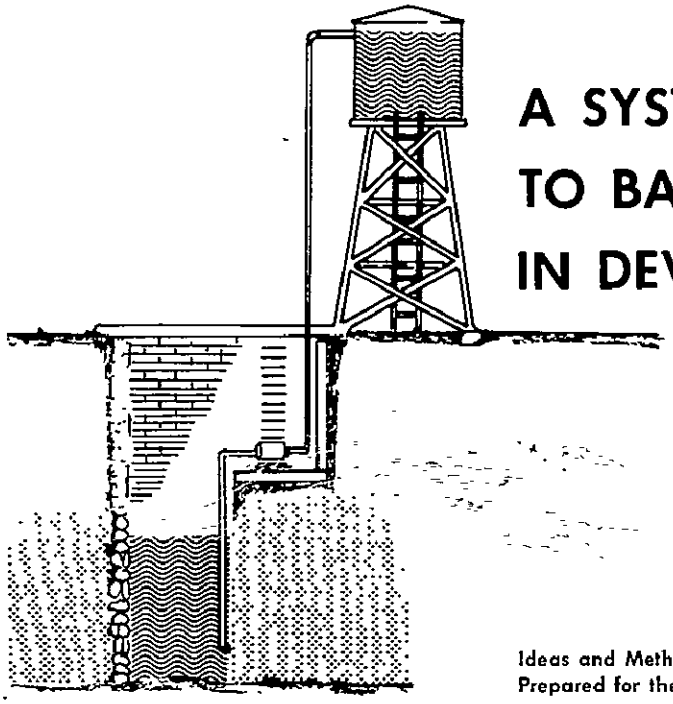


A SYSTEMATIC APPROACH TO BASIC UTILITIES IN DEVELOPING COUNTRIES

Ideas and Methods Exchange No. 70
Prepared for the Agency for International Development

Department of Housing and Urban Development
Office of International Affairs
Washington, D.C. 20410

A SYSTEMATIC APPROACH TO BASIC UTILITIES IN DEVELOPING COUNTRIES

Ideas and Methods Exchange No. 70
Based on Material by Oktay Ural
Prepared for the Agency for International Development

May 1974
Reprinted December 1974

Department of Housing and Urban Development
Office of International Affairs
Washington, D.C. 20410

A SYSTEMATIC APPROACH

TO BASIC UTILITIES

IN DEVELOPING COUNTRIES

IDEAS AND METHODS EXCHANGE NO. 70
BASED ON MATERIAL BY OKTAY URAL
PREPARED FOR THE AGENCY FOR INTERNATIONAL DEVELOPMENT

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
OFFICE OF INTERNATIONAL AFFAIRS
WASHINGTON, D.C. 20410

TABLE OF CONTENTS

PAGE

Chapter I

INTRODUCTION 1

Providing Water to a Community 3

The Sewage Disposal System 4

The Road System 5

Planning and Managing Basic Utilities 6

Chapter II

THE SYSTEMATIC APPROACH TO BASIC UTILITIES..... 8

Systematic Analysis

The Four Basic Rules 12
Task Analysis -- The Six Major Steps 13

The Constraints Matrix 18

Chapter III

DESIGN AND CONSTRUCTION OF BASIC UTILITIES

The Water Supply System 25

Water Sources 25
Water Quality Standards 31
Water Distribution Systems 36

The Sewage Disposal System 40

Types of Sewers 40
Factors for Sewer System Design 47
The Sewer System Design 48
Hydraulics of Sewers 50

The Road System 51

Pavement Design 52

REFERENCES 55

CHAPTER I

INTRODUCTION

Not enough can be said about the impact of economic growth and its effects. It is inevitable that people will move to the places where employment exists. Too often, these employment centers are not prepared to receive new workers and their families with adequate housing and the amenities which are required for decent living conditions. Throughout the world, especially in the developing nations, squatter settlements are springing up in urban areas where industry is on the rise. While these settlements are characterized mainly by high levels of density, which are constantly rising, they also are becoming permanent fixtures. They start with make-shift housing, and at best, jerry-built water and sewer systems. They are not good places to live, but quite frequently they manage to improve because of the initiative of the residents and organized assistance from government and industry.

The majority of planners in developing countries, as well as many international agencies working with them, are inclined to consider economic growth of primary importance. Often they fail to consider the impact this growth has on human requirements, nor do they make provision for it. The needs of the people, which should be met in relative proportion to economic growth, too often receive lower planning priorities. This is especially so in housing structures, water, sewage, and road systems.

A study of the need for basic utilities in developing countries cannot produce definite conclusions adaptable to every case in various parts of the world. However, it can bring into focus many factors whose understanding will improve and facilitate the planning and construction of such projects.

While basic utilities in the developing countries contrast drastically with those in industrialized nations, there is similarity in their origins. Only time and the wherewithal make the difference. Most settlements in the industrialized countries started without plans for water, sewer, and road systems. The lack of basic utilities--sanitary water supplies and adequate sewage disposal systems--caused major health hazards and economic constraints. Major plagues took untold numbers of lives and isolated city from city and country from country. These cataclysms occurred with regularity until the importance of basic utilities in terms of health and sanitation was understood and implemented. With improved health standards, people flourished and so did economic development.

Today, for example, in some countries of South and Central America, the death rate from enteric diseases is still higher than 200 per 100,000 population--and rates double that are not uncommon. Human suffering aside, the economic burden of an unhealthy community goes a long way toward nullifying the gains of economic growth. Economic benefits, which should uplift the lives of people, are dissipated by the less positive, but necessary, aspects of relieving human suffering.

The term *basic utilities** conjurs up different images in people's minds. To the engineer or planner *basic* utilities could mean a well-designed *sites and services area* which includes a road network, electrical service, piped water, and a piped sewag disposal system. To the inhabitant of a squatter settlement *basic* utilities may mean pumping water by hand from a community well and carrying it home in buckets.

The character and quality of a basic utilities system can range from a relatively complex system to a primitive arrangement. The primitive method is on the low end of the convenience scale, but if it provides the only feasible sanitary water supply, it is adequate until something better comes along. Ideally, a well-designed sites and services area assures achievement of sanitation and convenience. Unfortunately, the means to achieve what is generally considered to be the minimum requirement is often beyond the means of some developing nations. Fortunately there are compromises to this discouraging situation which permit planners either to establish or upgrade water supplies and sewage disposal systems within the means at hand. There are relatively simple methods and approaches that can raise the sanitary environment of people. Also, there are systematic approaches, which if applied over periods of time, can raise the level of consumer convenience. However, the immediate objective of a basic utilities system is to satisfy elemental human needs and minimum health requirements.

---

* The use of electricity as part of the basic utilities sytem is not discussed, for obvious reasons. Experience shows that while the residents of squatter settlements may lack financial and technical competence in building adequate water and sewer systems, they display ingenuity and expertise in providing themselves with electrical power, if there is a nearby source. A classic example is the Che Guevara settlement near Santiago, Chile (HUD International BRIEF # 12, "Housing and Urbanism in Marxist Chile," U.S. Government Printing Office, Washington, D.C. 20402, price 15¢).

In selecting a basic utilities system several factors must be considered:

- Minimum needs of the consumers in terms of sanitation and convenience.
- Availability of physical resources to obtain potable water and to dispose of sewage.
- Methods of transporting water to users and to dispose of sewage.
- Roads.
- The financial feasibility, materials availability, and manpower requirements to develop a basic utilities system; how these requirements can be met, including self-help capabilities.

Providing Water to a Community

Population densities, lay-out patterns in communities, the amount and location of water resources, and the means of distribution are the focal points of any basic utilities system.

While the community water-well and the public fountain are time-honored fixtures in many small communities, they can be health hazards if inadequate sewage disposal is allowed to contaminate them. It is incumbent upon planners and managers when relying on these types of water sources, to insure that sanitary sewage disposal is practiced.

Where water is in short supply, it may be trucked into a community and stored either in the transporting vehicle or transferred to a regular storage tank which must be covered to prevent the possibility of contamination. The cost of transporting water and the limited amount available make conservation necessary. Spring-loaded faucets, which automatically close when pressure is released from the handle, can control wastage.

In areas of adequate rainfall, water resources can be supplemented by collection of rainwater into tanks or cisterns. Protection from contamination, and a means of distribution must also be considered. A source of spring water above ground water contamination can be dammed and piped into a small community. The use of river and stream water is questionable unless it is filtered and purified.

If an adequate and potable water supply is within a reasonable distance of a community, it may be piped in. If financially feasible, it may be piped directly to individual houses, or to outside faucets placed at intervals to serve a group of houses. Pipes may be laid above the ground, although it is preferable to bury them. While this method is more costly to install, it is a necessity in climates where freezing conditions arise.

Where households are directly served by water lines, single or multiple faucets may be used, depending on the economic resources of the community. Single taps are more economical both from an installation investment and where the water supply is limited. Direct service lines provide the last means to control water sanitation from its source to the user. Also, it eliminates many man-hours of labor in carrying water by hand.

Water sources need to be sufficient to provide a continuous supply to the community. Disruptive service creates hoarding and promotes excessive use of water. Intermittent supply may also create negative pipeline pressure which could result in possible pollution because of backing up.

All of these supply methods offer the planner a means to provide *the* basic utility--*water*--in a manner compatible with the needs and capabilities of a community. Very often the most simple system is all that a small community may be able to afford--or may desire. Most likely, such methods may provide the only means available until more efficient systems can be developed.

The Sewage Disposal System

Water and sewer systems go hand in hand, but they must be isolated from each other. Sewage is dangerous because it is the breeding place of bacteria and viruses that threaten human life. More often, adequate disposal of sewage is more difficult and expensive than obtaining a water system.

Sewage disposal in less densely populated communities is relatively simple and inexpensive. Septic tanks can be used if the soil is porous enough to allow infiltration. Simple privies also may be used; however, in either case they must be so constructed that sewage does not seep into the water system and cause dangerous contamination. Sewage, particularly human waste, may be collected and transported to disposal areas where it is stored and treated by natural aerobic action and converted into fertilizer.

In large, densely populated areas there can be little compromise in selecting and building an adequate sewage disposal system if health standards are to be maintained. An *adequate* disposal system consists of sealed sewer lines that eliminate seepage and move the sewage away from the community. It has been the custom to discharge this waste conveniently into large bodies of water such as lakes, rivers, or the sea. *But the adverse environmental effects of this handling are proving disastrous and must be avoided.*

Sewage lagoons and treatment plants are the best answer to this problem. They are expensive to construct and maintain; however, solid wastes can be removed from sewage and the water treated to the point where it can be returned safely to rivers and streams. The solid waste material from the sewage can be used as fertilizer, or compressed and dried and used as fuel.

The Road System

Road systems neither contribute nor detract from the health aspects of a community as do water and sewer complexes. However, they are closely related to economic growth because they are the avenues by which people go to and from work, travel to market centers, and visit friends.

Left to natural means roads tend to grow by a haphazard process starting with a well-worn path that is the shortest distance between several points. Some of the oldest and largest cities of the world have winding street systems that began in just this manner. Unfortunately, the press of population growth and modern forms of transportation have turned some of these streets into frequent and monumental traffic jams. As urban areas in less developed countries grow, the same phenomenon is already apparent. The current world-wide energy crisis may have a dampening effect on this problem and it may be useful to planners to consider this factor when deliberating road systems for their communities.

Paved roads or walkway systems serve a useful purpose, if nothing more than to reduce mud during wet weather, and dust when it is dry. If communities are beyond reasonable walking distance to places of employment, bus transportation may be needed to serve the community. This would require a road of sufficient strength to support a heavy vehicle.

It is almost axiomatic that as economic affluence progresses so does the demand for more sophisticated forms of transportation. These days, humans are content to walk until they can afford bicycles. Graduation to the motor scooter is the next step with the private automobile as the ultimate goal.

While low-cost road construction is practical to meet the immediate demands of a community, planners should take the long view by providing for road widths and rights-of-way for future expansion. The likelihood of this contingency is not only possible, but highly probable. Road foundations are another consideration. If heavy vehicle traffic is anticipated, feasibility studies will be needed to determine materials for construction, topography, the ground water line, drainage, and other conditions. Otherwise, oil-treated or cement-treated pavement will serve adequately over a long period of time where traffic flow is light.

Planning and Managing Basic Utilities

Planning, designing, construction, and managing basic utilities systems requires a systematized and centralized approach. Whether this is done at the highest government level, or performed by the local government, is a matter of preference. However, in terms of financing, standardization of systems and materials (for reasons of economy), education and training programs (to provide necessary working skills), and effective enforcement procedures (to maintain health standards), the resources of the highest level of government are needed.

Financing is necessary to one degree or another in all phases of providing basic utilities systems. Ordinarily, the planning, designing, and overseeing of such projects would be the function of central government and the cost would be absorbed as a regular function of government. The purchase of materials and the hiring of labor for construction most likely would be supported by central goverment through grants or loans, or a combination of both. Much of the labor cost could be reduced through the institution of self-help programs. It would not be unreasonable to expect the beneficiaries of these basic utilities to contribute their labor in lieu of taxation or other charges for the systems. This presumes that recipients of such systems (on a self-help basis) would be on the low end of the income scale and have no other financial means to support such a program.

In the case of self-help programs, considerable organizational effort would be needed to train and direct the skills needed during construction. Again, the support of central government would be needed to oversee the effort.

General management activities, beyond actual project control, extend well into the community. The question arises as to the funding of continuing operational expenses of utilities systems. Who pays to keep the service going? Repairmen must be trained to service the system.

The manufacture of equipment for construction and repair must be provided. Public education will be necessary to generate interest and participation in the planning, maintenance, and management of public utilities. For in general, the greater the participation of the community in these affairs, the greater will be the success of the projects.

CHAPTER II

THE SYSTEMATIC APPROACH TO BASIC UTILITIES

Planning and constructing water systems, sewers, and roads, for new and existing communities involves a number of diverse factors such as:

- Size of the community.
- Density of the population
- Topographic variations.
- Climatic conditions.
- Water supply sources.
- Means of sewage disposal and treatment.
- The need for roads.
- Availability of local construction materials.
- Manpower.
- Educational level of the people in terms of providing technical skills.
- Finances and funding (loans, grants, or other sources.

As the number of these factors increases, decisions based on them become more complex. Effective decision making can be achieved through a systematic approach of analysis and action. This might be called *systems analysis* or the *systems approach;* however, what is presented here is far more simplistic than a true systems approach, although some of its elements are used.

Systematic Analysis

In a broad sense, systematic analysis is the assemblage and orderly arrangement of all the known facts of a given situation (or project). It is necessary to understand that all recognizable operations must be defined completely and accurately because of the interrelationships* of one activity with another.

For basic rules apply to a systematic approach to problem solving:

- Identify and recognize all relevant factors of the problem.
- Define the logic of their interrelationships to be able to perform an analysis.
- Assign realistic decision values to all defined factors.
- Optimize the results with respect to a defined factor for best results.

When these general rules are understood the analysis task can proceed under a more rigid format. Six major steps are involved, which, if adhered to, will minimize omissions and errors during the analysis process.

- Objectives (What is needed?).
- Elements (Of what is it composed?).
- Resources (What is available?).
- Constraints (What stands in the way of fulfillment?).
- Management (How will it be operated and maintained?).
- Evaluation (A decision based on the above).

Discussion of the four basic rules and six steps might best be illustrated with a "case study" of an idealized, hypothetical situation:

---

* For example, a water system must have a means of disposal for waste water, *ergo*, its interrelationship with a sewage system. However, an even finer distinction is the capacity of a water system in relation to the capacity of sewer system. Correct analysis and evaluation of the interrelationship is that the capacity of the sewer must be equal to the maximum output of the water supply to be effective.

A light-industry complex, with a capacity of 1,000 semi-skilled and unskilled jobs, was established on the outskirts of a medium-sized city in a small country. Most of the semi-skilled jobs were filled by residents of the city, who had relatively good educational opportunities and could learn complex tasks rapidly. The majority of the 1,000 jobs were in unskilled categories, low-paying, and least desired by the city dwellers.

By word of mouth, or direct recruiting, laborers were drawn from agricultural districts where employment was limited and available jobs paid less than industrial work. Housing in the city was limited and the growing number of in-migrating workers, many with families, soon outstripped all housing resources. An unused tract of land, adjacent to the industrial complex, was soon taken over by squatters. The first arrivals were people who worked at the complex. Quite rapidly a squatter settlement developed and the population burgeoned beyond the employment needs of the industrial complex.

*The squatter population, which was of self-sufficient peasant stock, constructed a well-organized housing environment, with a series of wells for water, and electric power pirated from the industrial complex. Unfortunately, the squatters, who had no experience with high-density living, overlooked the hazards of poor sewage disposal and soon their wells became contaminated. Serious enteric diseases broke out, resulting in several infant deaths and debilitating illness among many of the adults. The sickness rose to near-epidemic proportions and alarmed officials of the industrial complex, primarily because of work loss, and they called in public health officials.**

---

* Having recognized this potential hazard, the Venezuelan government is concerned with improving its *barrios* by bringing in water, sewer, and road systems. This is a difficult operation because almost all *barrios* are built on steep slopes and construction of paved roads is usually impossible. Steps made of reinforced concrete are solving the problem. At present, the occupants of *barrios* hand-carry water from scattered wells or public fountains. They use pit privies located near their homes. Water must be pumped to storage tanks at high locations and the main distribution pipes are being laid. The squatters are encouraged, through available loans, to make connections to the water and sewer connections. Each home will, under this program, have a single tap of water supply. Sewers operate with gravity flow and discharge to the river and then to the sea.

*Public health officials were reluctant to move because of a government policy which opposed "invader" or squatter settlements. The problem was passed to the central government which was equally apathetic, although it took actions with threats of eviction and resettlement and a small show of police power to intimidate the squatters. Militants among the squatters organized a series of loud demonstrations that were supported by the rest of the squatters.** A local newspaper which was lukewarm to the government saw an opportunity to embarrass it and conducted an investigation of conditions in the settlement. It was revealed, with blaring headlines, that the health hazard was communicable and threatened to extend beyond the squatter settlement. Public indignation rose and the settlement's health problem became a citywide controversy. Public officials in the city became alarmed at the growing number of protests, particularly since this was an election year. Because the city administration was of the same political party as the administration of the central government, it had little difficulty in persuading it to reverse its stance. The action was also supported by the industrial complex, a heavy party contributor, which reacted to pressures from major stockholders upset at its loss of productivity. This turn of events spurred the central government into priority action through its agencies responsible for public health and housing.*

A public health task force from the central government moved into the settlement to assist local officials solve immediate problems and undertake long range measures. Part of the task force was a specialist from the housing agency, who acted as an observer. Preliminary evaluation revealed three alternatives: water must be boiled before drinking; fresh water must be brought in by tankers; or a means must be found to purify the well water as it is pumped from the ground. The first alternative was impractical because fuel or electrical heating units to boil the water were limited.

** Comas, on the outskirts of Lima, Peru, was a squatter settlement 10 years ago. The people who settled Comas organized themselves and persuaded the central government to give high priority for the urbanization of their community. Today it is one of the better settlements in the area.

*Water tankers were in short supply and could deliver less than minimum needs; however, they were employed as a stop-gap. A priority call was placed through central government to the military which had a number of rubberized water tanks equipped with gasoline powered pumps and chlorination units. These were delivered within a few days, with one field unit set up at each well head. The problem was solved--temporarily.**

The Four Basic Rules

It is obvious that the temporary solution given in the hypothesis requires a permanent solution in very short order.

The relevant factors are:

1. The settlement was permanent and the population density was rising.

2. External sources of water, or the means to bring it into the settlement, were not available.

3. The only source of water was from the polluted wells.

4. Filtration and chlorination were the only satisfactory ways the water could be treated.

5. The immediate necessity of a sewage disposal system did not arise within the context of the hypothesis; however, it was implicit.

The interrelationship of factors 2 and 3 is an either/or situation, with but one obvious choice. There were no external sources of water, so the polluted well water must be used. Filtration and chlorination (factor 4) of the polluted well water were necessary because of the lack of a sewage disposal system (factor 5), and this was made imperative because of factor 1. The settlement was there to stay and the problem was growing with the rising population.

---

* The main source of water in Lima, Peru, is the Rimac River. Even though there are water treatment plants, the government urges the population to boil the water before drinking. There are a limited number of deep wells which are used in times of drought. Main water lines are concrete; however, more plastic pipe is used to connect houses to the water mains. There are no sewage treatment plants in Lima, and all sewers end in the Pacific Ocean.

Realistic decision values can be assigned only to factors 1,3, and 4. A decision value on factor 5 is secondary in this context, although under most other circumstances it would have equal priority. More simply stated, *decision values are arrived at by a process of elimination.*

A permanent solution to the water supply problem through filtration and chlorination was possible without immediate action on sewage contamination because proper purification cancelled out its polluting effects. This is not to say that adequate sewage disposal was not necessary, but only a matter of phasing in relation to the time-frame of the immediate problem. At this point, *a factor was defined which would produce the best results.*

The four basic rules, demonstrated above, can be expressed in a simple equation:

Relevant factors + Interrelationships + Decision values = Best results

While it may appear that simple logic has solved a difficult problem, what really has been achieved is merely a direction to follow. Many pitfalls are ahead and each must be bypassed with refined analysis and evaluation before final action can be taken.

Task Analysis--the Six Major Steps

Objectives (What was needed?)

The objectives of a project depend on the various factors associated with it and are derived from analysis and evaluation conducted under the four basic rules. In other words, the objectives are already established when task analysis begins. Within the context of the hypothesis the objectives are apparent:

Construction of a permanent filtration and chlorination system of sufficient capacity to serve the needs of the squatter settlement.

Elements (Of what was it composed?)

The elements which make a water supply system operational must be defined. Each element can be considered an independent, small sub-system of the system. Each is a discrete activity with minimum interaction among the others. The elements to be considered are:

- Site investigation.
- Land procurement.
- Land surveying.
- Location of water supply source.
- Type of storage facilities.
- Pump stations.
- Water treatment facilities.
- Excavation, backfill, and eompaction.
- Pipe system, connection boxes, and connection lines to points of use.
- Installation of meters (if appropriate).

Based on consideration of sub-system requirements, the broad elements of a water supply system emerges:

A cast concrete or lined cement block water storage tank, with eover, consisting of sufficient distribution pipes and taps, electric or gasoline powered pumps (s), and a filtration/chlorination system. The storage tank to be located in a cleared area at the highest point of the settlement and provided with a specially drilled well. Distribution pipes buried underground to lead to points coinciding with the existing wells which will be sealed.

Resources (What was available?)

The resources of a system are the objective and subjective forces which allow the activity to function and must be properly channeled to the right locations at the correct times:

- Financing.
- Technical assistance (information, research, and design).
- Manpower.

Financing

The housing agency of the central government was able to provide a grant for the cost of materials and equipment for the water supply system. However, national law limited the making of public works grants only to recognized local government entities. Since the squatter settlement was just outside the city limits, administering of the grant was the responsibility of the district government. The district government declined the grant on grounds that it did not have sufficient personnel to administer it. The city government was prevailed upon to annex the squatter settlement, which it agreed to do provided the industrial complex was included in the annexation. The industrial complex refused because it would have come under the city government's property tax system which was greater than the district government's. Threatened by a lowering of its own tax base, the district government sided with the industrial complex. The city government, its appetite whetted by the prospect of an improved tax base and future tax schemes, persisted in the annexation bid. The situation was on the verge of becoming a public squabble when an official of the industrial complex quietly pointed out to the city fathers that annexation would also include the welfare problems of the squatter settlement. In a reverse action, the same official pointed out to the district government that the squatter land was legally unclaimed, that improvement would raise its taxable value as unimproved land and that the squatters could be taxed for living there. The district government relented, immediately annexed the land and accepted the grant. The city withdrew its bid.*

---

* Basic utilities for small towns in Columbia are under the control of the *Instituto Fomento Municipal*. Urbanization and housing planning and production are generally controlled and financed by the *Instituto de Credito Territorial* and the *Banco Centro Hipotecario*. The *Instituto de Credito Territorial* (INSCREDIAL) was created in 1939 as a decentralized autonomous organization, supported by the Ministry of Economic Development. INSCREDIAL is responsible for all low-income housing planning, as well as urbanization of communities. It provides all new developments with water, sewer, and road systems, using the sites and services concept. A progressive organization, INSCREDIAL follows a systematic approach in planning all new communities. Its analysis and design teams include not only architects and engineers, but experts from many disciplines such as economics, material science, sociology, education, and health.

The housing agency of the central government could also make long-term, low-interest loans to private industry to finance labor costs involved in the construction of industry-oriented housing and basic utilities. However, in the case of squatter settlements, the central government also had the option to require that self-help labor be used when possible, and that the loan funds be used primarily for supervisory or technical employees. Well aware that the industrial complex did not own the land, the government proposed a scheme whereby the complex would accept responsibility for the loan, provide supervisory and technical personnel, and receive a subsidy for their services. The complex would benefit because many of these personnel were underemployed in their jobs, but because of their qualifications and scarce skills had to be carried at full wages. The complex was skeptical because it was a short-range solution. Although it would benefit immediately and in the future with a more stable work force, the cost of the loan repayment and interest outweighed the advantages. Seeing an opportunity to turn the proposal to further advantage, the complex suggested that it be given title to the land so that it could charge the squatters rent which would amortize the loan and meet interest payments. When this proposal was passed on to the district government, rejection was vehement. The central government suggested that the industrial complex also could act as the tax collector and could save the district government the administrative expenses. This was accepted by all parties. As word of this proposal filtered down to the squatters, general dissatisfaction was voiced, although squatters employed by the industrial complex were more amenable to it. Militants among the other squatters violently opposed the measure, citing the high incidence of unemployment within their group, and inability to pay. To counter the opposition, the government proposed that it arrange to have the payments of those on welfare increased to match the rental cost, if those of the group who were gainfully employed outside the industrial complex accepted the rent proposal. The opposition ceased and the loan went through.

Technical Assistance

The housing agency of central government was able to furnish engineering specialists to design and oversee placement and installation of the water supply system. Job foremen and building trade specialists were provided by the industrial complex which paid them from funds derived from the labor construction loan.

Materials and Equipment

As part of its operation, the industrial complex ran a small cement block casting plant and a pipe fabrication shop. It provided the cement blocks and mortar materials, as well as threaded pipe, connectors, and faucets, all at cost. One of the larger filtration/chlorination units provided by the military during the emergency period broke down and it proved cheaper to be replaced than repaired. This item was declared as surplus and unuseable property and turned over for use in the squatter settlement's water system. Employees in the industrial complex's pipe shop, who lived in the squatter settlement, fabricated replacement parts and redesigned it to handle a larger capacity so that it would meet the full needs of the water system.

Manpower

With all skilled labor requirements paid for under the labor construction loan, it was necessary to obtain manual laborers from the squatter settlement on a voluntary, self-help basis. A squabble soon developed among the squatters as to who should provide the labor. The employed squatters claimed exemption because they would be paying for the water system from their own labor, while the squatters on welfare would be subsidized. The central government stepped in as arbiter and ruled that able-bodied squatters receiving welfare would perform the labor.

Constraints (What stood in the way of fulfillment?)

In the preceding step, "Resources," the narrative disclosed some of the constraints that were encountered in the hypothesis, and what actions were taken to counter them. There are six areas of *constraint* which should be included in making any analysis and evaluation:

- Natural.
- Economic.
- Technological,
- Legal.
- Social (health and welfare).
- Political.

THE CONSTRAINTS MATRIX

Area of Constraint	The Constraint Problem	The Alternative
NATURAL	*Land located at the highest point in the squatter settlement where the water system tank must be located is already occupied by several houses.* *The squatters refuse to move because the location of their houses offers living advantages they do not want to sacrifice.*	Disassemble the houses to make the space and move them to another location within the settlement for reassembly. Adjacent space is available within the confines of the industrial complex, and is used for the water storage tank.
ECONOMIC	*Public health authorities determine that the polluted levels of the water supply are so high that a correspondingly high level of chlorine is mandatory to make the water potable. The chemical is a critical supply item in the country's economy and its cost and availability threatens viability of the water system.*	Earlier legislation provided the central government with priority and price control of chlorine supplies. Under public health legislation, it was authorized to subsidize, wholly or in part, costs of the chemical in situations where the public health and welfare was involved. The alternative used under the Technological constraint (below) was invoked.
TECHNOLOGICAL	*Filtration/chlorination systems are not manufactured in the country and must be imported. Because of the country's precarious balance of payments situation, such importation must be limited to emergency use. This is also complicated by the critical supply of chlorine.*	Use of the treatment system is abandoned in favor of deep drilling of a well below the subsurface contaminated water supply. The additional cost of drilling is offset by equipment and materials savings over the treatment system.

Area of Constraint	The Constraint Problem	The Alternative
LEGAL	*Ownership of the land is contested by private parties who see an opportunity to exploit the situation for personal gain.*	Claimants refuse the proposal and persist in their claim.
	The claim is tenuous, but of sufficient validity to threaten drawn-out legal action. The central government agrees to honor the claim provided the claimants accept the labor loan, rental, and tax responsibilities.	The central government suggests that the claimants may be held legally and financially responsible for past and future problems in the settlement. Also, there is vague mention about back taxes. The claim is withdrawn.
SOCIAL (health and welfare)	*In addition to contaminating the subsurface water supply, sewage overflow is discharging into a small stream which provides the water supply for a small lake in a park which is located within the adjacent city. The pollution threatens the wildlife of the lake and also creates a human health hazard.*	A temporary sewage lagoon is built on the low side of the settlement to catch the sewage overflow. It is so constructed that evaporation and aerobic action limits ground contamination until a permanent system can be planned and built.
POLITICAL	*Local leaders of the opposition party see an opportunity to embarrass the central government when the issue of self-help labor arises in constructing the water system. It agitates among the welfare recipients arguing that the free labor aspect is discriminatory and tantamount to slavery.*	The central government invokes its option to provide supplemental wages for self-help labor to the welfare recipients. It increases the size of its loan to the industrial complex to cover this contingency.

Since the solutions to the constraints offered in the hypothesis are more than likely over-simplifications, it should be pointed out that the constraints may be equally over-simplified. It is more than probable that the constraints analysis will cause more difficulty than any other phase of the systematic approach and that more time will be spent resolving them than in any other analytic action. For example, a matrix is provided to show some of the other constraints that could possibly have arisen within the context of the hypothesis. These are presented in the order of the six areas of constraint listed above. While alternative solutions are presented with each of the constraints, it must be remembered that in a true-to-life situation an entirely different set of constraints could arise, each requiring an entirely different set of alternatives.

Management (How was it operated and maintained?)

The assignment, or delegation of management responsibility, begins well before the task analysis is undertaken. Usually, this is a group or committee action, frequently *ad hoc* in nature, which takes over until proper management can be established. Management is involved in all activities and methods to be used in planning, designing, constructing, and operating a project once it is completed. Two of the most important aspects of management are the *establishment of priorities* and *coordination of activities;* the objective being to obtain the most economical and efficient use of resources within the schedules set for the project. The aspects of *management* are obvious in the context of the hypothesis and the first five steps of the task analysis. However, management responsibility is a series of stratified actions dependent upon who and what entities have the authority, or obligation to that role. For example, within the range of the hypothesis, the central, district, and municipal governments entered into decision-making that had affect upon the problem of the squatter settlement. Likewise, the industrial complex, a political group and the squatters voiced opinions and took actions that contributed to or detracted from successful completion of the project. In general, management responsibility belonged in part to the central government and in part to the industrial complex, because both entities were capable of acting on decisions or providing resources that were vital to the project. To complete the hypothesis, and to demonstrate how management requirements extend beyond completion of the actual project, post-completion of the water supply system is described.

It developed that deep drilling of a new well below the polluted subsurface water table eliminated the need for a filtration/chlorination system. District public health authorities had the responsibility of periodically checking the potability of the water supply. Maintenance of water supply system was limited to equipment checks and repairs. Since this was a part-time requirement, responsibility was assumed by the industrial complex, which turned the job over to its pipe fabrication shop as a permanent duty.

Evaluation of the Task Analysis

Within the context of the hypothesis, it is evident that in analyzing and evaluating all of its factors, actual construction of the water supply system was the least problematic. Ordinarily, a systematic approach would limit itself to the immediate problems of providing a basic utility, such as cost, physical and material resources, logistics, and manpower needs. This assumes, of course, that all of the necessary activities and constraints outside the engineering aspects of the project are solved beforehand.

As is evident in the hypothesis, construction of the water supply system was an afterthought that came to light as the result of an emergency situation. All of the problems (and their ramifications) of the squatter settlement were case-hardened by the time the emergency arose. It is entirely possible that one or more unsolvable constraints could have brought the task analysis to a negative conclusion. For example, if the industrial complex, for one reason or another, did not want the squatter land, the central government would have been unable, or unwilling, to provide anything more than emergency assistance. Ultimately, the squatter settlement would have had to be cleared to remove the health hazard. The only alternative would have been to provide a sites and services area to accommodate the squatters. In the process of this analysis and evaluation, that possibility would have, or should have been considered. This returns to the premise that *constraints*, rather than *resources*, often dictate the outcome in decision-making.

While this case study concerns itself only with a water supply system, it is obvious that a drainage and sewer system is imperative. A systematic approach in evaluating this circumstance would lead to this conclusion. The question would arise as to whether the emergency nature of the crisis precludes this consideration. The evaluation work would have been done and it would be little more difficult to tack on two critical elements. It would be just as easy to negotiate and fund the entire package, as

it would only one part. Certainly, the full package would be easier to justify under emergency conditions than to face apathy or outright rejection later when the heat is off.

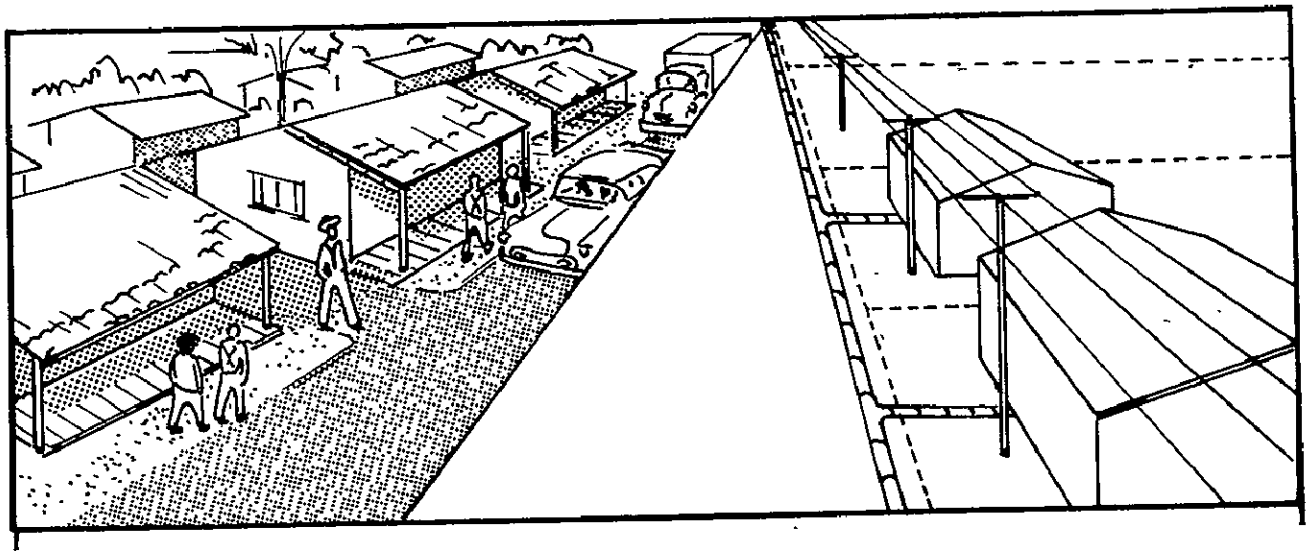
CHAPTER III

DESIGN AND CONSTRUCTION OF BASIC UTILITIES

The range of problems that can arise in the development of basic utilities, and the decisions that have to be made to solve them, extend well beyond the specifics of logistics and hardware. However, if the planner is to succeed in his analysis and evaluation he must be as familiar with the basics of hydraulic mechanics as he would be, say, with the possible intentions of a politcal action group involved in the decision-making process.

Since analysis and evaluation of the factors involved in developing a basic utilities system covers many disciplines (legal, health, social, economic, and engineering) it is reasonable to expect only that the planner understand the basics of each discipline. Input from technical assistance resources can be used to assist the planner when a problem goes beyond his technical competence. For that reason, the technical aspects of the design and construction of basic utilities covered in this chapter are limited to that scope.

The three basic utilities are water supply, sewage disposal, and roads, with their priority in that order. Their interrelationship is apparent and while it is possible to develop each as an independent entity, it is not desirable to do so. Exceptions are permissible in emergency situations, such as described in the hypothesis; however, in that example, many negative factors already existed which tended to impede successful completion of only one phase of a project which should have included at least two, or possibly three phases (water, sewers, and roads). This brings to importance the value of the sits and services approach when considering basic utilities.



THE "SITES AND SERVICES" CONCEPT*

Urbanization of undeveloped land is the basis of sites and services, generally initiated and funded (through grants and loans) by appropriate agencies of central government.

Under this program, the land is purchased and subdivided into plots of various sizes. Access roads are built and water and sewer systems installed prior to the construction of housing.

Various levels of services can be generated by the approach to coincide with economic conditions:

- Streets may be unpaved and common water taps and latrines service a number of plots.
- Streets may or may not be paved; each plot served by a water tap and its own latrine, septic tank, or sewer connection (or a small outbuilding containing sanitary core facilities).
- Each plot fully serviced with a partly finished house.

The sites and services concept has several advantages because:

- It is adaptable to a national level development program.
- It can be controlled by an administrative body.
- Total funding can be scheduled for a large community since it is least expensive for long-term financing.

---

* Kennedy, a low- and medium-income housing development in Bogota, Columbia was planned for 300,000 people and began construction in 1962. It has schools and shopping and recreational areas, and is connected to downtown Bogota by public transportation systems. The area was urbanized by the government before construction of dwelling units. Roads were paved with asphalt and sidewalks serve both sides of the streets. Each house is connected to a water and sewer system. Locally available concrete and brick were used as construction materials. Manpower was hired from the area, and self-help activities were encouraged.

- It is economical since infrastructures are placed during urbanization and conflicts with construction of superstructures are avoided.

- Every new community will have adequate water, sewer, and roads systems.

- The sanitary core building, which includes bathroom, and kitchen, is usually built on site. The owner is encouraged to add other rooms at his own expense in keeping with his economic situation.

THE WATER SUPPLY SYSTEM

Water is the most critical need, outside the air that is breathed and the food that is eaten. The industrialized nations have already learned that rising populations and a growing technology demand greater and greater quantities of potable water. This is equally apparent in the less developed countries as areas become urbanized and health problems are magnified.

Lakes and rivers provide the largest portion of the world water supply. Very often, in many places wells are the only source of water. Rainwater is collected and stored in some countries, while in a few seawater is desalinated for human consumption.

Water Sources

Determination of current and future water supply needs of a neighborhood are related to various factors.

- Quality and quantity of sources of water.

- Topography of the region.

- Climate of the area.

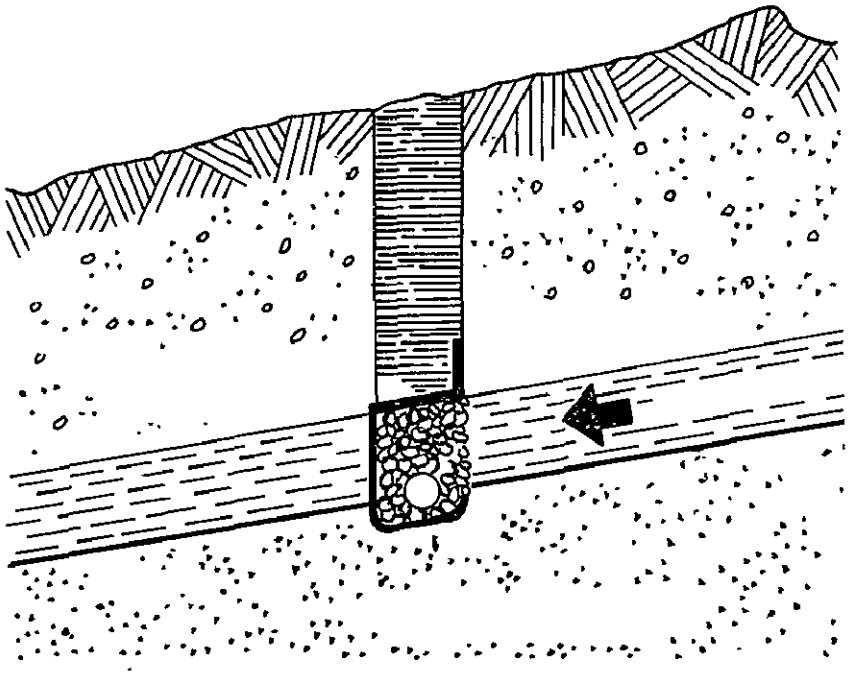
- Physical condition of the existing system.
- Pressure expected in the water lines (even though higher pressures are desirable, they often cause leaks in the system).
- Economic status and standards of the population to be served.
- Control of water distribution by measuring devices (meters).
- Cost to the consumer.

There are major variations in the quantity of water consumption with respect to the time of the day as well as the month of the year, depending upon the:

- Degree of industrialization of the population.
- Life-pattern of the population.
- Seasonal changes in the climate.
- Fire demand.

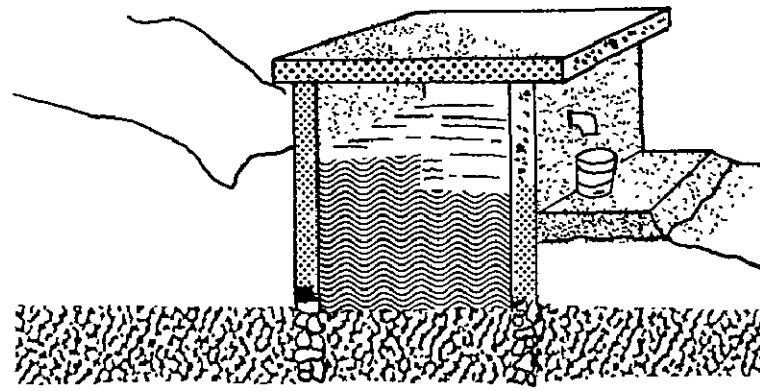
In urban centers, two different sources of water may be used; one to supply potable water for domestic use, non-purified water for industrial and fire protection purposes. Water for laundry and toilets may come from untreated sources. This is acceptable where potable water is in short supply and a second water distribution system is economical.

WATER SOURCES -- SPRINGS

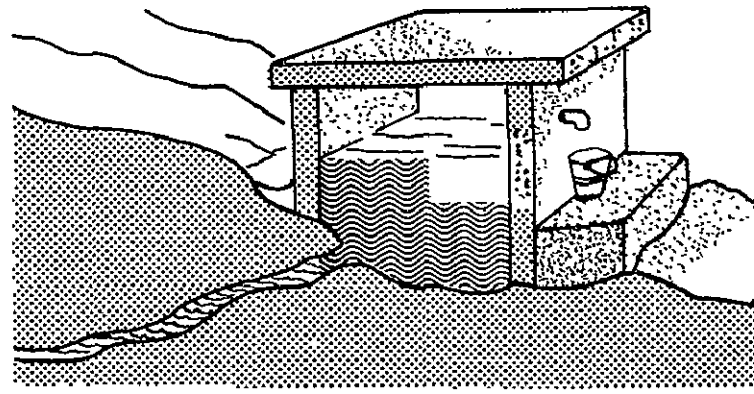


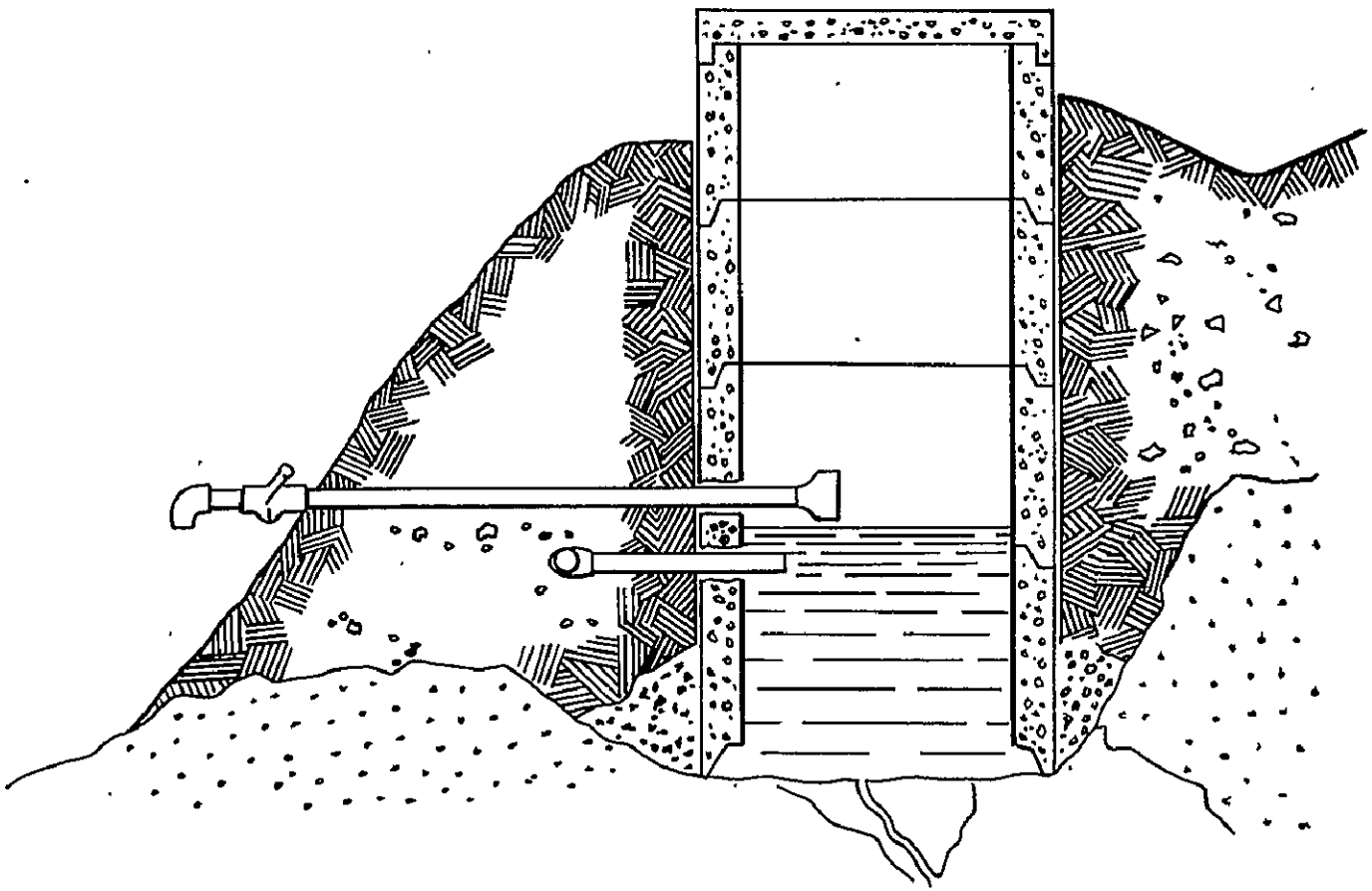
A spring leading into a marshy area may be used as a water source. A diversion ditch is cut across the vein of water below the bottom path. A perforated pipe is laid in the ditch, covered with gravel, and a plastic barrier is installed to retain the water. Perforated plastic pipe may be used in place of terra-cotta pipe.

A concrete retaining box can be built over a vein of spring water in this manner. Runoff water may be collected in buckets, or piped to houses.

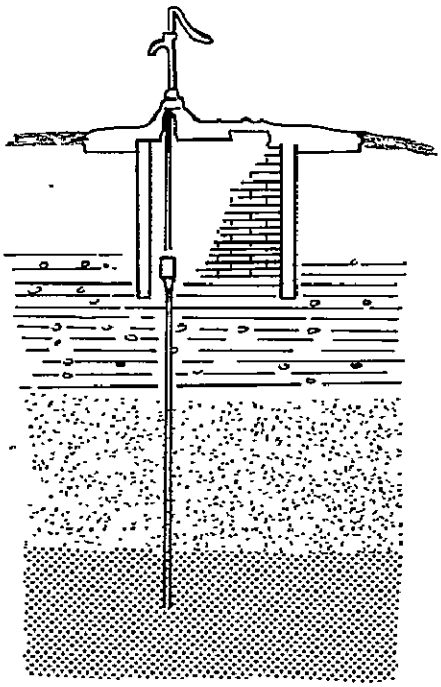


The same may be done with a rock spring; however, the rate of flow of the water may not be sufficient for pipe service to houses. The necessity to handcarry water would provide the water distribution discipline needed to insure that users get equitable supplies.

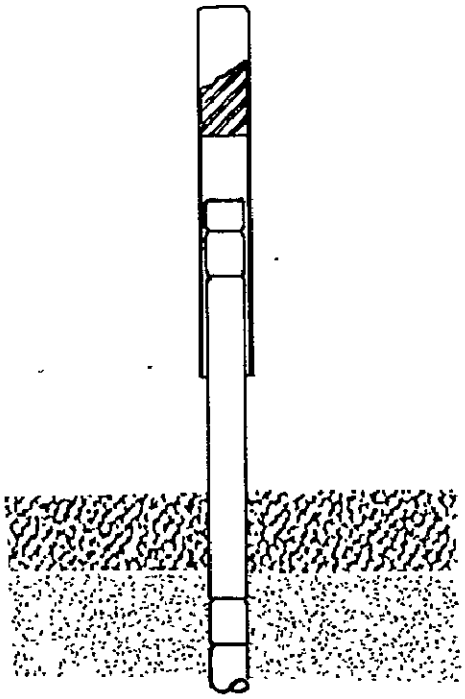




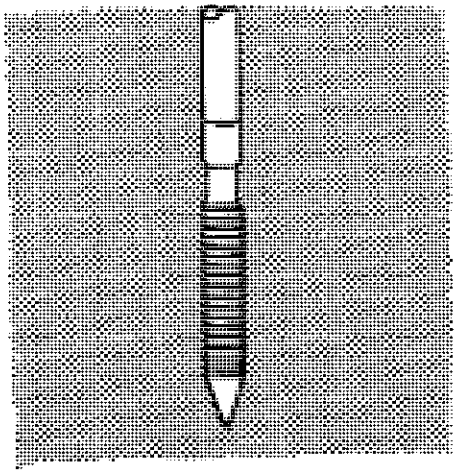
Development of a spring in a deep rock formation requires a more sophisticated arrangement. Proper protection to avoid pollution of the water is essential.



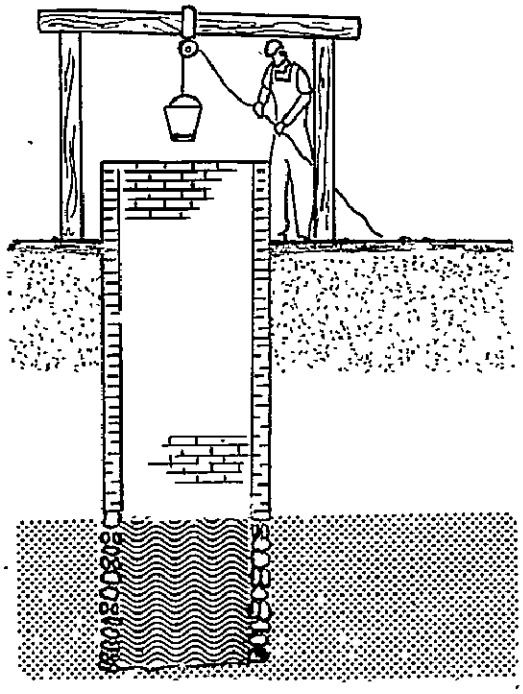
When older wells become contaminated it is best to abandon them, or to drill through the confining layer into the aqueous rock. The bottom of the old well should then be sealed off so as not to contaminate the water further down.



Driven wells may be the quickest and cheapest way to get water in coarse sand or gravel formations. Threaded steel pipe, attached to a perforated steel driving nose, can be pounded into the ground with hand labor.

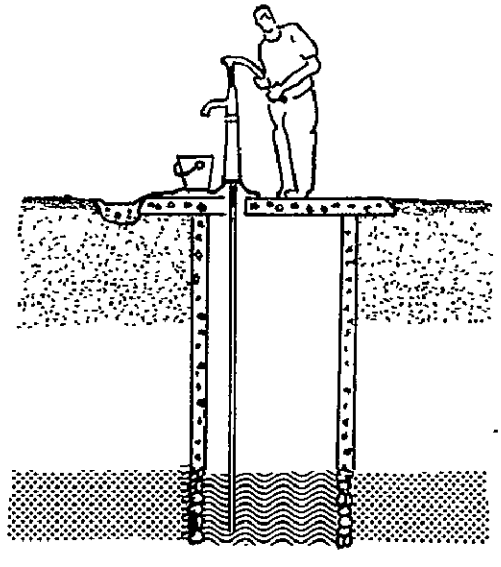


WATER SOURCES -- WELLS.



Where the water table is relatively close to the surface, a common well may be dug to provide water. A scaffold and pulley are convenient to lower and raise the bucket. The well sides may be constructed of wood, brick, or masonry to prevent cave-ins.

A handpump may be installed to facilitate drawing water, or an electric pump may be used to supply a tank or standpipe from which pipes may lead to houses to provide service. Wells should be covered for sanitary and safety reasons. Well water may be contaminated from surface sewage and treatment methods should be considered when relying on this method of water supply.



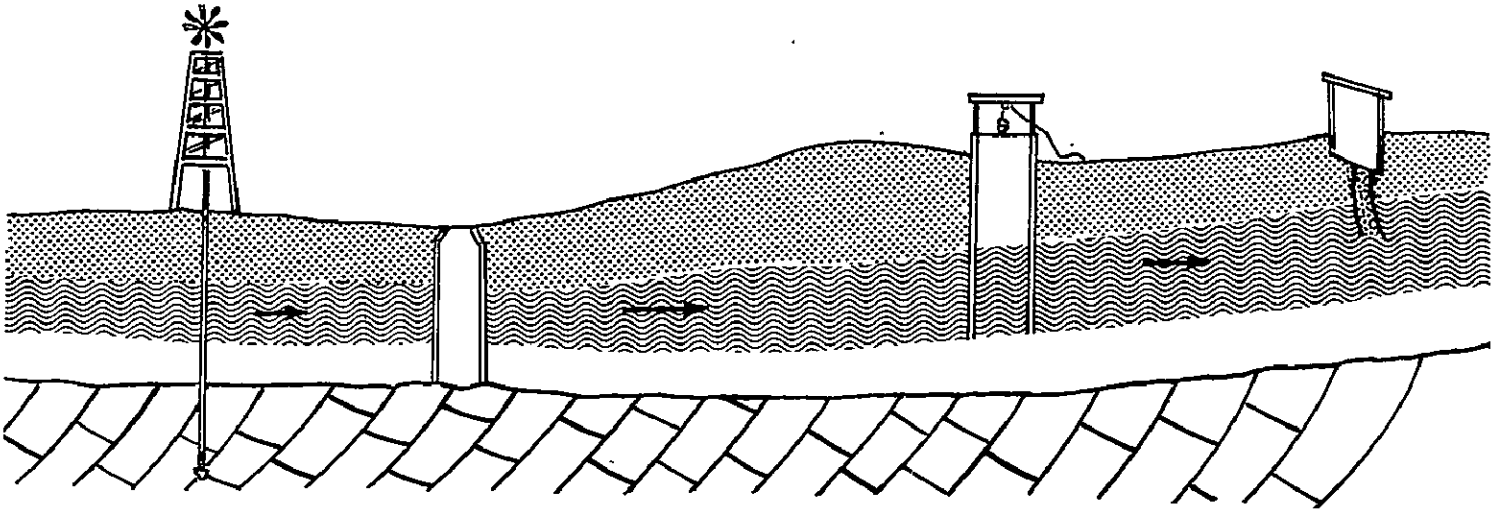
Water Quality Standards

Whatever the source of water, if it is to be used for human consumption, it should have two qualities:

- Safe for use because it is free of pathogenic microorganisms, such as viruses, bacteria, and protozoa and poisonous substances, organic matter and excessive minerals.

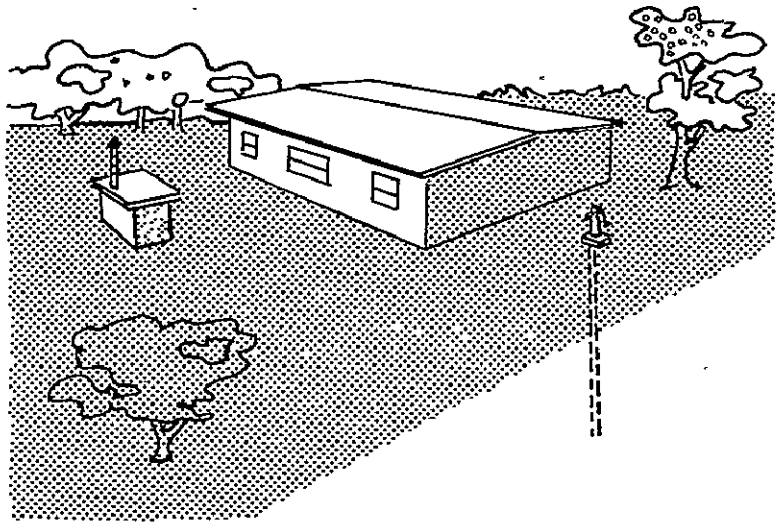
- Free of unpleasant tastes, odors, and colors, and turbidity and excess temperature.

Often water supplies must be treated to obtain the proper standards of quality and safety. Mechanical and chemical methods are used in treatment and described in the accompanying illustration.



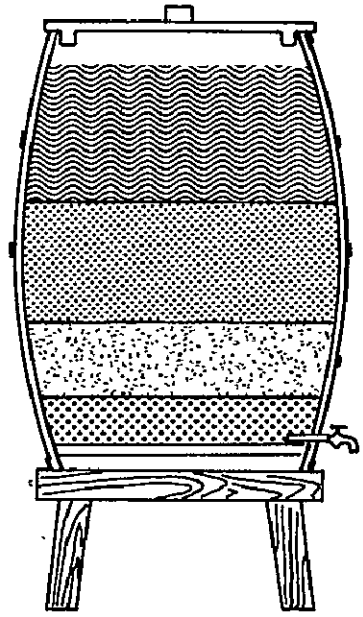
Ground water is found in two layers, the subsurface water table and deeper in aquified rock. The layers are usually separated by a confining layer. The subsurface water may be subject to contamination from surface sewage, while aquified rock water remains pure. Wells should be dug or drilled past the surface water and into the aqueous rock, insuring there is no seepage between the two.

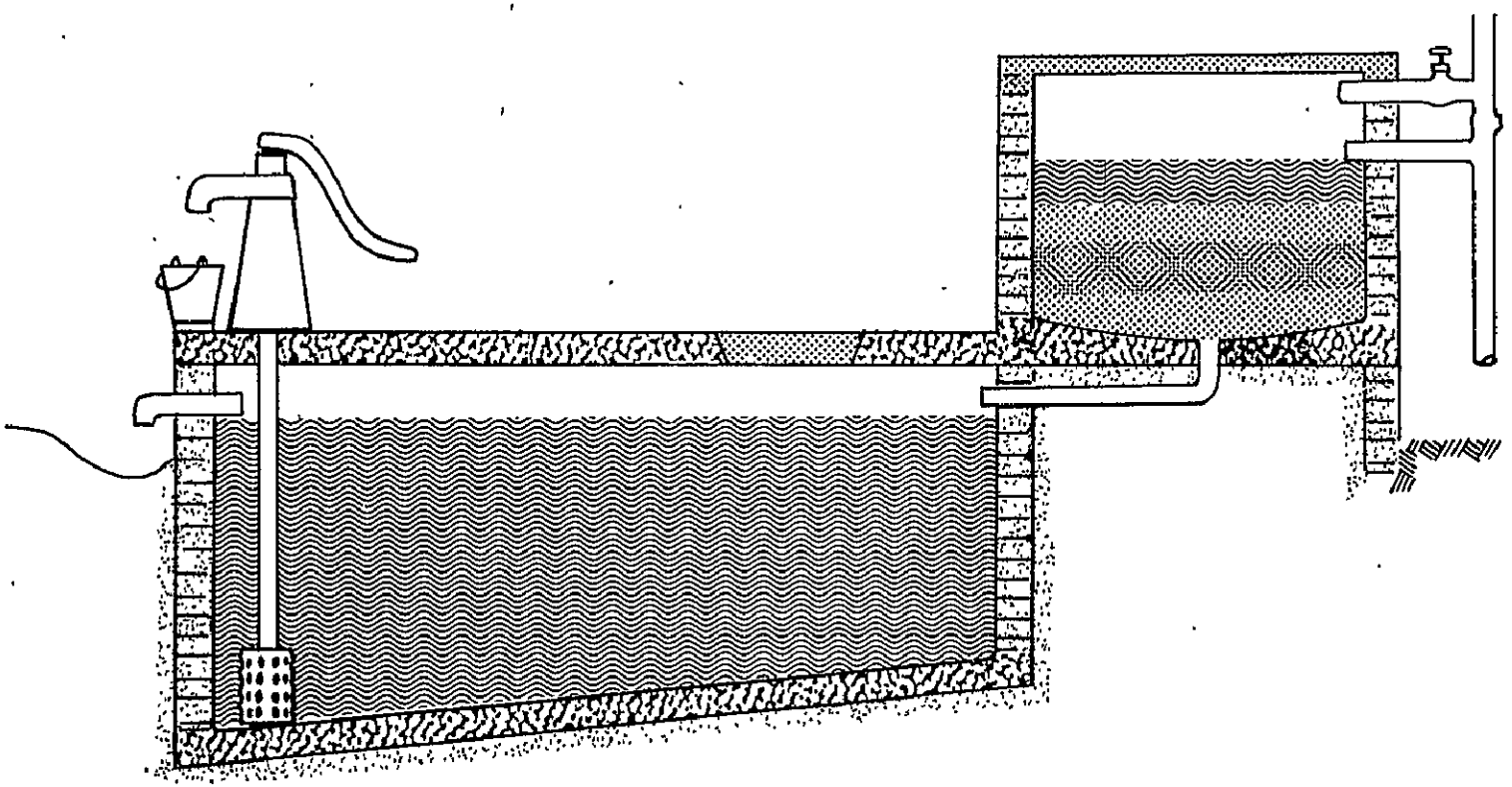
WATER SOURCES -- SANITATION AND PURIFICATION



The location of a privy adjacent to a water well is not recommended because of the high probability of contamination, unless the well is drilled well below ground water level and is properly sealed.

Contaminated water should never be used for human consumption. If it is high in particulate matter it may be filtered in a barrel which has layers of gravel, sand, and charcoal as shown here. However, bacterial and viral contaminants will remain in the water. The water should be boiled or chlorinated for drinking purposes. If the water comes from roof drainoff, or similar collection sources, it most likely will not be contaminated by other than particulate matter. When filtered, it most likely is safe to drink.



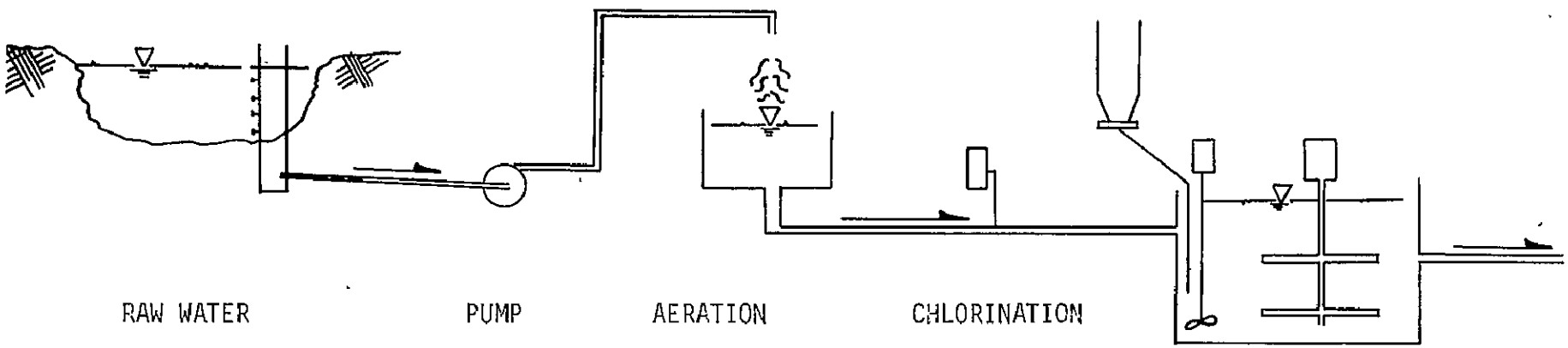


A combined water filtration and storage system may be constructed of brick, concrete block, or poured concrete. The water source could be from a drilled well, spring, or rainwater runoff. This system is predicated on a potable water source where there may be some particulate matter which must be removed. A more sophisticated version of this system would include a chlorination capability. It could be chlorinated with chlorine tablets or powder to control bacteria and viral organisms.

WATER TREATMENT
(Unit Operations and Processes)

CHEMICAL FEED

For coagulation, softening, control of taste & odor



RAW WATER

Contains turbidity, bacteria, color, taste & odor, hardness, iron & manganese

PUMP

Lifts water

AERATION

Helps remove gases such as CO_2 & odorous H_2S; helps oxidize iron & manganese

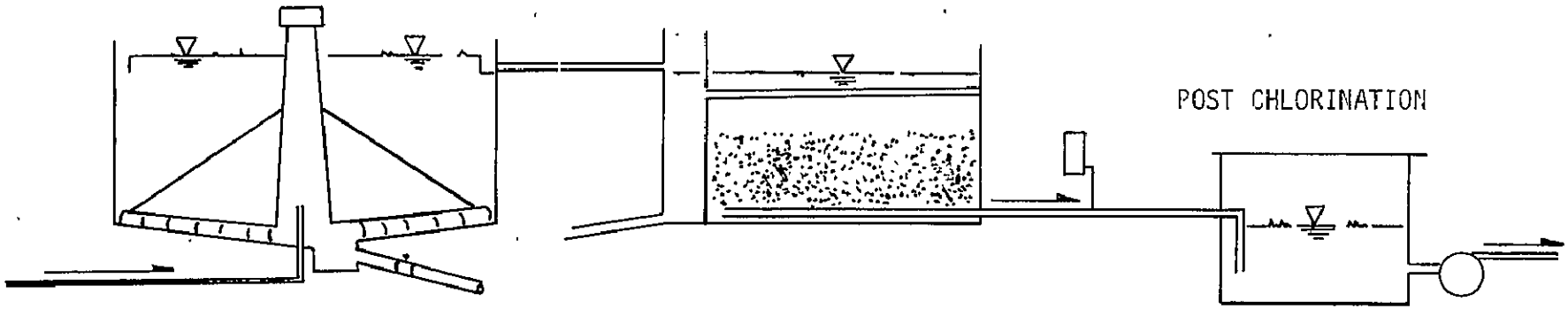
CHLORINATION

Kills bacteria; oxidizes taste & odor

COAGULATION

Rapid and slow mix of chemicals neutralizes electric charges on the colloidal pa ticles causing turbidity, groups them into larger easier settling agglomerates (floc)

WATER TREATMENT (Cont'd)



SEDIMENTATION

Allows floc to settle, removing turbidity, bacteria, color, some taste and odor, hardness

RAPID SAND FILTRATION

Polishes water by removing excess floc.

CLEARWELL

Stores treated water

PUMP

Moves water into distribution system

Water Distribution Systems

A water distribution system can range from the most primitive (buckets, roof catchment, barrels, and water tank trucks) to a reservoir with service piped directly to the consumer's house. Three major factors must be considered when designing a water distribution system, based on whether it is to be a new or improved complex:

- A master plan (which considers the size and character of the area to be served; population size and habits of the people to be served; economic structure--industrial or agricultural; location and number of schools and hospitals; projection of future needs).

- Knowledge of the mechanics of the system (age and condition of pipes and corrosion and failure probabilities).

- Improvement plan of the system (economic justifications and financial resources; technical feasibility studies; political preferences and pressures).

In planning water supply design and construction these points should be considered:

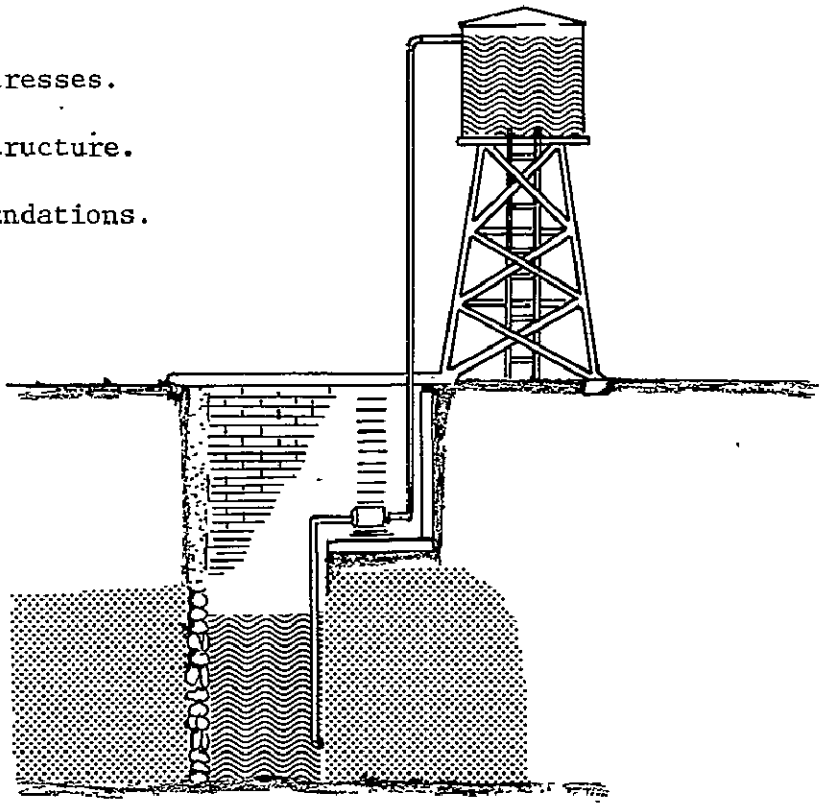
- Preparation of a detailed map of the area to be supplied, indicating all relevant factors such as origins of supply, soil conditions, frost line, fire hazards, slopes, earthquake zones.

- Drawing of existing and proposed water lines in the community; marking main lines, cross-overs, and interconnections.

- Estimation of the demand by the public at various sections of the community water system by the rule of thumb or using statistical data as available.

Standpipes are elevated reservoirs which are useful to generate pressure for the distribution of water. It is a good idea to select a hill as the location for the standpipe to obtain the necessary pressure for distribution. Basic factors to be considered in the planning of a standpipe are:

- Economical size.
- Determination of stresses.
- Stability of the structure.
- Strength of the foundations.
- Wind pressure.



- Selection of the diameter of the pipes according to the formula,

$$D = 2\sqrt{Q/TV}$$

where V = velocity (3 to 5 feet per second (.9 to 1.5 meters per second)

D = diameter of the pipe, feet (meters)

Q = rate of flow, feet (meters) per second

The rate of flow, Q, through an opening is expressed by:

$$Q = K_0 \; A \sqrt{2gh}$$

where KO= coefficient of discharge

g = acceleration due to gravity

h = head at center of opening

A = area of opening

This design procedure will develop a self-cleaning flow through the pipes and computations of pressure at various locations in the system. The design should also provide for:

- Locating valves, service pipes, and hydrants according to local needs and preferably in areas of easy accessibility.

- Easy access for quick and effective maintenance operations. This can be accomplished by including sufficient service pipes and equipment necessary to make the repairs.

There are three distribution layout systems to choose from: gridiron, tree, and circle. Design of a water supply system must consider the following:

- The best distribution system is the gridiron or closed loop system where each point is served at least by two pipes from different directions.

- Dead-end systems are more susceptible to low pressures and may cause dangerous back siphonage from soil and plumbing into the water lines.

- There must be no cross connections between water and sewage because of pollution hazards.

- Pressures should never be below 20 pounds per square inch (9 kilograms per 6.4 square centimeters) at any time in the system; 40-50 (18 to 23 kilograms) psi should be considered normal for most systems, and 75 (34 kilograms) psi should be considered in buildings over three stories.

- Valves should be located no farther than 800 feet (240 meters) apart on long lines, and in cities close enough so that only a few blocks would be out of water at any time. It is considered poor design and potentially dangerous to health where a major part of a city could be put out of water due to a break.

- Flow design should be based on the maximum day's flow plus fire demand or the maximum hour's flow, whichever is the largest.

- In small cities almost all water is used during a 12 hour period; the maximum hourly rate will be approximately twice the maximum daily rate, and the maximum daily rate is 1 1/2 to 2 times the average annual rate. In small villages, these peak flows may be even larger; in this case, the maximum hour may be 9 to 10 times the average daily flow rate for the village.

Transporting water from its source to the point of consumption usually uses pipe, or similar conveyors, such as:

- Aquaducts (used since ancient times, they are common to some mountainous regions).

- Asbestos cement pipe - sizes from 4 inches to 36 inches (10 to 90 centimeters in diameter), maximum pressure 200 pounds per square inch (90 kilograms per 6.4 square centimeters) (Advantages: corrosion resistance, light weight, low maintenance; good flow characteristics due to small friction factor. Disadvantages: low flex strength which causes failure under beam action due to differential settlement and excessive load, hard to use with a regular tapping machine, difficult to locate once buried.) *Caution: Current medical opinion in the United States suspects asbestos fibers may have carcinogenic (cancer-producing) characteristics and recommends against use as a conveyor of water for human consumption.*

- Cast iron pipe--sizes from 4 inches to 48 inches (10 to 120 centimeters in diameter), maximum pressure 350 pounds per square inch (150 kilograms per 6.4 square centimeters) (Advantages: durable, high flex strength, large carrying capacity, easy to tap. Disadvantages: subject to heavy corrosion).

- Concrete pipe - sizes 12 inches to 168 inches (30 to 410 centimeters in diameter), maximum pressure 250 pounds per square inch (115 kilograms per 6.4 square centimeters (Advantages: durable, good corrosion resistance, low maintenance. Disadvantages: may deteriorate in certain soils, heavy, hard to tap).

- Steel pipe - size 4 inches to 120 inches (10 to 305 centimeters in diameter), (Advantages: lightweight, flexible in moving soil. Disadvantages: (subject to exterior corrosion, hard to tap).

- Plastic pipe -- sizes up to 16 inches (40 centimeters in diameter), pressure is limited to strength of given plastic. (This is a relatively new form of pipe but rapidly gaining acceptance. Advantages: lightweight, easy to lay, excellent flow characteristics, easily tapped. Disadvantages: subject to freeze damage, difficult to locate once buried. Generally considered excellent for interior piping but not for interior mains and submains).

- Wood Stave Pipe -- size 12 inches to 168 inches (30 to 430 centimeters) and larger in diameter. (Still common for large transmission pipe lines in the mountains. Does not freeze and is easily repaired. Presently used for penstocks and cross country water transmission. Depending on the region of the country, it can be the cheapest type of material for large pipes).

The Sewage Disposal System

The lack of some type of system to handle the sewage of a community is always a serious threat to its health and welfare and the following facts must be recognized:

- About 60 to 70 percent of water supply of a neighborhood ends up as waste water.

- Industrial wastes can contribute to the sewage, depending on the size and nature of the factories in the neighborhood.

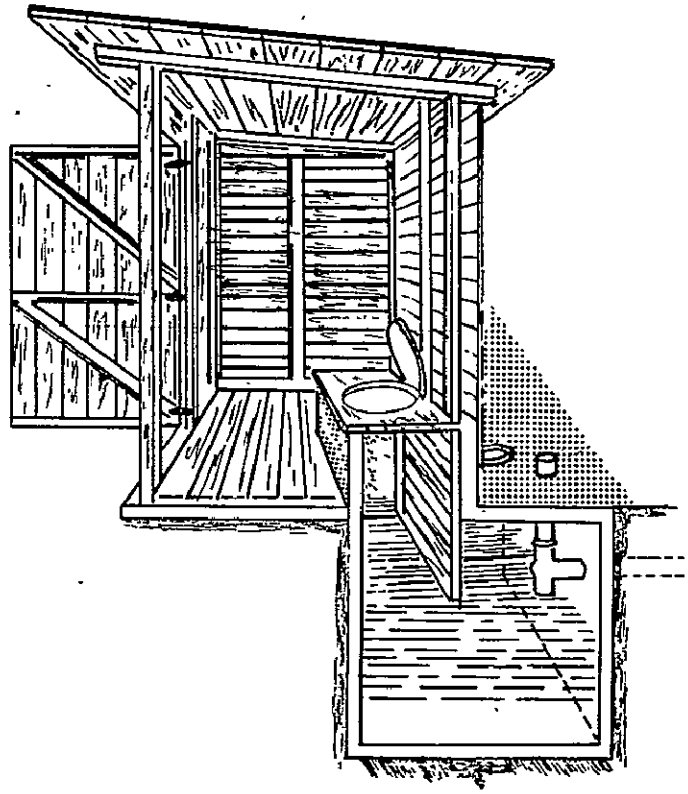
- Rainfall increases the flow in the sewers due to excessive leaking into the pipes.

- Combined systems which carry both storm water runoff, as well as sanitary sewage, are to be avoided if possible. They create major difficulties for sewage treatment plants because of overloading.

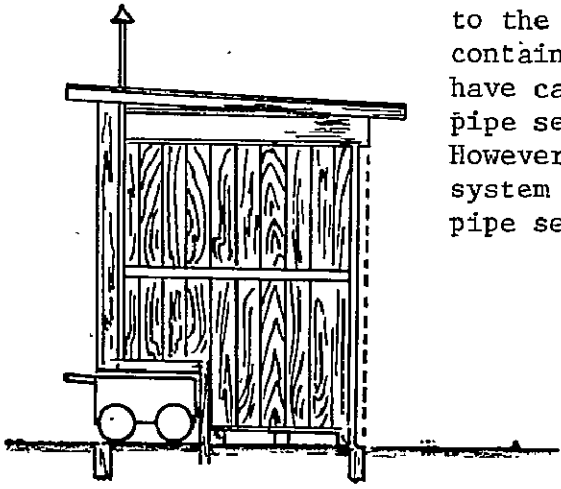
Types of Sewers

There are several types of sewer discharge and/or treatment systems, ranging from the primitive to the sophisticated, such as: the pit privy; container privy; aqua privy; septic tanks; classical system; sewage lagoons; and vacuum systems.

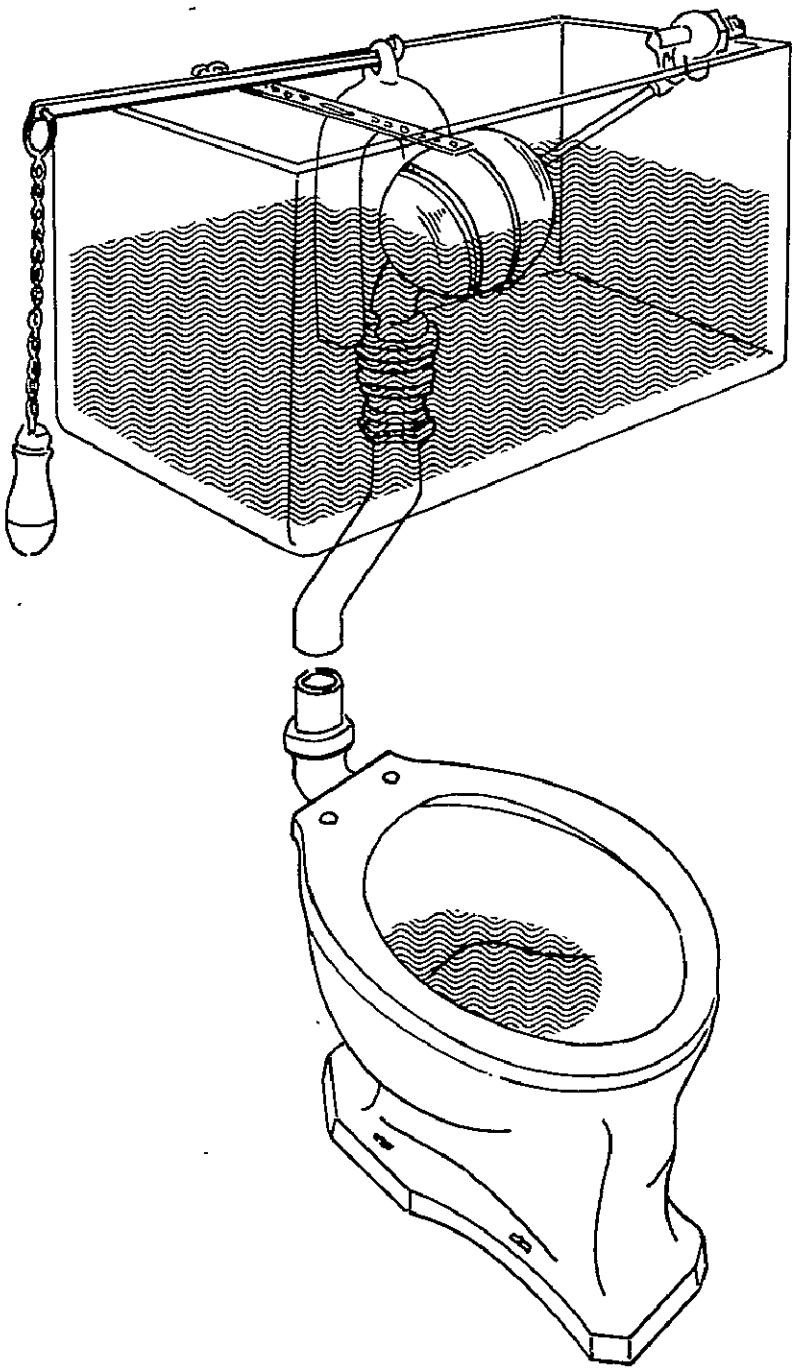
Pit Privy -- The pit privy location should be downgrade from water sources, with the bottom 1 1/2 feet (.5 meter) above ground-water level since it operates on the seepage principle. It should be located away from streams or lakes, and at a safe distance from the household food preparation areas. The pit privy must be designed to exclude disease carriers such as insects and rodents. At the same time, the pit privy must be located conveniently to the users. Probably the floor-level squat type with a tightly closing trap door is the most economical. The enclosure should be provided with screened ventilation openings to dissipate offensive odors.

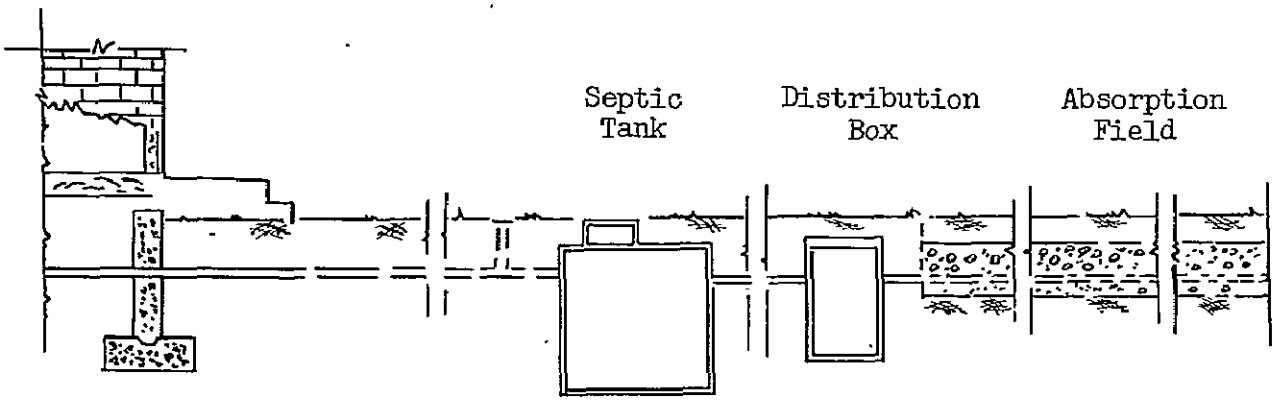


Container Privy -- Where other forms of privies cannot be used, alternatives are covered cans, pails, or containers to transport human excreta to a safe disposal area. Accumulations of so-called night soil in privies and cesspools can be periodically removed in honey-wagon vehicles to points of safe disposal. Spillage from various types of containers, the offensive honey-wagons and the great danger to the health of the many workers picking up containers and manually cleaning cesspools have caused rapid changeover to the aqua-privy pipe sewer system whenever funds can be obtained. However, the container, night-soil vehicular system is labor intensive, while the water-borne pipe sewer is capital intensive.



Aqua Privy -- Most commonly called the "flush toilet," the aqua privy is connected directly to a cesspool, septic tank or classical sewer system. Most frequently it is also attached to the water system to provide the flushing action to move sewage into the disposal network. It is automatic in operation, although the flushing bowl can be fed by hand. Self-contained aqua privies are available which do not connect to a sewer system, and must be filled with water. Waste water is captured in a self-contained tank which must be emptied by hand. Either aqua privy is very sanitary and convenient; however, installation is a matter of cost in both cases.





Section Through Septic Tank System

Septic Tanks -- Where adequate public sewer systems are not available sewage may be disposed in septic tanks. Septic tanks rely on biological processes for the treatment of sewage, and if designed, constructed, and operated properly, can provide a safe and relatively cheap method of treating domestic wastes.

The septic tank system has two major parts:

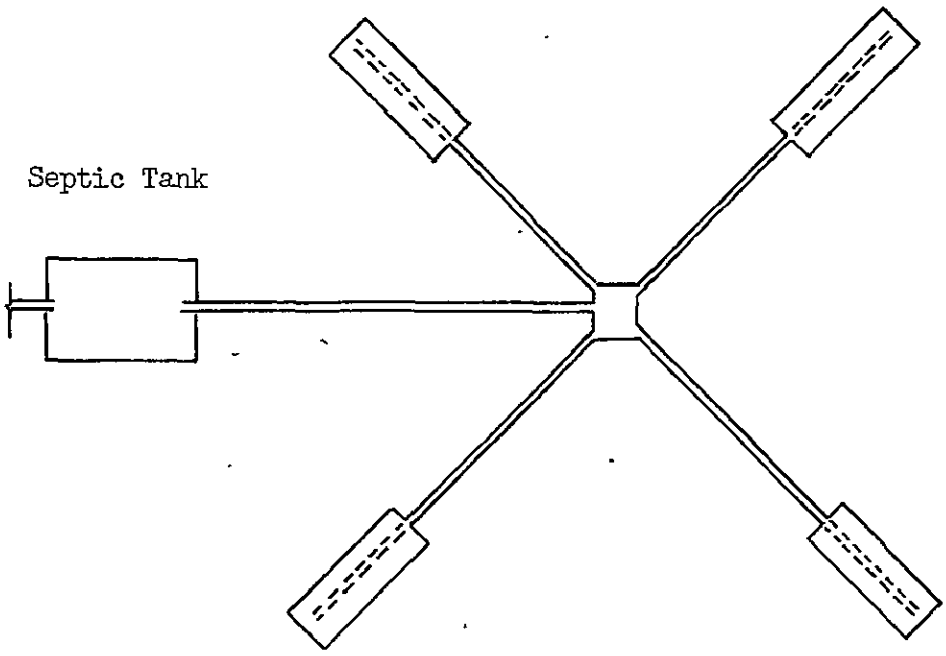
- Septic tank.
- Absorption field.

One of the most important items to be checked before a septic tank is constructed is the absorption characteristics of the surrounding area. The septic tank is pre-fabricated and buried or built in place. It receives raw sewage and allows the solids to settle out to be partially digested by bacteria.

The absorption field is a sub-surface network which distributes the liquid effluent over an area where it can seep into the soil. The filtering capabilities of the soil, with additional bacterical action removes harmful organisms. The efficiency of the absorption field can be increased by incorporating absorption trenches filled to a depth of 6 inches (15 centimeters) with graded gravel. Heavy equipment should not pass over the absorption field, since this disturbs the natural form of the soil and diminishes its absorption capability.

The following should be considered in selecting the location of a septic tank:

- The tank should be located adjacent to the absorption area, but not in swampy places.
- Topography of the location should provide sufficient slope so that raw sewage flows by gravity from the house to the tank and from the tank to the absorption field.



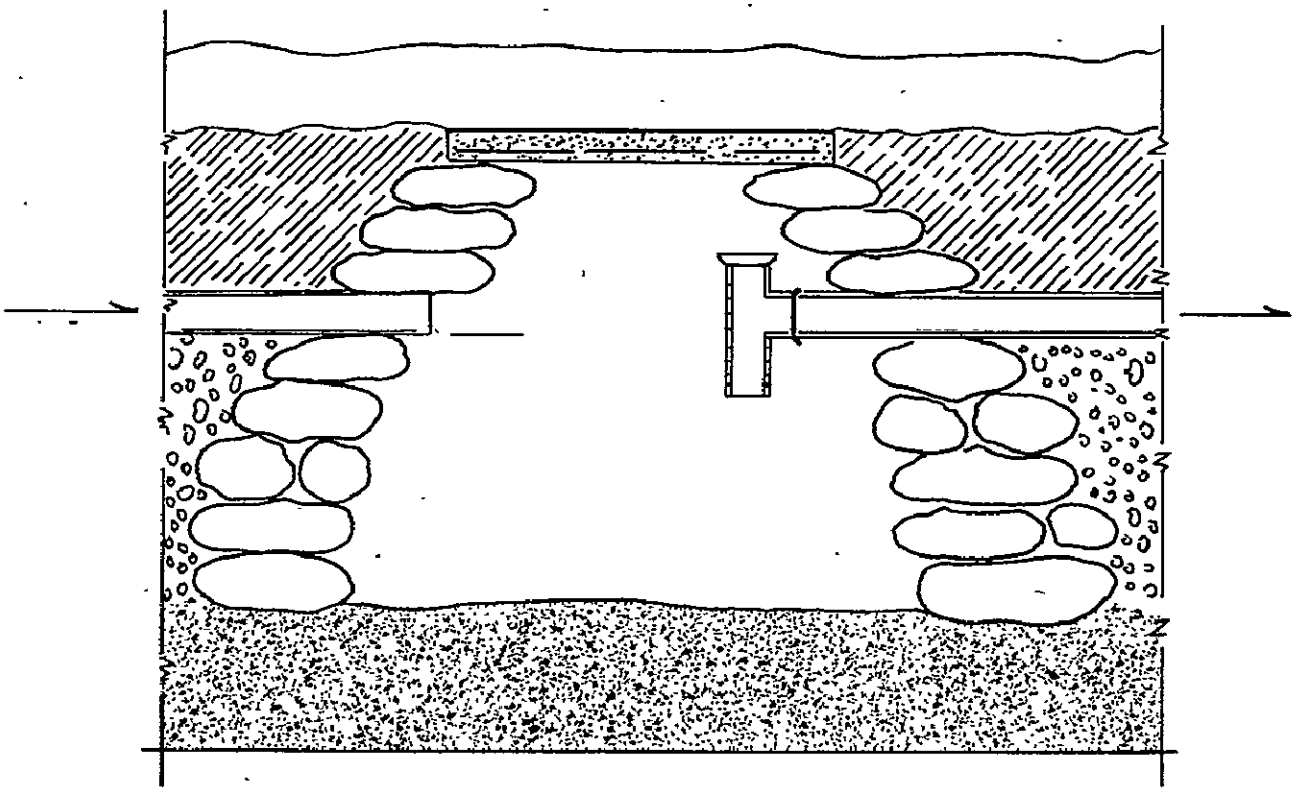
Absorption Field (Schematic Plan)

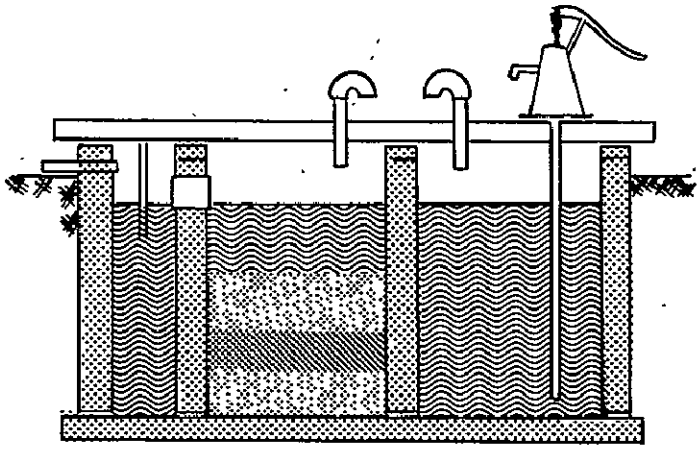
- Tank trucks should be able to approach with ease so that they can pump it out.
- Tanks should be located at least 75 feet (20 to 25 meters) away from water supply sources such as wells and springs.
- Location should not be on weak and loose soil since settlement will cause failures of the plumbing connections and the septic tank.

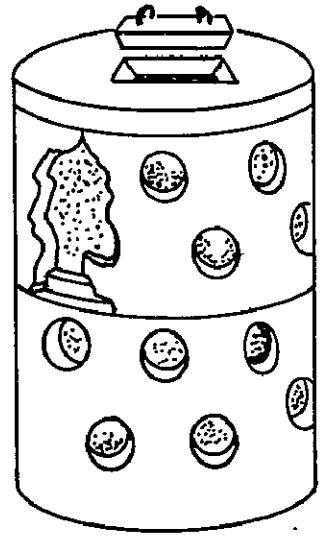
Classical System -- Essentially, this is the network of collector pipes which transport sewage from the point of origin to the point of disposal. It can range from a simple system of pipes running directly to the point of disposal, to a complex network of collector points and manholes for maintenance. The classical system always is a part of the most sophisticated systems; its degree of complexity is dependent upon the size of the area to be served, the amount of sewage flow, and the method of disposal.

Dry wells are used with classical systems to avoid overloading sewage disposal systems. Rainfall collected on roofs of buildings is dissipated through the soil media through dry wells. Dry wells should not be connected to seeping pits, and should be far removed from water supply sources.

Cesspools -- They are used to receive and dispose of raw sewage through filtration and should be constructed in a porous soil with high gravel and sand content. Cesspools should not be used if ground water is high and always should be placed downgrade from all water sources. Cesspools can be built in non-porous soil to collect solids and connected to seepage pits to dispose of the liquid effluents.





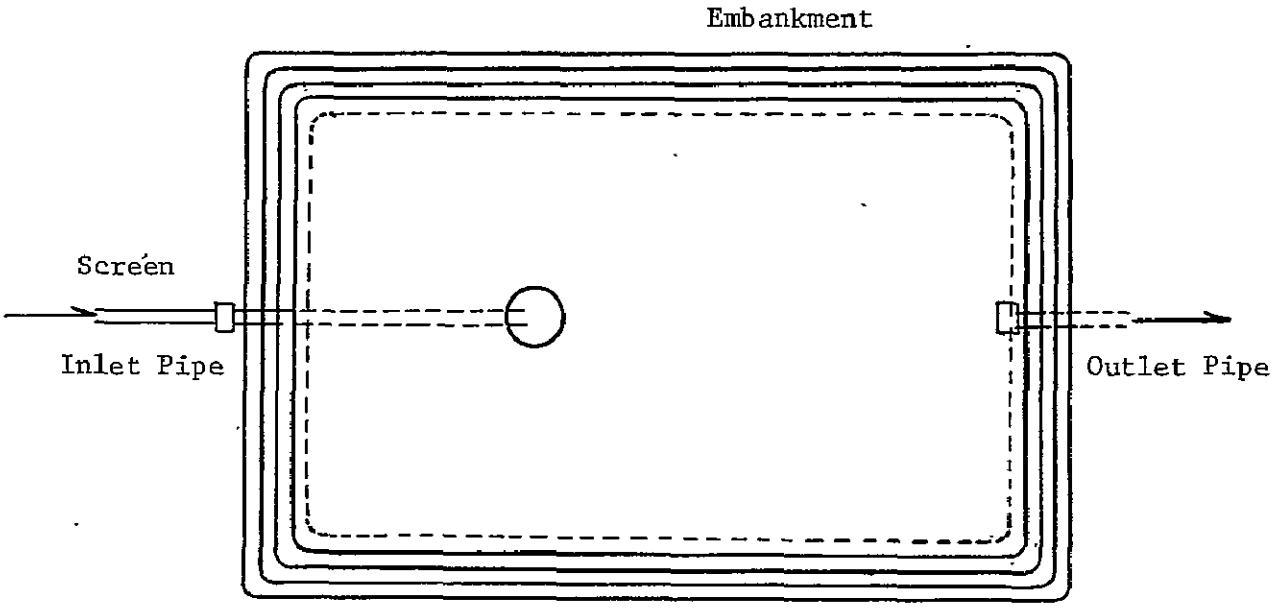


Sewage Lagoons -- They are rather simple to construct and provide an efficient treatment for raw sewage through the process of oxidation. Lagoons are constructed for flexible operation because the raw sewage can be put through them either in series or in parallel, depending on the quantity of sewage flow. Lagoons in series operate independently of each other. It is advisable that several lagoons be built and operated in parallel. When expansion of the sewage treatment system is needed the lagoons can be operated in series.

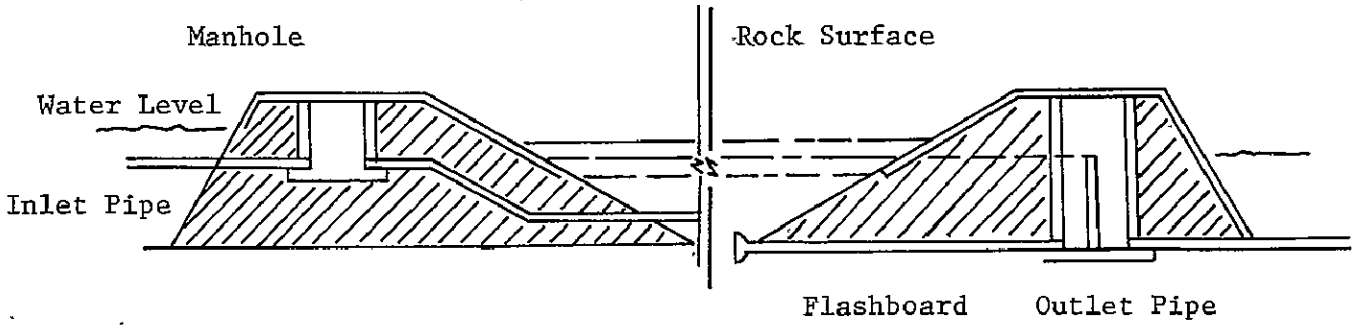
Construction planning of a lagoon system involves these factors:

- *Site location:* Cost of the lagoon greatly depends on the cost of the land to be used. It should be as cheap as possible to keep the expenditures within economic constraints of the community. The site should have a relative low location to eliminate the need for lift stations.

Plan of a Sewage Lagoon



- *Wind directions:* Wind is necessary to stimulate the aeration of the sewage. Prevailing winds should not run parallel to normal flow of the sewage. This decreases the treatment time and efficiency of the lagoon. If high winds, more than 30 miles per hour (48 km.) are expected, the edges of the lagoons must be reinforced by rocks or concrete blocks to stop possible erosion. The odor of the lagoon could negatively affect the population living around the area and houses should be no closer than 1/4 miles away.



Cross Section of a Sewage Lagoon

- *Percolation problems:* Percolation must be minimized to avoid excessive seepage because, if the water table is comparatively high, it will pollute the natural water supply; lack of sufficient water in the lagoon will slow the aerobic treatment process. When necessary, the bottom of the lagoons should be lined with proper materials such as soil-cement mixtures, asphalt or other sealant materials.

Vacuum System -- In developed countries where there are limitations of the use of water, vacuum systems are used for the removal of the raw sewage. There are three conditions under which this system is effective:

- Where water supply is very limited.
- The soil has anti-seepage characteristics.
- Regions of long cold winters where water freezes during the major part of the year.

The vacuum system is based on the theory of hydraulics, and the sewage is moved into storage centers by powerful vacuum pumps. This is not a low-cost system, but an innovative method which might satisfy a region's needs.

Factors for Sewer System Design

A complete study must be developed whenever a new sewer system or a major improvement is planned, based on these factors:

- Topographical characteristics of the neighborhood, complete map of the area served with the identification of roads, streams, and natural slopes.
- Plans of all existing sewers with coordinate identifications.

- Specifications governing the construction of the sewer system. If there are no specifications or if existing specifications are inappropriate, then design manuals or text books should be consulted and used as references.

- Volume of sewage expected.

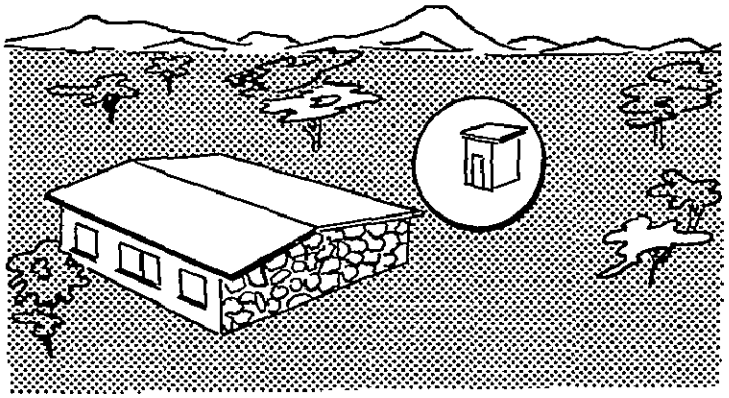
- Sewer sizing and velocity requirements for sanitary and storm sewers.

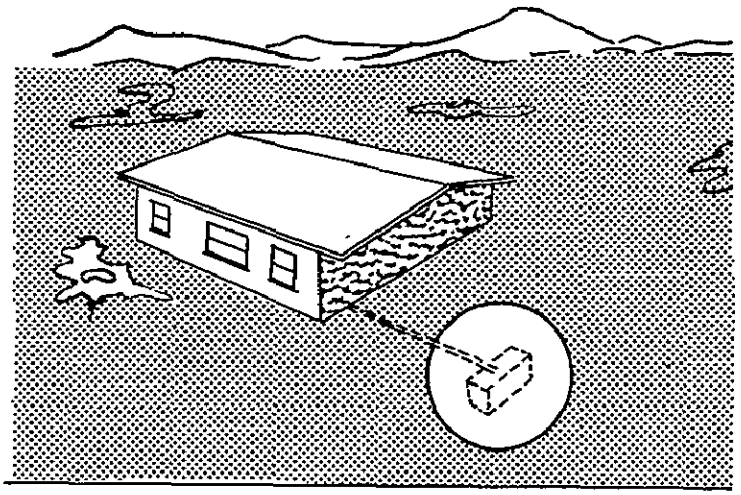
- Locations of manholes.

- Depth of sewers.

- Schemes for joining sewers.

- Financing procedures, with details.





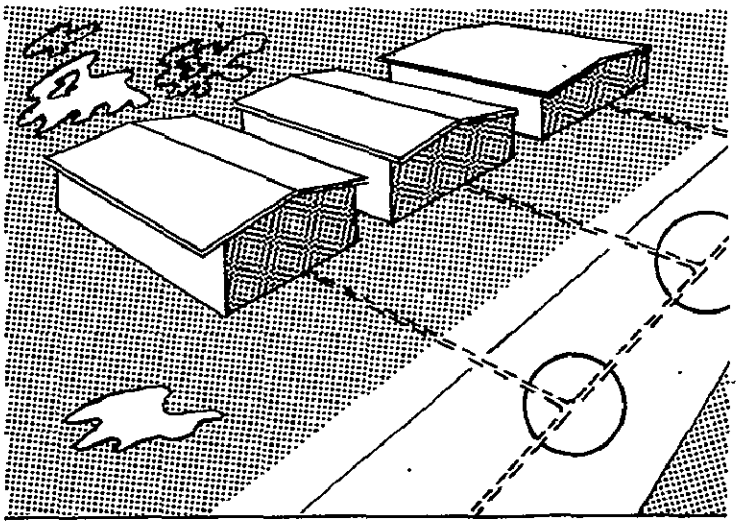
The Sewer System Design

The design of sewage disposal systems must be efficient and economical. Efficiency depends on the engineering design and economics depends on the type of the system to be installed. Areas which are highly populated require large sewage disposal and treatment systems. High-rise buildings, common in urban centers, demand elaborate sewage systems. In less dense areas, houses may be clustered around large septic tanks, and result in large savings.

Surveys must be run to develop the basic data for a design; this should include information on:

- Surface and subsurface physical conditions.

- Area development trends (population size and type, water use forecasts, location of business, roads, airports and homes).



- Political boundaries and ordinances.

- Finances of design, construction, operation, and maintenance.

While the planner should rely on competent technical assistance to develop factor inputs and design recommendations, it is useful for him to understand some of the engineering aspects in making overall judgments in basis utilities. schemes. This is particularly true where hardware applications may meet with consumer resistance. The planner would be in a better informed and more sympathetic position to resolve such problems, and most likely would be able to anticipate potential problems involving social factors.

The following points provide some *do's* and *don'ts* which may be useful as background:

- Once the population and water use patterns have been determined, flows may be estimated by multiplying the population by the water consumption rate and adding in infiltration rates. In some areas, infiltration may be very large due to soil and rainfall conditions; the use of polyvinyl chloride joined pipe or other similar materials can, however, effectively limit this to an acceptable value.

- Pipe velocities should be a 2-10 feet per second (6 to 4 meters) based on average or maximum flow; this is to prevent sedimentation of particles and yet not scour the pipe.

- Manholes should never be designed more than 500 feet apart to allow cleaning and inspection of the lines.

- Pipe diameters should never be less than 6 inches (16 centimeters) in diameter, because of cleaning difficulties.

- At no point in the system should there be a positive pressure head in a sewer pipe unless the section was specifically designed for it. All positive sewers should operate under essentially open channel flow.

- No roof run-off or storm water should be allowed in the sanitary sewer system.

- Sewers should be designed and laid at a depth sufficient to allow all wastes from buildings to flow to the main by gravity.

- All loads, both backfill and superimposed surface loads, should be considered when selecting pipe materials and pipe bedding type. A factor of safety of 1.5 should be used in calculating loads.

Hydraulics of Sewers

The flow in sewers is normally obtained through the natural slope. The topography of the area has great influence on proper sewage flow as well as on the cost of the project. The desired velocities in sewers are computed according to the following formula; however, the specifics of this function are best handled through technical assistance advice.

1 - OPEN CHANNEL FLOW:

Knutter's formula $V = \frac{(41.7+0.0028/S)+181/n}{1+(41.7+0.0028/S \quad n/\sqrt{R}} \sqrt{RS}$

Manning's formula $V = \frac{1.486}{n} R^{2/3} S^{1/2}$

(by far the most popular)

Where V= mean flow velocity - feet (meters) per second

R= hydraulic radius - feet (meters) (area of stream/wetted perimeter)

S= slope of hydraulic grade line - feet/feet (meters)

n= roughness coefficient (normally assumed constant even though it is a function of many items including depth.)

2 - PRESSURE FLOW:

These problems are handled exactly as in water problems using either the

Hazen-Williams' Eq. $V = 1.318CR^{0.63}S^{0.54}$

or

the Darcy-Weisbach Eq. $H_f = f\frac{L}{D}\frac{V^2}{2g}$

Where H_f= lost head - feet (meters)

L = pipe length - feet (meters)

D = pipe diam. - feet (meters)

f = friction factor which is a function of

$$N_{RC} = \frac{DVP}{M}$$

P= density of fluid

M = kinematic viscosity

The Road System

Communities must have adequate roads in order for people to reach their job locations without excessive loss of time, to get to market places, and to meet with friends. To obtain this, sufficient right-of-way must be allowed for construction and expansion of the roads to accommodate motor vehicles. The width of the pavement should be selected according to the national standards. If national standards do not exist, the roadway should have a width between 9 feet (2.8 meters) and 12 feet (3.6 meters) per lane. Selection should be a compromise between space and financial resources and adequate clearances between passing vehicles. The width for the right-of-way of a road depends on the location and judgment of the planners. Selection of a width should be based on consideration for future widening as traffic increases. Local roads should have a right-of-way at least 40 feet (12 meters) wide. Main roads and highways should have rights-of-way of 100 to 300 feet (30 to 90 meters). These widths will provide room for future pavement widening, foot paths, public utility lines, and shrubbery. Rights-of-way considerations should be determined on the basis of circulation needs and efficient land use. Many communities in developed countries are restricting vehicles on older narrow streets and limiting them to foot traffic only.

Many newer communities in the developed nations are built with the idea that city streets are for walkers only, and vehicle traffic is provided for on the periphery. The social advantages of pedestrian-only streets are many and should be weighed against providing streets and roads that anticipate greater vehicle traffic.

Economic constraints might prohibit paving operations. This is not a major item, since unpaved roads can serve communities rather adequately until funds are available for improvements. However, the criteria for deciding if paving is needed is based on traffic, vehicle types, speeds, and the type of paving required to meet varying demands. Where paving is planned, the installation of pipes for water and sewage systems should be anticipated to avoid tearing up expensive paving materials. The type of road design depends on the base material as well as on the climatic conditions. All roads of a new settlement must be connected to the major transportation system of the country. The types of roadways which can be built are:

- Compacted roads.
- Gravel roads.
- Dirt roads, with dust stabilized with oil.
- Asphalt pavement.
- Concrete pavement.

Pavement Design

Pavement designs must obey rigorous construction steps in order to make them economical, safe, and lasting. There are various sections of a pavement: subgrade, sub-base, base, and the rigid or flexible surface. It is desirable that as many layers as possible be used to construct a lasting roadway. However, a small volume of vehicular travel might not justify high expenditures and a low-cost roadway would be more practical. Low-cost roadways are surfaced by treating the natural subgrade with oil, calcium chloride, and soil-cement mixtures. It is also possible to surface them with untreated sand clay, shell, soft lime-rock, gravel and crushed stone.

There are many considerations in road surface planning:

- Soil types of the pavement foundation have great effect on the construction cost of the project. Granular soils, such as sand and gravel, particularly well-graded ones, are desirable. Fine grained soils, such as highly plastic clays and rather uniform silts, are generally poor foundations. Black cotton soil and other heaving types usually consist of expansive clays and are undesirable for any kind of foundation.

- Poor soils should be treated for strength and stability before a pavement is constructed on them. Soil-cement mixtures are generally used for this purpose.

- Pavement design must be coordinated with all other factors such as budgeting and space limitations; existing and predicted traffic densities; needs of the community (such as transporting their goods to larger market places) in order that an efficient cost-benefit optimization can be reached.

- Engineering judgment and management are needed for the success of any pavement design and construction. These are the selection of the geometric design criteria and materials of construction, project control of manpower, equipments, and materials.

To control the cost of pavement construction, careful choice of land and materials is necessary. Geometric design and alignments must be done in such a way as to minimize land use and cut and fill operations of the region. It is desirable to by-pass existing buildings since removal is an expensive venture. Local manpower should be used extensively because:

- Developing countries have large numbers of unemployed unskilled labor force. They are able to perform tasks related to road construction such as digging, carrying, compacting, spreading, and watering.

- Equipment for road construction in developing countries is scarce and should be substituted with manpower as much as possible.

Drainage facilities must be incorporated in the planning and design phases. The topography of the region should be

studied and the road lines should pass along high points with good natural drainage. This approach helps to avoid seasonal pavement failures due to excessive rainfall, permafrost, water level. Otherwise, expensive drainage structures such as culverts, bridges, ditches, and canals must be built and maintained.

REFERENCES

Anandjivala, Krishna, "Social Service Programme-A Tool to Assimilate Newcomers in the City Life", St. Louis, Missouri School of Architecture, Washington University.

"Annual Bulletin of Housing and Building Statistics for Europe" United Nations, New York, 1968

"Anthropics: Man in Relation to His Settlements", Ekistics, June, 1968

Arnold, G.-E., "Water Supply Projects in Developing Countries", Journal of American Water Works Association, 62, No. 12, p. 750, 1970

Babbitt, H.E., "Engineering in Public Health", McGraw Hill Book Co., N.Y., pp 247-299, 1952

"Basic Law and Developments on Housing and Urban Development", U.S. Congress House Committee on Banking and Currency, Washington, D.C.

Benson, C.S. and P.B. Lund, "Neighborhood Distribution of Local Public Services, p. 181, University of California, Berkeley, 1969.

Boyd, R.L., "Man's Reaction to His Thermal Environment", Building Research, July-August, 1966.

Breese, Gerald, "Urbanization in Newly Developing Countries", Englewood Cliffs, N.J., Prentice-Hall, Inc.

"Building the American City", U.S. National Commission on Urban Problems, Government Printing Office, Washington, D.C., 1969

Caminos, H., "Urban Dwelling Environments: An Elementary Survey of Settlements for the Study of Design Determinants", M.I.T. Press, Cambridge, Massachusetts, 1969

"Change for the Better: Help People Change Through Housing and Urban Renewal", NAHRO, Washington, D.C.

Committee on the Hygiene of Housing, "An Appraisal Method for Measuring the Quality of Housing: A Yard-stick for Health Officers, Housing Officials and Planners", Part II: Appraisal of Dwelling Conditions, Vol. B. Field Procedures, 1946, Part III: Appraisal of Neighborhood Environment, 1950, New York, N.Y., American Public Health Association

Committee on the Hygiene of Housing, "Construction and Equipment of the Home", Chicago, Ill., Public Administration Service, American Public Health Association, 1951.

Committee on the Hygiene of Housing, "Principles for Healthful Rural Housing", New York, N.Y., Publication Office, American Public Health Association, Inc., 1957.

Dansereau, P., "Challenge for Survival; Land, Air, and Water for Man in Megalopolis", Columbia University Press, New York, 1970

Davies, Richard O., "Housing Reform During the Truman Administration", University of Missouri Press, Columbia, Missouri, 1968.

"Design and Construction of Sanitary and Storm Sewers", Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C., 1967

Downing, P.B., "The Economics of Urban Sewage Disposal", Praeger, New York, 1969

Duhl, L.J., "The Urban Condition: People and Policy in the Metropolis", Basic Books, New York, 1963

Eckler, A.R., "New One-Family Homes", U.S. Department of Commerce, Bureau of the Census, Washington, D.C.

Eckstein, O., "Water Resource Development: The Economics of Project Evaluation", Harvard University Press, Cambridge, Massachusetts, Third Printing, 1965.

Ehlers, V.M., and E.W. Steel, Municipal and Rural Sanitation, Sixth Edition, p. 1, McGraw-Hill Company, 1965

"Engineering" Its Role and Function in Human Society", edited by Davenport, W.H. and D. Rosenthal, Pergamon Press, New York, 1971

"Environmental Health Problems", U.S. Department of Health, Education and Welfare, Public Health Service, Washington D.C., 1962

"FHA Techniques of Housing Market Analysis", FHA Economic and Market Analysis Division, Washington, D.C.

Freedman, L., "Public Housing: The Politics of Poverty", Holt, Rinehart and Winston, New York, 1969.

Golani, Y., and Schwarze, D.G.V. (Editors), "Israel Builts 1970 -- Interdisciplinary Planning", Ministry of Housing, Israel.

Grava, S., "Urban Planning Aspects of Water Pollution Control", Columbia University Press, New York, 1969

"Handbook for FHA Multifamily Projects", Federal Housing Administration, Washington, D.C., July, 1965.

"Handbook for Housing and Urban Renewal Commissioners", NAHRO, Washington, D.C., 1972.

Hauser, Philip M. (Editor), "Urbanization in Latin America, New York, N.Y., International Documents Service 1961.

Hopkins, E.S., and W.H. Schulze, "The Practice of Sanitation", Baltimore, Williams and Wilkins, pp. 331-365, 1954.

"Housing Market Analysis in Latin America", Department of State, Agency for International Development, Washington, D.C., 1965.

Kaiser, E.F., "A Decent Home", The President's Committee on Urban Housing, Washington, D.C. 1968.

Kaiser, E.F., "The Report of the President's Committee on Urban Housing", Vol. I and Vol. II, U.S. Government Printing Office, Washington, D.C., 1967

Kizzia, J.W., "Home Buying Traps," American Builder, April, 1968

Kizzia, J.W., "Mobile Home Form-Contemporary Apartment", American Builder April, 1968.

Kizzia, J.W., "Who Really Gives a Damn about Housing", American Builder, November, 1968

Kneese, A.V. and B.T. Bower, "Managing Water Quality: Economics, Technology, Institutions", The Johns Hopkins Press, Baltimore, Maryland, 1968.

Lamont, Robert P. and R.L. Wilbur, "Housing Objectives and Programs", The President's Conference on Home Building and Home Ownership, Washington, D.C.

Maass, A., et al, "Design of Water - Resource System; New Techniques for Relating Economic Objectives, Engineering Analysis and Governmental Planning", Harvard University Press, Cambridge, Massachusetts, 1967.

Malt, H.L., "Furnishing the City", McGraw-Hill, 1970.

Mandelker, D.R., "Managing our Urban Environement: Cases, Text and Problem", Bobs Merrill Publishers, N.Y., 1971

National Commission on Urban Problems: The Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 1968

Page, A.N. and W.R. Segfried, "Readings in Housing and Urban Development", Scott, Foresman and Company, Glenview, Illinois.

"People and Downtown: Use, Attitudes, Settings", College of Architecture and Urban Planning, University of Washington Press, Seattle, 1970

Pfister, Franqois, "House Types and Family Life", Kumasi-Ghana, Department of Housing and Planning Research, 1968.

Phelps, Earl B., "Public Health Engineering", John Wiley and Sons, New York, pp. 82-115, 1948.

"Planning of Metropolitan Areas and New Towns", United Nations Symposium on the Planning and Development of New Towns, Moscow, 1964.

"Proceedings of the International Symposium on Low-Cost Housing Problems Related to Urban Renewal and Development", University of Missouri-Rolla, Oktay Ural, Editor, 1970

"Proceedings of the Second International Symposium on Lower-Cost Housing Problems", Oktay Ural, Editor, University of Missouri-Rolla, 1972

"Proposed Minimum Standards for Permanent Low-Cost Housing and for the Improvement of Existing Substandard Areas", Division of International Affairs, Department of Housing and Urban Development, Washington, D.C. 1966

Rodwin, Lloyd, "Housing and Economic Progress", Harvard University Press & The Technology Press, Cambridge, Massachusetts.

Salvator, J.A., "Environmental Engineering and Sanitation", John Wiley and Sons, Inc., New York, Second Edition, 1972

Sangster, R.P., "Ecology: A Selected Bibliography", School of Architecture and Urban Planning, University of California, Los Angeles, 1971

Shipman, R. Harold, "Water Rate Structures in Latin America", Journal of American Water Works Association, 59, No. 1, p 3, 1967

Smith, C.W., "New Town Planning", Building Research, Jan-Feb., 1966

Smith, W.F., "The Social and Economic Elements", University of California Press, Ltd., 1970

"Social Aspects of Housing and Urban Development: A Bibliography" National Swedish Institute for Building Research, Stockholm, 1969.

Steel, E.W., Water Supply and Sewerage, 4th Edition, pl, McGraw-Hill Book Company, 1960

"Strengthening Urban Administration in Developing Countries with Emphasis on Latin America", Agency for International Development, Department of Housing and Urban Development, Washington, D.C., 1971

"The Housing Situation and Perspectives for Long-Term Housing Requirements in European Countries", United Nations, N.Y., 1968

"The Rural Housing Situation in Europe", United Nations, N.Y., 1962

Tucker, L.S., "Sewered Drainage Catchments in Major Cities", ASCE Urban Water Resources Research Program, Technical Memo #10.

Tyler, K., "City and Suburban Housing", The Reference Shelf, Vol. 29 No. 6, the H.W. Wilson Co., New York

Wealt, P.F., "Housing Policy--The Search for Solution", University of California Press, Berkley, California, 1963

Werthman, C., Mendel, J.S. Dienstfrey, I., "Planning and the Purchase Decision: Why People Buy in Planned Communities" Berkeley, California, The Community Development Project, 1965. (Reissued, 1970)

Workshop, A., "Rehabilitation of Housing", Building Research, Nov-Dec, 1966.