

DESIGN CRITERIA FOR SEWAGE WORKS

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FINLASWP.DOC Criteria fo Slow Rate Land Treatment & Urban Water Reuse (State of Georgia Criteria)

Appendices Excel files converted from Lotus 123 files

Design Criteria for Sewage Works

State of Tennessee
Department of Health and Environment
Division of Water Pollution Control

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CHAPTER 1

General Engineering Requirements

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GENERAL ENGINEERING REQUIREMENTS

1.1 General Information

_____1.1.1 Purpose

The purpose of this chapter is to describe the engineering and procedural steps required by the Tennessee Department of Health and Environment from beginning to completion of a sewerage project. These criteria apply to the development of the following facilities:

1.1.1.1 Municipal sewerage systems, subdivisions, trailer parks, apartments, resorts, etc.

1.1.1.2 Publicly or privately owned sewerage systems required to obtain a charter from (certificate of need and convenience) the Tennessee Public Service Commission.

1.1.1.3 Public corporation sewerage systems organized under the General Corporation Act of Tennessee.

1.1.1.4 Public sewerage systems organized under the Federal Housing Authority Title bond.

1.1.1.5 All sewerage systems owned by the State of Tennessee.

1.1.1.6 Industrial waste systems.

1.1.1.7 Industrial sewerage systems.

1.1.1.8 Federally owned systems.

1.1.1.9 Sewerage systems for schools, service stations, shopping centers, truck stops, or motels.

1.1.1.10 Sewerage and industrial waste systems for laundries and car wash facilities.

It should be understood that these criteria may not be sufficiently comprehensive to apply to all waste treatment and disposal problems in the State. The design engineer should rely upon his experience and judgement in supplementing these criteria. Additionally, these criteria may prove too comprehensive (for example, in the treatment of industrial wastes); in either case, the Department will consider variances to the requirements provided the engineer can justify the variances requested.

In an effort to be consistent the following procedures have been established:

- a. Upon receipt of a letter requesting planning limits of a proposed discharge, the Division of Water Pollution Control will investigate the proposed point of discharge and may establish appropriate planning limits. Planning limits do not approve point of discharge the actual plant site will be investigated and the owner and consulting engineer will be informed of the standards in an official letter of site review.
- b. Divisional review of the final engineering report and preliminary plans will commence only after the issuance of the effluent planning limits and the site approval.

Detailed information is found in "Wastewater Discharge Checklist", Appendix 1-A.

1.1.2 Requirements

The technical engineering information must be certified by an engineer licensed to practice within the State of Tennessee, representing the municipality, industry, or owner and submitted to the Department in two parts:

- a. An engineering report and, if the design engineer feels it necessary, preliminary plans. (If preliminary plans are submitted, approval should be obtained before final plans are started.)
- b. Final construction plans and specifications.

In addition, a Preliminary Engineering Conference may be necessary on large or complex treatment plant projects. This will be determined by the Division of Water Pollution Control during or prior to the site visit for planning limits.

Following these steps will reduce the time needed for approval of the project.

The engineers of the Department cannot act as consulting engineers for industries, municipalities, or owners, but assistance will be given insofar as possible in developing a suitable and economical project.

1.1.3 Sewage Treatment Works, General Requirements

1.1.3.1 Plant Location

a. General

The following items shall be considered when selecting a plant site:

- 1) Proximity to residential areas.
- 2) Direction of prevailing winds.
- 3) Necessary routing to provide accessibility by all weather roads.
- 4) Area available for expansion.

- 5) Local zoning requirements.
- 6) Local soil characteristics, geology and topography available to minimize pumping.
- 7) Access to receiving stream.
- 8) Compatibility of treatment process with the present and planned future land use, including noise, potential odors, air quality, and anticipated sludge processing and disposal techniques.

b. Critical Sites

Where a site must be used which is critical with respect to the items in subsection (a), appropriate measures shall be taken to minimize adverse impacts.

c. Flood Protection

The treatment works structures, electrical and mechanical equipment shall be protected from physical damage by the maximum 100 year flood. Treatment works shall remain fully operational during the 25 year flood. This requirement applies to new construction and to existing facilities undergoing major modification. Flood plain regulations of State and Federal agencies shall be considered.

d. Plant Accessibility

All plant facilities shall be accessible by an all weather road.

1.1.3.2 Quality of Effluent

The required degree of wastewater treatment shall be established by reference to applicable effluent criteria issued by the Division of Water Pollution Control for all projects involving new plants, new discharge locations or major upgrades.

1.1.3.3 Design

The goal of the preparers of this Design Criteria is to promote the simplest treatment scheme available that will meet the requirements of the permit while providing maximum ease of operation. While cost comparisons are important, long term operability and reliability should be an overriding influence in developing new sewerage collection and treatment works.

a) Type of Treatment

- 1) As a minimum, the following items shall be considered in the selection of the type of treatment:
 - A) Present and future effluent requirements.

- B) Location and local topography of the plant site.
 - C) The effects of industrial wastes likely to be encountered.
 - D) Ultimate disposal of sludge.
 - E) System capital costs.
 - F) System operating and maintenance costs and basic energy requirements.
 - G) Existing unit process performance and capacity.
 - H) Process complexity governing operating personnel requirements.
 - I) Environmental impact on present and future adjacent land use.
- 2) The plant design shall provide the necessary flexibility to perform satisfactorily within the expected range of waste characteristics and volumes

b. Required Engineering Data for New Process Evaluation

- 1) The policy of the Agency is to encourage rather than obstruct the development of any methods or equipment for treatment of wastewaters. The lack of inclusion in these standards of some types of wastewater treatment processes or equipment should not be construed as precluding their use. The Agency may approve other types of wastewater treatment processes and equipment under the condition that the operational reliability and effectiveness of the process or device shall have been demonstrated with a suitably-sized prototype unit operating at its design load conditions, to the extent required.
- 2) To determine that such new processes and equipment have a reasonable and substantial change of success, the Agency will require the following:
 - A) Monitoring observations, including test results and engineering evaluations, demonstrating the efficiency of such processes.
 - B) Detailed description of the test methods.
 - C) Testing, including appropriately-composited samples, under various ranges of strength and flow rates (including diurnal variations) and waste temperatures over a sufficient length of time to demonstrate performance under climatic and other conditions which may be encountered in the area of the proposed installations.
 - D) Other appropriate information.

- 3) The Agency will require that appropriate testing be conducted and evaluations be made under the supervision of a competent process engineer other than those employed by the manufacturer or developer.

1.2 Engineering Report and Preliminary Plans

_____ 1.2.1 Purpose

Before plans and specifications are prepared for new wastewater facilities or for changes to existing facilities, every owner or an authorized agent shall submit an engineering report to the Department. The purpose of the engineering report is to outline the goals and objectives of the project and to determine whether the proposed project follows the Department's treatment guidelines and satisfies the applicable minimum requirements set by these guidelines. The report should also serve as a comprehensive guide to the municipality in the decision to adopt a project.

1.2.2 Contents

The engineering report shall assemble the basic information, present design criteria and assumptions, evaluate alternative solutions, and offer conclusions and recommendations. The report must be sufficiently complete to facilitate further plans and specifications development.

As a minimum, the engineering report shall include the following information where appropriate:

- 1.2.2.1 Purpose and need for the proposed project.
- 1.2.2.2 Present and design population with the method of determination.
- 1.2.2.3 Nature and extent of the area to be served, including immediate and probable future development.
- 1.2.2.4 Description of the existing collection and/or treatment system, including its condition and problems, renovation and rehabilitation or replacement requirements.
- 1.2.2.5 Present basis of design, including reliable measurements or analysis of flow and wastewater constituents and hydraulic, organic and solids loadings attributed to residential, commercial, and industrial users. (See Chapter 2, Appendix 2-A.)
- 1.2.2.6 Treatment process and schematic flow diagrams giving the plant unit design parameters.
- 1.2.2.7 Solids handling and disposal options and recommendations.
- 1.2.2.8 The 25- and 100-year flood conditions.
- 1.2.2.9 Soil and geologic conditions

Sufficient soils and geologic data shall be submitted with the engineering report (or, if the design engineer feels it to be more appropriate depending upon the project scope, with the plans) to evaluate site conditions for all new or major

upgrades to treatment plants. At a minimum, the following is required:

- a. Soil tests performed sufficient to provide moisture and compaction data for construction.
- b. Borings for representative subsurface conditions. A minimum of 10 feet below the bottom footing grade of major structures is recommended.
- c. Boring logs or schematic drawings indicating changes of soil types and/or refusal depths.
- d. Unsuitable soil conditions must be identified and correction or removal contingencies shall be provided.
- e. Karst features must be noted with an evaluation of surface water drainage.
- f. Where rock is encountered above the bottom footing grade of structures, representative core data shall be provided to 5 feet below grade. Weathered rock conditions shall be indicated along with mud seams or weathered bedding planes.

1.2.2.10 Domestic potable wells within 1000 feet of a plant shall be located along with land use of the surrounding area (residential, agricultural, industrial).

1.2.2.11 Perched water tables shall be noted with construction contingencies provided.

1.2.2.12 An evaluation of alternative solutions and the rationale for recommending the chosen alternative, considering economics of operations and effectiveness.

1.2.2.13 A mass balance must be submitted for all plants. The mass balances must include loadings to each unit process and operation, including all recycle and sidestream flows. Mass balances must include the following initial and design operating conditions: maximum, minimum, and average flow, BOD and suspended solids loadings; and maximum, minimum, and average nutrient loadings, especially nitrogen for plants with considerable industrial loadings where appropriate or where nutrient removal is employed.

The report shall identify and be consistent with all applicable areawide projects, drainage basins, service areas, comprehensive, and metropolitan area plans; e.g. 208, and 303(e) plans.

The design period should be for 20 years unless growth of the area dictated other design parameters.

Preliminary plans can be included with the engineering report. Preliminary plans will be reviewed for adequacy, but will not be approved for construction.

1.2.3 Submission of Engineering Report and Preliminary Plans

The engineering report shall be submitted to the appropriate Division of the Tennessee Department of Health and Environment. The Department will

review and either approve or comment on the report within 30 days. In the event of a delay, the owner will be notified and the reason given. A conference may be scheduled at the owner's or municipality's request after review has been completed.

1.3 Plans and Specifications

_____ 1.3.1 General Content of Final Engineering Plans

All plans and specifications must be in accordance with the approved engineering report, unless modifications are justified based on newly discovered data or problems. If this is the case, a supplement to the engineering report shall be submitted with the plans. All plans for sewerage systems or sewage treatment works shall bear a title showing the name of the municipality, sewer district, institution, or other owner and the seal and signature of the design engineer. The title should show the scale in feet, the north direction, and the date. The cover sheet and all other sheets should bear a general title and be logically numbered. Appropriate subtitles should be included on plan sheets.

The plans should be clear and legible and drawn to a scale which permits all necessary information to be shown plainly. The size of the plans should be approximately 24 inches by 36 inches, and the data used should be indicated. All plans shall include appropriate design data, including, but not limited to initial and design flow. A location map must be included with each set of plans. The cover letter or letter of transmittal should clearly indicate the system and design engineer with addresses.

Detail plans should include plan views, elevations, sections, profiles, and supplementary views. Plans should also specify dimensions and relative elevations of structures, the location and outline form of equipment, location and size of piping, water levels, ground elevations, and erosion control facilities.

1.3.2 Plans of Sewers

The plans shall show the location, size, and direction of flow of all proposed and existing sewers draining to the concerned treatment facility. Hydraulic calculations are required for all lines in the project. All receiving lines must be shown to be adequate for the proposed project. Topography and elevations, both existing and any changes proposed, and all bodies of water (including direction of flow and high water elevations) should be clearly shown. Hydraulic calculations of pumping stations must also be furnished, taking into consideration existing loading plus projected loading from developments under construction as well as projected loading from the proposed extension. Hydraulic and organic loadings of the proposed project shall be examined with respect to the treatment facility and its present treatment capacity.

Profiles for sewer detail should have a horizontal scale of not more than 100 feet to the inch and a vertical scale of not more than 10 feet to the inch. Plan views should be drawn to a corresponding horizontal scale.

Plans and profiles should show:

1.3.2.1 Locations of streets and sewers.

1.3.2.2. Lines of ground surface, pipe type and size, manhole stationing, invert and surface elevation at each manhole, and grade of sewer between adjacent manholes. Manholes should be labeled

on the plan and also on the profile correspondingly. Where there is any question of the sewer being sufficiently deep to serve any residence or other source, the elevation and location of the basement floor or other low point source shall be plotted on the profile of the sewer which is to serve the house or source in question.

- 1.3.2.3 Locations of all special features such as inverted siphons, concrete incasements, elevated sewers, and flow monitoring key manholes.
- 1.3.2.4 Location of all existing structures below and above ground which might interfere with the proposed construction; particularly water mains, gas mains, storm drains, etc.
- 1.3.2.5 Detail drawings of all stream crossings with elevations of the stream bed and of normal and extreme high and low water levels to include 25- and 100- year flood plain. See Section 2.4.3.
- 1.3.2.6 Detail drawings of special sewer joints, cross sections, and appurtenances such as manholes, flush valves, inspection chambers, etc.
- 1.3.2.7 Location of adjacent streams and the extent of streamside vegetation.
- 1.3.2.8 An analysis of existing infiltration/inflow should be submitted (and may be required) where I/I is known to be a problem in the existing sewer, and extensions are proposed.
- 1.3.2.9 General topography including trees within 25 feet of center line of the proposed sewer main.

1.3.3 Plans of Sewage Pumping Stations

Plans must be submitted on all sewage pump stations that serve more than two residences. Any pump station of this size or larger is considered a "sewerage system" by the State of Tennessee and, as such, must be designed and built in conformance with this criteria. Although it is desirable for the station to be owned and maintained by a municipality, public utility or a utility district, private ownership of small stations is permissible. Larger stations (serving more than 50 residences shall be owned by a utility or operate under the terms of a State Operation Permit.

- 1.3.3.1 A general layout plan must be submitted for projects involving construction or substantial modification of pumping stations. The plan should show:
 - a. The location and extent of the tributary area.
 - b. A contour map of the property to be used.
 - c. Any municipal boundaries within the tributary area.
 - d. The location of the pumping station and force main, and pertinent elevations.
 - e. A site plan showing the forms of land use (commercial, residential, and agricultural) existing or proposed for the near future within a 100-foot radius of the pumping

station. Existing buildings and their types within 100 feet of the pumping station property lines should be included.

1.3.3.2 Detail plans must be submitted showing:

- a. The proposed pumping station, including provisions for installation of future pumps or ejectors.
- b. Elevation of known high groundwater at the site and maximum elevation of sewage in the collection system upon occasion of power failure.
- c. Test boring locations and test boring information, including groundwater elevation, if encountered above the bottom of the proposed excavation.
- d. Plan and elevation views of the pump suction (from the wet well), and discharge piping showing all isolation valves and gates.

1.3.4 Plans of Sewage Treatment Plants

1.3.4.1 General

A plan must be submitted showing the sewage treatment plant in relation to the collection system. Sufficient topographic features should be included to indicate the plant's location in relation to streams and the point of discharge of treated effluent. The forms of land use (industrial, commercial, residential, and agricultural) existing or proposed for the near future within a 700-foot radius of the plant site property lines should be indicated.

Existing buildings and their types within 700 feet of the plant site property should be adequately described, by items such as topographic maps, aerial photos, and drawings.

1.3.4.2 Layouts of the proposed sewage treatment plant should be submitted, showing:

- a. Topography of the site.
- b. Size and location of plant structures.
- c. A schematic flow diagram including main and side stream or recycles with unit and pipe sizing through various plant units, in plan view.
- d. A summary of design and initial wasteloads, unit sizes, and design parameters for each unit process, from the engineering report; noting particularly any changes in design assumptions.
- e. Piping, the materials handled and the direction of flow through the pipes, and any arrangements for bypassing individual units.

- f. Minimum, average, and maximum hydraulic profiles showing flow of sewage, supernatant liquor, and sludge.
- g. Test borings and groundwater elevations, if encountered.
- h. Ultimate disposal of sludge.

1.3.4.3 Detail plans must show the following:

- a. Location, dimensions, and elevations of all existing and proposed plant facilities.
- b. Elevation of high-water level of the body of water into which the plant effluent is to be discharged, at the 100-year flood, if known.
- c. Elevation of the low-water level of the body of water into which the plant effluent is to be discharged.
- d. Pertinent data concerning the rated capacity of all pumps, blowers, motors and other mechanical devices. All or part of such data can be included in the specifications if the equipment is identified on the plans.

1.3.5 Specifications

The objective of the specifications is to supplement the plans by describing the intended project in sufficient detail for competitive bidding and construction.

The specifications shall include, but not be limited to, all construction information which is not shown on the drawings and is necessary to inform the builder in detail of the design requirements as to: the quality of materials, workmanship and fabrication of the project, and the type, size, operating characteristics, and rating of equipment; allowable leakage; machinery; valves, piping, and jointing of pipe; electrical apparatus, wiring, and meters; laboratory fixtures and equipment; operating tools; construction materials; special materials such as stone, sand, gravel or slag; miscellaneous appurtenances; instructions for testing materials and equipment as necessary to meet design standards; and operating tests for the completed works and component units.

The specifications and/or plans must contain sufficient information to construct an all-weather access road to all plants, major pump stations and inverted siphons. As a minimum, this road shall be gravel for pump stations and inverted siphons and paved for treatment plants. The road shall be maintained by the owner for the life of the plant, pump station or siphon. Where necessary, the road to the property line of the site should be upgraded to the minimum standard.

All wastewater treatment plants shall be surrounded by a fence. The fence shall be constructed of fabric that is at least six feet high, is of a type that is difficult to climb and shall be topped with at least two strands of barbed wire. The exceptions to this type of fencing are lagoons and land application systems. Such treatment plants can use livestock fence, provided that a sufficient number of signs are attached which contain a warning against trespassing and indicate that the fenced area is used for

treating sewage. Generally, pumping stations shall be fenced similarly to plants with the exception that the entrance tube to "canned" lift stations need not be fenced.

The plans and/or specifications shall indicate what methods are to be taken by the contractor to minimize erosion during the construction period.

1.3.6 Review and Approval Procedure

Every owner or his authorized representative, before installing wastewater or industrial waste facilities, or for changes in the existing system, shall submit no less than three copies of complete plans and specifications of the proposed facilities to the Department. Approval must be obtained before construction can begin. A maximum of four sets of plans will be stamped approved.

If the owner of the project is not the ultimate recipient of the wastewater, the recipient must approve the plans and specifications and must agree to receive wastes and provide treatment, before construction begins.

All plans and specifications shall be prepared under the supervision of a professional engineer. All copies of plans and specifications submitted for review shall bear the seal and signature of the professional engineer, licensed to practice in the State of Tennessee, who supervised their preparation. Each sheet of the plans shall be hand dated with a copy of the seal and signature of the engineer. Only the title sheet and front cover of the specifications are required to be marked with original seal, signature and date.

The Department will review and either approve or comment on the final plans and specifications within 30 days. One copy of plans and specifications will be retained for the record, with the remaining returned to the owner.

The Department requires that one stamped copy of the approved plans and specifications be on the construction site and ready to show to the state inspector. Failure to do so may result in a shut down of construction until an approved copy of the plans is available on site.

_____ 1.3.7 Revisions to Approved Plans

Any deviations from approved plans or specifications affecting capacity, flow, operation of units, or point of discharge shall be approved in writing, before any changes are made. Plans or specifications so revised should, therefore, be submitted well in advance of any construction work which will be affected by such changes to permit sufficient time for review and approval. Minor structural revisions will be permitted during construction with the concurrence of the design engineer. However, "as built" plans clearly showing all alternations shall be submitted to the reviewing agency at the completion of the work.

1.3.8. Construction Supervision

The importance of frequent, comprehensive, and sound inspection of construction cannot be overly emphasized. The owners shall ensure that competent and experienced personnel, preferably the design engineer or his representative, carefully monitor the progress of construction to see that all work conforms to the approved plans and specifications. The owner or his representative shall maintain records of inspection activities, and, based on those records, certify that the project has been constructed as designed and approved. Continuous on-site inspection is recommended.

Any modifications to the plans or specifications during construction must have approval by the Division (Section 1.3.7).

1.3.9 Operation During Construction

In order to minimize damage to the environment from inadequately treated wastewater due to construction activities, all construction shall be performed in accordance with the Policy Statement found at the end of this Chapter in Appendix 1-B.

1.3.10 Final Inspection of Treatment Facilities

The Department must receive a written request for final inspection approval of the treatment facilities at least two weeks in advance of the requested date.

This final inspection will be performed by State personnel accompanied by the engineer and the agent or agents for the entity responsible for the operation and maintenance of the treatment facilities. There should be no discharge from the facility until the final inspection has been completed and final approval given.

Where a plant has been upgraded or modified, individual units may be allowed to operate prior to final inspection in order to facilitate construction. Prior approval to do so must be obtained from the Division of Water Pollution Control (see Section 1.3.9).

1.3.11 Reliability Classification

1.3.11.1 General

Reliability standards establish minimum levels of reliability for three classes of sewerage works. The reliability classification shall be established by the State and will be a major consideration for discussion at the preliminary engineering conference described earlier in this chapter (Section 1.1.2). Pump stations associated with, but physically removed from, the actual treatment works may have a different classification than the treatment works itself. The reliability classification will be based on the water quality and public health consequences of a component or system failure. Specific requirements pertaining to treatment plant unit processes for each reliability class are described in EPA's technical bulletin, Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability, EPA 430-99-74-001; available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (Portions of this document are noted below.)

The reliability classification will be assigned by the Division of Water Pollution Control during the planning limits/site approval phase of the project.

1.3.11.2 Guidelines for classifying sewerage works as follows:

a. Reliability Class I

Works which discharge into navigable waters that could be permanently or unacceptably damaged by effluent which was degraded in quality for only a few hours. Examples of Reliability Class I works might be those discharging near drinking water reservoirs, into shellfish waters, or in close proximity to areas used for water contact sports.

b. Reliability Class II

Works which discharge into navigable waters that would not be permanently or unacceptably damaged by short-term effluent quality degradations, but could be damaged by continued (on the order of several days) effluent quality degradation. An example of a Reliability Class II works might be one which discharges into recreational waters.

c. Reliability Class III

These are works not otherwise classified as Reliability Class I or Class II.

1.3.11.3 Component Backup Requirements

Requirements for backup components for the main wastewater treatment system are specified below for Reliability Class I, II, and III works.

Alternate methods of sludge disposal and/or treatment shall be provided for each sludge treatment unit operation without installed backup capability.

Except as modified below, unit operations in the main wastewater treatment system shall be designed such that, with the largest flow capacity unit out of service, the hydraulic capacity (not necessarily the design-rated capacity) of the remaining units shall be sufficient to handle the peak wastewater flow. There shall be system flexibility to enable the wastewater flow to any unit out of service to be distributed to the remaining units in service.

Equalization basins or tanks shall not be considered a substitute for component backup requirements.

a. Reliability Class I

For components included in the design of Reliability Class I works, the following backup requirements apply.

Mechanically-Cleaned Bar Screens or Equivalent Devices

A backup bar screen shall be provided. It is permissible for the backup bar screen to be designed for manual cleaning only. Works with only two bar screens shall have at least one bar screen designed to permit manual cleaning.

Pumps

A backup pump shall be provided for each set of pumps which performs the same function. The capacity of the pumps shall be such that, with any one pump out of service, the remaining pumps will have the capacity to handle the peak flow. It is permissible for one pump to serve as backup to more than one set of pumps.

Comminution Facility

If comminution of the total wastewater flow is provided, then an overflow bypass with an installed manually- or mechanically-cleaned bar screen shall be provided. The hydraulic capacity of the comminutor overflow bypass shall be sufficient to pass the peak flow with all comminution units out of service.

Primary Sedimentation Basins

There shall be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units shall have a design flow capacity of at least 50 percent of the total design flow to that unit operation.

Final and Chemical Sedimentation Basins, Trickling Filters, Filters and Activated Carbon Columns

There shall be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units shall have a design flow capacity of at least 75 percent of the total design flow to that unit operation.

Activated Sludge Process Components

Aeration Basin

A backup basin shall not be required; however, at least two equal volume basins shall be provided. (For the purpose of this criterion, the two zones of a contact stabilization process are considered as only one basin.)

Aeration Blowers or Mechanical Aerators

There shall be a sufficient number of blowers or mechanical aerators to enable the design oxygen transfer to be maintained with the largest capacity unit out of service. It is permissible for the backup unit to be an uninstalled unit, provided that the installed unit can be easily removed and replaced. However, at least two units shall be installed.

Air Diffusers

The air diffusion system for each aeration basin shall be designed such that the largest section of diffusers can be isolated without measurably impairing the oxygen transfer capability of the system.

Disinfectant Contact Basins

There shall be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units shall have a design flow capacity of at least 50 percent of the total design flow to that unit operation.

b. Reliability Class II

The Reliability Class I requirements shall apply except as modified below.

Primary and Final Sedimentation Basins and Trickling Filters

There shall be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units shall have a design flow capacity of at least 50 percent of the design basis flow to that unit operation.

Components Not Requiring Backup

Requirements for backup components in the wastewater treatment system shall not be mandatory for components which are used to provide treatment in excess of typical biological (i.e., activated sludge or trickling filter), or equivalent physical/chemical treatment, and disinfection. This may include such components as:

Chemical Flash Mixer

Flocculation Basin

Chemical Sedimentation Basin

Filter

Activated Carbon Column

c. Reliability Class III

The Reliability Class I requirements shall apply except as modified below.

Primary and Final Sedimentation Basins

There shall be at least two sedimentation basins.

Activated Sludge Process Components

Aeration Basin

A single basin is permissible.

Aeration Blowers or Mechanical Aerators

There shall be at least two blowers or mechanical aerators available for service. It is permissible for one of the units to be uninstalled, provided that the installed unit can be easily removed and replaced.

Air Diffusers

The Reliability Class I requirements shall apply.

Components Not Requiring Backup

Requirements for backup components in the wastewater treatment system shall not be mandatory for components which are used to provide treatment in excess of primary sedimentation and disinfection, except as modified above. This may include such components as:

Trickling Filter

Chemical Flash Mixer

Flocculation Basin

Chemical Sedimentation Basin

Filter

Activated Carbon Column

1.3.11.4 Component Design Features and Maintenance Requirements

Provisions for Isolating Components

Each component shall have provisions to enable it to be isolated from the flow stream to permit maintenance and repair of the component without interruption of the works' operation. Where practicable, simple shutoff devices, such as slide gates, shall be used.

Main Wastewater System Pump Isolation

The use of in-line valves to isolate the main wastewater pumps shall be minimized. It is permissible to place shutoff valves on the suction and discharge lines of each pump. However, in such a case, alternate means shall be provided for stopping flow through the pump suction or discharge lines to permit maintenance on the valve.

Example: Pump discharge isolation and check valves are not needed if the pumps have a free discharge

into an open channel rather than discharging into a pressurized discharge header. Pump suction isolation valves can be maintained if the plant has a two compartment wetwell design and if the plan can continue operation (during the diurnal low-flow period, for example) with one part of the wetwell isolated.

1.3.11.5 Electric Power System

The following criteria shall apply to those portions of the system supplying power to vital components. A vital component is one whose operation or function is required to prevent a controlled diversion, is required to meet effluent parameters, or is required to protect other vital components from damage. Vital components should be identified in the permit/site approval phase, depending on the reliability class and treatment scheme employed. Further information is found in Chapter 14, Instrumentation, Control and Electrical Systems.

Power Sources

Two separate and independent sources of electric power shall be provided to the works from either two separate utility substations or from a single substation and a works (plant and/or main pump station) generator. If available from the electric utility, at least one of the works' power sources shall be a preferred source (i.e., a utility source which is one of the last to lose power from the utility grid due to loss of power generating capacity). In geographical areas where it is projected that sometime during the design period of the works, the electric utility may reduce the rated line voltage (i.e., "brown out") during peak utility system load demands, a works-based generator shall be provided as an alternate power source, where practicable. As a minimum, the capacity of the backup power source for each class of treatment works shall be:

Reliability Class I

Sufficient to operate all vital components, during peak wastewater flow conditions, together with critical lighting and ventilation.

Reliability Class II

Same as Reliability Class I, except that vital components used to support the secondary processes (i.e., mechanical aerators or aeration basin air compressors) need not be included as long as treatment equivalent to sedimentation and disinfection is provided.

Reliability Class III

Sufficient to operate the screening or communication facilities, the main wastewater pumps, the primary sedimentation basins, and the disinfection

facility during peak wastewater flow condition, together with critical lighting and ventilation.

Note: This requirement concerning rated capacity of electric power sources is not intended to prohibit other forms of emergency power, such as diesel-driven main wastewater pumps.

Power Distribution External to the Works

The independent sources of power shall be distributed to the works' transformers in a way to minimize common mode failures from affecting both sources.

Example: The two sets of distribution lines shall not be located in the same conduit or supported from the same utility pole. The two sets of overhead distribution lines, if used, should not cross or be located in an area where a single plausible occurrence (e.g., fallen tree) could disrupt both lines. Devices should be used to protect the system from lightning.

Transformers

Each utility source of power to the works shall be transformed to usable voltage with a separate transformer. The transformers shall be protected from common mode failure by physical separation or other means.

Power Distribution Within the Works

Service to Motor Control Centers

The internal power distribution system shall be designed such that no single fault or loss of a power source will result in disruption (i.e., extended, not momentary) of electric service to more than one motor control center associated with the Reliability Class I, II, or III vital components requiring backup power.

Division of Loads at Motor Control Centers

Vital components of the same type and serving the same function shall be divided as equally as possible between at least two motor control centers. Nonvital components shall be divided in a similar manner, where practicable.

Power Transfer

Where power feeder or branch circuits can be transferred from one power source to another, a mechanical or electrical safety device shall be provided to assure that the two power sources cannot be cross-connected, if unsynchronized. Automatic transfer shall be provided in those cases when the time delay required to manually transfer power could result in a failure to meet effluent limitations, a failure to process peak influent flow, or cause damage to equipment. Where automatic pump control is used, the control panel power source and pump power source shall be similarly transferred.

The actuation of an automatic transfer switch shall be alarmed and annunciated.

Example: The two power sources from utility substations are connected to the motor control centers through circuit breakers. A circuit breaker is provided to cross-connect the two motor control centers in the event one of the two normally energized power feeders fail. Additional backup capability has been achieved for the main pump by connecting one of the three pumps to the motor control center cross-connect. This assures that two out of three pumps will be available in the event of a panel fire or panel bus short circuit.

Breaker Settings or Fuse Ratings

Breaker settings or fuse ratings shall be coordinated to effect sequential tripping such that the breaker or fuse nearest the fault will clear the fault prior to activation of other breakers or fuses to the degree practicable.

Equipment Type and Location

Failures resulting from plausible causes, such as fire or flooding, shall be minimized by equipment design and location. The following requirements apply:

Switchgear Location

Electric switchgear and motor control centers shall be protected from sprays or moisture from liquid processing equipment and from breaks in liquid handling piping. Where practicable, the electric equipment shall be located in a separate room from the liquid processing equipment. Liquid handling piping shall not be run through this room. The electric switchgear and motor control centers shall be located above ground and above the one hundred (100) year flood (or wave action) elevation.

Conductor Insulation

Wires in underground conduits or in conduits that can be flooded shall have moisture resistant insulation as identified in the National Electric Code.

Motor Protection from Moisture

All outdoor motors shall be adequately protected from the weather. Water-proof, totally enclosed or weather-protected, open motor enclosures shall be used for exposed outdoor motors. Motors located indoors and near liquid handling piping or equipment shall be, at least, of splash-proof design. Consideration shall be given to providing heaters in motors located outdoors or in areas where condensation may occur.

The following criteria shall apply to motors (and their local controls) associated with vital components. All outdoor motors, all large indoor motors (i.e., those not

readily available as stock items from motor suppliers), and, where practicable, all other indoor motors, shall be located at an elevation to preclude flooding from the one hundred (100) year flood (or wave action) or from clogged floor drains. Indoor motors located at or below the one hundred year flood (or wave action) elevation shall be housed in a room or building which is protected from flooding during the one hundred year flood (or wave action). The building protection shall include measures such as no openings (e.g., doors, windows, hatches) to the outside below the flood elevation and a drain sump pumped to an elevation above the flood elevation.

Explosion Proof Equipment

Explosion proof motors, conduit systems, switches and other electrical equipment shall be used in areas where flammable liquid, gas or dust is likely to be present.

Routing of Cabling

To avoid a common mode failure, conductors to components which perform the same function in parallel shall not be routed in the same conduit or cable tray. Conduits housing such cables shall not be routed in the same underground conduit bank unless the conduits are protected from common mode failures (such as by encasing the conduit bank in a protective layer of concrete).

Motor Protection

Three-phase motors and their starters shall be protected from electric overload and short circuits on all three phases.

Large motors shall have a low-voltage protection device which, on the reduction or failure of voltage, will cause and maintain the interruption of power to that motor.

Consideration shall be given to the installation of temperature detectors in the stator and bearings of large motors in order to give an indication of overheating problems.

Provisions of Equipment Testing

Provisions shall be included in the design of equipment requiring periodic testing, to enable the tests to be accomplished while maintaining electric power to all vital components. This requires being able to conduct tests, such as actuating and resetting automatic transfer switches, and starting and loading emergency generating equipment.

Maintainability

The electric distribution system and equipment shall be designed to permit inspection and maintenance of individual items without causing a controlled diversion or causing violation of the effluent limitations.

Emergency Power Generator Starting

The means for starting a works-based emergency power generator shall be completely independent of the normal electric power source. Air starting systems shall have an accumulator tank(s) with a volume sufficient to furnish air for starting the generator engine a minimum of three (3) times without recharging. Batteries used for starting shall have a sufficient charge to permit starting the generator engine a minimum of three (3) times without recharging. The starting system shall be appropriately alarmed and instrumented to indicate loss of readiness (e.g., loss of charge on batteries, loss of pressure in air accumulators, etc.).

1.3.12 New Technology

New technology is defined as any method, process, or equipment which is used to treat or convey wastewater and which is not discussed in this manual. This does not refer to innovative technology as defined by EPA.

After review of treatability data and the complete engineering report, the Department may approve the plans if it is satisfied that the method, process or equipment will efficiently operate and meet the treatment requirements. Pilot plants may be required or special restrictions may be placed on the system in terms of operational control aspects, sampling, monitoring, etc. Additionally, the number of systems approved initially may be limited until the technology is demonstrated to the satisfaction of the Department.

Appendix 1-A

Wastewater Discharge Checklist

1. Applicant contacts Field Office, discusses proposed project and is advised of information required for submittals.
2. On all proposed discharges in the smaller flow ranges, the applicant must first investigate subsurface disposal (even at a remote site) and transference to a public sewer system. Only if the Division is satisfied that these options are not feasible will consideration be given to a discharge to waters of the State.
3. Applicant submits required information and requests site inspection/planning limits. Field Office responds to applicant on results, including the assigned reliability classification.
4. Applicant submits NPDES application with associated information; i.e., owner/operator, financial information and preliminary engineering report to the Field Office. As part of preliminary engineering report development, a meeting of all concerned parties should be made to discuss selection of the appropriate technology which would maximize the reliability and design operability of the selected technology. Field Office advises applicant when information is complete and forwards same to Permit Section.
5. Permit Section forwards draft permit to Field Office and applicant and issues public notice of intent to (not to) issue NPDES permit.
6. Permit Section evaluates responses to draft permit and public notice, makes decision on necessity for public hearing, issues public notice of hearing, if required, conducts public hearing, evaluates comments, makes and publicizes issuance decision.
7. Final engineering report submitted, reviewed and approved.
8. Final plans and specifications submitted, reviewed and approved for construction.
9. Construction proceeds and applicant requests final inspection by the Field Office. Field Office advises Permit Section when construction has been completed in substantial compliance with final plans and specifications. Permit Section issues final permit.

APPENDIX 1B
POLICY STATEMENT
DIVISION OF WATER POLLUTION CONTROL
FLOW DIVERSION DURING CONSTRUCTION

April 1987

In order to reduce the occurrence of permit violations due to construction activities, the following statement or its equivalent should be included in all State and EPA project specifications:

"No discharge of untreated wastewater or reduction in existing hydraulic capacity or organic treatment capacity, due to activities of the contractor, will be permitted under this contract."

If this statement cannot be included in the specifications, then prior to our approval of the plans and specifications, the following should be accomplished.

1. The municipality shall develop a Project Plan including but not limited to the following.
 - a. The Project Plan shall be a part of the plans and specifications and evaluate economically all identifiable options to by-passing such as temporary lagoons, use of portable treatment units, trucking waste, flow diversion back to collection system, etc.
 - b. Prior to by-pass, sufficient 24-hour influent flow monitoring data should be evaluated to determine flow patterns; by-passing should be scheduled for periods of lowest flow, often 10:00 p.m. till 5:00 a.m.
 - c. The method of disinfection should be discussed. We have had success with gas chlorination from a portable unit with injection directly into the sewer line 3-4 blocks up-line of the point of discharge. The discharge should be screened through a rotating wire mesh drum or other screening device. The receiving area should be equipped with floating booms to trap floating materials.
 - d. A monitoring program shall be implemented. At a minimum effluent fecal coliform and total chlorine monitoring will be required. Other parameters such as a dissolved oxygen and ammonia may be required during warm months. All other parameters and scheduling requirements will be approved on a case by case basis.
 - e. A schedule of approximate data and duration of each occurrence should be included.
 - f. This plan shall be sent to the appropriate field office of Water Pollution Control (WPC) for concurrence. A copy shall be sent to the Division of Construction Grants and Loans (CGL) on all projects where CGL moneys are involved.

2. The municipality shall issued public notice 14 days prior to any by-pass event. This notice shall contain but not be limited to the project impact zone, the date, and the duration of each bypass.
3. As a function of monitoring, care should be taken by the municipal staff to discourage water contact activities. In areas of frequent recreational use, temporary posting may be required.
4. Where economically feasible by-pass operation should be confined to cold weather months. On flow regulated streams, TVA can provide additional flow to help mitigate adverse impacts.
5. The burden of co-ordination, communication, and notification is the responsibility of the municipality including written notification. The state does not approve by-pass activities and reserves enforcement options should significant water quality degradation occur.
6. Upon completion of all of the above, the reviewer can proceed with review/approval of the plans and specifications.

Kenneth Bunting, Director
Water Pollution Control

Date

Elmo L. Lunn, Administrator
Office of Water Management

Date

RDL:E3079053

18 July 1995

THIS IS CHAPTER 2

CHAPTER 2

Sewers and Sewage Pump Stations

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Appendix 2-C

SEWERS AND SEWAGE PUMP STATIONS

2.1 General Requirements for Collection Systems

2.1.1 Construction Approval

In general, construction of new sewer systems or extensions of existing systems will be allowed only if the downstream conveyance system and the receiving sewage treatment plant is 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 Department.**

2.1.2 Ownership

Sewer systems including pumping stations will not be approved unless ownership and responsibility for operation are by a public entity or other acceptable long term operation or maintenance scheme is approved in advance by the Department.

2.1.3 Design

Sewer systems shall be designed and constructed to achieve total containment of sanitary wastes and maximum exclusion of infiltration and inflow. No combined sewers will be approved.

2.1.4 Emergency High Level Overflows

For use during possible periods of extensive power outages, mandatory power reductions, or uncontrollable emergency conditions, consideration should be given to providing a controlled, high-level overflow to supplement alarm systems and emergency power generation in order to prevent backup of sewage into basements, or other discharges which may cause severe adverse impacts on public interests, including public health and property damage. Where a high level overflow is utilized, consideration shall also be given to the installation of storage /detention tanks, or basins, which shall be made to drain to the station wet well where possible. All such constructed overflow structures must be telemetered to the control authority's headquarters where records must be maintained as to frequency and duration of the overflow.

2.1.5 Calculations

Computations and other data used for design of the sewer system shall be submitted to the Department. The Engineer shall utilize the format shown in Appendix 2-B or an approved equivalent.

2.1.6. SLOPE PROTECTION AND EROSION CONTROL

2.1.6.1 GENERAL

- A. This Section shall consist of temporary control measures as shown in the Plans or directed by the Engineer during the life of the Contract to control erosion and pollution through the use of berms, dikes, dams, sediment basins, fiber mats, netting, mulches, grasses, silt drains, temporary silt fences, and other control devices.**
- B. The temporary pollution control provisions contained herein shall be coordinated with the permanent erosion control features, to assure economical, effective, and continuous erosion features, to assure economical, effective, and continuous erosion control throughout the construction and post-construction period.**

2.1.6.2: MATERIALS

2.1.6.2.1 TEMPORARY BERMS

A. A temporary berm is constructed of compacted soil, with or without a shallow ditch, at the top of fill slopes or transverse to centerline on fills.

B. These berms are used temporarily at the top of newly constructed slopes to prevent excessive erosion until permanent controls are installed or slopes stabilized.

2.1.6.2.2 TEMPORARY SLOPE DRAINS: A temporary slope drain is a facility consisting of stone gutters, fiber mats, plastic sheets, concrete or asphalt gutters, half-round pipe, metal pipe, plastic pipe, sod or other material acceptable to the Engineer that may be used to carry water down slopes to reduce erosion.

2.1.6.2.3 SEDIMENT STRUCTURES: Sediment basins, ponds and traps, are prepared storage areas constructed to trap and store sediment from erodible areas in order to protect properties and stream channels below the constructed areas from excessive siltation.

2.1.6.2.4 CHECK DAMS

A. Check dams are barriers composed of logs and poles, large stones or other materials placed across a natural or constructed drainway.

B. Stone check dams shall not be utilized where the drainage area exceeds fifty (50) acres. Log and pole structures shall not be used where the drainage area exceeds five (5) acres.

2.1.6.2.5 TEMPORARY SEEDING AND MULCHING

Temporary seeding and mulching are measures consisting of seeding, mulching, fertilizing and mating utilized to reduce erosion. All cut and fill slopes including waste sites and borrow pits shall be seeded when and where necessary to eliminate erosion.

2.1.6.2.6 BRUSH BARRIERS

A. Brush barriers shall consist of brush, tree trimmings, shrubs, plants, and other approved refuse from the clearing and grubbing operations.

B. Brush barriers are placed on natural ground at the bottom of fill slopes, where the most likely erodible areas are located to restrain sedimentation particles.

2.1.6.2.7 BALED HAY OR STRAW CHECKS

A. Baled hay or straw erosion checks are temporary measures to control erosion and prevent siltation. Bales shall be either hay or straw containing five (5) cubic feet or more of material.

B. Baled hay or straw checks shall be used where the existing ground slopes toward or away from the embankment along the toe of the slopes, in ditches or other areas where siltation erosion or water run-off is a problem.

2.1.6.2.8 TEMPORARY SILT FENCES Silt fences are temporary measures utilizing woven wire or other approved material attached to post with filter cloth composed of burlap, plastic filter fabric, etc., attached to the upstream side of the fence to retain the suspended silt particles in the run-off water.

2.1.6.3 EXECUTION

2.1.6.3.1 PROJECT REVIEW Prior to the pre-construction conference the Contractor shall meet with the Engineer and go over in detail the expected problem areas in regard to the erosion control work. Different solutions should be discussed so that the best method might be determined. It is the responsibility of the Contractor to develop an erosion control plan acceptable to the Engineer.

2.1.6.3.2 PRE-CONSTRUCTION CONFERENCE At the pre-construction conference the Contractor shall submit for acceptance his schedule for accomplishment of temporary and permanent erosion control work, as are applicable for clearing and grubbing, grading, bridges and other structures at water courses, construction and paving. He shall also submit for acceptance his proposed method for erosion control on haul roads and borrow pits and his plan for disposal of waste materials. No work shall be started until the erosion control schedules and methods of operations have been accepted by the Engineer.

2.1.6.3.3 CONSTRUCTION REQUIREMENTS

A. The Engineer has the authority to limit the surface area of erodible earth material exposed by clearing and grubbing, the surface of erodible earth material exposed by excavation, borrow and fill operations and to direct the Contractor to provide immediate permanent or temporary pollution control measures to prevent contamination of adjacent streams or other watercourses, lakes, ponds or other water impoundment. Such work may involve the construction of temporary berms, dikes, dams, sediment basins, slope drains and use of temporary mulches, mats, seeding or other control devices or methods to control erosion. Cut and fill slopes shall be seeded and mulched as the excavation proceeds to the extent directed by the Engineer.

B. The Contractor shall be required to incorporate all permanent erosion control features into the project at the earliest practicable time as outlined in his accepted schedule. Temporary pollution control measures shall be used to correct conditions that develop during construction that were not foreseen during the design stage; that are needed prior to installation of permanent pollution control features; or that are needed temporarily to control erosion that develops during normal construction practices, but are not associated with permanent control features on the project.

C. Where erosion is likely to be a problem, clearing and grubbing operations should be so schedule and performed that grading operations and permanent erosion control features can follow immediately thereafter if the project conditions permit; otherwise erosion control measures may be required between successive construction stages. Under no conditions shall the surface area of erodible earth material exposed at one time by clearing and grubbing exceed 750,000 square feet without approval of the Engineer.

D. The Engineer will limit the area of excavation, borrow and embankment operations in progress commensurate with the contractor's capability and progress in keeping the finish grading, mulching, seeding and other such permanent pollution control measures current in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion control measures shall be taken immediately to the extent feasible and justified.

E. Under no conditions shall the amount of surface area or erodible earth material exposed at one time by excavation or fill within the project area exceed 750,000 square feet without prior approval by the Engineer.

F. The Engineer may increase or decrease the amount of surface area of erodible earth material to be exposed at one time by clearing and grubbing, excavation, borrow and fill operations as determined by his analysis of project conditions.

G. In the event of conflict between these requirements and pollution control laws, rules or regulations, or other Federal, State or Local agencies, the more restrictive laws, rules or regulations shall apply.

2.1.7 SEPTIC TANK EFFLUENT PUMP OR GRAVITY (STEP/STEG) SEWER PROJECTS

2.1.7.1 APPLICABILITY

These criteria apply to STEP units discharging to pressurized common sewers, and to STEP or STEG units discharging to small-diameter gravity systems. Pressurized and small-diameter collectors have interactive hydraulic effects and solids handling limitations which warrant a comprehensive engineering design.

These criteria do not apply to individual or single dwelling septic tank or grinder pump units discharging a conventional gravity sewer.

Septic tanks discharging to a drainfield.

Vacuum sewer collection systems.

2.1.7.2 STEP SYSTEMS

In a typical STEP system, household sewage is pretreated in a watertight septic tank where gross solids and grease are held back. A “clear” effluent from the mid-depth of the tank is transported to a common or lateral sewer. Usually the effluent is pumped from the septic tank under pressure to a small-diameter, pressurized collector sewer.

Effluent may also flow by gravity, where terrain allows, to small-diameter gravity collector lines.

2.1.7.3 SCOPE

A STEP/STEG system is considered to include all of its components beginning with the septic tanks, and ending at the point(s) of discharge into a conventional gravity sewer or treatment plant.

2.1.7.4 ADMINISTRATIVE REQUIREMENTS

All additions and extensions to existing STEP (or STEG) systems, as well as new systems, must be reviewed by the DIVISION OF WATER POLLUTION CONTROL.

The OWNER is defined as the municipality, sanitary district, private sewage utility or sanitary authority which is responsible for the operation of the system. The property being served is defined as the “USER”.

Legal title to tanks, pumps, or other components must be vested with the OWNER. The objective of having title invested to the OWNER rather than the USER is to avoid potential for cost disputes over equipment selection and repair methods.

Regardless of where title is vested, the OWNER shall completely control all tanks, pumps, service lines and other components of the system on private property. This requirement is essential to assure operable hydraulics and overall system reliability.

The OWNER shall possess a recorded general easement or deed restriction to enter the private property being served, and to access the system and its components. Access must be guaranteed to operate, maintain, repair, restore service and remove sludge.

No system shall be operated without the direct field supervision of qualified collection operator certified by the STATE OF TENNESSEE. An operations and maintenance manual shall be submitted for review prior to startup.

OWNERS shall operate and maintain STEP/STEG facilities without interruption, sewage spills on the grounds, sewage backup into buildings, or other unhealthy conditions.

2.2 Design Considerations

2.2.1 Design Period

2.2.1.1 Collection Sewers (Laterals and Submains)

Collection sewers should be designed for the ultimate development of the tributary areas.

2.2.1.2 Main, Trunk and Interceptor Sewers

Selection of the design period for trunk and interceptor sewers should be based on evaluation of economic, functional, and other considerations. Some of the factors that should be considered in the evaluation are:

- 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 Design Basis

New sewer systems shall be designed on the basis of per capita flows or alternative methods. Documentation of the alternative methods shall be provided.

2.2.2.1 Per Capita Flow

New sewer systems designed on the basis of an average daily per capita flow may be designed for flow equal to that set forth in Appendix 2-A. These figures are assumed to cover normal infiltration and inflow, but an additional allowance should be made where conditions are unfavorable. If there is an existing water system in the area, water consumption figures can be used to help substantiate the selected per capita flow. Generally, the sewers should be designed to carry, when running full, not less than the following:

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

“Lateral” is defined as 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 than 250 percent of the average design flow.

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

“Interceptor” is defined as a sewer that receives flow from a number of main or trunk sewers, force mains, etc.

2.2.2.2 Alternative Methods

New sewer systems may be designed by 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, and modification of per capita flow rates (based on specific data). Documentation of the alternative method used shall be provided. When infiltration is calculated separately from the normal sanitary flow, the maximum allowable infiltration rate shall be 25 gallons per day per inch diameter of the sewer per mile of sewer.

2.2.3 Design Factors

The following factors must be considered in the design of sanitary sewers:

- a. Peak sewage flows from residential, commercial, institutional, and industrial sources
- b. Groundwater infiltration and exfiltration
- 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

2.2.4 Design Definitions

2.3 Design and Construction Details

2.3.1 Gravity Sewers

2.3.1.1 Minimum Size

No sewer shall be less than 8 inches in diameter except that, in special cases, 6-inch-diameter sewer lines may be approved by the Department if they meet the following criteria:

- a. The maximum number of services should not exceed 40 residences. This applies to 6” service lines as well as 6” mains.

- b. A manhole shall be provided where the 6-inch connects to 8-inch or larger line. This does not include a 6-inch side sewer to serve 1 or 2 single-family dwellings.
- c. A manhole or cleanout shall be provided at the end of the 6-inch line. This requirement shall be at the discretion of the Division.
- d. Extension of the 6-inch line will not be possible at a later date.
- e. The minimum slope allowable for 6-inch lines will be 0.60 feet per 100 feet.
- f. Small diameter gravity (SDG) systems will be considered on a case by case basis. These systems should be discussed with TDEC personnel prior to initiation of detailed design work.

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 and should receive sewage from existing dwellings by gravity.

2.3.1.3 Roughness Coefficient

The roughness coefficient should be documented for the type of pipe used. However, for ease of calculations, an “n” value of 0.0115 may be used in Manning’s formula for the design of all sewer facilities.

2.3.1.4 Slope

All conventional gravity sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second. The following minimum slopes should be provided; however, slopes greater than these are desirable:

Table 2-1

Sewer Size (inches)	Minimum Slope (feet per 100 feet)
6	0.38
8	0.26
10	0.193
12	0.151
14	0.123
15	0.112
16	0.103
18	0.088
21	0.072
24	0.060
27	0.051
30	0.045
36	0.035
42	0.028
48	0.024

Under special conditions, 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 shall 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 sewage agency must recognize and accept in writing the problems of additional maintenance caused by decreased slopes.

Sewers shall be laid with uniform slope between manholes.

Sewers on 18 percent slope or greater shall be anchored securely with concrete anchors or equal. Suggested minimum anchorage spacing is as follows:

1. Not over 36 feet center to center on grades 18 percent and up to 25 percent.
2. Not over 24 feet center to center on grades 25 percent and up to 35 percent.
3. Not over 16 feet center to center on grades 35 percent and over.

2.3.1.5 Alignment

Generally, gravity sewers shall be designed with straight alignment between manholes. However, curved sewers may be approved where circumstances warrant, but only in large (i.e., 36" and larger) diameter segments.

2.3.1.6 Increasing Size

Where a smaller sewer joins a larger one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient. An approximate method for securing these results is to place the 0.8 depth point of both sewers at the same elevation.

2.3.1.7 High-Velocity Protection

Where velocities greater than 15 feet per second are expected, special provision shall be made to protect against internal erosion or displacement by shock.

2.3.2 Materials

Any generally accepted material for sewers will be given consideration. The material selected should be adapted to local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, abrasion and similar problems. Careful consideration should be given to pipes and compression joint materials subjected to corrosive or solvent wastes. Such pipe and compression joint material should be evaluated for vulnerability to chemical attack, chemical/stress failure and stability in the presence of common household chemicals such as cooking oils, detergents and drain cleaners.

The specifications shall stipulate that the pipe interior, sealing surfaces, fittings and other accessories should be kept clean. Store pipe bundles on flat surfaces with uniform support. Stored pipe should be protected from prolonged exposure (six months or more) to sunlight with a suitable covering (canvas or other opaque material). Air circulation should be provided under the covering. Gaskets should 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

Shall include, but not be limited to, vitrified clay, concrete, and cast iron pipe. Any rigid pipe shall have a minimum crushing strength of 2000 pounds per lineal foot. All pipe should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.2 Semi-rigid Pipe

Shall include, but not be limited to, Polyvinyl Chloride (PVC) composite (truss) pipe and ductile iron. PVC composite pipe ends shall be sealed. Rubber gasket joints shall be specified. All pipe should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.3 Flexible Pipe

Shall include, but not be limited to, 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 maximum Standard Dimension Ratio (SDR) of 35. All other flexible pipe that is not classified by the SDR system should have the same calculated maximum deflection under identical conditions as the SDR 35 PVC pipe.

Flexible pipe deflection under earth loading may be calculated using the formula presented in the ASCE/WPCF publication, Design and Construction of Sanitary and Storm Sewers.

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

2.3.3 Pipe Bedding

All sewers shall be designed to prevent damage from superimposed loads. Proper allowance for loads on the sewer shall be made because of the width and depth of trench. Trench widths should be kept to a minimum. Backfill material up to three feet above the top of the pipe should not exceed 6 inches in diameter at its greater dimension.

As a general rule, in roadways where cover is less than 4 feet, ductile iron pipe, solid wall flexible plastic pipe, or concrete encasement shall be used. In such cases, a minimum cover of six inches (12 inches for solid wall flexible plastic pipe) is required. For structural reasons, ductile iron pipe, concrete encasement, or relocation shall be required when culverts or other conduits are laid such that the top of the sewer is less than 18 inches below the bottom of the culvert or conduit.

Uncased borings are not permitted for pipe larger than 3 inches.

Special care shall be used in placing bedding in the haunch region.

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) shall be used for all rigid pipe, provided the proper strength pipe is used with the specified bedding to support the anticipated load. Bedding and backfill shall be placed as described in ASTM C-12.

2.3.3.2 Semi-rigid Pipe

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

Underground installation of Ductile iron shall be installed as per ASTM A-746.

2.3.3.3 Flexible Pipe

Bedding Classes I, II, or III as described in ASTM D-2321 shall be used for all flexible pipe provided, the proper strength pipe is used with the specified bedding to support the anticipated load.

Bedding, haunching, initial backfill, and backfill shall be placed in accordance to ASTM D-2321.

It is recommended that polyethylene pipe be installed with Class I bedding material for bedding, haunching, and initial backfill as described in 2.3.3.4.

2.3.3.4 Alternate Bedding Option

As an alternative to sub-sections 2.3.3.1, 2.3.3.2 and 2.3.3.3, all sewers shall be bedded and backfilled with a minimum of six inches of Class I material over the top and below the invert of the pipe.

2.3.3.5 Deflection Testing

Deflection testing of all flexible pipe shall be required. The test shall be conducted after the backfill has been in place at least 24 hours.

No pipe shall exceed a deflection of 5%.

The test shall 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 must be performed by manually pulling the test device through the line.

2.3.3.6 Check Dams

Check dams shall be installed in the bedding and backfill of all new or replaced sewer lines to limit the drainage area subject to the french drain effect of gravel bedding. Major rehabilitation projects should also include check dams in the design. Dams shall consist of compacted clay bedding and backfill at least three (3) feet thick to the top of the trench and cut into the walls of the trench two (2) feet. Alternatively, concrete may be used, keyed into the trench walls. Dams shall be placed no more than 500 feet apart. The required location is upstream of each manhole. All stream crossings will include check dams on both sides of the crossing.

2.3.4 Joints

The method of making joints and the materials used should be included in the specifications. Sewer joints shall be designed to eliminate infiltration and exfiltration to prevent the entrance of roots.

Elastomeric gaskets, other types of pre-molded (factory made) joints are required. The butt fusion joining technique is acceptable for polyethylene pipe. On concrete pipe of 36" and greater diameter, the Anderson type joint shall be required. Cement mortar joints are not acceptable. Field solvent welds for PVC, PVC Truss and PE pipe and fittings are not acceptable.

2.3.5 Leakage Testing

Leakage tests shall be specified.

2.3.5.1 Testing Methods

Testing methods may include appropriate water or low pressure air testing. The use of television cameras for inspection prior to placing the sewer into service and prior to acceptance is recommended.

2.3.5.2 Low Pressure Air Testing

Low pressure air-testing shall be performed as per ASTM C-828 on all gravity pipe. 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 test criteria should be based on the air loss rate. 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 H₂O = 0.433 psi).

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

Table 2-2

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 Low Pressure Systems

Low pressure sewer systems are considered Developmental Technology.

2.3.6.1 Application

Low-pressure systems should be considered for situations in which gravity sewers are extremely costly or impractical, such as rock or high groundwater table.

2.3.6.2 Grinder Pumps

All raw wastewater should be collected from individual buildings/dwellings and transported to the pressure or gravity system by appropriately sized grinder pumps. A SEPTIC TANK/GREASE TRAP MUST BE USED PRIOR TO THE GRINDER PUMP FOR RESTAURANTS.

Grinder pumps do not require a septic tank except when used at restaurants..

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

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

Odor considerations must be evaluated.

2.3.6.3 Septic Tank Effluent Pump (STEP) System

All STEP installations require careful attention to design details and construction techniques. The following criteria must be considered:

- A. There are two methods of designing the STEP. The preferred method is to have the effluent pump in the septic tank itself and the other method is to have a separate enclosure for the effluent pump.
- B. All STEPs must have a watertight designed septic tank. Retrofitting a septic tank to meet the requirements of a STEP is not acceptable.

C.. If a STEP is to be retrofitted to an existing septic tank and drain field, a positive means of preventing groundwater from backing up through the drainfield to the STEP shall be provided.

- D. The STEP shall be located as close as possible to the septic tank.
- E. Electrical power should be supplied through the main circuit box. Electricity is furnished to a separate circuit box installed on the exterior wall of the building, near the STEP.

2.3.6.4 Provision for Maintenance

Approval of a low-pressure sewer system shall be contingent on the following minimum provisions being made for operation and maintenance.

- A. An adequate reserve stock of replacement pumping units shall be maintained by the municipality or utility.
- B. There shall be qualified grinder pump or STEP maintenance personnel available as long as the system exists.
- C. There shall be a written service agreement with the manufacturer assuring the availability of factory-trained maintenance personnel, the continued availability of standby equipment and replacement parts, other provisions assuring the Department that breakdowns will be repaired within 24 hours, and a written preventive maintenance plan.
- D. STEPs shall be owned by the municipality and shall be maintained by the municipality or its assignee but, in any case, under supervision of the municipality.
- E. The owner of each building served by a grinder pump or STEP will give an easement and/or right-of-way to the municipality for maintenance and inspection services. All persons exercising rights under this document shall be suitably bonded against theft and/or damages to the building and its contents. Notification of entry shall be a matter between owner/occupant/user and the municipality.
- F. Replacement parts should be available for the entire life of the pumping unit. If parts become unavailable, provision should be made to replace pumps that fail with improved or updated models. A sinking fund should be established for this replacement and should take into account life expectancy of the pumping unit and regular maintenance cost.

2.3.6.5 Hydraulic

Calculations are of extreme importance, due to the fact that head losses within the low-pressure system will change each time a pump is activated. For this reason, future connections to a low-pressure system may not be feasible.

2.3.6.6 Minimum Velocity

The minimum operating velocity in the pressure system shall be 2 feet per second.

2.3.6.7 Flushing

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

2.3.6.8 Pressure Testing

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

2.3.6.9 Alarms

There should be a dual audio and visual warning system both inside the building and out, indicating malfunction or nonfunction of the pump. The high-level (in storage tank) warning system should also be a dual system. The warning systems should be an audio/visual one.

2.3.6.10 Cleanouts

Cleanouts should be provided at maximum of 400- foot intervals.

2.3.6.11 Ventilation

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

2.3.7 Manholes

2.3.7.1 Location

Manholes shall be installed at the end of each line of 8-inch diameter or greater unless the 8-inch line is expected to be extended in the foreseeable future; in which case a cleanout shall be installed at the end of the line; 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 and 500 feet for sewer 18 inches to 30 inches (except that distances up to 600 feet may be approved in cases where adequate modern cleaning equipment for such spacing is provided). Greater spacing may be permitted in larger sewers and in those carrying a settled effluent. Cleanouts may be used in lieu of manholes at the end of lines 6 or 8 inches in diameter and not more than 150 feet long.

With prior municipality or utility approval greater distances between manholes may be allowed.

2.3.7.2 Drop Connection

An outside drop connection shall be provided 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, the invert should be filleted to prevent solids deposition.

2.3.7.3 Diameter

The minimum diameter of manholes should be 48 inches; larger diameters are preferable. The minimum clear opening in the manhole frame should be 24 inches to provide safe access for emergencies.

Manholes connecting significant industries to the system should be larger, to provide space for monitoring and sampling equipment.

2.3.7.4 Flow Channels

Flow channels in manholes shall be of such shape and slope to provide smooth transition between inlet and outlet sewers and to minimize turbulence. A minimum slope of 0.1 ft. drop across the bottom of the manhole must be provided to maintain cleaning and the hydraulic gradient. Channeling height shall be to the crowns of the sewers. Benches shall be sloped from the manhole wall toward the channel to prevent accumulation of solids.

2.3.7.5 Watertightness

Watertight manhole covers shall be used wherever the manhole tops may be flooded. Manholes of brick or segmented block are not acceptable.

2.3.7.6 Testing

All new or rehabilitated manholes shall be vacuum tested to assure watertightness before backfilling. The exterior surface must be painted with waterproofing material as the vacuum is being pulled to seal the pores of the concrete.

2.3.7.7 Connections

Line connections directly to the manholes or to short stubs integral with the manholes should be made with flexible joints. Flexible joints are joints which permit the manholes to settle without destroying the watertight integrity of the line connections.

2.3.7.8 Ventilation

Ventilation of gravity sewer systems should be considered where continuous watertight sections greater than 1,000 feet in length are incurred. Vent height and construction must consider flood conditions.

2.3.7.9 Frames, Covers, and Steps

Frames, covers, and steps shall 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 use of galvanized steel should be avoided and aluminum or plastic with reinforcing bar is preferred.

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 Waterworks Structures

It is generally recognized that sewers shall be kept remote from public water supply wells or other water supply sources and structures.

2.4.1.3 Relation to Water Mains

Horizontal Separation: Whenever practical, sewers should be laid at least 10 feet horizontally from any existing or proposed water main. The distance should be measured edge to edge. Should local conditions prevent a lateral separation of 10 feet, a sewer may be laid closer than 10 feet to a water main if it is laid 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 sewer shall be laid at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main. When the elevation of the sewer cannot be varied to meet the above requirement, the water main shall be relocated to provide this separation or reconstructed with mechanical-joint pipe for a distance of 10 feet on each side of the sewer. One full length of water main should be centered over the sewer so that both joints will be as far from the sewer as possible.

When it is impractical to obtain proper horizontal and vertical separation as stipulated above, the sewer shall be designed and constructed equal to the water main pipe and shall be pressure-tested to assure water-tightness (see drinking water criteria). Such arrangements are discouraged and adequate reason shall be provided to justify the design. Any variations from this statement must be approved by the DIVISION OF WATER POLLUTION CONTROL prior to construction..

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 lift station. A list of approved backflow preventers may be obtained from the Division of Water Supply.

Backflow preventers shall be installed as per the Design Criteria for Community Public Water Systems, Division of Water Supply. Below-ground pit installations are not acceptable.

2.4.3 Sewers in Relation to Streams

2.4.3.1 Location of Sewers in Streams

The top of all sewers entering or crossing streams shall be at a sufficient depth below the natural bottom of the stream bed to protect the sewer line. In general, the following cover requirements must be met:

- a. One (1) foot of cover (poured in place concrete) is required where the sewer is located in rock.
- b. Three (3) feet of cover is required in stabilized stream channels.
- c. Seven (7) feet of cover or more is required in shifting stream channels.

Sewers located along streams shall be located outside of the stream bed and sufficiently removed therefrom to minimize disturbance or root damage to streamside trees and vegetation.

Sewer outfalls, headwalls, manholes, gateboxes or other structures shall be located so they do not interfere with the free discharge of flow of the stream.

Sewers crossing streams shall be designed to cross the stream as nearly perpendicular to the stream flow as possible and shall be free from change in grade.

To prevent the french drain effect of the sewer crossing the stream , check dams must be installed up stream and down stream in the pipe conduit trench. This must be separate from any concrete encasement.

2.4.3.2 Construction

Sewers entering or crossing streams shall be constructed of ductile iron pipe with mechanical joints, concrete encased, or shall be so otherwise constructed that they will remain watertight and free from changes in alignment or grade. Sewer systems shall be designed to minimize the number of stream crossings. The construction methods that will minimize siltation shall be employed. Upon completion of construction, the stream shall be returned as nearly as possible to its original condition. The stream banks shall be seeded, planted or other erosion prevention methods employed to prevent erosion. Stream banks shall be sodded, if necessary, to prevent erosion. Where tree canopy has been removed, replacement trees shall be planted of natural species. The consulting engineer shall specify the specific method or methods to be employed in the construction of the sewers in or near the stream to control siltation.

During construction of sewerage projects, the contractor shall be prohibited by clauses in the specifications from 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.

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

Specifications shall require that cleanup, grading, seeding, planting or restoration of the work area shall be carried out as early as practical as the construction proceeds.

Uncased borings are not permitted.

The design engineer is encouraged to read and become familiar with the Tennessee Erosion and Sediment Control Handbook available from the Department.

2.4.3.3 Special Construction Requirements

Special design requirements shall be employed to prevent stream drainage from sinking at the crossing and following along the sewer pipe bedding. This can be accomplished with an in- trench impounding structure of compacted clay or other impermeable materials. Other proposals will be considered.

2.4.3.4 Aerial Crossings

Sewers laid on piers across ravines or streams shall be allowed when it can be demonstrated that no other practical alternative exists or, in the design engineers judgement, other methods will not be as reliable.

Support shall be provided for all joints. All supports shall be designed to prevent frost heave, overturning or settlement. Precautions against freezing, such as insulation or increased slope, shall be provided. Expansion jointing shall be provided between above-ground and below-ground sewers. The impact of flood waters and debris shall be considered. The bottom of the pipe should be placed no lower than the elevation of the fifty (50) year flood stage.

2.4.3.5 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 Pollution Control.

2.4.4 Inverted Siphons

Under normal conditions inverted siphons should not be used; but if they are, then the following conditions must be met:

Inverted siphons shall have a minimum of two barrels, with a minimum pipe size of six inches and shall be provided with necessary appurtenances for convenient flushing and maintenance. The manholes shall have adequate clearances for rodding. Sufficient head shall be provided and pipe sizes selected to secure velocities of at least 3.0 feet per second for average flows.

The inlet and outlet details shall be arranged so that the normal flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning. When inverted siphons are used,

the design engineer must furnish hydraulic calculations the plans. Proper access must be

maintained.

2.5 General Requirements for Pump Stations

2.5.1 Location and Flood Protection

Sewage pump stations should be located as far as practicable from present or proposed built-up residential areas, and an all-weather road should be provided. Noise control, odor control, and station architectural design should be taken into consideration. Sites for stations shall be of sufficient size for future expansion or addition, if applicable. The station site (larger stations) shall also be fenced and locked.

The station's operational components shall be located at an elevation that is not subject to the 100-year flood or shall otherwise be adequately protected against the 100-year flood damage.

Where the wet well is at a depth greater than the watertable elevation, special provisions shall be made to ensure water tight construction of the wet well. Any connections to the pump station should be made at an elevation higher than the maximum watertable elevation, where possible.

2.5.2 Pumping Rate and Number of Units

At least two pump units shall be provided, each capable of handling the expected maximum flow. Pump head and system head curves shall be submitted to the Department for review purposes.

Where three or more units are provided, they shall be designed to fit actual flow conditions and must be of such capacity that, with any one unit out of service, the remaining units will have capacity to handle the maximum sewage flow. The number of pump units may be controlled by the reliability classification of the adjacent receiving waters. See Chapter 1.3.11.3.

When the station is expected to operate at a flow rate less than one half the average design flow for an extended period of time, the design shall address measures taken to prevent septicity due to long holding times in the wet well.

Consideration should be given to the use of variable-speed or multiple staged pumps, particularly when the pump station delivers flow directly to a treatment plant, so that sewage will be delivered at approximately the same rate as it is received at the pump station.

2.5.3 Grit and Clogging Protection

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

For large pump stations (generally, larger than 1 MGD) handling raw sewage, consideration should be given to installation of readily accessible bar racks with clear openings not exceeding 2-1/2 inches, unless pneumatic ejectors are used or special devices are installed to protect the pumps from clogging or damage. Where the size of the installation warrants, a mechanically cleaned bar screen with grinder or comminution device is recommended. Where screens are

located below ground, convenient facilities must be provided for handling screenings. 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

Pumps shall be capable of passing spheres of at least 3 inches in diameter. Pump suction and discharge openings shall be at least 4 inches in diameter.

2.5.4.2 Priming

Pumps shall be so placed 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

Control float switches should be so located as not to be affected by the flows entering the wet well or by the suction of the pumps. Controls must be able to activate additional pumps if water in the wetwell continues to rise. Air-operated pneumatic controls are preferred for all sewage pump stations. Provisions should be made to automatically alternate the pumps in use. Pump stations with motors and/or controls below grade should be equipped with a secure external disconnect switch. If float switches are used, an "intrinsically safe" power source must be considered.

2.5.5 Flow Measurement

Suitable devices for measuring sewage flow should be provided at pumping stations with flow capacity greater than 1.0 million gallons per day (mgd). Hour timers (totalizers) shall be installed on all pumps unless otherwise approved by the Department.

2.5.6 Alarm System

An alarm system should be provided for all pumping stations. Consideration of telemetry alarm to 24-hour monitoring stations or telephone alarms to duty personnel should be given when reliability classification or property damage warrants it. When telemetry is not used, an audiovisual device should be installed at the station for external observation.

An alarm system may not be needed, in certain cases, where a utility has adopted a daily inspection routine. A statement from the utility, indicating that it has a daily inspection program, will be required. In certain cases, an alarm system may be required regardless of any other practices.

Alarms for high wet well and power failure shall be provided, as a minimum, for all pump stations. For larger stations, alarms signaling pump and other component failures or malfunctions should also be provided.

A backup power supply, such as a battery pack with an automatic switchover feature, should be provided for the alarm system, such that a failure of the primary power source

will not disable the alarm system. Test circuits should be provided to enable the alarm system to be tested and verified that it is in good working order.

2.5.7 Emergency Overflow Pumping

Regardless of the type of emergency power standby system provided, a riser from the force main with rapid connection capabilities and appropriate valving shall be provided for all lift stations to hook up portable pumps.

2.6 Special Details

2.6.1 General

2.6.1.1 Materials

In the selection of materials, consideration should be given to the presence of hydrogen sulfide and other corrosive gases, greases, oils, and other constituents frequently present in sewage.

2.6.1.2 Electrical Equipment

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

2.6.1.3 Water Supply

There shall be no physical connection between any potable water supply and a sewage pumping station which under any conditions might cause contamination of the potable water supply. If a potable water supply is brought to the station, it shall comply with conditions stipulated in section 2.4.2.

2.6.1.4 Lighting

Adequate lighting for the entire pump station shall be provided.

2.6.1.5 Pump and Motor Removal

Provisions shall be made to facilitate removing pumps, motors, and other equipment, without interruption of system service.

2.6.1.6 Access

Suitable and safe means of access should be provided to equipment requiring inspection or maintenance. Stairways and ladders shall satisfy all OSHA requirements. Consideration should be given to fencing pump stations to discourage the entrance of unauthorized persons.

2.6.1.7 Valves and Piping

Suitable shutoff valves shall be placed on suction and discharge lines of each pump for normal pump isolation. A check valve should be placed 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 pump station.

2.6.1.8 Ventilation

Ventilation should be provided for all pump stations during all periods when the station is manned. Where the pump is below ground, mechanical ventilation is required and should be arranged so as to independently ventilate the dry well. If screens or mechanical equipment, which might require periodic maintenance and inspection, are located in the wet well, then it should also be mechanically ventilated. There should be no interconnection between the wet well and the dry well ventilation systems. In pits over 15 feet deep, multiple inlets and outlets are desirable. Dampers should not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts should be avoided to prevent clogging. Switches for operation of ventilation equipment should be marked and conveniently located above grade and near the pump station entrance. Consideration should be given also to automatic controls where intermittent operation is used. The fan wheel should be fabricated from nonsparking material. In climates where excessive moisture or low temperature is a problem, consideration should be given to installation of automatic heating and/or dehumidifying equipment. Where heat buildup from pump motors may be a problem, consideration should be given to automatic ventilation to dissipate motor heat.

2.6.2 Wet Well - Dry Well Stations

2.6.2.1 Separation

Wet and dry wells, including their superstructures, should be completely separated.

Where continuity of pump station operation is necessary, consideration should be given to dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning.

2.6.2.2 Wet Well Size

The effective capacity of the wet well should be evaluated based on pumping requirements and reliability classifications.

2.6.2.3 Floor Slope

The wet well floor should have a minimum slope of 1-to-1 in the hopper bottom. The horizontal area of the hopper bottom should be no greater than necessary for proper installation and function of the inlet.

2.6.2.4 Ventilation

Wet well ventilation may be either continuous or intermittent. Ventilation, if continuous, should provide at least 12 complete air changes per hour; if intermittent, at least 30 complete air changes per hour. Such ventilation should be accomplished by introduction of fresh air into the wet well by mechanical means.

Dry well ventilation may be either continuous or intermittent. Ventilation, if continuous, should provide at least 6 complete air changes per hour; if intermittent, at least 30 complete air changes per hour.

Portable ventilation equipment is acceptable for small pump stations where occupancy is rare.

2.6.2.5 Dry Well Dewatering

A separate sump pump should be provided in the dry wells to remove leakage or drainage with the discharge above the high water level of the wet well. Water ejectors connected to a potable water supply will not be approved. 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 pump 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 pump 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

All suction lift pumps must be provided with an air relief line on the pump discharge piping. 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. Air relief piping shall be sized appropriately. A separate air relief line shall be provided for each pump discharge. The air relief line should terminate in the wet well or suitable sump and be open to the atmosphere.

b. Air Relief Valves

Air relief valves should be provided 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

Suction lift pumps should not be located 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. Continuity of operation of the other units should be maintained.

A hoist and accessories for removing the pumps from the wet well should be provided.

2.6.4.2 Controls

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

2.6.4.3 Valves

All control valves on the discharge line for each pump should be placed in a convenient location outside the wet well in separate pits and be suitably protected from weather and vandalism. Outside valve covers should not be installed.

2.6.4.4 Submergence

Positive provision, such as backup controls, should be made to assure submergence of the pumping units.

2.7 Operability and Reliability

2.7.1 Objective

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

2.7.2 Backup Units

A minimum of two pumps shall be provided in each station in accordance with section 2.5.2.

2.7.3 Emergency Power Supply

2.7.3.1 General

Provision of an emergency power supply for pumping stations (and treatment plants) should be made, and may be accomplished by connection of the station to at least two independent public utility sources, or by provision 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. See Chapter 1.3.11.5.

Emergency power shall 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 are less than 10 years, an evaluation of a similar area served by the power utility for 10 years would be appropriate.

2.7.3.2 In-Place Equipment

Where in-place internal combustion equipment is utilized, the following guidelines are recommended:

A. Placement

The unit should be bolted in place. Facilities should be provided for unit removal for purposes of major repair or routine maintenance.

B. Controls

Provision should be made for automatic and manual startup and cut-in.

C. Size

Unit size should be adequate to provide power for lighting and ventilating systems and such further systems that affect capability and safety as well as the pumps.

D. Engine Location

The unit internal combustion engine should be located above grade, with suitable and adequate ventilation of exhaust gases.

E. Underground Fuel Storage Tank

If the fuel tank for the generator is to be placed below ground level, 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.

2.7.3.3 Portable Equipment

Where portable equipment is utilized, the following guidelines are recommended:

Pumping units should have connections to operate between the wet well and the discharge side of station, and the station should be provided with permanent fixtures that will facilitate rapid and easy connection of lines. Electrical energy generating units should be protected against burnout when normal utility services are restored, and should have sufficient capacity to provide power for lighting and ventilating systems and any other station systems affecting capability and safety, in addition to the pumping units.

2.7.4 Storage

Where storage is provided in lieu of an emergency power supply, wet well and tributary main capacity above the high-level alarm should be 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 should be not less than 4 inches in diameter, except for grinder pumps, septic tank effluent or vacuum applications.

2.8.2 Velocity

At pumping capacity, a minimum self-scouring velocity of 2 feet per second (fps) should be maintained unless flushing facilities are provided. Velocity should not exceed 8 feet per second.

2.8.3 Air Relief Valve

An air relief valve shall be placed at the necessary high points in the force main to relieve air locking.

2.8.4 Termination

The force main shall 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 shall 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.

Consideration should be given to the use of inert materials or protective coatings for the receiving manhole to prevent deterioration as a result 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 shall contain appropriate requirements based on the criteria, standards, and requirements established by the industry in its technical publications. Requirements shall 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 ovalation of the pipe, nor seriously impair flow capacity.

All pipes shall be designed to prevent damage from superimposed loads. Proper allowance for loads on the pipe shall be made because of the width and depth of trench.

2.8.6 Pressure Tests

Before backfilling, all force mains shall be tested at a minimum pressure of at least 50 percent above the design operating pressure for at least 30 minutes. Leakage shall not exceed the amount given by the following formula:

$$L = \frac{ND(P)}{7,400}^5$$

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

Force mains shall be sufficiently anchored within the pump station and throughout the line length. The number of bends shall be as few as possible. Thrust blocks, restrained joints, and/or tie rods shall be provided where restraint is needed.

2.8.8 Friction Losses

A C factor shall be used that will take into consideration the conditions of the force main at its design usage. A pipe that is coated with grease after several years will not have the same C factor as it did when it was first placed into operation.

2.8.9 Water Hammer

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

Appendix 2C:

Sample Specifications

VACUUM TESTING OF MANHOLES

The method of vacuum testing manholes REQUIRES the use of the following criteria:

1. This method is applicable to all manholes.
2. All lifting holes and exterior joints shall be filled and pointed with non-shrink grout for concrete manholes or sealed with compatible sealant for other materials. The exterior of the manhole must be painted as the vacuum is being applied to seal the pores of the concrete.
3. Manholes are to be tested immediately after assembly or construction and before backfilling. No standing water shall be allowed in the manhole excavation which may affect the accuracy of the test.
4. All pipes and other openings into the manhole shall be suitably plugged in such a manner as to prevent displacement of the plugs while the vacuum is pulled.
5. Installation and operation of the vacuum equipment and indicating devices shall be in accordance with equipment specifications and instructions provided by the manufacturer.
6. The test head may be placed in the cone section of the manhole. The rim-cone is not usually tested.
7. A vacuum of 10.0 inches of mercury shall be drawn. The time for the vacuum to drop to 9.0 inches of mercury shall be recorded.
8. Acceptance for 4 ft. diameter manholes shall be defined as when the time to drop to 9 inches of mercury meets or exceeds the following:

MANHOLE DEPTH	DIAMETER	TIME TO DROP 1" HG
4 ft to 10 ft	4 ft	75 seconds
10 ft. to 15 ft.	4 ft.	90 seconds
15 ft. to 25 ft.	4 ft.	105 seconds

9. For manholes 5 ft. in diameter, add an additional 15 seconds and for manholes 6 ft. in diameter, add an additional 30 seconds to the time requirements for four foot diameter manholes.
10. If the manhole fails the test, necessary repairs shall be made and the vacuum test repeated until the manhole passes the test.
11. If the manhole joint mastic or gasket is displaced during the vacuum test, the manhole shall be disassembled and the seal replaced.

Appendix 2C

Appendix- 2-A
Table for
DESIGN BASIS FOR NEW SEWAGE WORKS

Discharge Facility	Design Units	Flow (gpd)	BOD (lb/day)	TSS (lb/day)	Flow Duration (hr)
Dwellings	per person	100	0.17	0.2	24
School with showers and cafeteria	per person	16	0.04	0.04	8
School without showers and with cafeteria	per person	12	0.025	0.025	8
Boarding School	per person	75	0.2	.2	16
Motels at 65 gal/person (rooms only)	per person	130	0.26	.26	16
Trailer courts at 3 persons/trailer	per trailer	225	0.6	0.6	24
Restaurants	per seat	40	0.2	0.2	16
Interstate or through highway restaurants	per seat	180	0.7	0.7	16
Interstate rest areas	per person	5	0.01	0.01	24
Service stations	per vehicle serviced	10	0.01	0.01	16
Factories	per person per 8 hr shift	25	0.05	0.05	Operating Period
Shopping center (no food)	per 1,000 sq. Ft. Of ultimate floor	150	0.01	0.01	12
Hospitals	per bed	300	0.6	0.6	24
Nursing home (add 75 gals for laundry)	per bed	120	0.3	0.3	24
Homes for the Aged	per bed	60	0.2	0.2	24
Child Care Center	per child and adult	10	0.01	0.01	Operating period
Laundromats, 9 to 12 machines	per machine	250	0.3	0.3	16
Swimming pools	per swimmer	10	0.001	0.001	12
Theaters, auditorium type	per seat	5	0.01	0.01	12
Picnic areas	per person	5	0.01	0.01	12
Resort camps, day & night with limited plumbing	per campsite	50	0.05	0.05	24
Luxury camps with flush toilets	per campsite	100	0.1	0.1	24
Churches (no kitchen)	per seat	3	.005	0.005	Operating period

*** Includes normal infiltration**

Note: In all cases use actual data from similar facilities when possible. Note variations due to factors such as age, water conservation, etc. Submit all design data used.

Hydrolic Design Criteria

[illegible]

Appendix 2-A
Table for
DESIGN BASIS FOR NEW SEWAGE WORKS

Discharge Facility	Design Units	Flow (gpd)	BOD (lb/day)	TSS (lb/day)	Flow Duration (hr)
Dwellings	per person	100	0.17	0.2	24
Schools with showers and cafeteria	per person	16	0.04	0.04	8
Schools without showers and with cafeterias	per person	12	0.025	0.025	8
Boarding Schools	per person	75	0.2	0.2	16
Motels at 65 gal/person (rooms only)	per person	130	0.26	0.26	16
Trailer courts at 3 persons/trailer	per trailer	225	0.6	0.6	24
Resturants	per seat	40	0.2	0.2	16
Interstate or through highway resturants	per seat	180	0.7	0.7	16
Interstate rest areas	per person	5	0.01	0.01	24
Service stations	per vehicle serviced	10	0.01	0.01	16
Factories	per person per 8-hr shift	25	0.05	0.05	Operating Period
Shopping centers (no food)	per 1000 sq. ft. of ultimate floor	150	0.01	0.01	12
Hospitals	per bed	300	0.6	0.6	24
Nursing home (add 75 gal for laundry)	per bed	120	0.3	0.3	24
Homes for the Aged	per bed	60	0.2	0.2	24
Child care center	per child and adult	10	0.01	0.01	Operating Period
Laundrymats, 9 to 12 machines	per machine	250	0.3	0.3	16
Swimming pools	per swimmer	10	0.001	0.001	12
Theaters, auditorium type	per seat	5	0.01	0.01	12
Picnic areas	per person	5	0.01	0.01	12
Resort camps, day & night with limited pluimbing	per campsite	50	0.05	0.05	24
Luxury camps with flush toilets	per campsite	100	0.1	0.1	24
Churches (no kitchen)	per seat	3	0.005	0.005	Operating Period

* Includes normal infiltration

Note: In all cases use actual data from similar facilities when possible. Note variations due to factors such as age, water conservation ect. Submit all design data used.

Appendix 2a

CHAPTER 3

Laboratory, Personnel, Maintenance Facilities and Safety Design

3.1 General

3.2 Laboratory Facilities

- 3.2.1 General
- 3.2.2 Space Requirements
- 3.2.3 Design

- 3.2.3.1 Location
- 3.2.3.2 Layout

3.3 Personnel Facilities

3.4 Maintenance Facilities

- 3.4.1 Maintenance Shop
- 3.4.2 Storage Requirements
- 3.4.3 Yard Requirements

3.5 Safety Design

Appendix 3-A On-site Checklist

LABORATORY, PERSONNEL, MAINTENANCE FACILITIES & SAFETY DESIGN

3.1 General

Suggested considerations are presented in this chapter for laboratory, personnel, maintenance facilities, and safety. If testing is contracted out (particularly for lagoon systems) minimal maintenance facilities will only be required.

3.2 Laboratory Facilities

3.2.1 General

A guide to provision of laboratory facilities is the EPA publication Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA-430/9-74-002.

Lab work involves a significant portion of a small facility's work tasks. Each facility should estimate work tasks by obtaining the following documents:

- a. "Minimum sampling schedule" should be obtained from the Permit Section of the Division of Water Pollution Control, containing compliance parameters from NPDES Permit as well as operation test.
- b. List of Approved Analytical Procedures. See Code of Federal Regulations (CFR), June 30, 1986, pp. 23693-23700 for lab methods and preservation procedures for NPDES data.
- c. Tennessee "Lab Manual" 1986. Contact the Julian Fleming Training Center in Murfreesboro.
- d. Tennessee "Laboratory Equipment and Supplies for Wastewater Treatment Plants." Contact the Julian Fleming Training Center in Murfreesboro.

3.2.2 Space Requirements

Specific laboratory facilities should be based on the needs of the treatment plant. Minimum suggested space for one MGD facilities is:

Floor space of 200 sq. ft.

Percent of floor space required for bench area is 40%

Cabinet volume of 200 cubic foot.

These figures apply to a typical treatment plant monitoring program. If laboratory testing will be performed for other sources, such as industrial discharges, receiving waters, and sewer overflows, appropriate space increases should be provided. If some of the plant monitoring tests are performed at other facilities, the space required could be significantly less.

3.2.3. Design

The following factors should be key considerations in design of plant laboratories:

Flexibility, which provides for changes in use requirements

Adaptability, for changes in occupancy requirements

Expandability, for changes in space requirements

3.2.3.1 Location

The laboratory should be located at ground level and easily accessible to all sampling points. To assure sufficient environmental control, the laboratory should be located away from vibrating machinery, corrosive atmospheres, or equipment which might have adverse effects on the performance of laboratory instruments or the analyst.

3.2.3.2 Layout

New lab layouts should be modeled after proven exemplary layouts. Efficient laboratory operation depends largely on the physical layout of the laboratory. The physical layout includes items such as working area arrangement, the number and location of sinks and electrical outlets, the arrangement of laboratory equipment, materials of construction, and lighting. The details of the layout can affect the accuracy of the laboratory tests. For example, tests that include identification of a colorimetric end point, as in heavy metals determinations, can be drastically affected by the type of lighting and the finishes on laboratory facilities.

The following factors should be considered when laying out a laboratory:

- a. A northern exposure is preferred for colorimetric analysis.
- b. Adequate lighting should be provided. Color-corrected fluorescent lighting is suggested.
- c. Wall and floor finishes should be nonglare-type and light in color. Flat-finish wall paint is suggested. Floor finishes should be of a single color for ease of locating small items that have been dropped.
- d. Floor covering, in addition to being nonglare, should be easy to clean and comfortable.
- e. Doors shall have large glass windows for visibility into and out of the laboratory. There should be no obstructions near the doors.
- f. Aisle width between work benches should be at least 4 feet. Adequate spacing should be provided around free-standing equipment, workbenches, and file cabinets to facilitate cleaning.
- g. Storage space for reagent stock should be under workbenches. Reagent containers removed from storage areas under workbenches are less likely to be dropped than reagent containers removed from storage in the inconvenient and hard-to-reach areas above the workbenches. Only items that are infrequently used or chemicals of a nonhazardous nature should be stored above workbenches. Strong acids or bases should be stored within convenient reach of the laboratory personnel, preferably beneath or adjacent to the fume hood.
- h. Sufficient cabinet and drawer space should be provided for the storage of equipment and supplies. Wall cabinets should be no more than 30 inches above the workbench top so that the contents of the top shelving can be reached. The base cabinets under the

workbenches should contain a combination of drawers and storage spaces for large items. All cabinets and drawers should be acid resistant.

- i. One sink with a large gooseneck faucet, large enough to wash laboratory equipment, should be provided for every 25 to 30 feet of bench length. One sink should be sufficient when total bench length is less than 25 feet. The sink should be made of chemical-resistant material.

Cup sinks, also of chemical-resistant material, should be provided at strategic locations on the bench surface to facilitate laboratory testing. The number of cup sinks depends largely on the type of tests that will be run; the general rule is one cup sink for every 25 to 30 feet of bench length. Cup sinks should be alternated with the wash sinks at 12- to 15-foot intervals.

Where workbench assemblies are provided in the center of the laboratory, a trough-type sink down the center of the workbench may be provided in lieu of cup sinks. A hot and cold water tap should be placed at approximately every 5 to 10 feet along the trough.

The use of an automatic dishwasher should be considered. Where dishwashers are provided, some of the sinks can be replaced by cup sinks.

- j. Electrical receptacles should be provided at strategic points for convenient and efficient operation of the laboratory. Duplex-type receptacles should be spaced at intervals along benches used for laboratory tests. Strip molding receptacles may be used. All receptacles must be elevated to prevent spills from entering the receptacles.
- k. Gas and vacuum fixtures should be provided at convenient locations.
- l. Bench tops should be suitable for heavy-duty work and resistant to chemical attack. Resin-impregnated natural stone and other manmade materials provide such a surface and should be used.
- m. Bench surfaces should be approximately 36 inches high for work done from a standing position and 30 inches high for work done while sitting.
- n. Bench surfaces should be approximately 30 inches wide.
- o. Equipment arrangement should be given special consideration in laying out the laboratory facility in conjunction with the facility's owner and operators. Plumbing, and/or electrical connections should be provided for units such as the distillation apparatus, drying ovens or other wall-mounted equipment. Pieces of equipment used for making common tests should be in proximity. For example, the drying oven used in making total, suspended, and dissolved solids tests should be close to the muffle furnace for use in determining total volatile solids and volatile suspended solids from the samples dried in the drying oven. The drying oven and the muffle furnace should be near the balance table because the balance is used in the weight determinations for the various solids tests.

- p. Safety is a prime consideration of a laboratory. The first aid kit, fire extinguisher, eye wash, and emergency shower should be near the main working area of the laboratory. If the safety shower is not provided in a separate shower stall, a floor drain should be nearby.
- q. Sources of loud or startling noises, such as alarms or composite sampling equipment, should be located at sites remote or otherwise isolated from the laboratory.
- r. The analytical balance should be on a separate table at least 30 inches long and 24 inches deep. The table should not transmit vibrations that would adversely affect the operation of the balance.
- s. A separate table is desirable for microscopes. This table should be about 30 inches long, 24 inches deep, and 27 inches high.
- t. Fume hoods, if provided, should be near the area where most laboratory tests are made.
- u. All labs which run BOD₅ require air-conditioning to achieve a sufficiently high, stable D.O. in the dilution water. Laboratories should be separately air-conditioned, with external air supply for 100-percent makeup volume. Separate exhaust ventilation should be provided. Window air-conditioning should not blow directly on the analytical balance or furnaces.
- v. Panic hardware should be provided for doors opening to the outside to allow for rapid exiting in an emergency.

3.3 Personnel Facilities

Personnel facilities are generally located in the administration building. This building serves the needs of the supervisory staff, the operation and maintenance personnel, and often the laboratory staff. Sewer maintenance personnel may also share the administration building. However, facilities for the laboratory and operations and maintenance staff need not be provided in the administration building, even though this is customary.

A wastewater treatment plant staffed for 8 hours or more each day should contain support facilities for the staff. Toilets shall be provided in conformance with applicable building codes. The following should be provided:

- a. Wash-up and changing facilities: Showers, lockers, sinks, and toilets sufficient for the entire staff at design conditions. A heated and ventilated mudroom is desirable for changing and storage of boots, jackets, gloves, and other outdoor garments worn on the job. Each staff member should have separate lockers for street clothes and plant clothes. Separate wash-up and changing facilities should be available for men and women, with the exception of the mudroom.
- b. Eating Facilities: A clean, quiet area with facilities for storage and eating of light meals.
- c. Meeting facilities: A place to assemble the plant staff and visitors. In many cases, meeting facilities and the eating facilities will be the same.
- d. Supervisors' facilities: A place where discussion and writing can be carried out in private. A desk station should be provided for data entry.

Facilities should be provided for the storage of analytical methods and records, catalogs, as-built plans, operation and maintenance manual(s), etc.

Small mechanical treatment plants that are not manned 8 hours per day need not contain all of the personnel facilities required for larger plants, but shall contain a lavatory, and a storage area.

3.4 Maintenance Facilities

To assure adequate maintenance of equipment, convenient maintenance facilities should be available. Such facilities generally include a maintenance shop, a garage, storage space, and yard maintenance facilities.

Access to nearby municipal garages and other maintenance centers should be considered. Duplication of facilities should be avoided where possible.

3.4.1 Maintenance Shop

A separate maintenance shop should be designated where treatment plant equipment and vehicles can be repaired. The maintenance shop should be provided with the following facilities:

- a. Work space with adequate area and lighting, including a workbench with vise.
- b. Conveyances to move heavy items from the point of delivery to the appropriate work space.
- c. Storage for small tools and commonly used spare parts.
- d. Adequate power outlets and ratings for the equipment.

3.4.2 Storage Requirements

Storage space should be provided for paints, fuels, oils and lubricants, grounds maintenance equipment, spare parts, and collection system equipment.

In larger facilities, it may be desirable to have a separate storage building for things such as paints, fuel, oils and lubricants, spare parts, and yard supplies. For storage of flammable materials, the requirements of the uniform building code shall be met. In smaller facilities, it might be desirable to combine storage with the shop or garage so that the stored material can be protected against unauthorized use.

Where underground tanks are to be used to store controlled substances, the Division of Ground Water Protection shall be contacted regarding Underground Storage Tank (UST) requirements.

3.4.3 Yard Requirements

A landscaped yard helps to soften the visual impact of a treatment facility. Shrubs and trees judiciously located can screen unsightly areas from public view. Care must be taken that the plantings do not become a hindrance to operation. Deciduous leaves falling in clarifiers can hinder skimming and add unnecessarily to the digester loading. Roots from trees too close to pipes can cause clogging. Fencing should be adequate to prevent unauthorized or unattended entry.

3.5 Safety Design

The field of wastewater treatment has always been one of the most hazardous fields of employment. This fact is accented by job-related deaths and accidents which happen each year. Safety designs are needed which should be supplemented by yearly inspections to gain awareness.

Adequate provisions shall be included in the design of all wastewater treatment facilities to minimize exposure of facility personnel and visitors to safety hazards. Treatment facilities shall be designed in full compliance with the Occupational Safety and Health Standards of the State of Tennessee, Division of Occupational Safety and Health (TOSHA).

Pertinent safety design requirements as well as safety design practices are included in the attached on-site checklist for wastewater treatment plants (Appendix 3-A).

To gain awareness each operator should have other safety resources such as:

- 1.) Safety & Health in Wastewater Systems (MOP-1 by WPCF)
- 2.) Individual safety manual adopted by each plant's safety committee.
- 3.) Safety meetings with city.

Any unsafe practices or incidents should be reported to TOSHA and each facility's safety committee. As a last resort, complaints can be made anonymously by the operator or any other concerned citizen.

Appendix 3-A

On-Site Checklist

STANDARD SAFETY

1. Personnel Protective Clothing:
 - a. Safety helmets (for operators and visitors)
 - b. Ear protectors for high noise areas
 - c. Goggles
 - d. Gloves
 - e. Rubber boots with steel toes

2. Safety Devices Available for Use:
 - a. Non-sparking tools in areas where flammable or explosive gases may be present
 - b. Fire extinguishers readily available
 - c. Oxygen deficiency/explosive gas indicator
 - d. Self-contained breathing apparatus near entrance to chlorine room, away from fan discharge
 - e. Safety harness
 - f. First aid kits readily available
 - g. Ladders to enter manholes or wetwells (fiberglass or wooden for around electrical work)
 - h. Traffic control cones
 - i. Safety buoy at activated sludge plants
 - j. Live preservers for around lagoons
 - k. Portable crane/hoist

3. General Plant Safety:
 - a. Railing around all tanks, with openings chained off
 - b. No uncovered pits or wells
 - c. Explosion-proof fixtures, where needed
 - d. Equipment guards in place

- e. Emergency telephone numbers posted
 - f. Proper flammable liquid storage
 - g. Covered trash cans
 - h. Ladders have safety cages or equipped with safety slide rail
 - i. Portable hoists for equipment removal; e.g., pumps, aeration equipment
4. Are plant personnel immunized for typhoid and tetanus?
5. No cross connections exist between a potable water supply and a non-potable source:
- a. Pump and mixer seals
 - b. Digester heating system make-up water
 - c. Vacuum filter water sprays
 - d. Chemical mixing tank
 - e. Chlorinator water source
 - f. Yard hydrants
 - g. Properly installed backflow preventers
6. If anaerobic digesters are used, are the following present?:
- a. Pressure/vacuum relief valves
 - b. "No smoking" signs
 - c. Explosimeter
 - d. Drip trap
 - e. Flame traps within 25' of the flame source
7. Electrical Safety:
- a. All electrical circuitry enclosed and identified
 - b. Electrical test equipment available, such as a voltmeter and amperage meter
 - c. Rubber mats present for electrical work
 - d. The personnel are familiar with the electrical work to be performed
 - e. All personnel are trained in electrical safety, such as lockout procedures

- f. Warning and/or caution signs present
 - g. Rubber gloves available
 - h. Ground fault interrupter used
8. Chlorine Safety:
- a. NIOSH-approved self-contained 30 minute air pack
 - b. All standing chlorine cylinders are chained in place
 - c. All personnel are trained in the use of chlorine
 - d. Chlorine repair kit is available
 - e. Chlorine leak detector tied into the plant alarm system
 - f. Ammonia for checking chlorine leaks is present
 - g. Ventilator fan with an outside switch is present
 - h. Safety precautions posted
 - i. Doors open outward and are equipped with "panic" hardware
9. Process Chemical Safety:
- a. Respirator to protect the operator against dust inhalation, when needed
 - b. All personnel are trained to handle the chemicals properly
 - c. Proper safety clothing for the chemical to be handled, such as rubber aprons, boots and gloves for handling ferric chloride
 - d. Has complied with the Tennessee Department of Labor, Hazardous Chemical Right To Know Law, T.C.A. 50-3-2001 thru 2019.
 - e. Emergency Action Plan on file with local Fire Department and appropriate Emergency Agency
 - f. Containment of chemical storage areas, including curbing and floor drains to appropriate areas
10. Laboratory Safety:
- a. Eye wash and shower station is present
 - b. Fume hood is present
 - c. All chemicals properly labeled and stored
 - d. Laboratory safety devices such as pipette suction bulbs

INNOVATIVE SAFETY

1. Warning Signs:
 - a. Non-potable water
 - b. Chlorine hazard
 - c. No smoking
 - d. High Voltage
 - e. "Watch your step" signs in certain areas
 - f. Exit signs
 - g. Piping signs
2. Safety programs
3. Operators provided with a shower and a locker for their work clothes
4. Are the operators trained in first aid and CPR?

CHAPTER 4

Preliminary and Pretreatment Facilities

4.1 Screening and Grinding

- 4.1.1 General
- 4.1.2 Location
- 4.1.3 Bar Screens
- 4.1.4 Fine Screens
- 4.1.5 Communion
- 4.1.6 Operability
- 4.1.7 Disposal

4.2 Grit Removal

- 4.2.1 General
- 4.2.2 Location
- 4.2.3 Design
- 4.2.4 Disposal
- 4.2.5 Operability

4.3 Pre-aeration

4.4 Flow Equalization

- 4.4.1 General
- 4.4.2 Location
- 4.4.3 Design and Operability

4.5 Swirls and Helical Bends

PRELIMINARY AND PRETREATMENT FACILITIES

4.1 Screening and Grinding

4.1.1 General

Some type of screening and/or grinding device shall be provided at all mechanical wastewater plants. The effective removal of grit, rocks, debris, excessive oil or grease and the screening of solids shall be accomplished prior to any activated sludge process. Any grinding which does not dispose of the shredded material outside of the wastewater stream must be evaluated with regard to the influent characteristics (rags, combined sewers) of the waste prior to any activated sludge process.

4.1.2 Location

4.1.2.1 Indoors

Screening devices installed in a building where other equipment or offices are located shall be accessible only through an outside entrance. Adequate lighting, ventilation and access for maintenance or removal of equipment and screenings shall be provided.

4.1.2.2 Outdoors

The removal point for screenings should be as practical as possible for the plant personnel, preferably at ground level. Ladder access is not acceptable unless hoisting facilities for screenings are provided. Separate hoisting is not required for bar screens in manual bypass channels.

4.1.2.3 Deep Pit Installations

Stairway access, adequate lighting and ventilation with a convenient and adequate means for screenings removal shall be provided.

4.1.3 Bar Screens

4.1.3.1 Manually Cleaned

Clear openings between bars shall be from 1 to 2 inches. Slope of the bars shall be 30 to 60 degrees from the vertical. Bar size shall be from 1/4 to 5/8 inches with 1 to 3 inches of depth, depending on the length and material to maintain integrity. A perforated drain plate shall be installed at the top of the bar screen for temporary storage and drainage.

4.1.3.2 Mechanically Cleaned

Mechanically cleaned bar screens are recommended for all plants greater than 1 MGD. Both front cleaned or back cleaned models may be acceptable. Clear openings no less than 5/8 inch are acceptable. Protection from freezing conditions should be considered.

Other than the rakes, no moving parts shall be below the water line.

4.1.3.3 Velocities

Approach velocities no less than 1.25 fps nor a velocity greater than 3.0 fps through the bar screen is desired.

4.1.4 Fine Screens

4.1.4.1 General

Fine screens shall be preceded by a trash rack or coarse bar screen. Comminution shall not be used ahead of fine screens. A minimum of two fine screens shall be provided, each capable of independent operation at peak design flow. The design engineer must fully evaluate a proposal where fine screens are to be used in lieu of primary sedimentation. Fine screens shall not be considered equivalent to primary sedimentation or grit removal, but will be reviewed on a case-by-case basis. Oil and grease removal must be considered.

4.1.4.2 Design

The operation should be designed to not splash operating personnel with wastewater or screenings. Fine screens will generally increase the dissolved oxygen content of the influent which may be beneficial in certain circumstances. The screens must be enclosed or otherwise protected from cold weather freezing conditions. Disposal of screenings must be addressed. To be landfilled, screenings must be dried to approximately 20% solids. Odors may be a problem in sensitive locations.

4.1.5 Comminution

4.1.5.1 General

In-line comminution may not be acceptable prior to an activated sludge process for facilities with a history of problems with rags. Out-of-stream comminution or disintegration is acceptable for activated sludge processes; however, screenings should not return to the wastewater stream.

4.1.5.2 Design

A coarse bar screen with an automatic bypass shall precede comminution for all mechanical plants. Gravel traps shall precede comminution which is not preceded by grit removal. Clear openings of 1/4 inch are preferred in the comminution device. An automatic unit bypass or other means of protection shall be provided to protect the comminutor motor from flooding. The design shall incorporate a method for removing the equipment from service and for repairs or sharpening of the teeth.

4.1.6 Operability

All screening devices shall have the capability of isolation from the wastewater stream. Sufficient wash water shall be available for cleanup of the area. All mechanical screening devices shall be provided with a manually cleaned bar screen bypass. Multiple bar screens should be considered for plants with rag problems instead of comminutors.

Adequate space must be provided for access to each screening or comminution device. This is critical in elevated, indoor or deep pit installations.

4.1.7 Disposal

All screenings shall be disposed of in an approved manner. Suitable containers shall be provided for holding the screenings. Run-off control must be provided around the containers, where applicable. If fine screens are proposed, consideration must be given to the wastewater overflow if the screens clog or blind. Overflows must be contained and bypassed around the screens by dikes or other means.

4.2 Grit Removal

4.2.1 General

Grit removal is recommended for all mechanical wastewater plants and is required in duplicate for plants receiving wastewater from combined sewers. Systems with a history of substantial grit accumulations may be required to provide for grit removal. Where a system is designed without grit removal facilities, the design shall allow for future installation by providing adequate head and area. Grit washing may be required.

4.2.2 Location

Wherever circumstances permit, grit removal shall be located prior to pumps and comminution when so equipped. Bar screens shall be prior to grit removal. Adequate lighting, ventilation and access for maintenance and removal of grit shall be provided. Stairway access is required if the chamber is above or below ground level. Adequate and convenient means of grit removal shall be provided.

4.2.3 Design

4.2.3.1 Channel Type

A controlled velocity of one foot per second is recommended. Control by either suture or proportional weir should be used. If a Parshall flume is used for control, the grit chamber must be designed to approach a parabolic cross-section. The length of the channel depends on the size of grit to be removed. The design engineer shall provide this information. Inlet and outlet turbulence must be minimized.

4.2.3.2 Square Type

Square-type basins or similar arrangements should be sized for an overflow rate of 46,300 (WPCF) gallons per day per square foot at the peak flow based on 65-mesh grit at a specific gravity of 2.65. Other overflow rates may be used when the design incorporates particle travel distance and detention. Inlet and outlet turbulence must be minimized.

4.2.3.3 Aerated Type

Aerated grit chambers shall be designed on the basis of detention and/or particle travel distance. Detention time of 2-5 minutes at peak flow is acceptable. Control of the air shall be provided for flexibility. Skimming equipment must be provided in the aerated grit chamber if the outlet is below the water surface.

4.2.3.4 Other Types

Cyclone or swirl-type grit removal processes may be acceptable. The design engineer will be expected to provide a complete treatment analysis for approval.

4.2.4 Disposal

Temporary storage containers shall be provided to hold the grit. Run-off control shall be provided. Attention should be given to operations which may splash waste or grit on operating personnel. Grit washing is required before removal to drying beds. If not washed, the grit shall be disposed of in an approved landfill.

4.2.5 Operability

Adjustable control valves shall be included in each diffuser air line to control mixing and particle segregation. Variable speed arrangements should be provided in cyclone or mechanical type systems. Provisions shall be made for isolation and dewatering each unit or units.

4.3 Pre-Aeration

Pre-aeration is desirable in certain instances, such as to reduce septicity. Pre-aeration may be required where pressure or small diameter collection systems are used. Long detention times in pump stations or collection lines should also be considered. Units shall be designed so that removal from service will not interfere with normal plant operations.

4.4 Flow Equalization

4.4.1 General

Equalization may be used to minimize random or cyclic peaking of organic or hydraulic loadings when the total flow is ultimately processed through the plant. Either in-line or side-line equalization is acceptable. Equalization may be required where peak flows are greater than 2 times the average design flow.

4.4.2 Location

Tanks are generally located after screening and grit removal. Care should be taken in design to minimize solids deposition if located upstream of primary clarifiers. Equalization downstream of primary clarifiers should be investigated, as primary clarifier performance is less sensitive to flow peaking when compared to other processes. Other locations will be evaluated on a case-by-case basis.

4.4.3 Design and Operability

Generally, aeration will be required. Minimum requirements are to maintain 1.0 mg/l of dissolved oxygen. Odor consideration must be addressed when a plant is located in a sensitive area or large equalization basins are used. Large tanks must be divided into compartments to allow for operational flexibility, repair and cleaning. Each compartment shall be capable of dewatering and access. In plant upgrades, existing units which are otherwise to be abandoned may be used for equalization, where possible. Sizing the tankage and compartments will depend on the intended use; i.e., when equalization is for periodic high organic loadings, peak flow events, toxics, etc. A complete analysis shall accompany all engineering report (or plan)

submission. The tank must be capable of being drained and isolated.
Controlling the flow rate from the equalization tank to the plant is desirable.

4.5 Swirls and Helical Bends

General

These units are not to be used in lieu of primary clarification unless special design considerations are used. They are primarily designed for 'coarse' floating and settleable solids removal and will be considered only on a case-by-case basis for in-plant processes. They will, however, be approved for replacing regulators in combined sewer systems, as an interim measure until separation of the sanitary and storm flows is completed. Treatability studies will be required as part of the design. A separate NPDES permit will be required for each of these units that will discharge to a surface water.

CHAPTER 5

Clarifiers

5.1 General Criteria

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- 5.1.2 Number of Units
- 5.1.3 Arrangements
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5.5 Protective and Service Facilities

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- 5.6.3 Unit Dewatering
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- 5.6.5 Sludge Removal
- 5.6.6 Other Design Considerations

CLARIFIERS

5.1 General Criteria

5.1.1 Purpose

Clarifiers (sedimentation basins, settling tanks) are designed to perform three (3) functions in a treatment scheme:

- A. Remove solids from liquids by sedimentation
- B. Remove scum from liquid by flotation
- C. Thicken solids for removal and further treatment

Specific application of clarifier functions will be dependent upon the treatment process employed. This chapter does not attempt to set criteria for all types of clarifiers. If a unique clarifier is proposed, the design engineer shall submit operational and design data justifying its use.

5.1.2 Number of Units

Multiple units capable of independent operation shall be provided in all facilities where design flows exceed 250,000 gallons per day. Otherwise, the number of units required shall satisfy reliability requirements (see Section 1.3.11). Facilities not having multiple units shall include other methods to assure adequate operability and flexibility of treatment.

5.1.3 Arrangements

Clarifiers shall be arranged for greatest operating and maintenance convenience, flexibility, economy, continuity of maximum effluent quality, and ease of installation of future units.

5.1.4 Tank Configurations

Consideration should be given to the probable flow pattern in the selection of tank size and shape and inlet and outlet type and location.

5.1.5 Flow Distribution

Effective flow measuring devices and control appurtenances (i.e., valves, gates, splitter boxes, etc.) shall be provided to permit proper proportion of flow to each unit (see Section 13.2.1).

5.2 Design Loading

5.2.1 Primary Clarifiers

Primary clarifier designs are primarily based upon surface overflow rate. The following criteria are recommended for design:

Hydraulic Loading Rate

Average Design Flow
Peak Design Flow

Surface Overflow Rate

800-1200 gpd/sq. ft.
2000-3000 gpd/sq. ft.

If WAS is returned to the primary then

Hydraulic Loading Rate

Surface Overflow Rate

Average Design Flow	600-800 gpd/sq. ft.
Peak Design Flow	1200-1500 gpd/sq. ft.

Primary clarifier sizing shall be calculated for both flow conditions and the larger surface area derived shall be utilized. A properly designed primary clarifier should remove 30 to 35% of the influent BOD. However, anticipated BOD removal for wastewater containing high quantities of industrial wastewater should be determined by laboratory tests and considerations of the quantity and characteristics of the wastes.

5.2.2 Intermediate Clarifiers

Surface overflow rates for intermediate clarifiers should be based upon the following criteria:

<u>Hydraulic Loading Rate</u>	<u>Maximum Surface Overflow Rate</u>
Average Design Flow	1000 gpd/sq. ft.
Peak Design Flow	2500 gpd/sq. ft.

5.2.3 Final Clarifiers

Final clarifier designs shall be based upon the type of secondary treatment application used. Surface overflow and solids loading rates shall be the general basis for clarifier designs. Pilot studies of biological treatment is recommended when unusual wastewater characteristics are evident or when the proposed loading exceeds those noted in this section.

Table 5-1 depicts the criteria established for final clarifier surface overflow and solids loading rates. In activated sludge systems, the surface overflow rate for final clarifiers should be based on influent wastewater flows and not include return activated sludge flows (RAS). Solids loading rate criteria assume sludge recycle is 100% of the average design flow and the design mixed liquor suspended solids (MLSS) concentration.

TABLE 5-1
FINAL CLARIFIER DESIGN PARAMETERS

<u>Type of Process</u>	<u>Maximum Surface Overflow Rate</u> <u>gpd/sq. ft.</u>		<u>Solids Loading Rate</u> <u>lb/day/sq. ft.</u>	
	<u>Average Flow</u>	<u>Design Peak Flow</u>	<u>Average Flow</u>	<u>Design Peak Flow</u>
Trickling Filter	600	1200	25	40
Activated Sludge	800 (600 for plants less than 1 MGD)	1200	30	50
Extended Aeration 35	400	1000	25	
Nitrification 35	400	800	25	
Pure Oxygen 40	700	1200	25	

5.2.4 Weir Loading Rates

Weir loadings should not exceed 15,000 gallons per day per linear feet (gpd/li ft).

5.2.5 Depth/Detention Time

The sidewater depth (SWD) for clarifier designs associated with design surface overflow rates should dictate the hydraulic detention time of the clarifier. For design purposes, the following criteria in Table 5-2 are established specific to clarifier application:

TABLE 5-2
CLARIFIER DEPTH

<u>Type of Process</u>	<u>Diameter (ft)</u>	<u>Minimum Sidewater Depth (ft)</u>
*Primary	-	8
Trickling Filter	-	10
**Activated Sludge	less than 40	11
	40 - 70	12
	71 - 100	13
	101 - 140	14
	over 140	15

*The hydraulic detention time in primary clarifiers is not recommended to be greater than 2.5 hours as a function of the surface overflow rate and SWD, since septic conditions resulting in poor performance and odor conditions can occur.

**For rectangular-shaped clarifiers following activated sludge treatment, the recommended SWD shall be no less than 12 feet at the shallow end.

5.3 Design Details

5.3.1 Inlets

Inlets should be designed to dissipate the influent velocity, to distribute the flow equally in both the horizontal and vertical vectors, and to prevent short-circuiting. Channels should be designed to maintain an inlet velocity of at least one (1) foot per second at one-half the design flow. Corner pockets and dead ends should be eliminated and corner fillets or channeling used where necessary. Provisions shall be made for elimination or removal of floating materials in inlet structures having submerged ports.

5.3.2 Submerged Surfaces

The tops of troughs, beams, and similar submerged construction elements shall have a minimum slope of 1.75 vertical to 1 horizontal. The underside of such structures should have a slope of 1 to 1 to prevent accumulation of scum and solids.

5.3.3 Weir Troughs

Weir troughs shall be designed to prevent submergence at maximum design flow, and to maintain a velocity of at least one (1) foot per second at one-half design flow.

5.3.4 Freeboard

Walls of clarifiers shall extend at least six (6) inches above the surrounding ground surface and shall provide not less than twelve (12) inches of freeboard.

5.4 Sludge and Scum Removal

5.4.1 Scum Removal

Effective scum collection and removal facilities, including baffling ahead of the outlet weirs, shall be provided for all clarifiers. Provisions may be made for discharge of scum with sludge; however, other provisions may be necessary to dispose of floating materials which may adversely affect sludge handling and disposal. The unusual characteristics of scum which may adversely affect pumping, piping, sludge handling and disposal, should be recognized in the design. Scum piping should be glass lined or equivalent. Precautions should be taken to minimize water content in the scum.

5.4.2 Sludge Removal

Sludge collection and withdrawal facilities shall be designed to assure rapid removal of the sludge. Provisions shall be made to permit continuous sludge removal from settling tanks. Final clarifiers in activated sludge plants shall be provided with positive scraping devices. Suction withdrawal should be provided for activated sludge plants designed for the reduction of nitrogenous oxygen demand.

5.4.3 Sludge Removal Piping

Each sludge hopper shall have an individually valved sludge withdrawal line at least six (6) inches in diameter if pumped and at least eight (8) inches in diameter if gravity flow is used. This does not apply to air lift methods of sludge removal, as this should be determined by the sludge removal rate. Static head available for sludge withdrawal shall be at least thirty (30) inches, as necessary, to maintain a three (3) feet per second velocity in the withdrawal pipe. Clearance between the end of the withdrawal line and the

hopper walls shall be sufficient to prevent "bridging" of the sludge. Adequate provisions shall be made for rodding or back-flushing individual pipe runs.

***Air lift type sludge removal will not be approved for removal of primary sludges.

5.4.4 Sludge Removal Control

Sludge wells equipped with telescoping valves or other appropriate equipment shall be provided for viewing, sampling and controlling the rate of sludge withdrawal. A means for measuring the sludge removal rate and sludge return rate shall be provided. Sludge pump motor control systems shall include time clocks and valve activators for regulating the duration and sequencing of sludge removal. Gravity flow systems should have back-up pumping capabilities.

5.4.5 Sludge Hopper

The minimum slope of the side walls shall be 1.75 vertical to 1 horizontal. Hopper wall surfaces should be made smooth with rounded corners to aid in sludge removal. Hopper bottoms shall have a maximum dimension of two (2) feet. Extra-depth sludge hoppers for sludge thickening are not acceptable.

5.5 Protective and Service Facilities

5.5.1 Operator Protection

All clarifiers shall be equipped to enhance safety for operators. Such features shall appropriately include machinery cover lift lines, stairways, walkways, handrails and slip-resistant surfaces.

5.5.2 Mechanical Maintenance Access

The design shall provide for convenient and safe access to routine maintenance items such as gear boxes, scum removal mechanisms, baffles, weirs, inlet stilling baffle area, and effluent channels.

5.5.3 Electrical Fixtures and Controls

Electrical fixtures and controls in enclosed settling basins shall meet the requirement of the National Electrical Code. The fixtures and controls shall be located so as to provide convenient and safe access for operation and maintenance. Adequate area lighting shall be provided.

5.6 Operability, Flexibility, and Reliability

5.6.1 Scum Removal

5.6.1.1 A method of conveying scum across the water surface to a point of removal should be considered, such as water or air spray. Baffles should be designed to ensure capture of scum at minimum and maximum flow rates.

5.6.1.2 Facilities designed for flows of 0.1 MGD and greater should have mechanical scum removal equipment.

5.6.1.3. Scum holding tanks may be provided, with a method of removing excess water.

5.6.1.4 Large scum sumps should have a mixing device (pneumatic, hydraulic, or mechanical) to keep the scum mixed while being pumped.

5.6.1.5 Manual scum pump start-stop switches should be located adjacent to scum holding tanks.

5.6.2 Overflow Weirs

5.6.2.1 Since closely spaced multiple overflow weirs tend to increase hydraulic velocities, their spacing should be conservative.

5.6.2.2 Center-feed, peripheral draw-off clarifiers shall not have the overflow weir against the clarifier sidewall. Weir placement shall be 1/10 diameter or greater toward the center.

5.6.2.3 The up-flow rate shall not be greater than the surface overflow rate at any location within the solids separation zone of a clarifier.

5.6.2.4 Overflow weirs should be of the notched type; straight edged weirs will not be approved.

5.6.2.5 Overflow weirs shall be adjustable for leveling.

5.6.3 Unit Dewatering

5.6.3.1 The capacity of dewatering pumps should be such that the basin can be dewatered in 24 hours; eight hours is preferable.

5.6.3.2 The contents of the basin should be discharged to the closest process upstream from the unit being dewatered that can accept the flow.

5.6.3.3 Consideration shall be given to the need for hydrostatic pressure relief devices to prevent flotation of structures.

5.6.4 Hydraulics

5.6.4.1 Lift/pump stations located immediately upstream of secondary clarifiers shall have flow-paced controls to reduce shock loadings.

5.6.4.2 Square clarifiers with circular sludge withdrawal mechanisms shall be designed such that corner hydraulic velocities do not cause sludge carry-over.

5.6.5 Sludge Removal

5.6.5.1 When two or more clarifiers are used, provisions shall be made to control and measure the rate of sludge withdrawal from each clarifier.

5.6.5.2 Consideration should be given to removing activated sludge from the effluent end of rectangular clarifiers.

5.6.5.3 Consideration shall be given to chlorination of return activated sludge and digester supernate. Sufficient mixing and contact time should be provided.

5.6.6 Other Design Considerations

- 5.6.6.1 Designs should consider the possible need for future modifications to add chemicals such as flocculants.
- 5.6.6.2 A method of foam control should be considered for all inlet channels and feed wells in activated sludge systems.

CHAPTER 6

Fixed Film Reactors

6.1 Trickling Filters

- 6.1.1 General
- 6.1.2 Pretreatment
- 6.1.3 Types of Processes
- 6.1.4 Consideration For Design
- 6.1.5 Estimation of Performance
- 6.1.6 Special Details

6.2 Rotating Biological Contactors

- 6.2.1 General
- 6.2.2 Media
- 6.2.3 Design Loadings
- 6.2.4 Special Details

6.3 Activated Biofilter

- 6.3.1 General
- 6.3.2 ABF Media
- 6.3.3 Design
- 6.3.4 Special Details

FIXED FILM REACTORS

6.1 Trickling Filters

6.1.1 General

Trickling filters may be used for treatment of wastewater amenable to treatment by aerobic biological processes. This process is less complex and has a lower power requirement than some of the other processes.

6.1.2 Pretreatment

Trickling filters shall be preceded by effective clarifiers equipped with scum removal devices or other suitable pretreatment facilities. (See Chapters 4 & 5)

6.1.3 Types of Processes

Trickling filters are classified according to the applied hydraulic and organic loadings. The hydraulic loading is the total volume of liquid applied, including recirculation, per unit time per square unit of filter surface area. Organic loading is the total mass of BOD applied, including recirculation, per unit time per cubic unit of filter volume.

6.1.3.1 Low or Standard Rate

These are loaded at 1 to 4 million gallons per acre per day (mgad) and 5 to 25 pounds BOD per 1,000 cubic feet per day (lb BOD/1000 cu ft/day). Nitrification of the effluent often occurs.

6.1.3.2 Intermediate Rate

These are loaded at 4 to 10 mgad and 10 to 40 lb BOD/1000 cu ft/day. Nitrification is less likely to occur.

6.1.3.3 High Rate

These are loaded at 10 to 40 mgad and 25 to 300 lb BOD/1000 cu ft/day. Nitrification is not likely to occur.

6.1.3.4 Super Rate

These are loaded at 15 to 90 mgad (not including recirculation) and up to 300 lb BOD/1000 cu ft/day. Filters designed as super rate require a manufactured media. Nitrification is not likely to occur.

6.1.3.5 Roughing

These are loaded at 60 to 180 mgd (not including recirculation) and 100 lb BOD/1000 cu ft/day. Nitrification will not occur. Roughing filters shall be followed by additional treatment, and will be equipped with manufactured media.

6.1.4 Considerations for Design

The following factors should be considered when selecting the design hydraulic and organic loadings:

Characteristics of raw wastewater
Pretreatment
Type of media
Recirculation
Temperature of applied wastewater
Treatment efficiency required

The following table presents allowable ranges for the design of trickling filters. Modifications of these criteria will be considered on a case-by-case basis.

Design Loading Table

<u>Operating Characteristics</u>	<u>Low or Standard Rate</u>	<u>Intermediate Rate</u>	<u>High Rate</u>	<u>Super High Rate Manufactured Media</u>
<u>Roughing</u>				
Hydraulic Loading: mgd/acre gpd/sq ft 1400-4200*	1-4 25-90	4-10 90-230	10-40 230-900	15-90 60-180* 350-2000*
Organic Loading: lb BOD/acre-ft/day lb BOD/1000 cu ft/day	200-1000 5-25	700-1400 10-40	1000-12000 25-300	up to 300 100+
Depth (ft) BOD Removal (%) 40-65	5-10 80-85	4-8 50-70	3-6 65-80	3-8 65-85 15-40

*Does not include recirculation

6.1.5. Estimation of Performance

A number of equations are available for use in estimating trickling filter performance. Any design should evaluate several different formulas to compare the various parameters in different combinations with one another. Winter operating conditions must be analyzed since winter operations normally result in lower efficiency than summer operations. The trickling filter design must evaluate the impacts of recirculation, air draft temperatures and medium.

6.1.5.1 Recirculation

Recirculation capability is required for all variations of the trickling filter process except roughing filters provided that minimum hydraulic loading rates are maintained at all times. The recirculation ratio should be in the range of 0.5 to 4.0. Recirculation should be provided for manufactured media to maintain 0.5 to 1.0 gallon per minute per square foot (gpm/sq ft) or the manufacturer's recommended minimum wetting rate at all times. Recirculation ratios greater than 4.0 should not be used to calculate effluent quality.

6.1.5.2 Staging

Staging of filters can be considered for high-strength wastes or for nitrification.

6.1.6 Special Details

6.1.6.1 Media

a. Rock, Slag, or Similar Media

Rock, slag, and similar media should not contain more than 5 percent by weight of pieces whose longest dimension is three times the least dimension. They should be free from thin, elongated and flat pieces, dust, clay, sand, or fine material and should conform to the following size and grading when mechanically graded over a vibrating screen with square openings:

Passing 4-1/2 inch screen: 100 percent by weight

Retained on 3-inch screen: 90-100 percent by weight

Passing 2-inch screen: 0-2 percent by weight

Passing 1-inch screen: 0 percent by weight

Hand-picked field stone should be as follows:

Maximum dimension of stone: 5 inches

Minimum dimension of stone: 3 inches

Material delivered to the filter site should be stored on wood-planked or other approved clean hard-surfaced areas. All material should be rehandled at the filter site, and no material should be dumped directly into the filter. Crushed rock, slag, and similar media should be rescreened or forked at the filter site to remove all fines. Such material should be placed by hand to a depth of 12 inches above the tile underdrains, and all materials should be carefully placed so as not to damage the underdrains. The remainder of the material may be placed by means of belt conveyors or equally effective methods approved by the engineer. Trucks, tractors, or other heavy equipment should not be driven over the filter during or after construction.

b. Manufactured Media

Application of manufactured media should be evaluated on a case-by-case basis. Suitability should be evaluated on the basis of experience with installations handling similar wastes and loadings.

Media manufactured from plastic, wood, or other materials are available in many different designs. They should be durable, resistant to spalling or flaking, and relatively insoluble in wastewater. They are generally applied to super high rate and roughing filter designs.

6.1.6.2 Underdrainage System

a. Arrangement

Underdrains with semicircular inverts or equivalent should be provided and the underdrainage system should cover the entire floor of the filter. Inlet openings into the underdrains should have an unsubmerged gross combined area equal to at least 15 percent of the surface area of the filter.

b. Slope

The underdrains should have a minimum slope of 1 percent. Effluent channels should be designed to produce a minimum velocity of 2 feet per second at average daily rate of application to the filter.

c. Flushing

Provision should be made for flushing the underdrains and effluent channel. In small filters, use of a peripheral head channel with vertical vents is acceptable for flushing purposes. Inspection facilities should be provided.

d. Ventilation

The underdrainage system, effluent channels, and effluent pipe shall be designed to permit free passage of air. The size of drains, channels, and pipe should be such that not more than 50 percent of their cross-sectional area will be submerged under the design hydraulic loading. Provision should be made in the design of the effluent channels to allow for the possibility of increased hydraulic loading.

6.1.6.3 Dosing Equipment

a. Distribution

The sewage shall be distributed over the filter by rotary distributors or other suitable devices which will permit reasonably uniform distribution to the surface area. At design average flow, the deviation from a calculated uniformly distributed volume per square foot of the filter surface should not exceed plus or minus 10 percent at any point. Provisions must be made to spray the side walls to avoid growth of filter flies.

b. Application

Sewage may be applied to the filters by siphons, pumps, or by gravity discharge from preceding treatment units when suitable flow characteristics have been developed. Application of sewage should be practically continuous. Intermittent dosing shall only be considered for low or standard rate filters. In the case of intermittent dosing, the dosing cycles should normally vary between 5 and 15 minutes, with distribution taking place approximately 50

percent of the time. The maximum rest should not exceed 5 minutes, based on the design average flow.

c. Hydraulics

All hydraulic factors involving proper distribution of sewage on the filters should be carefully calculated. For reaction-type distributors, a minimum head of 24 inches between the low-water level in the siphon chamber and center of the arms should be required. Surge relief to prevent damage to distributor seals, should be provided where sewage is pumped directly to the distributors.

d. Clearance

A minimum clearance of 6 inches between medium and distributor arms should be provided. Greater clearance is essential where icing occurs.

e. Seals

The use of mercury seals is prohibited in the distributors of newly constructed trickling filters. If an existing treatment facility is to be modified, any mercury seals in the trickling filters shall be replaced with oil or mechanical seals.

6.1.6.4 Recirculation Pumping

Low-head, high-capacity pumps are generally used. Submersible pumps are commonly used. A means to adjust the flow is recommended in order to maintain constant hydraulic operation.

6.1.6.5 Waste Sludge Equipment

Pumps for trickling filter sludge should be capable of pumping material up to 6-percent solids (or more if needed) when pumping directly to the digester. Time clock controlled on-off control is desirable. When secondary sludge is pumped to the primary clarifier, the sludge pumps should be designed to pump material with low solid concentrations and high flow rates.

6.1.6.6 Miscellaneous Features

a. Flooding

Consideration should be given to the design of filter structures so that they may be flooded.

b. Maintenance

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, or drained.

c. Flow Measurement

A means shall be provided to measure recirculated flow to the filter.

6.2 Rotating Biological Contactors

6.2.1 General

6.2.1.1 Description

This section presents the requirements for fixed-film reactors using either partially submerged vertical media rotated on a horizontal shaft or other designs with similar concepts.

6.2.1.2 Applicability

Rotating biological contactors (RBC) may be used for treatment of wastewater amenable to treatment by aerobic biological processes. The process is especially applicable to small communities. These requirements shall be considered when proposing this type of treatment.

6.2.1.3 Pretreatment

Primary clarifiers or fine screens should be placed ahead of the RBC process to minimize solids settling in the RBC tanks. (See Chapters 4 & 5)

6.2.2 Media

6.2.2.1 Description

Typical media consists of plastic sheets of various designs with appropriate spacings to maximize the surface area, allow for entrance of air and wastewater, the sloughing of excess biological solids and prevention of plugging. The medium is mounted on a horizontal steel shaft. Other similar systems will be considered on a case-by-case basis.

6.2.2.2 Types

Two types of medium are currently available.

a. Standard Density

Standard-density medium is available in sizes up to 100,000 square feet (sq ft) per shaft. It should be used for all secondary treatment applications.

b. High Density

High-density medium is available in sizes up to 150,000 sq ft per shaft. It should be used only for nitrification or effluent polishing where the influent BOD is sufficiently low to ensure that plugging of the medium will not occur.

6.2.3 Design Loadings

6.2.3.1 RBC Media

Design loadings should be in terms of total organic loading expressed as pounds BOD₅ per day per 1000 square feet of media surface area (lb BOD₅/day/1000 sq. ft.). The development of design

loadings should consider influent BOD, soluble BOD, effluent BOD, flows, temperature, and the number of treatment stages. The design loading should generally range between 2.5 and 3.5 lb BOD₅/day/1000 sq. ft.

6.2.3.2 Final Clarifiers

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers."

The overflow rate should be less than or equal to 600 gpd/sq ft at the average daily design flow.

6.2.4 Special Details

6.2.4.1 Enclosures

Enclosures should be provided for the RBC medium to prevent algae growth on the medium and minimize the effect of cold weather. Enclosures may be either fabricated individual enclosures or buildings enclosing several shafts. Buildings may be considered for installations with several shafts or, where severe weather conditions are encountered, to promote better maintenance.

a. Fabricated Individual Enclosures

Enclosures should be made of fiberglass or other material resistant to damage from humidity or corrosion. The exterior of the enclosures should be resistant to deterioration from direct sunlight and ultraviolet radiation. Access points should be provided at each end of the enclosure to permit inspection of shafts and to perform operation and maintenance. Enclosures shall be removable to allow removal of the shaft assemblies. Access around enclosures shall be sufficient to permit suitable lifting equipment access to lift covers and shafts.

b. Buildings

Adequate space should be provided to allow access to and removal of shafts from enclosures. Buildings should be designed with provisions to remove shafts without damage to the structure. Buildings should be designed with adequate ventilation and humidity control to ensure adequate atmospheric oxygen is available for the RBC shafts, provide a safe environment for the operating staff to perform normal operation and maintenance, and minimize the damage to the structure and equipment from excess moisture.

6.2.4.2 Hydraulic Design

The RBC design should incorporate sufficient hydraulic controls, such as weirs, to ensure that the flow is distributed evenly to parallel process units. RBC tank design should provide a means for distributing the influent flow evenly across each RBC shaft. Intermediate baffles placed between treatment stages in the RBC system should be designed to minimize solids deposition. The RBC units should be designed with flexibility to permit series or parallel operation.

6.2.4.3 Dewatering

The design should provide for dewatering of RBC tanks.

6.2.4.4 Shaft Drives

The electric motor and gear reducer should be located to prevent contact with the wastewater at peak flow rates.

6.2.4.5 Recycle

Effluent recycle should be provided for small installations where minimum diurnal flows may be very small. Recycle should be considered in any size plant where minimum flows are less than 30% of the average design flow.

6.2.4.6 Access

Access shall be allowed for lifting equipment to provide maintenance in the event of a failure.

6.3 Activated Biofilter

6.3.1 General

6.3.1.1 Description

The activated biofilter (ABF) process is a combination of the trickling filter process using artificial media and the activated sludge process.

6.3.1.2 Applicability

The activated biofilter process may be used where wastewater is amenable to biological treatment. This process requires close attention and competent operating supervision, including routine laboratory control. These requirements should be considered when proposing this type of treatment. The process is more adaptable to handling large seasonal loading variations, such as those resulting from seasonal industries or changes in population, than are some of the other biological processes. Where significant quantities of industrial wastes are anticipated, pilot plant testing should be considered.

6.3.2 ABF Media

Artificial media are used in the trickling filter portion of the process to allow high BOD and hydraulic loadings and permit recycle of activated sludge through the trickling filter without plugging. Either wood or plastic artificial medium may be used. Medium depth typically ranges from 7 to 25 feet.

6.3.3 Design

6.3.3.1 General

Calculations shall be submitted to justify the basis of design of the ABF tower pump station, ABF tower, aeration basin, aeration equipment, secondary clarifiers, activated sludge return equipment, and waste sludge equipment.

6.3.3.2 ABF Tower Pump Station

The ABF tower pump station shall be designed to pump the peak influent flow plus the maximum design ABF tower recirculation and return activated sludge flows. Application of wastewater to the ABF tower should be continuous.

6.3.3.3 ABF Tower

The ABF tower shall be designed based on organic loading expressed as pounds of influent BOD per 1,000 cubic feet per day (lb BOD/1,000 cu ft/day). The organic loading should be established using data from similar installations or pilot plant testing. A minimum hydraulic wetting rate should be maintained and be expressed as gallons per minute per square foot (gpm/sq ft). Typical values for organic loading range from 100 to 350 lb BOD/1,000 cu ft/day (4,300 to 15,000 pounds BOD per acre-foot per day), and hydraulic wetting rates range from 1.5 to 5.5 gpm/sq ft, including recirculations and return flows.

6.3.3.4 Aeration Basin

The aeration basin should be designed in accordance with Chapter 7, "Activated Sludge," based on the food-to-microorganism (F/M) ratio expressed as pounds of influent BOD per day per pound of mixed liquor volatile suspended solids (MLVSS). The F/M ratio should be based on the influent total BOD to the ABF tower or the estimated soluble BOD leaving the ABF tower. Designs using total BOD to the ABF tower should be based on data from similar installations or pilot plant testing. Designs using the estimated soluble BOD leaving the ABF tower should use typical F/M ratios (presented in Chapter 7, "Activated Sludge"). Estimate of BOD removal in the ABF tower should be based on similar installations or pilot plant testing. Calculations of mixed-liquor suspended solids should include the influent suspended solids and solids sloughing from the ABF tower in addition to growth of activated sludge due to removal of soluble BOD. Determination of aeration basin volume should include consideration of aeration basin power levels (using aeration equipment horsepower) expressed as horsepower per 1,000 cubic feet of basin volume. Aeration basin power levels should be limited to prevent excessive turbulence, which may cause shearing of the activated sludge floc.

Aeration prior to the ABF tower may also be considered.

6.3.3.5 Aeration Equipment

Oxygen requirements should be estimated as outlined in Chapter 7, "Activated Sludge," for the ABF tower effluent plus the oxygen requirements of the sloughed solids from the ABF tower.

6.3.3.6 Secondary Clarifiers

Secondary clarifiers should be equipped with rapid sludge withdrawal mechanisms and be designed in accordance with Chapter 5, "Clarifiers," and Chapter 7, "Activated Sludge."

6.3.3.7 Return Sludge Equipment

Return sludge equipment should be designed in accordance with Chapter 5, "Clarifiers."

6.3.3.8 Waste Sludge Equipment

Waste sludge equipment should be designed in accordance with Chapter 12, "Sludge Processing and Disposal."

6.3.3.9 ABF Tower Recirculation

ABF tower recirculation should normally be provided. At a minimum, recirculation capacity should meet the requirements for the minimum hydraulic wetting rate.

6.3.4 Special Details

6.3.4.1 ABF Tower

The ABF tower dosing equipment and underdrainage system should be designed in accordance with Section 6.1.6.3 "Dosing Equipment." Fixed or rotating distributors may be used. In addition, the design of the ABF tower should incorporate a skirt around the top to prevent spray from falling to the ground around the tower.

6.3.4.2 Maintenance Provisions

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, and drained.

6.3.4.3 Flow Measurement

Devices should be provided to permit measurement of flow to the ABF towers, ABF tower recirculation, return activated sludge, and waste activated sludge flows.

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CHAPTER 7

Activated Sludge

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ACTIVATED SLUDGE

7.1 General

7.1.1 Applicability

The activated sludge process and its various modifications may be used where sewage is amenable to biological treatment. This process requires close attention and more competent operator supervision than some of the other biological processes. A treatability study may be required to show that the organics are amenable to the proposed treatment. For example, industrial wastewaters containing high levels of starches and sugars may cause interferences with the activated sludge process due to bulking.

Toxic loadings from industries and excessive hydraulic loadings must be avoided to prevent the loss or destruction of the activated sludge mass. If toxic influents are a possibility, a properly enforced industrial pretreatment program will prove extremely beneficial to the WWTP and will be required. It takes days and sometimes weeks for the plant to recover from a toxic overload and will likely result in permit violations. Flow equalization, as detailed in Chapter 4, may be required in some instances. These requirements shall be considered when proposing this type of treatment.

7.1.2 Process Selection

The activated sludge process and its several modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of BOD and ammonia. Choice of the process most applicable will be influenced by the proposed plant size, type of waste to be treated, and degree and consistency of treatment required. All designs should provide for flexibility to incorporate as many modes of operation as is reasonably possible.

Calculations and/or documentation shall be submitted to justify the basis of design for the following:

- a. Process efficiency
- b. Aeration tanks
- c. Aeration equipment (including oxygen and mixing requirements)
- d. Operational rationale (including maintenance)
- e. Costs (capital and operating)

In addition, the design must comply with any requirements set forth in other chapters such as clarifiers, sludge processing, etc.

7.1.3 Pretreatment

Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease, and comminution or screening of solids shall be accomplished prior to the activated sludge process.

Where primary settling is used, provisions should be made for discharging raw sewage directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life. Also, primary effluents are often low in D.O. This should be planned for in the design.

7.2 Types of Processes

Figure 7.1 shows the flow schematics of the major types of activated sludge processes, excluding pretreatment. The types that are simply modifications of these processes are not shown.

7.2.1 Conventional

Conventional activated sludge is characterized by introduction of influent wastewater and return activated sludge at one end of the aeration tank, a plug-flow aeration tank, and diffused aeration.

7.2.2 Complete Mix

Complete mix activated sludge is characterized by introduction of influent wastewater and return activated sludge throughout the aeration basin and the use of a completely mixed aeration tank. Complete mix aeration tanks may be arranged in series to approximate plug flow and conventional activated sludge.

7.2.3 Step Aeration

Step aeration activated sludge is characterized by introduction of the influent wastewater at two or more points in the aeration tank, use of a plug-flow aeration tank, and diffused aeration.

7.2.4 Tapered Aeration

Tapered aeration is similar to conventional activated sludge except that the air supply is tapered to meet the organic load within the tank. More air is added to the influent end of the tank where the organic loading and oxygen demand are the greatest.

7.2.5 Contact Stabilization

Contact stabilization activated sludge is characterized by the use of two aeration tanks for each process train, one to contact the influent wastewater and return activated sludge (contact tank) and the other to aerate the return activated sludge (stabilization tank) and promote the biodegradation of the organics absorbed to the bacterial flocs.

7.2.6 Extended Aeration

Extended aeration activated sludge is characterized by a low F/M ratio, long sludge age, and long aeration tank detention time (greater than 18 hours). For additional details on oxidation ditches see Section 7.7).

7.2.7 High-Rate Aeration

High-rate aeration activated sludge is characterized by high F/M ratio, low sludge age, short aeration tank detention time, and high mixed-liquor suspended solids. High-rate aeration should be followed by other BOD and suspended solids removal processes to provide secondary treatment.

7.2.8 High-Purity Oxygen

High-purity oxygen activated sludge is characterized by the use of high-purity oxygen instead of air for aeration.

7.2.9 Kraus Process

Kraus process activated sludge is characterized by use of an aeration tank to aerate a portion of the return activated sludge, digester supernatant, and digested sludge in order to provide nitrogen (ammonia) to a nitrogen-deficient wastewater.

7.2.10 Sequencing Batch Reactors (SBR)

The SBR process is a fill-and-draw, non-steady state activated sludge process in which one or more reactor basins are filled with wastewater during a discrete time period, and then operated in a batch treatment mode. SBR's accomplish equalization, aeration, and clarification in a timed sequence. For additional details see Section 7.6.

7.3 Aeration Tanks

7.3.1 Required Volume

The size of the aeration tank for any particular adaptation of the process shall be based on the food-to-microorganism (F/M) ratio, using the influent BOD (load per day) divided by the mixed-liquor volatile suspended solids. Alternatively, aeration tanks may be sized using sludge age. The calculations using the F/M ratio or sludge age shall be based on the kinetic relationships.

APPENDIX 7A shows the permissible range of F/M ratio, sludge age, mixed-liquor suspended solids, aeration tank detention time, aerator loading, and activated sludge return ratio for design of the various modifications of the activated sludge process. All design parameters shall be checked to determine if they fall within the permissible range for the selected F/M ratio or sludge age and the aeration tank size. Diurnal load variations and peak loadings must be considered when checking critical parameters.

7.3.2 Shape and Mixing

The dimensions of each independent mixed-liquor aeration tank or return sludge reaeration tank should be such as to maintain effective mixing and utilization of air when diffused air is used. Liquid depths should not be less than 10 feet or more than 30 feet except in special design cases. For plug-flow conditions using very small tanks or tanks with special configuration, the shape of the tank and/or the installation of aeration equipment should provide for elimination of short-circuiting through the tank.

Aerator loadings should be considered and the horsepower per 1,000 cubic feet of basin volume required for oxygen transfer should be limited to prevent excessive turbulence in the aeration basins, which might reduce activated sludge settleability.

7.3.3 Number of Units

Multiple tanks capable of independent operation may be required for operability and maintenance reasons, depending on the activated sludge process, size of the plant, and the reliability classification of the sewerage works (refer to Section 1.3.11).

7.3.4 Inlets and Outlets

7.3.4.1 Controls

Inlets and outlets for each aeration tank unit in multiple tank systems should be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit control of the flow and to maintain reasonably constant liquid level. The hydraulic properties of the system should permit the maximum instantaneous hydraulic load to be carried with any single aeration tank unit out of service.

7.3.4.2 Conduits

Channels and pipes carrying liquids with solids in suspension should be designed to maintain self-cleaning velocities or should be agitated to keep such solids in suspension at all rates of flow within the design limits.

7.3.4.3 Hydraulics

Where multiple aeration tanks and secondary clarifiers are used, provisions should be made to divide the flow evenly to all aeration tanks in service and then recombine the flows, and to divide the flow evenly to all secondary clarifiers in service and then recombine the flows. Treatment plants using more than four aeration tanks and secondary clarifiers may divide the activated sludge systems into two or more process trains consisting of not less than two aeration tanks and secondary clarifiers per process train.

7.3.4.4 Bypass

When a primary settling tank is used, provisions shall also be made for discharging raw wastewater directly to the aeration tanks following pretreatment for start-ups.

7.3.5 Measuring Devices

For plants designed for less than 250,000 gallons per day, devices shall be installed for indicating flow rates of influent sewage, return sludge, and air to each aeration tank. For plants designed for greater than 250,000 gallons per day, devices shall be installed for totalizing, indicating, and recording influent sewage and returned sludge to each aeration tank. Where the design provides for all returned sludge to be mixed with the raw sewage (or

primary effluent) at one location, the mixed-liquor flow rate to each aeration tank shall be measured, and the flow split in such a manner to provide even loading to each tank, or as desired by operations.

7.3.6 Freeboard and Foam Control

Aeration tanks shall have a freeboard of at least 18 inches. Freeboards of 24 inches are desirable with mechanical aerators.

Consideration shall be given for foam control devices on aeration tanks. Suitable spray systems or other appropriate means will be acceptable. If potable water is used, approved backflow prevention shall be provided on the water lines. The spray lines shall have provisions for draining to prevent damage by freezing.

7.3.7 Drain and Bypass

Provisions shall be made for dewatering each aeration tank for cleaning and maintenance. The dewatering system shall be sized to permit removal of the tank contents within 24 hours. If a drain is used, it shall be valved. The dewatering discharge shall be upstream of the activated sludge process.

Provisions shall be made to isolate each aeration tank without disrupting flow to other aeration tanks.

Proper precautions shall be taken to ensure the tank will not "float" when dewatered.

7.3.8 Other Considerations

Other factors that might influence the efficiency of the activated sludge process should be examined. Septic and/or low pH influent conditions are detrimental, particularly where primary clarifiers precede the activated sludge process or when the collection system allows the sewage to go septic. Often, the pH is buffered by the biological mass, but wide variations in the influent should be avoided and, if present, chemical addition may be necessary.

Aerobic organisms require minimum quantities of nitrogen and phosphorus. Domestic wastewater usually has an excess of nitrogen and phosphorus; however, many industrial wastewaters are deficient in these elements. A mass balance should be performed to see if the combined industrial and domestic influent contains sufficient nitrogen and phosphorus or if nutrient levels will have to be supplemented.

7.4 Aeration Equipment

7.4.1 General

Oxygen requirements generally depend on BOD loading, degree of treatment, and level of suspended solids concentration to be maintained in the aeration tank mixed liquor. Aeration equipment shall be designed to supply sufficient oxygen to maintain a minimum dissolved oxygen concentration of 2 milligrams per liter (mg/l) at average design load and 1.0 mg/l at peak design loads throughout the mixed liquor. In the absence of experimentally determined values, the design oxygen requirements for all

activated sludge processes shall be 1.1 lbs oxygen per lb peak BOD₅ applied to the aeration tanks, with the exception of the extended aeration process, for which the value shall be 2.35. Aeration equipment shall be of sufficient size and arrangement to maintain velocities greater than 0.5 foot per second at all points in the aeration tank.

The oxygen requirements for an activated sludge system can be estimated using the following relationship:

$$O_2 = (a) (BOD) + b (MLVSS)$$

$$O_2 = \text{pounds of oxygen required per day}$$

$$BOD = \text{pounds of BOD removed per day (5-day BOD)*}$$

$$MLVSS = \text{pounds of mixed liquor volatile suspended solids contained in the aeration basin}$$

$$a = \text{amount of oxygen required for BOD synthesis. "a" will range from 0.5 to 0.75 pound of oxygen per pound of BOD removed}$$

$$b = \text{amount of oxygen required for endogenous respiration or decay. "b" will range from 0.05 to 0.20 pound of oxygen per pound of MLVSS}$$

*BOD removal shall be calculated as influent BOD₅ minus soluble effluent BOD₅.

For preliminary planning before process design is initiated, a rough estimate can be obtained by using 1.0 to 1.2 pounds of oxygen per pound of BOD removed (assuming no nitrification).

7.4.2 Diffused Air Systems

7.4.2.1 Design Air Requirements

The aeration equipment shall be designed to provide the oxygen requirements set forth above. Minimum requirements for carbonaceous removal are shown below. (Oxygen requirements for nitrification are in addition to that required for carbonaceous removal where applicable; i.e., low F/M.)

<u>Process</u>	<u>Cubic Feet of Air Available per Pound of BOD Load Applied to Aeration Tank</u>
Conventional	1,500
Step Aeration	1,500
Contact Stabilization	1,500
Modified or "High Rate"	400 to 1,500 (depending upon BOD removal expected)
Extended Aeration	2,100

Air required for channels, pumps, or other air-use demand shall be added to the air volume requirements.

Manufacturers' specifications must be corrected to account for actual operation conditions (use a worst case scenario). Corrections shall be made for temperatures other than 20°C and elevations greater than 2,000 feet.

7.4.2.2 Special Details

The specified capacity of blowers or air compressors, particularly centrifugal blowers, shall take into account that the air intake temperature might reach extremes and that pressure might be less than normal. Motor horsepower shall be sufficient to handle the minimum and maximum ambient temperatures on record.

The blower filters shall be easily accessible. Spare filters should be provided.

The blowers shall be provided in multiple units, arranged and in capacities to meet the maximum air demand with the single largest unit out of service. The design shall also provide for varying the volume of air delivered in proportion to the load demand of the plant.

The spacing of diffusers shall be in accordance with the oxygen and mixing requirements in the basin. If only one aeration tank is proposed, arrangement of diffusers should permit their removal for inspection, maintenance, and replacement without de-watering the tank and without shutting off the air supply to other diffusers in the tank.

Individual units of diffusers shall be equipped with control valves, preferably with indicator markings, for throttling or for complete shutoff. Diffusers in each assembly shall have substantially uniform pressure loss. The adjustment of one diffuser should have minimal influence on the air supply rate to any other diffusers.

Flow meters and throttling valves shall be placed in each header. Air filters shall be provided as part of the blower assembly to prevent clogging of the diffuser system. Means shall be provided to easily check the air filter so that it will be replaced when needed.

7.4.3 Mechanical Aeration Equipment

Power input from mechanical aerators should range from 0.5 to 1.3 horsepower per 1,000 cubic feet of aeration tank.

The mechanism and drive unit shall be designed for the expected conditions of the aeration tank in terms of the proven performance of the equipment.

Due to the high heat loss, consideration shall be given to protecting subsequent treatment units from freezing where it is deemed necessary. Multiple mechanical aeration unit installations shall be designed to meet the maximum oxygen demand with the largest unit out of service. The design shall normally also provide for varying the amount of oxygen transferred in proportion to the load demand on the plant.

A spare aeration mechanism shall be furnished for single-unit installations. Access to the aerators shall be provided for routine maintenance.

7.4.4 Flexibility and Energy Conservation

The design of aeration systems shall provide adequate flexibility to vary the oxygen transfer capability and power consumption in relation to oxygen demands. Particular attention should be given to initial operation when oxygen demands may be significantly less than the design oxygen demand. The design shall always maintain the minimum mixing levels; mixing may control power requirements at low oxygen demands.

Dissolved oxygen probes and recording should be considered for all activated sludge designs. Consideration will be given to automatic control of aeration system oxygen transfer, based on aeration basin dissolved oxygen concentrations, provided manual back-up operation is available. A dissolved oxygen field probe and meter is to be provided for all activated sludge installations.

Watt-hour meters shall be provided for all aeration system drives to record power usage.

Energy conservation measures shall be considered in design of aeration systems. For diffused aeration systems, the following shall be considered:

- a. Use of small compressors and more units
- b. Variable-speed drives on positive-displacement compressors
- c. Intake throttling on centrifugal compressors
- d. Use of timers while maintaining minimum mixing and D.O. levels (consult with manufacturer's recommendations for proper cycling)
- e. Use of high-efficiency diffusers
- f. Use of separate and independent mixers and aerators

For mechanical aeration systems, the following shall be considered:

- a. Use of smaller aerators
- b. Variable aeration tank weirs
- c. Multiple-speed motors
- d. Use of timers

7.5 Additional Details

7.5.1 Lifting Equipment and Access

Provisions shall be made to lift all mechanical equipment and provide sufficient access to permit its removal without modifying existing or proposed structures.

7.5.2 Noise and Safety

Special consideration shall be given to the noise produced by air compressors used with diffused aeration systems and mechanical aerators. Ear protection may be required. Silencers for blowers may be required in sensitive areas.

Handrails shall be provided on all walkways around aeration tanks and clarifiers.

The following safety equipment shall be provided near aeration tanks and clarifiers:

- Safety vests
- Lifelines and rings
- Safety poles

Walkways near aeration tanks shall have a roughened surface or grating to provide safe footing and be built to shed water.

Guards shall be provided on all moving machinery in conformance with OSHA requirements.

Sufficient lighting shall be provided to permit safe working conditions near aerations tanks and clarifiers at night.

7.6 Sequencing Batch Reactors (SBRs)

SBRs shall be designed to meet all the requirements set forth in preceding sections on activated sludge. Special consideration shall be given to the following:

- 7.6.1 A pre-aeration, flow-equalization basin is to be provided for when the SBR is in the settle and/or draw phases. If multiple SBR basins are provided, a pre-aeration basin will not be needed if each SBR basin is capable of handling all the influent peak flow while another basin is in the settle and/or draw phase.
- 7.6.2 When discharging from the SBR, means need to be provided to avoid surges to the succeeding treatment units. The chlorine contact tank shall not be hydraulically overloaded by the discharge.
- 7.6.3 The effluent from the SBRs shall be removed from just below the water surface (below the scum level) or a device which excludes scum shall be used. All decanters shall be balanced so that the effluent will be withdrawn equally from the effluent end of the reactor.
- 7.6.4 Prevailing winds must be considered in scum control.

7.7 Oxidation Ditch

7.7.1 General

The oxidation ditch is a complete-mixed, extended aeration, activated sludge process which is operated with a long detention time. Brush-rotor (or disk type) aerators are normally used for mixing and oxygen transfer. All requirements set forth in previous sections and/or chapters must be met, with the exception of those items addressed below.

7.7.2 Special Details

7.7.2.1 Design Parameters

The design parameters shall be in the permissible range as set forth in Table 7.1 for F/M, sludge age, MLSS, detention time, aerator loading, and activated sludge return ratio.

7.7.2.2 Aeration Equipment

Aeration equipment shall be designed to transfer 2.35 pounds of oxygen per pound of BOD at standard conditions. The oxygen requirement takes into account nitrification in a typical wastewater. Also, a minimum average velocity of one foot per second shall be maintained, based on the pumping rate of the aeration equipment and the aeration basin cross-sectional area.

A minimum of two aerators per basin is required.

7.7.2.3 Aeration Tank Details

a. Influent Feed Location

Influent and return activated sludge feed to the aeration tank should be located just upstream of an aerator to afford immediate mixing with mixed liquor in the channel.

b. Effluent Removal Location

Effluent from the aeration channel shall be upstream of an aerator and far enough upstream from the injection of the influent and return activated sludge to prevent short-circuiting.

c. Effluent Adjustable Weir

Water level in the aeration channel shall be controlled by an adjustable weir or other means. In calculating weir length, use peak design flow plus maximum recirculated flow to prevent excessive aerator immersion.

d. Walkways and Splash Control

Walkways must be provided across the aeration channel to provide access to the aerators for maintenance. The normal location is above the aerator. Splash guards shall be provided to prevent spray from the aerator on the walkway. Bridges should not be subject to splash from the rotors.

e. Baffles

Horizontal baffles, placed across the channel, may be used on all basins with over 6 feet liquid depth, and may be used where the manufacturer recommends them to provide proper mixing of the entire depth of the basin.

Baffles should be provided around corners to ensure uniform velocities.

7.7.3 45-Degree Sloping Sidewall Tanks

7.7.3.1 Liquid Depth

Liquid depth shall be 7 to 10 feet, depending on aerator capability, as stated by the manufacturer.

7.7.3.2 Channel Width at Water Level

The higher ratios (channel width at water level divided by aerator length) are to be used with smaller aerator lengths.

3- to 15-foot-long rotors, ratio 3.0 to 1.8.

16- to 30-foot-long rotors, ratio 2.0 to 1.3

Above 30-foot-long rotors, ratio below 1.5

7.7.3.3 Center Island

When used, the minimum width of center island at liquid level, based on aerator length, should be as follows (with center islands below minimum width, use return flow baffles at both ends):

3- to 5-foot-long rotor, 14 feet

6- to 15-foot-long rotor, 16 feet

16- to 30-foot-long rotor, 20 feet

Above 30-foot-long rotors, 24 feet

7.7.3.4 Center Dividing Walls

Center dividing walls can be used but return flow baffles at both ends are required. The channel width, W , is calculated as flat bottom plus $1/2$ of sloping sidewall. Baffle radius is $W/2$. Baffles should be offset by $W/8$, with the larger opening accepting the flow and the smaller opening downstream compressing the flow.

7.7.3.5 Length of Straight Section

Length of straight section of ditch shall be a minimum of 40 feet or at least two times the width of the ditch at liquid level.

7.7.3.6 Preferred Location of Aerators

Aerators shall be placed just downstream of the bend, normally 15 feet, with the long straight section of the ditch downstream of the aerator.

7.7.4 Straight Sidewall Tanks

7.7.4.1 Liquid Depth

Liquid depth shall be 7 to 12 feet, depending on aerators.

7.7.4.2 Aerator Length

Individual rotor length shall span the full width of the channel, with necessary allowances required for drive assembly and outboard bearing.

7.7.4.3 Center Island

Where center islands are used, the width should be the same as with 45-degree sloping sidewalls, or manufacturer's recommendation.

7.7.4.4 Center Dividing Walls

When a center dividing wall is used, return flow baffles are required at both ends. Return flow baffle radius is width of channel, W , divided by 2, $W/2$. Baffles should be offset by $W/8$, with the larger opening accepting the flow and the smaller opening downstream compressing the flow.

7.7.4.5 Length of Straight Section

Length of straight section downstream of aerator shall be near 40 feet or close to two times the aerator length. In deep tanks with four aerators, aerators should be placed to provide location for horizontal baffles.

7.7.4.6 Preferred Location of Aerators

Aerators should be placed just downstream of the bend with the long straight section of the tank downstream of the aerator. Optimal placement of rotors will consider maintaining ditch center line distance between rotors close to equal.

CHAPTER 8

Nitrification

8.1 General

- 8.1.1 Applications
- 8.1.2 Process Selection

8.2 Suspended Growth Systems

- 8.2.1 Single - Stage Activated Sludge
- 8.2.2 Two - Stage with Activated Sludge Nitrification

8.3 Fixed - Film Systems

- 8.3.1 Trickling Filters
- 8.3.2 Activated Biofilter (ABF) Process
- 8.3.3 Submerged Media
- 8.3.4 Rotating Biological Contactors

NITRIFICATION

8.1 General

8.1.1 Applications

Nitrogen exists in treated wastewater primarily in the form of ammonia which is oxidized to nitrate by bacteria. This process requires oxygen and can exert a significant oxygen demand on the receiving water.

Nitrification shall be considered when ammonia concentrations in the effluent would cause the receiving water to exceed the limitations established to prevent ammonia toxicity to aquatic life, or when the effluent ammonia quantity would cause the dissolved oxygen level of the receiving stream to deplete below allowable limits. The degree of treatment required will be determined by the NPDES permit limit.

8.1.2 Process Selection

Calculations shall be submitted to support the basis of design. The following factors should be considered in the evaluations of alternative nitrification processes:

- a. Ability to meet effluent requirements under all environmental conditions to be encountered, with special emphasis on temperature, pH, alkalinity, and dissolved oxygen.
- b. Cost (total present worth)
- c. Operational considerations, including process stability, flexibility, operator skill required, and compatibility with other plant processes.
- d. Land requirements.

8.2 Suspended Growth Systems

8.2.1 Single - Stage Activated Sludge

This section details the requirements for activated sludge systems designed to both remove carbonaceous matter and oxidize ammonia.

8.2.1.1 Process Design

Design must provide adequate solids retention time in the activated sludge system for sufficient growth of nitrifying bacteria. A safety factor of 2.5 or greater should be used to calculate the design mean cell residence time or sludge age. This safety factor must be large enough to provide enough operational flexibility to handle diurnal, peak, and transient loadings. The calculation of the solids retention time shall consider influent BOD, TSS, BOD₅/TKN (Total Kjeldahl Nitrogen) ratio and kinetic parameters. The kinetic parameters can be taken from the literature, similar installations, or pilot plant studies. The effect of temperature on the kinetics must be considered since nitrification will not proceed as rapidly during winter months.

8.2.1.2 Special Details

The following requirements are in addition to those included in Chapter 5, "Clarifiers", and Chapter 7, "Activated Sludge":

- a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed for BOD removal.
- b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.
- c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.
- d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.
- e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.
- f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O. levels in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.2.2 Two-Stage with Activated Sludge Nitrification

This section details the requirements for systems in which carbonaceous BOD is removed in the first stage and ammonia is oxidized by activated sludge in the second stage. BOD removal in the first stage could be by activated sludge, trickling filters, or physical - chemical treatment.

8.2.2.1 Process Design

The first stage shall be designed using the requirements of the appropriate chapters, such as activated sludge, trickling filters, and clarifiers. To promote a sludge with good settling characteristics in the second stage clarifier, some carbonaceous BOD shall enter the second stage aeration basin. This allows a less conservative design of the first stage as long as total BOD removal is sufficient. The requirements for the process design of the second stage are the same as those presented previously for the single-stage nitrification system.

8.2.2.2 Special Details

The following details are in addition to those in Chapter 5, "Clarifiers," Chapter 6, "Fixed Film Reactors," and Chapter 7, "Activated Sludge."

- a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed for BOD removal.
- b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.
- c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.
- d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.
- e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.
- f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O. levels in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.3 Fixed - Film Systems

8.3.1 Trickling Filters

8.3.1.1 Process Design

Recirculation is required to provide a constant hydraulic loading on the medium.

a. Single - Stage

This section details the requirements for a trickling filter that is designed for both carbonaceous BOD removal and ammonia oxidation. Design shall be based on the organic loading expressed as pounds BOD per 1,000 cubic feet. The design loading rate shall be justified from literature, similar installations, or pilot plant data for a particular depth and type of filter medium. Design shall consider temperature effects on ammonia removal and organic loading rates, and any proposal to attain nitrification in a single-stage rock media trickling filter will be more closely scrutinized than with other types of media.

b. Two - Stage

This section details the requirements of using a trickling filter for nitrification which is preceded by a trickling filter, activated sludge system, or physical - chemical

treatment for carbonaceous BOD removal. Design must be based on either a surface area loading expressed as square feet per pound $\text{NH}_4\text{-N}$ oxidized per day or a volumetric loading expressed as pounds $\text{NH}_4\text{-N}$ per 1,000 cubic feet per day. Loading rates must be justified from literature, similar plants, or pilot plant data. The effects of temperature on loading rates and ammonia oxidation must be considered in the design.

8.3.1.2 Special Details

The following requirements are in addition to those in Chapter 5, "Clarifiers," and Chapter 6, "Fixed Film Reactors."

- a. Clarifiers will be required for second-stage trickling filters for nitrification.
- b. Higher specific surface area and lower void ratio media may be used for second-stage trickling filters providing nitrification.

8.3.2 Activated Biofilter (ABF) Process

8.3.2.1 Process Design

Process design shall be based on the literature, similar installations, or pilot plant data. The design shall consider the effects of temperature, pH, and aeration basins.

8.3.2.2 Special Details

- a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirement for nitrification, in addition to the oxygen needed for BOD removal.
- b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.
- c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.
- d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.
- e. Nitrification requires alkalinity, 7.1 pounds as CaCO_3 per pound $\text{NH}_2\text{-N}$ oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.
- f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O. in

the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.3.3 Submerged Media

8.3.3.1 General

This section includes all designs for fixed-film reactors using stones, gravel, sand, anthracite coal, or plastic media or combinations thereof in which the medium is submerged and air or oxygen is used to maintain aerobic conditions. Pilot plant testing or a similar full-scale installation with a minimum of 1 year of operation is required before consideration will be given to a submerged design. No design will be considered unless the following can be demonstrated:

- a. Reliable operation
- b. Ability to transfer sufficient oxygen
- c. Ability to handle peak flows without washout of medium
- d. Methods of separating suspended solids from effluent, removing waste sludge, and stabilization and dewatering of waste sludge
- e. Media resistance to plugging

8.3.3.2 Process Design

Data for design and calculations shall be submitted upon request to justify the basis of design.

8.3.4 Rotating Biological Contactors

8.3.4.1 Process Design

Process design shall be based on the surface area loading expressed as gallons per day per square foot. Design surface area loading shall consider the number of stages, temperature, BOD concentration entering and leaving each stage, and ammonia concentration entering and leaving each stage. Calculations shall be submitted upon request to justify the basis of design.

8.3.4.2 Special Details

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers," and Chapter 6, "Fixed Film Reactors."

- a. Standard media (100,000 square feet per shaft or less) shall be used until influent BOD concentration is less than manufacturer's recommendation for high-density media (150,000 square feet per shaft or more). High-density media may be used for influent BOD concentrations less than manufacturer's recommendation for high-density media.
- b. Clarifiers will be required following rotating biological contactors that follow a secondary process.

CHAPTER 9

Ponds and Aerated Lagoons

9.1 General

- 9.1.1 Applicability
- 9.1.2 Supplement to Engineering Report
- 9.1.3 Effluent Requirements

9.2 Design Loadings

- 9.2.1 Stabilization Ponds
- 9.2.2 Aerated Lagoons

9.3 Special Details

- 9.3.1 General
- 9.3.2 Stabilization Ponds
- 9.3.3 Aerated Lagoons

9.4 Pond Construction Details

- 9.4.1 Liners
- 9.4.2 Pond Construction
- 9.4.3 Prefilling
- 9.4.4 Utilities and Structures Within Dike Sections

9.5 Hydrograph Controlled Release (HCR) Lagoons

9.6 Polishing Lagoons

9.7 Operability

9.8 Upgrading Existing Systems

PONDS AND AERATED LAGOONS

9.1 General

This chapter describes the requirements for the following biological treatment processes:

- a. Stabilization ponds
- b. Aerated lagoons

Additionally, this chapter describes the requirements for use of hydraulic control release lagoons for effluent disposal.

A guide to provisions for lagoon design is the EPA publication Design Manual - Municipal Wastewater Stabilization Ponds, EPA-625/1-83-015.

9.1.1 Applicability

In general, ponds and aerated lagoons are most applicable to small and/or rural communities where land is available at low cost and minimum secondary treatment requirements are acceptable. Advantages include potentially lower capital costs, simple operation, and low O&M costs.

9.1.2 Supplement to Engineering Report

The engineering report shall contain pertinent information on location, geology, soil conditions, area for expansion, and any other factors that will affect the feasibility and acceptability of the proposed treatment system.

The following information should be submitted in addition to that required in the Chapter 1 section titled "Engineering Report and Preliminary Plans":

- a. The location and direction of all residences, commercial development, and water supplies within 1/2 mile of the proposed pond
- b. Results of the geotechnical investigation performed at the site
- c. Data demonstrating anticipated seepage rates of the proposed pond bottom at the maximum water surface elevation
- d. A description, including maps showing elevations and contours, of the site and adjacent area suitable for expansion
- e. The ability to disinfect the discharge is required.

9.1.3 Effluent Requirements

See Chapter 1, Section 1.1.

9.2 Design Loadings

9.2.1 Stabilization Ponds

Stabilization ponds are facultative and are not artificially mixed or aerated. Mixing and aeration are provided by natural processes. Oxygen is supplied mainly by algae.

Design loading shall not exceed 30 pounds BOD per acre per day on a total pond area basis and 50 pounds BOD per acre per day to any single pond (from Middlebrooks).

9.2.2 Aerated Lagoons

An aerated lagoon may be a complete-mix lagoon or a partial-mix aerated lagoon. Complete-mix lagoons provide enough aeration or mixing to maintain solids in suspension. Power levels are normally between 20 and 40 horsepower per million gallons. The partial-mix aerated lagoon is designed to permit accumulation of settleable solids on the lagoon bottom, where they decompose anaerobically. The power level is normally 4 to 10 horsepower per million gallons of volume.

BOD removal efficiencies normally vary from 80 to 90 percent, depending on detention time and provisions for suspended solids removal.

The aerated lagoon system design for minimum detention time may be estimated by using the following formula; however, for the development of final parameters, it is recommended that actual experimental data be developed.

$$\frac{S_e}{S_o} = \frac{1}{1 + 2.3K_1 t}$$

where:

t = detention time, days

K₁ = reaction coefficient, complete system per day, base 10. For complete treatment of normal domestic sewage, the K₁ value will be assumed to be:
K₁ = 1.087 @20°C for complete mix
K₁ = 0.12 @20°C for partial mix

S_e = effluent BOD₅, mg/l

S_o = influent BOD₅, mg/l

The reaction rate coefficient for domestic sewage that includes significant quantities of industrial wastes, other wastes, and partially treated sewage should be determined experimentally for various conditions that might be encountered in the aerated ponds. Conversion of the reaction rate coefficient to temperatures other than 20 degrees C should be according to the following formula:

$$K_1 = K_{20} 1.036^{(T-20)} \quad (T = \text{temperature in degrees C})$$

The minimum equilibrium temperature of the lagoon should be used for design of the aerated lagoon. The minimum equilibrium temperature should be estimated by using heat balance equations, which should include factors for influent wastewater temperature, ambient air temperature, lagoon surface area, and heat transfer effects of aeration, wind, and humidity. The minimum 30-day average ambient air temperature obtained from climatological data should be used for design.

Additional storage volume shall be considered for sludge storage and partial mix in aerated lagoons.

Sludge processing and disposal should be considered.

9.3 Special Details

9.3.1 General

9.3.1.1 Location

a. Distance from Habitation

A pond site should be located as far as practicable from habitation or any area that may be built up within a reasonable future period, taking into consideration site specifics such as topography, prevailing winds, and forests. Buffer zones between the lagoon and residences or similar land use should be at least 300 feet to residential property lines, and 1000 feet to existing residence structures.

b. Prevailing Winds

If practical, ponds should be located so that local prevailing winds will be in the direction of uninhabited areas. Preference should be given to sites that will permit an unobstructed wind sweep across the length of the ponds in the direction of the local prevailing winds.

c. Surface Runoff

Location of ponds in watersheds receiving significant amounts of runoff water is discouraged unless adequate provisions are made to divert storm water around the ponds and protect pond embankments from erosion.

d. Water Table

The effect of the ground water location on pond performance and construction must be considered.

e. Ground Water Protection

Ground Water Protection's main emphasis should be on site selection and liner construction, utilizing mainly compacted clay. Proximity of ponds to water supplies and other facilities subject to contamination and location in areas of porous soils and fissured rock formations should be critically evaluated to avoid creation of health hazards or other undesirable conditions. The possibility of chemical pollution may merit appropriate consideration. Test wells to monitor potential ground water pollution may be required and should be designed with proper consideration to water movement through the soil as appropriate.

An approved system of ground water monitoring wells or lysimeters may be required around the perimeter of the pond site to facilitate ground water monitoring. The use of wells and/or lysimeters will be determined on a case-by-case basis depending on proximity of water supply and maximum ground water levels. This determination will be at the site approval phase (see Section 1.1).

A routine ground water sampling program shall be initiated prior to and during the pond operation, if required.

f. Floodwaters

Pond sites shall not be constructed in areas subject to 25-year flooding, or the ponds and other facilities shall be protected by dikes from the 25-year flood.

9.3.1.2 Pond Shape

The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular ponds should have a length to width ratio near 1:1 for complete mix ponds. Rectangular ponds with a length not exceeding three times the width are considered most desirable for complete mix aerated lagoons. However, stabilization ponds should be rectangular with a length exceeding three times the width, or be baffled to ensure full utilization of the basin. No islands, peninsulas, or coves are permitted. Dikes should be rounded at corners to minimize accumulations of floating materials. Common dike construction should be considered whenever possible to minimize the length of exterior dikes.

9.3.1.3 Recirculation

Recirculation of lagoon effluent may be considered. Recirculation systems should be designed for 0.5 to 2.0 times the average influent wastewater flow and include flow measurement and control.

9.3.1.4 Flow Measurement

The design shall include provisions to measure, total, and record the wastewater flows.

9.3.1.5 Level Gauges

Pond level gauges should be located on outfall structures or be attached to stationary structures for each pond.

9.3.1.6 Pond Dewatering

All ponds shall have emergency drawdown piping to allow complete draining for maintenance.

Sufficient pumps and appurtenances should be available to facilitate draining of individual ponds in cases where multiple pond systems are constructed at the same elevation or for use if recirculation is desired.

9.3.1.7 Control Building

A control building for laboratory and maintenance equipment should be provided.

9.3.1.8 General Site Requirements

The pond area shall be enclosed with an adequate fence to keep out livestock and discourage trespassing, and be located so that travel along the top of the dike by maintenance vehicles is not obstructed. A vehicle access gate of width sufficient to accommodate mowing equipment and maintenance vehicles should be provided. All access gates shall be provided with locks.

Cyclone-type fences, 5 to 6 feet high with 3 strands of barbed wire, are desirable, with appropriate warning signs required.

9.3.1.9 Provision for Sludge Accumulation

Influent solids, bacteria, and algae that settle out in the lagoons will not completely decompose and a sludge blanket will form. This can be a problem if the design does not include provisions for removal and disposal of accumulated sludge, particularly in the cases of anaerobic stabilization ponds and aerated lagoons. The design should include an estimate of the rate of sludge accumulation, frequency of sludge removal, methods of sludge removal, and ultimate sludge handling and disposal. Abandoning and capping of the lagoon is an acceptable solution (Re: The Division of Solid Waste Management guidelines for abandonment of a lagoon). However, the design life shall be stated in the report.

9.3.2 Stabilization Ponds

9.3.2.1 Depth

The primary (first in a series) pond depth should not exceed 6 feet. Greater depths will be considered for polishing ponds and the last ponds in a series of 4 or more.

9.3.2.2 Influent Structures and Pipelines

a. Manholes

A manhole should be installed at the terminus of the interceptor line or the force main and should be located as close to the dike as topography permits; its invert should be at least 6 inches above the maximum operating level of the pond to provide sufficient hydraulic head without surcharging the manhole.

b. Influent Pipelines

The influent pipeline can be placed at zero grade. The use of an exposed dike to carry the influent pipeline to the discharge points is prohibited, as such a structure will impede circulation.

c. Inlets

Influent and effluent piping should be located to minimize short-circuiting and stagnation within the pond and maximize use of the entire pond area.

Multiple inlet discharge points shall be used for primary cells larger than 10 acres.

All gravity lines should discharge horizontally onto discharge aprons. Force mains should discharge vertically up and shall be submerged at least 2 feet when operating at the 3-foot depth.

d. Discharge Apron

Provision should be made to prevent erosion at the point of discharge to the pond.

9.3.2.3 Interconnecting Piping and Outlet Structures

Interconnecting piping for pond installations shall be valved or provided with other arrangements to regulate flow between structures and permit variable depth control.

The outlet structure can be placed on the horizontal pond floor adjacent to the inner toe of the dike embankment. A permanent walkway from the top of the dike to the top of the outlet structure is required for access.

The outlet structure should consist of a well or box equipped with multiple-valved pond drawoff lines. An adjustable drawoff device is also acceptable. The outlet structure should be designed so that the liquid level of the pond can be varied from a 3.0- 5.0 foot depth in increments of 0.5 foot or less. Withdrawal points shall be spaced so that effluent can be withdrawn from depths of 0.75 foot to 2.0 feet below pond water surface, irrespective of the pond depth.

The lowest drawoff lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface. A two-foot deep baffle may be helpful to keep algae from the effluent. The structure should also have provisions for draining the pond. A locking device should be provided to prevent unauthorized access to level control facilities. An unvalved overflow placed 6 inches above the maximum water level shall be provided.

Outlets should be located nearest the prevailing winds to allow floating solids to be blown away from effluent weirs.

The pond overflow pipes shall be sized for the peak design flow to prevent overtopping of the dikes.

9.3.2.4 Minimum and Maximum Pond Size

No pond should be constructed with less than 1/2 acre or more than 40 acres of surface area.

9.3.2.5 Number of Ponds

A minimum of three ponds, and preferably four ponds, in series should be provided (or baffling provided for a single cell lagoon design configuration) to insure good hydraulic design. The objective in the design is to eliminate short circuiting.

9.3.2.6 Parallel/Series Operation

Designs, other than single ponds with baffling, should provide for operation of ponds in parallel or series. Hydraulic design should allow for equal distribution of flows to all ponds in either mode of operation.

9.3.3 Aerated Lagoons

9.3.3.1 Depth

Depth should be based on the type of aeration equipment used, heat loss considerations, and cost, but should be no less than 7 feet. In choosing a depth, aerator erosion protection and allowances for ice cover and solids accumulation should be considered.

9.3.3.2 Influent Structures and Pipelines

The same requirements apply as described for facultative systems, except that the discharge locations should be coordinated with the aeration equipment design.

9.3.3.3 Interconnecting Piping and Outlet Structures

a. Interconnecting Piping

The same requirements apply as described for facultative systems.

b. Outlet Structure

The same requirements apply as described for facultative systems, except for variable depth requirements and arrangement of the outlet to withdraw effluent from a point at or near the surface. The outlet shall be preceded by an underflow baffle.

9.3.3.4 Number of Ponds

Not less than three basins should be used to provide the detention time and volume required. The basins should be arranged for both parallel and series operation. A settling pond with a hydraulic detention time of 2 days at average design flow must follow the aerated cells, or an equivalent of the final aerated cell must be free of turbulence to allow settling of suspended solids.

9.3.3.5 Aeration Equipment

A minimum of two mechanical aerators or blowers shall be used to provide the horsepower required. At least three anchor points should be provided for each aerator. Access to aerators should be provided for routine maintenance which does not affect mixing in the lagoon. Timers will be required.

9.4 Pond Construction Details

9.4.1 Liners

9.4.1.1 Requirement for Lining

The seepage rate through the lagoon bottom and dikes shall not be greater than a water surface drop of 1/4 inch per day. (Note: The seepage rate of 1/4 inch per day is 7.3×10^{-6} cm/sec coefficient of permeability seepage rate under pond conditions.) If the native soil cannot be compacted or modified to meet this requirement, a pond liner system will be required.

If a lagoon is proposed to be upgraded, it must be shown that it currently meets the 1/4-inch per day seepage rate before approval will be given.

9.4.1.2 General

Pond liner systems that should be evaluated and considered include (1) earth liners, including native soil or local soils mixed with commercially prepared bentonite or comparable chemical sealing compound, and (2) synthetic membrane liners. The liner should not be subject to deterioration in the presence of the wastewater. The geotechnical recommendations should be carefully considered during pond liner design. Consideration should also be given to construct test wells when required by the Department in any future regulations, or when industrial waste is involved.

9.4.1.3 Soil Liners

The thickness and the permeability of the soil liners shall be sufficient to limit the leakage to the maximum allowable rate of 1/4 inch per day. The evaluation of earth for use as a soil liner should include laboratory permeability tests of the material and laboratory compaction tests. The analysis should take into consideration the expected permeability of the soil when compacted in the field. All of the soil liner material shall have essentially the same properties.

The analysis of an earth liner should also include evaluation of the earth liner material with regard to filter design criteria. This is required so that the fine-grained liner material does not infiltrate into a coarser subgrade material and thus reduce the effective thickness of the liner.

If the ponds are going to remain empty for any period of time, consideration should be given to the possible effects on the soil liners from freezing and thawing during cold weather or cracking from hot, dry weather. Freezing and thawing will generally loosen the soil for some depth. This depth is dependent on the depth of frost penetration.

The compaction requirements for the liner should produce a density equal to or greater than the density at which the permeability tests were made. The minimum liner thickness should be 12 inches, to ensure proper mixing of bentonite with the native soil. The soil should be placed in lifts no more than 6 inches in compacted thickness. The moisture content at which the soil is placed should be at or slightly above the optimum moisture content.

Construction and placement of the soil liner should be inspected by a qualified inspector. The inspector should keep records on the uniformity of the earth liner material, moisture contents, and the densities obtained.

Bentonite and other similar liners should be considered as a form of earth liner. Their seepage characteristics should be analyzed as previously mentioned, and laboratory testing should be performed using the mixture of the native or local soil and bentonite or similar compound. In general, the requirements for bentonite or similar compounds should include the following: (1) The

bentonite or similar compound should be high swelling and free flowing and have a particle size distribution favorable for uniform application and minimizing of wind drift; (2) the application rate should be at least 125 percent of the minimum rate found to be adequate in laboratory tests; (3) application rates recommended by a supplier should be confirmed by an independent laboratory; and (4) the mixtures of soil and bentonite or similar compound should be compacted at a water content greater than the optimum moisture content.

9.4.1.4 Synthetic Membrane Liners

Requirements for the thickness of synthetic liners may vary due to the liner material, but it is generally recommended that the liner thickness be no less than 20 mils; that is, 0.020 inch. There may be special conditions when reinforced membranes should be considered. These are usually considered where extra tensile strength is required. The membrane liner material should be compatible with the wastewater in the ponds such that no damage results to the liner. PVC liners should not be used where they will be exposed directly to sunlight. The preparation of the subgrade for a membrane liner is important. The subgrade should be graded and compacted so that there are no holes or exposed angular rocks or pieces of wood or debris. If the subgrade is very gravelly and contains angular rocks that could possibly damage the liner, a minimum bedding of 3 inches of sand should be provided directly beneath the liner. The liner should be covered with 12 inches of soil. This includes the side slope as well. No equipment should be allowed to operate directly on the liner. Consideration should be given to specifying that the manufacturer's representative be on the job supervising the installation during all aspects of the liner placement. An inspector should be on the job to monitor and inspect the installation.

Leakage must not exceed 1/4-inch per day.

9.4.1.5 Other Liners

Other liners that have been successfully used are soil cement, gunite, and asphalt concrete. The performance of these liners is highly dependent on the experience and skill of the designer. Close review of the design of these types of liners is recommended.

9.4.2 Pond Construction

9.4.2.1 General

Ponds are often constructed of either a built-up dike or embankment section constructed on the existing grade, or they are constructed using a cut and fill technique. Dikes and embankments shall be designed using the generally accepted procedures for the design of small earth dams. The design should attempt to make use of locally available materials for the construction of dikes. Consideration should also be given to slope stability and seepage through and beneath the embankment and along pipes.

9.4.2.2 Top Width

The minimum recommended dike top width should be 12 feet on tangents and 15 feet on curves to permit access of maintenance vehicles. The minimum inside radius of curves of the corners of the pond should be 35 feet.

9.4.2.3 Side Slopes

Normally, inside slopes of either dikes or cut sections should not be steeper than 3 horizontal to 1 vertical. Outer slopes should not be steeper than 2 horizontal to 1 vertical. However, in many instances, the types of material used, maintenance considerations, and seepage conditions can indicate that other slopes should be used.

9.4.2.4 Freeboard

There should be sufficient freeboard to prevent overtopping of the dike from wave action and strong winds. A minimum of one foot is required.

9.4.2.5 Erosion Control

Erosion control should be considered for the inside slopes of the dike to prevent the formation of wavecut beaches in the dike slope. In the event that earth liners or membrane liners with earth cover are used, consideration should be given to erosion protection directly beneath aeration units. If the currents are strong enough, considering the type of material used for the earth cover, erosion pads may be necessary beneath the aeration units. Erosion control should also be considered wherever influent pipes empty into the pond. If a grass cover for the outer slopes is desired, they should be fertilized and seeded to establish a good growth of vegetative cover. This vegetative cover will help control erosion from runoff. Consideration should also be given to protection of the outer slopes in the event that flooding occurs. The erosion protection should be able to withstand the currents from a flood.

9.4.3 Prefilling

The need to prefill ponds in order to determine the leakage rate shall be determined by the Department and incorporated into the plans and specifications. The strongest consideration for prefilling ponds will be given to ponds with earth liners. Ponds in areas where the surrounding homes are on wells will also be given strong consideration for prefilling.

9.4.4 Utilities and Structures Within Dike Sections

Pipes that extend through an embankment should be bedded up to the springline with concrete. Backfill should be with relatively impermeable material. No granular bedding material should be used. Cutoff collars should be used as required. No gravel or granular base should be used under or around any structures placed in the embankment within the pond. Embankments should be constructed at least 2 feet above the top of the pipe before excavating the pipe trench.

9.5 Hydrograph Controlled Release (HCR) Lagoons

All lagoons requirements apply to HCR lagoons with the following additional concerns:

HCR lagoons control the discharge of treated wastewater in accordance with the stream's assimilative capacity. Detention times vary widely and must be determined on a case-by-case basis.

HCR sites require much receiving stream flow pattern characterization. For this purpose, EPA Region IV has developed a computer design program. The Division of Water Pollution Control can assist in sizing the HCR basin using this program. HCR sites may be more economical if the design is combined with summertime land application. Their design is more economical if summer/winter or monthly standards are available.

The design and construction of the in-stream flow measurement equipment are critical components of an HCR system. The United States Geological Survey (USGS) should be contacted during the design phase. The USGS also has considerable construction experience concerning in-stream monitoring stations, although construction need not necessarily be done or supervised by the USGS.

9.6 Polishing Lagoons

Polishing lagoons following activated sludge are not permissible in Tennessee due to the one-cell algae interference.

9.7 Operability

Once a pond is designed, little operation should be required. However, to avoid NPDES permit violations, pond flexibility is needed. Operation flexibility is best facilitated by the addition of piping and valves to each pond which allows isolation of its volume during an algal bloom.

9.8 Upgrading Existing Systems

There are approximately sixty existing lagoons in Tennessee which were built utilizing standards and criteria from the 1960 period. Most are single- or double-cell units which need upgrading. Many are required to meet tertiary standards. The upgrade case should, in general, utilize the guidance in this chapter or proven configurations. It is noted, however, that there are many lagoon combinations available, such as complete-mix pond, partial-mix pond, stabilization pond, HCR pond and marsh-pond (wetlands) concepts. The combination of these alternatives should be based upon the effluent permit design standards as well as site economics.

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CHAPTER 10

Disinfection

10.1 General

- 10.1.1 Requirement for Disinfection
- 10.1.2 Methods of Disinfection
- 10.1.3 Dechlorination

10.2 Chlorination

- 10.2.1 General
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- 10.2.4 Safety

10.3 Alternate Methods

- 10.3.1 Ozonation
- 10.3.2 Ultraviolet Disinfection

DISINFECTION

10.1 General

10.1.1 Requirement for Disinfection

Proper disinfection of treated wastewater before disposal is required for all plants (with the exception of some land application systems) to protect the public health.

Disinfection as a minimum shall:

- a. Protect public water supplies
- b. Protect fisheries and shellfish waters
- c. Protect irrigation and agricultural waters
- d. Protect water where human contact is likely

10.1.2 Methods of Disinfection

10.1.2.1 Chlorination

Chlorination using dry chlorine (see definition in following section) is the most commonly applied method of disinfection and should be used unless other factors, including chlorine availability, costs, or environmental concerns, justify an alternative method.

10.1.2.2 Ozonation

Ozonation may be considered as an alternative to chlorination for the reasons described above. Ozonation is considered as Developmental Technology, and should only be considered for very large installations.

10.1.2.3 Other

Other potential methods of disinfection, such as by ultraviolet light, are available and their application will be considered on a case-by-case basis.

10.1.3 Dechlorination

Capability to add dechlorination should be considered in all new treatment plants. Dechlorination of chlorinated effluents shall be provided when permit conditions dictate the need.

10.2 Chlorination

10.2.1 General

10.2.1.1 Forms of Chlorine

- a. Dry Chlorine

Dry chlorine is defined as elemental chlorine existing in the liquid or gaseous phase, containing less than 150 mg/l water. Unless otherwise stated, the word "chlorine" wherever used in this section refers to dry chlorine.

b. Sodium Hypochlorite

Sodium hypochlorite may be used as an alternative to chlorine whenever dry chlorine availability, cost, or public safety justifies its use. The requirements for sodium hypochlorite generation and feeding will be determined on a case-by-case basis.

c. Other

Other chlorine compounds such as chlorine dioxide or bromine chloride may be used as alternatives to chlorine whenever cost or environmental concerns justify their use. The acceptability of other chlorine compounds will be determined on a case-by-case basis.

10.2.1.2 Chlorine Feed Equipment

Solution-feed vacuum-type chlorinators are generally preferred for large installations. The use of hypochlorite feeders of the positive displacement type may be considered. Dry chlorine tablet type feeders may also be considered for small flows, into large streams.

Liquid chlorine evaporators should be considered where more than four 1-ton containers will be connected to a supply manifold.

10.2.1.3 Chlorine Supply

a. Cylinders

Cylinders should be considered where the average daily chlorine use is 150 pounds or less. Cylinders are available in 100-pound or 150-pound sizes.

b. Containers

The use of 1-ton containers should be considered where the average daily chlorine consumption is over 150 pounds.

c. Large-Volume Shipments

At large installations, consideration should be given to the use of truck or railroad tank cars, or possibly barge tank loads, generally accompanied by gas evaporators.

10.2.1.4 Chlorine Gas Withdrawal Rates

The maximum withdrawal rate for 100- and 150- pound cylinders should be limited to 40 pounds per day per cylinder.

When gas is withdrawn from 2,000-pound containers, the withdrawal rate should be limited to 400 pounds per day per container.

10.2.2 Design Considerations

10.2.2.1 General

Chlorination system designs should consider the following design factors:

Flow

Contact time

Concentration and type of chlorine residual

Mixing

pH

Suspended solids

Industrial wastes

Temperature

Concentration of organisms

Ammonia concentration

10.2.2.2 Capacity

Required chlorinator capacities will vary, depending on the use and point of application of the chlorine. Chlorine dosage should be established for each individual situation, with those variables affecting the chlorine reaction taken into consideration. For normal wastewater, the following dosing capacity may be used as a guideline.

<u>Type of Treatment</u>	<u>Dosage Capacity* (mg/l)</u>
Prechlorination for Odor Control	20-25
Activated Sludge Return	5-10
Trickling Filter Plant Effluent (non-nitrified)	3-15
Activated Sludge Plant Effluent (non-nitrified)	2-8
Tertiary Filtration Effluent	1-6
Nitrified Effluent	2-6

* Based on Average Design Flow.

The design should provide adequate flexibility in the chlorination equipment and control system to allow controlled chlorination at minimum and peak flows over the entire life of the treatment plant. Special consideration should be given to the chlorination requirements during the first years of operation to ensure the chlorination system is readily operable at less than design flows without overchlorination. Chlorination equipment should operate between 25% and 75% of total operating range, to allow for adjusting flexibility at design average flow.

10.2.2.3

Mixing

The mixing of chlorine and wastewater can be accomplished by hydraulic or mechanical mixing.

Hydraulic mixing is preferred in smaller plants over mechanical mixing and should be done according to the following criteria.

a. Pipe Flow:

A Reynolds Number of greater than or equal to 1.9×10^4 is required.

Pipes up to 30 inches in diameter: chlorine injected into center of pipe.

Pipes greater than 30 inches in diameter: chlorine injected with a grid-type diffuser.

Chlorine applied at least 10 pipe diameters upstream from inlet to contact tank.

b. Open channel flow: a hydraulic jump with a minimum Froude Number of 4.5 is necessary to provide adequate hydraulic mixing. Point of chlorine injection must be variable because jump location will change with changes in flow.

When mechanical mixing must be used, the following criteria apply:

Use where Reynolds Number for pipe flow is less than 1.9×10^4 or for open channel flow without a hydraulic jump.

A mixer-reactor unit is necessary that provides 6 to 18 seconds contact.

Inject chlorine just upstream from mixer.

Mixer speed a minimum of 50 revolutions per minute (rpm).

Jet Chlorinators may be used in a separate chamber from the contact chamber. The contact chamber shall conform to Section 10.2.2.4 with an average design flow minimum detention time reduced to 15 minutes and a peak detention time of 7.5 minutes.

10.2.2.4 Contact Period

Contact chambers shall be sized to provide a minimum of 30 minutes detention at average design flow and 15 minutes detention at daily peak design flow, whichever is greater. Contact chambers should be designed so detention times are less than 2 hours for initial flows.

10.2.2.5 Contact Chambers

The contact chambers should be baffled to minimize short-circuiting and backmixing of the chlorinated wastewater to such an extent that plug flow is approached. It is recommended that baffles be constructed parallel to the longitudinal axis of the chamber with a minimum length-to-width ratio of 30:1 (the total length of the channel created by the baffles should be 30 times the distance between the baffles). Shallow unidirectional contact chambers should also have cross-baffles to reduce short-circuiting caused by wind currents.

Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent. To accomplish continuous disinfection, the chlorine contact tank should be designed with duplicate compartments to permit draining and cleaning of individual compartments. A sump or drain within each compartment, with the drainage flowing to a raw sewage inlet, shall be provided for dewatering, sludge accumulation, and maintenance. Unit drains shall not discharge into the outfall pipeline. Baffles shall be provided to prevent the discharge of floating material.

A readily accessible sampling point shall be provided at the outlet end of the contact chamber.

In some instances, the effluent line may be used as chlorine contact chambers provided that the conditions set forth above are met.

10.2.2.6 Dechlorination

a. Sulfur Dioxide

Sulfur dioxide can be purchased, handled, and applied to wastewater in the same way as chlorine. Sulfur dioxide gas forms sulfurous acid, a strong reducing agent, when combined with water. When mixed with free and combined chlorine residuals, sulfurous acid will neutralize these active chlorine compounds to the nontoxic chloride ion. Sulfur dioxide dosage required for dechlorination is 1 mg/l of SO_2 for 1 mg/l of chlorine residual expressed as Cl_2 . Reaction time is essentially instantaneous. Detention time requirements are based on

the time necessary to assure complete mixing of the sulfur dioxide.

b. Other Methods

For very small treatment systems, detention ponds should be considered for dechlorination.

Design rationale and calculations shall be submitted upon request to justify the basis of design for all major components of other dechlorination processes.

10.2.2.7 Sampling, Instrumentation, and Control

For treatment facility designs of 0.5 mgd and greater, continuously modulated dosage control systems should be used. The control system should adjust the chlorine dosage rate to accommodate fluctuations in effluent chlorine demand and residual caused by changes in waste flow and waste characteristics with a maximum lag time of five minutes. These facilities should also utilize continuous chlorine residual monitoring.

Flow proportional control is preferred over manual control for smaller facilities and may be required on a case-by-case basis. The design shall shut off the chlorination for small systems where the flow is zero, such as late at night.

In all cases where dechlorination is required, a compound loop control system or equivalent should be provided.

All sample lines should be designed so that they can be easily purged of slimes and other debris and drain or be protected from freezing.

Alarms and monitoring equipment that adequately alert the operators in the event of deficiencies, malfunctions, or hazardous situations related to chlorine supply metering equipment, leaks, and residuals may be required on a case-by-case basis.

Design of instrumentation and control equipment should allow operation at initial and design flows.

10.2.2.8 Residual Chlorine Testing

Equipment should be provided for measuring chlorine residual. There are five EPA accepted methods for analysis of total residual chlorine and they are 1) Ion Selective Electrode, 2) Amperometric End Point Titration Method, 3) Iodometric Titration Methods I & II, 4) DPD Colormetric Method and, 5) DPD Ferrous Titrimetric Method. Where the discharge occurs in critical areas, the installation of facilities for continuous automatic chlorine residual analysis and recording systems may be required.

10.2.3 Design Details

10.2.3.1 Housing

a. General

An enclosed structure shall be provided for the chlorination equipment.

Chlorine cylinder or container storage area shall be shaded from direct sunlight.

Chlorination systems should be protected from fire hazards, and water should be available for cooling cylinders or containers in case of fire.

Any building which will house chlorine equipment or containers should be designed and constructed to protect all elements of the chlorine system from fire hazards. If flammable materials are stored or processed in the same building with chlorination equipment (other than that utilizing hypochlorite solutions), a firewall should be erected to separate the two areas.

If gas chlorination equipment and chlorine cylinders or containers are to be in a building used for other purposes, a gastight partition shall separate this room from any other portion of the building. Doors to this room shall open only to the outside of the building and shall be equipped with panic hardware. Such rooms should be at or above ground level and should permit easy access to all equipment.

A reinforced glass, gastight window shall be installed in an exterior door or interior wall of the chlorinator room to permit the chlorinator to be viewed without entering the room.

Adequate room must be provided for easy access to all equipment for maintenance and repair. The minimum acceptable clearance around and in back of equipment is 2 feet, except for units designed for wall or cylinder mounting.

b. Heat

Chlorinator rooms should have a means of heating and controlling the room air temperature above a minimum of 55° F. A temperature of 65° F is recommended.

The room housing chlorine cylinders or containers in use should be maintained at a temperature less than the chlorinator room, but in no case less than 55° F unless evaporators are used and liquid chlorine is withdrawn.

All rooms containing chlorine should also be protected from excess heat.

The room containing ozone generation units shall be maintained above 35°F at all times.

c. Ventilation

All chlorine feed rooms and rooms where chlorine is stored should be force-ventilated, providing one air change per minute, except "package" buildings with less than 16 square feet of floor space, where an entire side

opens as a door and sufficient cross-ventilation is provided by a window. For ozonation systems, continuous ventilation to provide at least 6 complete air changes per hour should be installed. The entrance to the air exhaust duct from the room should be near the floor and the point of discharge should be so located as not to contaminate the air inlet to any building or inhabited areas. The air inlet should be located to provide cross-ventilation by air at a temperature that will not adversely affect the chlorination equipment.

Chlorinators and some accessories require individual vents to a safe outside area. The vent should terminate not more than 25 feet above the chlorinator or accessory and have a slight downward slope from the highest point. The outside end of the vent should bend down to preclude water entering the vent and be covered with a screen to exclude insects.

d. Electrical

Electrical controls for lights and the ventilation system should operate automatically when the entrance doors are opened. Manually controlled override switches should be located adjacent to and outside of all entrance doors, with an indicator light at each entrance. Electrical controls should be excluded, insofar as possible, from rooms containing chlorine cylinders, chlorine piping, or chlorination equipment.

e. Dechlorination equipment (SO₂) shall not be placed in the same room as the Cl₂ equipment. SO₂ equipment is to be located such that the safety requirements of handling Cl₂ are not violated in any form or manner.

10.2.3.2 Piping and Connections

a. Dry Chlorine

Piping systems should be as simple as possible, with a minimum number of joints; piping should be well supported, adequately sloped to allow drainage, protected from mechanical damage, and protected against temperature extremes.

The piping system to handle gas under pressure should be constructed of Schedule 80 black seamless steel pipe with 2,000-pound forged steel fittings. Unions should be ammonia type with lead gaskets. All valves should be Chlorine Institute-approved. Gauges should be equipped with a silver protector diaphragm.

Piping can be assembled by either welded or threaded connections. All threaded pipe must be cleaned with solvent, preferably trichlorethylene, and dried with nitrogen gas or dry air. Teflon tape should be used for thread lubricant in lieu of pipe dope.

b. Injector Vacuum Line

The injector vacuum line between the chlorinator and the injector should be Schedule 80 PVC or fiber cast pipe approved for moist chlorine use.

c. Chlorine Solution

The chlorine solution lines can be Schedule 40 or 80 PVC, rubber-lined steel, saran-lined steel, or fiber cast pipe approved for moist chlorine use. Valves should be PVC, PVC-lined, or rubber-lined.

10.2.3.3 Water Supply

An ample supply of water shall be available for operating the chlorinator. Where a booster pump is required, duplicate equipment shall be provided, and, when necessary, standby power as well. When connection is made from domestic water supplies, equipment for backflow prevention shall be provided. Where treated effluent is used, a wye strainer shall be required. Pressure gauges should be provided on chlorinator water supply lines.

10.2.3.4 Standby Equipment and Spare Parts

Standby chlorination capabilities should be provided which will ensure adequate disinfection with any unit out of operation for maintenance or repairs. An adequate inventory of parts subject to wear and breakage should be maintained at all times.

10.2.3.5 Scales

Scales shall be provided at all plants using chlorine gas. At large plants, scales of the indicating and recording type are recommended. Scales shall be provided for each cylinder or container in service; one scale is adequate for a group of cylinders or containers connected to a common manifold. Scales should be constructed of or coated with corrosion-resistant material.

Scales shall be recommended for day tanks when using HTH.

10.2.3.6 Handling Equipment

Handling equipment should be provided as follows for 100- and 150-pound cylinders:

A hand truck specifically designed for cylinders

A method of securing cylinders to prevent them from falling over

Handling equipment should be provided as follows for 2,000-pound containers:

Two-ton-capacity hoist

Cylinder lifting bar

Monorail or hoist with sufficient lifting height to pass one cylinder over another

Cylinder trunnions to allow rotating the cylinders for proper connection.

10.2.3.7 Container Space

Sufficient space should be provided in the supply area for at least one spare cylinder or container for each one in service.

10.2.3.8 Automatic Switchover of Cylinders and Containers

Automatic switchover of chlorine cylinders and containers at facilities having less than continuous operator attendance is desirable and will be required on a case-by-case basis.

10.2.4 Safety

10.2.4.1 Leak Detection and Controls

A bottle of 56% ammonium hydroxide solution shall be available for detecting chlorine leaks.

All installations utilizing 2,000-pound containers and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors. Continuous chlorine leak detectors would be desirable at all installations. Whenever chlorine leak detectors are installed, they should be connected to a centrally located alarm system and shall automatically start exhaust fans.

10.2.4.2 Breathing Apparatus

At least one gas mask in good operating condition and of a type approved by the National Institute for Occupational Safety and Health (NIOSH) as suitable for high concentrations of chlorine gas shall be available at all installations where chlorine gas is handled and shall be stored outside of any room where chlorine is used or stored. Instructions for using, testing, and replacing mask parts, including canisters, shall be posted. At large installations, where 1-ton containers are used, self-contained air breathing apparatus of the positive pressure type shall be provided.

10.2.4.3 Container Repair Kits

All installations utilizing 1-ton containers should have Chlorine Institute Emergency Container Kits. Other installations using cylinders should have access to kits stored at a central location.

10.2.4.4 Piping Color Codes

It is desirable to color code all piping related to chlorine systems.

10.3 Alternate Methods

____ 10.3.1 Ozonation

10.3.1.1 Application

Ozonation may be substituted for chlorination whenever chlorine availability, cost, or environmental benefits justify its application.

Ozone is generated on-site from either air or high-purity oxygen. Ozonation should be considered if high-purity oxygen is available at the plant for other processes.

10.3.1.2 Design Basis

The design requirements for ozonation systems should be based on pilot testing or similar full-scale installations. As a minimum, the following design factors should be considered:

- a. Ozone dosage
- b. Dispersion and mixing of ozone in wastewater
- c. Contactor design

All design criteria shall be submitted upon request to justify the basis of design of the ozonation system. The detailed design requirements will be determined on a case-by-case basis.

10.3.2 Ultraviolet Disinfection

10.3.2.1 Application

UV disinfection may be substituted for chlorination, particularly whenever chlorine availability, cost, or environmental benefits justify its application. For tertiary treatment plants where dechlorination is required or chlorine toxicity is suspected, UV disinfection is a viable alternative.

10.3.2.2 Design Basis

In the design of UV disinfection units there are three basic areas that should be considered:

- a. Reactor hydraulics
- b. Factors affecting transmission of UV light to the microorganisms
- c. Properties of the wastewater being disinfected.

UV disinfection is considered as Developmental Technology and all design criteria shall be submitted upon request to justify the basis of the UV disinfection system. The detailed design requirements will be determined on a case-by-case basis.

CHAPTER 11

Tertiary Treatment/Advanced Wastewater Treatment

11.1 Filtration

- 11.1.1 General
- 11.1.2 High Rate Gravity Filters
- 11.1.3 Pressure and Vacuum High Rate Filters
- 11.1.4 Standard Rate Gravity Filters
- 11.1.5 Shallow Bed Filters (Slow Sand Filters)
- 11.1.6 Operability

11.2 Post Aeration

- 11.2.1 General
- 11.2.2 Aeration Tank Systems
- 11.2.3 Cascade Systems
- 11.2.4 Operability

11.3 Nutrient Removal

TERTIARY TREATMENT/ADVANCED WASTEWATER TREATMENT

11.1 Filtration

_____ 11.1.1 General

Supplementary solids separation, following secondary clarification of wastewater, may be needed either as a final treatment step or prior to discharging to an ion exchange bed, carbon bed, reverse osmosis or other system. Filtration should be accomplished through a filter consisting of sand; sand and anthracite; anthracite; or anthracite, sand and garnet (or ilmenite).

11.1.2 High Rate Gravity Filters

11.1.2.1 Design

A minimum wastewater depth of 3 feet, measured from the normal operating wastewater surface to the surface of the filter medium, shall be provided. Even distribution of the wastewater over the filter area shall be provided. The top filter material shall not be displaced by the influent wastewater. The bottom wastewater trough elevation shall be above the maximum level of expanded medium during backwashing. A top wastewater trough elevation shall be no more than 30 inches above the filter surface. Spacing of the troughs shall be such that horizontal partial travel distance is not greater than 3 feet, and equal spacing between troughs is provided so that the same number of square feet of filter area is served by each trough.

For High Rate Filtration, dual or multi-media only shall be used. The maximum filter rate shall be 4 gpm/ft² immediately after backwash with a nominal rate of less than 4 gpm/ft² at the peak daily flow. A minimum of two filters shall be provided. Filtration shall be designed so that, with one filter out of service, each of the remaining filter(s) shall filter no greater than 4 gpm/ft² at the design peak daily flow. Equipment for the application of filter aids to the filter influent should be provided.

11.1.2.2 Medium

- a. Sand - The medium shall be clean silica sand having
 - (i) a depth of 30 inches;
 - (ii) an effective size of from 0.35 mm to 0.55 mm, depending upon the loading of the wastewater, and;
 - (iii) a uniformity coefficient not greater than 1.70.
- b. Anthracite - a combination of sand and clean crushed anthracite may be used. The anthracite shall have
 - (i) an effective size of 0.8 mm - 1.2 mm, and;
 - (ii) a uniformity coefficient not greater than 1.85;
 - (iii) anthracite layer shall not exceed 20 inches in a 30-inch bed.

- c. A 3-inch layer of torpedo sand may be used as a supporting medium for the filter sand; such torpedo sand shall have
 - (i) an effective size of 0.8 mm to 2.0 mm, and,
 - (ii) a uniformity coefficient not greater than 1.70.
- d. Gravel - Gravel, when used as the supporting medium, shall consist of hard, rounded silicious particles.
 - (i) The minimum gravel size of the bottom layer should be 3/4 inch or larger.
 - (ii) For proper grading of intermediate layers:
 - (1) the minimum particle size of any layer should be as large as the maximum particle size in the layer next above and;
 - (2) within any layer the maximum particle size should not be more than twice the minimum particle size.
 - (iii) The depth of any gravel layer should not be less than 2 inches or less than twice the largest gravel size for that layer, whichever is greater. The bottom layer should be thick enough to cover underdrain laterals, strainers, or other irregularities in the filter bottom.
 - (iv) The total depth of gravel above the underdrains should not be less than 10 inches.

(Reduction of gravel depths may be considered upon justification when proprietary filter bottoms are installed.)
- e. Multi-media - To be approved on a case-by-case basis.

The medium should consist of anthracite, silica sand, and/or other suitable sand. Since filters presently utilizing dual media and mixed media are proprietary in nature, no attempt will be made to set standards for minimum filter media depth, effective size and uniformity coefficient of filter media, or the specific gravity of that medium.

11.1.2.3

Underdrains.

Porous-plate bottoms shall not be used. Perforated pipe underdrains should be used, consisting of a manifold and laterals. Underdrain systems allowable in water plants such as Leopold or Wheeler bottoms are acceptable. The orifice loss in backwashing must exceed the sum of the minor hydraulic losses in the underdrain system to secure good distribution of flow over the entire area of the filter bottom. In order to insure adequate design of perforated pipe underdrain systems the following ratios must fall within the ranges shown:

$\frac{\text{orifice area}}{\text{bed area}}$	=	$\frac{0.0015}{1}$	to	$\frac{0.005}{1}$
$\frac{\text{lateral area}}{\text{area of orifices served}}$	=	$\frac{2}{1}$	to	$\frac{4}{1}$
$\frac{\text{manifold area}}{\text{area of laterals served}}$	=	$\frac{1.5}{1}$	to	$\frac{3}{1}$

Orifices should have 3 to 12 inch spacing, and laterals the same. Underdrains should be made of corrosion and scale resistant materials, or properly protected against corrosion.

Orifices through false filter bottoms or underdrain design are preferred. The glazed tile filter block used in some filter bottoms and the stainless steel modulares used in other filter bottom designs are recommended to provide even and uniform distribution of backwash water. Hydraulic distribution data on each standard filter size should be submitted.

11.1.2.4 Backwash

Provisions shall be made for washing filters as follows:

- a. a rate to provide for a 50 percent expansion of the medium is recommended, consistent with water temperatures and specific gravity of the filter medium; a minimum rate of 15 gpm/ft² is recommended, however 20 gpm/ft² may be required for adequate expansion of the filter medium.
- b. filtered wastewater provided at the required backwash rate by washwater tanks, a washwater pump(s) or a combination of these is required,
- c. washwater pumps in duplicate unless an alternate means of obtaining washwater is available; air release must be provided;
- d. washwater supply to backwash two filters for at least 5 minutes at the design rate of wash; plus surface wash requirements;
- e. A washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters completely open is required.
- f. Air scouring at 3-5 cu ft/min/ft² of filter area for at least 3 minutes preceding water backwash is acceptable.
- g. Rate of flow indicators on the main washwater line shall be provided and should be located so that it can be easily read by the operator during backwash.
- h. Backwash wastewater treatment and disposal must be accomplished within the rated design capacities of the treatment system. Backwash wastewater cannot be discharged to a stream without first receiving adequate

treatment. If it is desired to recycle the backwash wastewater through a secondary system, then the hydraulic design of the entire system (including the clarifier and filter) must be based on the anticipated rate of raw influent flow plus the flow rate at which the backwash water enters the system. In most systems a backwash water holding tank and controlled discharge system will be required. This holding system must be capable of storing the wastes from two backwashes and discharging the wastes to the treatment system within 24 hours at a rate which, in combination with the raw influent, does not exceed the hydraulic design of any system component when the loading period for the plant is 24 hours. For plants with loading periods less than 24 hours, additional backwash holding capacity may be required. For example, a school's sewage treatment plant with an 8-hour loading period and a backwash holding system which pumps from its holding tank to the head of the treatment process only during low loading periods may require a holding tank with a capacity for three or more backwash volumes.

- i. Backwash may be initiated either automatically or manually; the length of the backwash period must be automatically controlled by a timing device adjustable in one minute increments up to a possible 15 minute backwash duration.

11.1.2.5 Surface Wash

Surface wash facilities are required. Disinfected filtered wastewater effluent should be used for surface wash. Revolving-type surface washers should be provided; however, other types may be considered. All rotary surface wash devices should be designed with:

- a. Provisions for minimum washwater pressures of 40 psi and;
- b. Provisions for adequate surface washwater to provide 0.5 to 1 gallon per minute per square foot of filter area.

11.1.3 Pressure and Vacuum High Rate Filters

11.1.3.1 General

Pressure sand filters are those operating under pressure in a closed container. Generally, a pump discharge line delivers the influent to the pressure filter. Vacuum sand filters are those operating under partial vacuum within the underdrain system; they can have open beds. Generally, a pump suction line is connected to the underdrain of a vacuum sand filter.

11.1.3.2 Design

Design requirements for pressure or vacuum filters include all of those listed for High Rate Gravity Filters in paragraphs 11.1.2.1 through 11.1.2.5, plus the following;

Pressure filter containers must meet all applicable safety codes and requirements. Containers must be large enough to permit a

man to work inside for medium removal and underdrain maintenance. A minimum diameter of 3 feet is suggested. An access port must be provided for inspection and maintenance purposes.

11.1.4 Standard Rate Gravity Filters

11.1.4.1 General

A minimum of two complete units is required. Each unit must be designed to treat 100 percent of plant flow except where design flow is 100,000 gpd or greater (see Design Section 11.1.4.2). The sand surface must be submerged at all times. Generally, standard rate filters are monomedium sand filters (see Media Section 11.1.4.3).

11.1.4.2 Design

The hydraulic design loading for each filter must be within the range of 1.0 to 2.0 gpm/ft². For installation less than 100,000 gpd the nominal filter rate shall be 1.0 gpm/ft² with one cell loaded no more than 2.0 gpm/ft² during backwash of the other cell. For installations greater than 100,000 gpd it is expected that each filter cell will be loaded at 2 gpm/ft² and during periods of backwash; no other cell may be loaded higher than 4 gpm/ft². Even distribution of the wastewater over the filter shall be provided. The filter sand shall not be displaced by the influent wastewater. The bottom washwater trough elevation shall be above the maximum level of expanded medium during backwash. A top washwater trough elevation shall be no more than 30 inches above the filter surface. Spacing of the troughs shall be such that horizontal partical travel distance is not greater than 3 feet, and equal spacing between troughs is provided so that the same number of square feet of filter area is served by each trough.

11.1.4.3 Medium

The filter medium should have the following properties:

a. Sand

A sieve analysis should be provided by the design engineer. The medium should be clean silica sand having (1) a depth of not less than 27 inches and generally not more than 30 inches after cleaning and scraping and (2) an effective size of 0.35 mm to 0.5 mm, depending upon the quality of the applied wastewater, and a uniformity coefficient not greater than 1.6. Clean crushed anthracite or a combination of sand and anthracite may be used. Such media should have (1) an effective size from 0.45 mm to 0.8 mm and (2) a uniformity coefficient not greater than 1.7.

b. Supporting medium for the filter sand

A sieve analysis should be provided by the design engineer. A 3-inch layer of torpedo sand should be used as the supporting medium for the filter sand. Such torpedo sand should have (1) an effective size of 0.8 mm

to 2.0 mm and (2) a uniformity coefficient not greater than 1.7.

c. Gravel

Gravel when used as a supporting medium should consist of hard, rounded particles and should not include flat or elongated particles. The coarsest gravel should be 2 1/2 inches in diameter when the gravel rests directly on the strainer system and should extend above the top of the perforated laterals or strainer nozzles. Not less than four layers of gravel should be used.

11.1.4.4 Underdrains

All requirements of Section 11.1.2.3 apply.

11.1.4.5 Backwash

All requirements of Section 11.1.2.4 apply with the additional consideration:

There shall be the capability to backwash at a rate of 20 gpm/ft² for adequate expansion of the filter medium.

11.1.4.6 Surface Wash

All requirements of Section 11.1.2.5 apply.

11.1.5 Shallow Bed Filters (Slow Sand Filters)

These filters are normally used at small treatment facilities and will be reviewed on a case-by-case basis.

11.1.6 Operability

11.1.6.1 The clear well must be protected to keep unfiltered effluent from entering the clear well in the event that some accident or malfunction causes a filter to overflow.

11.1.6.2 It is suggested that a supplementary clean water source, such as a high volume hydrant (protected by a back-flow prevention device) be available for filling the clear well.

11.1.6.3 Any wastewater treatment facility that has a flow peaking factor equal to or greater than 1.5 shall have an equalization/surge tank to control filtration rate. The size of the equalization/surge tank must be determined on the basis of rate and duration of peak flows including the recirculated backwash water. For systems with a flow peaking factor less than 1.5, the rate of filtration may be accomplished by valves in such a way that will not cause water to surge through the filter at rates higher than design. Position indicators must be provided for automatic valves. Pressure or head loss gages must be provided on the influent and effluent side of each filter. Micro switches will also be acceptable. On larger installations (75,000 gpd or greater) a rate of flow indicator will be required. Rapid variations of filtration rate are undesirable as they may cause dislodging of deposited matter and subsequent deterioration of effluent quality.

- 11.1.6.4 A by-pass around the filters must be provided and controlled by an easily accessible valve with markings for open or closed positions.
- 11.1.6.5 The capability to disinfect both prior to and after the filters shall be provided.
- 11.1.6.6 Vertical walls within the filter are required unless otherwise approved.
- 11.1.6.7 There shall be no protrusion of the filter walls into the filter medium.
- 11.1.6.8 Sufficient head room shall be provided when filters are indoors to permit normal inspection and operation.
- 11.1.6.9 The minimum depth of filter shall be 8 feet.
- 11.1.6.10 Trapped effluent to prevent backflow of air to the bottom of the filters is required.
- 11.1.6.11 Washwater drain capacity shall be designed to carry maximum flow.
- 11.1.6.12 Walkways around filters, not less than 24 inches wide, shall be provided where the installation is above ground level.
- 11.1.6.13 When backwash is automatically controlled, the backwash rate shall increase gradually or "step up" in a manner so to not displace the media or "blow" the filter bottom with a sudden surge.

11.2 Post Aeration

____ 11.2.1 General

Post aeration is used to maintain a required minimum dissolved oxygen residual in treated wastewater effluent. Post aeration is often needed following a dechlorination process where an oxygen depleting chemical such as sulfur dioxide is used.

11.2.2 Aeration Tank Systems

Design consists of determining the oxygen requirements and providing sufficient oxygen transfer capability to satisfy these requirements. The design should consider the quantity of oxygen to satisfy the oxygen deficit required to meet the receiving water standards plus the oxygen-utilization rate of the effluent wastewater. Design of the oxygen transfer equipment in an aeration tank stage should be based on the final dissolved oxygen leaving that aeration tank stage. Design of aeration tanks and equipment should conform to the pertinent requirements of Chapter 7, "Activated Sludge."

Calculations shall be submitted to justify the basis of design.

Aeration equipment may be any of the following;

1. Fine-bubble diffused air
2. High or Low speed surface aerators
3. Submerged turbine
4. High-purity oxygen

Other types will be considered based on performance and design data submitted with the request.

11.2.3 Cascade Systems

Cascade aeration consists of a series of steps or weirs over which the wastewater is passed in thin layers to maximize turbulence and promote transfer of atmospheric oxygen. The engineer shall demonstrate that the design will meet the receiving water standards either by use of data from the literature or pilot testing. Calculations shall be submitted to justify the basis of design.

11.2.4 Operability

11.2.4.1 The design should incorporate provisions for the control of foam.

11.2.4.2 A series of basins may improve transfer efficiency and also reduce total horsepower required as opposed to one large basin.

11.2.4.3 Baffles should be used with mechanical aerators to prevent vortexing.

11.3 Nutrient Removal

Nutrient removal, either supplementary or incorporated within standard secondary treatment facilities may be required in areas where receiving waters are greatly used and re-used or where highly restrictive use classifications have been established. For organization purposes, a very broad definition of "nutrients" shall be adopted herein to include refractory organics, nitrogen, phosphorus and inorganic salts. Sufficient operating data and information are not available to permit the establishment of detailed criteria outlining the proper application of the various available processes and operations to a specific treatment situation. Until sufficient operating data are obtained, the development and design of nutrient removal processes must be based upon the best obtainable pilot plant data (developed by the application of standard processes and operations to the specific waste treatment problem on a small scale basis). In order for approval of any type of supplementary nutrient removal system, sufficient pilot plant operating data must be made available to allow an evaluation of the adequacy and efficacy of the proposed process. No process will be approved unless adequate provisions are made for the ultimate disposal of concentrated pollutants "created" by the process (such as spent ion exchange regenerants, concentrated brines from reverse osmosis and electrodialysis systems, contaminated sorption media, chemical sludges and so forth).

CHAPTER 12

Sludge Processing and Disposal

12.1 General

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SLUDGE PROCESSING AND DISPOSAL

12.1 General

_____ 12.1.1 Definition

Sludge is a broad term used to describe the various aqueous suspensions of solids encountered during treatment of sewage. The nature and concentration of the solids control the processing characteristics of the sludge. Grit screenings and scum are not normally considered as sludge and therefore are not discussed in this section.

12.1.2 Total Systems Approach to Design

The most frequently encountered problem in wastewater treatment plant design is the tendency to optimize a given subsystem, such as sludge dewatering, without considering the side effects of this optimization on the overall plant operation and treatment costs.

Sludge handling processes can be classified as thickening, conditioning, stabilization, dewatering, and disposal. Numerous process alternatives exist within each of these categories. Each unit process should be evaluated as part of the total system, keeping in mind that the objective is to use that group of processes that provides the most cost-effective method of sludge disposal.

The analysis should include a materials balance to identify the amounts of material which enter, leave, accumulate, or are depleted in the given process and the system as a whole. Energy requirements should also be provided to aid in determining capital and operating costs of the total system.

12.1.3 Recycle Streams

Recycle streams from the process alternatives, including thickener overflow, centrate, filtrate, and supernatant, should be returned to the sewage treatment process at appropriate points to maintain effluent quality within the limits established. Volume and strength of each recycle stream should be considered in the plant design. Sidestream treatment should be provided if the load is not included in the plant design or if the side stream will upset the treatment process. Equalization of side streams should be considered to reduce instantaneous loading on the treatment process.

12.1.4 Multiple Units

Multiple units and/or storage facilities should be provided so that individual units may be taken out of service without unduly interrupting plant operation.

12.1.5 Sludge Pumps

12.1.5.1 Capacity

Pump capacities should be adequate to maintain pipeline velocities of 3 feet per second. Provisions for varying pump capacity are desirable.

12.1.5.2 Duplicate Units

Duplicate units shall be provided where failure of one unit would seriously hamper plant operation.

12.1.5.3 Type

Plunger pumps, progressing cavity pumps, or other types of pumps with demonstrated solids handling capability should be provided for handling raw sludge.

12.1.5.4 Minimum Head

A minimum positive head of 24 inches (or the manufacturer's recommendation) should be provided at the suction side of centrifugal-type pumps and is desirable for all types of sludge pumps. Maximum suction lifts should not exceed 10 feet (or the manufacturer's recommendation) for plunger pumps.

12.1.5.5 Sampling Facilities

Unless sludge sampling facilities are otherwise provided, quick-closing sampling valves should be installed at the sludge pumps. The size of valve and piping should be at least 1-1/2 inches.

12.1.6 Sludge Piping

12.1.6.1 Size and Head

Sludge withdrawal piping shall have a minimum diameter of 8 inches for gravity withdrawal and 6 inches for pump suction and discharge lines. Where withdrawal is by gravity, the available head on the discharge pipe should be at least 2 feet and preferably more, with provisions to backflush the line.

12.1.6.2 Slope

Gravity piping shall be laid on uniform grade and alignment. Slope on gravity discharge piping should not be less than 3 percent.

12.1.6.3 Cleaning

Provision should be made for draining and flushing suction and discharge lines. Where sludge pumps are available, piping should be such that suction lines can be backflushed with pump discharge or rodded. Glass-lined or equivalent pipe should be considered for raw sludge piping and scum lines.

12.1.6.4 Corrosion Resistance

Special consideration shall be given to the corrosion resistance and continuing stability of pipes and supports located inside digestion tanks.

12.2 Sludge Production

_____ The sludge production rates listed in the literature have often been shown to be underestimated. The sludge production rates (SPR) listed below in Table 12-1 have been determined from various studies and provide a more realistic basis for designing solids

handling facilities. These values shall be used for design unless other acceptable data is submitted.

Table 12-1
Sludge Production Rates

<u>Type of Treatment</u>	<u>(lb sludge) SPR (lb BOD removed)</u>
Conventional Activated Sludge	0.85
Extended Aeration	0.75
Contact Stabilization	1.00
Other Activated Sludge	0.85
Trickling Filter	0.75
Roughing Filters	1.00

12.3 Thickening

12.3.1 General

The cost-effectiveness of sludge thickening should be considered prior to treatment and/or disposal.

12.3.1.1 Capacity

Thickener design should provide adequate capacity to meet peak demands.

12.3.1.2 Septicity

Thickener design should provide means to prevent septicity during the thickening process. Odor consideration should be considered.

12.3.1.3 Continuous Return

Thickeners should be provided with a means of continuous return of supernatant for treatment. Provisions for side-stream treatment of supernatant may be required.

12.3.1.4 Chemical Addition

Consideration should be given to the use of chemicals or polymer to improve solids capture in the thickening process. This will not normally increase the solids level of the thickened sludge.

12.3.2 Gravity Thickeners

12.3.2.1 Stirring and skimming

Mechanical thickeners should employ pickets on rake arms for continuous gentle stirring of the sludge. Skimmers should be considered for use with biological sludges.

12.3.2.2 Depth and Freeboard

Tank depth shall be sufficient so that solids will be retained for a period of time needed to thicken the sludge to the required concentration and to provide storage for fluctuations in solids loading rates. The thickener should be operated to avoid denitrification.

At least two feet of freeboard shall be provided above the maximum water level.

12.3.2.3 Continuous Thickening

Variable-speed sludge draw-off pumps may be provided so that thickening can be continuous, or an adjustable on-off time clock control for pulse withdrawal may be used with constant-speed pumps to improve control over the thickening.

12.3.2.4 Solids and Surface Loading Rates

The engineer shall provide the design basis and calculations for the solids and surface loading rates and the support calculations upon request. Thickener solids loading rates vary with the type of sludge.

Some typical solids loading rates are given below in Table 12-2. These values shall be used for design unless other acceptable data are submitted. For loading rates of other type sludges, refer to Table 5.2 of the EPA Process Design Manual-Sludge Treatment and Disposal.

Table 12-2
Solids Loading Rate

<u>Type of Sludge</u>	<u>Solids Loading Rate</u> <u>(lb/day/sq ft)</u>	
Primary	20-30	5-6
Activated sludge		
Trickling filter	8-10	6-10
Primary and activated combined		
Primary and trickling filter combined		10-12

Surface loading rates of 400 gallons per day per square foot (gpd/sq ft) or less will normally result in septic conditions. To prevent septic conditions, surface overflow rates should be maintained between 500 and 800 gpd/sq ft. For very thin mixtures or WAS only, hydraulic loading rates of 100-200 gpd/sq ft are appropriate. An oxygen-rich water source, such as secondary effluent, shall be available as a supplemental flow to the thickener to achieve the necessary overflow rates.

The diameter of a gravity thickener should not exceed 80 feet.

12.3.2.5 Bottom Slope

Bottom slopes shall be sufficient to keep the sludge moving toward the center well with the aid of a rake. Generally, the slope should be greater than conventional clarifiers. A floor slope of 2-3 inches per foot is recommended.

12.3.3 Flotation Thickeners

Flotation thickeners are normally used to concentrate waste activated sludge.

12.3.3.1 Air-Charged Water

The thickener underflow is generally used as a source of water for the air-charging units, although primary tank effluent or plant effluent may also be used.

12.3.3.2 Design Sizing

The engineer shall provide the design basis for sizing the units and for the support calculation. Design sizing should be based on rational calculations, including: total pounds of waste sludge anticipated, design solids and hydraulic loading of the unit, operating cycle in hours per day per week, removal efficiency, and quantity and type of chemical aids required. Flotation thickeners are normally sized by solids surface loadings. Typical design loadings range from 1.0 to 2.5 pounds per hour per square foot. (See Table 12-3, for typical solids loading rates to produce a minimum 4% solids concentration.)

12.3.3.3 Hydraulic Loading Rates

If polymers are used, hydraulic loading rates of 2.5 gpm/sq ft or less should be used. The hydraulic loading rates shall be lower if polymers are not used. Hydraulic loading rates shall be based on the total flow (influent plus recycle). The design of any thickened sludge pump from DAF units should be conservative. Frequently, polymer conditioned sludge will result in a solids concentration greater than 4%. Pumps shall be capable of handling a sludge of at least 5% thickness.

TABLE 12-3
TYPICAL DAF THICKENER SOLIDS LOADING RATES NECESSARY TO PRODUCE
A MINIMUM 4 PERCENT SOLIDS CONCENTRATION

<u>Type of sludge</u>	<u>Solids loading rate, lb/sq ft/hr</u>	
	<u>No chemical addition</u>	<u>Optimum chemical addition</u>
Primary only	0.83 - 1.25	up to 2.5
Waste activated sludge (WAS)		
Air	0.42	up to 2.0
Oxygen	0.6 - 0.8	up to 2.2
Trickling filter	0.6 - 0.8	up to 2.0
Primary + WAS (air)	0.6 - 1.25	up to 2.0
Primary + trickling filter	0.83 - 1.25	up to 2.5

_____12.3.4 Centrifugal Thickeners

12.3.4.1 Pretreatment

Any pretreatment required is in addition of that required for the main wastewater stream. For example, separate and independent grit removal may be needed for the centrifuge feed stream.

Disc nozzle centrifuges require pretreatment of the feed stream. Both screening and grit removal are required to reduce operation and maintenance requirements. Approximately 11% of the feed stream will be rejected in pretreatment, consideration should be given to the treatment of this flow. It is usually routed to the primary clarifier.

Basket centrifuges do not require pretreatment and are recommended in small plants (1.0-2.0 MGD) without primary clarification and grit removal.

Solid bowl decanter centrifuges require grit removal in the feed stream and are a potentially high maintenance item.

12.3.4.2 Chemical Coagulants

Provisions for the addition of coagulants to the sludge should be considered for improving dewatering and solids capture.

12.3.4.3 Design Data

The engineer shall provide the design basis for loading rates and support calculations. Both hydraulic and solids loading rate limitations should be addressed.

12.3.5 Other Thickeners

Other thickener designs will be evaluated on a case-by-case basis. Pilot plant data shall be provided by the design engineer upon request.

12.4 Conditioning

_____12.4.1 General

Pretreatment of the sludge by chemical or thermal conditioning should be investigated to improve the thickening, dewatering, and/or stabilization characteristics of the sludge.

The effects of conditioning on downstream processes and subsequent side-stream treatment should be evaluated. Thermal conditioning will concentrate the BOD level of the side stream. Its treatment must be considered in calculating organic loadings of other units.

12.4.2 Chemical

Type of chemical, location of injection, and method of mixing should be carefully considered to ensure obtaining anticipated results. Pilot testing

is often necessary to determine the best conditioning system for a given sludge.

12.5 Digestion

_____12.5.1 Anaerobic Digestion

12.5.1.1 General

a. Operability

Anaerobic digestion is a feasible stabilizing method for wastewater sludges that have low concentrations of toxins and a volatile solids content above 50%. It should not be used where wide variations in sludge quantity and quality are common. Anaerobic digestion is a complex process requiring close operator control. The process is very susceptible to upsets as the microorganisms involved are extremely sensitive to changes of their environment. Frequent monitoring of the following parameters is required:

- (i) pH (6.4 - 7.5 recommended)
- (ii) volatile acids/alkalinity ratio (always 0.5 or greater)
- (iii) toxics (volatile acids, heavy metals, light metal cations, oxygen, sulfides, and ammonia)
- (iv) temperature (within 1° F of design temperature)
- (v) recycle streams (BOD, SS, NH₃, phenols)

The importance of avoiding digester upsets cannot be overlooked. The methane-producer bacteria have a very slow growth rate and it will take two weeks or more to resume normal digester performance.

b. Multiple Units

Multiple units should be provided. Staged digestion design may be used, provided the units can be used in parallel as well as in series. Where multiple units are not provided, a lagoon or storage tanks should be provided for emergency use so that digestion tanks may be taken out of service without unduly interrupting plant operation. Means of returning sludge from the secondary digester unit to the primary digester should be provided. In large treatment plants where digesters are provided, separate digestion of primary sludges should be considered.

c. Depth

The proportion of depth to diameter should provide for the formation of a supernatant liquor with a minimum depth of 6 feet. Sidewall depth is generally about one-half the diameter of the digester for diameters up to 60 feet, and decreases to about one-third the diameter for diameters approaching 100 feet.

d. Maintenance Provisions

To facilitate emptying, cleaning, and maintenance, the following features are required:

(i) Slope

The tank bottom shall slope to drain toward the withdrawal pipe. A slope of between 1 inch per foot and 3 inches per foot is recommended.

(ii) Access Manholes

At least two access manholes should be provided in the top of the tank, in addition to the gas dome. One opening should be large enough to permit the insertion of mechanical equipment to remove scum, grit, and sand. A separate side wall manhole should be provided at ground level.

(iii) Safety

Nonsparking tools, rubber-soled shoes, safety harness, gas detectors for flammable and toxic gasses and the hose type or self-contained type breathing apparatus shall be provided.

- e. Pre-thickening of sludge may be advantageous, but the solids content shall be less than 8% to ease mixing problems.

12.5.1.2 Sludge Inlets and Outlets

Multiple sludge inlets and draw-offs and multiple recirculation suction and discharge points should be provided to facilitate flexible operation and effective mixing of the digester contents, unless adequate mixing facilities are provided within the digester. One inlet should discharge above the liquid level and be located at approximately the center of the tank to assist in scum breakup. Raw sludge inlet points should be located to minimize short-circuiting to the supernatant drawoff.

12.5.1.3 Tank Capacity

a. General

Two cultures of bacteria are primarily involved in anaerobic digestion: acid formers and methane formers. Capacity of the digester tank shall be based on the growth rate of the methane-formers, as they have extremely slow growth rates.

b. Solids Basis

Where the composition of the sewage has been established, tank capacity should be computed from the volume and character of sludge to be digested. The total digestion tank capacity should be determined by rational calculations based upon factors such as volume of sludge added, its percent solids and character, volatile solids loading, temperature to be maintained in the digesters, and the degree or extent of mixing to be obtained. These

detailed calculations shall be submitted to justify the basis of design.

Where composition of the sewage has not been established, the minimum combined digestion tank capacity outlined below shall be provided. Such requirements assume that the raw sludge is derived from ordinary domestic wastewater, a digestion temperature is maintained in the range of 85° to 100° F, there is 40 to 50 percent volatile matter in the digested sludge, and that the digested sludge will be removed frequently from the process.

(i) Completely Mixed Systems

For heated digestion systems providing for intimate and effective mixing of the digester designed for a constant feed loading rate of 150 to 400 pounds 1,000 cubic feet of volume per day in the active digesting unit. The design average detention time in completely mixed systems shall have sufficient mixing capacity to provide for complete digester turnover every 30 minutes.

(ii) Moderately Mixed Systems

For digestion systems where mixing is accomplished only by circulating external heat exchanger, the system may be loaded up to 40 pounds of volatile solids per 1,000 cubic feet of volume per day in the active digestion units. This loading may be modified upward or downward, depending upon the degree of mixing provided. Where mixing is accomplished by other methods, loading rates will be determined on the basis of information furnished by the design engineer.

c. Population Basis

Where solids data are not available, the following unit capacities shown in Table 12-4 for conventional, heated tanks shall be used for plants treating domestic sewage. The capacities should be increased by allowing for the suspended solids population equivalent of any industrial wastes in the sewage. The capacities stated apply where digested sludge is dewatered on sand drying beds and may be reduced if the sludge is dewatered mechanically or otherwise frequently withdrawn.

Table 12-4
Cubic Feet Per Capita

<u>Type of Plant</u>	<u>Moderately Mixed Systems</u>	<u>Completely Mixed Systems</u>
Primary	2 to 3	1.3
Primary and Trickling Filter	4 to 5	2.7 to 3.3

Primary and
Activated Sludge

4 to 6

2.7 to 4

For small installations (population 5,000 or less) the larger values should be used.

12.5.1.4 Gas Collection System

a. General

All portions of the gas system, including the space above the tank liquor, storage facilities, and piping shall be so designed that under all normal operating conditions, including sludge withdrawal, the gas will be maintained under positive pressure. All enclosed areas where any gas leakage might occur shall be adequately ventilated.

b. Safety Equipment

All necessary safety facilities shall be included where gas is produced. Pressure and vacuum relief valves and flame traps, together with automatic safety shutoff valves, are essential. Water-seal equipment shall not be installed on gas piping.

c. Gas Piping and Condensate

Gas piping shall be of adequate diameter and shall slope to condensation traps at low points. The use of float-controlled condensate traps is not permitted. Condensation traps shall be placed in accessible locations for daily servicing and draining. Cast iron, ductile iron, and/or stainless steel piping should be used.

d. Electrical Fixtures and Equipment

Electrical fixtures and equipment in enclosed places where gas may accumulate shall comply with the National Board of Fire Underwriters' specifications for hazardous conditions. Explosion-proof electrical equipment shall be provided in sludge-digestion tank galleries containing digested sludge piping or gas piping and shall be provided in any other hazardous location where gas or digested sludge leakage is possible.

e. Waste Gas

Waste gas burners shall be readily accessible and should be located at least 50 feet away from any plant structure, if placed near ground level, or may be located on the roof of the control building if sufficiently removed from the tank. Waste gas burners shall not be located on top of the digester. The waste gas burner should be sized and designed to ensure complete combustion to eliminate odors.

f. Ventilation and Cover

Any underground enclosures connecting with digestion tanks or containing sludge or gas piping or equipment shall be provided with forced ventilation. Tightly fitting, self-closing doors shall be provided at connecting passageways and tunnels to minimize the spread of gas.

A floating cover should be provided instead of a fixed cover for increased operational flexibility and safety.

g. Metering

Gas meters with bypasses should be provided to meter total gas production and utilization.

h. Pressure Indication

Gas piping lines for anaerobic digesters should be equipped with closed-type pressure indicating gauges. These gauges should read directly in inches of water. Normally, three gauges should be provided, one to measure the main line pressure, a second to measure the pressure upstream of gas-utilization equipment, and the third to measure pressure to wasteburners. Gas-tight shutoff and vent cocks shall be provided. The vent piping shall be extended outside the building, and the opening shall be screened to prevent entrance by insects and turned downward to prevent entrance of rainwater. All piping shall be protected with safety equipment.

i. Gas Utilization Equipment

Gas-burning boilers, engines, and other gas utilization equipment should be located at or above ground level in well-ventilated rooms. Gas lines to these units shall be provided with suitable flame traps.

12.5.1.5

Heating

a. Insulation

Digestion tanks should be constructed above the water table and should be suitably insulated to minimize heat loss.

b. Heating Facilities

Sludge may be heated by circulating the sludge through external heaters or by units located inside the digestion tank.

(i) External Heating

Piping should be designed to provide for the preheating of feed sludge before introduction to the digesters. Provisions should be made in the layout of the piping and valving to facilitate cleaning of these lines.

Heat exchanger sludge piping should be sized for heat transfer requirements.

(ii) Internal Coils

Hot water coils for heating digestion tanks should be at least 2 inches in diameter and the coils, support brackets, and all fastenings should be of corrosion-resistant material. The use of dissimilar metals should be avoided to minimize galvanic action. The high point in the coils should be vented to avoid air lock.

(iii) Other Methods

Other types of heating facilities will be considered on their own merits.

c. Heating Capacity

Sufficient heating capacity shall be provided to consistently maintain the digesting sludge temperature to within 1°F (0.6°C) of the design temperature. An alternate source of fuel should be available and the boiler or other heat source should be capable of using the alternate fuel if digester gas is the primary fuel. Thermal shocks shall be avoided. Sludge storage may be required to accomplish this.

d. Hot Water Internal Heating Controls

(i) Mixing Valves

A suitable automatic mixing valve should be provided to temper the boiler water with return water so that the inlet water to the heat jacket or coils can be held to below a temperature (130° to 150°F) at which sludge caking will be accentuated. Manual control should also be provided by suitable bypass valves.

(ii) Boiler Controls

The boiler should be provided with suitable automatic controls to maintain the boiler temperature at approximately 180°F to minimize corrosion and to shut off the main fuel supply in the event of pilot burner or electrical failure, low boiler water level, or excessive temperature.

(iii) Thermometers

Thermometers shall be provided to show temperatures of the sludge, hot water feed, hot water return, and boiler water.

12.5.1.6

Mixing

Facilities for mixing the digester contents shall be provided where required for proper digestion by reason of loading rates, or other features of the system.

12.5.1.7 Supernatant Withdrawal

a. Piping Size

Supernatant piping should not be less than 6 inches in diameter, although 4-inch lines will be considered in special cases.

b. Withdrawal Arrangements

(i) Withdrawal Levels

Piping should be arranged so that withdrawal can be made from three or more levels in the tank. A positive unvalved vented overflow shall be provided.

(ii) Withdrawal Selection

On fixed-cover tanks the supernatant withdrawal level should preferably be selected by means of interchangeable extensions at the discharge end of the piping.

(iii) Supernatant Selector

If a moveable supernatant selector is provided, provision should be made for at least one other draw-off level located in the supernatant zone of the tank in addition to the unvalved emergency supernatant draw-off pipe. High-pressure backwash facilities should be provided.

c. Sampling

Provisions shall be made for sampling at each supernatant draw-off level. Sampling pipes should be at least 1-1/2 inches in diameter.

d. Supernatant Handling

Problems such as shock organic loads, pH, and high ammonia levels associated with digester supernatant shall be addressed in the plant design. Recycle streams should be bled continuously back to the treatment process.

12.5.2 Aerobic Sludge Digestion

12.5.2.1 Mixing and Aeration

Aerobic sludge digestion tanks shall be designed for effective mixing and aeration. Minimum mixing requirements of 20 cubic feet per minute per 1,000 cubic feet for air systems and 0.5 horsepower per 1,000 cubic feet for mechanical systems are recommended. Aeration requirements may be more or less than the mixing requirements, depending on system design and actual solids loading. Approximately 2.0 pounds of oxygen per pound volatile solids are needed for aeration. If diffusers are used, types should be provided to minimize clogging and designed to permit removal for inspection,

maintenance, and replacement without dewatering the tanks, if only one digester is proposed.

12.5.2.2

Size and Number of Tanks

The size and number of aerobic sludge digestion tank or tanks should be determined by rational calculations based upon such factors as volume of sludge added, its percent solids and character, the degree of volatile solids reduction required and the size of installation with appropriate allowance for sludge and supernatant storage.

Generally, 40 to 50 percent volatile solids destruction is obtained during aerobic digestion. To ensure a stabilized sludge which will not emit odors, the volatile solids content should be less than 60 percent in the digested sludge. Calculations shall be submitted upon request to justify the basis of design. The following design parameter ranges should be considered the minimum in designing aerobic digestion facilities.

a. Hydraulic Detention Time

Hydraulic detention time at 20°C should be in the range of 15 to 25 days, depending upon the type of sludge being digested. Activated sludge alone requires the lower detention time and a combination of primary plus activated or trickling filter sludges requires the high detention time. Detention times should be adjusted for operating temperatures other than 20°C.

b. Volatile Solids

The volatile solids loading shall be in the range of 0.1 to 0.2 pound of volatile solids per cubic foot per day.

c. Dissolved Oxygen

Design dissolved oxygen concentration should be in the range of 1 to 2 mg/l. A minimum of 1.0 mg/l shall be maintained at all times.

d. Mixing Energy

Energy input requirements for mixing should be in the range of 0.5 to 1.5 horsepower per 1,000 cubic feet where mechanical aerators are used; 20 to 35 standard cubic feet of air per minute per 1,000 cubic feet of aeration tank where diffused air mixing is used on activated sludge alone; and greater than 60 cubic feet per minute per 1,000 cubic feet for primary sludge alone and primary plus activated sludge.

e. Storage

Detention time should be increased for temperatures below 20°C. If sludge cannot be withdrawn during certain periods, additional storage capacity should be provided. Plants smaller than 75,000 gpd should have storage capacity of 2 cubic foot per population equivalent served.

12.5.2.5 Supernatant Separation

Facilities should be provided for separation or decantation of supernatant. Provisions for sidestream treatment of supernatant should be considered.

12.6 Composting

_____ Composting operations will be considered on a case-by-case basis, provided that the basis for design and a cost-effective analysis are submitted by the engineer.

12.7 Sludge Dewatering

_____ 12.7.1 General

Drainage from drying beds and centrate or filtrate from dewatering units should be returned to the sewage treatment process at appropriate points preceding the secondary process. The return flows shall be returned downstream of the influent sample and/or flow measuring point and a means shall be provided to sample return flows. These organic loads must be considered in plant design.

12.7.2 Sludge Drying Beds

12.7.2.1 Area

It is recommended that wastewater systems have a hybrid sludge disposal method because of the seasonal downtime associated with drying beds. The amount of rainfall normal for our state makes the use of sludge drying beds insufficient at times.

Consideration shall be given to the location of drying beds to avoid areas where moisture in the air is higher than normal (i.e., adjacent to rivers where morning fog is common).

In determining the area for sludge drying beds, consideration shall be given to climatic conditions, the character and volume of the sludge to be dewatered, type of bed used, and methods of ultimate sludge disposal. Design calculations shall be submitted upon request to substantiate the area used.

Drying bed design should be based on square feet per capita or pounds of sludge solids per square foot per year. Table 12-5 presents the range of values that should be used, these values are for drying anaerobically digested sludges. Additional area is required for wetter sludges such as those resulting from aerobic digestion; therefore, use the higher number of the required range.

Table 12-5 DRYING BED DESIGN CRITERIA *

<u>Type of Sludge</u>	Per Capita (sq ft/capita)	<u>Open Beds</u>	<u>Covered Beds</u>
		Solids (lb/sq ft/yr)	Per Capita (sq ft/capita)
Primary	1.0 to 1.5	27.5	0.75 to 1.0

Attached Growth	1.25 to 1.75	22.0	1.0 to 1.25
Suspended Growth	2.50	15.0	2.00

*The design engineer should rely on his experience and the plant location.

These criteria are a minimum.

_____ 12.7.2.2.

Percolation Type

a. Gravel

The lower course of gravel around the underdrains should be properly graded to range in size from 1/4-inch to 1-inch and should be 12 inches in depth, extending at least 6 inches above the top of the underdrains. It is desirable to place this in 2 or more layers. The top layer of at least 3 inches should consist of gravel 1/8 inch to 1/4 inch in size. The gravel shall be laid on an impervious surface so that the filtrate will not escape to the soil.

b. Sand

The top course shall consist of at least nine inches of sand with a uniformity coefficient of less than 3.5. For trickling filter sludge, the effective size of the sand shall be between 0.8 to 3.0 millimeter. For waste activated sludge, the effective size of the sand shall be between 0.5 to 0.8 millimeter. For combinations, use the lower size range.

c. Underdrains

Underdrains should be clay pipe, concrete drain tile, or other underdrain acceptable material and shall be at least 4 inches in diameter and sloped not less than 1 percent to drain. Underdrains shall be spaced between 8 and 20 feet apart. The bottom of the bed shall slope towards the underdrains. Consideration should be given to placing the underdrain in a trench.

12.7.2.3

Impervious Types

Paved surface beds may be used if supporting data to justify such usage are acceptable to the Department. The use of paved beds for aerobically digested sludge is generally not recommended.

12.7.2.4

Walls

Walls should be watertight and extend 15 to 18 inches above the ground surface. Outer walls should be curbed to prevent soil from washing onto the beds.

12.7.2.5

Sludge Removal

Not less than two beds should be provided and they should be arranged to facilitate sludge removal. Concrete truck tracks should be provided for all percolation-type sludge beds with pairs of tracks for the beds on appropriate centers. If truck access is by way of an opening in the drying bed wall, the opening shall be designed so that no sludge will leak out during the filling process.

12.7.2.6 Sludge Influent

The sludge pipe to the beds should terminate at least 12 inches above the surface and be arranged so that it will drain. Concrete splash plates shall be provided at sludge discharge points.

12.7.3 Mechanical Dewatering

12.7.3.1 Methods and Applicability

The methods used to dewater sludge may include use of one or more of the following devices:

- a. Rotary vacuum filters
- b. Centrifuges, either solid bowl or basket type
- c. Filter presses
- d. Horizontal belt filters
- e. Rotating gravity concentrators
- f. Vacuum drying beds
- g. Other "media type" drying beds

The technology and design of sludge dewatering devices are constantly under development; therefore, each type should be given careful consideration. The applicability of a given method should be determined on a case-by-case basis, with the specifics of any given situation being carefully evaluated, preferably in pilot tests. The engineer shall justify the method selected using pilot plant data or experience at a similar treatment plant.

12.7.3.2 Considerations

Considerations in selection should include:

- a. Type and amount of sludge
- b. Variations in flow rate and solids concentration
- c. Capacity of the equipment
- d. Chemicals required for conditioning
- e. Degree of dewatering required for disposal
- f. Experience and qualifications of plant staff

- g. Reliability
- h. Operation and maintenance cost
- i. Space requirements

12.7.3.3 Storage

Adequate storage shall be provided for all systems.

12.8 Sludge Storage Lagoons

_____ Refer to Chapter 9, Ponds and Aerated Lagoons, for the requirements of sludge storage lagoons.

12.9 Sludge Disposal

_____ The ultimate disposal of sludge through various methods (i.e., landfilling, land application) is subject to the regulations and/or guidelines of the Tennessee Division of Water Pollution Control (DWPC). Approval by DWPC is required prior to initiation of the selected disposal alternative.

CHAPTER 13

Plant Flow Measurement and Sampling

13.1 Purpose

13.2 Flow Measurement

- 13.2.1 General Considerations
- 13.2.2 Parshall Flumes
- 13.2.3 Sharp Crested Weirs
- 13.2.4 Venturi and Modified Flow Tube Meters
- 13.2.5 Other Flow Metering Devices
- 13.2.6 Hydrograph Controlled Release (HCR) Systems

13.3 Sampling

- 13.3.1 Automatic Sampling Equipment
- 13.3.2 Manual Sampling
- 13.3.3 Long Outfall Lines
- 13.3.4 Sampling Schedules

PLANT FLOW MEASUREMENT AND SAMPLING

13.1 Purpose

Complete and accurate flow measuring and sampling are essential in the proper treatment of wastewater. Compliance with discharge limits requires proper flow measurement and sampling. They provide the operator with the information to optimize process control and operational costs, as well as providing an accurate data base of flows and process performance which can be used to analyze changes in operational strategy or assist future plant design.

13.2 Flow Measurement

13.2.1 General Considerations

- 13.2.1.1 Facilities for measuring the volume of sewage flows should be provided at all treatment works.
- 13.2.1.2 Plants with a capacity equal to or less than 100,000 gallons per day (gpd) shall be equipped, as a minimum, with a primary metering device such as: a Parshall flume having a separate float well and staff gauge, a weir box having plate and staff gauge, or other approved devices. Continuous recording devices may be required where circumstances warrant.
- 13.2.1.3 Plants having a capacity of greater than 100,000 gpd shall be provided with indicating, recording, and totalizing equipment using strip or circular charts and with flow charts for periods of 1 or 7 days. The chart size shall be sufficient to accurately record and depict the flow measured.
- 13.2.1.4 Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.
- 13.2.1.5 Measuring equipment shall be provided which is accurate under all expected flow conditions (minimum initial flow and maximum design peak flow). The accuracy of the total flow monitoring system (primary device, transmitter, and indicator) must be acceptable. The effect of such factors as ambient temperature, power source voltage, electronic interference, and humidity should be considered. Surges must be eliminated to provide accurate measurement. Two primary devices and flow charts may be required in some cases.
- 13.2.1.6 Metering devices within a sewage works shall be located so that recycle flow streams do not inadvertently affect the flow measurement. In some cases, measurement of the total flow (influent plus recycle) may be desirable.
- 13.2.1.7 All clarifiers must be provided with a means for accurate flow measurement of sludge wasting and sludge return lines so that solids handling can be controlled. Sludge digesters, thickeners, and holding tanks should be provided with some way to determine the volume of sludge added or removed. This can be accomplished by a sidewall depth scale or graduation in batch operations.
- 13.2.1.8 Flow meter and indicator selection should be justified considering factors such as probable flow range, acceptable headloss, required accuracy, and fouling ability of the water to be measured. For more

detailed information the consultant is encouraged to read the EPA Design Information Report "Flow Measurement Instrumentation"; Journal WPCF, Volume 58, Number 10, pp. 1005-1009. This report offers many installation details and considerations for different types of flow monitoring equipment.

13.2.1.9 Flow splitter boxes shall be constructed so that they are reliable, easily controllable, and accessible for maintenance purposes.

13.2.1.10 Where influent and effluent flow-proportional composite sampling is required, separate influent and effluent flow measuring equipment is required.

13.2.1.11 Consideration should be given to providing some types of flow meters with bypass piping and valving for cleaning and maintenance purposes.

13.2.2 Parshall Flumes

Parshall Flumes are ideal for measuring flows of raw sewage and primary effluents because clogging problems are usually minimal.

The properly sized flume should be selected for the flow range to be encountered. All Parshall Flumes must be designed to the specified dimensions of an acceptable reference.

The following requirements must be met when designing a Parshall Flume.

13.2.2.1 Flow should be evenly distributed across the width of the channel.

13.2.2.2 The crest must have a smooth, definite edge. If a liner is used, all screws and bolts should be countersunk.

13.2.2.3 Longitudinal and lateral axes of the crest floor must be level.

13.2.2.4 The location of the head measuring points (stilling well) must be two-thirds the length of the converging sidewall upstream from the crest. Sonar-type devices are only acceptable when foaming or turbulence is not a problem.

13.2.2.5 The pressure tap to the stilling well must be at right angles to the wall of the converging section.

13.2.2.6 The invert (i.e., inside bottom) of the pressure tap must be at the same elevation as the crest.

13.2.2.7 The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.

13.2.2.8 The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well.

13.2.2.9 Free-flow conditions shall be maintained under all flow rates to be encountered by providing low enough elevations downstream of the flume. No constrictions (i.e., sharp bends or decrease in pipe size) should be placed after the flume as this might cause submergence under high flow conditions.

- 13.2.2.10 The volume of the stilling well should be determined by the conditions of flow. For flows that vary rapidly, the volume should be small so that the instrument float can respond quickly to the changes in rate. For relatively steady flows, a large-volume stilling well is acceptable. Consideration should be given to protecting the stilling well from freezing.
- 13.2.2.11 Drain and shut-off valves shall be provided to empty and clean the stilling well.
- 13.2.2.12 Means shall be provided for accurately maintaining a level in the stilling well at the same elevation as the crest in the flume, to permit adjusting the instrument to zero flow conditions.
- 13.2.2.13 The flume must be located where a uniform channel width is maintained ahead of the flume for a distance equal to or greater than fifteen (15) channel widths. The approach channel must be straight and the approaching flow must not be turbulent, surging, or unbalanced. Flow lines should be essentially parallel to the centerline of the flume.

13.2.3 Sharp Crested Weirs

The following criteria are for V-notch weirs, rectangular weirs with and without end contractions, and Cipolletti weirs. The following details must be met when designing a sharp crested weir:

- 13.2.3.1 The weir must be installed so that it is perpendicular to the axis of flow. The upstream face of the bulkhead must be smooth.
- 13.2.3.2 The thickness of the weir crest should be less than 0.1 inch or the downstream edge of the crest must be relieved by chamfering at a 45° angle so that the horizontal (unchamfered) thickness of the weir is less than 0.1 inch.
- 13.2.3.3 The sides of rectangular contracted weirs must be truly vertical. Angles of V-notch weirs must be cut precisely. All corners must be machined or filed perpendicular to the upstream face so that the weir will be free of burrs or scratches.
- 13.2.3.4 The distance from the weir crest to the bottom of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot.
- 13.2.3.5 The distance from the sides of the weir to the side of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot (except for rectangular weirs without end contractions.)
- 13.2.3.6 The nappe (overflow sheet) must touch only the upstream edges of the weir crest or notch. If properly designed, air should circulate freely under and on both sides of the nappe. For suppressed rectangular weirs (i.e., no contractions), the enclosed space under the nappe must be adequately ventilated to maintain accurate head and discharge relationships.
- 13.2.3.7 The measurement of head on the weir must be taken at a point at least four (4) times the maximum head on the crest upstream from the weir.
- 13.2.3.8 The cross - sectional area of the approach channel must be at least eight (8) times that of the nappe at the crest for a distance upstream of

15-20 times the maximum head on the crest in order to minimize the approach velocity. The approach channel must be straight and uniform upstream of the weir for the same distance, with the exception of weirs with end contractions where a uniform cross section is not needed.

13.2.3.9 The head on the weir must have at least three (3) inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

13.2.3.10 All of the flow must pass over the weir and no leakage at the weir plate edges or bottom is permissible.

13.2.3.11 The weir plate is to be constructed of a material equal to or more resistant than 304 Stainless Steel.

13.2.4 Venturi and Modified Flow Tube Meters

The following requirements should be observed for application of venturi meters:

13.2.4.1 The range of flows, hydraulic gradient, and space available for installation must be suitable for a venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.

13.2.4.2 Venturi meters shall not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.

13.2.4.3 Cleanouts or handholes are desirable, particularly on units handling raw sewage or sludge.

13.2.4.4 Units used to measure air delivered by positive - displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.

13.2.4.5 The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for 6 pipe diameters upstream of the venturi meter, unless treated effluent is being measured when straightening vanes are provided.

13.2.4.6 Other design guidelines as provided by manufacturers of venturi meters should also be considered.

13.2.5 Other Flow Metering Devices

Flow meters, such as propeller meters, magnetic flow meters, orifice meters, pitot tubes, and other devices, should only be used in applications in accordance with the manufacturer's recommendations and design guidelines.

13.2.6 Hydrograph Controlled Release (HCR) Systems

For plants utilizing HCR systems, accurate stream flow measurements are required. Detailed plans must be submitted outlining the construction of the primary stream flow measuring device and the associated instrumentation. The following factors should be emphasized in the design.

13.2.6.1 Accuracy over the flow range required for effluent discharge limiting purposes.

13.2.6.2 Operational factors such as cleaning and maintenance requirements.

13.2.6.3 Cost

The use of sharp crested weirs as described in Section 13.2.3 will not be allowed due to the installation requirements such as approach channel details and upstream pool depth and since entrapment and accumulation of silt and debris may cause the device to measure inaccurately. Parshall Flumes may be used due to their self-cleaning ability but field calibration will be required. Self-cleaning V-notch weirs are recommended due to their accuracy in low flow ranges. The weir can be made self-cleaning by sloping both sides of the weir away from the crest. The top portion of the crest shall be covered with angle-iron to prevent its breakdown. The angle of the V-notch should be determined by the stream characteristics; however, a smaller angle will increase accuracy in the low flow range. The primary device shall be built with sufficient depth into the stream bed to prevent undercutting and sufficient height to cover the required flow range.

It is recommended that the wastewater system director, engineer, or other city official contact the U.S. Geological Survey (USGS), Water Resources Division, in Nashville, Tennessee, for assistance with the design and installation of the flow measuring device. They offer a program which shares much of the costs for designing and maintaining the device. After visiting the site, they can assist with the design of a self-cleaning weir for the stream. They provide the consultant with a field design that shows the proper location and installation of the weir. From this field design, the consultant must provide detailed plans to the State. The wastewater system is responsible for constructing the weir at their own cost. The flow measuring station is installed, maintained, and calibrated by USGS personnel so that accurate results are insured. The primary device will record continuous flow of the stream and can be designed to send a feedback signal to the WWTP for other purposes such as controlling plant discharge rates. This program benefits both the local wastewater system, the State of Tennessee, and the USGS, as it adds to stream flow data bases archived for public use. Cost sharing allows the flow measuring station to be built and operated at a lower cost for all parties concerned.

13.3 Sampling

13.3.1 Automatic Sampling Equipment

The following general guidelines should be adhered to in the use of automatic samplers:

13.3.1.1 Automatic samplers shall be used where composite sampling is necessary.

13.3.1.2 The sampling device shall be located near the source being sampled, to prevent sample degradation in the line.

13.3.1.3 Long sampling transmission lines should be avoided.

13.3.1.4 If sampling transmission lines are used, they shall be large enough to prevent plugging, yet have velocities sufficient to prevent sedimentation. Provisions shall be included to make sample lines cleanable. Minimum velocities in sample lines shall be 3 feet per second under all operating conditions.

13.3.1.5 Samples shall be refrigerated unless the samples will not be effected by biological degradation.

13.3.1.6 Sampler inlet lines shall be located where the flow stream is well mixed and representative of the total flow.

13.3.1.7 Influent automatic samplers should draw a sample downstream of bar screens or comminutors. They should be located before any return sludge lines or scum lines.

13.3.1.8 Effluent sampling should draw a sample immediately upstream of the chlorination point. This will eliminate the need to dechlorinate and then re-seed the sample.

13.3.2 Manual Sampling

Because grab samples are manually obtained, safe access to sampling sites should be considered in the design of treatment facilities.

13.3.3 Long Outfall Lines

Many wastewater systems are constructing long outfall lines to take advantage of secondary or equivalent permit limits. Due to possible changes in effluent quality between the treatment facility and the outfall, a remote sampling station will be required at or near the confluence of the outfall line and the receiving stream on all outfall lines greater than one mile in length. Dissolved oxygen, fecal coliform, and chlorine residual may have to be measured at the remote sampling station for permit compliance purposes.

13.3.4 Sampling Schedules

Samples must be taken and analyzed for two purposes: permit compliance and process control. Any time a new permit is issued, a sampling schedule for permit compliance will be determined by the Division of Water Pollution Control. An additional sampling program needs to be set up for process control purposes. This would include all testing required for completing the monthly operational report, as well as any other tests that might aid the operation of the plant. This schedule can be determined by the Division of Water Pollution Control, Wastewater Treatment Section or the appropriate field office once final plans are approved. The designer shall provide safe access points to collect representative influent and effluent samples of all treatment units and to collect samples of all sludge transmission lines. This makes it possible to determine the efficiency of each treatment process. Additional information about methods of analyses can be obtained from the Federal Register 40 CFR Part 136. Information about sampling locations and techniques can be obtained from the EPA Aerobic Biological Wastewater Treatment Facilities Process Control Manual and EPA's NPDES Compliance Inspection Manual.

CHAPTER 14

Instrumentation, Control and Electrical Systems

14.1 General Requirements

- 14.1.1 Codes and Regulations
- 14.1.2 Plan Requirements

14.2 Instrument and Control Systems Requirements

- 14.2.1 General
- 14.2.2 Backup Equipment
- 14.2.3 Automatic Control
- 14.2.4 Calibration
- 14.2.5 Test Circuits
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14.3 Electrical System Requirements

- 14.3.1 Electric Power Sources
- 14.3.2 Power Distribution within the Plant

14.4 Miscellaneous Requirements

- 14.4.1 Fire and Flooding
- 14.4.2 Housing of Electrical Equipment
- 14.4.3 Ventilation
- 14.4.4 Spare Components
- 14.4.5 Lighting

INSTRUMENTATION, CONTROL AND ELECTRICAL SYSTEMS

14.1 General Requirements

14.1.1 Codes and Regulations

Sewage treatment systems are classified by reliability as noted in publication number EPA-430-99-74-001. Plant instrumentation, control and electrical systems shall be designed to comply with the applicable requirements of this standard. See Chapter 1, Section 1.3.11.

The design of the treatment facilities instrumentation, control and electrical systems shall conform to applicable codes and regulations including:

National Electric Code (NEC)
Occupational Safety and Health Act (OSHA)
State and Local Building Codes
National Electrical Safety Code (NESC)
Instrument Society of America (ISA)

14.1.2 Plan Requirements

The instrument and control plans shall include, as a minimum, the following drawings:

Instrumentation, control and systems legend and general notes

Process and instrumentation diagram (P&ID)

Process flow diagram (may be combined in P&ID)

Site plan

Plant power distribution plan (can be included in site plan)

Switching logic or schematic drawings

Complete electrical one-line diagram

Building lighting plans

Building power plans

Motor control diagram

Equipment and installations details as required

Instrument loop diagram

14.2 Instrumentation and Control Systems Requirements

14.2.1 General

An instrumentation and control system must be designed with both operational reliability (accurate and repeatable results) and maintainability if it is to properly serve its purpose.

14.2.2 Backup Equipment

Instrumentation whose failure could result in wastewater bypassing or a violation of the effluent limitations shall be provided with an installed backup sensor and readout. The backup equipment may be of a different type and located at a different point, provided that the same function is performed. No single failure shall result in disabling both sets of parallel instrumentation.

14.2.3 Automatic Control

Where system automation is employed, a manual intervention/override or backup shall be provided.

14.2.4 Calibration

Vital instrumentation and control equipment shall be designed to permit alignment and calibration without requiring bypassing of wastewater or a violation of the effluent limitations. Automated systems shall have provisions for operator verification of performance and all necessary systems calibration devices.

14.2.5 Test Circuits

Test circuits shall be provided to enable the alarms and annunciators to be tested and verified to be in working order.

14.2.6 Alarms and Annunciators

Alarms and annunciators shall be provided to monitor the condition of equipment whose failure could result in wastewater bypassing or a violation of the effluent limitations. Alarms and annunciators shall also be provided to monitor conditions which could result in damage to vital equipment or hazards to personnel. The alarms shall sound in areas normally manned and also in areas near the equipment. The combination of alarms and annunciators shall be such that each announced condition is uniquely identified.

14.3 Electrical System Requirements

14.3.1 Electric Power Sources

14.3.1.1 Primary Power Source

Generally, the local electric utility will be the primary source of electrical power. Second source of electrical power may be on-site generation or a second connection to the electric utility. If the second source is a connection to the electric utility, it must be arranged that a failure of one source does not directly effect the other. See Chapter 1, Reliability Class.

14.3.1.2 Standby Power Source

All treatment facilities greater than 100,000 gpd (average design flow) shall be equipped with an emergency generator to provide an alternate power source when a second power source is not available. The capacity of the backup emergency generator system shall conform to the Reliability Classification together with critical lighting and ventilation. If a main pump station is on site (or near) and would result in zero flow reaching the plant

during power outages, it shall have a second power feed or standby power.

14.3.2 Power Distribution Within the Plant

The electrical power distribution system within the plant should be planned and designed on the following basis:

Plant electrical loads (peak and average demand)

Maximum fault currents available

Proper protective device coordination and device fault current withstand and interrupt ratings

Plant physical size and distribution of electrical loads

Plant power factor correction requirements

Location of other plant utility systems and facilities

Reliability requirements

Voltage drop limitations

Planned future plant expansions

Feasibility and possible economic justification for electrical demand control system

Life-cycle cost of major electrical equipment

All codes and regulations, and good engineering practice

14.4 Miscellaneous Requirements

14.4.1 Fire and Flooding

Failure of electrical equipment from such causes as fire and flooding shall be minimized by provision of suitable equipment housing and location, as well as by proper equipment design.

14.4.2 Housing of Electrical Equipment

Where practicable, electrical equipment shall be located in a separate room having an adequately controlled environment.

14.4.3 Ventilation

Mechanical ventilation shall be provided as necessary to protect electrical equipment from excessive temperatures.

14.4.4 Spare Components

An adequate number of spare components shall be specified by the design engineer to permit in-plant repairs or modifications and adjustment. These components include starters, low voltage contactors, and buried conduit. Spare electrical components which are subject to wear, such as

motor brushes and switches, should also be specified by the design engineer as appropriate to minimize downtime.

14.4.5 Lighting

Adequate lighting throughout the wastewater treatment facility shall be provided, particularly in areas of operation and maintenance activities. Adequate emergency lighting shall be provided in the event of power failure.

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THIS IS CHAPTER 15

CHAPTER 15

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SMALL ALTERNATIVE SYSTEMS

15.1 Preface

This chapter is prepared as a supplement to the main design criteria. This supplement attempts to elaborate on some of the critical considerations of small flow design which may modify or complement the general design criteria. This chapter presents the method to determine the proper design for small flows including the examination of new treatment alternatives. Small flows are defined as domestic wastewater flows from approximately 1,000 to 150,000 gallons per day.

15.2 General Considerations

Small treatment plants require different design considerations than larger plants. During the design of a small treatment facility, the design engineer shall evaluate the feasibility of various process alternatives (including subsurface disposal) to meet the design disposal requirements. An engineering report must be submitted to the Department of Environment and Conservation, Division of Water Pollution Control, detailing the method of determining the chosen treatment alternative. The engineering report shall present an economic analysis of alternative treatment types; both capital, operation and maintenance costs. The reliability of the treatment alternatives must be examined with respect to the sensitivity of the receiving stream for direct discharges and ground water protection for subsurface disposal. If subsurface disposal is eliminated due to soil or groundwater conditions, a letter from the Division of Ground Water Protection must accompany the engineering report. Thus, engineering and environmental judgments shall be used to balance the economy of construction and operations with the reliability of appropriate treatment alternatives based on the sensitivity of the site.

15.3 Selection Guidelines

The following steps shall be utilized to select the treatment scheme or alternative for each site. In general these are:

15.3.1 First, examine the possibility of transporting flows to a nearby wastewater treatment plant.

15.3.2 Exhaust the possibility of disposing of flows by subsurface disposal. For example, given favorable site conditions, up to 10,000 gpd may be disposed of in a low pressure pipe disposal field. Remote sites should be considered.

15.3.3 Exhaust the possibility of water conservation and/or reuse systems to limit the disposal flows. Examples include spray irrigation for laundry wastes and surface drip (Israel emitters) irrigation.

15.3.4 Exhaust the development of "passive" treatment systems such as lagoons, artificial wetlands or hydragraphic controlled release (HCR), which are less prone to mechanical and operational problems. HCR systems may be designed to discharge only during winter months or high flow conditions. HCR's must include automatic controls and stream flow measurement devices.

15.3.5 Exhaust the possibility of easy-to-operate mechanical systems such as recirculating sand filters (see Section 15.7.1 for specific criteria), as opposed to suspended media systems.

15.3.6 As a last resort, a mechanical package activated sludge plant may be used. Package activated sludge plants, however, will not be approved for flows below 50,000 gallons per day due to economic, operational and maintenance requirements.

15.3.7 DESIGN BY ANALOGY

Data from similar existing systems may be utilized in the case of new design concepts which have reliability and operability merit; however, thorough investigation and adequate documentation shall be made to establish the reliability and applicability of such data.

15.4 Planning

The applicant shall contact the appropriate Water Pollution Control Field Office as early as possible in the planning process. The proposed project shall be discussed and the applicant or design engineer will be advised of information required in submittals. The treatment works will be designated an appropriate Reliability Classification as detailed in Chapter 1. Also, the designer shall refer to the Wastewater Discharge Checklist, Appendix 1-A.

15.5 Influent Problems

15.5.1 General

Small treatment facilities are more sensitive to influent problems due to a reduction in hydraulic or organic buffering capacity. Small plants are much more susceptible to peak flow variations and nighttime, weekend or seasonal variations.

15.5.2 Characterization of the Waste and Flow

An accurate characterization of the waste and flow conditions must be projected for the site and must include FLOW, BOD5, AMMONIA AND GREASE. While best engineering judgments for waste characterizations are sometimes necessary, an attempt should be made to project this character from similar facilities, instead of the absolute use of flow tables. For example, excess ammonia should be considered during design of a treatment system for a rest stop, truck stop or recreational vehicle park. These types of facilities can have five times the normal influent ammonia of domestic systems.

15.5.3 Flow Equalization

Flow equalization shall be considered for all mechanical treatment plants whose variations in hydraulic and/or organic loadings might interfere with operations. Flow equalization shall be located after preliminary treatment facilities. Refer to Chapter 4 for specific design consideration.

15.5.4 Preliminary Treatment

Preliminary treatment involves the removal of large solids that could damage pumps and equipment in the downstream treatment process. Properly designed septic tanks (See Appendix 15-A) or, for mechanical plants, screening and grit removal, may be required. In the case of package activated sludge plants, comminutors are discouraged due to their tendency to create rope-like conditions which clog unit processes and pumps. A series of graded bar screens or rag catchers is preferable. A bypass channel utilizing a bar screen is required.

15.5.5 Grease and Oil

Restaurants shall be equipped with an effective grease and oil separator. Other potential sites of grease/oil production should be investigated by the design engineer. The sizing of the grease trap procedure will be forthcoming.

15.5.5.1 Grease and Oil Separator Design

One or more separators in series are required where grease or oil waste is produced that could hinder sewage disposal or treatment, and/or create line stoppages. Separators must be located so as to provide easy access for inspection, cleaning and maintenance. The dishwasher must not be connected to the grease trap in restaurants.

As vegetable oil usage has become more common, it should be understood that oils will not solidify until approximately 70 °F. or less. Therefore, the minimum design shall be a baffled, three-compartment, elongated chamber to allow for cooling. The minimum size of the separator shall be 1,500 gallons. The tank shall be buried, with manhole accesses to all compartments. Cleaning should be performed as required but no less than every three months.

15.6 Plant Operation and Certification

All wastewater treatment plants are required to be operated by certified operators. Copies of the Certification Regulations may be obtained from the Murfreesboro Fleming Training Center. The costs of operators' salaries and lack of reliable automation restrict good operation of package activated sludge plants. Passive systems will require less operator attention; hence, lower salary requirements.

15.7 Alternative Systems Design

The following systems are considered to be the predominant choices for small flow designs. Each system is suitable for a variety of applications and should be chosen based on Section 15.3.

15.7.1 Recirculating Sand Filter (RSF)

The RSF consists of a septic tank (See Appendix 15-A), recirculation tank, open bed sand filter with a special distribution system, and flow splitter device. The RSF treatment offers an economical alternative to the intermittent subsurface sand filter from which it evolved, and shares its characteristics of a quality effluent and simplicity of operations and maintenance. RSF designs are economically feasible between 1,000 to approximately 30,000 gallons per day. WHERE THE STEP SYSTEMS UTILIZE TURBINE PUMPS AND SCREENS IN THE WATERTIGHT TANKS, THE FLOWS MAY RUN FROM 1,000 TO AS MUCH AS 150,000 GALLONS.

15.7.1.1 General

The treatment system utilizes the following basic components:

- a. Grease/oil separator(s), where needed
- b. Watertight septic tank (See Appendix 15-A)
- c. Recirculation tank with pump and filter
- d. Open bed sand filter media to treat the wastewater
- e. Distribution and collection systems to load the sand filter evenly
- f. Flow Splitter
- g. Disinfection of effluent

15.7.1.2 Hydraulic Flow

Submit the justification for design flow, both average and peak.

15.7.1.3 Septic Tank

A WATERTIGHT TANK IS REQUIRED. IT IS ALSO REQUIRED THAT SEPTIC TANKS (FOR A STEP SYSTEM) USE A TURBINE TYPE WATER WELL PUMP WITH A FILTER SCREEN. IT HAS BEEN SHOWN THAT THE PUMPING OF THE STEP TANKS MAY GO AS LONG AS FIFTEEN (15) YEARS BETWEEN PUMPINGS. GREASE/OIL TANKS MUST COMPARTMENTALIZED REQUIRING PUMPINGS AT LEAST EVERY THREE (3) MONTHS. THE ORENCO CONCEPT SEPTIC TANK WITH FILTER DOES NOT NEED TO BE COMPARTMENTALIZED.

15.7.1.4 GREASE - OIL SEPARATOR(S)

The removal of grease and oil in this system is very important. (SEE APPENDIX 15-B) Grease and oil separators should be oversized to give adequate detention time for cooling of the wastewater, particularly where automatic dishwashing is used. Maintenance of the separator should be scheduled. THE MINIMUM SIZE TANK OR SEPARATOR SHOULD BE 1,500 GALLONS CAPACITY. UNDER HEAVY FLOW CONDITIONS TANKS SHOULD BE IN SERIES TO ALLOW COOLING OF THE GREASE AND OIL TO AID COAGULATION OF THE OILS USED IN COOKING.

15.7.1.5 Recirculation Tank and Pump System

The tank serves as a wetwell for the septic tank EFFLUENT and filtered recirculated effluent to be pumped to the sand filter. The effective volume shall be EQUAL TO one days average flow. The tank shall be equivalent in strength and materials. No internal baffles are necessary. An access manhole is necessary for replacement of submersible dosing pumps if such are used.

Two alternating recirculation pumps are required. EACH RECIRCULATING PUMP MUST BE CONTROLLED BY A TIMER, IN CONTINUOUS CYCLES OF 5 MINUTES ON, 25 MINUTES OFF. THIS DOSING SCHEDULE PROVIDES 48 DOSING PERIODS IN A 24 HOUR PERIOD, ALLOWING THE INFLUENT/FILTRATE MIXTURE TO CYCLE THROUGH THE FILTER ABOUT 5 TIMES BEFORE DISCHARGE. FLOAT SWITCHES ARE WIRED IN PARALLEL WITH THE TIMER TO CONTROL THE PUMPS DURING PERIODS OF EXCESSIVE WASTEWATER FLOWS, AND INFLUENT OF TIMER MALFUNCTION. BOTH TIMER AND FLOAT SWITCH CONTROLS ARE REQUIRED.

A quick disconnect coupler and hanger pipe are recommended for pump removal and convenience.

15.7.1.6 Sand Filter Bed

The filter bed should be sized on the basis of 3.0-5.0 gallons per square foot per day of average strength domestic sewage (Carbonaceous BOD₅ of approximately 200 and influent ammonia of 15.).

The sand filter medium shall consist of 24-30 inches of clean coarse sand (chemically nonreactive) which has an effective size of 1.0 - 3.0 millimeters,

and a uniformity coefficient of less than 3.5. It shall be washed and free of clay and silt. Synthetic manufactured medium may be used which meets the criteria.

The bedding material supporting the filter sand shall consist of 6 inches of 1/4-inch to 1/2-inch stone. Below this layer SHALL BE 6 inches of a 1/2-inch to 1-inch stone. Below this SHALL BE 12 inches of 1-inch stone containing the underdrains. Two inches of compacted chokestone shall bed the 12-inch bottom layer. All support media shall be reasonably well graded with a low ratio of fines.

An impermeable plastic liner 20 mils thick is required for the bottom of the sand filter. The plastic liner may lie directly on the graded soil. The liner shall be properly seamed to form a leakproof basin for the filter and should be protected from puncturing. FENCING IS REQUIRED AROUND THE FILTER AND AROUND THE RECIRCULATION TANK.

15.7.1.7 Distribution and Collection Systems

The distribution system must be level. Distribution pipes shall be no smaller than 1 1/4-inches with appropriate holes drilled on site with sizing and spacing per the Low Pressure Pipe Design procedure available from the Division of Ground Water Protection. The holes shall be at the "4 o'clock and 8 o'clock" positions, 120° apart. Distribution pipes may rest upon concrete blocks. Splash plates need not be provided. Clean-out caps shall be provided on the ends of the distribution pipes.

15.7.1.8 Disinfection

See Chapter 10. THE USE OF ULTRAVIOLET DISINFECTION IS ENCOURAGED ON THE RSF AS ITS CLEAR EFFLUENT AND CONSTANT DISCHARGE WORKS WELL.

15.7.1.9 Flow Splitter

The flow splitter shall be designed so that recirculation rates can be easily controlled between a 1:1 and 5:1 recirculation ratio. A 4 to 1 ratio is the design recirculation ratio. AN OVERSIZED SPLITTER BOX IS RECOMMENDED

15.7.2 Artificial Wetlands

Artificial wetlands is an engineered marsh-like area which uses the physical, chemical, and biological processes in nature to treat wastewater, instead of using complicated mechanical systems. In the wetlands, organisms and plants use organics and nutrients in the wastewater for food. The pollutants are transformed into basic elements, plant biomass and compost. Several variations of wetlands have been developed including a marsh-pond-meadow, subsurface flow marsh or root-zone system, and a gravel marsh system.

The wetland may be used for total treatment (with appropriate preliminary screening) or as a polishing or tertiary addition to other processes.

Information on wetlands may be obtained from the Tennessee Valley Authority, Water Quality Branch, 270 Haney Building, Chattanooga, Tennessee 37401.

15.7.3 Lagoons and Hydrograph Controlled Release (HCR) Systems

See Chapter 9 for design details. A PRIMARY FLOW DEVICE OR CONTRACT WITH USGS TO DEVELOP A STREAM RATING CURVE MUST BE PROVIDED.

15.7.4 Aerobic Bio Reactors

Several manufacturers market aerobic bioreactors for various uses. Their use in domestic small flow applications is not yet widespread but appears promising.

Supplemental treatment will be required for ammonia removal and dissolved oxygen considerations. In addition, a polishing step may be required for BOD removal depending on permit requirements.

15.7.5 Package Activated Sludge Plants

Package Activated Sludge Plants will only be approved for design flows of 30,000 gpd or greater, after all other alternatives have been exhausted.

Among the various processes, the one most widely used for small treatment systems is the extended aeration process.

However, for any activated sludge or fixed film process, the criteria presented in Chapters 4, 5, 6, 7, 8, 10, 11, and 12 must be utilized for each unit process.

Of particular importance is the sludge production and wasting facilities. The design must include aerobic digestion or sludge holding for sludge wasting.

A sludge wasting schedule should be included in the engineering report to better define operator time requirements. The disposal site or landfill must be given. Where tertiary filters are employed, the use of an equalization tank is mandatory. Also, based on the Reliability Classification as determined by the appropriate WPC field office, multiple units and standby power (or a generator) may be required. These costs must be included in the cost effective/reliability analysis.

APPENDIX - A CHAPTER 15

SUGGESTED SPECIFICATIONS

A. ON-SITE INTERCEPTOR TANKS

1. GENERAL

- a. Interceptor tanks shall be modified 1000-gallon precast concrete, fiberglass or ABS and shall have been designed by a registered engineer and approved by the local regulatory agencies. The manufacturer shall provide the structural design and certification to the engineer for review. The design shall be in accordance with accepted engineering practice.
- b. The tanks shall be designed for the following loads:
Top-300 psf Lateral Loads-62.4 psf

Cold weather installations requiring deep burial will need special consideration.

- c. All tanks shall be guaranteed in writing by the tank manufacturer for a period of two years from the date of delivery to the project. Manufacturer's signed guarantee shall accompany bids.
- d. Tanks shall be manufactured and furnished with access openings 18 inches in diameter and of the configuration shown on the drawings. Modifications of completed tanks will not be permitted.
- e. Inlet plumbing shall penetrate 18 inches into the liquid from the inlet flow line.
- f. Tanks shall be capable of successfully withstanding an above-ground static hydraulic test and shall be individually tested.
- g. All tanks shall be installed in strict accordance with the manufacturer's recommended installation instructions.

2. CONCRETE

- a. Walls, bottom and top of reinforced-concrete tanks shall be designed across the shortest dimension using one-way analysis. Stresses in each face of monolithically-constructed tanks may be determined by analyzing the tank cross-section as a continuous fixed frame.
- b. The walls and bottom slab shall be poured monolithically.
- c. Reinforcing steel shall be ASTM A-615 Grade 60, $f_y = 60,000$ psi. Details and placement shall be in accordance with ACI 315 and ACI 318.
- d. Concrete shall be ready-mix with cement conforming to ASTM C150, Type II. It shall have a cement content not less than six (6) sacks per cubic yard and maximum aggregate size of 3/4 inch. Water/cement ratio shall be kept low (0.35+/-), and concrete shall achieve a minimum compressive strength of 5000 psi in 28 days.
- e. Tanks shall be protected by applying a heavy cement-base waterproof coating (Thoroseal or equal), on both inside and outside surfaces, in compliance with Council of American Building Officials (CABO) report # NRB-168;6181.
- f. Form release used on tank molds shall be Nox-Crete or equal. Diesel or other petroleum based products are not acceptable.

- g. Tanks shall not be moved from the manufacturing site until the tank has cured for seven (7) days or has reached two-thirds of the design strength.
- h. Tanks shall have a 1/2 inch wide by 1/2 inch deep groove, 21 inches, 24 inches or 30 inches in diameter, as required, surrounding the access opening. The groove shall be formed in the top of the tank at the time of manufacture to facilitate the installation of the riser.
- i. In order to demonstrate watertightness, tanks shall be tested twice prior to acceptance. Each tank shall be tested at the factory, prior to shipping, by filling to the soffit and letting stand. After 24 hours, the tank shall be refilled to the soffit and the exfiltration rate shall be determined by measuring the water loss during the next two hours. Any leakage shall be cause for rejection. After installation is completed, each tank shall be filled with water and retested as previously described. If filled to the top of the riser, backfill of a depth equal to the height of the riser must be placed over the tank to prevent damage due to hydrostatic uplift.

B. RISERS & LIDS

1. INLET RISERS (required only on 2-compartment tanks and tanks with greater than 1500-gallon capacity) shall be ribbed PVC as manufactured by ORENCO SYSTEMS, INC., or equivalent. Risers shall extend to the ground surface and shall have a minimum nominal diameter of 21 inches.
2. OUTLET RISERS shall be ribbed PVC as manufactured by ORENCO SYSTEMS, INC., or equivalent. Risers shall be at least 12 inches high, shall have a minimum of nominal diameter of 24 inches when used with 12-inch or 15-inch diameter pump vaults, or 30-inch when used in a duplex application and shall be factory-equipped with the following:
 - a. Rubber Grommets. Two-1-inch diameter grommets, one for the splice box and one for the pump discharge, installed as shown on the drawing.
 - b. Adhesive. Two-part epoxy, one pint per riser, for bonding riser to tank. One quarter for 30-inch diameter.
3. LIDS shall be furnished with each riser. Lids shall be ORENCO SYSTEMS Model FL-21g, FL-24g, or FL-30g, or equivalent as appropriate, fiberglass with green non skid finish, and provided with elastomeric gasket, stainless steel bolts, and wench. The riser and lid combination shall be able to support a 2500 lb. wheel load. (Note: this is not to imply that PVC risers are intended for traffic areas. Please refer to section on traffic protection.)
4. INSULATION (If Required) Ridge closed-cell foam insulation of 2" or 4" thickness shall be bonded to the underside of the lid.
5. RISER INSTALLATION shall be accomplished according to the manufacture's instructions.

C. STEG - GRAVITY ASSEMBLIES

1. OUTLET RISER shall be ribbed PVC as manufactured by ORENCO SYSTEMS, INC., or equivalent. Risers shall extend to the ground surface, shall have a minimum nominal diameter of 21 inches. Two-part epoxy, one pint per riser, for bonding riser to tank.
2. LID shall be furnished with each riser. Lids shall be ORENCO SYSTEMS Model FL-21g, or equivalent, fiberglass with green non skid finish, and provided with elastomeric gasket, stainless steel bolts, and wrench. The riser and lid combination shall be able to support a 2500 lb. wheel load. (Note: this is not to imply that PVC risers are intended for traffic areas. Please refer to section on traffic protection.)
3. RISER INSTALLATION shall be accomplished according to the manufacture's instructions.
4. EFFLUENT FILTER Gravity system tanks for single-family dwellings shall be equipped with the ORENCO SYSTEM Model F-1248125 Effluent Filter, or equivalent, installed in conformance with the standard plans. (Note: Commercial and multiple-user tanks require larger Effluent Filters, the sizes of which must be individually determined and spelled out in the specifications.) The Effluent Filter shall consist of a 12-inch diameter, 48-inch deep PVC vault with eight (8) 1-1/4-inch diameter holes evenly spaced around the perimeter, 16-inches up from the bottom, and with a fiberglass base. Housed inside the PVC vault shall be a 1/8-inch mesh polyethylene screen. The 1-1/4-inch diameter vertical intake pipe within the screened vault shall have an overflow protection screen on the top and a one 1/2-inch diameter hole near the base for flow modulation. The Effluent Filter shall also be equipped with 5-1/2 feet of 1-1/4-inch flexible PVC flex hose with a plastic quick-disconnect fitting on the vault end. (For sites with riser greater than 24 inches in height, hose length shall be increased by one foot for each additional foot of riser. Also furnished shall be PVC flex hose bushed to fit a 4-inch sanitary tee, air relief vent and fittings as shown on the plans.) The Effluent Filter shall be suspended from the top of the septic tank by supports which shall be provided by ORENCO SYSTEMS, INC., or equivalent. The lateral from the tank to the collection line shall be laid to a uniform grade with no high points.

D. STEP PUMPING ASSEMBLIES for Single-Family Dwellings

1. MATERIALS All pumping systems shall be ORENCO SYSTEMS High-Head Pumping Assemblies or equivalent composed of:
 - a. Risers & Lids. Same as B., through 5, above.
 - b. Screened Pump Vault. Model SV1260Fi or SV1548Fi, PVC vault, or equal, fitted with 1/8-inch mesh polyethylene screen and a 4-inch diameter PVC flow inducer for a high head pump.
 - c. Discharge Hose and Valve Assembly. Model HV100BX, or equal, 1-inch diameter, 150 psi PVC ball valve, PVC flex hose with working pressure rating of 100 psi, Schedule 40 PVC pipe, and a 12-inch length of PVC flex hose with fittings to be installed outside the riser. Six-gpm flow controller optional.
 - d. Mercury Switch Float Assembly. Model MF-ABR, or equivalent, with three mercury switch floats mounted on a fixed PVC stem attached to the pump vault. The high- and low- level alarms and on-off functions shall be present as shown on the drawing. Each mercury switch float shall be secured with a nylon strain relief bushing. The "A" & "R" floats shall be UL- or CSA- listed and shall be rated for 4.5 A@ 120 V. The "B" float shall be UL- or CSA- listed and shall be rated for 13 A@ 120 V.
 - e. High-Head Effluent Pump. Model 8 OS105HH, or equal, 1/2 Hp, 115V, single phase, 60 Hz, 2-wire motor, 8-foot long extra heavy duty (SO) electrical cord with the ground to motor plug. Pump shall be UL listed as an effluent pump. (Note: if working heads over 150 feet are expected, a Model 8OS107HH or larger equivalent pump may be specified.)

f. Electrical Splice Box. UL approved for wet locations, equipped with four (4) electrical cord grips and a 3/4-inch outlet fitting. Also included shall be UL-listed butt splice connectors. (Note: Specifications for the EY conduit seal shall be covered in another section.)

g. Controls & Alarms. Model A-1RO, or equivalent control panel with the following:

- 1) Redundant-Off Relay: 115V., automatic, single pole.
 - 2) Audible Alarm: Panel mount with a minimum of 80 dB sound pressure at 24 inches. Continuous sound.
 - 3) Visual Alarm: NEMA 4-rated, 7/8-inch diameter, oiltight, with push-to-silence feature.
 - 4) Audio-Alarm Reset Relay: 115 V, automatic, with DIN rail mount socket base
-
- 5) Toggle Switch: 15 amp motor rated, single -pole, double-throw with three positions: manual (MAN), (OFF) and automatic (AUTO).
 - 6) Fuse Disconnect: DIN rail mount socket base with 2 amp SLO BLOW fuse.
 - 7) Current-Limiting Circuit Breaker: Rated for 20 amps, OFF/ON switch, DIN rail mounting with thermal magnetic tripping characteristics.
 - 8) Enclosure: NEMA 4X-rated, fiberglass with stainless steel or non-metallic hinges, stainless steel screws and padlockable latch. 8-inches high X 6-inches wide X 5-1/8 inches deep.
 - 9) Alarm Circuit: Wired separately from the pump circuit so that, if the pump's internal overload switch or current-limiting circuit breaker is tripped, the alarm system remains functional.
-
2. INSTALLATION All pumping systems shall be installed in accordance with the manufacture's recommendations and the standard plans.
 3. LOCATION The pump control panel shall be mounted on the side of the house nearest the tank and pump. NEC requires that the control panel be located within 50 feet of and within sight of the pump.

E. STEP PUMPING ASSEMBLIES for Commercial or Multiple-User Tanks

Note: Standard dimensions and materials for specifying pumping assemblies for other than single-family dwellings can be found in OSI's price list and in OSI's design-aid chart entitled "Commercial & Multiple User Effluent Pumping Systems". Engineers at OSI are available to provide assistance. The sizing of the larger capacity tanks should be based on a 4 to 1 length to width ratio.

CAUTION

To avoid accidents and limit liability, districts should issue frequent reminders to their constituents that:

1. Open manholes are potentially hazardous, so it is essential that the lids be bolted securely at all times.
2. The atmosphere in interceptor tanks can be dangerous, so maintenance should be performed only by trained personnel.
3. Control/alarm panels should be mounted out of the reach of small children and must be kept locked.

APPENDIX 15-B Grease Disposal Tips

Suggestions For Preventing Grease Plugs

- à Train employees not to pour grease down the drain.
- à Wipe food off dirty dishes into the trash before you load the dishwasher.
- à Recycle your grease. Several grease rendering companies are located in Tennessee. One of these can supply you with a grease barrel and pick up the grease when the barrel is full. The cost for this service is quite low.
- à Install a pretreatment device. Grease traps, grease interceptors and grease devices can be effective in removing grease from washwater. These devices can range in size from a small truck to large underground tanks. They need regular maintenance. Depending on your volume of grease and the size of your system, you may need to check it twice a day or twice a year! If you decide to install a system, check with the Section 15.7.1.4 for sizing instructions.
- à Use enzyme or bacterial additives to cut down on grease. Many local vendors supply enzymes and bacteria which consume and convert it into harmless by-products. These products work best in conjunction with a grease trap or interceptor. Product success varies greatly. Take special precaution to find products that will not harm your septic system.

Things To Avoid Doing

- * Pouring fats, oil or grease down the drain causes problems. When these materials meet cooler water in the sewer line, they can get hard and coat the sewer line. Eventually this could cause a blockage in the sewer line and sewage could back up into your business. (This is similar to cholesterol causing plaque deposits in your blood vessels and causing heart attacks.)
- * If you pour grease down the drain with plenty of hot water, you are just washing the problem down stream. State parameters for oil and grease limit the amount of oil and grease in the wastewater to 30 parts per million. That's approximately one teaspoon in 43 gallons of water. That's not much at all. Violators are subject to penalties as described in the Tennessee Water Quality Control Act including fines of up to \$10,000 dollars per day.
- * If grease clogs your side sewers, you can end up with a sewage backup in your business. That's a serious problem that can cause the Health Department to temporarily close your business. If grease blocks the city's sewer lines, sewage can back up into many businesses and homes and you could be held liable.

28 March 1994

CHAPTER 16

Slow Rate Land Treatment

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Appendix 16-A

SLOW RATE LAND TREATMENT

16.1 General

16.1.1 General

This chapter provides guidelines and criteria for the design of slow rate land treatment systems. It is not applicable to overland flow or rapid infiltration.

There are basically two types of slow rate systems. Type 1 systems are designed to apply the maximum amount of wastewater to the minimum amount of land area. The wastewater loading rate is limited by the maximum amount of a particular wastewater constituent that can be applied to a specific site. For wastewater from municipalities, the limiting design factor is usually either the hydraulic capacity of the soil or the nitrogen content of the wastewater. For industrial wastewater, the limiting design factor may be the hydraulic capacity of the soil, nitrogen or any other wastewater constituent such as metals, organics, etc. Type 2 systems are designed to apply the available wastewater to the maximum land area possible. The objective is usually crop irrigation and the design involves determining the water needs of the particular crop.

Although this chapter is written around Type 1 systems, the methodology can be adapted to satisfy Type 2 systems.

16.1.2 Applicability

Slow rate systems are designed and operated so that there is no direct discharge to surface waters. Disposal is by evaporation directly to the atmosphere, by transpiration to the atmosphere via vegetation uptake and by percolation to groundwater. A State of Tennessee Operating Permit is required for operation of slow rate land treatment systems.

16.1.3 Location

The disposal site should generally be relatively isolated, easily accessible and not susceptible to flooding. The site can be developed on agricultural land and/or forests or can include parks, golf courses, etc. Site location shall take into account dwellings, roads, streams, etc. A site approval by the Division will be required before review of the Engineering Report.

16.1.4 Topography

Maximum grades for wastewater spray fields should be limited to 8% for row crops, 15% for forage crops and 30% for forests. The maximum grade for any surface spreading system should be 10%. Ideally, any site should have a minimum slope of 2 - 3%. Sloping sites promote lateral subsurface drainage and make ponding and extended saturation of the soil less likely than on level sites. Depressions, sink holes, etc., are to be avoided.

16.1.5 Soils

In general, soils with a USDA Soil Conservation Service permeability classification of moderately slow (0.2 to 0.6 inches/hour) or more are

suitable for wastewater irrigation. However, groundwater and drainage conditions must also be suitable. Soils which are poorly drained, have high groundwater tables or restrictive subsurface soil layers are not suitable for slow rate land treatment without drainage improvements.

16.2 Soil Investigations

16.2.1 General

The land treatment soil investigation must characterize the infiltration rate, permeability, and chemical properties of the first 5 to 10 feet of the soil profile. It must verify Soil Conservation Service soil mapping. It must also determine the elevation of the seasonal high groundwater, establish the groundwater flow direction and gradient, and identify any subsurface conditions which may limit the vertical or lateral drainage of the land treatment site. The number of soil samples necessary to supply all of this information will be dependent on the nature of the particular site. As a minimum, however, TDHE recommends that at least one sample be taken for every acre in order to develop a detailed soils map of the site for the Engineering Report. Samples from soils with similar characteristics can be combined and the analyses can be performed on each soil group sample.

16.2.2 Saturated Hydraulic Conductivity Testing

Saturated vertical hydraulic conductivity testing is required for the most limiting horizon of each soil series present. The most limiting soil horizon should be determined from soil survey information. A minimum of three (3) tests for each soil series should be performed, unless the flooding basin method is used, in which case, only one test per series is needed. Testing for saturated horizontal hydraulic conductivity is additionally required when subsurface drainage systems are planned or when lateral subsurface drainage is the predominant drainage mechanism for the land treatment site.

Acceptable methods for saturated hydraulic conductivity testing are listed in Table 16-1. Percolation tests as performed for septic tank drain fields are not acceptable.

16.2.3 Soil Chemical Testing

The pH, Cation Exchange Capacity, and Percent Base Saturation, of each soil series must be determined from samples taken from the A and B horizons. These chemical tests determine the retention of wastewater constituents in the soil and the suitability of the soil for different cover crops. A minimum of three (3) samples for each soil series should be taken. The samples can be mixed together and tested for each soil series if the series is uniform. Testing for soil nutrients (nitrogen, phosphorus and potassium) and agronomic trace elements may be included if appropriate for the vegetative management scheme.

Soil chemical testing should be in accordance with the latest edition of Methods of Soil Analysis published by the American Society of Agronomy, Madison, Wisconsin.

16.3 Preapplication Treatment Requirements

16.3.1 General

Wastewater irrigation systems have a demonstrated ability to treat high strength organic wastes to low levels. However, such systems require a high degree of management with particular attention paid to organic loading rates and aeration of the soil profile between wastewater applications.

The TDHE requires that all domestic and municipal wastewaters receive biological treatment prior to irrigation. This is necessary to:

- a. Protect the health of persons contacting the irrigated wastewater.
- b. Reduce the potential for odors in storage and irrigation.

Some industrial wastewaters may be suitable for direct land treatment by irrigation under intensive management schemes. The TDHE will evaluate such systems on a case-by-case basis.

16.3.2 BOD and TSS Reduction, and Disinfection

Preapplication treatment standards for domestic and municipal wastewaters prior to storage and/or irrigation are as follows:

- a. Sites Closed to Public Access

All wastewater must be treated to a level afforded by lagoons which are designed in accordance with chapter 9.

Disinfection is generally not required for restricted access land treatment sites. The TDHE may, however, require disinfection when deemed necessary.

- b. Sites Open to Public Access

Sites open to public access include golf courses, cemeteries, green areas, parks, and other public or private land where public use occurs or is expected to occur. Wastewater irrigated on public access sites must not exceed a 5-day Biochemical Oxygen Demand and Total Suspended Solids of 30 mg/l, as a monthly average. Disinfection to reduce fecal coliform bacteria to 200 colonies/100 ml is required.

The preapplication treatment standards for wastewater that is to be applied to public access areas will be reviewed by the TDHE on a case-by-case basis. More stringent preapplication treatment standards may be required as the TDHE deems necessary. TDHE recommends that the engineer give preference to pretreatment systems that will provide the greatest degree of reliability.

16.3.3 Nitrogen

Maximum nitrogen removal occurs when nitrogen is applied in the ammonia or organic form. Nitrate is not retained by the soil and leaches to the groundwater, especially during periods of dormant plant growth. Therefore, the preapplication treatment system must not produce a nitrified effluent.

The TDHE recommends that aerated or facultative wastewater stabilization ponds be used for preapplication treatment where

possible. These systems generally produce a poorly nitrified effluent well-suited for wastewater irrigation. When mechanical plants are employed for preapplication treatment, they should be designed and operated to limit nitrification.

The Engineering Report should indicate the expected range of nitrogen removal in the preapplication treatment system. Predictive equations for nitrogen removal in facultative wastewater stabilization ponds have been developed by Pano and Middlebrooks (1982), and Reed (1985).

16.3.4 Treatment and Storage Ponds

The storage pond and irrigation pump station must be hydraulically separate from the treatment cells (i.e., pumping must not affect hydraulic detention time in these cells). The TDHE recommends the use of Chapter 9 of the Design Criteria for Sewage Works, as well as the United States Environmental Protection Agency's October 1983 Design Manual: Municipal Wastewater Stabilization Ponds as a reference for design of preapplication treatment ponds.

16.4 Inorganic Constituents of Treated Wastewater

Inorganic constituents of effluent from preapplication treatment should be compared with Table 16-2 to insure compatibility with land treatment site soils and cover crops.

16.5 Protection of Irrigation Equipment

Prior to pumping to the spray field distribution system, the wastewater must be screened to remove fibers, coarse solids, oil and grease which might clog distribution pipes or spray nozzles. As a minimum, screens with a nominal diameter smaller than the smallest flow opening in the distribution system should be provided. Screening to remove solids greater than one third (1/3) the diameter of the smallest sprinkler nozzle is recommended by some sprinkler manufacturers. The planned method for disposal of the screenings must be provided.

Pressurized, clean water for backwashing screens should be provided. This backwash may be manual or automated. Backwashed screenings should be captured and removed for disposal. These screenings should not be returned to the storage pond(s) or preapplication treatment system.

16.6 Determination of Design Percolation Rates

16.6.1 General

One of the first steps in the design of a slow rate land treatment system is to develop a "design percolation rate" (Perc). This value is used in water balance calculations to determine design wastewater loading(s) and, thus, spray field area requirements. The percolation rate is a function of soil permeability and drainage.

16.6.2 Design Values

The most limiting layer; i.e., A, B or C horizon, of each soil series must be identified. Any surface conditions which limit the vertical or lateral drainage of the soil profile must also be identified. Examples of such conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil permeability. Values of saturated vertical hydraulic conductivity from soil testing are used to develop the design percolation rate.

Values of saturated vertical hydraulic conductivity must be modified by an appropriate safety factor to determine design percolation. The safety factor reflects the influence of several elements including: the fact that long periods of saturation are undesirable, the uncertainty of test values, the drainage characteristics of the land treatment site, the variation of permeability within and between different soil series, the rooting habits of the vegetation, the soil reaeration factors, and the long-term changes in soil permeability due to wastewater application. The TDHE recommends that the design percolation rate of land treatment sites be no more than 10 percent of the mean saturated vertical hydraulic conductivity of the most limiting layer within the first five feet from the surface, in accordance with the following equation:

$$\text{Perc} = K \times 0.10 \quad \text{Eq. 16-1}$$

Where, Perc = Design percolation rate, (in/month)

K = Permeability of limiting soil layer, (in/month)

0.10 = Safety factor

Sites with seasonal high groundwater less than 5 feet deep may require drainage improvements before they can be utilized for slow rate land treatment. The design percolation at such sites is a function of the design of the drainage system.

16.7 Determination of Design Wastewater Loading

16.7.1 General

The design wastewater loading is a function of:

- a. Precipitation.
- b. Evapotranspiration.
- c. Design percolation rate.
- d. Nitrogen loading limitations.
- e. Other constituent loading limitations.
- f. Groundwater and drainage conditions.
- g. Average and peak design wastewater flows.

Therefore, developing the design wastewater loading is an iterative process. An initial value is selected from water balance calculations and used to determine wetted field area. This loading is then compared to nitrogen and other constituent loading limitations (reference Section 16.8). If the initial value exceeds these limitations, the design wastewater loading is reduced and the process is repeated. This iterative process is illustrated in Appendix 16-A.

16.7.2 Water Balance

Maximum allowable monthly wastewater hydraulic loadings are determined from the following water balance equation:

$$L_{wh} = (PET + \text{Perc}) - Pr \quad \text{Eq. 16-2}$$

Where, L_{wh} = Maximum allowable hydraulic wastewater loading (in/month).

PET = Potential Evapotranspiration, (in/month)

Perc = Design percolation rate (in/month);

Pr = Five-year return monthly precipitation, (in/month).

Example water balance calculations are presented in Appendix A. From these, critical water balance months; i.e., months with the smallest allowable hydraulic wastewater loading, are identified.

16.7.3 Potential Evapotranspiration (PET)

Reliable field data for evapotranspiration are difficult to obtain. Therefore, values for average monthly potential evapotranspiration (PET) generated from vegetative, soil and climatological data are used in water balance calculations. The method used to estimate average monthly potential evapotranspiration for water balance calculations must be referenced in the Engineering Report. In addition, these values must be based on a record of 30 years of historical climatic data.

The Thornthwaite method is an empirical equation developed from correlations of mean monthly air temperatures with evapotranspiration from water balance studies in valleys of the east-central United States where soil moisture conditions do not limit evapotranspiration (The Irrigation Association, 1983, pp. 112 to 114). The Thornthwaite method is applicable to slow rate land treatment systems in the southeast United States, including Tennessee.

A modified version of the Thornthwaite equation is outlined below. Note that the results are expressed in inches, for a month period. Finally, for water balance calculations as described in this Section, a 30-year record of historical climatic data (referred to as the climatological normal) is required to determine monthly temperature normals used in the Thornthwaite equation.

$$PET = 0.63 \times S \times \frac{50 \times (T-32)^A}{9 \times I} \quad \text{Eq. 16-3}$$

Where, PET = 30 - day Thornthwaite Potential Evapotranspiration,(in)

S = Daylight hours, in units of 12 hours

T = Mean (normal) monthly air temperature, in degrees Fahrenheit

I = Annual heat index obtained by summing the 12 monthly heat indexes, i, where:

$$i = \frac{(T-32)^{1.514}}{9}$$

A = Power term derived from annual heat index, I, where:

$$A = 0.000000675(I)^3 - 0.0000771(I)^2 + 0.01792(I) + 0.49239$$

Climatic information more appropriate to any specific location in Tennessee can be used, but its use must be documented in the Design Report. Also, other methods of calculating the PET can be used, provided that the use of an alternative method has been given prior approval by the TDHE.

16.7.4 Five-Year Return Monthly Precipitation

The TDHE requires the use of five-year return, monthly precipitation values in calculating the water balance. These values can be determined by either of the following methods:

a. Use the five-year annual rainfall and apportion this amount to each month, using each month's average for a 30-year period.

b. $Pr = Pr(Ave) + (0.85 \times \text{std. dev.})$ Eq. 16-4

where $Pr(Ave)$ = average monthly precipitation from a 30- year historic record

std. dev. = standard deviation for same

Thirty-year records of precipitation (as well as temperature) are available for specific locations in Tennessee as well as for the four geographic divisions, shown in Figure 16-1. Climatic information can be obtained from the National Oceanic and Atmospheric Administration (NOAA) in Asheville, North Carolina. The source of any data that are used in designing a slow-rate irrigation system must be referenced in the Design Report.

16.8 Nitrogen Loading and Crop Selection and Management

16.8.1 General

Nitrate concentration in percolate from wastewater irrigation systems must not exceed 10 mg/L. Percolate nitrate concentration is a function of nitrogen loading, cover crop, and management of vegetation and hydraulic loading. The design wastewater loading determined from water balance calculations must be checked against nitrogen loading limitations. If, for the selected cover crop and management scheme, the proposed wastewater loading results in estimated percolate nitrate concentrations exceeding 10 mg/l, either the loading must be reduced or a cover crop with a higher nitrogen uptake must be selected.

16.8.2 Nitrogen Loading

In some instances, the amount of wastewater that can be applied to a site may be limited by the amount of nitrogen in the wastewater. A particular site may be limited by the nitrogen content of the wastewater during certain months of the year and limited by the infiltration rate during the remainder of the year.

Equation 16-5 is used to calculate, on a monthly basis, the allowable hydraulic loading rate based on nitrogen limits:

$$L_{wn} = \frac{C_p (Pr - PET) + U(4.424)}{(1 - f)(C_n) - C_p} \quad \text{Eq. 16-5}$$

Where: L_{wn}	=	allowable monthly hydraulic loading rate based on nitrogen limits, inches/month
C_p	=	nitrogen concentration in the percolating wastewater, mg/l. This will usually be 10mg/l
P_r	=	Five-year return monthly precipitation, inches/month
PET	=	potential evapotranspiration, inches/month
U	=	nitrogen uptake by crop, pounds/acre/month
C_n	=	nitrogen concentration in applied wastewater, mg/l (after losses in preapplication treatment)
f	=	fraction of applied nitrogen removed by denitrification and volatilization.

The values of L_{wh} and L_{wn} are compared for each month. The lesser of the two values, designated as L_{wd} , will be used in subsequent calculations to determine the amount of acreage needed.

The monthly values for nitrogen uptake by crops, U , can be derived by several methods:

1. Assume that the annual nitrogen uptake is distributed monthly in the same ratio as is the PET .
2. If data on nitrogen uptake versus time are available for the crops and climatic region specific to the project under design, then such information may be used.

Appendix A contains an example that illustrates the use of equations 16-2 and 16-5.

16.8.3 Cover Crop Selection and Management

Row crops may be irrigated with wastewater only when not intended for direct human consumption. Livestock must not be allowed on wet fields so that severe soil compaction and reduced soil infiltration rates can be avoided. Further, wet grazing conditions can also lead to animal hoof diseases. Pasture rotation should be practiced so that wastewater application can be commenced immediately after livestock has been removed. In general, a pasture area should not be grazed longer than 7 days. Typical regrowth periods between grazings range from 14 to 35 days. Depending on the period of regrowth provided, one to three water applications can be made during the regrowth period. At least 3 to 4 days drying time following an application should be allowed before livestock are returned to the pasture. Unmanaged, volunteer vegetation (i.e., weeds) is not an acceptable spray field cover. Disturbed areas in forest systems must be initially grassed and replanted for succession to forest.

Spray field cover crops require management and periodic harvesting to maintain optimum growth conditions assumed in design. Forage crops should be harvested and removed several times annually. Pine forest systems should be harvested at 20 to 25 year intervals. Hardwood forest systems should be harvested at 40 to 60 years. It is recommended that whole tree harvesting be considered to maximize nutrient removal. However, wastewater loadings following the harvesting of forest systems must be reduced until the hydraulic capacity of the site is restored. Spray field area to allow for harvesting and the regeneration cycle should be considered in design.

While high in nitrogen and phosphorus, domestic and municipal wastewaters are usually deficient in potassium and trace elements needed for vigorous agronomic cover crop growth. High growth rate forage crops such as Alfalfa and Coastal Bermuda will require supplemental nutrient addition to maintain nitrogen uptake rates assumed in design. Industrial wastewaters considered for irrigation should be carefully evaluated for their plant nutrient value.

16.9 Land Area Requirements

16.9.1 General

The land area to which wastewater is applied is termed a "field". The total land requirement includes not only the field area, but also land for any preapplication treatment facilities, storage reservoir(s), buffer zone, administration/maintenance structures and access roads. Field and buffer zone requirements are addressed in this Section. Land area for storage reservoirs is discussed in Section 16.10. All other land requirements will be dictated by standard engineering practices and will not be addressed in this document.

16.9.2 Field Area Requirements

The area required for the field is determined by using the following equation:

$$A = \frac{(Q_y + V)C}{L_{wd}} \quad \text{Eq. 16-6}$$

where

A = field area, acres

Q_y = Flow, MG per year

V = net loss or gain in stored wastewater due to precipitation, evaporation and/or seepage at the storage reservoir, gallons per day

L_{wd} = design hydraulic loading rate, in/year

$$C = \frac{1,000,000 \text{ gal}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{12 \text{ in}}{\text{ft}} \times \frac{\text{acre}}{43,560 \text{ ft}^2} = 36.83$$

The first calculation of the field area must be made without considering the net gain or loss from the storage reservoir. After the storage reservoir area has been calculated, the value of V can be

completed. The final field area is then recalculated to account for V. The Appendix includes the use of Equation 16-6.

16.9.3 Buffer Zone Requirements

The objectives of buffer zones around land treatment sites are to control public access, improve project aesthetics and, in case of spray irrigation, to minimize the transport of aerosols. Since development of off-site property adjacent to the treatment site may be uncontrollable, the buffer zone must be the primary means of separating the field area from off-site property. Table 16-3 gives minimum widths of buffer zones for varying site conditions:

Table 16-3
On-Site Buffer Zone Requirements

	Surface Spread		Sprinkler Systems (Edge of Impact Zone)	
			Open Fields	Forested
Site Boundaries	100 ft.	300 ft.	150 ft.	
On-site streams, ponds and roads	50 ft.	150 ft.	75 ft.	

16.10 Storage Requirements

16.10.1 General

The design of a land application system must take into account that wastewater application will be neither continuous nor constant. Provisions must be made for containing wastewater when conditions exist such that either wastewater cannot be applied or when the volume of wastewater to be applied exceeds the maximum application rate.

The storage requirement can be determined by either of two methods. The first method involves the use of water balance calculations and is illustrated in Appendix A. The second method involves the use of a computer program that was developed based upon an extensive NOAA study of climatic variations throughout the United States. The program entitled EPA-2 would probably be the most appropriate of the three programs available. For information on the use of the computer program, contact the National Climatic Center of NOAA at (704) 259-0448.

16.10.2 Estimation of Storage Requirements Using Water Balance Calculations

The actual wastewater that is available is compared to the actual amount that can be applied. Any excess wastewater must be stored. The actual wastewater volume must be converted to units of depth for that comparison. Equation 16-7 will be used:

$$W_p = \frac{Q_m \times C}{A_p} \quad \text{Eq. 16-7}$$

where

$$W_p = \text{depth of wastewater, in inches}$$

Q_m = volume of wastewater for each month of the year, in million gallons

$$C = \frac{1,000,000 \text{ gal}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{\text{acre}}{43,560 \text{ ft}^2} \times 12 \frac{\text{in}}{\text{ft}} = 36.83$$

A_p = field area, in acres

The months in which storage is required are cumulated to determine the maximum amount of total storage needed. The use of the method is illustrated in Appendix A.

The maximum storage amount in inches, over the field area, is converted to a volume, in cubic feet. A suitable depth is chosen and a storage basin surface area is calculated.

This storage basin will be affected by three factors: precipitation, evaporation and seepage. These three factors are determined and the result is V , which is then introduced back into equation 16-6. A new, final field area is calculated and a corresponding new storage volume is determined.

In Tennessee, the maximum seepage is 1/4 inch per day. This amount can be used unless the storage basin will be constructed so that a lesser seepage rate will result. In some cases, where an impervious liner will be constructed, the seepage rate will be zero.

16.11 Distribution System

16.11.1 General

The design of the distribution system is a critical aspect of the land application. The field area and the storage volume were derived with the assumption that wastewater would be evenly distributed. For high strength wastes or wastes with high suspended/settleable solids, sprinkler applications are preferred. Sprinklers will distribute these wastes more evenly over the treatment area whereas surface application may result in accumulation of solids and odors near the application point.

16.11.2 Surface Spreading

With surface spreading, wastewater is applied to the ground surface, usually by perforated pipe or by an irrigation-type ditch, and flows uniformly over the field by gravity. The uniform flow is critically dependent upon a constant slope of the field, both horizontal and perpendicular to the direction of flow. Several other factors are of importance:

- a. Uniform distribution cannot be achieved on highly permeable soils. The wastewater will tend to percolate into the soil that is nearest to the point of application.
- b. A relatively large amount of wastewater must be applied each time so that wastewater will reach all portions of the field. The dosing must account for the fact that the field area nearest the point of application will be wetted for a longer period of time and, thus, will percolate more wastewater.

- c. Erosion and/or runoff may be a problem. Since a surface discharge will not be allowed to occur, a return system may be necessary.

16.11.3 Sprinkler Spreading

Sprinkler systems can be classified into one of three general categories: (1) solid set, (2) portable and (3) continuously moving. The following factors should be considered during design:

- a. The hydraulic conditions within the distribution system must be given a thorough review. Head losses through pipes, bends, nozzles, etc., must be balanced so that the wastewater is uniformly applied to the field.
- b. Design must consider the effects of cold weather. Nozzles, risers, supply pipes, etc., must be designed to prevent wastewater from freezing in the various parts.
- c. Wind can distort the spray pattern. Also, aerosols may be carried off the field area. A properly designed buffer zone should alleviate most of the aerosol problems. Also, the O&M manual can include a provision which would prevent spraying when the wind velocity is high enough to carry wastewater off the field area.
- d. Crop selection is important. The higher humidity level may lead to an increase in crop disease.
- e. Higher slopes can be used than in surface spreading (see Section 16.1.3). Also, slopes do not need to be constant. Further, the type of crop is nearly unlimited. Forests can be irrigated with solid set sprinklers. Forage crops can be irrigated with any of the three basic types of systems.
- f. The system layout must take into consideration the method that will be used for harvesting the crop.

16.12 Spray Irrigation of Wastewater from Gray Water Facilities

16.12.1 General

This Section provides criteria for facilities that produce a "gray water" wastewater. These facilities include coin-operated laundries, car washes and swimming pool backwash filters. Wastewater disposal requirements are not as complex as are those for domestic wastewater. An engineering report which provides information on the design of the facilities must be submitted to the Division.

16.12.2 Site Location

- 16.12.2.1 The Division of Water Pollution Control must inspect and approve the proposed site prior to any construction being undertaken.

- 16.12.2.2 The site must be chosen such that the operation of the system will not affect surrounding property owners. No surface runoff or stream discharge will be allowed.

16.12.3 Design Flow

Since these are service enterprises, the amount of wastewater that is generated is directly related to the desire of people to use the facilities. Thus, an estimate of the number of potential users (and frequency) is extremely important. Various factors must be taken into consideration:

- a. A rural setting would tend to have a shorter daily usage period than would an urban location.
- b. An area that is predominately single-family houses would tend to have a lesser usage rate for laundries and car washes than would an area with apartment complexes.
- c. The amount of water that washing machines use will vary among manufacturers and models. The Division recommends the use of water-saving machines.

The engineer should use 250 gpd/washer for laundries and 700 gpd/bay for car washes unless more reliable data is available.

16.12.4 Pretreatment

16.12.4.1 General

Facilities that produce gray water have different pretreatment requirements, designed not only to the type of facility but also to the specific establishment.

16.12.4.2 Laundries

- a. All laundry wastewater (does not include sanitary wastes) shall pass through a series of lint screens. A series will consist of five screens, starting with a screen with 1-inch mesh and ending with a screen that is basically equivalent to a window screen.
- b. Since some detergents produce a wastewater with a pH in the range of 11.0 - 11.5, some type of pH adjustment may be necessary. This may occur as a retrofit if the vegetation in the spray plots is being stressed by the high pH.
- c. Disinfection will generally not be required unless the operation of the facilities will result in a potential hazard to the public. The need for disinfection will be determined by the Division on a case-by-case basis.

16.12.4.3 Car Washes

- a. All car wash wastewater shall pass through a grit removal unit. The flow-through velocity shall be less than 0.5 feet per second. The grit removal unit shall be constructed to facilitate the removal of grit.
- b. The use of detergents with a neutral (or nearly neutral) pH is recommended. The use of high-pH detergents may require neutralization if the vegetation is being stressed by the high pH.

16.12.4.4 Swimming Pools

- a. A holding tank/pond shall be provided to receive the backwash water from the swimming pool filters. The solids shall be allowed to settle to the bottom before the supernatant is removed for disposition on the spray plots.
- b. Dechlorination may be required if the vegetation on the plots is being stressed by the chlorine in the water.
- c. If the entire pool volume is to be emptied, by using the spray plots, the rate shall be controlled so as to not exceed the application rate that is specified in Section 16.7.1.

16.12.5 Field Requirements

- 16.12.5.1 The maximum wastewater that can be sprayed on a site is based either on the nitrogen content of the wastewater or an amount equal to 10% of the infiltration rate of the most restrictive layer of soil which shall be determined with input from a qualified soil scientist.
- 16.12.5.2 The application of wastewater shall alternate between at least two separate plots. Each plot shall not receive wastewater for more than three consecutive days and must have at least three days rest between applications. Reserve land area of equivalent capacity must be available for all greg water systems.
- 16.12.5.3 Ground slopes shall not exceed 30%. Extra precautions must be taken on steep slopes (15-30%) to prevent runoff and erosion.
- 16.12.5.4 The field shall be covered with a good lawn or pasture grass unless an existing forested area is chosen. The ground cover should be a sturdy perennial that will resist erosion and washout. Forested areas should be chosen so that installation of sprinkler equipment will not damage the root systems of the trees and will not produce runoff due to the usual lack of grass in forested areas.

16.12.6 Application Equipment

- 16.12.6.1 Sprinklers shall be of a type and number such that the wastewater will be evenly distributed over the entirety of a plot. Information on sprinklers shall be included in the engineering report. In forest plots, sprinklers shall be on risers which shall be tall enough to allow the wastewater to be sprayed above the undergrowth. Sprinklers shall be of the type that are not susceptible to clogging.
- 16.12.6.2 All piping (excluding risers) shall be buried to a depth that will prevent freezing in the lines. An exception to this burial requirement can be made in the case where piping will be laid in forested areas. Burial in this case may be difficult, expensive and may kill some trees. All risers shall be designed such that wastewater will drain from them when wastewater is not

being pumped. This can be accomplished by either draining all lines back into the pump sump or by placing a gravel drain pit at the base of each riser. Each riser would necessarily be equipped with a weep hole. Particular attention must be given during the design so that the entire subsurface piping does not drain into these pits.

16.12.6.3 The engineering report must contain hydraulic calculations that show that each nozzle distributes an equivalent amount of wastewater. Differences in elevation and decreasing pipe sizes will be factors which need to be addressed.

16.12.6.4 The piping must be of a type that will withstand a pressure equal to or greater than 1-1/2 times the highest pressure point in the system. The risers should be of a type of material such that they can remain erect without support. The pipe joints should comply with the appropriate ASTM requirements. Adequate thrust blocks shall be installed as necessary.

16.12.6.5 A sump shall be provided into which the wastewater will flow for pumping to the spray plots. The pump can be either a submersible type, located in the sump, or a dry-well type, located immediately adjacent to the sump in a dry-well. The pump shall be capable of pumping the maximum flow that can be expected to enter the sump in any 10-minute period. The pump shall be operated by some type of float mechanism. The float mechanism shall activate the pump when the water level reaches 2/3 of the depth of the sump and should de-activate the pump before the water level drops to the point to where air can enter the intake.

If the distribution system is designed to drain back into the sump, the sump shall be enlarged to account for that volume.

If desired, the sump for laundries can also contain the lint screens. The screens shall, in any case, be constructed so that they cannot be bypassed. They shall be built so that they can be easily cleaned. A container shall be provided for disposal of the lint which is removed from the screens.

16.12.6.6 The pipe from the facility to the sump shall be large enough to handle the peak instantaneous flow that could be realistically generated by the facility. Flow quantities, head loss calculations, etc., shall be included in the engineering report.

16.12.7 Operation of System

16.12.7.1 The operator shall insure that wastewater is applied to alternate plots on a regular basis.

16.12.7.2 Monthly operating reports shall be submitted to the appropriate field office of the Division of Water Pollution Control. The parameters to be reported shall

be delineated by field office personnel but should include, as a minimum, dates of spray plot alternation.

- 16.12.7.3 The owner of the system shall apply for and receive an operating permit from the Division prior to initiation of operation of the system.
- 16.12.7.4 The system operator shall inspect and maintain the pump and sprinklers in accordance with manufacturer's recommendations. An operations manual shall be located at the facility for ready reference.
- 16.12.7.5 The operator shall inspect the wastewater facilities on a regular basis. The inspection shall include the spray plots to determine whether or not runoff and/or erosion are or have occurred, the spray patterns of the sprinklers, the physical condition of the system (looking for damage due to adverse pH conditions), etc.
- 16.12.7.6 The spray plots shall be mowed on a regular basis to enhance evapotranspiration. Grass height shall not exceed 6".
- 16.12.7.7 The lint screen at laundries shall be cleaned on a schedule that is frequent enough to prevent upstream problems due to head loss through the screens. Disposition of the lint shall be in accordance with applicable requirements.
- 16.12.7.8 The grit traps at car washes shall be cleaned at a frequency that is sufficient to keep the trap in its designed operating condition.
- 16.12.7.9 If the car wash is equipped with an automatic wax cycle, the operator shall be especially attentive to the possibility of wax build-up on the sump, pump and all downstream piping.
- 16.12.7.10 The operator shall insure that the car wash facility is not used as a sanitary dumping station for motor homes or for washing trucks/trailers that are used for hauling livestock. If necessary, the facility shall be posted with signs which clearly indicate this prohibition.
- 16.12.7.11 The sludge holding tank/pond at a swimming pool facility shall be cleaned at a frequency that is sufficient to prevent solids from being carried over into the pump sump. Cleaning shall be performed in a manner that will minimize re-suspending the solids and allowing them to enter the pump sump.

16.13 Plan of Operation and Management

A plan of Operation and Management is required before an Operating Permit can be issued. The Plan is written by the owner or the owner's engineer during construction of the slow rate land treatment system. Once accepted by the Division, the Plan becomes the operating and monitoring manual for the facility and is incorporated by reference into the Permit. This manual must be kept at the facility site and must be available for inspection by personnel from the Tennessee Department of Health and Environment.

This Plan should include, but not be limited to, the following information:

16.13.1 Introduction

a. System Description:

1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, preapplication treatment system and spray fields.
2. A map of the land treatment facility showing the preapplication treatment system, storage pond(s), spray fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.
3. A map of force mains and pump stations tributary to the land treatment facility. Indicate their size and capacity.
4. A schematic and plan of the preapplication treatment system and storage pond(s) identifying all pumps, valves and process control points.
5. A schematic and plan of the irrigation distribution system identifying all pumps, valves, gauges, sprinklers, etc.

b. Discuss the design life of the facility and factors that may shorten its useful life. Include procedures or precautions which will compensate for these limitations.

c. A copy of facility's Tennessee Operating Permit.

16.13.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:

1. Describe the various job titles, number of positions, qualifications, experience, training, etc.
2. Define the work hours, duties and responsibilities of each staff member.

16.13.3 Facility Operation and Management

a. Preapplication Treatment System:

1. Describe how the system is to be operated.
2. Discuss process control.
3. Discuss maintenance schedules and procedures

b. Irrigation System Management:

1. Wastewater Application. Discuss how the following will be monitored and controlled. Include rate and loading limits.
 - (a) Wastewater loading rate (inches/week)
 - (b) Wastewater application rate (inches/hour)
 - (c) Spray field application cycles
 - (d) Organic, nitrogen and phosphorus loadings (lbs/acre per month, etc)
2. Discuss how the system is to be operated and maintained.
 - (a) Storage pond(s)
 - (b) Irrigation pump station(s)
 - (c) Spray field force main(s) and laterals
3. Discuss start-up and shut-down procedures.
4. Discuss system maintenance.
 - (a) Equipment inspection schedules
 - (b) Equipment maintenance schedules
5. Discuss operating procedures for adverse conditions.
 - (a) Wet weather
 - (b) Freezing weather
 - (c) Saturated Soil
 - (d) Excessive winds
 - (e) Electrical and mechanical malfunctions
6. Provide troubleshooting procedures for common or expected problems.
7. Discuss the operation and maintenance of back-up, stand-by and support equipment.

c. Vegetation Management:

1. Discuss how the selected cover crop is to be established, monitored and maintained.

2. Discuss cover crop cultivation procedures, harvesting schedules and uses.
 3. Discuss buffer zone vegetative cover and its maintenance.
- d. Drainage System (if applicable):
1. Discuss operation and maintenance of surface drainage and runoff control structures.
 2. Discuss operation and maintenance of subsurface drainage systems.

16.13.4 Monitoring Program

- a. Discuss sampling procedures, frequency, location and parameters for:
 1. Preapplication treatment system.
 2. Irrigation System:
 - (a) Storage pond(s)
 - (b) Groundwater monitoring wells
 - (c) Drainage system discharges (if applicable)
 - (d) Surface water (if applicable)
- b. Discuss soil sampling and testing:
- c. Discuss ambient conditions monitoring:
 1. Rainfall
 2. Wind speed
 3. Soil moisture
- d. Discuss the interpretation of monitoring results and facility operation:
 1. Preapplication treatment system.
 2. Spray fields.
 3. Soils.

16.13.5 Records and Reports

- a. Discuss maintenance records:
 1. Preventive.
 2. Corrective.

- b. Monitoring reports and/or records should include:
 1. Preapplication treatment system and storage pond(s).
 - (a) Influent flow
 - (b) Influent and effluent wastewater characteristics
 2. Irrigation System.
 - (a) Wastewater volume applied to spray fields.
 - (b) Spray field scheduling.
 - (c) Loading rates.
 3. Groundwater Depth.
 4. Drainage system discharge parameters (if applicable).
 5. Surface water parameters (if applicable).
 6. Soils data.
 7. Rainfall and climatic data.

APPENDIX A

Due to the complexity of working with all of the variables that are inherent with land application systems, the most beneficial use of these criteria might be afforded by designing a slow-rate irrigation system for a hypothetical town in Tennessee. The following information is given:

Given: The town is in the Cumberland Plateau Section

The first step involves Equation 16-2, the water balance equation:

$$L_{wh} = (PET + Perc) - Pr \quad \text{Eq. 16-2}$$

The Thornthwaite equation, Equation 16-3, will be used to derive the potential evapotranspiration (PET) term:

$$PET = 0.63 \times S \times \frac{50 \times (T-32)^A}{9 \times I} \quad \text{Eq. 16-3}$$

The use of this equation requires that daylight hours at the particular latitude and the monthly air temperatures be used. Tennessee lies between latitudes of about 35° and 36° 40'. Since the latitudinal distance in Tennessee is not large, the daylight hours at the 36° latitude will be adequate for any town in Tennessee. Table A-1 lists the average monthly daylight hours, in units of 12 hours, 36° latitude.

Table A-1
Monthly Average Daylight Hours (S), in Units
of 12 hours, for the 36° Latitude

36⁰

January	0.84
February	0.91
March	1.00
April	1.09
May	1.17
June	1.21
July	1.19
August	1.12
September	1.04
October	0.94
November	0.86
December	0.81

The National Oceanic and Atmospheric Administration has published information on air temperature. A 30-year monthly average for the Cumberland Plateau Section, for the period of 1951 - 1980, will be used. Table A-2 is used to show the monthly daylight hours, air temperature and PET for this system.

Table A-2
Data Used, and Results Derived, for PET

per	S at 36 Degree Latitude	Air Temp. Degrees Fahrenheit	PET, inches month
January	0.84	35.6	0.10
February	0.91	38.6	0.27
March	1.00	46.9	0.97
April	1.09	57.3	2.30
May	1.17	64.7	3.59
June	1.21	71.6	4.90
July	1.19	75.0	5.44
August	1.12	74.3	5.00
September	1.04	68.8	3.79
October	0.94	57.3	1.98
November	0.86	46.7	0.82
December	0.81	39.1	0.27
TOTAL =			29.43

Air temperature data for a specific location can be used, but its use must be documented by the NOAA. Also, other methods of calculating the PET can be used, provided that the use of an alternate method has been given prior approval by the TDHE.

Table A-3 is an indication of the Pr value in Eq. 16-2. Section 16.7.4 contains Equation 16-4 which is used in this case:

$$Pr = Pr(\text{average}) + (0.85 \times \text{std. dev.}) \quad \text{Eq. 16-4}$$

Table A-3
Five-Year Annual Rainfall, Using the 30-Year
Average Monthly Rainfall and Standard Deviation

30-Year Average Rainfall, Inches	Standard Deviation	Pr Inches
---	-----------------------	--------------

January	5.46	2.54	7.62
February	4.83	2.22	6.72
March	6.45	2.82	8.85
April	4.95	1.93	6.59
May	4.75	1.62	6.13
June	4.32	1.41	5.52
July	5.06	2.10	6.85
August	3.60	1.33	4.73
September	4.10	1.69	5.54
October	3.08	1.63	4.47
November	4.39	2.02	6.11
December	5.43	2.49	7.55
TOTAL	56.42		76.68

An assumption is made that a site, with adequate acreage, has been selected, based on a site study. The following information is given:

Given: the most limiting soil layer has an infiltration rate of 0.3 inches/hour.

$$0.3 \text{ in/hr} \times 24 \text{ hr/day} \times 7 \text{ day/week} \times 0.10 = 5.04 \text{ in/week.}$$

The 0.10 figure is the 10 percent design percolation limit.

Given: Wastewater can be applied in January only ten days, due to frozen soil, snow cover, etc.

Given: Wastewater can be applied in February and December on only 20 days.

Equation 16-2 can now be used to determine the maximum allowable monthly hydraulic wastewater loading, L_{wh}. Table A-4 illustrates the results:

Table A-4
Determination of Maximum Allowable Monthly
Hydraulic Wastewater Loading, D (allowed), Inches/Month

	(1) PET	(2) Pr	(3) (1)-(2)Perc.	(4) L _{wh}	(5) (3)+(4)
January	0.10	7.62	-7.52	7.20	0
February	0.27	6.72	-6.45	14.40	7.95
March	0.97	8.85	-7.88	22.32	14.44
April	2.30	6.59	-4.29	21.60	17.31
May	3.59	6.13	-2.54	22.32	19.78
June	4.90	5.52	-0.62	21.60	20.98
July	5.44	6.85	-1.41	22.32	20.91
August	5.00	4.73	0.27	22.32	22.59
September	3.79	5.54	-1.75	21.60	19.85
October	1.98	4.47	-2.49	22.32	19.83
November	0.82	6.11	-5.29	21.60	16.31
December	0.27	7.55	-7.28	14.40	7.12
TOTALS	29.43	76.68	-47.25	234.00	187.07

Based upon a maximum infiltration rate of 5.04 in/week, a water loss (PET), and a precipitation water gain, column 5 illustrates the maximum yearly and monthly hydraulic wastewater application rates. These rates will be used in the design of the system unless other limitations occur.

The most important of those other limitations is the percolate nitrogen concentration. If percolating water from a slow rate (SR) system will enter a potable ground water aquifer, then the system should be designed such that the concentration of nitrate nitrogen in the receiving ground water at the project boundary does not exceed 10 mg/l. Section 16.8.1 indicates that the nitrate concentration in the percolate must not exceed 10 mg/l. The approach to meeting this requirement involves estimating an allowable monthly hydraulic loading rate based on an annual nitrogen balance and comparing these monthly rates to the monthly rates that are based on an application rate of 2.5 inches/week.

Equation 16-5 is used to determine monthly wastewater application rates based on a nitrate concentration of 10 mg/l.

$$L_{wn} = \frac{C_p (Pr - PET) + U (4.424)}{(1-f) (C_n) - C_p} \quad \text{Eq. 16-5}$$

The following information is given:

Given: $C_p = 10 \text{ mg/l}$
 Given: $C_n = 25 \text{ mg/l}$
 Given: $f = 25\%$
 Given: $U = 200 \text{ pounds/acre/year}$. This uptake is not constant; rather, the uptake is at a minimum in the cold months and is at a maximum in the warm months. Table A-5 indicates what percentage of U was allocated to each month.
 Given: Pr and PET have been developed previously and have been included in Table A-5.

The monthly use of Equation 16-5 is illustrated in Table A-5. Also, this table includes a comparison of the monthly rates that were developed from the infiltration and the nitrogen bases.

Table A-5
 Determination of Maximum Allowable Monthly Hydraulic
 Wastewater Loading Based on Nitrogen Concentration
 Comparison Between Infiltration and Nitrogen Loading Rates

	(2) (8) Pr Lwd in. in./mo.	(1) PET in.	(6) U %	(7) Lwn lbs. in./mo.	(5) Lwh in./mo.	
January	7.62	0.10	1	2	9.61	0
February	6.72	0.27	2	4	9.39	7.95
March	8.85	0.97	4	8	13.05	14.44
April	6.59	2.30	8	16	12.99	17.31
May	6.13	3.59	12	24	15.04	19.78
June	5.52	4.90	15	30	15.88	20.98
July	6.85	5.44	17	34	18.80	20.91
August	4.73	5.00	15	30	14.86	22.59
September	5.54	3.79	12	24	14.13	19.85
October	4.47	1.98	8	16	10.94	19.83
November	6.11	0.82	4	8	10.09	16.31

December	7.55	0.27	2	4	10.34	7.12	0
TOTALS	76.68	29.43	100	200	155.12	187.07	133.73

As can be seen in Table A-5, soil infiltration is the limiting factor in the months of December, January and February. All other months have a limiting factor that is based on the nitrogen uptake rates of the crop.

The preliminary amount of land, A_p , that will be necessary for application of wastewater is determined by using Equation 16-6:

$$A_p = \frac{(Q_y + V) C}{(L_{wd})} \quad \text{Eq. 16-6}$$

The equation will be first solved without using the V term. The following information is given:

Given: Q_y = MG per year = 36.5 MG
Given: L_{wd} = 133.73 inches/year (see column (8) Table A-5)
Given: C = 36.83

Substituting into Equation 16-6 gives the following:

$$A_p = 10.05 \text{ acres}$$

This preliminary acreage is used in determining storage needs. When the storage requirements are determined, the V term can then be derived and the actual field area, A_f , can be calculated.

Storage volume requirements will be performed here by using water balance calculations. The basic steps are as follows:

1. The available monthly wastewater volume is converted to a unit of depth, in inches, by using the following equation:

$$W_p = \frac{Q_m \times 36.83}{A_p} \quad \text{Eq. 16-7}$$

In using the equation, the Q_m term is assumed to be either 3.1 MGM, 3.0 MGM or 2.8 MGM, depending on the number of days in any particular month. No yearly variation is taken into account. In actuality, infiltration and inflow (I/I) and daily flow variations will require actual flow values.

Table A-6 is illustrative of the use of Eq. 16-7.

Table A-6
Estimation of Storage Volume Requirements
Using Water Balance Calculations

	(8) L_{wd} Cumulative	(9) W_p	(10) Change (9)-(8)	(11) Storage
January	0.00	11.36	11.36	24.04
February	7.95	10.26	2.31	26.35(b)
March	13.05	11.36	-1.69	24.66
April	12.99	10.99	-2.00	22.66

May	15.04	11.36	-3.68	18.98	
June	15.88	10.99	-4.89	14.09	
July	18.80	11.36	-7.44	6.65	
August	14.86	11.36	-3.50	3.15	
September	14.13	10.99	-3.14	0.01(c)	
October	10.94	11.36	0.42(a)	0.42	
November	10.09	10.99		0.90	1.32
December	<u>0.00</u>	<u>11.36</u>		11.36	12.68
	133.73	133.74			

- (a) Starting at October, in this example, will result in the maximum storage.
(b) Maximum storage.
(c) Rounding error; assume zero.

The storage volume is calculated by multiplying the maximum cumulative storage by the field area, as indicated below:

$$\begin{aligned}\text{Storage volume} &= (26.35 \text{ in}) (10.05 \text{ acres}) (\text{ft}/12 \text{ in}) (43,560 \text{ ft}^2/\text{acre}) \\ &= 961,000 \text{ ft}^3 \text{ (rounded off)}\end{aligned}$$

The storage volume will be dependent upon three factors: precipitation, evaporation, and allowed seepage. To obtain the final volume, the following steps are used:

1. Calculate the area of the storage volume.

Assume a maximum depth of 10 feet

$$\text{Area} = \text{Volume} \div \text{depth}$$

$$\text{Area} = 961,000 \text{ ft}^3 \div 10 \text{ ft}$$

$$\text{Area} = 96,100 \text{ ft}^2$$

2. Determine the monthly gain or loss in storage volume due to precipitation, evaporation and seepage in accordance with the following equation (see Table A-7):

$$V_m = (\text{Pr} - \text{evaporation} - \text{seepage})$$

Column 14 is the result of using this equation. Precipitation has been presented previously in Table A-5. Evaporation is assumed to be 20 inches per year, distributed monthly in the same ratios of monthly PET to annual PET. Seepage rate shall not exceed 1/4 inch per day, in accordance with criteria in Chapter 9.

V_m is converted from inches (Column 14) to MG (Column 15) by using the following equation:

$$V_m = (\text{Column 14}) \times 1 \text{ ft}/12 \text{ in} \times 96,100 \text{ ft}^2 \times 7.48 \text{ gal}/\text{ft}^3 \times 1 \text{ MG}/1,000,000 \text{ gal}$$

$$V_m = (\text{Column 14}) \times 0.0599$$

3. The monthly storage losses and gains are added for a yearly total, V_t . This term is inserted back into Eq. 16-6 to calculate the actual, final field area.

$$A = \frac{(Q_y + V_t)C}{L_w d} \quad \text{Eq. 16-6}$$

$$\text{where } Q_y = 36.5 \text{ MG}$$

$$V_t = -2.073 \text{ (from Column 15, Table A-7)}$$

$$C = 36.83$$

$$L_{wd} = 133.73 \text{ in/year}$$

Substituting into Eq. 16-6 yields the following:

$$A_f = 9.48 \text{ acres}$$

4. The water loss or gain is subtracted or added to the monthly available wastewater, previously used in Eq. 16-7 (see Columns 15, 16 and 17, Table A-7).
5. The monthly available wastewater amounts, from column 17 of Table A-7, are converted to depths, in inches, by using Eq. 16-7.

$$W_f = \frac{Q_m \times (36.83)}{A_f} \quad \text{Eq. 16-7}$$

where

$$Q_m = \text{MG}$$

$$A_f = 9.48 \text{ acres}$$

6. Substituting the monthly values of Q_{mf} into Eq. 16-7 yields column 18 of Table A-7. This is the amount of wastewater that will be available, in inches per month, for application to the field.
7. The available wastewater will be limited to field application due to weather, soil conditions, etc. This has been determined previously, was shown as Column 8 in Table A-5 and is re-indicated in Column 8 in Table A-7.
8. The difference between available wastewater and the amount that can be applied to the field is indicated in Column 19 of Table A-7. This column is derived by subtracting Column 8 from Column 18. A positive number indicates that more wastewater is available than can be applied; thus, storage is necessary. A negative number indicates that the soil can receive more wastewater than is received on a daily basis; thus, the wastewater that has been stored can be applied to the field along with the daily flow.
9. The cumulative storage is re-calculated, beginning with the storage basin(s) empty; in this case, at the beginning of October. This cumulative storage is shown in Column 20 of Table A-7 and indicates that a storage basin must be large enough to contain a volume of water equal to 27.00 inches of wastewater over the field area of 9.48 acres.

The final storage volume is determined as follows:

$$\text{Vol.} = (27.00 \text{ in}) (9.48 \text{ acres}) (\text{ft}/12 \text{ in}) (43,560 \text{ ft}^2/\text{acre})$$

$$\text{Vol.} = 929,000 \text{ ft}^3 \text{ (rounded off)}$$

10. Without changing the surface area of 96,100 ft^2 , the depth is re-calculated:

$$\begin{aligned} \text{Depth} &= \text{Volume} \div \text{area} \\ &= 929,000 \text{ ft}^3 \div 96,100 \text{ ft}^2 \end{aligned}$$

Depth = 9.67 feet

//w//

Table A-7

	(2) Pr inches	(12) Evap. inches	(13) Seepage, inches	(14) Water loss/gain, V (2)-(12)-(13) inches	(15) Qm MG	(16) Wastewater Qmf MG	(17) Wf (16)+(15)
January	7.62	0.07	7.75	-0.20-0.012	3.1	3.088	12.00
February	6.72	0.18	7.00	-0.46	-0.028	2.8	2.772
March	8.85	0.66	7.75	0.44 0.026	3.1	3.126	12.14
April	6.59	1.56	7.50	-2.47	-0.148	3.0	2.852
May	6.13	2.44	7.75	-4.06	-0.243	3.1	2.857
June	5.52	3.33	7.50	-5.31	-0.318	3.0	2.682
July	6.85	3.70	7.75	-4.60	-0.276	3.1	2.824
August	4.73	3.40	7.75	-6.42	-0.385	3.1	2.715
September	5.54	2.58	7.50	-4.54	-0.272	3.0	2.728
October	4.47	1.34	7.75	-4.62	-0.277	3.1	2.823
November	6.11	0.56	7.50	-1.95	-0.117	3.0	2.883
December	7.55	0.18	7.75	-0.38	-0.023	3.1	3.077
Total	76.68 20.00	91.25	-34.57-2.073	36.5	34.427	133.75	133.73

RDL/E6078048
Appendix A
Sewer Regs

Table 16-1
HYDRAULIC CONDUCTIVITY TEST METHODS

1.0 SATURATED VERTICAL HYDRAULIC CONDUCTIVITY^a

1.1 Laboratory Tests:^b

Constant Head Method (coarse grained soils)	ASTM D 2434-68 AASHTO T 215-70 Bowles (1978), pp 97-104 Kezdi (1980), pp 96-102
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Falling Head Method ^c (cohesive soils)	Bowles (1978), pp 105-110 Kezdi (1980), pp 102-108
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1.2 Field Tests:

Flooding Basin Method ^c	U.S. EPA (1981), pp 3-13 to 15
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Ring Permeameter Method	Boersma (1965) U.S. EPA (1981), pp 3-22 to 23
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Double Tube Method ^c	Bouwer and Rice (1967) U.S. EPA (1981), pp 3-17 to 24
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Air-Entry Permeameter ^c Method	Bouwer (1966) Reed and Crites (1984), pp 176 to 180 Topp and Binns (1976) U.S. EPA (1981), pp 3-24 to 27
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2.0 SATURATED HORIZONTAL HYDRAULIC CONDUCTIVITY^d

2.1 Field Tests:

Auger Hole Method	Reed and Crites (1984), pp 165 to 168 U.S. EPA (1984), pp 3-32 to 35 U.S. Dept. of Interior (1978), pp 55-67
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Slug Test	Bouwer and Rice (1976)
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^a Other methods, properly documented, may be accepted by the TDHE. However, "standard" percolation tests as performed for septic tank drain fields are not acceptable.

^b These tests require undisturbed field samples properly prepared to insure saturation. Reconstructed field samples are not acceptable. A description of the field sampling technique should accompany the laboratory testing results.

^c Methods recommended by the TDHE.

^d Testing for saturated horizontal hydraulic conductivity is required at land treatment sites where drainage improvements are planned and where lateral, as opposed to vertical, subsurface drainage is the predominant drainage pathway.

Table 16-2
Suggested Values for Inorganic Constituents
in Wastewater Applied to Land

Potential Problem and Constituent	No Problem	Increasing Problem	Severe
pH (std. units)	6.5 - 8.4		<5.0 >9.0
Permeability			
Electrical Conductivity (mho/cm)	>0.50	<0.50	<0.2
Sodium Adsorption Ratio (a)	<5.0	5.0 - 9.0	>9.0
Salinity			
Electrical Conductivity (mmho/cm)	<0.75	0.75 - 3.0	>3.0
Specific Ion			
Anions:			
Bicarbonate (meq/l) (mg/l as CaCO ₃)	<1.5 <150	1.5 - 8.5 150 - 850	>8.5 >850
Chloride (meq/l) (mg/l) <100	<3.0 >100	>3.0 >350	>10
Fluoride (mg/l)	<1.8		
Cations:			
Ammonia (mg/l as N)	<5.0	5.0 - 30	>30
Sodium (meq/l) (mg/l) <70	<3.0 >70	>3.0	>9.0
Trace Metals (mg/l):			
Aluminum <10			
Arsenic	<0.2		
Beryllium <0.2			
Boron	<0.5	0.5 - 2.0	>2.0
Cadmium	<0.02		
Chromium <0.2			
Cobalt	<0.1		
Copper	<0.4		
Iron	<10		
Lead	<10		
Lithium	<2.5		
Manganese	<0.4		
Molybdenum	<0.02		
Nickel	<0.4		
Selenium <0.04			
Zinc	<4.0		

^a Sodium Adsorption Ratio =
$$\frac{Na+1}{SQR (Ca+2 + Mg+2)/ 2)}$$

Where, Na+1, Ca+2 and Mg+2 in the wastewater are expressed in milliequivalents per liter (meq/l). SQR represents 'square root of'.