CHAPTER 2

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Appendix 2-A: Design Basis for Wastewater Flow and Loadings

2.1 General Requirements for Collection Systems

2.1.1 Construction Approval

In general, construction of new sewer systems or extensions of existing systems must ensure that the downstream conveyance system and the receiving wastewater treatment plant are either:

a. Capable of adequately conveying or processing the added hydraulic and organic load, or

b. Capable of providing adequate conveyance or treatment facilities on a time schedule acceptable to the Division

2.1.2 Ownership

Sewer systems including pumping stations integral to gravity sewer and low-pressure sewer designs require ownership by a responsible party, such as a public entity, for operation and maintenance.

2.1.3 Design

The design and construction of new sewer systems must achieve total containment of sanitary wastes and exclusion of infiltration and inflow (I/I). This includes installing pipe with watertight joints, watertight connections to manholes, and watertight connections to service laterals or service lateral stubs and trench design that minimizes the potential for migration of water along the trench. However, the new sewer system and appurtenances must be able to convey the wastewater load, including existing I/I, from upstream areas as appropriate.

2.1.4 Overflows

The Division of Water Resources (Division) will not permit overflows in separate sanitary sewers or new overflows in existing combined sewers. The Division will not permit overflows in new interceptor sewers intercepting existing combined sewers. An alarm system to signal existing overflow conditions and procedures for reporting overflows may be required.

2.1.5 Calculations

The Division requires the submittal of all computations and other data used for design of the sewer system.

2.2 Design Considerations

2.2.1 Design Period

2.2.1.1 Collection sewers (Laterals and Submains)

The Division requires collection sewers for the ultimate development of the tributary areas.

2.2.1.2 Main, Trunk, and Interceptor Sewers

The Division requires certain design factors for trunk sewers:

a. Possible solids deposition, odor, and pipe corrosion that might occur at initial flows
b. Population and economic growth projections and the accuracy of the projections
c. Comparative costs of staged construction alternatives
d. Effect of sewer sizing on land use and development

2.2.2 Basis of Design

The Division's design requirements for new sewer systems are on the basis of per capita flows or alternative methods.

2.2.2.1 Per Capita Flow

The Division requires the use of Appendix 2-A. Substitutions or additions to the information presented in this table are acceptable if better or more accurate data is available.

The Division requires the following:

a. Lateral and Submains: Minimum peak design flow should be not less than 400 percent of the average design flow.

   "Lateral" - a sewer that has no other common sewers discharging into it.

   "Submain" is defined as a sewer that receives flow from one or more lateral sewers.

b. Main, Trunk, and Interceptor sewers: Minimum peak design flow should be not less 250 percent of the average design flow.

   "Main" or "trunk" is defined as a sewer that receives flow from one or more submains.

   "Interceptor" - a sewer that receives flow from a number of main or trunk sewers, force mains, etc.

2.2.2.2 Alternative Methods

The Division allows alternative methods other than on the basis of per capita flow rates. Alternative methods may include the use of peaking factors of the contributing area, allowances for future commercial and industrial areas, separation of infiltration and inflow from the normal sanitary flow (for new sewers serving existing upstream sewers), and modification of per capita flow rates (based on specific data). There should be no allowance for infiltration or inflow into newly constructed or proposed sewers.

2.2.3 Design Factors

The Division requires consideration of the following factors:

a. Peak wastewater flows from residential, commercial, institutional, and industrial sources
b. Potential for groundwater infiltration from existing upstream sewers
c. Topography and depth of excavation
d. Treatment plant location
e. Soils conditions
f. Pumping requirements
g. Maintenance, including manpower and budget
h. Existing sewers
i. Existing and future surface improvements
j. Controlling service connection elevations
k. Proximity to surface streams, including minimizing the potential for draining or diversion of stream water into the pipe trench
l. Watertight and exclude groundwater and surface water.

2.3 Design and Construction Details

2.3.1 Gravity Sewers

The Division requires gravity sewers to be approximately one-half full when conveying the anticipated peak daily dry weather flow and does not surcharge when conveying the anticipated peak wet weather flow.

2.3.1.1 Minimum Size

The minimum size of new public sewers should be 8 inches (nominal) in diameter.

2.3.1.2 Depth

Generally, sewers should not be less than 2 ½ feet deep but should be sufficiently deep to prevent freezing and physical damage.

2.3.1.3 Roughness Coefficient

The Division requires that a roughness coefficient "n" value of 0.013 be used in Manning's formula for the design of all sewer facilities unless a roughness coefficient specific to the given pipe material is available. The roughness coefficient selected must consider the long-term condition of the sewer. However, the Division requires an "n" value equal to or greater than 0.011.

2.3.1.4 Slope

Sewers must be self-cleansing and capable of transporting most solids to the desired point, usually a treatment facility. Two methods are approved for design in the State of Tennessee: 1) Tractive Force and 2) Traditional (Ten-State Standards). For reasons of economical design and long-term maintenance, the Division prefers the Tractive Force Method.

Tractive Force Method:

ASCE and WEF (WEF Manual of Practice No. FD-5 *Gravity Sanitary Sewer Design and Construction*, 2007, Section 5.6) now advocates a transition to the tractive force approach for self-cleansing design. "Tractive Force (TF) design is a major improvement over traditional methods to achieve self-cleansing in gravity sewers. This approach results in a self-cleansing pipe slope value (S_{min}) for the design minimum flow rate (Q_{min}) in each sewer reach. Q_{min} is the predicted largest 1-hour flow rate in the reach during the lowest flow week over the sewer design life. Past design practices seldom included accurate estimation of Q_{min} values, but good estimates of Q_{min} are crucial for TF design. The engineer should show in the engineering report the calculations for Q_{min} for new sewer pipe projects. As compared to traditional minimum slopes, S_{min} slopes via the TF method are flatter for sewers carrying typical to larger Q_{min} values and steeper for sewers carrying smaller Q_{min} values." (Merritt, LaVere B., *Tractive Force Design for Sanitary Sewer Self-Cleansing*, ASCE, May 2009)

Once a good estimate has been developed for Q_{min}, then Table 2-1 (WEF, 2007, Table 5.5, page 148) for calculating minimum slopes for a typical condition in sewers is provided to assist designers with applying TF principles.

Table 2-1 Tractive Force Equations for Minimum Slope

Sewer Size (inches)	When n is Variable* value of S_{min} = (Q in cfs)
8	$0.000848\ Q_{min}^{-0.5707}$
10	$0.000887\ Q_{min}^{-0.5721}$
12	$0.000921\ Q_{min}^{-0.5731}$
15	$0.000966\ Q_{min}^{-0.5744}$
18	$0.001004\ Q_{min}^{-0.5754}$
21	$0.001038\ Q_{min}^{-0.5761}$
24	$0.001069\ Q_{min}^{-0.5768}$
27	$0.001097\ Q_{min}^{-0.5774}$
30	$0.001123\ Q_{min}^{-0.5778}$
36	$0.001169\ Q_{min}^{-0.5787}$
42	$0.001212\ Q_{min}^{-0.5812}$

3Based on Darcy-Weisbach

Traditional Method:

The Traditional Method for conventional gravity sewers requires mean velocities, when flowing full, of not less than 2.0 feet per second. Table 2-2 provides minimum slopes when using the traditional method; however, slopes greater than these are desirable.

Table 2-2 Minimum Slope from Traditional Method

Sewer Size (inches)	Minimum Slope***** (feet per 100 feet)
8	0.40
10	0.28
12	0.22
15	0.15
18	0.12
21	0.10
24	0.08
27	0.067
30	0.058
36	0.05 **
42	0.042***

* Great Lakes Upper Mississippi River Board, 1997.

** Recommended steeper – to give velocity of 2.1 ft/sec (WEF, 2007)

*** Recommended steeper – to give velocity of 2.3 ft/sec (WEF, 2007)

Under special condition, the using the Traditional Method, the Division may allow slopes slightly less than those required for the 2.0 feet-per-second velocity when flowing full may be permitted. Such decreased slopes will only be considered where the depth of flow will be 0.3 of the diameter or greater for design average flow. Whenever such decreased slopes are proposed, the design engineer should furnish with his report his computations of the depths of flow in such pipes at minimum, average, and daily or hourly rates of flow. The maintaining wastewater agency must recognize and accept in writing the problems of additional maintenance caused by decreased slopes.

Uniform slope between manholes is required.

A minimum of 5 feet of horizontal separation between gas mains is required.

Anchors are required for sewers on 20 percent slope or greater. Secure anchors will have a minimum two-foot thick tightly compacted clay collar or equal. Suggested minimum anchorage spacing is as follows:

a. Not over 36 feet center to center on grades 20 percent and up to 35 percent.

b. Not over 24 feet center to center on grades 35 percent and up to 50 percent.

c. Not over 16 feet center to center on grades 50 percent and over.

2.3.1.5 Alignment

Straight alignment between manholes is required for gravity sewers. However, curved sewers may be approved where circumstances warrant but only in large (i.e., 24" and larger) diameter segments.

2.3.1.6 Increasing Size

When a smaller sewer joins a larger one, the Division requires the alignment to maintain the same energy gradient. An approximate method for securing these results is to match the crowns of the sewers entering/ exiting the manhole or junction structure.

2.3.1.7 High-Velocity Protection

Where velocities greater than 15 feet per second are expected, the Division requires protective measures against internal erosion or displacement by shock.

2.3.2 Materials

The Division will consider any generally accepted material for sewers. The material selected should be adapted to local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, abrasion and similar problems. The Division requires careful consider of pipes and compression joint materials subjected to corrosive or solvent wastes. Chemical/stress failure and stability in the presence of common household chemicals such as cooking oils, detergents and drain cleaners are factors.

The specifications should stipulate need to keep clean the pipe interior, sealing surfaces, fittings and other accessories. Pipe bundles should be stored on flat surfaces with uniform support. The protection of stored pipe is required. Pipe with prolonged exposure (six months or more) to sunlight requires a suitable covering (canvas or other opaque material). The Division requires care be given to gaskets. Ensure that gasket not be exposed to oil, grease, ozone (produced by electric motors), excessive heat and direct sunlight. Consult with the manufacturers for specific storage and handling recommendations.

2.3.2.1 Rigid Pipe

Rigid pipe includes, but is not be limited to, concrete pipe. Any rigid pipe should have a minimum crushing strength of 2000 pounds per lineal foot. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.2 Semi-rigid Pipe

Semi-rigid pipe includes, but is not be limited to, ductile iron. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.3 Flexible Pipe

Flexible pipe includes, but is not be limited to, ABS solid wall pipe, polyvinyl chloride pipe (PVC), polyethylene pipe (PE), fiberglass composite pipe, reinforced plastic mortar pipe (RPM) and reinforced thermosetting resin pipe (RTR). PVC pipe should have a minimum Standard Dimension Ratio (SDR) of 35. The Division requires that all other flexible pipe have the same calculated minimum deflection under identical conditions as the SDR 35 PVC pipe.

To calculate the flexible pipe deflection under earth loading use the formula presented in the ASCE/WPCF publication, Design and Construction of Sanitary and Storm Sewers.

All pipes should meet appropriate ASTM and/or ANSI specifications. ASTM D-3033 and D-3034 PVC pipes differ in wall thickness and have non-interchangeable fittings.

2.3.3 Pipe Bedding and Backfilling

The Division requires that all sewers designs provide protection from damage from superimposed loads. The width and depth of the trench require allowances be made for loads on the sewer. Backfill material up to three feet above the top of the pipe should not exceed 6 inches in diameter at its greater dimension.

The Division requires ductile iron pipe in roadways where cover is less than 4 feet. In such cases, a minimum cover of six inches is required.

The Division requires ductile iron pipe or relocation when the top of the sewer is less than 18 inches below the bottom of a culvert or conduit.

2.3.3.1 Rigid Pipe

Bedding Classes A, B, or C as described in ASTM C-12 or WPCF MOP No. 9 (ASCE MOP No. 37) should be used for all rigid pipe, provided the proper strength pipe is used with the specified bedding to support the anticipated load. The Division requires the use of ASTM-C-12 (placement of bedding and backfill).

2.3.3.2 Semi-Rigid Pipe

The Division requires the use of Bedding Classes I, II, III, or IV (ML and CL only) as described in ASTM D-2321 for all semi-rigid pipe provided with the specified bedding to support the anticipated load.

The Division requires ASTM-A-746 be used to install ductile iron pipe.

2.3.3.3 Flexible Pipe

The Division requires the use of Bedding Classes I, II, or III as described in ASTM D-2321 for all flexible pipe. The Division requires the proper strength pipe with the specified bedding to support the anticipated load.

The Division requires ASTM-D-2321 for bedding, haunching, initial backfill, and backfill.

The Division requires Class I bedding material for bedding, haunching, and initial backfill as described in 2.3.3.4. (polyethylene pipe).

2.3.3.4 Alternate Bedding Option

The Division will allow all sewers bedded and backfilled with a minimum of 12 inches of Class I material over the top and below the invert of the pipe--an alternative to sub-sections 2.3.3.1, 2.3.3.2 and 2.3.3.3.

2.3.3.5 Deflection Testing

The Division requires deflection testing of all flexible pipes. The Division requires backfill testing after it has been in place at least 24 hours.

No pipe should exceed a deflection of 5%.

The test should be run with a rigid ball or an engineer approved 9-arm mandrel having a diameter equal to 95% of the inside diameter of the pipe. The test requires manually pulling the test device through the line.

2.3.4 Joints

The Division requires the specification to include the method of making joints and the materials used. The Division requires that sewer joints eliminate infiltration and prevent the entrance of roots.

Elastomeric gaskets, other types of pre-molded (factory made) joints, and ABS solvent-cement welded joints are required. The Division requires the use of ASTM-F2620 for butt fusion joining technique with polyethylene pipe. The Division requires the removal of internal beads for butt fusion joints on pipelines with slopes less than one percent. Cement mortar joints are not acceptable. Field solvent welds for PVC and PE pipe and fittings are not acceptable.

2.3.5 Leakage Testing

The Division requires the use of ASTM-C-828 for low-pressure air testing for all pipes. The time required for the pressure to drop from the stabilized 3.5 psig to 2.5 psig should be greater than or equal to the minimum calculated test time (the Division requires that air loss rate be part of the test criteria).
The testing method should take into consideration the range in groundwater elevations projected and the situation during the test. The height of the groundwater should be measured from the top of the invert (one foot of H_20 = 0.433 psi).

Table 2-3 provides the minimum test times and allowable air loss values for various pipe size per 100 ft.

Table 2-3 Leakage Test Parameters

Pipe Size (inches)	**Time**, T (sec/100 ft)	**Allowable Air Loss**, Q (ft^3/min)
6	42	2.0
8	72	2.0
10	90	2.5
12	108	3.0
15	126	4.0
18	144	5.0
21	180	5.5
24	216	6.0
27	252	6.5
30	288	7.0

2.3.6 Visual Inspection

The Division requires that new sewers be video inspected to confirm proper installation and to provide a visual record of the condition of the newly constructed sewer for future reference.

2.3.7 Low Pressure Systems

2.3.7.1 Application

The Division requires the consideration of low-pressure systems for situations in which gravity sewers are extremely costly or impractical, such as rock or high groundwater table.

2.3.7.2 Grinder Pumps

The Division requires all the collection and transport of raw wastewater from individual buildings/dwellings to the pressure system by appropriately sized grinder pumps.

Grinder pumps do not require a septic tank.

All pumps should have operating curves that do not allow backflow under maximum head conditions.

Pumps should be watertight and located above the seasonal groundwater table were possible where possible.

2.3.7.3 Septic Tank Effluent Pump (STEP) system

All STEP installations require careful attention to the following design details and construction techniques:

a. All STEPs preceded by a watertight septic tank. Retrofitting a STEP to an existing septic tank will require a visual inspection of the tank.

   Replacement of all defective septic tanks.

b. STEPs retrofitted to an existing septic tank and drain field must provide a positive means of preventing groundwater from backing up through the drain field to the STEP.

c. The STEP should be located as close as possible to the septic tank.

d. Electrical power supplied through the main circuit box. Electricity furnished to a separate circuit box installed on the exterior wall of the building, near the STEP.

2.3.7.4 Hydraulic

Hydraulic calculations are of extreme importance. Head losses within the low-pressure system will change with each pump activation.

2.3.7.5 Minimum Velocity

The recommended minimum operating velocity in a pressure system should be 2 feet per second (fps).

2.3.7.6 Flushing

There should be a means of cleaning the system, particularly to clear any settleable solids or grease accumulation.

2.3.7.7 Pressure Testing

There should be means for isolating and pressurizing sections of the system to detect and locate leaks.

2.3.7.8 Alarms

There should be an external visual warning system to indicate the malfunction of the pump. The high-level (in storage tank) warning system should be a dual audio / visual system.

2.3.7.9 Cleanouts

The Division requires cleanouts at a maximum of 400-foot intervals.

2.3.7.10 Ventilation

Ventilation of the pumping station should be provided via house vents where allowable or through a separate system.

2.3.8 Manholes

2.3.8.1 Location

The Division requires manholes at the end of each 8-inch diameter sewer or greater. The Division will waive this requirement if a stub-out is installed (assumes line will be extended in near future).

The Division requires manholes at all changes in grade, size, or alignment; at all intersections; and at distances not greater than 400 feet for sewers 15 inches or less. The Division requires manholes at 500 feet for sewer 18 inches to 30 inches. The Division may allow greater spacing in larger sewers and in those carrying a settled effluent.

2.3.8.2 Drop Connection

The Division requires a drop connection for a sewer entering a manhole at an elevation of 24 inches or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, a filleted invert will prevent solids deposition.

2.3.8.3 Diameter

The minimum diameter of manholes should be 48 inches; larger diameters are preferable. The minimum clear opening in the manhole frame shall meet current OSHA standards.

2.3.8.4 Flow Channels

Flow channels in manholes should be of such shape and slope to provide smooth transition between inlet and outlet sewers and to minimize turbulence. Channeling height should be to the crowns of the sewers. Benches should be sloped from the manhole wall toward the channel to prevent accumulation of solids.

2.3.8.5 Water tightness

The Division requires watertight manhole covers wherever the manhole tops may be flooded. Manholes of brick or segmented block are not appropriate materials for manhole construction where groundwater conditions are unfavorable. In pre-cast concrete manholes, the Division requires plastic gaskets, pre-molded rubber gaskets or flexible, plastic gaskets.

2.3.8.6 Connections

The Division requires special attention be paid to the connection between the manhole wall and the sewer pipe in order to minimize long-term infiltration into the system. The Division requires flexible joints for line connections directly to the manholes, or to short stubs integral with the manholes. Flexible joints are joints that permit the manholes to settle without destroying the watertight integrity of the line connections.

2.3.8.7 Ventilation

The Division requires consideration of ventilation of gravity sewer systems where continuous watertight sections are greater than 1,000 feet in length. Vent height and construction must consider flood conditions.

2.3.8.8 Frames, Covers, and Steps

Frames, covers, and steps, if utilized, should be of suitable material and designed to accommodate prevailing site conditions and to provide for a safe installation.
Materials used for manhole steps should be highly corrosion-resistant. The Division requires aluminum or plastic with reinforcing bar.

2.3.8.9 Vacuum Testing

New manholes should be vacuum tested after construction to verify they will not be new sources of infiltration or inflow. The Division requires the test to include the manhole frame. The Division considers the test acceptable if the vacuum remains at 10 inches of mercury or drops to no less than 9 inches of mercury within one minute. The Division may allow alternative testing methods--if demonstrated to be equal of better than vacuum testing.

2.4 Special Details

2.4.1 Protection of Water Supplies

2.4.1.1 Water Supply Interconnections

There shall be no physical connection between a public or private potable water supply system and a sewer or appurtenance thereto.

2.4.1.2 Relation to Water Mains

Horizontal Separation: Whenever possible, the Division requires at least 10 feet horizontal separation of the sewer from any existing or proposed water main. Should local conditions prevent a lateral separation of 10 feet, the Division may allow the sewer closer than 10 feet to a water main if in a separate trench and if the elevation of the top (crown) of the sewer is at least 18 inches below the bottom (invert) of the water main.

Vertical Separation: Whenever sewers must cross under water mains, the Division requires the sewer at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main. The Division will consider other alternatives if the sewer evaluation cannot be varied.

When it is impossible to obtain proper horizontal and vertical separation as stipulated above, the sewer should be designed and constructed equal to the water main pipe and should be pressure-tested to assure water-tightness (see drinking water criteria) or the joints of the sewer pipe should be encased in concrete to inhibit infiltration/exfiltration. Details of the encasement should be clear and extend the necessary distance to achieve design goals. The designer should consider the temperature differential between the pipe and the surrounding materials in their determination if reinforcement is necessary. Such arrangements are discouraged.

The Division requires the designer's evaluation, calculations, and conclusions in the project record and provided to all interested parties upon request.

2.4.2 Backflow Preventers

State approved reduced pressure backflow prevention devices are required on all potable water mains serving the wastewater treatment plant or pumping station. The Division can provide a list of approved backflow preventers.

2.4.3 Sewers in Relation to Streams

2.4.3.1 Site Characterizations for Sewers in Proximity to Streams

For new sewers or existing sewers replaced in the same trench that cross or have an alignment within 50 feet of the bank of a surface stream, upon notification of the potential route of the proposed sewer, the Division will perform a site characterization to determine the potential for stream capture. (See Section 1.2.4.1 of Chapter 1) If the Division determines there is potential for stream capture, a site-specific Aquatic Resource Alteration Permit (ARAP) is required, and obtaining this permit will require the design engineer to provide a plan to prevent stream capture. This may require additional study of the characteristics of the stream, including soil classification data, rock depth (if present), recommendations for controlling seepage, cut and fill recommendations, a trench dewatering plan, and other site specific data.

2.4.3.2 Location of Sewers in Streams

Open trench sewers located along streams should be located outside of the streambed and sufficiently removed there from to minimize disturbance or root damage to streamside trees and vegetation.

Sewer outfalls, headwalls, manholes, gate boxes or other structures should be located so they do not interfere with the free discharge of flood flows of the stream.

The Division requires open trench sewer crossings of streams to cross the stream as nearly perpendicular to the stream flow as possible and be free from change in grade.

2.4.3.3 Construction

Sewers entering or crossing streams should be ductile iron pipe from manhole to manhole, wrapped in plastic and encased in high strength flowable fill. (Note: This provision is subject to a case-by-case review. In this case, the Division requires an impermeable barrier that might be flowable fill, concrete, liners, casing pipe or a combination. The best practice may be different depending upon stream flow, local soils, topography and geology).

The sewer should be free of alignment or grade changes. The Division requires sewer systems designs to minimize the number of stream crossings. The Division requires the stream returned as nearly as possible to its original condition upon completion of construction. The Division requires the stream banks to be seeded or other erosion prevention methods employed to prevent erosion. Stream banks should be sodded, if necessary, to prevent erosion. The consulting engineer should specify the method or methods in the construction of the sewers in or near the stream to control siltation.

With regard to prohibitions on the contractor, the Division requires that the specifications contain the following clauses:

- unnecessarily disturbing or uprooting trees and vegetation along the stream bank and in the vicinity of the stream,
- dumping of soil and debris into streams and/or on banks of streams,
- changing course of the stream without encroachment permit,
- leaving cofferdams in streams,
- leaving temporary stream crossings for equipment,
- operating equipment in the stream, or
- pumping silt-laden water into the stream.

The Division requires provisions in the specifications to:

- retard the rate of runoff from the construction site,
- control disposal of runoff,
- liberal use of silt fencing to trap sediment resulting from construction in temporary or permanent silt-holding basins,
- pump discharges resulting from dewatering operations;
- deposit out of the flood plain area all material and debris removed from the streambed.

Specifications should require that cleanup, grading, seeding, planting or restoration of the work area should be carried out as early as practical as the construction proceeds. The Division requires the specifications mandate a trench-dewatering plan for new sewer alignments that cross a stream or are within 50 feet of the bank of the stream defined in Section 1.2.4.1.

2.4.3.4 Special Construction Requirements

The Division requires the employment of special design requirements to prevent stream drainage from sinking at the crossing and following along the sewer pipe bedding. The Division requires an in trench impounding structure of compacted clay or concrete check dams. The Division will consider other proposals.

2.4.3.5 Aerial Crossings

The Division may allow sewers that lay on piers across ravines or streams if no other practical alternative exists or, in the design engineer’s judgment, other methods will not be as reliable.

The Division requires support for all joints. All supports designs must prevent frost heave, overturning or settlement. The Division requires precautions against freezing, such as insulation or increased slope and expansion joints between aboveground and belowground sewers. The Division requires deigns to consider the impact of floodwaters and debris. The design should consider maintenance of an adequate waterway for the 100-year flood flows. The design engineer should analyze the impact of the proposed aerial crossing(s) on flooding, including hydraulic modeling, such as Hydrologic Engineering Center-River Analysis System (HEC-RAS) modeling, as necessary.

2.4.3.6 Permits

It is the owner's responsibility to obtain all necessary permits along streams or rivers; i.e., Corps of Engineers, TVA, or the Natural Resources Section of the Division of Water Resources.

2.4.4 Inverted Siphons

Under normal conditions, the Division will not allow inverted siphons. However, if they are, the Division requires that the following:

- Minimum of two barrels,
- Minimum pipe size of six inches--provided with necessary appurtenances for convenient flushing and maintenance,
- Manholes with adequate clearances for rodding,
- Sufficient head and pipe sizes to secure velocities of at least 3.0 feet per second for average flows,
- Inlet and outlet details arranged so that the normal flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning,
- Design engineer furnishes hydraulic calculations with the plans,
- Proper access maintained.

2.5 General Requirements for Wastewater Pumping Stations

2.5.1 Location and Flood Protection

The Division requires wastewater pumping stations located as far as practicable from present or proposed built-up residential areas, with an all-weather road and noise control, odor control, and station architectural design taken into consideration. Sites for stations should be of sufficient size for future expansion or addition, if applicable. The Division requires security for the pumping station and controls.

The Division requires protection from the 100-year flood for the station's operational components.

Where the wet well is at a depth greater than the water table elevation, special provisions should be made to ensure watertight construction of the wet well. The Division requires connections to the pumping station at an elevation higher than the maximum water table elevation, where possible.

2.5.2 Pumping Rate and Number of Units

At least two pump units should be provided, each capable of handling the expected maximum flow. The Division requires the submittal of pump head and system head curves.

For three or more units the Division requires a design to fit actual flow conditions and must be of such capacity that, with any one unit out of services, the remaining units will have capacity to handle the maximum wastewater flow.

A station expected to operate at a flow rate less than one-half the average design flow for an extended period may create septic conditions due to long holding times in the wet well. The design should consider the need for additional measures to prevent the formation of odors.

The design should the use of variable-speed or multiple staged pumps, particularly when the pumping station delivers flow directly to a treatment plant. The design allows delivery of the wastewater at approximately the same rate as received at the pumping station.

2.5.3 Grit and Clogging Protection

Where it may be necessary to pump wastewater prior to grit removal, the design of the wet well should receive special attention, and the design of the discharge piping should be to prevent grit settling in pump discharge lines of pumps not operating.

Design of the pumping station should consider the protection of the pump from damage caused by grit and debris, where warranted. To accomplish this--maintain minimum pump operational speeds, through the installation of bar screens with a grinder or comminutor, or similar devices. For the larger or deeper stations, duplicate protection units, each sized at full capacity, are preferred.

2.5.4 Pumping Units

2.5.4.1 Pump Openings

The Division requires pumps be capable of passing a 3-inch compressible solid. The Division requires pump suction and discharge openings to be at least 4 inches in diameter unless it is a pump with chopping or grinding capabilities.

2.5.4.2 Priming

The Division requires the placement of pumps so that under normal operating conditions they will operate under a positive suction head (except for suction lift pumps).

2.5.4.3 Intake

Each pump should have an individual intake. Wet well design should be such as to avoid turbulence near the intake.

2.5.4.4 Controls

The location of controls should ensure that the flows entering the wet well to not affect them, by the suction of the pumps, or by proximity to wet well walls. Controls must be able to activate additional pumps if the water in the wet well continues to rise. Controls can be float switches, air-operated pneumatic, radar, ultrasonic or capacitance probe types. Provisions should be made to automatically alternate the pumps in use. Pumping stations with motors and/or controls below grade should be equipped with a secure external disconnect switch. The Division requires consideration of an “intrinsically safe” power source if float switches are used.

The Division requires consideration of redundant controls and/or remote monitoring to assist in preventing overflows.

2.5.5 Flow Measurement

At pumping stations with flow capacity greater than 0.5 million gallons per day (mgd), the Division recommends providing suitable devices for measuring flow.

2.5.6 Alarm System

The Division recommends an alarm system for all pumping stations such as, telemetry alarm to 24-hour monitoring stations or telephone alarms to duty personnel (when reliability classification or property damage warrants it). The Division requires an audiovisual device at the station for external observation when telemetry is not used.

The Division requires alarms for high wet well and power failure, as a minimum, for all pumping stations. For larger stations, the Division requires alarms signalizing pump and other component failures or malfunctions.

The Division requires a backup power supply, such as a battery pack with an automatic switchover feature, for the alarm system, such that a failure of the primary power source will not disable the alarm system. The alarm system must be tested and verified that it is in good working order.

2.5.7 Overflows and/or Bypasses

Pumping stations should be designed and built without any type of overflow or bypass structure.

2.6 Special Details

2.6.1 General

2.6.1.1 Materials

Materials must not contain hydrogen sulfide and other corrosive gases, greases, oils, and other constituents frequently present in wastewater. The Division recommends the use of concrete additives or protective coatings to prevent deterioration caused by corrosive gases.

2.6.1.2 Electrical Equipment

Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, and control circuits) in enclosed or partially enclosed spaces where flammable mixtures occasionally may be present (including raw wastewater wet wells) should comply with the National Electrical Code requirements for Class I Division 1 locations.

2.6.1.3 Water Supply

There should be no physical connection between any potable water supply and a wastewater pumping station that under any conditions might cause contamination of the potable water supply. A potable water supply must comply with conditions stipulated in section 2.4.2.

2.6.1.4 Lighting

Adequate lighting is required for the entire pumping station.

2.6.1.5 Pump and Motor Removal

The Division requires the removal of pumps, motors, and other equipment, without interruption of system service.

2.6.1.6 Safety

The Division requires suitable and safe means of access to equipment requiring inspection or maintenance and that stairways and ladders satisfy all OSHA requirements.

2.6.1.7 Valves and Piping

The Division requires suitable shutoff valves on suction and discharge lines of each pump for normal pump isolation and a check valve on each discharge line between the shutoff valve and the pump. Pump suction and discharge piping should not be less than 4 inches in diameter except where design of special equipment allows. The velocity in the suction line should not exceed 6 feet per second and, in the discharge piping, 8 feet per second. A separate shutoff valve is desirable on the common line leaving the pumping station.

2.6.1.8 Ventilation

The Division requires ventilation for all pumping stations during all periods when the station is manned. Portable ventilation equipment is acceptable for small pumping stations. Mechanical ventilation is required if screens or mechanical equipment, which might require periodic maintenance and inspection, are located in the wet well. In pits over 15 feet deep, multiple inlets and outlets are desirable. The Division requires that dampers not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts should be avoided to prevent clogging.

2.6.2 Wet Well - Dry Well Stations

2.6.2.1 Separation

The Division requires complete separation of wet and dry wells, including their superstructures.

The Division recommends dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning where continuity of pumping station operation is necessary.

2.6.2.2 Wet Well Size and Design

Provide an evaluation of the effective capacity of the wet well based on pumping requirements and reliability classifications.

Wet well design should consider approaches for minimizing solids deposition.

2.6.2.3 Dry Well Dewatering

The Division requires a separate sump pump in the dry wells to remove leakage or drainage with the discharge above the high water level of the wet well. The Division will not approve water ejectors connected to a potable water supply. All floor and walkway surfaces should have an adequate slope to a point of drainage.

2.6.3 Suction Lift Stations

2.6.3.1 Priming

Conventional suction-lift pumps should be of the self-priming type, as demonstrated by a reliable record of satisfactory operation. The maximum recommended lift for a suction lift pumping station is 15 feet, using pumps of 200 gallons per minute (gpm) capacity or less.

2.6.3.2 Capacity

The capacity of suction lift pumping stations should be limited by the net positive suction head and specific speed requirements, as stated on the manufacturer's pump curve, for the most severe operating conditions.

2.6.3.3 Air Relief

a. Air Relief Lines
An air relief line on the pump discharge piping is required for all suction lift pumps. This line should be located at the maximum elevation between the pump discharge flange and the discharge check valve to ensure the maximum bleed-off of entrapped air. The air relief line should terminate in the wet well or suitable sump and be open to the atmosphere.

b. Air Relief Valves
The Division requires air relief valves in air relief lines on pumps not discharging to gravity sewer collection systems. The air relief valve should be located as close as practical to the discharge side of the pump.

2.6.3.4 Pump Location

For standard designs, suction lift pumps are mounted on the wet well but not within the wet well.

2.6.3.5 Access to Wet Well

Access to the wet well should not be through the dry well, and the dry well should have a gastight seal when mounted directly above the wet well.

2.6.4 Submersible Pumps

2.6.4.1 Pump Removal

Submersible pumps should be readily removable and replaceable without dewatering the wet well or requiring personnel to enter the wet well.

The Division recommends a hoist or crane system for removing the pumps from the wet well either through a permanent installation at the site or a mobile system that could be utilized at multiple sites.

2.6.4.2 Controls

The control panel should be located outside the wet well and suitably protected from weather, humidity, vandalism, and gases migrating from the wet well.

2.6.4.3 Valves

The Division recommends all control valves on the discharge line for each pump in a convenient location outside the wet well in separate pits and protected from weather and vandalism.

2.6.4.4 Submergence

Positive provision, such as backup controls, is required to assure submergence of the pumping units.

2.6.5 Grinder and Effluent Pumps

The requirements for grinder pumps are included in Section 2.3.6.

2.7 Operability and Reliability

2.7.1 Objective

The objective of reliability is to prevent the discharge of raw or partially treated wastewater to any waters and to protect public health by preventing backup of wastewater and subsequent discharge to basements, streets, and other public and private property.

2.7.2 Backup Units

A minimum of two pumps or pneumatic ejectors are required in each station in accordance with section 2.5.2.

2.7.3 Power Outages

An emergency power source or auxiliary power is required for all pumping stations larger than 1 MGD to ensure continuous operability unless experience has shown the frequency and duration of outages to be low and the pumping station and/or sewers provide storage sufficient for expected interruptions in power service.

2.7.4 Emergency Power Supply (for Treatment Plants as well as Pumping stations)

2.7.4.1 General

The Division requires provision of an emergency power supply for pumping stations (and treatment plants) to at least two independent public utility sources, or by provision of portable or in-place internal combustion engine equipment that will generate electrical or mechanical energy, or by the provision of portable pumping equipment. Emergency power must be provided for all stations which are 1 MGD or larger, or as determined by the reliability classification.

Emergency power should be provided that, alone or combined with storage, will prevent overflows from occurring during any power outage that is equal to the maximum outage in the immediate area during the last 10 years. If available data were less than 10 years, an evaluation of a similar area served by the power utility for 10 years would be appropriate.

2.7.4.2 In -Place Equipment

The utilization of in-place internal combustion equipment requires the following guidelines:

a. Placement: bolted in place. Facilities for unit removal for purposes of major repair or routine maintenance.
b. Controls: automatic and manual startup and cut-in.
c. Size: adequate to provide power for lighting and ventilation systems and such further systems that affect capability and safety as well as the pumps.
d. Engine Location: located above grade, with suitable and adequate ventilation of exhaust gases.
e. Underground Fuel Storage Tank: design and construction must conform to the applicable requirements of Federal Regulations 40 CFR 280 and 281. Contact the Tennessee Division of Superfund, Underground Storage Tank Program, for guidance.

2.7.4.3 Portable Equipment

The utilization of portable equipment requires the following guidelines:

Pumping units have connections to operate between the wet well and the discharge side of station and the station provided with permanent fixtures that will facilitate rapid and easy connection of lines.

2.7.5 Storage

The Division requires wet well and tributary main capacity above the high-level alarm sufficient to hold the peak flow expected during the maximum power outage duration during the last 10 years.

2.8 Force Mains

2.8.1 Size

Minimum size force mains required to be not less than 4 inches in diameter, except for grinder pumps or septic tank effluent applications

2.8.2 Velocity

At pumping capacity, a minimum self-scouring velocity of 3 feet per second (fps) should be maintained unless flushing facilities are provided. Velocity should not exceed 8 fps.

2.8.3 Air/Vacuum Relief Valve

An air relief valve is required at the necessary high points in the force main to relieve air locking. Vacuum relief values may be necessary to relieve negative pressures on force mains to protect against pipe collapse.

2.8.4 Termination

The force main should enter the receiving manhole with its centerline horizontal and with an invert elevation that will ensure a smooth flow transition to the gravity flow section; but in no case should the force main enter the gravity sewer system at a point more than 1 foot above the flow line of the receiving manhole. The design should minimize turbulence at the point of discharge.

The Division requires the use of inert materials or protective coatings for the receiving manhole to prevent deterioration because of hydrogen sulfide or other chemicals where such chemicals are present or suspected to be present because of industrial discharges or long force mains.

2.8.5 Materials of Construction

The pipe material should be adapted to local conditions, such as character of industrial wastes, soil characteristics, exceptionally heavy external loadings, internal erosion, corrosion, and similar problems.

Installation specification should contain appropriate requirements based on the criteria, standards, and requirements established by the industry in its technical publications. Requirements should be set forth in the specifications for the pipe and methods of bedding and backfilling thereof so as not to damage the pipe or its joints, impede cleaning operations, not create excessive side fill pressures or ovality of the pipe, nor seriously impair flow capacity.

The Division requires that the design of all pipes prevent damage from superimposed loads. Proper design allowance for loads on the pipe because of the width and depth of trench is required.

2.8.6 Pressure Tests

The Division requires testing, before backfilling, of all force mains at a minimum pressure of at least 50 percent above the design operating pressure for at least 30 minutes. Leakage should not exceed the amount given by the following formula:

$$\mathbf{L = ND\ (P)}^{.5}/7{,}400$$

Where **L** is allowable leakage in gallons per hour
N is the number of pipe joints
D is the pipe diameter in inches
P is the test pressure in psi

2.8.7 Anchorage

The Division requires sufficient anchorage of force mains within the pumping station and throughout the line length to include, thrust blocks, restrained joints, and/or tie rods.

2.8.8 Friction Losses

The Division requires the use of a C factor that will take into consideration the conditions of the force main at its design usage. For example, a grease-coated pipe after several years will not have the same C factor as a new pipe.

2.8.9 Water Hammer

The force main design should investigate the potential for the existence of water hammer.

2.8.10 Isolation and Valving

The Division recommends the installation of isolation valves at strategic locations along the force main to facilitate maintenance of the system.

APPENDIX 2-A

Design Basis for Wastewater Flow and Loadings

Table 2-A.1. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Airport	Passenger	2 - 4	3
Apartment House	Person	40 - 80	50
Automobile Service Station	Vehicle served	8 - 15	12
	Employee	9 - 15	13
Bar	Customer	1 - 5	3
	Employee	10 - 16	13
Boarding House	Person	25 - 60	40
Department Store	Toilet Room	400 - 600	500
	Employee	8 - 15	10
Hotel	Guest	40 - 60	50
	Employee	8 - 13	10
Industrial Building (Sanitary waste only)	Employee	7 - 16	13
Laundry (self-service)	Machine	450 - 650	550
	Wash	45 - 55	50
Office	Employee	7 - 16	13
Public Lavatory	User	3 - 6	5
Restaurant (with toilet)	Meal	2 - 4	3
Conventional	Customer	8 - 10	9
Short order	Customer	3 - 8	6
Bar/cocktail lounge	Customer	2 - 4	3
Shopping Center	Employee	7 - 13	10
	Parking Space	1 - 3	2
Theater	Seat	2 - 4	3

Table 2-A.2. Typical Wastewater Flow Rates from Institutional Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Assembly Hall	Seat	2 - 4	3
Hospital, Medical	Bed	125 -240	165
	Employee	5 - 15	10
Hospital, Mental	Bed	75 - 140	100
	Employee	5 - 15	10
Prison	Inmate	80 - 150	120
	Employee	5 - 15	10
Rest Home	Resident	50 - 120	90
	Employee	5 - 15	10
School, day-only:			
With cafeteria, gym, showers	Student	15 - 30	25
With cafeteria only	Student	10 - 20	15
Without cafeteria, gym, or showers	Student	5 - 17	11
School, boarding	Student	50 - 100	75

Table 2-A.3. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Apartment, resort	Person	50 - 70	60
Bowling Alley	Alley	150 - 250	200
Cabin, resort	Person	8 - 50	40
Cafeteria	Customer	1 - 3	2
	Employee	8 - 12	10
Camps:			
Pioneer Type	Person	15 - 30	25
Children's, with central toilet/bath	Person	35 - 50	45
Day, with meals	Person	10 - 20	15
Day, without meals	Person	10 - 15	13
Luxury, private bath	Person	75 - 100	90
Trailer Camp	Person	75 - 125	125
Campground-developed	Person	20 - 40	30
Cocktail Lounge	Seat	12 - 25	20
Coffee Shop	Customer	4 - 8	6
	Employee	8 - 12	10
Country Club	Guests on-site	60 - 130	100
	Employee	10 -15	13
Dining Hall	Meal Served	4 - 10	7
Dormitory/bunkhouse	Person	20 - 50	40
Fairground	Visitor	1 - 2	2
Hotel, resort	Person	40 - 60	50
Picnic park, flush toilets	Visitor	5 - 10	8
Store, resort	Customer	1 - 4	3
	Employee	8 - 12	10
Swimming Pool	Customer	5 - 12	10
	Employee	8 - 12	10
Theater	Seat	2 - 4	3
Visitor Center	Visitor	4 - 8	5