PN-ABJ-963
ISN 74734

GUIDELINES FOR PRELIMINARY APPRAISALS OF CAPITAL PROJECTS

Part II - Water and Sewerage Projects

Prepared for

AGENCY FOR INTERNATIONAL DEVELOPMENT
Under Contract AID/csd-2583

by

ROBERT R. NATHAN ASSOCIATES, INC.
Washington, D.C.

April 1971

CONTENTS

FOREWORD

The project analyst using these guidelines should first read Part I, General Guidelines. It discusses key considerations for preliminary project appraisals (PPA's) in all sectors, with a detailed discussion of the methodology for calculating the internal rates of return, the benefit-cost ratios, and other relevant measures of the worth of a project.

These guidelines deal expressly with those matters relevant to water supply and sewerage. They tell the analyst how to think about a water project; what to look for; and how to assure consideration of all elements essential to a project. They suggest institutional, cultural, political, and other factors which can weigh heavily on a project. They encourage concentration on big issues in broad orders of magnitude, leaving details and matters of lesser importance to be explored later in a feasibility study .

I. INTRODUCTION

Purpose and Scope

Water supply projects, broadly defined, comprise facilities to provide water for (1) agricultural purposes, (2) exclusively industrial uses which may or may not require fully treated water, and (3) general use by private households, industrial and commercial establishments, and public and private institutions. These guidelines are concerned primarily with the third type of facility, and with sewerage systems for general use by the community as a whole. Special facilities used exclusively for treatment of industrial effluents are excluded from the scope of these guidelines.

These guidelines provide ground rules for selecting and analyzing engineering and economic data for PPA's in the field of water supply and sewerage. They should help the analyst to evaluate the need for a proposed project and to make a preliminary judgment as to the technical, economic, financial and institutional soundness of the proposed project. The PPA is intended to provide a very approximate judgment of a project's feasibility more quickly and with far less effort than is entailed in a full feasibility study. The need for a feasibility study, and suggested scope of work if one is required, should be determined by the PPA.

Chapter I of the General Guidelines describes the objectives of a PPA. The General Guidelines also establish the overall methodology and principles for treating the technical and economic facets of a project. Methodological matters are, therefore, not repeated here. Rather, attention is focused on developing the concepts and facts particularly relevant to water supply and sewerage. The analyst is given guidelines to aid his search for alternative approaches to projects and also to help insure that all essential information for a correct analysis is considered. The analyst should refer to the General Guidelines, particularly chapters III and VII, for guidance on how to utilize the facts he has gathered to arrive at a conclusion on a project's worth.

These guidelines cover principal elements of water supply and sewerage systems, including investment in outside and inside physical plant, operations and maintenance, management and technical personnel, operating procedures, financial analysis, and systems planning. A general description of the physical components of water supply and sewerage systems, treatment processes, and the environmental aspects of these facilities is presented in appendix A of these guidelines.

The General Guidelines emphasize the net national rate of return for a project as the preferred measure of its worth. How does this rate of return compare with the opportunity cost of capital and return in other projects? To arrive at that return is a rather complex operation: all costs and revenues must be measured; clearly identifiable benefits which do not yield revenues must be assessed and, if possible, assigned values; shadow prices must be applied as appropriate; and best estimates must be qualified with sensitivity analyses. These tasks are particularly complex for water and sewerage projects because there is no conventional commercial market price for these services; they may freely be provided or may enjoy partial subsidies. These matters are discussed later.

General Characteristics of Water Supply and Sewerage Projects

Water projects often are among the "felt needs" of rural areas. Particulary for towns and villages, but also for cities, potable water has great appeal, and public demands for subsidized water projects are extremely strong.

Sewerage projects cater primarily to urban areas. They are the counterpart to the indoor supply of water. Users are generally expected to pay the full costs of such projects.

Both types of projects, but particularly water supply projects, are sensitive to maintenance practices. Many countries have invested enough in water supply projects to obtain good water, yet still do not enjoy a reliable supply of wholesome water because of inadequate maintenance.

Both types of projects pose questions of tradeoffs involving economies of scale, varying operational costs, foreign exchange, and total investment. In making rational choices among alternatives, the analyst will find the least-cost procedures described in chapter IV of the General Guidelines fully applicable and straightforward. The placing of proposed projects of water supply and sewerage on a comparable basis with projects in other uses depends on a suitable value being set on outputs.

II. RELATIONSHIP OF MACROECONOMIC FACTORS AND SECTOR STUDIES TO WATER SUPPLY AND SEWERAGE PROJECTS

Macroeconomic Factors

To a considerable degree, the capital investments required to supply water and sewerage services are set by macroeconomic objectives and strategies. A few examples follow:

- The rate of population growth will affect the need for water. Acceleration of urban population growth and rising living standards intensify the demand for potable water supplies and for sewage disposal.

- There may be a rapid increase in output in water-using industries, arising from water needed both for manufacturing and the disposal of waste. If the economic development plan encourages such industries, the plan will also have to provide water.

- The country's balance of payments position will affect the quantity and possibly the type of capital equipment available from foreign sources of supply.

- The country's price stabilization policy -- particularly as it affects wage rates and the cost of capital -- will affect the cost, timing, and scope of water projects.

- The country's policies regarding the generation of public capital for investment will substantially influence the funds available for water and sewerage projects.

- Water supply projects may be used by national planners to help implement certain overall economic objectives, including regional growth, income redistribution, land development, and increased employment and income.

Other macroeconomic factors will affect projects in the sector. The analyst must judge which of these are likely to exert significant impacts on his project, and must express this judgment in his assessment of the project's feasibility.

Relationship to Sector Study

An adequate water sector study can provide very valuable background data for the analyst (see appendix B for checklist). It will provide such information and insights as:

- Stream flow and other hydrologic characteristics for the purposes of surface water supply and sewerage planning

- Geological characteristics and success or failure rates of well-drilling programs for the purpose of ground-water supply planning

- An inventory of existing water supply and sewage treatment facilities, including their design capacities and current throughputs

- Present and projected population by size of community

- Projected per capita water requirements by community size, with a comparison of existing capacities and future requirements

- Recent investment costs and current operation and maintenance costs by type of supply, by system capacity, by region in million gallons per day (m.g.d.) and on a per-capita-served basis

- Rate schedules and current revenues by class of consumer (domestic, commercial, industrial, institutional, and governmental)

- Government subsidies (if any), with reasons for their existence

- Current maintenance practices and problems

- Personnel availabilities, with recommendations for overcoming any existing shortages and for providing a future supply of the specialized skills required in the sector

- Organizational deficiencies

- Levels and kinds of water pollution in waterways and along coastlines

- Types and geographic incidence of waterborne diseases

- Review of national policies, legislated or not, covering the spectrum of water resources management.

If such data are not available from a sector study, the analyst must decide what information is absolutely essential to a preliminary appraisal of the project, and must formulate plans to obtain it. He must gain access to information on alternative water sources and on water requirements which are realistic for the proposed service area. These are absolutely required, even for a PPA.

The General Guidelines discuss useful sources of macroeconomic and sectoral economic data. For the particular needs of water, obvious sources of information are public health statistics on morbidity and mortality rates for waterborne diseases; meteorological and hydrological data; collecting networks; ground water studies; and geological and topographic mapping.

III. STEPS IN THE PRELIMINARY APPRAISAL

Project preparation and appraisal consist of the following:

1. Identification of need for project and category of project
2. Formulation of physical input and outputs for project
3. Pricing the project, including inputs (costs) and benefits
4. Computation of rates of return on the project
5. Examination of the most promising alternatives
6. Sensitivity analysis of rates of return
7. Evaluation summary.

While the above steps can be discussed as discrete steps that will occur in the stated order, it should be recognized that in the course of carrying out these steps there will be considerable interaction. For example, in carrying out step 5, the analyst may find that other alternatives suggest themselves, so that he may find it necessary to go back to step 2.

Identification of Need for Project and the Category of Project

The value of safe and dependable domestic water supplies is widely recognized in relation to public health and economic development. Nevertheless, the vast majority of the rural -- and even substantial portions of the urban -- population in LDC's do not have access to safe and dependable supplies of water.

Local projects may germinate in any number of ways, and the bases for the proposals will vary in their quality. The project analyst should attempt *a priori* to determine the extent of need and what kind of project is appropriate to meet it. Sector studies, if available, may provide specific information on needs. If they are not available, the analyst will normally prepare the essential projections on the basis of data available from other sources.

In general, water supply projects can be classified into two categories: original installations and plant additions.

Original Installations

The provision of new water supply systems is usually limited to the smaller towns in a country and to villages in rural areas. The project analyst evaluates a program to provide potable water which consists of small but possibly numerous projects. In preparing a PPA, the analyst must discuss and offer analysis on (1) the geographic alternatives, based on existing sources of supplies, population, potential benefits, costs, etc.; and (2) the possible alternative sources of supply: surface, ground, or the extension of a municipal system. Technical factors, hence costs, vary considerably among alternative means of supplying the same need, and technically feasible alternatives must be evaluated through rate-of-return calculations.

Plant Additions

Every proposal for plant additions must be compatible with the existing system. Within this constraint the analyst should assure that additions reflect continuing advances in the state-of-the-art.

Plant additions are brought about by requirements for additional capacity or service extension into presently unserved areas. In the planning of the original installation, consideration may have been given to future requirements, and quite possibly the proposed plant additions will fit into this planning scheme. In the case of unexpected additional requirements, new or enlarged facilities may be required that were not part of the original planning. For example, an area at high elevation may have been considered unlikely for development. If that area is developed, the supplying of water will require distribution facilities and a source of supply. A pumping station and a large supply line to the station may be required. This new requirement is a unit unto itself, and its cost should be gauged against the anticipated revenue. Some cities make an additional charge for water that must be repumped.

Projected Requirements

PPA's of water supply and sewerage systems require estimates of future demands on the systems. The usual method for arriving at projected water requirements is to multiply a population forecast for some future time period by some selected daily requirement expressed on a per capita basis. (For obvious reasons, available data on per capita consumption in developed countries cannot be used for developing countries.) A water requirements schedule should be developed for the particular country through the use of available incountry sources. Data can be obtained from actual observation of withdrawals from public standpipes or hand pumps, and from existing water departments' water production records.

It is very convenient for planning purposes and future PPA's to classify requirements by size of community. Projected requirements can be estimated on a higher basis (if historical growth rates are not available) that reflects higher per capita consumption in larger urban areas by virtue of more widespread use of plumbing facilities and water-using appliances.

An example of a requirements schedule developed by a study group for an African country is given in table 1.

Table 1. Estimated Per Capita Water Requirements by Community Size

Community size	Estimated per capita water requirements a/			
	1970	1980	1990	2000
Less than 1,000.....	5	5	5	5
1,000-2,000.........	5	5	5	6
2,000-5,000.........	7	8	9	10
5,000-10,000........	8	10	11	12
10,000-20,000.......	8	12	14	16
20,000-50,000.......	14	16	18	20
50,000-100,000......	18	22	26	30
100,000-500,000.....	24	28	32	36
More than 500,000...	30	35	40	45

a/ Figures are in imperial gallons per day. A 25-percent increase was allowed for system leakages.

The figures in the schedules may be taken as averages. Normally there will be variations among communities in the number of water-using institutions (hospitals, schools, etc.) and industrial firms that choose to purchase rather than self-supply their water requirements. Projections should take into account the policies to be applied with respect to metering, and also the proposed user charges. The latter may be an important determinant of the quantities required from public systems for industrial purposes. At some rate level industrial users will provide their own sources.

With respect to industry, heavy water users generally self-supply their own requirements and therefore locate near dependable sources of supply. Most industrial water returns to the water course for reuse downstream by other industries or municipalities. However, industries are the largest and most serious polluters of water, and their waste-water discharges compound the problem of adequate sewage treatment and disposal. Thus, pollutant-prone industries are an important determinant of the demand for sewerage systems. In some cases such industries may be required to provide their own facilities for treatment of industrial effluents. This possibility should be considered in PPA's for sewerage facilities. If treatment of industrial wastes is to be included in the proposed public system, the analyst should be particularly sensitive to the kinds of industrial connections there will be in the service area and the chemical, thermal, etc., characteristics of the discharges.

The other requirements placed on a proposed sewerage system include those from domestic, commercial, and institutional (schools, hospitals, etc.) users. These classes of users seldom impose special problems on load forecasting, and analysts can follow the simple rule that the volume of water supply that the utility delivers must be collected by the sewerage utility.

Development of Physical Resource Flow Plans

The physical flow plans should relate physical resources to needs. Appendix A outlines some of the principal physical elements that will influence alternatives to be considered in water supply, treatment techniques, transmission methods, distribution, pumping requirements, storage facilities, service connections and site selection.

Basic Physical Factors

Several basic physical factors influence planning of water and sewerage projects.

The most economical source of water is generally underground water because its treatment and transmission are usually less costly than those for surface water. Underground supplies seldom need treatment other than chlorination. The disadvantages of underground water are the danger of exhaustion of supply and the possibility of a heavy mineral content that may require special treatment.

Probable per capita consumption and growth of demand over time will determine design requirements. Distribution storage reduces capacity requirements at peak hours of demand and supplies a safety factor in the event of breakdowns. Metering of consumer services is effective in reducing waste.

Pressure must be designed to provide adequate service without damaging plumbing. Where consumers are located at a great variety of elevations, different pressure zones may be required.

The capacity of a pipeline varies with the square of the diameter. Thus, an increase in diameter will greatly increase the capacity. For example, one 6-inch pipe will carry more than twice as much water as two 4-inch pipes. A major portion of the cost of a pipeline is in the excavation, backfill and paving. It is less expensive to install a 6-inch pipe than to duplicate a 4-inch pipe after a few years. Pumping units and filter capacity can be installed as needed but the connecting piping to a pumping station or filter plant should be of sufficient size to serve the anticipated requirements.

Street sewers normally cost much more than water mains because of the depth of the sewer below the street surface. Pipe is a minor cost; installation is the major cost.

Pricing the Project

Conversion to Value Flows

At this point in the PPA it is important for the analyst to be familiar with the pricing methods described in chapter II and appendix B of the General Guidelines. It is especially important to distinguish between the pricing of inputs and outputs for computation of the net national rate of return (where shadow pricing may be required) and the pricing of inputs and outputs for the computation of the business enterprise rate of return (where shadow pricing is not used).

Use of Costing Modules

For PPA's in the water sector, major input elements to the various kinds of systems should be available in "prepackaged" modules which are "prepriced" in the local currency. Cost estimating modules are required for construction and annual operating elements. These should be based on local labor costs and capabilities. These modules help to establish quickly the approximate cost of a project, given the capacity or size of the proposed service area.

Before examples of costing modules are provided, methods by which they can be put together will be given. One method is to take the original costs of the existing plant and, for each of the capacity categories (50-100 m.g.d., 100-250 m.g.d., etc.), to raise them to present costs using an appropriate construction cost index. Another method is to obtain current quotations from suppliers for capacity-rated elements covering the spectrum of plant sizes suitable throughout the nation. One set should be done for surface water, one for ground water, one for primary sewage treatment, etc. With data in this form, one can express new construction costs on a per gallon or per capita basis. For the latter, one needs, of course, an estimate of daily requirements.

Annual operating, maintenance and administrative cost modules, on the other hand, are obtained from the most recent plant accounting statements of actual incurred expenses and then, for each category of plant size, averaged over all operating plants in that category. This method is only feasible when fairly reliable accounting practices are used in a country.

If expenses are not properly recorded, then estimates need to be made for the various subelements in the module, including the very important category of assumed operating labor requirements.

Although the second of the methods given for both the construction and operating costs is the more difficult and time-consuming one, it avoids the inclusion of past mistakes in the pricing of elements. This is especially true for countries which historically have had poor planning.

Examples of input estimating modules in the water sector are

- Cost per unit volume of buildings
- Cost per mile of underground transmission and distribution pipe
- Purification cost per m.g.d.
- Cost per foot for drilling deep wells by type of local substrata
- Cost of pumping per thousand gallons an hour
- Cost per m.g.d. for primary and secondary treatment levels
- Operation and maintenance cost per m.g.d.
- Operation and maintenance cost per thousand persons served daily

Village Water Supply Costing

A unique consideration often arises in the cost estimation of rural or village water supply projects. This consideration is the willingness of the local people to participate in some type of cost-sharing arrangement with the water development authority. Cost-sharing may take the form of small monetary donations or of voluntary labor where well-digging or earth damming of streams is required. Unfortunately, voluntary labor can play only a minor role in the construction of systems that entail mechanical well-digging, treatment and storage, and pipe-laying (other than trenching operations).

In the costing of such small systems, a project analyst should not place too much emphasis on a cost-offsetting allowance derived from local contributions. This is because a good deal of the total cost of even the most simple well is accounted for by outside technicians who must site the well, line it, and supervise the building of appurtenances and the installation of handpumps, etc. Also, visits by outside technicians are usually required for continued maintenance and periodic testing of the water quality.

Other Costs

There are possible project inputs or costs other than those which arise from construction or operation outlays. These are the economic costs -- tangible and intangible -- which may arise in conjunction with the construction or operation of a project. The damming of a river and the subsequent flooding of land to provide a reservoir for a municipal water supply provides an example. If the inundated land had a value in an alternative use (e.g., agriculture), then this flooding represents a cost to society, and the estimated loss should be included in the calculation of the net national rate of return whether or not the monetary cost is charged to the project.

For municipal water supply and sewerage systems in LDC's, it has been estimated that 60 to 70 percent of the total construction costs are accounted for by foreign-made equipment and foreign technical assistance. Annual operation and maintenance costs include a much smaller proportion (20 to 25 percent) of foreign inputs. These percentages will vary among countries.

Valuation of Output: Water Supply Projects

The valuation of output of water supply projects is rendered difficult by two characteristic conditions:

1. Treated water is frequently distributed on a free basis, or under a schedule of prices designed neither to exact

the full price consumers would be willing to pay nor to recover the full cost of producing the output.

2. Treated water supplies and the sewerage systems associated with piped-in water yield external benefits accruing to a wider group of beneficiaries than those consumers enjoying direct benefits. These indirect benefits accruing to the community at large include reduced incidence of certain types of diseases and improved environmental conditions.

As a result of these preceding characteristics, the market price of water supply and sewerage disposal systems can seldom be used as a measure of the total value of the services.

Where water is supplied for either a metered or flat-rate charge, and consumers have a free choice to utilize the service or not, the value of the direct benefits of the output can be viewed as being at least equal to the revenues received. If the demand for such services is greater than can be met from existing capacity at the prevailing schedule of charges, this is an indication that consumers attach a higher value to the service than the prices charged. It is also a strong indication that expanded capacity is justified on purely economic grounds if the schedule of rates produces revenues adequate to cover the total costs of providing the service, including a return on investment equal to or higher than the marginal opportunity cost of capital. Where this set of conditions is satisfied, the schedule of prices provides some guidance in the valuation of output of water and sewerage systems -- at least insofar as the direct benefits are concerned. As noted above, the total value of benefits will be greater than the value of the direct benefits for which a price can be imposed as a condition for receiving the service.

In the case of large-scale industrial and commercial users, the cost of self-supplying their requirements (by the least costly means) may be a useful measure of the value of the output consumed by these users. At some level of charges, these users would choose to supply their own requirements as an alternative to purchase; if this level can be ascertained, it is probably a better measure of the value of the direct benefits of the output than the water actually charged.

As an alternative approach to the valuation of output of water supply and sewerage projects, rates may be set at levels adequate to cover costs and to yield an internal rate of return equal to or higher than the marginal opportunity cost of capital. Then, by an estimation of the quantities demanded at the predetermined schedule of rates, the predetermined schedule of prices can be tested against consumers' (subjective) valuations, as evidenced by their willingness to pay. In this estimation it is important to note that projected population growth and increases in per capita consumption are taken into account. If this estimation indicates a relatively high rate of utilization of the capacity of the proposed installation, the rate schedules used may be considered to reflect the minimum value users place on the direct benefits provided.

Because the indirect benefits provided by water and sewerage projects are large (and difficult to value) and also because government may decide to subsidize users of water and sewerage services to obtain the maximum of indirect benefits (and also to minimize costs to low-income groups), the valuation of all benefits may not be practical. Therefore, computation of rates of return based on these valuations will not be possible. In these circumstances, economic and financial feasibility tests will be necessary for the determination of the least-cost alternative form of the project capable of meeting the identified need.

Given the least-cost alternative, decision-makers will have to judge whether the direct and indirect benefits are worth the costs. In arriving at this decision, consideration should be focused on:

- Estimated value of reductions in waterborne diseases, mortality and morbidity rates, and loss of working time
- The convenience to users of the services supplied
- Improved fire protection
- The comparative benefits from other projects that must be foregone if the proposed water supply project is undertaken
- Protection and improvement of the environment.

Some but not all of these can be quantified; fewer can be expressed in meaningful values suitable for rate of return (NNRR and BERR) computations.

Some approaches to quantification and valuation are suggested below.

Health improvement may sometimes be quantified as a direct benefit resulting from an increase in the number of man-days of productive labor (including life expectancy) and also from the reduction of medical costs associated with such water-related diseases as bilharziasis, dysentery, and typhoid. Furthermore, a water supply system may considerably reduce the probability of certain types of epidemics, particularly in cities.

To quantify the health benefits of water supply the following formula can be applied for endemic diseases:

Health benefits = [(total pop. affected)(proportion in labor force)(proportion of labor force employed)(disease incidence)(average working days sick)] X (daily wage)

This formula provides an estimate of the annual value of economic benefits.

In estimating the value of benefits from the reduction of disease, caution is in order, because it is easy to err on the high side. The temptation is strong to assume that large proportions of the population will become diseased and lose working days, whereas in reality the incidence of the disease may be quite low and the unemployment levels high in the particular water supply area under consideration. Therefore, recourse should be made whenever possible to those records of the public health authorities concerned with the types and prevalence of waterborne diseases.

Although it should be possible to make rough estimates of the effect of clean water on the incidence of diseases and the effects on earnings, such economic effects should be regarded as partial and incomplete. The economic effects of health measures (such as water supply and sewerage) are quite complex and require consideration of interactions with mortality, birth rates, productivity and resulting per capita income effects over time. Tracing such interactions is beyond the scope of a PPA.

Greater Convenience in Obtaining Water

There are situations where substantial time is required for families to obtain water. Where this is the case and the project reduces this time, one might wish to quantify it as follows:

Annual hours saved = number of families X time saved per day X 365

It is unlikely that the savings in time has substantial economic value, because water is generally carried by women and children whose opportunities for gainful employment is quite limited.

Fire Protection

If fire protection capacity is built into the water system (such capacity normally requires pipe diameters of 6 inches or more), the additional cost entailed may be offset by a reduction in fire insurance rates over the life of the project. However, rate reduction is also dependent on other factors, including the type of building materials used in the particular area, the distances between hydrants and buildings, the type and size of the fire department, fire prevention precautions taken by building owners, etc. These factors must be considered before an economic justification is attempted for the incremental costs associated with fire protection capacity.

Valuation of Output: Sewerage Projects

Sewerage systems are almost invariably built with the understanding that they are to be financially self-supporting. Because of cost considerations, they are geographically limited to areas of relatively high population density and of the economic capacity to support such activities. Thus, assessments can readily be levied against urban landowners, commercial enterprises and industrial firms which, in turn, have a relatively large capacity-to-pay for such services. In fact, collecting mains can be installed almost on a "pay as you go" basis for a city block-by-block installation schedule with immediately payable assessments.

Finally, metering is not required, and periodic billings can be made on a real-property-by-real-property basis. Alternatively, the charge may be based on metered charges for water. In the case of large industrial or commercial users, charges may be negotiated, taking into account any special costs incurred in the treatment of industrial effluents. Payments for services can easily be enforced by means of disconnection. In short, the valuation of at least the direct benefits presents no great difficulty in determining net national or business enterprise rates of return to the project.

Very little attention has been paid in the past to the nonrevenue or indirect benefits of sewerage projects. Main drainage systems have been constructed in countless urban and suburban areas for reasons of aesthetics, convenience, and perhaps more significantly, public health maintenance. However, another aspect of waste water -- sewage treatment -- has become an increasingly important matter of concern, especially in the last decade, under the generalized term of water pollution control. Here, economic and aesthetic considerations, in addition to purely financial ones, are beginning to play a role in the calculations of the real costs and benefits of sewerage systems, including mains, storm drains and treatment plants.

The nonrevenue benefits of sewerage and treatment systems consist of the elimination or reduction of certain municipal costs and of a variety of other costs borne by the general population in the absence of systems for handling waste or storm waters.

Benefits accruing through the municipal structure include the elimination or reduction of expenses associated with:

- Night soil collectors engaged in conservancy, transport and disposal

. Public health crews to combat such nuisances as rodents and mosquitoes

. Public roads crews to repair roadways damaged by rainstorms.

The benefits to society in a broader sense may consist of the following:

. Economic cost reductions from the elimination of road traffic bottlenecks by the installation of storm drains. These costs can be estimated from techniques developed for highway analyses, but it should be noted that heavy rainstorms are stochastic phenomena, and the probability of occurrence must be included in the analysis.

. Flooding damage that could be eliminated by sewers or storm drains.

. Elimination of private cesspool maintenance in the areas to be served.

. Recreational enhancement opportunities on local waterways that are afforded by sewerage treatment. Here, benefits should be real rather than merely apparent, and the same calculating precautions hold as in the case of water supply systems.

. Aesthetic improvement of the community by the introduction of underground sewers. It is hardly necessary to mention the quantification problem faced here by project analysts. However, anyone accustomed to underground mains who moves to a city with open trenches realizes that substantial aesthetic benefits do indeed exist.

. Human health improvement and the resulting economic gains from higher labor productivity and reduced mortality and morbidity.

This last-mentioned benefit is usually considered the one providing the most justification (other than revenues) for a sewerage system. However, it is difficult to document, and, as discussed previously, can be done only partially and incompletely in a preliminary appraisal.

External Costs

Sewage treatment plants may depress the value of adjacent real estate, at least to the extent that residential use is precluded on zoning or aesthetic grounds. The cost can be quantified by discounting the acreage-value differential between average residential land values and those for the particular type of nonresidential zoning in the area adjacent to the plant. The simplifying assumption can be made that the two types of acreage values will appreciate at the same average annual rate in the future. The discounting period should be the expected life of the project

Selection of the Most Promising Alternative

In considering the various possible physical arrangements, the analyst will have formulated alternatives that appear promising. By applying the techniques of comparing alternatives and choosing the least-cost alternative as described in chapter IV of the General Guidelines, that analyst will point up one or possibly two alternatives that are most promising. In some cases alternatives may offer both different levels of service and cost that merit consideration by the decision-maker.

Alternatives can take on various forms: technical alternatives, alternatives regarding the postponement of the project, alternatives involving a with-or-without evaluation, and alternatives as to the scale and timing of the project.

With respect to technical alternatives at the level of a PPA, considerations affecting the least-cost alternative include the following:

. For a new water project, a comparison of surface versus ground water sources should be made. Ground water sources often involve smaller investments and lower cost of treatment, but may be adequate sources for a limited time period.

. For extensions to existing systems, the same comparison should be made, especially if proposed extensions are far from the main transmission lines.

. For increasing the capacity of an existing system, a comparison should be made of a new source and treatment site versus expansion of the old waterworks.

. For rural programs, a comparison should be made of mechanical versus manual digging of wells in terms of the long-range effectiveness of this type of water source.

. For a new sewerage system, a comparison should be made between service only to the high-volume commercial and industrial areas of the city and service to include high- and low-density residential areas as well (in the first stage).

. For new sewage treatment plants, a comparison should be made of primary versus secondary treatment in the light of antipollution policies (water quality standards).

More detailed technical considerations of alternatives should be left to a feasibility study or a final engineering study.

Scale and Timing of Facilities

Variations in the scale and timing of proposed facilities are two important aspects of alternatives. These two factors are interrelated; in addition, they influence the requirements for financing the project. Inasmuch as water supply systems historically have had steadily increasing demands, they are faced with the need for increasing capacities to meet ever-larger demands.

The choice of the scale and timing of water and sewerage system installations are influenced by the following factors:

1. Costs per unit of supplied water or treated sewage tend to be lower for larger installations. These economies of scale arise from both capital and operating costs, particularly in the case of surface water systems.

2. For the installation of facilities of a given type, size and location, the total construction cost will generally be lower if the entire facility is built at one time rather than in phases over a period of several years.

3. Capital invested in providing capacity that will not be used for several years involves waste equal to the net output that the capital could have produced had it been invested in some other project.

4. The rate of increase in demand for the services to be provided together with the marginal opportunity cost of capital will set the limits to the amount of excess capacity that can be built into a project.

The factors noted in 1 and 2 above are favorable to construction of facilities on a scale to meet more distant prospective demand, i.e., on a scale that will provide excess capacity over a considerable span of years. On the other hand, the opportunity-cost-of-capital consideration imposes a constraint on the scale-time decision, and the rate of growth in demand operates as the decisive factor in the choice of scale and timing.

This choice, involving tradeoffs between 1 and 2 on one hand and 3 on the other, can best be made by computation of the present value of various alternatives differing in scale, phasing, and timing of installation. The methods are explained and illustrated in chapter IV of the General Guidelines. In general, the lower the opportunity cost of capital and the faster the rate of growth in demand, the larger the scale and the earlier the timing that will be indicated by these computations.

Water and sewerage costs are very much affected by density of population and the time it takes to reach the ultimate density. This suggests that orderly and full settlement, as compared to sparse and irregular settlement, of new neighborhoods can reduce costs of water and sewerage substantially.

Computation of Rates of Return

One proposed project or more than one alternative may be indicated by the preliminary appraisal. The choice of the specific alternative may depend on the gathering of more information on the level of service that is preferred by the decision-maker. (It may be desirable to leave options open for the decision-maker.)

The business enterprise rate of return and the net national rate of return should be computed for each alternative (which has been reduced to its least-cost form). The BERR will be based insofar as possible on market prices; the NNRR, on shadow prices (see chapters III and VII of the General Guidelines).

Sensitivity Analysis of Rates of Return

As described in chapter VI of the General Guidelines, the sensitivity of rates of return to various factors should be determined.

Evaluation Summary

In accordance with the General Guidelines (chapter VII) an evaluation summary should be prepared in which the major findings are presented for consideration.

-25-

APPENDIX A. PRINCIPAL ENGINEERING ELEMENTS IN WATER SUPPLY AND SEWERAGE SYSTEMS

Principal elements in water supply and sewerage systems are described below, including their more important technical features.

Sources of Water Supply

Lakes and Rivers

Natural lakes and rivers are sources of much of the world's major water supplies. Lakes are usually fed by streams and springs, and the inflow to the lake may vary with the seasons; this results in variations in the elevation of the water surface. In most cases lakes have an outlet through which water flows away from the lake. The amount of the outflow will be governed by the elevation of the lake's water surface unless the outflow is intentionally regulated by man-made control works.

The flow of rivers may vary widely with the seasons or may be regulated by such control works as dams. The flooding of land adjacent to rivers is a factor to be considered in planning a water supply project. Some rivers dry up during parts of the year or may be reduced to a very small flow. These factors should also be considered in planning a water supply project. If stream flow or water level data are not available, an effort should be made to obtain general information from residents along the river or from observations of high water marks from previous floods.

The chemical and sanitary quality of water in lakes and rivers is important. Many lakes and streams are subject to pollution from runoff, sanitary sewage, or industrial waste. The type and degree of pollution will govern the degree of treatment necessary to render the water suitable for its intended use: domestic, industrial, irrigational or recreational. The quality of the water may also vary with the seasons and may be adversely or beneficially affected by storms. Records of water quality should be obtained at an early stage in the planning of a water supply project. If such records are not available, samples of the water should be obtained and sent to a qualified laboratory for analysis. A complete cycle of sanitary analyses will require a full year or perhaps several years of testing, but the preliminary appraisal of a project need not be delayed while this information is being obtained. Sampling and testing should proceed during the planning and financing stages of a project unless good records are already available.

Impounded Streams

To maintain constant flow, natural streams require regulation by the construction of dams that will store water during periods of high stream flow and release it during periods of low natural flow. The lake or reservoir formed by the construction of a dam may be utilized as the source of supply for a water supply project; in fact, this is usually the reason for construction of the dam. The elevation of the water surface behind the dam may vary widely, and the intake works for the water project must be designed to function at the limits of contemplated water elevation. The amount of water that may be withdrawn from an impounded supply is governed by the net safe yield of the drainage area above the dam.

The quality of the water in the reservoir will be affected by the degree of pollution in the inflow, subject to the beneficial effect of storage. When water is stored for periods of time (days, weeks, or months), natural sedimentation will remove some suspended matter and will improve the sanitary quality. The degree of treatment should be governed by the worst condition anticipated in the quality of the stored water at the point of intake to the water supply project. Obviously an accurate determination of this factor cannot be obtained until the dam has been constructed and the reservoir has been in operation for at least 1 full year. The design of the treatment works should not be delayed until this factor is determined, but fair estimates of water quality can be obtained from similar experience at other locations augmented by the application of mathematical formulas.

Underground Water Sources

A major source of water supply is underground water. This water is the most economical source in most cases, because the water is at or near the point of use and no collecting works or long transmission lines are necessary. In many cases the quantity of underground water that may be obtained is limited, and this source must be supplemented by water from other sources. If water withdrawn from underground exceeds its replenishment, the water table will fall and wells will need to be deepened.

As the water table declines, the amount of water obtainable lessens, because most underground basins are bowl-shaped and less water is retained in the deeper strata. If fresh-water basins along the seacoasts are overdrawn to the point that the water level falls below sea level, there is danger of salt water intrusion. This can permanently ruin an underground source of supply.

Water from underground sources is usually safe for human consumption because the water is protected against bacteriological contamination, but it may contain a high concentration of minerals such as calcium or iron. Hard water may be softened and the iron may be removed from solution, but the treatment process is relatively expensive. Chlorine is usually applied to underground supplies as a precaution against disease-bearing organisms. The treatment of the supply must be tailored to the chemical and bacteriological quality of the water.

Reclaimed Water

Waste water from communities or industry may be treated to produce water that is satisfactory for most uses, including human consumption. Sewage may be given full secondary treatment, and then may be filtered and disinfected to produce safe water supplies. Much of the water withdrawn from natural streams is contaminated with waste products, but it is treated by modern water purification plants to constitute a satisfactory, safe source of water supply. In areas of the world where water is scarce, the use of reclaimed water is gaining in favor and in some communities constitutes the major source of supply. However, treatment must be thorough and complete, and this may make reclaimed water more expensive than alternatives.

Desalination

The removal of minerals, especially chloride, from water may be accomplished by any of several methods, among which are distillation, reverse osmosis, chemical precipitation, and electrodialysis. All of these methods are expensive and, except in rare instances, water which needs such treatment should not be considered as the source of a community water supply. No further mention of this source will be made herein.

Treatment Techniques

Sedimentation

Water carrying a great deal of suspended sediment will deposit most of that sediment when the water's velocity of movement is reduced. Colloidal particles carried in suspension will settle out very slowly without the help of coagulating chemicals. Whether or not chemical coagulants are used, sedimentation is the first step in water treatment. With the use of chemical coagulants and proper mixing, a detention period of 2 hours or more should be provided to clarify the water. Care must be exercised to avoid disturbance of the water during the sedimentation period. Provision should be made to mechanically remove the settled matter from the bottom of the sedimentation basin. Settled water should be removed from the basins by being skimmed from the top and then passed into the filters without any disturbance that would break up the floc formed in the basin. The release of small air bubbles below the water's surface around the perimeter of the basin will assist in preventing ice formation in cold climates.

Filtration

The filters are the heart of the water treatment process. They remove the finely divided suspended particles and much of the bacteria from the water. Filters consist of beds of fine sand supported on gravel through which the water is passed. Filtration rates of 2 to 5 gallons per square foot per minute are customary. Back washing of the sand in place cleans the filters; filters must be washed when the head loss through the filter approaches the depth of the filter basin.

Disinfection

Disinfection is usually accomplished by adding chlorine, a powerful oxidizing agent that is very destructive to bacteria, to the water. Chlorine contact of 30 minutes or more is desirable with an effective chlorine residual. Measurement of chlorine residual is easy and accurate with simple equipment. Although there are other disinfecting agents besides chlorine, they are expensive and less effective.

Softening

Hard water may be softened by any of several processes. The usual methods are the lime-soda chemical process or the zeolite ionic-exchange method. Softening the entire water supply for a community is expensive and has certain disadvantages. Careful consideration should be given to a proposal for softening a water supply.

Transmission Methods

Pipes

The transmission of water from its source to its point of use is an important factor to be considered in appraising a water supply project. Pipelines are usually employed for transmission of water. Several materials are used for pipelines, including concrete, steel, cast iron and asbestos cement. Large-diameter pipelines are usually constructed of concrete or steel. Cast iron pipes are expensive and are not made in many countries, especially in large sizes. Asbestos cement pipes have certain limitations in diameters over 24 inches. Major feeder lines in distribution systems are frequently considered transmission lines and should not be used for direct consumer service.

Canals

In some instances open canals are utilized to transmit water over long distances. Open canals should be lined with impervious materials, usually concrete. Canals are less expensive than pipelines and are suitable where the terrain is relatively level or slightly sloped in the direction of the desired flow. Canals should be fenced on both sides to prevent the entrance of unauthorized persons or animals. The growth of algae or moss frequently occurs in open canals and reduces the capacity of the canal. Growths can be controlled by chemical means.

Natural streams which cross the route of the canal should be diverted over or under the canal to prevent the entrance of undesirable water.

Natural Streams

In some cases a natural stream may be used to transmit water. The stream should be relatively free from contamination and should be of sufficient capacity to handle the total flow without flooding.

Conduits

The term "conduit" is usually applied to a composite of all the elements in a transmission system. It may be a combination of tunnel, canal, pipeline and natural stream. In some cases pumping is necessary at one or more points along a conduit. The hydraulics of a conduit should be carefully calculated to ensure that the proposed conduit will transmit the desired quantity of water and will deliver it at the proper elevation. Treatment is usually applied after the water has been passed through the conduit.

Distribution

Trunk Mains

A distribution system is a series of pipelines that distribute water throughout the service area. Trunk mains are large-diameter principal feeders that supply water to the grid system of street mains at several points in the service area. Direct consumer service from trunk mains should be avoided as much as possible. Trunk mains should be valved at frequent intervals to avoid the necessity of shutting down large sections of the distribution system when repairs are needed.

Street Mains

The water mains located in the streets constitute the grid system that supplies customer service. Street mains should be installed in every street in which consumers' premises are located. The mains should be valved at frequent intervals to minimize the number of consumers deprived of water when shutdowns are necessary. Street mains should be interconnected frequently and dead ends should be avoided. The design of a distribution system, including the trunk mains, should be checked by the Hardy Cross method before the design is finalized.

Pressure Zones

When the terrain of a community includes areas of extensive difference in elevation, it may be necessary to separate the distribution system into zones designed to supply water at the proper pressure for each zone. (If the entire distribution system is operated at sufficient pressure to supply the higher elevations, the pressure at the lower elevations may be excessive. Damage to plumbing fixtures and abnormal leakage may result.) A saving in pumping costs may also be effected. Although entirely separate piping systems are desirable, separation may be effected by closing valves along the zone lines. A closed valve on a continuous pipeline creates two dead ends; there is also the danger that a valve may be opened by mistake, which would subject the lower zone to excessive pressure. The use of pressure-reducing valves should be kept to a minimum because such valves are delicate and frequently get out of order. In some cases, however, their use cannot be avoided without high expense.

Fire Protection

One of the purposes of a community water system is to provide water in sufficient quantities for fire fighting. The addition of fire hydrants will add little to the overall cost of a water system, and the additional cost will more than be compensated for by lower insurance rates. Fire hydrants should be placed along pipelines that are 6 inches or more in diameter. Pipelines that are 4 inches or less in diameter provide little protection for fire-fighting purposes. Fire hydrants should be of an approved design and should be standardized for an entire community.

Pumping Requirements

Transmission

Pumping is frequently necessary at the source of supply or along the transmission line. All pumping stations should be equipped to serve the maximum demand when the largest unit is out of service. Pumps may be centrifugal or reciprocating, vertical or horizontal shaft, and powered by electric motors or internal-combustion engines. The type of pump and driver must be selected to meet the specific conditions encountered. Centrifugal, horizontal shaft, electric-motor-driven pumps are commonly used and are relatively trouble free. They may be manually operated, remotely controlled, or automatic. Very high-speed pumps should be avoided: pumps that operate at more than 1,750 r.p.m. wear out quickly and are subject to high maintenance costs. Although high-speed pumps are usually cheaper to purchase, this saving is more than offset by maintenance and replacement costs. Salesmen will frequently try to sell high-speed pumps solely on the basis of first purchase cost.

Pumping stations at the intake from a lake or stream should be located at as low an elevation as possible to reduce the suction lift. The station must be protected against flooding by walls or embankments. Access for repair and maintenance must be provided, and stations containing large units should be equipped with an overhead crane. Pumping stations along a transmission line may get their suction directly from the pipeline, by pumping around a closed valve; or they may get suction from a receiving reservoir or tank. Pump discharge piping should be equipped with a check valve and a control or shut-off valve. Available suction pressure should be utilized if possible.

Distribution Pumping

If water systems are separated into pressure zones, repumping to reach the higher elevations is frequently necessary. In some instances, pumping in the distribution system is necessary to maintain pressure within a zone. Pumping stations should be insulated to protect the neighbors from noise. If more than one pumping station supplies a zone or a single area, there must be coordination between stations by adequate communication.

Ground-Water Pumping

Wells are pumped by multistage deep-well turbine pumps, which are usually driven from the surface of the ground by a drive shaft that extends the depth of the well to the pump.

Drive may be provided by directly connected electric motor or by internal-combustion engine through an angle drive unit. Many wells are pumped directly into the distribution system, allowing no time for contact with chlorine if the well water is to be disinfected. This may result in a chlorinous taste close to the well and inadequate disinfection. The use of a receiving tank requires repumping unless the tank is high enough to supply distribution pressure. All the factors should be studied in connection with the design.

Storage Facilities

Reservoirs

Impounding reservoirs behind dams are major sources of supply for many water systems. These reservoirs are usually of large capacity and are intended to assure a supply of water during dry seasons. Areas to be flooded with water should be cleared of all growth before water is impounded. The outlet works by which water is withdrawn from the reservoir should be designed with outlets at various levels so that water can be drawn at depths suitable to the condition of the water. Algae growths occur at times on exposed water surfaces, and provision must be made to treat these growths with chemicals as needed.

Distribution reservoirs are located in the distribution area at suitable elevations so stored water can be fed into the distribution system to maintain pressure. Such reservoirs are usually earth embankments or concrete constructions and may be covered or open. The use of reservoirs will enable the system to meet fluctuating water demands without increasing the supply from the source. They will also provide water supply during temporary periods of outage at the source.

Tanks

Storage tanks for water systems are usually made of steel or reinforced concrete, and may be located at ground level or be elevated. Their purpose is to provide water storage in the distribution system to meet peak demands and to equalize pumping rates. They may also provide contact time for chlorine. Tanks are usually covered to avoid the algae problem and to protect the water from airborne contamination. They are usually of much smaller capacity than reservoirs. In some cases, if system demands are high, several tanks may be located at the same place. Several small- or medium-sized tanks are more economical to build than one very large tank.

Basins

Basins are in effect shallow reservoirs. They are seldom used because of their limited capacity, and because the shallow water promotes the growth of bottom organisms. Although under certain conditions they may be useful, they are inferior to reservoirs or tanks.

Service Connections

Service Pipes

Connections between the street main and consumers' premises are made with small-diameter pipes. Service pipes should be copper, plastic, or other corrosion-resistant material. The connection to the main is made with a corporation cock that includes a shut-off valve. In some systems the property owner installs the entire service line; in other systems the utility installs the service pipe from the main to the curb line or the edge of the street, and the owner installs the remainder. The corporation cock in the street main should be installed by the utility, because skill and special equipment are required to make this connection when the street main is under pressure.

Water Meters

The metering of service connections is highly desirable. Without meters consumers will waste water; they will stop waste when they have to pay for all the water that goes through the meter. Studies have shown that unmetered cities use twice as much water per capita as do metered cities. It costs money to procure, treat, and distribute water, and consumers should pay for the water they use.

Positive displacement meters are superior to turbine-type meters. Small flows are accurately measured with positive displacement meters, but much of the water passing through a turbine meter at low flow rates goes unmeasured. People will soon learn that the loss of revenue to a utility by this practice can be very important. Compound meters should be used for large services (over 3 inches).

Typical Sewerage System Elements

Service Connections

House Connections

Service connections for sewerage are usually provided by the property owner from the building to the street. The connection into the street sewer should be made by the utility. The connecting pipe should be not less than 4 inches in diameter and should be of noncorrosive material. Vitrified tile or cast iron are the usual materials. The connecting pipe must slope downward toward the street sewer at all points. An opening for cleaning must be provided, usually on the consumer's property.

Industrial Monitoring and Special Connections

Large sewer connections for industrial plants or institutions must be designed for the particular need. In some cases metering of the sewage from industrial plants is required, which calls for special meters. In some cases monitoring of industrial processes is used instead of metering the sewage flow. The water entering the plant is metered and a percentage determined of the part of the water flow that enters the sewer system. In some cases, such as in a bottling plant, part of the water goes out in the product.

Street Sewers

All sewers, except pump discharge lines, must be laid on a grade or slope. The slope is determined by a formula based on the size of the sewer. The flow velocity of the sewage should be at least 2 feet per second to prevent deposition of solids in the sewers. Access manholes for cleaning and maintenance must be provided at frequent intervals and should always be placed at a change of grade or alignment. Sewers should be of corrosion-resistant material or provided with a corrosion-resistant lining. Bare cement products do not make satisfactory sewers because hydrogen sulfide gas will attack the cement. The size of the sewer must be determined by the anticipated flow requirements. Street sewers should be placed in all streets where occupied premises are located.

Collectors and Interceptors

Street sewers feed into collecting sewers of relatively large diameter, and collectors feed into still larger sewers frequently called interceptors. Sufficient grades must be maintained so that flow rates will be at least 2 feet per second. Collectors should be built of corrosion-resistant material or of concrete with corrosion-resistant lining. Collectors or interceptors are used to convey the sewage to the treatment plant or the outfall. Design must be based on the anticipated flow rates.

Pumping Requirements

Because sewers must be laid on a slope or grade, they soon reach uneconomical depths below ground surface in areas of flat terrain. For example, a 12-inch sewer should slope about 2 feet per thousand feet of length. At 10,000 feet of length the sewer will be 25 feet deep, which means that the sewage must be pumped approximately every 2 miles to maintain reasonable construction depth. A sewage pump is usually of the open impeller type because of the solids contained in the sewage. Bar screening of the sewage ahead of the pump is sometimes necessary to remove large objects which would clog the pump. Sewage in collectors and interceptors must sometimes be pumped, and sewage must frequently be pumped into the treatment plant. Collecting chambers are sometimes installed ahead of the pumps, especially when screening is necessary.

Treatment Techniques

Primary Treatment

Primary treatment consists of screening and sedimentation, with or without aeration and with or without chemical additives.

Sedimentation takes place in large tanks or lagoons and produces a fairly clear effluent plus raw sludge. In plain sedimentation, surface loadings of 900 to 1,200 gallons per day per square foot of surface with tank depths of 8 to 10 feet are common. Sludge may be removed mechanically, or the tanks may be periodically drained and cleaned.

Secondary Treatment

Secondary treatment of sewage follows the primary treatment described above. This type of treatment involves biological action and produces a much better quality of effluent and sludge. The activated sludge process is the most common form of secondary treatment. It consists of extensive aeration of the sewage in the presence of activated return sludge, trickling filtration and sludge digestion. The technicalities of the activated sludge process will not be covered herein.

Tertiary Treatment

Tertiary treatment of sewage is used only when a high-grade effluent is required for special purposes or when treated sewage is to be reused for domestic consumption. The process involves extensive chemical treatment, removal of phosphate and nitrogen, and usually carbon filtration. It is not likely that tertiary treatment will be used on projects in developing countries.

Disposal Requirements

Treated Effluent

The quality of the final effluent from a sewage treatment plant is usually governed by the requirements of an official agency. The BOD (biological oxygen demand) content and the concentration of certain chemicals are the measuring factors. In the absence of governing regulations, the quality of the effluent should be such as not to adversely affect the ecology of the area. If the effluent is to be used for agricultural, industrial, or domestic purposes, the higher the degree of treatment, the higher the cost will be. All the factors must be studied in determining the type of treatment to be used, keeping in mind the economics of the situation.

Sludge Disposal

Any degree of sewage treatment produces sludge that requires disposal. The sludge may be in liquid or solid form and may or may not be obnoxious, depending on the degree of treatment. The disposal of sludge is frequently a complex problem. Sludge makes good fertilizer, but chemical fertilizers are usually less costly to obtain and apply. Sludge must be disposed of in the most economical method possible without damaging the ecology of the area. Some common methods of disposal are incineration, burying, hauling to a place remote from habitation, composting with selected solid wastes, using for fertilizer, or disposing at sea.

Storm Drains

Combined Systems

Many of the older cities of the world utilize combined systems for storm drainage and sanitary sewers. This type of system is less costly than separate systems. In recent years drainage systems have been separated in some cities, but most such cities still have a combination of both systems. If economically possible, separate systems should be favored for future construction. When a combined system overflows, sewage may stand in the streets and contribute to health hazards. During and following storms, treatment plants must frequently be bypassed which results in the discharge of untreated sewage into streams, lakes, or the ocean.

Separate Systems

Separate storm drainage systems are designed to take run off and convey it to the point of discharge keeping it separate from sanitary sewerage. This system eliminates the hazards mentioned above. Surface channels are frequently utilized for storm drainage, a less costly means than buried pipe lines. Storm and runoff records are utilized in designing a storm drainage system. It is seldom economical to design storm drainage systems to handle maximum floods but the system should have sufficient capacity to take care of normal storms.

Site Selection of New Facilities

The selection of a new sewage treatment facility should take into consideration the following factors:

1. Sufficient area for facility and future expansion.
2. Adequate discharge facilities for effluent and/or storage of fluids and solids for reuse (irrigation and fertilizer).
3. Where possible, favorable elevation to allow gravity feed or to minimize pumping.
4. Favorable subsurface conditions to preclude contamination of potable water aquifers.
5. Where possible, favorable location in relation to prevailing winds.
6. Out of the path of future civic expansion.
7. Reasonable distance from community and industry.

Each community has its own individual problems and seldom, if ever, can all of these prerequisites be met.

Adverse Environmental Effects

Failure to meet several of these factors can produce adverse ecological effects, particularly when the system being installed is not up to "big city" standards. Such systems, with inadequate digestion capacity, will create air pollution problems in the vicinity of the plant and the "downwind" community.

Further, water pollution problems will result from the inadequately treated effluent, which may effect the local ground water supply, rivers and beaches.

To a lesser degree, the adverse effect on surrounding property values is another factor to be considered, particularly in the more developed communities.

Solution

To forestall such adverse conditions, there are but few solutions:

1. Locate facility sufficiently distant to minimize or eliminate the problem.

2. "Upgrade" the system to improve the quality of the effluent and design the surroundings to disguise the facility. (Surrounding park areas, tree rows, fences, etc.)

Each of the above will, of course, increase the cost of the overall facility.

Where budgeting considerations do not permit the additional expenditures, few, if any, actions can be taken, such as:

Enacting zoning restrictions to restrict residential encroachment in the vicinity of the facility.

In any case the adverse environmental effects of the facility will have to be weighted against the increased cost of moving or upgrading the facility. A thorough understanding of the problem which will evolve will help in the decision on which action to take.

Existing Facilities

In cases where expansion of an existing facility is contemplated, it will be necessary to weigh the cost of adequate treatment against the cost of moving the plant site to a more remote area.

Another important factor to consider is the problem of flies, mosquitoes, and other insects which may adversely effect the health of the local residents. The added expense of medical precautions to prevent plagues, malaria, etc., should be considered.

In smaller villages and towns a series of septic tanks may be the solution, providing the potable water aquifer is not affected.

APPENDIX B. CHECKLIST FOR STUDYING EXISTING WATER SUPPLY AND SEWERAGE SYSTEMS

A thorough study of existing systems entails the following:

I. Water

A. Area served
B. Population served
C. Per capita consumption of water, industrial usage
D. Leakage or unaccounted-for water
E. Adequacy and dependability of facilities
F. Distribution pressure and continuity
G. Source of supply, adequacy, dependability, quality
H. Treatment, water quality
I. Pumping, storage
J. Operating procedure and supervision
K. Maintenance schedule and adequacy
L. Meter reading, billing, collecting
M. Management and administration
N. Financial status, indebtedness

II. Sewerage

A. Area served
B. Population served
C. Per capita production of sewage and industrial wastes
D. Infiltration
E. Adequacy and dependability of facilities, overloading
F. Collection system, street sewers
G. Interceptors and trunk sewers
H. Pumping
I. Operating procedures and supervision
J. Sewer cleaning and maintenance schedule, adequacy
K. Method of payment for sewer service
L. Degree of treatment, disposal of treated effluent and sludge
M. Effect of disposal on surrounding area
N. Management and administration
O. Financial status, indebtedness

III. Health and Ecology

A. Endemic diseases, waterborne, vector-borne, contagious
B. Typhoid, cholera, dysentery index

C. Birth rate
D. Death rate, infant mortality
E. Medical facilities, hospitals
F. Climatological factors
G. History of disease in area, endemic graph, epidemics

IV. Storm Drainage

A. Rainfall and runoff records
B. Topography and usage of drainage area
C. Records of previous floods including flooded areas
D. Combined sewer and storm drain systems
E. Separate sewer and storm drain systems