHFIELD. MOUND, EVAPOTRANSPIRATION (ET)

A. PROCEDURES AND SCHEDULES

1. Inspection: annual or with main treatment system
 - a) Look for ponding or damp areas, odors, lush vegetation
 - b) If alternating beds, operate diversion valve to redirect flow (1-2 times/yr, in warm weather)
 - c) If distribution box; check levelness and level if necessary
 - d) For mounds: look for seepage around mound sides, and erosion. Perform landscaping necessary for erosion control.
 - e) For ET: look for erosion, evidence of misuse. Maintain stormwater drainage (bed crown, swales). Educate homeowner:
 - avoid bed compaction by vehicles, people, animals
 - maintain proper vegetation (mowed grass and shrubs, no gardens or trees)
 - attention to water conservation and water-saving devices

2. Monitor area groundwater semi-annually for
 - pH
 - specific conductance
 - nitrate
 - fecal coliforms
 - chloride
 - water table elevation at monitoring wellsMonitor at least four wells; three hydraulically down gradient at the limit of the waste management area, one hydraulically upgradient

3. Educate homeowners in water usage and conservation practices

B. PERSONNEL AND CONTRACTED WORK

Inspections: no additional labor for leachfields

Mound and ET Bed landscaping: 3 man-hrs/bed/yr, \$6/man-hr

Groundwater monitoring: sample collection; 4 man-hrs/yr, \$6/man-hr

Sample analysis: contract 8 samples/yr; \$35/sample

C. PARTS AND SUPPLIES

none

D. EQUIPMENT

Landscaping tools (shovel, hoe, rake, pick, etc.)	\$91/2 yrs
1000 ml water sampler and rope	\$46/5 yrs

Total: \$55/yr

Figure 11. Leachfield, mound, and ET bed O&M requirements.

E. POWER

none

F. ANNUAL COSTS PER HOME

Mound and ET landscaping:

$$\begin{array}{r}
 \text{man-hr} \quad \$ \quad 6.00 \quad \quad \quad \text{M \& ET} \quad \quad \quad 1 \\
 3.00 \text{ -----} * \text{ -----} * \quad 20.00 \text{ BEDS} * \text{ -----} = \quad \quad \quad \$ \quad 3.00 \\
 \text{bed} \quad \quad \quad \text{man-hr} \quad 120.00 \text{ HOMES}
 \end{array}$$

Groundwater Sampling:

$$\begin{array}{r}
 \quad \quad \quad \quad \quad \quad \$ \quad 6.00 \quad \quad \quad 1 \\
 4.00 \text{ man-hrs} * \text{ -----} * \text{ -----} = \quad \quad \quad \$ \quad 0.20 \\
 \quad \quad \quad \quad \quad \quad \text{man-hr} \quad \quad \quad 120.00 \text{ HOMES}
 \end{array}$$

Sample Analysis:

$$\begin{array}{r}
 \quad \quad \quad \quad \quad \quad \$ \quad 35.00 \quad \quad \quad 1 \\
 8.00 \text{ samples} * \text{ -----} * \text{ -----} = \quad \quad \quad \$ \quad 2.33 \\
 \quad \quad \quad \quad \quad \quad \text{sample} \quad \quad \quad 120.00 \text{ HOMES}
 \end{array}$$

Equipment:

$$\begin{array}{r}
 \quad \quad \quad \quad \quad \quad 1 \\
 \$ \quad 55.00 * \text{ -----} = \quad \quad \quad \$ \quad 0.46 \\
 \quad \quad \quad \quad \quad \quad 120.00 \text{ HOMES}
 \end{array}$$

Vehicle:

no additional mileage

optional: complete if repair

LEACHFIELD
 0.00 FAILURE RATE * 100.00 HOMES W LEACHFIELDS
 (FRACTION)

$$\begin{array}{r}
 \quad \quad \quad \quad \quad \quad \$ \quad 750.00 \quad \quad \quad 1 \\
 * \text{ -----} * \text{ -----} = \quad \quad \quad \$ \quad 0.00 \\
 \text{leachfield repair/home} \quad \quad \quad 120.00 \text{ HOMES}
 \end{array}$$

Figure 11. (continued).

optional: complete md repair

	MOUND	\$ 1500.00	
0.00 FAILURE RATE * 10.00 HOMES W MOUNDS * (FRACTION)	-----	mound repair/home	
		1	
	* ----- =		\$ 0.00
		120.00 HOMES	

optional: complete et repair

	ET	\$ 2000.00	
0.00 FAILURE RATE * 10.00 HOMES W ET BEDS * (FRACTION)	-----	ET bed repair/home	
		1	
	* ----- =		\$ 0.00
		120.00 HOMES	

TOTAL: (FIRST QUARTER 1982) \$ 5.99

UPDATED TOTAL:	TOTAL	OMR	82 OMR	
	\$ 5.99	* 3.49	/ 3.44 =	\$ 6.08

Figure 11. (continued).

predominate. Costs for complete system repairs are not included (failure rate equals 0.0 for illustration purposes only).

Comparison to Past Work

Klink et al. (1982) gives the following estimates of annual O&M costs:

- | | |
|------------------------------------|---------------|
| 1. septic tank/leachfield: | \$10 per home |
| 2. septic tank/effluent pump/mound | |
| b. cluster system: | \$20 per home |
| c. single home: | \$60 per home |

It is not stated what is included in the estimates. These figures are characteristic of those found in the literature. They are substantially less than those presented here. However, it can be seen that \$10 per home per year may not be sufficient for septic tank pumping alone, and \$20 per year is less than the annual cost of replacement parts for an effluent pump. The present work brings a completeness to these analyses which has generally been lacking. The user of these results may then delete costs as necessary to tailor his analysis to a particular situation.

Buried Sand Filters

This process is appropriate for single home, surface discharge applications (EPA, 1980c; Sack, 1981) and this application is assumed in this study. Field experience is very limited so far; however, the use of these systems is expected to grow due to high effluent quality, and low initial cost and energy requirements (Sack, 1981 EPA, 1980c). EPA (1980c) describes the units.

Operational Problems

These filters generally have an associated odor. Improperly designed or managed systems can clog, causing effluent to surface or "back up". Barry and Donnelly (1979) note a 15 percent failure rate for unmanaged buried sand filters in Erie County, New York.

O&M Requirements

Providing that the pretreatment process (sedimentation at minimum) is properly attended, the filter should require only periodic inspection and monitoring, as in Figure 12. Monitoring requirements for surface discharge are included here only for the case where the pretreatment unit is a septic tank, since other possible pretreatment units include monitoring for surface discharge already.

For areas with existing filters where a failure rate has been established, an optional provision is made in Figure 12F to include the cost of complete repair of failed systems (as was done for leachfields, mounds, and ET beds). If a failed system were repaired by increasing the area of the bed by 50 percent, the cost would be approximately \$2,500 for a single home (Nat'l Envir. Health Assoc., 1981; and Sack, 1981).

Since the filter must be preceded by another treatment process, the minimal annual inspection is not considered to require any additional time. Thus Figure 12F shows that buried sand filter O&M presents no additional expense unless effluent monitoring has not been previously accounted for.

BURIED SAND FILTERS (SINGLE HOME WITH SURFACE DISCHARGE)

A. PROCEDURES AND SCHEDULES

1. Inspect annually or with main treatment system
 - a) look for ponding, dampness, odors, lush vegetation
 - b) if alternating beds, operate diversion valve to redirect flow (1-2 times/yr, in warm weather)
 - c) check for good surface drainage

2. For filters which follow septic tanks, monitor effluent biochemical oxygen demand, suspended solids, fecal coliforms, pH and flow quarterly

B. PERSONNEL AND CONTRACTED WORK

Inspections: no additional labor

Chemical analysis (for filters following septic tanks):
 contract 4 samples/yr, \$31/sample

C. PARTS AND SUPPLIES

none

D. EQUIPMENT

none

E. POWER

none

F. ANNUAL COSTS PER HOME

Chemical Analysis:

	samples	\$ 31.00					
4.00	----- *	----- *	0.00	FILTERS	FOLLOWING	SEPTIC	*
	filter	sample			TANKS		
					1		
					----- =		\$ 0.00
					10.00	HOMES	

Figure 12. Buried sand filter O&M requirements.

Optional: comp. filter repair

	FAILURE	\$ 2500.00		1	
0.00	RATE	* -----	*	-----	=
	(FRACTION)	repair/home		10.00 HOMES	
					\$ 0.00

TOTAL: (FIRST QUARTER 1982) \$ 0.00

	TOTAL	OMR	82 OMR	
UPDATED TOTAL:	\$ 0.00	* 3.49 /	3.44 =	\$ 0.00

Figure 12. (continued).

Accessible Sand Filters (Surface Discharge)

Accessible sand filters are applicable to single or multiple home use, for surface discharge of effluent (EPA, 1980c; Sack, 1981). Again, effluent quality is high but experience is limited. Recirculation is a recent modification, virtually untried, which employs a small sump pump (see Septic Tank Effluent Pump). EPA (1980c) describes the systems.

Operational Problems

Odor is inherent to nonrecirculating types. Proper design and strict control of recirculation is critical with the recirculating filters to avoid plugging, ponding, or odors due to anaerobic conditions. Both types clog after a period of use and must be serviced.

O&M Requirements

The filter itself requires periodic raking and leveling to break up surface mat, prevent ponding, and assure even wastewater distribution over filter surface (Figure 13A). Eventually the top two to four inches of sand will need to be removed, and must be replaced whenever the sand depth falls below 24 inches. These tasks may require 10 man-hours per home per year (EPA, 1980c). This is in addition to maintenance of pump and septic tank or other prior treatment units (solids must not enter filter).

Since effluent monitoring has been included in the O&M requirements of lagoons and aerobic units, it is included here only for filters which follow septic tanks. Other requirements outlined in Figure 13 include replacement sand and tools. Sand availability may be a problem in

ACCESSIBLE SAND FILTERS (SURFACE DISCHARGE)

A. PROCEDURES AND SCHEDULES

1. Inspect every 3 months
 - a) rake and level filter surface to prevent ponding
 - b) remove vegetation on filter surface
 - c) if alternating filters, redirect flow to the other filter by operating diversion valve
 - d) for filters which follow septic tanks, monitor effluent biochemical oxygen demand, suspended solids, fecal coliforms.
2. Replace top 2-4 inches of sand, annually

B. PERSONNEL AND CONTRACTED WORK

Labor: trained person, \$6/hr
10 man-hrs/yr/filter

For filters following septic tanks, chemical analysis:
contract 4 samples/yr, \$28/sample

C. PARTS AND SUPPLIES

Sand: non-recirculating; 0.25 cub ft/sq ft/yr * 1 sq ft/4 gpd =
0.06 cub ft/gpd/yr @ \$5/cub ft

recirculating; 0.25 cub ft/sq ft/yr * 1 sq ft/8 gpd =
0.03 cub ft/gpd/yr @ \$5/cub ft

D. EQUIPMENT

rake, shovel \$44/2 yrs

E. POWER

none

F. ANNUAL COSTS PER HOME

Labor:

man-hrs	\$	6.00			1	
10.00	-----	*	-----	*	1.00 FILTERS	* ----- =
filter		man-hr			30.00 HOMES	
						\$ 2.00

Figure 13. Accessible sand filter O&M requirements.

Chemical analysis:

samples	\$ 28.00				FOLLOWING
4.00	----- *	----- *	0.00	FILTERS	SEPTIC
year	sample				TANKS
					1
					* ----- =
					30.00 HOMES
					\$ 0.00

Equipment:

					1
\$ 22.00	* ----- *				
					30.00 HOMES
					\$ 0.73

Sand: (non-recirc filters)

	cub ft		gpd	\$ 5.00		HOMES W
0.06	----- *	333.00	----- *	----- *	30.00	NON-REC
	gpd		home	cub ft		FILTERS
						1
					* ----- =	
					30.00 HOMES	\$ 99.90

Sand: (recirculating filters)

	cub ft		gpd	\$ 5.00		HOME W
0.03	----- *	333.00	----- *	----- *	0.00	RECIRC.
	gpd		home	cub ft		FILTERS
						1
					* ----- =	
					30.00 HOMES	\$ 0.00

TOTAL: (FIRST QUARTER 1982) \$ 102.63

		TOTAL	OMR	82 OMR	
UPDATED TOTAL:	\$ 102.63	* 3.49	/	3.44 =	\$ 104.13

Figure 13. (continued).

some areas, in which case transportation would increase the cost of sand shown.

Figure 13F presents costs for one nonrecirculating filter which is used as tertiary treatment following, for example, an aerated package plant servicing 30 homes. Sand is seen to be a very significant expense.

Tablet Chlorinators

These chlorinators would generally be used for surface discharge of aerobic or sand filter effluents. Tablet chlorinators are simple and relatively inexpensive initially. Despite their simplicity, O&M requirements are comparable to those of the chlorine solution feeder systems (Vogel, 1982). Tablet chlorine is generally two or three times as expensive as the liquid or granular forms. These units are described by EPA (1980c).

Operational Problems

The problem often encountered with these units is caking of the tablets due to moisture absorption. This prevents the tablets from dropping freely. Also, changes in flow necessitate varying the number of tubes which are to be stocked. Solids will accumulate in the contact chamber.

O&M Requirements

Tablet chlorinators must be restocked as necessary, cleaned periodically of solids accumulation, and monitored and adjusted for correct residual in the effluent (Figure 14A). Approximately 6 man-hours for single home units and 10 man-hours for multiple home units are allowed

TABLET CHLORINATORS

A. PROCEDURES AND SCHEDULES

1. Restock chlorine feed tubes as necessary (average every 6 months for single home, every month for cluster)
2. Clean unit internally every 6-12 months by flushing or pumping out, scraping, etc.
3. Monitor chlorine residual with color comparator and record. Every 6 months for single home, monthly for cluster, or as required by law. Adjust residual by varying the number of tubes to be stocked.

B. PERSONNEL AND CONTRACTED WORK

6 man-hr/individual unit/year, \$10/man-hr
 10 man-hr/cluster unit/year, \$10/man-hr

C. PARTS AND SUPPLIES

8 lb available chlorine/home/year
 \$3.00/lb available chlorine

D. EQUIPMENT

Brush	\$5/yr
Gloves	\$6/yr
Garden hose	\$20/2 yrs
Chlorine test kit	\$54/5 yrs

Total: \$32/yr

E. POWER

none

F. ANNUAL COSTS PER HOME

Labor: individual units

	man-hrs	\$ 10.00			
6.00			*		30.00 INDIV. UNITS *
	indiv. unit	man-hr			

	1			
				=
60.00 HOMES				\$ 30.00

Figure 14. Tablet chlorinator O&M requirements.

in Figure 14B per year (EPA, 1980c). Chlorine consumption can vary from 2 to 17 lbs. of available chlorine per home per year (EPA, 1980c; Boyle and Otis, 1979; Diamond Shamrock Corp., 1979). Tablet chlorine generally contains 70 percent to 90 percent available chlorine. An average cost of \$24 per home per year was obtained from local prices and from Boyle and Otis (1979). The cost to an individual home, however, could be as high as \$60 (Diamond Shamrock Corp., 1979). Since chlorine is a significant expense, the results for this system are especially applicable where more homes are involved. Figure 14 shows these costs for a community with 30 single-home units and one unit servicing a group of 30 additional homes, possibly utilizing a lagoon or package plant.

Summary

The operation and maintenance of a range of on-site wastewater treatment technology has been quantified. A computer model was developed to access this information. Printouts were shown above. The user of this program enters the community data shown in capital letters in the printouts. Other quantities are the results of the research, but may be modified by the user to reflect local conditions. Results are summarized in a computer-generated report such as the one shown in Appendix A of these proceedings. That report was generated for the Boulder County Health Department to help in setting up a county-wide on-site system management district. Costs are summarized in Table 1 of the computer-generated report.

Some comparisons can be made between systems, by drawing from the O&M information which has been presented and the computer-generated cost summary in Table 1 of Appendix A. First, systems which discharge to

surface waters are generally more expensive to operate than those which discharge to the ground, since: (1) higher effluent quality and, therefore, more operator attention is required; (2) chlorination and associated expense is required; and (3) effluent monitoring and analysis expense is also necessary and legally required. (Effluent monitoring expense does not show up for sand filters in Table 1 of the computer-generated report, since it is included for associated prior treatment units.) The most cost-effective process, when O&M is considered exclusively, is the standard septic tank/leachfield system where soils and the water table elevation are suitable. Where these siting requirements are not suitable, mound and evapotranspiration (ET) beds are alternatives. These systems are inexpensive to operate provided they are designed and used carefully. Lagoons and rotating disk processes are relatively stable, and the units are simple and inexpensive to operate and maintain. Extended aeration units (including individual aerobic plants) are more subject to upsets and are relatively complex and expensive to operate, though they may be cost-effective in surface discharge applications. Sand filters and chlorinators have application where it is necessary to discharge to surface waters. The O&M expense associated with septic tank effluent pumps is justified in a variety of applications, such as low-pressure sewer systems in areas of mountainous terrain.

It is hoped that these results will be helpful to consultants and city planners in evaluating small-scale wastewater treatment alternatives.

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COMPUTER STORAGE AND RETRIEVAL OF O&M REQUIREMENTS

by

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The computer system written to perform storage and retrieval of O&M requirements was a combined effort between a user and a programmer. Jim Englehardt played the part of the user by suggesting ways of getting data into the system and meaningful information out. The system design was completed during the 1981-82 school year. The following summer was spent implementing the design on the Apple II+ microcomputer and testing the finished system. In the following paragraphs I will give a quick overview of the system and explain the hardware configuration restrictions and how they can be avoided. A flow chart of the program is in Figure 1 and a complete listing of the program is in Appendix B at the end of the Proceedings.

The different O&M requirement data for each of the ten categories of on-site wastewater system technologies suggested the idea of a file of wastewater systems records. This prompted the first major component of the system. An update program was written to create, revise and edit this database. It was noted that many functions would be redundant throughout the system, such as string entry, error-proof integer and real number entry, and cursor commands for the screen. A library was assembled that contained various programs to perform these functions. Finally, the main program was written to assimilate the user's input data, the stored O&M requirements and a textural file into a user-specific report containing a cost analysis for the particular community and an appendix of O&M requirements.

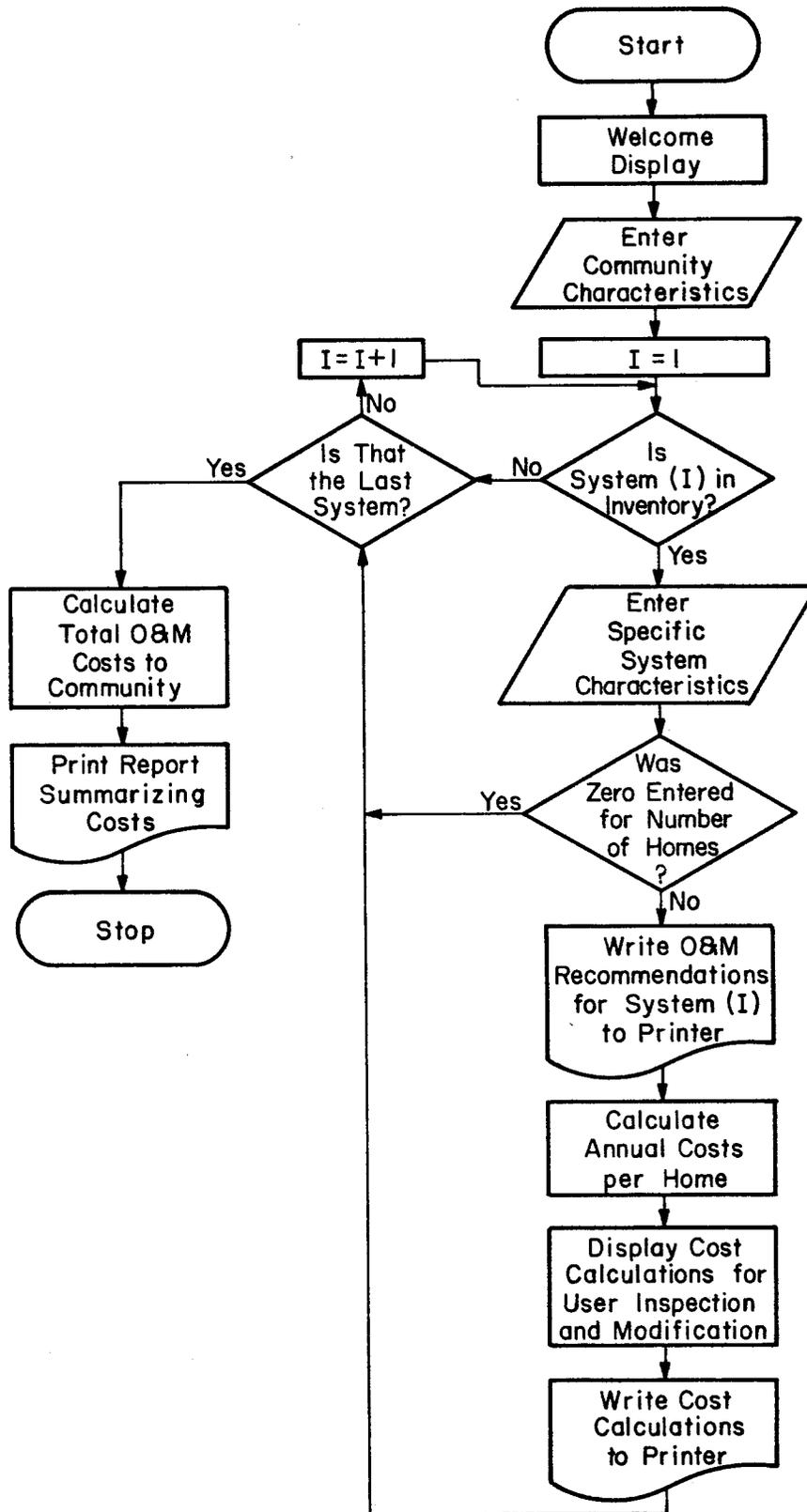


Figure 5. Structured flow of main computer program.

Several features were implemented in the system to make it friendly towards novice users and still provide a useful report for an engineer working with a community.

- (1) Error-Proof User Entries - All numerical entries are read in as strings and checked for boundary conditions and format accuracy before conversion. In most cases the user gets to look at his entries to assure correctness before he moves on.
- (2) Concise Sequential Data Entry - The flow of data entry is logical and straightforward, moving from one system to the next in a predetermined order.
- (3) An Individualized Report - The report generated by the program includes user specifics within it to give the user and his interested clients a better feeling for their particular community requirements.

The choice of the Apple II+ microcomputer as a host for the O&M requirements system was dictated by two major factors.

- (1) There are a great many Apple IIs already distributed around the country, making it a logical choice for use as a system host. The Apple II and accompanying printer were available to the Agricultural and Chemical Engineering Department for use by the project.
- (2) The programmer was most confident with the language and operating system offered by Apple Pascal. It facilitated system development with its structured programming and easy handling of complex data structures.

A list of the hardware that the program was developed to run on is as follows:

Apple II+ w/language card

or

Apple IIe w/64k (new offering by Apple)

Disk II card w/two disk drives

Printer interface card

IDS 460 "Paper Tiger" Printer

When we asked people in the field for suggestions on the use of a computer, the biggest request was for a program that would also run on the TRS-80. One of the reasons for using Apple Pascal as a development language is its portability to other machines by using the p-system from SofTech Microsystems. An extra \$800 above the hardware cost for a specific machine is required to obtain the UCSD-Pascal operating system. With this operating system, the disks supplied by us will work for the specific machine you have. SofTech Microsystems, Inc. can be contacted at:

16885 West Bernardo Drive
San Diego, CA 92127
(619) 451-1230

Printers were a major source of trouble when we tried to accumulate a list of possible hardware configurations. Only one printer was found to handle our particular typeset requirements of 12cpi and 6lpi: the IDS 460 "Paper Tiger." Other printers can be used through the P-KASO interface, such as the C. Itoh/Apple or Epson, but they require a small amount of extra programming.

In general, the disks that we distribute only work on the hardware configuration given above. Other hardware can be used but not without sacrificing more time to assure that it will work properly.

My conclusions after completion of the project are twofold. First, I found the p-system UCSD-Pascal to be very beneficial as a development system for a major project. It is an added plus to have the portability to most other small computers afforded by the p-system. Second, because

of the extensive size of the O&M requirements records for each particular wastewater technology, the Apple had problems with both disk and memory space. A larger disk and more main memory would have been appreciated. All things considered, I felt the project was successful in developing a useful consulting tool for wastewater engineers and sanitarians.

Some Answers to Common Questions

- (1) What other machines can the OMANAL diskettes be run on?

Your diskettes can be made to run on almost any common computer with a wide enough distribution. Some of the more well known are the TRS-80, the IBM PC, Zenith, Heath, Osborne, and TI 9900 computers.

- (2) What facilitates this move to another computer?

The program on the disk was written in Apple Pascal, a high-level programming language in the p-system. The p-system compilers translate the high-level language into p-code that is interpreted by the machine. SofTech Microsystems in San Diego has developed this system so that about 15 different microprocessors can interpret these programs written in p-code.

- (3) Is this an easy transfer to another machine?

A SofTech representative has assured me that the diskettes will "boot up," start to execute, on any machine that contains a p-code interpreter in its hardware. It is most likely that the program will not act the way its supposed to because of differences in machine dependencies, screen commands in particular. I expect a small amount of extra programming to account for these differences.

- (4) How much will this cost me?

You can expect to pay \$750 for p-system software, about \$400 for hardware (language card/interpreter) + programming costs to adapt to the new machine.

- (5) What kind of printers can I use?

You may use any printer that handles an 8-1/2 x 11 form and will give you 6cpi & 121pi. I only found one printer that satisfied these requirements without writing extra programs. That is the IDS 460 "Paper Tiger." Other common dot matrix printers such as the Epson or the Apple/C Itoh can be used with a special P-Kaso interface that requires a short preliminary program to send ctrl characters to the printer. If a high-quality form is required, a daisy wheel or other solid font printer can be used with the proper interface.

USER DOCUMENTATION OF COMPUTER PROGRAM FOR ON-SITE
WASTEWATER TREATMENT OPERATION AND MAINTENANCE REQUIREMENTS

by

David L. Nettles
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Colorado State University

On-site wastewater treatment technology has been utilized for many years to handle wastewater from individual homes. In many cases, however, the homeowner neglects to assume responsibility for operation and maintenance. This leads to failure of the system with the resulting health and environment problems being of concern to the general community.

If on-site technology is to play a role in the total wastewater management picture, its operation and maintenance must be professionally rendered. Often this is accomplished by a central management organization. The planning of such an organization requires estimates of personnel needs, equipment required, procedures, costs, etc. Until recently, this information was scattered in many publications and required considerable effort to develop good operation and maintenance estimates for on-site technology.

Jim Englehardt, with sponsorship from the National Science Foundation, developed a body of on-site technology operation and maintenance data (presented earlier) that was computerized. The purpose of this paper is to describe how the computerized O&M data is accessed and utilized.

I. Program Structure

The computer program was designed specifically for communities with populations of 5,000 or less. It will accept input populations up to 9,999. If a larger population is present, the population should be broken into representative groups of 9,999 people or less. (These considerations also apply to the number of homes in a community, i.e., a maximum of 9,999 homes.)

The program was also designed for homes only. Schools, businesses, motels, apartments, and churches may be incorporated by converting the estimated wastewater flows from these sources into numbers of equivalent homes as outlined in Section IV.

Other assumptions used in the design of this program are listed in the report generated by the program. These assumptions include:

1. A maximum of 30 homes discharging a total of 10,000 gallons per day to any single wastewater treatment unit;
2. Negligible sewer main operation and maintenance expense;
3. A 20-year planning period;
4. Generalized average costs for labor, mileage, etc. (capital expense, start-up expenses, taxes, insurance, etc.) are not included.

II. Hardware Requirements

The computer program was developed using a specific combination of computer hardware. This same hardware is needed to successfully operate the program although a few options are possible. The following is a list of the hardware needed to run the computer program.

- 1 Apple II Computer 48K;
- 1 Disk II Interface Card 650-X104;
- 1 Language Card (Pascal 670-X006);
- 1 Printer Interface Card;
- 2 Disk drives for 5 1/4 inch Mini-Floppy Disk (Apple II);
- 1 Cathode Ray Tube (Screen); and
- 1 Printer capable of printing 12 characters per inch horizontally and 6 lines per inch vertically (e.g., the IDS 460 Paper Tiger). The program will print on other printers but, the report will be very hard to read words and numbers cut in half, etc.

III. Data Input Procedures

Startup Procedure and Control Characters

The program has been placed on two disks: (1) OMAN and (2) DATABASE. The OMAN disk contains the program that interfaces between the user and the DATABASE. The program has been developed in as "User Friendly" manner as possible. The following discussion describes the startup procedures and the input data requirements.

Startup Procedure

- Put OMAN disk in disk drive 1
- Put DATABASE disk in disk drive 2
- Turn on the keyboard and screen
- Check the printer to insure it is set to give 12 lines per horizontal inch and 6 lines per vertical inch, also check to insure that paper is loaded and at the top of form.
- Turn printer on
- Begin program (machine will automatically give a "Welcome" screen)

Control Characters (used to improve printout appearance)

- / -- capitalizes all characters following on the line
- # -- capitalizes just the character that follows immediately
- CTRL X -- backspaces the whole line
- CTRL S -- stops and starts the whole program
- CTRL A -- shows the second 40 character screen that is not normally visible--must hit CTRL A again to return to the original screen
- CTRL Z -- moves the screen over a few lines at a time
- CTRL C -- cancels the whole program--this command should really never be used in normal operation

Data Required for the Program

It is strongly recommended that the data required by put in the following order. The data is required by the computer as listed below and once a particular system is passed in the program it is impossible to return to that system without starting the entire program again.

Community name

Consultant's name

Population

Date

Current Price Index (OMR)

Total Number of Homes

(All the following data must include a decimal point.)

Septic Tank

Number of tanks
Average miles per service
Number of homes

Septic Tank Effluent Pump

Number of pumps
Number of homes

Individual Aerobic (0-2000 gpd)

Number of surface discharge plants
Average miles per service
Number of homes

2000-10,000 gpd Extended Aeration Package Plants

Number of plants
Average miles per service
Number of surface discharge plants
Number of plants without separate disposal (digester
or land disposal)
Number of homes

0-10,000 gpd Lagoons

Number of surface discharging lagoons
Number of aerated lagoons
Total number of lagoons
Average miles per service
Number of homes

0-10,000 gpd Rotating Disk Package Plants

Number of plants
Number of surface discharge plants
Average miles per service
Number of homes

Leachfield, Mound, Evapotranspiration (ET) Beds

Number of homes with mounds
Number of homes with ET beds
Total number of mounds and ET beds
Number of homes with leachfields
Total number of homes
Optional Failed System Replacement for Leachfield, Mound
and ET Beds (yes or no) and failure rate if yes (1.0 =
100% failure)

Buried Sand Filters (Single home with surface discharge)

Filters following septic tanks
Number of homes
Failure rate

Accessible Sand Filters (Surface discharge)

Number of filters
Number of filters following septic tanks
Number of homes with recirculating filters
Number of homes with non-recirculating filters
Number of homes

Tablet Chlorinators

Number of individual units
Number of cluster units
Number of homes

IV. Data Preparation

The following paragraphs are a partial list of data preparation procedures that may apply.

As mentioned in Section I, the program was designed only for homes, thus businesses, motels, etc., must be converted into numbers of homes. This is accomplished very easily by realizing that the program assumes 100 gpcd design flow, 45 gpcd average daily flow, and 3.33 persons per home. The design flow for each business in gallons per day can be used with the embedded assumptions to arrive at an equivalent number of homes. (A fractional number of homes may be used). For example,

consider converting 1,000 gal/day design flow to the equivalent number of homes.

$$1,000 \frac{\text{gal}}{\text{day}} \times \frac{\text{persons-day}}{100 \text{ gal}} \times \frac{\text{home}}{3.33 \text{ persons}} = 3.0 \text{ homes}$$

Or consider converting 500 gal/day average daily flow to the equivalent number of homes.

average daily flow:

$$500 \frac{\text{gal}}{\text{day}} \times \frac{\text{persons-day}}{45 \text{ gal}} \times \frac{\text{home}}{3.33 \text{ persons}} = 3.34 \text{ homes}$$

Requirements for the 0-2000 gpd Aerobic Units are based on single home units, however, costs are assumed linear up to 6 homes. This should provide a reasonable estimate for units serving from 2 to 5 homes which is a relatively uncommon size.

Where a large area is to be managed centrally, the program will need to be tailored to the situation. For example:

-
- an out-of-town septage pumping rate could be needed (\$75.00 instead of \$50.00)
 - 1,300 homes require one full-time septic tank inspection person (Multiples of this number will require additional sets of equipment) i.e., for 13,000 homes, input 1,300 homes and multiply the cost in Table 1 of the report generated by 10 to get an accurate cost per home estimate.
 - communities with evapotranspiration (ET) beds but no mounds or leachfields will need ground-water monitoring and analysis, thus the ground-water test costs must be changed to 0.
 - where leachfields or mounds are used in more than on sub-division, ground-water basin, or aquifer, the ground-water test costs must be multiplied by the number of areas to be monitored.

The service vehicle mileage must include all scheduled and unscheduled travel, trips to suppliers, etc. As an example, suppose that a service

person travels 6 miles to inspect 3 closely grouped homes, then 6 miles back to a typical morning. The average miles per service would be:

$$\frac{2 \text{ trips} \times 6 \text{ miles/trip}}{3 \text{ inspections}} = 4 \text{ miles/inspection}$$

Temperature is an important factor in the performance of rotating disk units; thus such units should be enclosed for temperature maintenance. In situations where the wastewater temperature is less than 55°F either heat may be added to the enclosure or the unit may be sized larger to decrease hydraulic loading, increase detention time, increase volume-to-surface ratio, etc. The program has made no provision to calculate the cost of any added heat. This cost must be estimated on an individual basis and added to the costs estimated by the program.

The annual costs per home are calculated for each system using average costs for labor, mileage, etc. These costs may be examined and/or changed for all systems.

The most recent OMR (inflation) index may be obtained from:

Jon Hunter: (202) 382-2333
Robert Michel: (202) 775-4912

Address:

U.S. Environmental Protection Agency
401 M. Street Southwest
Mail Code WH 595
Washington, D.C. 20460

V. Output Information

The program will print the appendix first, then the main report. The appendix includes a list of procedures and schedules, personnel and contracted work, parts and supplies, equipment, and power for each system, as well as a calculation of the annual costs per home for each

system. This information is presented in the same form as the figures in Jim Englehardt's paper. The main report includes the objectives, assumptions, procedures, and results of the program.

In the appendix, it should be understood that in calculating the annual costs per home those values printed in all upper case were input information, and those values printed in lower case were internal to the program. Most of the internal values can be changed; an altered value will have an (Λ) under it in the printout. Example:

$$1.00 \frac{\text{Pumping}}{\text{plant}} \times \frac{\$75.00}{\text{pumping}} \times 1.00 \text{ PLANTS} \times \frac{1}{10 \text{ HOMES}} = \$7.50$$

Λ

Altered value Input data

The meaning of the (Λ) will also be footnoted at the end of that particular annual costs per home section.

The main report printed by the computer will list in a Table 1, the annual cost per home, the number of homes, and the annual cost to the community of each system. Table 1 in the printed report also contains the total annual costs to the community of all the systems combined. Table 2 of the main report lists, but does not calculate, the other expenses to be considered in the planning of a combined system. An example of a main report is presented in the appendix to Jim Englehardt's paper.

APPENDIX A.

Computer-Generated Report for
Boulder County, Colorado

COMMUNITY MANAGEMENT OF ON-SITE WASTEWATER TREATMENT FACILITIES

- Evaluation of Operation and Maintenance Costs -

for

Boulder County

October 29, 1982

Performed by

James Englehardt

Computer support for this analysis was developed by James D. Englehardt, Stewart Noyce and Robert C. Ward, Agricultural and Chemical Engineering Department, Colorado State University, Fort Collins, Colorado, under partial sponsorship of the National Science Foundation.

INTRODUCTION

On-site wastewater treatment technology is increasingly being viewed as a viable wastewater management alternative for small communities if the community can ensure that all management functions are properly addressed. These management functions are:

1. Planning
2. Design
3. Installation
4. Operation
5. Maintenance

Operation and maintenance, unlike the first three functions, is generally the responsibility of the homeowner. Surveys have revealed that while local (usually county) governments attempt to manage planning, design and installation, a majority of homeowners do not accept, in a conscientious manner, their designated operation and maintenance responsibilities.

Thus, for a community to consider on-site technology as a viable wastewater treatment alternative, it must first address weaknesses in the current management structure. While this should entail a close examination of all five management functions, it is the operation and maintenance (O&M) area that will need the most attention.

This latter fact stems, until recently, from a poorly defined role for O&M. In 1980, the National Science Foundation, through its Appropriate Technology Program, supported a research effort at Colorado State University to develop O&M data for on-site technology and a means of utilizing this data. This report is developed from the results of that project using additional site specific data provided by James Englehardt.

OBJECTIVES

The intent of this report is to present the costs for any or all phases of a comprehensive small flow wastewater O&M program, specific to Boulder County. A proposed or existing combination of small flow technology has been specified by James Englehardt. A computer program has been used to detail all factors involved and present the associated costs individually (appendix) and in summary form. Any individual costs may have been altered or deleted by James Englehardt to tailor the results to this case study. These changes are noted with the results. Thus, the report may be used in cost studies of many different kinds.

It is felt that these procedures and costs provide some of the critical information a community needs to make an informed decision as to the selection of a wastewater management alternative that best meets its needs.

ASSUMPTIONS

The O&M analysis is based on a number of assumptions which should be understood if the results are to be interpreted properly. The following general assumptions and constraints apply:

- a) A maximum of 30 homes discharging a total of 10,000 gpd to any single wastewater treatment unit (average 3.33 persons per home, 100 gpcd design flow, 45 gpcd average daily flow).
- b) Sewer main (gravity or pressure) O&M expense is therefore negligible.
- c) 20 year planning period.
- d) Procedures presented in the appendix are generalized, yet specific enough to justify man-hrs, cost, etc. Actual operating procedures should consider manufacturers' recommendations, when applicable.
- e) Calculations are performed in first quarter, 1982 dollars, then updated using the EPA Municipal Wastewater Treatment (5 mgd activated sludge) Operation, Maintenance, and Repair (OMR) Cost Index.
- f) Capital expense, system rehabilitation, initial start-up expense, insurance, taxes, licenses, and administrative expenses are not included.

The program used to calculate the costs for Boulder County includes many necessarily "average" values for costs, man-hours, etc. Any of these values may have been modified or deleted by James Englehardt to more accurately reflect local conditions. These changes are noted with the results.

The complete, unaltered program would generate the total annual O&M expense to the community assuming a well established, environmentally responsible management program. Included are labor, contracted work, equipment, power, supplies, and replacement of all parts with an expected life less than the 20 year planning period. Replacement of system components with an expected life of greater than 20 years would be considered a capital expense. Costs for initial years of the program are expected to be higher, as operator training and other startup expenses would be incurred. Costs presented may be somewhat conservative. This, however, will vary with the number of homes utilizing a particular treatment system and other factors, and must be evaluated individually.

PROCEDURES

James Englehardt's personnel have surveyed the community and determined the number and type of the on-site systems to be included in the ongoing O&M program. Site specific data, such as the distance between homes (service vehicle mileage) have been determined. The above information, along with data and information provided by the NSF funded research at CSU, has been used to compute the total community costs, as follows. Costs were calculated for each component (unit process) of the small flow systems to be used in Boulder County, in 1982 dollars. (Each home may utilize any combination of these components, for instance a septic tank with an effluent pump and a leachfield.) These costs were then updated using the EPA cost index mentioned above, and summed for the community.

RESULTS

Boulder County, population 195800 has 14,000 homes where small flow systems will be updated and/or installed to provide the community's wastewater treatment needs. Table 1 summarizes the O&M costs for these components. Again, detailed derivation of costs can be found in the

Appendix.

Table 1. O&M Cost Summary

Small-flow technology	Annual cost per home		Number of homes	Annual cost to community
Septic Tank	\$ 32.99	*	14000	= \$ 461903.00
Septic Tank Effluent Pump	\$ 71.13	*	250	= \$ 17782.3
Individual Aerobic	\$ 572.97	*	163	= \$ 93394.5
Ext aeration package plants	\$ 464.80	*	72	= \$ 33465.9
Rotating disk package plants	\$ 64.33	*	18	= \$ 1157.87
Lagoons	\$ 21.12	*	54	= \$ 1140.60
Leachfield, Mound, ET	\$ 1.04	*	14000	= \$ 14782.00
Accessible Sand Filters	\$ 114.47	*	15	= \$ 1717.10
Tablet Chlorinators	\$ 32.13	*	72	= \$ 2313.14
Total:				\$ 198640.

Other costs which must be considered in evaluating this wastewater alternative are listed in Table 2.

Table 2. Other Expenses

Capital expense:	equipment
	contractors
	land
	interest during construction
	- salvage value
Insurance, taxes, license fees	
Administrative:	administrator/engineer (part time)
	secretary, clerk, accountant (part time)
	office space, equipment, supplies
Startup and operator training (% of total O&M and administrative expense)	

APPENDIX B.

Listing of Main Program

```

(*SS-*)
(*%L CONSOLE:*)

PROGRAM OMANAL;

USES EXTRAS,CURMOVE,INTEXT,TEXTWRITER;

CONST
  A = 31;
  B = 15;
  C = 10;
  D = 4;
  E = 12;
  MAXLNE = 6;
  MAXCST = 8;
  MAXVALS = 3;
  MAXIVT = 7;
  MAXTH = 8;
  OLDCPI = 3.44;

TYPE
  SYSTEMS = (STNK,STEP,INDAER,EAPP,RDPP,GOONS,LMET,BSF,ASF,TABCLR,NOTSYSTEM);
  SETOFSYSTEMS = SET OF SYSTEMS;
  ONEVAL = RECORD
    VALTYPE: INTEGER;
    XCRD,YCRD: INTEGER;
    POSTN: INTEGER;
    VALUE: STRING5
  END;
  ONELINE = RECORD
    STR: STRING;
    VALUES: (YES,NO);
    NUMVALS: INTEGER;
    VARR: ARRAY[1..MAXVALS] OF ONEVAL
  END;
  LINEREC = RECORD
    CNAME: STRING30;
    LNENUM: INTEGER;
    LARR: ARRAY[1..MAXLNE] OF ONELINE
  END;
  COSTREC = RECORD
    OPTIVT: INTEGER;
    OPTLNE: INTEGER;
    IVTNUM: INTEGER;
    IVTARR: ARRAY[1..MAXIVT] OF STRING30;
    CSTNUM: INTEGER;
    CARR: ARRAY[1..MAXCST] OF LINEREC
  END;
  DATAREC = RECORD
    NAME: STRING;
    SUMNAME: STRING30;
    PROCEDRES: ARRAY[1..A] OF STRING;
    NUMPROC: INTEGER;
    PERSONNEL: ARRAY[1..B] OF STRING;
    NUMPERS: INTEGER;
    SUPPLIES: ARRAY[1..C] OF STRING;
    NUMSUPP: INTEGER;
    POWER: ARRAY[1..D] OF STRING;
    NUMPOWR: INTEGER;
    EQUIPREQ: ARRAY[1..E] OF STRING;
    NUMEQUP: INTEGER;
    COSTS: COSTREC
  END;
  DATAFILE = FILE OF DATAREC;

VAR
  I,J,K,POPLTN,HMES,LINECOUNT: INTEGER;
  CPI: REAL;
  COMNAME,CONSNAME,DATE: STRING30;
  INST5: STRING5;
  CH: CHAR;
  REPORTDAT,LP: TEXT;
  DATA: DATAFILE;
  USED: BOOLEAN;
  CURREC: DATAREC;
  SYSTYPE: SYSTEMS;
  SYSUSED: SETOFSYSTEMS;
  TOTAL: ARRAY[STNK..TABCLR] OF REAL;
  RCALC: ARRAY[1..MAXCST] OF REAL;
  HOMES: ARRAY[STNK..TABCLR] OF REAL;
  SMNAME: ARRAY[STNK..TABCLR] OF STRING30;

```

```

SEGMENT PROCEDURE SETUP;
PROCEDURE INTRO;
BEGIN   (* INTRO *)
  CLRSCREEN;
  GOTOXY(5,5);
  WRITELN('WELCOME TO OMANAL. THIS PROGRAM');
  WRITELN('HAS BEEN WRITTEN WITH THE SANITATION');
  WRITELN('ENGINEER OR CITY MANAGER IN MIND TO');
  WRITELN('FACILITATE OPERATIONS & MAINTENANCE');
  WRITELN('ANALYSIS FOR SMALL SYSTEM TECHNOLOGYS');
  WRITELN('WE SUGGEST YOU KEEP THE USER MANUAL');
  WRITELN('CLOSE BY IN CASE A QUESTION SHOULD');
  WRITELN('COME UP. HIT THE SPACE BAR TO CONTINUE');
  WRITE('WITH THE ANALYSIS. ');
  READ(CH);
  REPEAT
    CLRSCREEN;
    GOTOXY(7,2);
    WRITE('COMMUNITY CHARACTERISTICS');
    GOTOXY(12,5);
    WRITE('COMMUNITY NAME');
    GOTOXY(11,8);
    WRITE('CONSULTANT'S NAME');
    GOTOXY(14,11);
    WRITE('POPULATION');
    GOTOXY(17,14);
    WRITE('DATE');
    GOTOXY(10,17);
    WRITE('CURRENT PRICE INDEX');
    GOTOXY(12,20);
    WRITE('NUMBER OF HOMES');
    GETSTRING(COMNAME,10,6);
    GETSTRING(CONSNAME,9,9);
    READNT(POPLTN,9999,1,17,12);
    GETSTRING( DATE, 12,15);
    GETREAL(INSTS,17,18);
    REALCONV(INSTS,CPI);
    READNT(HMES,9999,1,17,21);
    GOTOXY(0,23);
    WRITE('IS THE ABOVE INFORMATION CORRECT? Y/N ');
    READ(CH);
  UNTIL CH = 'Y'
END;   (* INTRO *)
PROCEDURE INITVARS;
BEGIN   (* INITVARS *)
  SYSUSED := [];
  COMNAME := '';
  CONSNAME := '';
  POPLTN := 1;
  HMES := 1;
  DATE := '';
  INSTS := '0.0';
  FOR SYSTYPE := STNK TO TABCLR DO
    HOMES(SYSTYPE) := 0.0
END;   (* INITVARS *)
BEGIN   (* SETUP *)
  RESET(DATA, '#5:DATA');
  INITVARS;
  INTRO
END;   (* SETUP *)

```

SECMET PROCEDURE CLOSING;

PROCEDURE REPORT;

PROCEDURE TITLEPAGE;

VAR

I: INTEGER;

BEGIN (* TITLEPAGE *)

```
LFEED(LP,10);
FSLP(LP,14);
WRITE(LP,'COMMUNITY MANAGEMENT OF ON-SITE WASTEWATER TREATMENT');
WRITE(LP,'FACILITIES');
LFEED(LP,8);
FSLP(LP,23);
WRITE(LP,'- Evaluation of Operation and Maintenance Costs -');
LFEED(LP,2);
FSLP(LP,46);
WRITE(LP,'for');
LFEED(LP,2);
FSLP(LP,(96-LENGTH(COMNAME)) DIV 2);
WRITE(LP,COMNAME);
LFEED(LP,8);
FSLP(LP,(96-LENGTH(DATE)) DIV 2);
WRITE(LP,DATE);
LFEED(LP,10);
FSLP(LP,41);
WRITE(LP,'Performed by ');
LFEED(LP,2);
FSLP(LP,(96-LENGTH(CONSNAME)) DIV 2);
WRITE(LP,CONSNAME);
LFEED(LP,12);
FSLP(LP,12);
FOR I := 1 TO 76 DO
  WRITE(LP,CHR(95));
LFEED(LP,1);
FSLP(LP,12);
WRITE(LP,'Computer support for this analysis was developed ');
WRITE(LP,'by James D. Englehardt');
LFEED(LP,1);
FSLP(LP,13);
WRITE(LP,'Stewart Noyce and Robert C. Ward, Agricultural and ');
WRITE(LP,'Chemical Engineering');
LFEED(LP,1);
FSLP(LP,13);
WRITE(LP,'Department, Colorado State University, ');
WRITE(LP,'Fort Collins, Colorado, under partial');
LFEED(LP,1);
FSLP(LP,13);
WRITE(LP,'sponsorship of the National Science Foundation.')
```

END; (* TITLEPAGE *)

PROCEDURE FINALPAGE;

BEGIN (* FINALPAGE *)

```
LFEED(LP,18);
FSLP(LP,43);
WRITE(LP,'APPENDIX');
LFEED(LP,3);
FSLP(LP,32);
WRITE(LP,'Onsite Systems O&M Requirements');
LFEED(LP,1)
```

END; (* FINALPAGE *)

PROCEDURE SUMMARY;

VAR

GRAND: REAL;
LEN: INTEGER;

```

BEGIN  (* SUMMARY *)
  GRAND := 0.0;
  FOR SYSTYPE := STNK TO TABCLR DO
    IF SYSTYPE IN SYSUSED THEN BEGIN
      WRITE(LP, SMNAME[SYSTYPE]);
      REALLENGTH(TOTAL[SYSTYPE], LEN);
      FSLP(LP, 38 - LENGTH(SMNAME[SYSTYPE]) - LEN);
      WRITE(LP, '$', TOTAL[SYSTYPE]:6:2, '*');
      REALLENGTH(HOMES[SYSTYPE], LEN);
      IF HOMES[SYSTYPE] < 10.0 THEN
        WRITE(LP, ' ');
      FSLP(LP, 12 - LEN);
      WRITE(LP, TRUNC(HOMES[SYSTYPE]), '=');
      TOTAL[SYSTYPE] := TOTAL[SYSTYPE] * HOMES[SYSTYPE];
      REALLENGTH(TOTAL[SYSTYPE], LEN);
      IF LEN < 10 THEN
        FSLP(LP, 1);
      WRITE(LP, '$', TOTAL[SYSTYPE]:9:2);
      LFEED(LP, 2);
      FSLP(LP, 12);
      GRAND := GRAND + TOTAL[SYSTYPE];
    END;  (* SUMMARY LINE *)

  WRITE(LP, 'Total:');
  FSLP(LP, 53);
  WRITE(LP, '$', GRAND:9:2);
  LFEED(LP, 1)

END;  (* SUMMARY *)

BEGIN  (* REPORT *)

  NEWPAGE(LP);
  TITLEPAGE;
  NEWPAGE(LP);
  LFEED(LP, 6);
  WRTEXT(REPORTDAT, LP, COMNAME, CONSNAME, DATE, POPLTN, HMES);
  SUMMARY;
  WRTEXT(REPORTDAT, LP, COMNAME, CONSNAME, DATE, POPLTN, HMES);
  NEWPAGE(LP);
  FINALPAGE;
  NEWPAGE(LP)

END;  (* REPORT *)

BEGIN  (* CLOSING *)

  REPORT

END;  (* CLOSING *)

SEGMENT PROCEDURE SYSCHK;

PROCEDURE SYSINV;

VAR
  REALS: ARRAY[1..MAXTH] OF STRINGS;

PROCEDURE GETVALS;

BEGIN  (* GETVALS *)

  WITH CURREC.COSTS DO BEGIN

    REPEAT

      CLRSCREEN;
      WRITE(' INPUT REAL NO.S FOR THE FOLLOWING');

      FOR I := 1 TO OPTIVT - 1 DO BEGIN
        J := 2 * I;
        GOTOXY(0, J);
        WRITE('IVTARR[11.??)');
      END;

      CR(2);
      WRITELN('NUMBER OF HOMES?');
      CR(1);
      WRITELN('HOMES = 0.0 INDICATES SYSTEM IS NOT USED');
      GOTOXY(19, 19);
      WRITE('FOR');
      GOTOXY(20 - (LENGTH(CURREC.SUMNAME) DIV 2), 20);
      WRITE(CURREC.SUMNAME);

      FOR I := 1 TO OPTIVT - 1 DO BEGIN
        J := 2 * I;
        GETREAL(REALS[I], 30, J)
      END;
      GETREAL(REALS[IVTNUM+1], 30, J+2);

      GOTOXY(0, 23);
      WRITE('IS THE ABOVE INFORMATION CORRECT? Y/N ');
      READ(CH);

    UNTIL CH = 'Y';

  END;

END;

```

```

IF OPTIVT (= IVTNUM THEN BEGIN
  CLRSCREEN;
  COTOXY(0,10);
  WRITELN('IS THE OPTIONAL FAILED SYSTEM');
  WRITE('REPLACEMENT TO BE USED? Y/N - ');
  READ(CH);

  IF CH = 'Y' THEN
    REPEAT
      CLRSCREEN;
      WRITELN('OPTIONAL FAILED SYSTEM REPLACEMENT');
      WRITE('FOR ',CURREC.SUMNAME);
      FOR I := OPTIVT TO IVTNUM DO BEGIN
        J := 2 * I;
        COTOXY(0,J);
        WRITE('IVTARR[11,?')
      END;

      FOR I := OPTIVT TO IVTNUM DO BEGIN
        J := 2 * I;
        GETREAL(REALS[11,30,J])
      END;

      GOTOXY(0,23);
      WRITE('IS THE ABOVE INFORMATION CORRECT? Y/N ');
      READ(CH);

    UNTIL CH = 'Y'
  ELSE
    CSTNUM := OPTLINE - 1
  END (* IF OPTIVT < IVTNUM *)
END (* WITH *)

END; (* GETVALS *)

PROCEDURE SETVALS;
BEGIN (* SETVALS *)
  WITH CURREC.COSTS DO
    FOR I := 1 TO CSTNUM DO
      FOR J := 1 TO CARRI1.LNENUM DO
        WITH CARRI1.LARRI[J] DO
          IF VALUES = YES THEN
            FOR K := 1 TO NUMVALS DO
              WITH VARR[K] DO
                IF VALTYPE > 0 THEN
                  VALUE := REALS[VALTYPE]
            END;
          END;
        END;
      END;
    END;
  END; (* SETVALS *)

BEGIN (* SYSINV *)
  REPEAT
    USED := TRUE;
    CLRSCREEN;
    GOTOXY(10,10);
    WRITELN('DO YOU HAVE ');
    WRITE(' ',CURREC.NAME);
    WRITE(' IN YOUR SYSTEM INVENTORY? Y/N ');
    READ(CH);
  UNTIL (CH = 'Y') OR (CH = 'N');

  FOR I := 1 TO CURREC.COSTS.IVTNUM+1 DO
    REALS[11] := '0.0';

  IF CH (<) 'N' THEN BEGIN
    GETVALS;
    REALCONV(REALS[CURREC.COSTS.IVTNUM+1],HOMES[SYSTYPE]);
    IF HOMES[SYSTYPE] = 0.0 THEN
      USED := FALSE
    ELSE
      SETVALS
    END
  ELSE
    USED := FALSE
  END;
END; (* SYSINV *)

BEGIN (* SYSCHK *)
  CURREC := DATA^;
  IF SYSTYPE (<) TABCLR THEN
    GET(DATA);

  SMNAME[SYSTYPE] := CURREC.SUMNAME;
  SYSINV

END; (* SYSCHK *)

(*I #5:SYSTINFO.TEXT *)

```

```

BEGIN      (* OMANAL *)
  REWRITE(LP, 'PRINTER:');
  REPEAT
    SETUP;
    FOR SYSTYPE := STNK TO TABCLR DO BEGIN
      SYSCHK;
      IF USED THEN
        SYSTINFO
    END;
    CLOSE(DATA);
    RESET(REPORTDAT, '#4:REPT.TEXT');
    CLOSING;
  UNTIL TRUE
END.      (* OMANAL *)

SEGMENT PROCEDURE SYSTINFO:
TYPE
  VALREC = RECORD
    FLAG: BOOLEAN;
    OLDVAL: REAL
  END;
  INTARR = ARRAY[1..5] OF INTEGER;
VAR
  BARR: ARRAY[1..MAXCST, 1..MAXLNE, 1..MAXVALS] OF VALREC;
  STORE: INTARR;
  HOMENUM: INTEGER;
  CHNGES: BOOLEAN;

  FUNCTION CALCULATE(VAR COST: LINEREC; HOME: INTEGER): REAL; FORWARD;

SEGMENT PROCEDURE DUMPTXT;
VAR
  TAB: INTEGER;

  PROCEDURE NEXTPAGE;
  BEGIN (* NEXTPAGE *)
    IF LINECOUNT >= 54 THEN BEGIN
      NEWPAGE(LP);
      LFEEED(LP, 6);
      LINECOUNT := 0
    END
  END; (* NEXTPAGE *)

  PROCEDURE TEXTSPLIT;
  BEGIN (* TEXTSPLIT *)
    IF LINECOUNT > 50 THEN BEGIN
      LINECOUNT := LINECOUNT + 5;
      NEXTPAGE
    END
    ELSE BEGIN
      LFEEED(LP, 1);
      LINECOUNT := LINECOUNT + 1
    END
  END; (* TEXTSPLIT *)

  PROCEDURE WRTLINE(VAR INSTR: STRING);
  BEGIN (* WRTLINE *)
    NEXTPAGE;
    FSLP(LP, 12);
    WRITE(LP, INSTR);
    LFEEED(LP, 1);
    LINECOUNT := LINECOUNT + 1
  END; (* WRTLINE *)

```

```

BEGIN      (* DUMPTXT *)

NEWPAGE(LP);
LFEEED(LP,6);
TAB := (72 - LENGTH(CURREC.NAME)) DIV 2;
FSLP(LP,12+TAB);
WRITE(LP,CURREC.NAME);
LFEEED(LP,3);
LINECOUNT := 3;

WITH CURREC DO BEGIN

    FSLP(LP,12);
    WRITE(LP,'PROCEDURES AND SCHEDULES');
    LFEEED(LP,2);
    LINECOUNT := LINECOUNT + 2;
    I := 0;
    WHILE I < NUMPROC DO BEGIN
        I := I + 1;
        WRTLINE(PROCEDRES(I))
    END;

    TEXTSPLIT;
    FSLP(LP,12);
    WRITE(LP,'PERSONNEL AND CONTRACTED WORK');
    LFEEED(LP,2);
    LINECOUNT := LINECOUNT + 2;
    I := 0;
    WHILE I < NUMPERS DO BEGIN
        I := I + 1;
        WRTLINE(PERSONNEL(I))
    END;

    TEXTSPLIT;
    FSLP(LP,12);
    WRITE(LP,'PARTS AND SUPPLIES');
    LFEEED(LP,2);
    LINECOUNT := LINECOUNT + 2;
    I := 0;
    WHILE I < NUMSUPP DO BEGIN
        I := I + 1;
        WRTLINE(SUPPLIES(I))
    END;

    TEXTSPLIT;
    FSLP(LP,12);
    WRITE(LP,'EQUIPMENT ');
    LFEEED(LP,2);
    LINECOUNT := LINECOUNT + 2;
    I := 0;
    WHILE I < NUMEQUP DO BEGIN
        I := I + 1;
        WRTLINE(EQUIPREQ(I))
    END;

    TEXTSPLIT;
    FSLP(LP,12);
    WRITE(LP,'POWER');
    LFEEED(LP,2);
    LINECOUNT := LINECOUNT + 2;
    I := 0;
    WHILE I < NUMPOWR DO BEGIN
        I := I + 1;
        WRTLINE(POWER(I))
    END

END      (* WITH *)

END;      (* DUMPTXT *)

```

```

SEGMENT PROCEDURE COSTSCREEN;
PROCEDURE COSTINIT;
VAR
  I,J,K:INTEGER;
BEGIN  (* COSTINIT *)
  HOMENUM := CURREC.COSTS.IVTNUM+1;
  FOR I := 1 TO MAXCST DO
    FOR J := 1 TO MAXLNE DO
      FOR K := 1 TO MAXVALS DO
        WITH CURREC.COSTS DO BEGIN
          BARR(I,J,K).FLAG := FALSE;
          WITH CARR(I).LARR(J).VARR(K) DO
            IF VALTYPE = 0 THEN
              REALCONV(VALUE,BARR(I,J,K).OLDVAL)
          END
        END
      END
    END
  END;  (* COSTINIT *)

PROCEDURE PRINTCOST(VAR COST:LINEREC);
VAR
  START:INTEGER;
  STROUT:STRING;
  COSTVAL,REALVAL:REAL;
PROCEDURE CLEARAREA;
BEGIN  (* CLEARAREA *)
  GOTOXY(0,2);
  CLR(16)
END;  (* CLEARAREA *)
BEGIN  (* PRINTCOST *)
  CLEARAREA;
  COSTVAL := CALCULATE(COST.HOMENUM);
  WRITE(COST.CNAME);
  CR(2);
  FOR J := 1 TO COST.LNENUM DO
    WITH COST.LARR(J) DO BEGIN
      IF VALUES = NO THEN BEGIN
        WRITE(STR);
        IF J = COST.LNENUM-1 THEN
          WRITE(' $',COSTVAL:6:2);
        CR(1)
      END
      ELSE BEGIN
        START := 1;
        FOR K := 1 TO NUMVALS DO BEGIN
          STROUT := COPY(STR,START,VARR(K).POSTN-START);
          WRITE(STROUT);
          START := VARR(K).POSTN;
          REALCONV(VARR(K).VALUE,REALVAL);
          WRITE(REALVAL:6:2)
        END;
        STROUT := COPY(STR,START,LENGTH(STR)-START+1);
        WRITE(STROUT);
        IF J = COST.LNENUM-1 THEN
          WRITE(' $',COSTVAL:6:2);
        CR(1)
      END;  (* IF THEN ELSE *)
    END
  END
  IF J = 3 THEN
    CR(1)
  END  (* WITH *)
END;  (* PRINTCOST *)

PROCEDURE INDEX(VAR COST:LINEREC);
BEGIN  (* INDEX *)
  FOR J := 1 TO COST.LNENUM DO
    WITH COST.LARR(J) DO
      IF VALUES = YES THEN
        FOR K := 1 TO NUMVALS DO
          WITH VARR(K) DO
            IF VALTYPE = 0 THEN BEGIN
              GOTOXY(XCRD,YCRD);
              WRITE('(' '.J.K.' ')')
            END
          END
        END
      END
    END
  END;  (* INDEX *)

```

```

PROCEDURE COMMAND;
BEGIN  (* COMMAND *)
  CLRSCREEN;
  GOTOXY(20-(LENGTH(CURREC.SUMNAME) DIV 2),1);
  WRITE(CURREC.SUMNAME);
  GOTOXY(0,8);
  FOR I := 1 TO CURREC.COSTS.CSTNUM DO
    WITH CURREC.COSTS.CARR[I] DO
      WRITELN(I,' - ',CNAME);

  GOTOXY(3,18);
  WRITELN('YOU MAY LOOK AT A COST OR CHANGE ONE');
  WRITELN(' THE COSTS ARE LISTED ABOVE');
  WRITELN(' COMMANDS ARE:');
  WRITELN(' D - DISPLAY C - CHANGE X - EXIT');
  WRITE('ENTER COMMAND (SINGLE CHARCTR) - ');
  READ(CH)

END;  (* COMMAND *)

PROCEDURE DISPLAY;
BEGIN  (* DISPLAY *)
  WITH CURREC.COSTS DO BEGIN
    GOTOXY(0,18);
    WRITELN(CHR(11),'WHICH COST WOULD YOU LIKE TO SEE? ');
    WRITE(' (GIVE INTEGER)');
    I := 1;
    READNT(I,CSTNUM,1,35,18);

    PRINTCOST(CARR[I]);

    GOTOXY(0,18);
    WRITE(CHR(11),'HIT THE SPACEBAR TO CONTINUE');
    READ(CH)

  END  (* WITH *)
END;  (* DISPLAY *)

PROCEDURE CHANGE;
VAR
  OKAY: BOOLEAN;
  TOPS,INDX,ONES,TENS: INTEGER;
  REALNUM: REAL;
  PROCEDURE CHECKPOINT(VAR COST:LINEREC);
    PROCEDURE ERPRC;
      BEGIN  (* ERPRC *)
        OKAY := FALSE;
        GOTOXY(0,22);
        WRITELN('/// ERROR /// BAD INDEX');
        WRITE('INDEX MUST APPEAR ON SCREEN')
      END;  (* ERPRC *)
    BEGIN  (* CHECKPOINT *)
      WITH COST DO BEGIN
        ONES := INDX MOD 10;
        TENS := INDX DIV 10;
        IF (TENS < 1) OR (TENS > LNENUM) THEN
          ERPRC
        ELSE
          WITH LARRITENS1 DO
            IF VALUES = NO THEN
              ERPRC
            ELSE
              IF (ONES < 1) OR (ONES > NUMVALS) THEN
                ERPRC
              ELSE
                IF VARR[ONES].VALTYPE (<) 0 THEN
                  ERPRC
            END  (* WITH *)
          END;  (* CHECKPOINT *)
    END;

```

```

BEGIN      (* CHANGE *)
  WITH CURREC.COSTS DO BEGIN
    GOTOXY(0,18);
    WRITELN(CHR(11),'WHICH COST WOULD YOU LIKE TO CHANGE? - ');
    WRITE(' ( GIVE INTEGER )');
    I := 1;
    READNT(I,CSTNUM,1,39,18);
    OKAY := FALSE;
    FOR J := 1 TO CARR(I).LNENUM DO
      IF CARR(I).LARR(J).VALUES = YES THEN
        FOR K := 1 TO CARR(I).LARR(J).NUMVALS DO
          IF CARR(I).LARR(J).VARR(K).VALTYPE = 0 THEN
            OKAY := TRUE;
    IF OKAY THEN
      REPEAT
        PRINTCOST(CARR(I));
        INDEX(CARR(I));
        WITH CARR(I) DO
          REPEAT
            OKAY := TRUE;
            GOTOXY(0,18);
            CLR(2);
            WRITELN('WHICH VALUE TO CHANGE - ');
            WRITE(' ( GIVE INDEX )');
            INDX := 1;
            TOPS := (LNENUM+1)*10;
            READNT(INDX,TOPS,11,24,18);
            CHECKPOINT(CARR(I));
            J := TENS;
            K := ONES;
          UNTIL OKAY;
            GOTOXY(0,20);
            WRITE(CHR(11),'VALUE - ');
            GETREAL(CARR(I).LARR(J).VARR(K).VALUE,9,20);
            GOTOXY(0,21);
            WRITE('ANYMORE CHANGES? Y/N ');
            READ(CH);
            BARR(I,J,K).FLAG := TRUE;
            REALCONV(CARR(I).LARR(J).VARR(K).VALUE,REALNUM);
            IF BARR(I,J,K).OLDVAL = REALNUM THEN
              BARR(I,J,K).FLAG := FALSE;
          UNTIL CH = 'N'
        END      (* WITH *)
      END;      (* CHANGE *)
  END;
BEGIN      (* COSTSCREEN *)
  COSTINIT;
  REPEAT
    COMMAND;
    CASE CH OF
      'D': DISPLAY;
      'C': CHANGE;
    END;
  UNTIL CH = 'X'
END;      (* COSTSCREEN *)

```

```

SEGMENT PROCEDURE COSTCALC;
VAR
  I: INTEGER;
BEGIN
  (* COSTCALC *)
  FOR I := 1 TO CURREC.COSTS.CSTNUM DO
    WITH CURREC.COSTS DO
      RCALC(I) := CALCULATE(CARR(I),IVTNUM+1);
  TOTAL(SYSTYPE) := 0.0;
  FOR I := 1 TO CURREC.COSTS.CSTNUM DO
    TOTAL(SYSTYPE) := TOTAL(SYSTYPE) + RCALC(I)
  END;
  (* COSTCALC *)

SEGMENT PROCEDURE DUMPCALC;
VAR
  LEN: INTEGER;
  PROCEDURE FRMFEED(VAR COST:LINEREC);
  BEGIN
    (* FRMFEED *)
    WITH COST DO BEGIN
      IF ((LINECOUNT+LNENUM+2) >= 54) THEN BEGIN
        NEWPAGE(LP);
        LFEEED(LP,6);
        LINECOUNT := 0
      END
    END (* WITH *)
  END;
  (* FRMFEED *)
  PROCEDURE PRTCST(VAR COST:LINEREC);
  VAR
    START, SLEN, NEWLEN: INTEGER;
    STROUT: STRING;
    REALNUM: REAL;
  PROCEDURE FOOTNOTES;
  VAR
    ITER, START, K, COUNT: INTEGER;
    SETFLAG: BOOLEAN;
  PROCEDURE SORT(VAR STORE:INTARR;COUNT: INTEGER);
  VAR
    HIGH, LOC, I, TEMP: INTEGER;
  BEGIN
    (* SORT *)
    WHILE COUNT > 0 DO BEGIN
      HIGH := 0;
      FOR I := 1 TO COUNT DO
        IF STORE(I) >= HIGH THEN BEGIN
          HIGH := STORE(I);
          LOC := I
        END;
      TEMP := STORE(COUNT);
      STORE(COUNT) := HIGH;
      STORE(LOC) := TEMP;
      COUNT := COUNT - 1
    END (* WHILE *)
  END;
  (* SORT *)

```

```

BEGIN      (* FOOTNOTES *)
  WITH CURREC.COSTS.CARR(I) DO BEGIN
    START := J - 2;
    COUNT := 0;
    SETFLAG := FALSE;
    FOR ITER := START TO J DO
      FOR K := 1 TO LARR(ITER).NUMVALS DO
        IF BARR(I,ITER,K).FLAG THEN
          SETFLAG := TRUE;
    IF SETFLAG THEN BEGIN
      CHNGES := TRUE;
      FOR ITER := START TO J DO
        FOR K := 1 TO LARR(ITER).NUMVALS DO
          IF BARR(I,ITER,K).FLAG THEN BEGIN
            COUNT := COUNT + 1;
            STORECOUNT1 := LARR(ITER).VARR(K).XCRD + 16
          END;
      SORT(STORE.COUNT);
      START := 1;
      FOR ITER := 1 TO COUNT DO BEGIN
        FSLP(LP,STORE(ITER)-START);
        WRITE(LP,'^');
        START := STORE(ITER) + 1
      END (* FOR *)
    END (* IF SETFLAG *)
  END      (* WITH *)
END:      (* FOOTNOTES *)
BEGIN      (* PRTCST *)
  WITH COST DO BEGIN
    LINECOUNT := LINECOUNT + LNENUM + 3;
    IF LNENUM > 3 THEN
      LINECOUNT := LINECOUNT + 1;
    FSLP(LP,12);
    WRITE(LP,CNAME);
    LFEED(LP,2);
    FOR J := 1 TO LNENUM DO
      WITH LARR(J) DO BEGIN
        IF VALUES = NO THEN BEGIN
          FSLP(LP,12);
          WRITE(LP,STR);
          IF J = LNENUM-1 THEN BEGIN
            REALENGTH(RCALC(I),LEN);
            FSLP(LP,76-LENGTH(STR)-LEN);
            WRITE(LP,'$',RCALC(I):6:2)
          END;
          LFEED(LP,1)
        END
        ELSE BEGIN
          SLEN := 0;
          START := 1;
          FSLP(LP,12);
          FOR K := 1 TO NUMVALS DO BEGIN
            NEWLEN := VARR(K).POSTN-START;
            STROUT := COPY(STR,START,NEWLEN);
            WRITE(LP,STROUT);
            START := VARR(K).POSTN;
            REALCONV(VARR(K).VALUE,REALNUM);
            WRITE(LP,REALNUM:6:2);
            REALENGTH(REALNUM,LEN);
            SLEN := SLEN + NEWLEN + LEN
          END;
          NEWLEN := LENGTH(STR)-START+1;
          STROUT := COPY(STR,START,NEWLEN);
          WRITE(LP,STROUT);
          SLEN := SLEN + NEWLEN;
          IF J = LNENUM-1 THEN BEGIN
            REALENGTH(RCALC(I),LEN);
            FSLP(LP,76-SLEN-LEN);
            WRITE(LP,'$',RCALC(I):6:2)
          END;
          LFEED(LP,1)
        END;
      END;
    END;
  END;

```

```

        IF (J = 3) OR (J = 6) THEN BEGIN
            FOOTNOTES;
            LFEEED(LP,1)
        END
        END (* WITH *)

        END; (* WITH *)

        LFEEED(LP,1);
        LINECOUNT := LINECOUNT + 1

        END; (* PRTCST *)

BEGIN (* DUMPCALC *)

    IF LINECOUNT+CURREC.COSTS.CARRI11.LNENUM+10 > 54 THEN BEGIN
        LINECOUNT := 0;
        NEWPAGE(LP);
        LFEEED(LP,6)
    END
    ELSE BEGIN
        LFEEED(LP,6);
        LINECOUNT := LINECOUNT + 6
    END;

    FSLP(LP,12);
    WRITE(LP,'ANNUAL COSTS PER HOME');
    LFEEED(LP,2);
    LINECOUNT := LINECOUNT + 2;

    WITH CURREC.COSTS DO
        FOR I := 1 TO CSTNUM DO BEGIN
            FRMFEED(CARRI11);
            PRTCST(CARRI11)
        END;

    IF CHNGES THEN
        LINECOUNT := LINECOUNT + 1;

    IF LINECOUNT > 52 THEN BEGIN
        NEWPAGE(LP);
        LINECOUNT := 0;
        LFEEED(LP,6)
    END
    ELSE
        LFEEED(LP,2);

    FSLP(LP,12);
    WRITE(LP,'TOTAL: (FIRST QUARTER 1982)');
    REALLENGTH(TOTAL[SYSTYPE1.LEN]);
    FSLP(LP,49-LEN);
    WRITE(LP,'$',TOTAL[SYSTYPE1:6:2]);
    LFEEED(LP,2);
    FSLP(LP,46);
    WRITE(LP,'TOTAL OMR 82 OMR');
    LFEEED(LP,1);
    FSLP(LP,12);
    WRITE(LP,'UPDATED TOTAL:');
    REALLENGTH(TOTAL[SYSTYPE1.LEN]);
    FSLP(LP,25-LEN);
    WRITE(LP,'$',TOTAL[SYSTYPE1:6:2,' * ',CPI:5:2,' / ',OLDCPI:5:2,' =');
    TOTAL[SYSTYPE1] := TOTAL[SYSTYPE1] * CPI / OLDCPI;
    REALLENGTH(TOTAL[SYSTYPE1.LEN]);
    FSLP(LP,18-LEN);
    WRITE(LP,'$',TOTAL[SYSTYPE1:6:2]);
    LFEEED(LP,1);

    IF CHNGES THEN BEGIN
        LFEEED(LP,1);
        FSLP(LP,17);
        WRITE(LP,'^ - Indicates a value that has been altered');
        LFEEED(LP,1)
    END
END; (* DUMPCALC *)

```

```

FUNCTION CALCULATE;
VAR
  REALNUM,TEMP:REAL
  J,K:INTEGER;
BEGIN (* CALCULATE *)
  IF COST.LNENUM > 1 THEN
    TEMP := 1.0
  ELSE
    TEMP := 0.0;
  WITH COST DO
    FOR J := 1 TO LNENUM DO
      WITH LARR[J] DO
        IF VALUES = YES THEN
          FOR K := 1 TO NUMVALS DO
            WITH VARR[K] DO BEGIN
              REALCONV(VALUE,REALNUM);
              IF VALTYPE = HOME THEN
                TEMP := TEMP / REALNUM
              ELSE
                TEMP := TEMP * REALNUM
            END;
          END;
        END;
      END;
    END;
  CALCULATE := TEMP
END; (* CALCULATE *)

BEGIN (* SYSTINFO *)
  SYSUSED := SYSUSED + [SYSTYPE];
  CHNCES := FALSE;
  DUMPTXT;
  COSTSCREEN;
  COSTCALC;
  DUMPCALC
END; (* SYSTINFO *)

```


APPENDIX C.

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OF
ON-SITE WASTEWATER TREATMENT SYSTEMS
FIFTH WORKSHOP ON HOME SEWAGE DISPOSAL
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Fifth Workshop on Home
Sewage Disposal
February 24, 1983
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