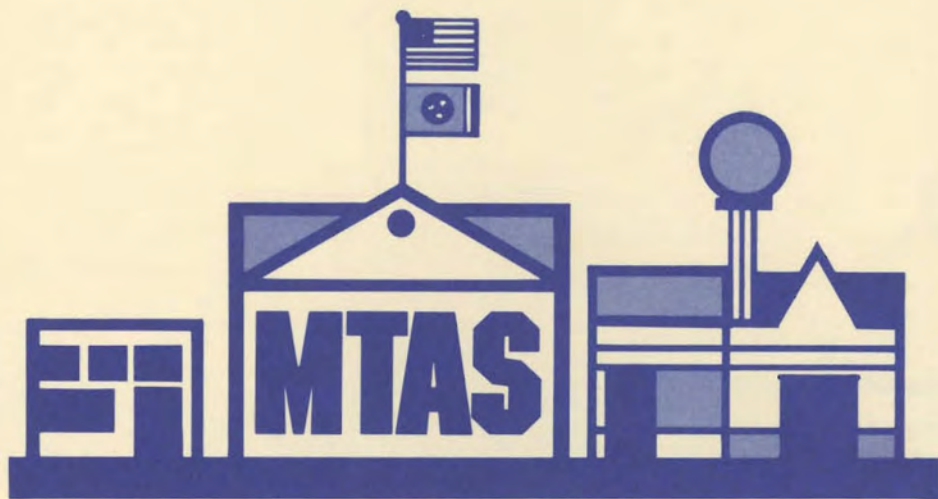


PUBLIC WORKS

A GUIDE TO PUBLIC WORKS STANDARDS & SPECIFICATIONS



Compiled by
MUNICIPAL TECHNICAL ADVISORY SERVICE
of The University of Tennessee
in cooperation with The Tennessee Municipal League

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Municipal Technical Advisory Service
A Statewide Agency of
The University of Tennessee's
Institute for Public Service
operated in cooperation with the
Tennessee Municipal League

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Municipal Technical Advisory Service

A GUIDE TO PUBLIC WORKS STANDARDS-- AN INTRODUCTION TO LOCAL GOVERNMENT PUBLIC WORKS STANDARDS & SPECIFICATIONS

MUNICIPAL TECHNICAL ADVISORY SERVICE
The University of Tennessee

in cooperation with the
TENNESSEE MUNICIPAL LEAGUE

July 1984

Municipal Technical Advisory Service

The University of Tennessee • 891 Twentieth Street • Knoxville, Tennessee 37996-4400 • Telephone 615/974-5301

Dear City Official:

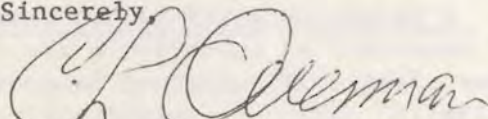
In May, 1982, MTAS published the Local Government Public Works Standards & Specifications, a comprehensive document which provided a wealth of information to municipal engineering and design personnel. In order to make the document more usable and understandable by elected and appointed officials, it was determined that a supplemental companion document should be produced to accompany the Standards & Specifications.

The result is this publication, A Guide To Public Works Standards -- An Introduction to Local Government Public Works Standards & Specifications, which provides a basic conceptual foundation to the entire subject. It should be especially helpful to elected officials, planning commissions and administrators in understanding the need for and purpose of public works standards and specifications as presented in the original document.

Mr. Frank Kirk, MTAS Public Works and Engineering Consultant, coordinated the development and preparation of this manual which was completed under a contract with Dr. Gregory D. Reed and Dr. R. Bruce Robinson, University of Tennessee Department of Civil Engineering.

All University staff involved in the production of this publication are to be commended. It is hoped that, in concert, these two publications will provide you and your staff with a broad scope reference to public works standards.

Sincerely,



C. L. Overman
Executive Director

CLO:ljp

INTRODUCTION

The primary purpose of this supplement to Local Government Public Works Standards & Specifications is to inform elected officials, planning commissions and administrators of some of the important issues which must be addressed before adoption of the standards. These issues can be discussed with the technical staff to determine if local conditions dictate modification of the standards.

This supplement will be elementary to the experienced professional planner. However, planners can use it as a aid in taking planning commissions through the review process. In addition, UT's Center for Government Training will be conducting workshops for local government officials.

Planning commissions frequently do not have the benefit of a technical staff to assist them. Whether or not to adopt public works standards presents a dilemma. The decision is a difficult one and agencies responsible for enforcement of subdivision regulations and the construction and maintenance of public works and utility improvements should carefully analyze proposed publicworks standards. It is important that the adopting agency clearly understand the content of a standards proposal and that it meets technical and political needs.

Many cities do not have the technical staff available to analyze these standards as to their feasibility in the particular jurisdiction. Public works standards will never eliminate the need for the services of a professional engineer, who should review all plans submitted by developers to the planning commission. It is equally important that such plans be reviewed by a professional planner.

It should be the goal of every planning commission to demand that every new development be an asset to the community and not a perpetual maintenance liability. Many of the physical problems in cities today are the direct result of the lack of standards or of poor enforcement of standards in past years. The absence of standards or poor enforcement will cause problems for the city in the future, causing unnecessary and, perhaps, unbearable financial burdens.

The Municipal Technical Advisory Service has previously published a document entitled Local Government Public Works Standards & Specifications. This publication was distributed to Tennessee cities over 2,000 in population. The document contains three basic sections: 1) Construction Standards and Specifications; 2) Design Criteria; and 3) Contract Documents for water distribution systems, sanitary sewer collection systems, streets and drainage. The intended purpose of this publication was to provide local government officials with specific basic regulations for all public works and utility projects for which the public agency might ultimately become responsible for maintaining.

A number of workshops and meetings with planning commissions were conducted to stress the importance of including the standards in the subdivision regulations. The response was general agreement that better standards were needed, but the proposed standards were of such an extremely technical nature that full understanding and consensus was frequently not reached.

Due to state regulations and a general knowledge of health requirements, almost all additions to water and sewer systems are of acceptable quality. This is not always true of streets and drainage facilities. A recent survey conducted by the National League of Cities revealed that streets were the number one problem facing cities today. By implication, drainage would be included, since drainage is an integral part of street construction and maintenance. There is general agreement that street and drainage standards can be improved to the betterment of almost all Tennessee cities. Without this improvement, the problem will worsen.

It is sincerely hoped that public officials in Tennessee will use these two documents for the betterment of the citizens of the cities. They will, indeed, make our cities a better place in which to work and live.

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A Guide to Public Works Standards-- An Introduction to Local Government Public Works Standards & Specifications

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MTAS GENERAL

1.0 INTRODUCTION TO WATER, SEWER, DRAINAGE, AND STREET SPECIFICATIONS

Few people would argue that modern cities could not exist without their investment in providing water, collecting sewage, draining stormwater, and building streets. These engineering works are costly and are expected to last a long time. With this in mind and also considering the variety of materials, engineers, and contractors, it is very important for every city to have a set of standard specifications governing the construction of these networks which form the city's circulatory and nervous systems.

1.1 THE IMPORTANCE OF SPECIFICATIONS

Each specification of the MTAS specifications has a reason for inclusion--many times arising from bitter experience. These specifications have been developed for adoption by cities in order to minimize problems which can cause expensive repairs and rehabilitations besides vigorous citizen protests.

The reader will note in the MTAS specifications references to other specifications like those of the American Water Works Association or the American Society for Testing of Materials. These specifications are widely used in this country and abroad and are formulated by committees comprised of representatives from utilities, public agencies, manufacturers, engineers, and contractors. The complete set of MTAS specifications including references to other organizations has arisen from experience and only after serious deliberation. Thus, the municipality should be very cautious about allowing deviations from these specifications and should consult with its own engineers, state officials, or MTAS advisors before allowing departures.

1.2 GENERAL CHECKLIST

This section is intended to discuss points in overseeing a project which are common to all types of urban developments covered in the MTAS specifications.

(1) The planner, developer, and engineer should preferably cooperate in achieving the submission and review of a project. It is very helpful for the engineer and developer to discuss their proposed project with the city planner before any detailed plans and specifications are drawn up. This gives the planner a chance to advise the engineer and developer of the cities' requirements and other special considerations. It is oftentimes difficult to bring about changes once the engineer has gone to the effort and expense to prepare detailed plans and specifications.

(2) Does the project submission include detailed plans as described in section 107 of the MTAS Specifications?

(3) Do the project specifications describe the allowable materials and installation procedures and do they agree with the MTAS Specifications?

(4) Do any other agencies such as the Tennessee Department of Public Health of the Tennessee Department of Transportation have to approve the project?

(5) Do the plans and specifications include provisions for continuity of services during the construction? That is, will people be without water, sewer, electricity, street access, etc. for unacceptably long times?

(6) Do the plans and specifications consider the order that utilities will be constructed? For example, it makes little sense to dig up the streets in order to install the water mains; this unnecessary expense can be eliminated by building the water mains first. Similarly, it may be wise to grade the site (i.e. develop the final surface elevations) before constructing any utility so that some utilities do not end up too deep or too shallow or even sticking out of the ground.

(7) Who will be responsible for inspecting and testing during the construction?

1.3 ROLE OF THE PLANNER

Planning is a systematic process of bringing together the many interrelated components of goals, alternatives, resources, priorities, and coordination. The planner is then the "clearinghouse" to ensure that the final project will meet all the needs of the community as efficiently as possible and without conflicting with other services. Planning is necessary at all levels of activity and should be updated continually. Preliminary plans should define the general objectives of the project. Feasibility planning with a designer determines which alternatives will be used and which discarded. Final planning develops the detailed design criteria to implement the construction. Any changes in the plan at this point should be coordinated carefully with the designer.

To better ensure a successful project that meets the needs of the community and is understood by the community, the planner should coordinate each of the following items with the designer:

- (1) Statement of goals and objectives.
- (2) Background information and catalog of existing data.
- (3) Development of the project plan.
- (4) Implementation of the project plan.
- (5) Inform and involve the public to gain better acceptance and understanding.
- (6) Evaluate the effectiveness of the project after it is used.

The planner and the designer should work together in order to draw on the experience and knowledge that each can bring to the project. The planner points to the target; the designer provides the technical means of hitting it.

1.4 ROLE OF THE DESIGNER

The designer is responsible to take the goals and objectives provided by the planner and develop the best technical solution to implement them. The designer should investigate all feasible solutions and evaluate the advantages and disadvantages of each. If no clearly superior alternative

is available, the designer should consult the planner for a value judgement of which of the feasible solutions is preferable.

The designer must consider many types of information to formulate the final technical solution. Information is needed in the areas of geology, meteorology, existing or planned utilities, location relative to other projects, resources, plant and animal life, and the peculiar characteristics of the project site. The more of this information that the designer has access to, the better will be the overall quality of the project.

The designer can and should present to the planner an estimate of the relationship of costs versus benefits for any major design alternative. This information will aid in the decision making process. All communities are faced with the problem of limited resources. It should be the community that decides whether a project alternative is worth the cost, not the designer alone.

1.5 CONSTRUCTION STANDARDS

The first section of the MTAS "Local Government Public Works Standards and Specifications" is a detailed listing and discussion of the standards and procedures that make up a good construction project. The goal of following these procedures is a uniformly good quality final product for the community. These standards or similar standards should be specified at the beginning of the project so that both the designer and the planner have a common basis for how the construction will be conducted.

While the details of this section are of most use to the designer, it is good practice for the planner to scan the sections to become familiar with the type and extent of construction practice and how all the components fit together to form a final product. There are a large number of details that have to be considered ahead of time. A guide such as the one provided by MTAS can prove invaluable as a resource to the planner as well as the designer.

1.6 CONTRACT DOCUMENTS

It is good practice to have all agreements and subsequent changes in writing. Because the projects require a great deal of detail and can span several months, memories cannot hope to keep up with all the individual details. The last section of the MTAS "Local Government Public Works Standards and Specifications" gives example documents and descriptive information on the types of documents that should be used in conjunction with the project. The planner should review these documents to develop an understanding of the form that the project will take and the timing of their use. A system of documents should be a standard operating procedure of any project.

MTAS WATER

2.0 WATER DISTRIBUTION SYSTEMS

2.1 GENERAL

The provision of water free of harmful contaminants and in plentiful quantity is essential to modern society. The average United States citizen is responsible for the consumption of about 165 gallons each day from municipal water systems. Although drinking water is responsible for part of this demand, far greater demands are caused by other domestic water uses such as laundry, bathing, lawn and garden watering, and toilet flushing and by industrial and commercial uses. Fire fighting and system flushing by opening hydrants cause further demands. Finally, water will be lost through pipe leaks since all water systems leak to some extent. Actual water use in any one city will depend on a number of factors including the population, climate, standard of living, types of industries, cost of water, system maintenance, and so forth. The best source of information to determine the total water demands for a specific city is from that city's records of water pumpage, while estimates of water demand for specific developments will come from other sources of information such as Section 103 of the MTAS Specifications.

A water system is composed of several components in order to get the aforementioned water demands to the right places, at the right times and at the right pressures. The engineer is responsible for providing a satisfactory design of these components in order to achieve the goals just cited, however, it is still worthwhile for the planner to understand what constitutes a complete water system. The components of a water system are listed below and their fundamental purpose described. The reader should realize that this description is greatly condensed since there are entire textbooks devoted to each topic.

(1) The first component is the raw water source which can be groundwater (i.e. a well or spring) or a surface water (i.e. a river, lake, or reservoir). In many parts of the country, groundwater has advantages compared to surface water in terms of reliability of supply since it will not dry up as quickly as surface waters during droughts and ease of treatment since the groundwater tends to get filtered as it passes through the soil. However, it may be more difficult to find and develop.

(2) Pumps will generally be used to get the water from the raw water source to the treatment plant. Additional pumps will get the water from the treatment plant to the points of use and to the various storage reservoirs.

(3) The treatment plant will remove undesirable contaminants from the raw water such as dirt and bacteria in order to produce a clear, safe water.

(4) The water system will also use storage tanks which will generally be water towers and ground storage tanks. Water towers which are also called overhead storage tanks provide a reserve of water for periods of high water demand and emergency situations such as a fire in which the water treatment plant cannot produce water fast enough. Water towers store

water at some height above ground, and although this is expensive, it has the advantage that the water can flow to the users without the necessity of pumping should the system suffer a power failure or pump breakdown. Ground storage tanks which are generally built of concrete at or slightly below ground can serve the same purposes as water towers, but pumps are required to get the water to flow from them. Many water systems provide both water towers and ground storage with the water towers providing reserve water during the normal peak water uses in the day and ground storage providing water for more extreme emergencies such as fires. Standpipes are another type of water storage structure which can function as a water tower or ground storage tank depending upon the situation.

(5) Water mains are the pipes through which the water flows to the consumers and storage tanks. These are the subject of most of the MTAS manual since they are being continually added to the system as new subdivisions and developments are built and are more easily regulated by specifications since there are not as many complex options as compared to other components. This in no way means they are any less important, to be sure. Water mains are part of the integral water system designed to get the water to the consumer or fire in adequate quantities and pressures upon demand.

2.2 MTAS SPECIFICATIONS

Sections 100 and 02713 of the MTAS Specifications concern themselves with water distribution systems. Each specification in these sections has a reason for being there--many times arising from bitter experience. These specifications have been developed for adoption by cities in order to minimize problems such as the following:

- (1) Breakage of the pipes due to inferior materials or improper installation.
- (2) Corrosion of pipe materials and consequent colored water problems.
- (3) Excessive leakage due to improper installation of materials which may allow pipe cracking and/or corrosion.
- (4) Health hazards from unacceptable pipe materials, not keeping materials clean during construction, improper clearance from sewers, or poor disinfection of the constructed pipe.
- (5) Inadequate pressures, flows, and fire protection because of undersized pipes, pipe breakage, or corrosion.

Problems such as the above often cause expensive repairs and rehabilitations besides vigorous citizen complaints.

The reader will note in the MTAS Specifications references to other specifications like those of the American Water Works Association, AWWA, and the American Society for Testing of Materials, ASTM. These specifications are widely used in this country and other parts of the world and are formulated by committees comprised of representatives from water utilities, manufacturers, engineers, and contractors. The complete set of MTAS Specifications including references to AWWA and ASTM has arisen from experience and only after serious consideration. Thus, the municipality should be very cautious about allowing deviations from these specifications and should consult with its state officials, city water works engineers, or MTAS advisers first.

Following is a discussion of various sections in more detail to explain their importance and consequences of alternatives.

2.2.1 SEPARATION OF PIPED UTILITIES (02605)

Since sewers carry contaminated water unfit for drinking and since they are almost always leaky, it is very wise to keep them separated from the water mains by some horizontal distance. When this is not possible, for example at crossing points, it is desirable to separate the water and sewer pipes by some vertical distance and take further protective measures to insure that sewage will not contact the water mains. Although water mains are usually pressurized so that sewage will not leak in, situations can arise in an undersized system where the pressure drops low enough to suck in polluted water.

2.2.2 PIPE MATERIALS (2.01 and 2.02)

See section 2.3.5.

2.2.3 WATER SERVICE ASSEMBLIES (2.04)

Water meters are used to measure the water consumed by each user so that an equitable billing can be made. Meters also serve to estimate the total water actually consumed by users in order to compare with the water pumped from the water plant and thus to determine how much water is lost to pipe leakage. Inferior meters which do not accurately measure the water flow or deteriorate too fast will defeat the above goals.

Water main connections and the associated corporate stops must be properly made in order to minimize leakage, and hence, are necessary to specify.

2.2.4 VALVES (2.05 and 2.06)

See section 2.3.6.

2.2.5 FIRE HYDRANTS AND BLOW-OFF HYDRANTS (2.07)

See section 2.3.6.

2.2.6 INSTALLATION (3.01-3.04 and 02221)

The new water main will provide years of trouble free service if it is properly installed. The trench bottom should be reasonably smooth so that the pipe is not bridging over wide depressions since it is not designed to

do this. The backfill **should** be free of large rocks and chunks of frozen earth and should be compacted around the pipe to prevent excessive loads on the pipe from **settlement**. The depth of bury of the pipe should be deep enough to avoid freezing; the loads of the pipes from the earth backfill and **street** traffic will determine the necessary pipe thickness.

2.2.7 TESTING AND DISINFECTION (3.05-3.08 and 106)

A leakage test on the newly installed pipe is a good indication whether it was built correctly and should always be done since once the pipe is covered up, there is no way to visually evaluate the work.

Many times the pipe will pick up **dirt** while it is being built. In order to assure that the water in the pipe is fit to drink, the new main should be disinfected prior to placing it in service.

2.3 DESIGN CRITERIA (100)

Several important design criteria that the planner should appreciate are discussed below.

2.3.1 ENGINEER'S REPORT (102)

The municipality must constantly assess the impact of new developments including subdivisions, shopping centers, and industries on the existing water system and its ability to provide water to future developments. The city must exercise planning to ensure that adequate water quantities and pressures will be available either by building new facilities, modifying existing facilities, or encouraging water use conservation. Some specific questions which need to be asked are:

(1) Will the water mains in **the** proposed development be large enough to handle the water needs of future developments beyond it? If not, then new water mains may be required later with corresponding high costs and inconvenience because the **construction** will be in an already established area. An alternative would be to increase the capacity of the pumping stations but would entail **some** construction costs, higher **energy** costs, and perhaps excessive pressures in some areas.

(2) Will the new development overload the existing water system by demanding more water than the system can reasonably supply? This has occurred gradually in **many** towns; the town was "nickled and dimed" to death by small developments each of which did not draw much water. However, the accumulated demand over several years was very significant. The planner should also realize how a policy of allowing substandard materials on small developments can soon lead to a system which has a lot of substandard materials.

(3) Related to the previous item, the question should be asked of how long will the present water facilities be adequate before major improvements are needed such as a larger water treatment plant or storage tanks? Each new development will use up excess capacity in the system and bring the system closer to the day when it will be undersized. Periodic eva-

valuations of the entire water system should be performed by a competent engineer to assess the need for improvements.

(4) Lastly, what are the long term costs of this design option? The planner should appreciate that there are many design options for a specific water system improvement. Unfortunately, too often the option with the lowest initial cost is chosen with little attention to the cost over the entire life of the facility. Generally, there is a premium to be paid in terms of higher energy and maintenance costs by choosing the cheapest initial cost which may soon counterbalance the cost of a system with a higher initial cost. The engineer should be able to explain these tradeoffs on a project so that the planner can make a decision.

2.3.2 SOURCE OF WATER SUPPLY (103.1)

Average water demand is not the only important factor; also important are the variations in demand. The rate of water use for a city is not constant, but rather the rate of use will show peaks and valleys depending on the time of day, time of year, and the current weather. For example, the rate of demand during hot, dry weather may be more than twice the average. The time of day from six until nine may also show a high rate of demand because of people preparing for work while the nighttime hours may show low rates of demand. In addition, fighting fires will require very high rates of water for relatively short times. Obviously, the designer will need to consider these factors so that everybody's water needs will be provided with minimum inconvenience.

2.3.3 FIRE FLOW (103.3)

An important mission of the water system is the provision of fire protection. In fact, the fire flows usually control the system design since such a high water flow rate is needed to fight a fire. Some systems do not have adequate fire flow capacity in their systems and therefore suffer the consequences of higher property loss and thus higher insurance rates.

2.3.4 PIPE SIZE (103.4 and 103.5)

The minimum pipe size allowable in municipal water systems is 6-inches. This size really applies to water mains in subdivisions; larger sized feeder mains will be required in the system in order to get the water to all areas. An analogy can be pictured with streets; there is a minimum width for residential streets but certainly not all streets and highways in the city can be that minimum size without serious traffic congestion on the main routes. The engineer should make some calculations to insure that the proposed pipe sizes can handle the expected water flow rates including the most extreme.

2.3.5 PIPE MATERIALS (104 and 02713-2.01 & 2.02)

The choice of whether to use polyvinyl chloride pipe (PVC) or ductile iron pipe (DIP) is generally the discession of the city. Both PVC and DIP manufacturers make claims of the superiority of their products. Although some cities do not allow PVC pipe probably because they are more familiar with DIP, the authors, save for the recommendation in section 104.2 of the MTAS specifications, know of no reasons why either cannot serve satisfactorily if properly designed and installed. The developer and planner should consult the local water utility personnel for their requirements and help.

2.3.6 APPURTENANCES (105 and 02713-2.05, 2.06, & 2.07)

Valves of several types are used in a water distribution system. Gate valves and butterfly valves are used to shut off the flow of water so that repairs can be made. Such valves should be placed frequently enough in the system so that when a water main break occurs, that part of the system can be shut off without eliminating service to large areas. Usually two or three valves are provided at each pipe intersection. Pressure reducing valves are used to lower the water pressure so that thinner wall, less expensive pipe can be used and to make customer use more convenient. Typical places where such valves are used are in hilly systems where the great elevation differences can cause high pressures in the valleys. Air release valves are also used at times to eliminate air that can collect a high points of the water system and thereby choke off flow.

Most people realize that fire hydrants are used to get large volumes of water to a fire. Another important function for which a fire hydrant or a blowoff is used, is to provide a means for flushing a system. Periodically, water utility personnel will open the hydrants in order to get a good flow of water through the hydrant and connecting water mains so that debris which slowly collects can be washed out of the system. Hydrants are also used in more thorough pipe cleaning programs whereby scale is cleaned off the pipes.

2.3.7 INSTALLATION AND TESTING (106)

See section 2.2.6 and 2.2.7.

2.4 CHECKLIST

Section 1.2 of this manual gives a list of general items which are common to all projects and which the reader should consult. The following checklist may be useful in overseeing a water distribution system project:

- (1) Does the project submission include detailed plans as per section 107 of the MTAS Specifications?
- (2) Do the specifications describe the allowable materials and do they generally agree with subsections 2.01 through 2.02 of section 02713 and

does the minimum pipe size correspond to section 103.4 of the MTAS specifications?

(3) Do the project specifications include installation procedures in accordance with subsection 3 of section 02713? Of particular importance to the final acceptance by the city of the constructed project are subsections 3.05 and 3.06 on leakage tests and section 3.08 on disinfection.

(4) Has the engineer assessed the water needs of the new development and whether the present system can supply these needs?

(5) Has the engineer performed calculations to check whether the proposed water mains can carry the expected flows and still maintain adequate pressures?

(6) Are there enough valves to be able to isolate parts of the system for repairs?

(7) Are hydrants spaced according to section 105 of the MTAS specifications?

(8) Does the Tennessee Department of Public Health need to approve the plans and specifications before bids are let?

(9) Who will be responsible for inspecting the new construction?

MTAS WASTEWATER

3.01 WASTEWATER SYSTEMS

3.1 INTRODUCTION

The history of wastewater collection devices, better known as sewers, goes back several thousand years. Several cities throughout the world have had sewer systems of one kind or another. The most famous of these were the sewers of Roman however. This is primarily because of the extensive written records that have been preserved and allow us to study the sewer systems. The Romans did not use sewers for health reasons but rather as a method of carrying malodorous waste away from the homes of the rich.

It was not until the cholera epidemic of the mid 1800's in Europe that the need for getting human waste carried out of the community in an organized fashion became important. It was during this cholera epidemic that the public became aware of the need for a safe drinking water supply and the need for removing human waste materials. It was recognized that the disease organisms could be spread by contact with the human waste in the open street sewers that were in cities of that day. London was the first city to organize a city wide sewer system to collect all human waste to be discharged outside of the city.

Little is known about the early sewer systems in the United States other than to say that isolated, private sewers occurred in eastern cities from time to time. The late 1800's also saw the application of city wide sewer systems into some of the cities of the United States. By the turn of the century, organized sewer systems within city limits had become a rapidly growing practice. In 1980 more than 150,000,000 people in the United States were served by a public sewer system of one sort or another. Communities of all sizes whether very small or very large now consider public sewer systems to be of a benefit to the health and well being of their community. Because sewer systems are relatively expensive to install, it is imparative that the system serve the present as well as the future needs of the community with the least number of changes to the design.

Gravity sewers (that is sewers that are laid on a downward slope) are the most common types of sewers. The sewers of the ancient cities were all gravity sewers and from the records we can learn about problems and mistakes that have been made. The record indicates that if careful construction was not used, some of the sewers were actually laid in an uphill fashion which meant that the wastewater would not flow through the sewers. Some of the sewers were laid with areas that tend to trap wastewater which allowed for the production of foul smelling gases that would leak out of the sewers and be a nuisance to the community. Some of the sewers were built too small for the amount of waste that was intended to be carried. During periods of peak use the sewer could not handle the flow and the flows would back up trying to seek a way out of the sewer system. This backup flow could either occur into the street or into a basement of a home or building.

The sewer system must be designed so that the pipes are large enough to carry the peak flow that will occur in that pipe anytime during the design period. Therefore, the design is based on an expected use patterns both in the present and the future, as well as an estimate of the flow that may get into the pipe due to leaking joints that will develop over a period of time. The leaking joints let groundwater or surface water during rainfall events get into the sewer lines and occupy part of its capacity. The most difficult part of the design is this first step of trying to estimate how much use will be made of the sewer and what the peaking conditions are. For this reason, some fairly sizeable factors of safety are incorporated into the standard design practices. This may seem like an overdesigning to the planner who is not familiar with the variability that can occur in the systems but actually it's less expense and less of a problem for the community in the long run to have these capacities provided for at the very beginning. Most home owners and land owners in commercial districts don't like to have their front yards torn up or the inconvenience of the streets being blocked in order to put in new sewers at some time in the future.

For the same reason, a good maintenance program is necessary in any sewer system. The maintenance program constantly checks for defects or problems that are developing in the sewer system and seeks to correct those before they cause the need for replacement of that section of the sewer system. A good maintenance program can also provide information on whether a particular section of the sewer is in fact performing properly or whether it has become over loaded because of development of one kind or another. This information can then be used to look at changes in the system with use rather than waiting for some problem to develop on the surface. The cheapest form of sewers are gravity sewers, where the force of gravity carries the fluid through the pipeline. In many communities, however, there is no continuous downward path that the sewers can follow to bring the flow from all parts of the city into the wastewater treatment plant. All of the wastewater flow must get to the wastewater treatment plant in order to properly treat those wastes before they are put back into the environment, whether it be a river or lake or spread onto the land. For those areas where downward flow would not take the wastewater totally to the treatment plant, pump stations have to be installed to lift it to an adjacent area that will flow downward to the wastewater treatment plant. However because the flow of wastewater occurs 24 hours a day, 7 days a week the pump stations must also operate 24 hours a day, 7 days a week to avoid any problems with backup and overflow of sewage. It's impossible to build any equipment that will never fail. Therefore, the number of pump stations should be kept to a minimum to avoid problems of pump failure. But there will be places in almost every city system that will require some pump stations. A very carefully design analyses as well as operation and maintenance of these pump stations is necessary to insure a minimum of problems. But every planner should keep in mind that pump stations at one time or another in their life may experience some problems that will lead to a backup or overflow of sewage and proper planning for the contingencies of how to deal with those situations should be a part of the communities planning and operating systems.

Historically there have been two kinds of sewer systems--separate and combined. Separate systems are designed to transport domestic or human wastewaters only. Combined systems were designed to carry both stormwater

as well as human waste. In more recent times, cities have preferred to have separate sewers for the reason that stormwater does not need to be treated before being put into a river or stream whereas domestic wastes do. By having two separate systems, the domestic waste can be routed to a wastewater treatment plant before release and the stormwater can be routed through the natural drainage channels of the community. The design of the system to route the stormwater through the drainage system of the community is covered under the section on drainage in this manual. Therefore, the remainder of the discussion on **sewer** systems planning and design will be geared to the separate sanitary sewer system.

3.2 PLANNING (203)

Any new plans or extensions of sewer systems must be approved by the Tennessee Department of Public Health prior to their installation. The design engineer is responsible to submit all design criteria and specifications to seek the approval of the Department of Public Health. The Public Health Department has a set of requirements that they wish to see in all sewer systems. They include such things as excluding rainwater from roofs, streets and other areas as well as groundwater and foundation drains from a sanitary sewer system. The designer will incorporate all of these needs into the design. The planner should then work with the designer to see what other characteristics are desirable for this particular community's system.

3.2.1 DESIGN PERIOD (203.2)

Sewer systems should be designed for the ultimate use of the area in which they are located in as well as the area that is hydrologically upgradient from them. Considerations should be given to the maximum anticipated development and type of development in the area. Often a design period of 50 years is used for the durability of the materials in the pipe as well as the estimate of the types of flows from developing areas that will go into one of the systems. The capacity of the sewer line then is determined by the ultimate maximum uses of the sewer system as well as the potential for the additional wastewaters from the commercial or industrial activities and a realistic estimate of the magnitude of the leaks that might occur in the system. Each of these must be analyzed with some judgement involved to determine the potential for change within that community. Some communities have a history of very rapid change while other communities have a history of very slow change over a period of years.

3.2.2 DESIGN BASIS (203.4)

In order to produce the technical design that results in the specifications of pipe sizes and pipe locations, it is necessary to make estimates of the amount of wastewater that will flow into the system. New systems are normally based on an average daily per capita flow of wastewater that

is geared to the type of activity in use of that community. These numbers are then multiplied by peaking factors which are a method of estimating what the maximum rate might be at any given point and time. Most of the time the sewer pipe is flowing at a fraction of its capacity. But it is those infrequent periods, when the sewer has to flow at its peak capacity in order to avoid problems, that the design is aimed at. If the design was not conducted in this manner, the community would run the risk of the sewer pipes surcharging and the flow backing up through manholes into the streets or backing up into individual basements. Once this type of a situation occurs the only way to correct it would be to go back in and to dig up sewer lines and put in additional sewer piping at a much greater expense than if the pipe had been sized larger when it was first installed.

3.3 DESIGN AND CONSTRUCTION OF GRAVITY SEWERS (204)

The design of a gravity sewer system requires the knowledge of many interrelated problems that can occur. One of those is the specification of the minimum pipe size. Clogging of a sewer can cause serious nuisances as well as damages within the sewer system. Therefore very small pipe diameters which are more susceptible to clogging are not used in sewer designs. In most cases a sewer will not be less than 8 inches in diameter no matter how small of a flow the sewer is intended to carry. The sewer line must also be deep enough so that it does not freeze during the winter time and it must be deep enough so that any surface loads, such as vehicles that pass over the sewer line, do not crush it.

Since gravity sewers are intended to flow downhill by the force of gravity, the sewer line must be laid in a continuous downhill fashion, often at very small slopes. Keep in mind that the sewer line does not have to follow the contour of the ground. Even though the ground maybe going uphill the sewer line can be laid at progressively deeper points and be moving generally in a downward fashion to get through the hill. There are specifications on the slope and the velocity that must be maintained within the sewer system under all conditions. There must be enough slope to maintain a minimum velocity to keep the solids moving through the system so that they do not build up and accumulate to form a plug. On the other hand the velocity must not be too high because of the abrasive kinds of materials that get into sewers would tend to then wear away at the piping material. The designer then has to accommodate all of these restrictions about the sewer system and create a design that will allow it to function properly and at the least cost.

3.3.1 PIPE MATERIALS (204.7)

Many different types of natural as well as manmade materials have been and are being used for sewer piping. Clay, tile, concrete, asbestos cement, and plastics are common materials for sewers. Some of them, such as concrete, are highly susceptible to corrosion from chemicals that are formed in the wastewater. Other materials may have good strength and corrosion resistance characteristics but be more expensive and require more

effort in the installation. The designer should be given information by the planner as to which of the alternatives of initial cost of materials versus longer term maintenance cost for upkeep is desirable for each community's method of operation.

Sometimes the designer will choose pipe materials because of the ease of their installation. Some of the materials have joining systems where one pipe is connected to the other very easily and quickly. These pipes require very little time in the trench to put the pipe in place. The use of these kinds of materials is becoming more common and can cut the total cost of a labor intensive installation of sewer pipes.

3.3.2 PIPE BEDDING (204.8)

Sewers should be designed to prevent damage to the pipe due to the shifting of the ground or the changes of loading that occurs on the pipe. The best way to do this is to insure that the pipe is equally supported along its entire length. Just digging a trench and putting a pipe in the ground and throwing dirt on it does not guarantee that voids do not occur at different points underneath the pipe. Bedding material will insure this equal support and minimize the likelihood of a failure of a pipe due to some bending or crushing action. The use of bedding material will pay large dividends in the long run in maintaining a piping system that does not fail due to structural bending problems.

Rigid pipe is the most susceptible to these kinds of failures and therefore should have the greatest care and attention to its installation. While the addition of this bedding material may seem like an unnecessary expense to the planner it is important to understand its purpose. The installation procedures, although somewhat time consuming, are necessary for a reliable final project. Flexible pipe is less susceptible to these problems and requires less care but should also have a bedding material to insure its long life application as well. The standards and specifications go into detail for the various characteristics that should be used not only in the bedding material but all of the pipe materials as well and the designer should abide by the specifications or its equivalent in producing a good design.

3.4 MANHOLES (205)

Since the sewer system is primarily a gravity system and is susceptible to clogging or damage, access points are necessary everywhere throughout the system. These access points are called manholes. Manholes are nothing more than a vertical tube that runs from the surface of the ground down to the pipe. It is large enough for a person to climb into in order to conduct maintenance or inspection activities. The spacing of manholes is determined primarily by the length of the cleaning equipment that is available to conduct maintenance and repair operations on the sewer lines. Therefore, manholes occur in great numbers in any gravity sewer system. The expense of all these manholes will be a sizable fraction of the total project cost but it is important that the planner understand that without those manholes there would be no way short of digging up the sewer line to

correct minor problems that occur from time to time. So in the long run good selective locations of manholes is much cheaper and much less of a nuisance than not having the manholes. The MTAS design criteria includes several pages of drawings of standard manhole configurations that are used in the sewer systems.

The various design specifications and requirements of manholes are given in the design criteria book. The designer who follows these specifications is insuring a system that will have a maximum opportunity for proper maintenance and operation and therefore long life. These manholes because of their location in the sewer line, often become junction points for all the various sewers that run together. The manhole is a strategic point in the overall sewer system.

3.5 ACCEPTANCE TESTING (206)

The installation of a sewer line requires testing prior to being put into service. This becomes particularly important since the sewer line is below ground and can not be seen and any defects in the construction would be hidden. The testing of the final product should be a part of the contract for the installation. The testing will include a test of the joints through some sort of pressure test. The testing will also include a test for the proper alignment of the pipe material. The alignment checking determines if the pipe in fact was laid at the proper slope and moves continuously downhill with no low points in the pipe from one end of the section to the other end that would tend to trap wastewater. The MTAS designed criteria give the specifications for conducting these tests. A sewer installation that passes all of these tests should then give many years of reliable service to the community.

3.6 PROTECTION OF WATER SUPPLIES (207)

It seems obvious that there should be no physical connection between a water supply and a sewer system. However without careful control procedures to insure that pipe connections are in fact connected to the right sources, this can happen. There have been a few cases in this country where contractors have connected sewer pipes to water supply systems. The contamination that results from that can be quite massive. It is very important that the community have a method of verifying the location and type of all connections and to enforce this very rigidly. To some it may seem as if a bit of harassment or nuisance on something which seems obvious but the dangers from such a cross connection are too great to allow a hap-hazard type of system. Even without the direct connection there is still the possibility of contamination if the sewer pipes are too close to water pipes. Sewer pipes will tend to form leaks with age which always presents a potential for entrance into a water pipe even if the probability is low. It is better to be safe than to be sorry, so there are specifications on where a sewer pipe can be located relative to water pipes. In a city system that has many pipes running through a particular locality, the location of a sewer can often be a very restricted. The general specifications call for minimum horizontal and vertical separations between any

water lines and the sewer lines. These specifications should be met at all times even though at times it will add to the expense of the sewer installation. The health considerations of making absolutely certain that disease organisms are not transmitted through the public utility systems are the overriding factor in these cases.

3.7 SEWER PLANS (209.2)

Because of the installation of a sewer system requires numerous exact measurements and location points, there are several documents that must be prepared and kept up-to-date. These documents will generally be plan sheets and books of specifications. The plan sheets are used to locate the horizontal and vertical position of every component of the sewer system. In most cases these sheets will include a street map showing the location of manholes, sewer pipes and connection points, as well as, detailed cross section drawings on each section of pipe within the entire sewer system. These detailed drawings will be labeled accurately with all dimension and position information so that not only will the contractor know exactly how to install the sewer system but the community will then have an accurate set of records that can be used in the future to modify or correct problems that occur in the sewer system. The MTAS design criteria calls for these detailed plans to show the following information: (1) The location of the streets and the sewers to be installed as well as any pipes that are already in place, (2) the line of the ground surface, the size, material, and type of pipe to be installed, the length between manholes, the elevations of the pipe as well as the surface of the ground, the grade (the slope) of the sewer between two adjacent manholes. All of the manholes are numbered on the plans so that manholes can be matched up within any section of the total system. Any exceptions or restrictions on the sewer system should be noted in detail on the plans for future reference, (3) locations of all special features such as concreted incasements or elevated sewers, drop manholes, anything which is out of the ordinary in the sewer system, (4) all known existing structures both above and below ground which might interfere with the proposed construction (For example, these would include water mains, gas mains, storm drains, etc.), and (5) special detail drawings made to scale to clearly show the nature of the design.

The planner can assist the designer in collecting this kind of detail by accumulating the documents and known information of the community so that the designer will have the information on hand. It is essential that this final set of plans go into as much detail and have as much exact numerical information as possible. The construction drawings are the guide for placing the pipe in the ground. However, during any construction project there are always problems that come up that require modifications of the design. These modifications should be put on the master set of design documents and at the end of the project the engineer should be asked to certify that the master design documents are "as built." These

"as built" should be the exact specifications of how the sewer system was installed and is in place in the community. They become the reference documents for all future activity. If these documents are inaccurate, then future activities will be much more time consuming and much more expensive because the next group that works on this system will have to spend much of the time searching out all the missing links or the missing pieces of information. There is nothing more frustrating or inefficient than for a sewer crew to go out into the city to do maintenance or inspection on a sewer system and not be able to locate the manholes because they were not put in the place that was shown on the design map.

3.8 CHECK LIST

- (1) Identify the area to be served by the sewer project.
- (2) Locate existing utility services in the project area.
- (3) Is a building code in place to prevent connection of foundation drains and roof leaders to the sanitary sewer system?
- (4) Does the community have an inspection program to check new connections?
- (5) Identify future land use through zoning so that estimates of wastewater flows can be made.
- (6) What are the cost versus maintenance relationships of the sewer pipe material?
- (7) Is bedding material being used in the trench? If not, is it justified?
- (8) Did all the sewer pipes pass testing?
- (9) Is a certified set of "as built" drawings provided by the engineer?

MTAS DRAINAGE

4.01 DRAINAGE

4.1 GENERAL

The subject of drainage is highly complicated and often controversial. The purpose of this chapter is to acquaint the planner with the concepts and alternatives connected with the design and construction of drainage systems. It is recommended that the reader also review the booklet Storm Water Management referred to later in this chapter.

There are three essential characteristics which must be provided around any development project, no matter how small. They are drainage - drainage - drainage. While this may seem a bit facetious, it does illustrate the importance of good drainage planning. A lack of good planning can negate all other factors. Unfortunately, drainage is often overlooked as a "minor" problem. However, a strong summer downpour often reveals how important that "minor" problem can become if the proper planning has not been performed. It is more expensive to correct a drainage problem after-the-fact than it is to provide the proper system in the beginning.

Drainage systems are provided for the orderly movement of excess water. These systems are categorized as either urban storm water drainage, highway (or streets) - drainage, or land drainage. Urban storm drainage collects runoff from small drainage basins to prevent ponding of the water which might cause damage or a nuisance. Street drainage removes storm water from the traveled way, cross drainage which would flow over the street due to the natural drainage patterns of the area (usually controlled with culverts or small bridges), and subsurface drainage to remove excess soil water which would weaken the road bed. Land drainage is provided to remove excess water from an area that tends to remain too wet for the intended use.

To fully understand drainage problems, the concept of the hydrologic cycle must be mastered. In Tennessee, the source of drainage water is principally rainfall. When rain falls to the ground, some of it soaks into the ground, a process which is called infiltration. The amount of infiltration depends upon the type of soil and cover material as well as the preceding weather conditions. Some of the rainfall could evaporate, depending on temperature and wind velocity conditions. However, this is usually an insignificant amount during runoff producing storms. Evaporation through plants also occurs but is insignificant during storm events. The portion of the rain which does not soak into the ground, evaporate, or get trapped in a depression flows downhill as runoff.

If the ground surface becomes impervious, that is, it will not allow water to soak in, then a larger portion of the rain becomes runoff. There are primarily two ways the ground can become more impervious. The ground can be covered with surfaces that do not allow water to pass through to the ground such as buildings, streets, and parking lots. In addition, the runoff reaches the drainage channels much faster because the smooth impervious roof and pavement surfaces do not retard the runoff flow as much as the rougher natural grass and forest cover. The end result is that more water is dumped into the drainage channels in a shorter period of time. In

other words, more urban development produces greater runoff flows even for the same rain storm. The other way is for the ground to be saturated with water from a previous rain storm. The soil can no longer accept more water so increased runoff results. The rainfall from the second storm would produce a higher percentage of runoff than did the first.

The basic philosophy applied to the design of storm drainage facilities, followed in the past and still widely practiced today, is to collect as much storm water runoff as possible and rapidly discharge it through a system of pipes to the nearest outlet.

Nevertheless, it has become apparent that in many instances we have ended up creating new problems, which now may become very difficult and expensive to solve.

The major problems that have been created can be summarized as follows:

(1) High peak flows in storm sewers and streams which require larger facilities at higher cost;

(2) Lowering of water tables, with a detrimental effect on existing vegetation;

(3) Reduction in base flows in receiving streams, effecting aquatic life;

(4) Excessive erosion of stream and sedimentation in lakes, due to high discharge velocities;

(5) Increased pollution of receiving streams and lakes due to industrial fallout on roofs, fertilizers from lawns and debris from streets and paved areas being conveyed directly to the streams;

(6) Damage due to flooding - runoff quantities which have been experienced rarely, now occur much more frequently.

Every area is part of a larger watershed and therefore, impacts the drainage of the entire watershed and visa versa. The drainage plan of every subarea should then be a component of and in agreement with the drainage plan of the entire watershed. This kind of pre-planning will prevent a multitude of expensive problems later. The rapid development of many areas requires such action. This philosophy is beneficial to all communities since development often is initiated suddenly. The American Society of Civil Engineers' (ASCE) manual on Residential Storm Water Management recommends the following basic concepts to minimize the long term problems and to maximize the benefits;

(1) The water falling on a given site should, in an ideal design solution, be absorbed or retained on-site to the extent that after development the quantity and rate of water leaving the site would not be significantly different than if the site had remained undeveloped.

(2) Optimum design of storm water collection, storage and treatment facilities should strike a balance among capital costs, operation and maintenance costs, public convenience, risk of significant water-related damage, environmental protection and enhancement, and other community objectives. The optimum balance among these factors is dynamic, changing over time with changing physical conditions and value perceptions.

(3) Just as the importance of water quality is being increasingly recognized, a major new emphasis needs to be placed on the identification and application of "natural" engineering techniques to preserve and enhance the natural features of a site. Engineering design can be used to improve the effectiveness of natural systems, rather than negate, replace or ignore them.

(4) Among the new trends that should be pursued are the use of on-site detention storage, the increased use of storage to balance out handling or treatment of peak flows, the use of land treatment systems for handling and disposal of storm water, and perhaps the most important a recognition that temporary ponding at various points in the system, including on the individual lot, is a potential design solution in many situations.

(5) A continuing recognition that there is a balance of responsibilities and obligations for collection, storage and treatment of storm water to be shared by individual property owners and the community as a whole.

(6) A growing emphasis on the recognition that every site or situation presents a unique array of physical resources, occupancy requirements, land use conditions, and environmental values. Variations of such factors within a community generally will require variations in design standards for optional achievement of runoff management objectives.

(7) Reevaluation of the approach to basin-wide runoff management is a universal need. It is the responsibility of, and should be an objective of, the public sector.

4.2 PROTECTION (301.2)

Areas which frequently overflow, or may be expected to be flooded, if the water shed area above this point is developed, should not be permitted to be subdivided into lots or building sites for any purpose without providing for sufficient drainage. (50 year period minimum).

The 50 year period minimum implies a certain risk that the drainage system will fail and flooding will occur. Every system is based on a design flow rate which is in turn based on the level of protection which is desired. Weather cannot be accurately predicted for next week much less for 50 years. Our records of rainfall cover a relatively short period (50 to 100 years). In order to make a rational selection, statistics and probability are used to determine what storm data should be used for the design flowrate. A 50 year period is a statistical value which can be related to a storm intensity which occurs on an average recurrence interval of 50 years over a long period of time. The higher the period, the more severe the storm (i.e. a 100 year storm is more severe than a 50 year storm). Examples of rainfall intensity - storm duration - frequency curves are shown on pages 14 through 17 of the Design Criteria Manual under Drainage. The length of the recurrence period does not mean that a 100 year storm cannot occur during a 50 year period. In fact, it is possible for a 100 year storm to occur today and another 100 year storm to occur tomorrow. But the probability of that occurring is low, although not zero. A design which protects against a 100 year storm has less chance of failure than a design which protects against a 50 year storm, but it is also more expensive. The value of the protection should be weighed against the cost of providing the protection to determine the design condition. This is a topic which requires careful consideration by both the planner and designer together. The planner should also keep in mind that development at the top of a drainage basin will produce more runoff flow at the bottom of the drainage basin which might exceed the previous design conditions.

It is often difficult to predict the damage from urban nuisance flooding. The selection of the return period is a judgement call. There may be little harm in full gutters and flooding intersections several times each year if it only lasts a short time. A greater degree of protection may be necessary in a commercial district because of the inconvenience involved. The willingness of the residents to fund the project may have a over-riding influence on the level of protection provided by the design.

James and Lee (1971) suggests an alternative approach for selecting the optimum level of protection when nuisance damage is the significant factor. They include:

(1) To install storm drains on a trial and error basis with additional facilities provided when public pressure develops.

(2) To regard nuisance damage as an intangible and to allow the planner to use his or her judgement in selecting the design frequency with economic analyses being used only to determine the least-cost design for accomplishing the objective.

(3) To postulate a function relating nuisance damage to the depth and duration of ponding and combine benefits for economic justification.

(4) To survey storm drainage practice to derive nuisance damage as a function of land use.

The first two have been widely used but produce variations in results with the possibility of public discontent.

Since the level of protection has a direct bearing on the cost of the project, the planner should carefully discuss with the designer the relative costs of each level of protection and what the protection means to the community. The planner and designer should come to an agreement as to the level of protection (or risk) that the community can afford and desires. By this method the planner should have a better understanding of what is being provided and what is not so there will be no surprises later.

In street drainage using open ditches, when a runoff peak exceeds the culvert capacity, water will back up until it gets deep enough to over flow the pavement. The ponding damage depends on land use and the overtopping damage depends on the type of construction and the traffic patterns. Overtopping should be minimized so longer return periods are often used. Underground storm water piping systems are more expensive but provide a way of minimizing the nuisance conditions.

4.3 DEFINITION OF STORM WATER RUNOFF SYSTEM

ASCE defines a storm water runoff system as:

(1) Composed of both natural and man-made elements. In the past, designers have often failed to capitalize upon natural elements and have at times ignored them when a constructed element was installed.

(2) Components including not only those which contain and convey storm water, but also those which absorb, store and otherwise use storm water rather than dispose of it.

(3) A single system having two purposes: (a) the control of storm water runoff to prevent or minimize damage to property and physical injury and loss of life which may occur during or after a very infrequent or description of activity as a result of runoff from more frequently occurring, less significant storms.

(4) A system where there are components that are designed primarily to obtain convenience at the smallest scale of the system at the individual site or intersection, during minor or frequent storms. During an infrequent or major storm, the capacities of many of the convenience-oriented components will be exceeded and flow capacity must be provided by other components designed to provide safety and minimize damage throughout the system. It must be recognized and emphasized that a total storm water runoff system cannot be expected to prevent inconvenience and minor property damage for all storms.

4.4 STORM SEWER SYSTEMS (301.3)

Systems shall be designed to protect against flooding of property of all classes, and maintain the required level of service for public facilities. Storm sewer systems shall be designed as a coordinated unit and may include any or all of the following elements:

(1) Enclosed storm sewers and appurtenances.

(2) Open channels.

(3) Swales on property lines.

(4) Definition of terms given in the Design Criteria Manual;

(a) Enclosed storm sewers - Enclosed storm sewers shall be used to collect and convey drainage on, across, and through public street rights-of-way. Outfall drains shall extend at least 60 feet to the rear of the front building line or 20 feet past the back line of the structure, whichever is greater, and on the inlet to 1 foot from the center of the side ditch.

(b) Open channels - Open channels are acceptable only to carry storm water runoff from tributary areas exceeding 100 acres, or from smaller tributary areas otherwise requiring an enclosed storm sewer pipe 48 inches in diameter or larger, except enclosed drainage structures shall be provided where open channels cross public right-of-way.

(c) Side ditches. Side ditches are generally not acceptable and may be used to convey drainage along public right of way only in rural areas when designated by the city engineer. Culverts and appurtenant drainage facilities shall be designed to permit their incorporation into a future enclosed storm sewer system when possible. Ditches shall be designed to meet the requirements for open channels.

(d) Velocity - Discharge velocity shall be controlled to prevent both erosion and siltation at and immediately downstream from the point of discharge. Energy dissipating structures shall be used if required.

4.4.1 TEMPORARY DETENTION SYSTEM

In areas where a stormwater outlet is available, then stormwater may be detained in the facility until such a time when releasing the water is permitted, or a constant allowable release rate may be applied throughout the runoff event. In such cases the infiltration capacity of the soil may also be considered for the detention period. This is acceptable to the enclosed storm sewer system and open channel, but it should be constructed before the area is highly developed.

4.4.2 METHODS TO REDUCE QUANTITY OF RUNOFF AND MINIMIZE POLLUTION

If the stormwater is permitted to follow its natural hydrological process it will inevitably result in a reduction in the quantity of stormwater runoff and a reduction of pollution loading in the receiving watercourses. Stormwater should be directed into the soil preferably to the same extent as nature did prior to development, and maybe to an even greater extent. By allowing stormwater to infiltrate back into the soil, it will not only reduce the quantity of runoff and recharge to water table, but the filtering properties of the soil will improve the water quality.

Whatever amount cannot be so accommodated at the point of rainfall should be detained in nearby locations for a controlled outlet to the receiving streams, with peak flows approaching the pre-development peak flows.

There are a variety of methods in common use today that can effectively control peak runoff rates, while at the same time, improving quality. The following Table lists such methods along with their effectiveness and is presented to give the planner an appreciation for the many alternatives that the designer must consider in order to produce the best design for each particular situation. Each drainage design is unique and requires careful consideration.

MEASURES FOR REDUCING QUANTITY OF RUNOFF AND MINIMIZE POLLUTION

MEASURE	REDUCE VOLUME OF RUNOFF	REDUCE PEAK RATE OF RUNOFF	IMPROVEMENTS TO RUNOFF WTR QUALITY	R E S I D E N T I S M E N T S	I N T E R N E T I O N A L I Z E D S Y S T E M S	C O M M U N I T Y B A S E S	I N T E R N E T I O N A L I Z E D S Y S T E M S	H I G H L Y P O L L U T E D A R E A S
Roof water to grassed surfaces	X	X	X	X				
Contour grading	X	X		X				
Porous Pavement - interlocking stones	X	X		X	X	X	X	
- gravelled surfaces	X	X		X	X	X	X	
- porous asphalt	X	X		X	X	X	X	X
Grassed ditches	X	X	X	X	X	X	X	X
Infiltration Basins	X	X	X	X	X	X	X	X
Blue-Green Storage		X		X	X	X	X	
Ponding on flat roofs		X			X	X	X	
Ponding on roadways		X					X	
Ponding on parking lots		X			X	X	X	
Detention Ponds (dry pond)		X	X	X	X	X	X	X
Retention Ponds no freeboard			X					
Retention Ponds with freeboard		X	X	X	X	X	X	
Subsurface Disposal - perforated storm sewer	X	X	X	X	X	X	X	X
- infiltration trenches	X	X	X	X	X	X	X	X
- dry wells	X	X	X	X	X	X	X	X
Subsurface Detention		X	X	X	X	X	X	X

All of these measures for reducing quantity of runoff and minimizing pollution are not applicable to every city, but many are, and the runoff can be reduced by using those that are suited to the varying conditions.

4.5 DESIGN PROCEDURES

Section 302 of the Design Criteria Manual lists thirteen (13) items which are incorporated into the overall design process. These items can serve as a practical check list for the planner to highlight important areas of the design.

4.5.1 MAPS (302.1)

Prints showing the water shed area, recorded plats, survey maps or other plans which are available showing the tributary area to be designed for shall be obtained.

4.5.2 SURVEYS (302.2)

Check and confirm survey reference data with the official plat book and other recorded information.

4.5.3 UTILITIES (302.3)

The location of all utility lines existing and proposed from files and other information supplied by utility companies and city records should be checked.

4.5.4 EXISTING INFORMATION (302.4)

Determine the ridge lines of the tributary area and establish the general routing of the proposed sewer line. Check connecting storm sewer lines, appurtenances, street grades and all other information pertaining to the location of the proposed sewer.

4.5.5 PRELIMINARY LAYOUT (302.5)

Prepare the preliminary layout and grades in pencil. The drainage pattern must be compatible with the existing pattern established in the area.

4.5.6 ULTIMATE DEVELOPMENT (302.6)

Compute the estimated ultimate density and impervious surfaces planned for the area. Information may be obtained from the city engineer's office or the planning and zoning department.

4.5.7 FIELD CHECK (302.7)

Verify the preliminary design by field checking of the water shed area, critical connections, crossings, slopes, etc., before proceeding with the final draft of the plan.

4.5.8 RUNOFF (302.8)

Establish and indicate curb grades, outline of the runoff area, and indicate cubic feet per second by increment at each point of interception.

4.5.9 CURB CAPACITIES (302.9)

Calculate curb capacities for each side of the street interdependently. Differences in curb elevations, off center crowns, etc., must be taken into consideration.

4.5.10 INLETS (302.10)

When calculations indicate that curb capacities are exceeded at a point, no further allowance shall be made for flow beyond that point and basins shall be used to intercept flow at the point. All flow shall be picked up by an inlet. Paved gutters may be used to intercept flow and drained to an approved outfall on approval of the Engineer.

4.5.11 INLET AND PIPE CAPACITY (302.11)

Calculate capacities for inlets and size pipe laterals. A 15 inch pipe is the minimum sizing for all laterals.

4.5.12 MAXIMUM DEPTH (302.12)

Drainage water must not exceed the depth of the curb at any intersection.

4.5.13 HYDRAULICS (302.13)

Calculate and show hydraulics of pipe inlets. Calculate velocity head and hydraulic profiles of flows exceeding a velocity of 15 feet per second.

4.6 RUNOFF CALCULATIONS

Section 303 of the Design Criteria Manual discusses the various formulas and criteria which are acceptable in calculating and specifying the design conditions. The design equations for flow rate incorporate the sep-

cific conditions of storm return frequency, area of the drainage, infiltration tendencies and slope (high slope, faster runoff). All of the equations are estimates but provide the best estimate based on available data and knowledge. The results of these calculations become the basis for sizing all the inlets and piping.

4.6.1 PIPE SIZING (304)

Minimum size stormsewer (drive pipe) shall be 15 inches in diameter and all other pipe to be a minimum of 18 inches in diameter. Flooding of adjacent property should be a prime consideration in determining the drainage structure to be installed. The agency responsible for the installation of drainage structures may be held accountable for damages, if it is too small and causes flood damages.

4.6.2 GUTTERS AND INLETS

Gutters are used to transport the runoff flow to the inlets of the piping system. Gutters should be designed to collect the runoff and convey it without causing ponding. Proper inlet design is critical. If the inlets are undersized, the runoff cannot properly flow into the storm sewer and thus wasting its value. Inlets are strategically placed in gutters to direct the flow into buried sewers before the gutter flow becomes too deep. So inlet positioning and spacing depends on the land used and design flow conditions and each point in the overall systems. Placement is often left the judgement of the planner and the designer based on the level of acceptable nuisance for each project.

4.6.3 EROSION

During construction, use temporary berms, bailed straw or hay, sediment traps, brush barrier, temporary slope drains. When the earth work is complete, pave ditches too steep for sod to protect (approximately 3% or over) and sod all other ditches. Cut berm ditch at top of cut sections and seed with mulch, all newly graded earthen areas that is not to be paved, sodded, or stabilized. Rip-rap fill slopes that neither sodding or seeding will protect. Planting of shrubbery will help to stop erosion. Failure to properly protect against erosion can mean the expense of having to rebuild the project at a future date.

4.6.4 EASEMENT (310)

Permanent drainage easements should be obtained for all storm sewers, and open drains, that is not within a public dedication, with the right of entry for inspection and maintenance.

Permanent easement should be obtained for a detention dam site will spillway and release facilities, and floodage rights for temporary deten-

tion and conveyance of storm drainage. Easements and floodage rights shall include all necessary provisions and sufficient land for entry to inspect and maintain facilities. Deeds and easements should be properly recorded.

4.6.5 SUBSURFACE DRAINAGE

Soil moisture is of three kinds: Gravitational, Cappillary, and Hygroscopic. This water must be removed to produce a stable subsoil. In rural areas, this can be accomplished by lowering the water table with deep ditches. In urban areas this water can be trapped in an underground drain placed in the shoulder parallel with the pavement at a depth sufficient to lower the water table.

4.6.6 ENERGY DISSIPATORS

Controls, both natural and artificial, determine the relation of stage to discharge and regulate the flow. Natural control of stream flow may occur at channel constriction, gravel bars, rock outcrops and debris jams. Vegetation growth and roughness reduces the velocity of the stream. Artificial controls includes dams, retarding structures, diversion dams, grade-control structures.

4.6.7 FOUNDATION DRAINS

Foundation drains (including downspout) should never be permitted to connect to sanitary sewer, and to storm sewer only if it was designed to take this additional water. It is much better if foundation drains can be piped to a sodded area and allowed to soak into the soil.

4.7 PLANNING CHECK LIST

The following check list is provided as a guide to the planner to identify the important components of the overall project which should be considered. Each planner should add additional items as needed for any particular project. The most important item is communication. The planner and designer should communicate on every facet of the project with the goal of producing a better final product. The designer should then produce the design to meet the stated requirements and certify that the design will meet the planners goals.

(1) Identify the total area to be protected by the project and the area to be affected by the drainage from the project.

(2) Evaluate the effect of the drainage from this project on the drainage characteristics of any "downstream" areas or piping systems.

(3) Determine the level of protection which is required for this project (section 4.2).

(4) Choose between surface (ditches) and subsurface (sewers) systems. (section 4.2).

(5) Will detention areas be designed into the development? (section 4.3.1)

(6) Identify the potential damages and the method of responding to those future damages.

(7) Detailed maps of the area showing the location of buildings, streets, existing drainage, topography, etc.

(8) As built drawings kept up-to-date and on file.

(9) Utility line locations.

(10) Connections to existing systems and the resultant effects.

(11) Review of preliminary layout.

(a) Predesign conference with the designer to discuss the requirements for the project.

(b) Review of a sketch of the design concept which is provided by the designer.

(c) Approval by the planner of the design concept in consultation with the designer.

(d) Review of the detailed design.

(e) Approval of the final design and proceed with construction.

(12) Estimate of ultimate development for peak runoff conditions (section 4.3.2).

(13) Adequacy of zoning control to ensure that the development plan does not change significantly and change the runoff characteristics. (This may be part of the risk uncertainty analysis.)

(14) Field check of the construction.

(15) Inlet placement to minimize nuisance conditions (section 4.5.2).

(16) Erosion protection on all surface transport systems (section 4.5.3).

(17) Control of foundation and eave drains (section 4.5.7).

(18) Open channels should be routed to minimize safety hazards (section 4.3).

(19) Inlet design should consider pedestrian and bicycle safety (section 4.5.2).

(20) Energy dissipators and other outfall protection should be designed where enclosed drains discharge onto erodible soils (section 4.5.6).

MTAS STREETS

5.0 STREETS

5.1 GENERAL

Streets are one of the largest investments made by a city. They are also one of the most permanent in the sense that once built, they are seldom moved or discarded. In fact, a city street map from one hundred years ago will look very much the same as the present street system less new additions. Hence, good planning of the street system is very important since their locations will be essentially fixed once built. Good street design is also important in order to minimize the burden on the taxpayer. Even if the streets are financed by a developer, the city or county will ultimately be responsible for the maintenance including resurfacing, patching, and sign upkeep.

Streets provide many essentials of city life: travel of people to and from work, movement of products into and out of the city, services such as police, fire, and ambulance, and access to recreational and cultural activities. Streets can be classified in a simple hierarchy of arterial streets, collector streets, and local streets. Arterial streets are the major roads in the city which handle large volumes of traffic and are the easiest routes to use in making long distance trips. Collector streets are intermediate between the arterial streets and local streets and pick up traffic from local streets to bring it to the arterials. Local streets provide access to individual homes and businesses.

As mentioned previously, planning the city streets system is extremely important. Everyone understands the frustration of trying to get home at rush hour on a road system that is poorly designed. Moreover, planning must not only consider the present needs but future needs as well. Inadequate anticipation of future traffic will make upgrading the streets very expensive especially if homes and businesses must be demolished for the new right of way. Planning and construction of streets differs from water main, sewer, and drainage projects in that many more people and groups take an interest in where the streets will be built and consequently street projects may generate great controversy.

Several considerations govern the planning and design of streets and highways. General criteria include (1): (a) Reduction of traffic congestion and travel time, (b) Safety, (c) Environmental considerations such as noise and attractiveness, (d) Cost of construction and maintenance and costs and benefits to the community and street users, and (e) Community attitudes towards a project. An excellent summary of additions planning principals for local residential streets is contained in a document written jointly by the Urban Land Institute (ULI), the American Society of Civil Engineers (ASCE), and the National Association of Homebuilders (NAHB) and titled "Residential Streets". (2) These principles are:

(1) Street and pedestrian circulation pattern in a new residential area should be compatible with objectives established by a community's major street plan.

(2) Planned layout should minimize overall length of streets.

(3) A residential area should be conveniently accessible from major streets and highways.

(4) Driveway entrances should be avoided on arterial streets and wherever possible on collector streets.

(5) Through-traffic on minor residential streets should be avoided.

(6) Residential streets should provide safe and convenient access to housing.

(7) All dwellings must be accessible by emergency and service vehicles.

5.2 MTAS SPECIFICATIONS

The MTAS specifications or other similar specifications play an important role in ensuring that urban street and highway projects will be designed and constructed satisfactorily with a minimum of problems over the projected life of the facility. The intent of this section is to explain the importance of various specifications and the consequences of alternatives.

5.2.1 BASE AND SUBGRADE TREATMENT (02215)

The base is the layer of material immediately beneath the pavement. Because it supports the pavement and ultimately the vehicles, its ability to withstand these loads without deforming is critical. The subgrade is the soil upon which the entire road ultimately rests. For roads that are built by filling in valleys and depressions, the imported fill material is the subgrade, otherwise the subgrade will usually be the original native soil. Since the subgrade supports the base and pavement and ultimately the vehicles, it must also resist the loads without deformation. Nearly everyone has driven on roads which have developed depressions or have warped as the result of base or subgrade failure. The engineer will achieve stability of the base and subgrade material by proper selection and compaction of that material. The correct moisture content in the soil is critical since too much moisture will lessen the stability of the soil (the reader can picture the suitability of mud for a roadway to understand this) whereas too little can also affect the strength and compaction. One function of the final pavement surface will be to reduce the penetration of moisture into the base and subgrade. Periodic testing of material during construction is imperative in order to determine whether the material and compaction are satisfactory.

5.2.2 GUARDRAIL (02451)

Guardrails perform an important safety function by preventing cars from leaving the roadway and thereby falling into rivers and ravines or crashing into objects. Of course the best solution is to remove the object if possible; if not possible then the guardrails specified have proven to be satisfactory, providing necessary strength, attractiveness, and safety.

Proper installation of the guardrails is important for them to function as intended, for example, the ends of guardrails facing traffic are often tied into the ground so as to prevent spearing of the rail through the vehicle windshield if the rail were hit head on.

5.2.3 HIGHWAY SIGNS (02452) AND PAVEMENT MARKINGS (02577)

Signs and pavement markings serve regulatory (stop, yield, etc.), warning (curve, deer crossing, etc.), and informational (city distances, route numbers, etc.) purposes. Such signs must be of uniform design across the United States in order for drivers not to be confused. Their locations should be chosen with an understanding of safety lest they cause more problems than they cure. They must also be durable so that they will not be lost from service frequently.

5.2.4 ASPHALTIC CONCRETE PAVING (02513) AND PORTLAND CEMENT PAVING (02515)

The pavement forms the wearing surface that vehicles travel upon and also prevents moisture from entering the base and subgrade. Asphaltic concrete and portland cement concrete contain mixtures of aggregate, typically gravel and sand, and asphalt or portland cement. The asphalt or bituminous material and the portland cement serve as a glue to bind the aggregate particles together; since these materials are more expensive than the aggregate, it is desirable to blend several sizes of aggregates in order to reduce the volume required for the asphalt or cement and form a strong, dense pavement. Proper selection of aggregate material and size and percentage of asphalt or cement is also important because it affects the ease of placement and forming of the pavement and affects the ultimate pavement strength. Too much asphalt or cement can be just as bad as too little.

The necessary pavement thickness in order to achieve a durable surface resistant to deformation will depend on the volume of traffic and the percentage of trucks. Good design will save money over the long run by reducing maintenance while also minimizing pavement costs.

Some of the terms discussed in these portions of the MTAS specifications may not be familiar to the reader, hence, a short list of definitions is included here:

(1) Hot mix asphaltic pavement is mixed at a central plant at temperatures of about 250-275° F and then formed into pavement while still hot. The high temperatures allow the bituminous material to evenly coat the aggregate and allows the concrete to be placed and formed before cooling and hardening.

(2) Cold mix asphaltic pavement can be stored and worked at normal outdoor temperatures making it more convenient for smaller jobs or where there is not a hot mix plant nearby.

(3) Tack coats are placed on old pavements prior to laying new asphaltic concrete pavement in order to promote bonding of the old and new pavements.

(4) Prime coats are liquid bituminous materials sprayed on the base to seal capillary pores and bind the base and asphalt pavement together.

5.2.5 CONCRETE CURBS, GUTTERS, AND SIDEWALKS

Concrete curbs and gutters serve to keep the vehicles on the roadway, reduce entry of water into the base and subgrade, prevent breakage of the pavement edge, and direct runoff into the stormwater system.

5.2.6 STREET LIGHTING (16550)

Lighting of city streets and major rural intersections is normal. Reduction of serious accidents is an important consideration in their placement and construction.

5.3 DESIGN CRITERIA (400)

The design of highways and streets is, of course, complex to the extent that engineers devote years of education and experience towards obtaining competence. However, the planner should understand several fundamentals as discussed in section 400 of the MTAS specifications and below in order to more wisely choose among various options.

5.3.1 DESIGN ELEMENTS (403)

Planning ahead for the city street system is imperative to foresee and prevent problems. Each city should have a master plan for its system that includes such things as location of arterial and collector streets at sufficient intervals to reduce congestion, travel times, and safety hazards. Such plans should be continually revised as new demands and developments are seen.

A critical step in the planning and design process for arterial and collector streets is the estimation of traffic volumes since this affects the pavement thickness, pavement width, and geometric layout of the street. Other factors will generally govern the design of local streets. Traffic volumes can be estimated from actual counts or published references. The state highway department can be very helpful and may already have traffic projections for the street in question. For arterial and collector streets, consideration must be given to the heavier traffic during rush hours and to the percentage of heavy vehicles such as trucks since they have a great impact on pavement thickness and intersection layout. In estimating future traffic, the generation of new traffic must be taken into account when a major road is improved; generally new business will locate near the road and thus create new traffic.

Superelevation is the banking of a curve so that the roadway slants with the highest point on the outside of the curve. Superelevation is commonly used on curves to help prevent vehicles from leaving the roadway because of their centrifugal motion.

Safety is of paramount concern in the planning and design of streets. Several general criteria from the manual "Residential Streets"* are reproduced here:

*See Ref. (2).

- (1) Assure necessary lighting along streets and walkways.
- (2) Use of signs should be minimized and signposts should be unobtrusive.
- (3) Informational signs should not compete with traffic control signs for driver attention.
- (4) Use of break-away street furniture should be considered wherever possible and should be grouped for aesthetic as well as safety values.
- (5) Sight distances should be consistent with probable traffic speed, terrain, alignments, and climatic extremes.
- (6) Separate pedestrian, bicycle, and vehicular traffic.
- (7) Limit through-traffic on residential streets.
- (8) Assure visibility of parks, play areas, and interior block open spaces from the street.

Other criteria govern the design of intersections:

- (1) Whenever possible, residential street layouts should be planned to avoid four-way intersections.
- (2) Residential street widths normally should be the minimum consistent with safety and adequate fulfillment of street function. Pedestrian accidents are somewhat proportional to street crossing travel distance.
- (3) Paved area within the intersections should be minimized.
- (4) Oblique intersections should be avoided.
- (5) Safe sight distances at intersections should be assured.
- (6) Turning lanes at heavily traveled intersections should be provided.
- (7) To the extent feasible, the number of street intersections should be minimized.
- (8) Large corner radii should be avoided.
- (9) Wherever possible, intersections on curves should be avoided.

5.3.2 PAVEMENT CROWN (404)

Streets and highways are generally designed so that the center of the pavement is higher than the edges. This arrangement causes good drainage of water off the pavement; without this drainage, standing water by itself and upon freezing can present safety problems besides possible damage to the road via the pressures exerted by the water when it freezes in cracks and via seepage to the base and subgrade.

5.3.3 NUMBER OF LANES (405), ROADWAY WIDTH (406), AND MEDIANS (407)

The number of lanes, roadway width, and median presence affect the capacity and safety of streets and highways. Obviously, more lanes can handle more traffic but not so obvious is that wide roads and use of medians tend to increase capacity by separating the vehicles thus making the driver feel safer to go faster besides preventing collisions. The choice of street widths for local residential streets are not controlled by the traffic volume so much as considerations of parking (one or both sides) and the ability to accommodate two lanes of traffic (e.g. perhaps only one lane of traffic is really necessary on short cul-de-sacs serving very few houses).

5.3.4 RIGHT-OF-WAY WIDTH (412)

Adequate right-of-way should be purchased to accommodate probable future expansions of arterial streets, however, local and collector streets should be designed so that they will not need future expansion. Development usually occurs on arterial streets so that failure to procure adequate right-of-way will result in excessive costs to purchase the now developed businesses and houses.

5.3.5 ACCOMMODATION OF UTILITIES (413)

Water mains and sewers and possibly gas, telephone, and electricity, are often laid next to or underneath streets. When planning and constructing a new development, it will save problems and money if all utility locations are planned together so that interferences can be eliminated. During construction, some thought should be given to the local sequence in which the utilities will be installed. It makes little sense to dig up one utility to install the next; it makes even less sense to dig up newly installed pavement to then lay the water and sewer lines.

5.3.6 STREET LIGHTING (415, see also section 5.2.6 of this manual)

Breakaway light poles have the advantage that when a vehicle hits them, they give and do not present an immovable object. However, in densely developed areas the danger of the falling pole harming someone else can outweigh the concern for the motorist.

5.3.7 PAVEMENT DESIGN (418)

See section 5.2.4 of this manual.

5.3.8 DRAINAGE

Although there is not a specific section in the street specifications on drainage, there are other sections in the MTAS specifications devoted to drainage. The point to be made here is that drainage is very important to street and highway design in order to prevent puddles forming on the roadway surface which will not drain and also prevent the flow of rain swollen creeks over the roadway; bridges and culverts must be of adequate size to preclude this. Also, all parts of the pavement surface must eventually drain so that water does not stand on the pavement until it evaporates. If this latter point is not provided, the street will gradually deteriorate at that location because of freeze-thaw action and or seepage of water to the subgrade which may weaken the subgrade.

5.4 CHECKLIST

Section 1 of this manual gives a general list of things to check for in overseeing a water, sewer, drainage, or street project. The checklist below includes additional points specific to street:

(1) Do the proposed streets fit in with the overall city transportation plan? Will the present streets and intersections near the development be able to handle the increased traffic?

(2) Do the plans and specifications meet those of the MTAS specifications especially sections 02215, 02451, 02452, 02513, 02515, 02528, 02577, and 16550? Is a minimum 29 foot wide roadway used as per section 406?

(3) Do the streets include curb and gutter?

(4) Will there be enough right-of-way for future expansions on collector and arterial streets?

(5) Is adequate drainage provided as per section 5.3.8 of this manual?

(6) Who will be responsible for inspection during construction including review of materials testing?

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