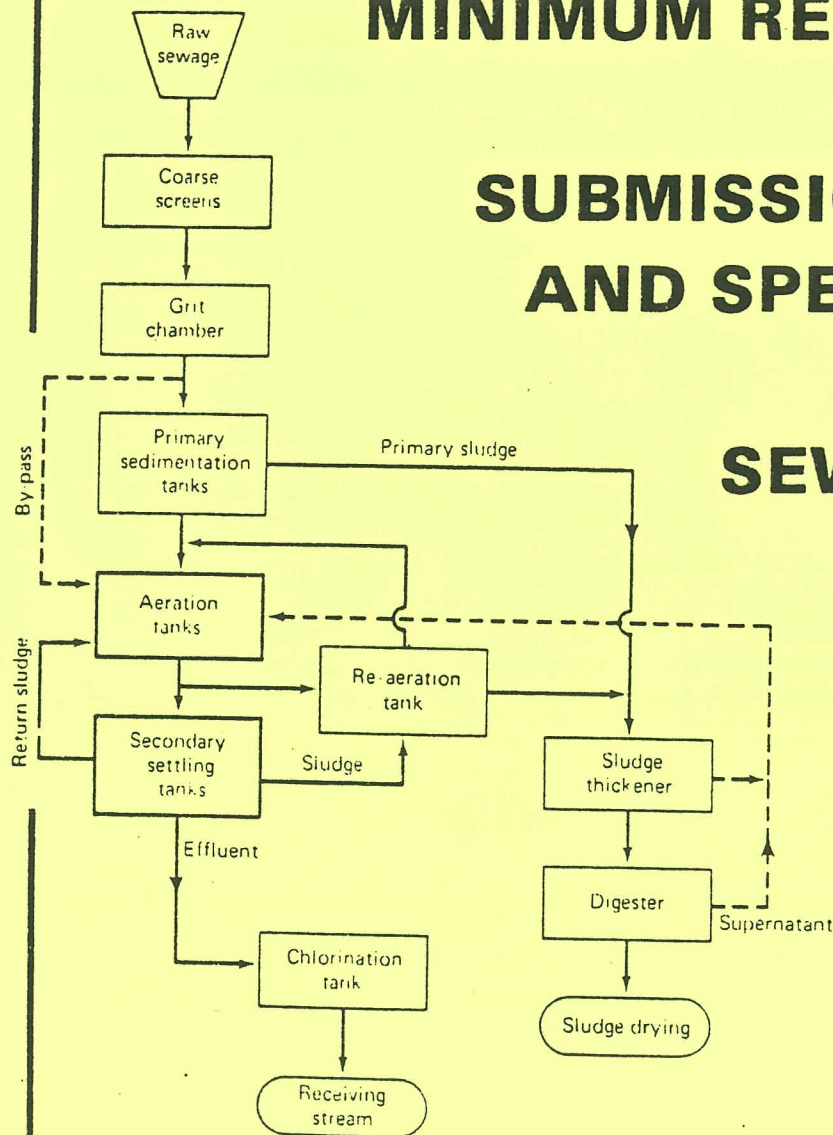


MINIMUM REQUIREMENTS FOR DESIGN, SUBMISSION OF PLANS AND SPECIFICATIONS OF SEWAGE WORKS



ARIZONA DEPARTMENT OF
ENVIRONMENTAL QUALITY

JULY 1978

engineering bulletin no. 11

Chapter 1

INTRODUCTION

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

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CHAPTER I - INTRODUCTION

A. REQUIREMENTS.

The Department's Rules and Regulations for Sewerage Systems and Treatment Works require the approval of design reports, plans and specifications by the Department prior to construction of such systems.

Arizona State Regulation R9-8-314.A. requires that an application to construct sewerage systems, sewerage system extensions, waste treatment works or any process or equipment in whole or in part be submitted at least thirty (30) days prior to the date of approval is desired. It also requires that engineering design reports, drawings, specifications, and other additional supporting data required by the Department accompany such application.

B. PURPOSE OF BULLETIN.

The purpose of this engineering Bulletin is two fold.

1. Minimum Standards - This Bulletin is set forth as a minimum standard for the design of sewerage systems and wastewater treatment works. It has been prepared to assist organizations in complying with the Department's Rules and Regulations regarding sewerage systems and treatment works and is a compilation of the latest design criteria and practices in the sanitary engineering profession.

This Bulletin will not address septic tank systems as a means of wastewater treatment. Septic tanks shall be designed in accordance with Engineering Bulletin No. 12. Where flows approach 20,000 gallons per day, consideration should be given to design of wastewater treatment methods other than septic tanks.

The Department may at its discretion, allow deviation from the recommended criteria based upon sufficient substantiating data that the criteria is restrictive and inoperative for the particular design under review.

2. Original Design - This Bulletin has been designed to serve as a guideline for the evaluation of an original design as detailed in Chapter III. Original design is defined as a newly developed or unique combination of existing processes.

Approval of any original design will be on an experimental basis only. It will be at the discretion of the Department as to when the experimental status will be removed. Each new process will be evaluated upon its conformance with physical and biological principles; and upon its performance under full load field conditions.

3. This Bulletin applies to existing systems being expanded, modified, upgraded, rehabilitated, and to construction of new facilities. Where a health hazard, a public menace, or operating difficulties occur at, or

because of existing facilities, this engineering Bulletin should be used to evaluate the acceptability of that system to properly operate and meet applicable engineering standards.

4. This Bulletin is not to be used as a construction specification.

C. GENERAL SUBMISSION OF PLANS, SPECIFICATIONS, AND REPORTS.

1. General Requirements - All information submitted to the Department for review shall be in such detail as to permit a comprehensive evaluation to assure compliance with the requirements of the Department.

a. Plan Documents - Any plan documents prepared for sewerage and/or wastewater treatment facilities construction shall be submitted to the Department at least 30 days prior to the date upon which action is desired.

b. Engineer's Report.

1) Preliminary Design Reports - Where the Engineer or his client deem a preliminary design report necessary, the report shall be prepared presenting the following information:

a) Sewerage System.

(1) Present area served, as well as future areas to be served, population data should accompany area analysis.

(2) Existing and final terrain data in sufficient detail to establish general topographical features of present and future service areas.

(3) Soil characteristics shall be outlined in the report. An indication of any unusual soil or foundation conditions at the location of all sewerage structures shall be given. The report shall also show the extent of the soil investigation, the location of all borings and sampling areas with a detailed report of the findings. Methods of dealing with special construction problems shall be discussed.

(4) Location of existing sewer lines, lift stations, future sewer lines and lift stations in a layout form.

(5) Discussion of the waste characteristics and volumes of industrial and commercial areas, present and future.

(6) Discussion of the estimated volumes of domestic sewage, infiltration, etc., that the sewerage system is handling and will be required to handle for the design period.

b) Wastewater Treatment Works.

- (1) Plant location, plant site plan, a description of the surrounding areas including a map of the area shall be included. Particular reference shall be made to the proximity of present and future developments, wells, streams, lakes, water plants, industrial sites, and other areas which will be affected environmentally by the plant. Discussion of the various sites available and the advantages of the final selection shall be outlined.
 - (2) Quantity and quality of domestic waste flows present and future. Field investigation reports shall accompany the preliminary reports to substantiate the waste flow characteristics.
 - (3) Quantity and quality of industrial and commercial wastes present and future. Field investigation reports shall accompany the preliminary reports to substantiate the waste flow characteristics.
 - (4) Maximum, average, and minimum domestic and industrial design flows being considered.
 - (5) Present and discuss treatment alternatives, environmental impacts, and reasons for selection of alternative.
 - (6) Present and discuss environmental impacts of the project during and after construction, including short- and long-term effects on the environment. The level of detail of the discussion should be sufficient to adequately address the short- and long-term impacts. Most generally, a brief synoptic approach will be sufficient. Certain projects may require in-depth research. In all cases, the latest Federal Register related to Environmental Impact Statements should be used as a guideline.
 - (7) Description of basic flow sheet of selected process with design criteria and flow diagram.
 - (8) The means of grit, grease, screenings, and sludge utilization and disposal shall be discussed in detail.
 - (9) The means of effluent utilization and disposal shall be discussed in detail. If discharge will require a discharge permit, analysis of the downstream use shall be included in the report.
- 2) Final Design Report - A final engineering design report shall be included with the final plans and specifications. The final report shall include the information set forth in the preliminary report with refinements dictated by design. Additional information required is as follows:

a) Sewerage System.

- (1) Design calculations for each sewer showing present and future flows with minimum velocities, and maximum velocities.
- (2) Capability of existing interceptors to carry present and future flows.
- (3) Design calculations for all sewage lift stations including wet well sizing.
- (4) Location of any bypasses and a detailed analysis of their anticipated use.
- (5) A time schedule of construction, lift station startup, and lift station operation and maintenance manual submittal.

b) Wastewater Treatment Works.

- (1) A detailed analysis of the method of treatment and its efficiency and ability to meet discharge requirements.
- (2) Design calculations showing size and capacity of each unit or component part in relation to the design criteria contained in this Bulletin. The calculations should show retention times, surface loadings, weir loadings, sludge return pump sizing, sludge wasting pumping rates, and any other pertinent information regarding plant design.
- (3) The means of grit, grease, screenings, and sludge utilization and disposal shall be discussed in detail, accompanied by the necessary design calculations.
- (4) Design calculations for effluent disposal if other than direct discharge to a navigable waterway.
- (5) A time schedule for completion of operation and maintenance manual submittal, plant construction and plant startup.

c. Detailed Plans - Minimum requirements of the plans are set forth in Chapter IV, Chapter V, and Chapter VI.

Plans relative to the modifications or extensions to existing systems shall indicate clearly the connections or relation thereto. If plans of the existing system are not on file with the Department, submission of as-built plans of the existing system or treatment works is required.

An as-built schematic of the collection system should be submitted, including approximate locations of all lines, line sizes, and inverts for major collection points. All lift stations and other special appurtenances and structures should be detailed sufficiently to determine their effects on the system. Plans of the existing treatment plant and effluent disposal system should be submitted which show the location and size of structures, equipment and piping; the hydraulic profile; and existing flow diagram in sufficient detail to determine their effects on the treatment plant.

- d. Specification - Complete detailed specifications for the construction of sewer system, wastewater treatment works, and their appurtenances, shall accompany the plans.

The specifications should include:

- 1) Contract Documents
- 2) General Conditions
- 3) Supplemental Conditions
- 4) Technical Specifications
- 5) Standard Details
- 6) Applicable Addenda

- e. Engineer's Seal - All plan documents for sewers and/or wastewater treatment works shall be prepared by a registered professional Engineer, licensed in the State of Arizona under provisions of ARS 32:141-145.

The necessary professional seal shall be legibly affixed to the plan documents.

- f. Revision of Approved Plans - Any deviations from approved plans or specifications adversely affecting the capacity, flow or operation of units must be approved in writing by the Department before such changes are made. Plans or specifications so revised shall be submitted a minimum of 30 days prior to the construction work which will be affected by such changes to permit sufficient time for review and approval before construction.

Special consideration will be given to emergency field conditions. Waiver of the written approval and 30-day requirement will be at the discretion of the Department.

Structural revisions or other minor changes, not affecting capacities, flows or operation, will be permitted during construction without approval.

As-built plans clearly showing all alterations shall be placed on file with the department after the completion of the work.

2. State Approval - In addition to the plans, specifications, and Engineer's reports, the submittal must be accompanied with the pertinent forms requesting approval. The following forms are a minimum requirement for each submittal.

- a. Subdivision.

- 1) Application for approval of sanitary facilities for subdivisions.
- 2) Application for approval to construct water and/or wastewater facilities.

- b. Trailer Coach Park.

- 1) Application for approval of a trailer coach park.
- 2) Application for approval to construct water and/or wastewater facilities.

- c. Sewerage and/or Wastewater Treatment Project.

- 1) Application for approval to construct water and/or wastewater facilities.

Each application shall be submitted in duplicate with four (4) copies of the plans and specifications and one (1) copy of the Engineer's report.

3. Other Approval - All phases of each project shall be co-ordinated with other agencies requiring review and approval.

Certain counties act as the review and enforcement arm of the Department. The Department has a current listing of delegated agencies and should be contacted for this list.

4. Approval to Operate - Two weeks prior to or the time differential between the preconstruction conference and commencement of construction, whichever is shorter, notice shall be given to the Department that the work will commence.

Two weeks prior to completion of project construction, the Department shall be notified for a final inspection by the Department. Upon satisfying the requirements of the final inspection, the Department shall issue an approval to operate. Operation of the constructed facility shall not commence until the approval to operate is issued to the Owner.

Rehabilitation and upgrading of facilities may require special prior arrangements with the Department in achieving the Certificate of Approval to Operate. Owners desiring an interim approval to operate for system shakedown shall request such in writing fourteen days prior to system startup.

5. NPDES Discharge Permit - Facilities which will discharge treated effluent into waters of the United States within the State are required to obtain a discharge permit by EPA. Forms for discharge permits may be obtained through the Department.

D. GRANTING EXCEPTION TO BULLETIN.

Persons requesting exceptions to the requirements of this Bulletin must do so in writing. An exception can be granted to portions of this Bulletin provided that the exact nature of the proposed differences be noted either in a letter or in the Engineer's Report. The justification and burden of proof for the proposed deviation is the responsibility of the applicant and his Engineer. If an exception to a design standard is requested, the request shall be accompanied by scientific justification, including computations, and practical data and experience on similar installations.

Exceptions will not be granted on items which are a State Regulation. The Department will grant exceptions at its discretion. Each exception will be reviewed individually. Granting of an exception does not nullify the established criteria of this Bulletin or provide a blanket approval to neglect the recommended design standard.

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Chapter 2

**EFFLUENT
LIMITATIONS**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

CHAPTER II - EFFLUENT QUALITY REQUIREMENTS

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CHAPTER II - EFFLUENT QUALITY REQUIREMENTS

The selection of a sewage treatment process used in treating wastewater is dictated by, among other criteria, the effluent quality required at discharge or for reuse. The Engineer should carefully review all applicable standards and effluent quality requirements in making the final process selection.

A. STREAM DISCHARGE REQUIREMENTS.

A sewage treatment plant discharging to a navigable water of the State of Arizona shall be designed to meet the effluent limitation requirements established in and by:

1. NPDES - The National Pollutant Discharge Elimination System established by PL-92-500 and administered by the Environmental Protection Agency has set discharge requirements in each state. The Department should be contacted for these discharge standards prior to final process selection. The Engineer shall use these standards in process selection to assure the Department that the effluent quality will meet the NPDES requirements.
2. Arizona Water Quality Standards - The Department's Rules and Regulations R9-21, entitled, "Water Quality Standards for Surface Waters," provide a detailed water quality standard for all surface waters of the State. The Engineer shall use these standards in process selection to assure the Department that the effluent discharge will not degrade the quality of the accepting stream.

Figure II - 1 and Table II - 1 show and list stream segments which generally require special investigation of the affects of the effluent on the water quality of the receiving stream. The Engineer should contact the Department for the established water quality limitations if his project is located within one of these segments.

3. Basin Plan - The Engineer shall refer to the appropriate basin plan to assure compliance of the selected process with the established basin requirements and criteria.
4. 208 Plan - The Engineer shall refer to the appropriate 208 Plan to assure compliance with the 208 requirements and criteria.
5. Tertiary Areas - Certain areas of the State have been designated as tertiary areas (areas requiring a minimum of tertiary treatment before effluent discharge). Table II - 2 shows a list of surface waters of Arizona and the effluent limitations of these waters.

The Engineer shall investigate the need for meeting tertiary treatment requirements before final process selection.

6. Continuing Planning Process - The CPP is a document published by the Department which gives input into future recommended effluent limitation policies. This document is available from the Department and shall be used by the Engineer in process selection (present and future).

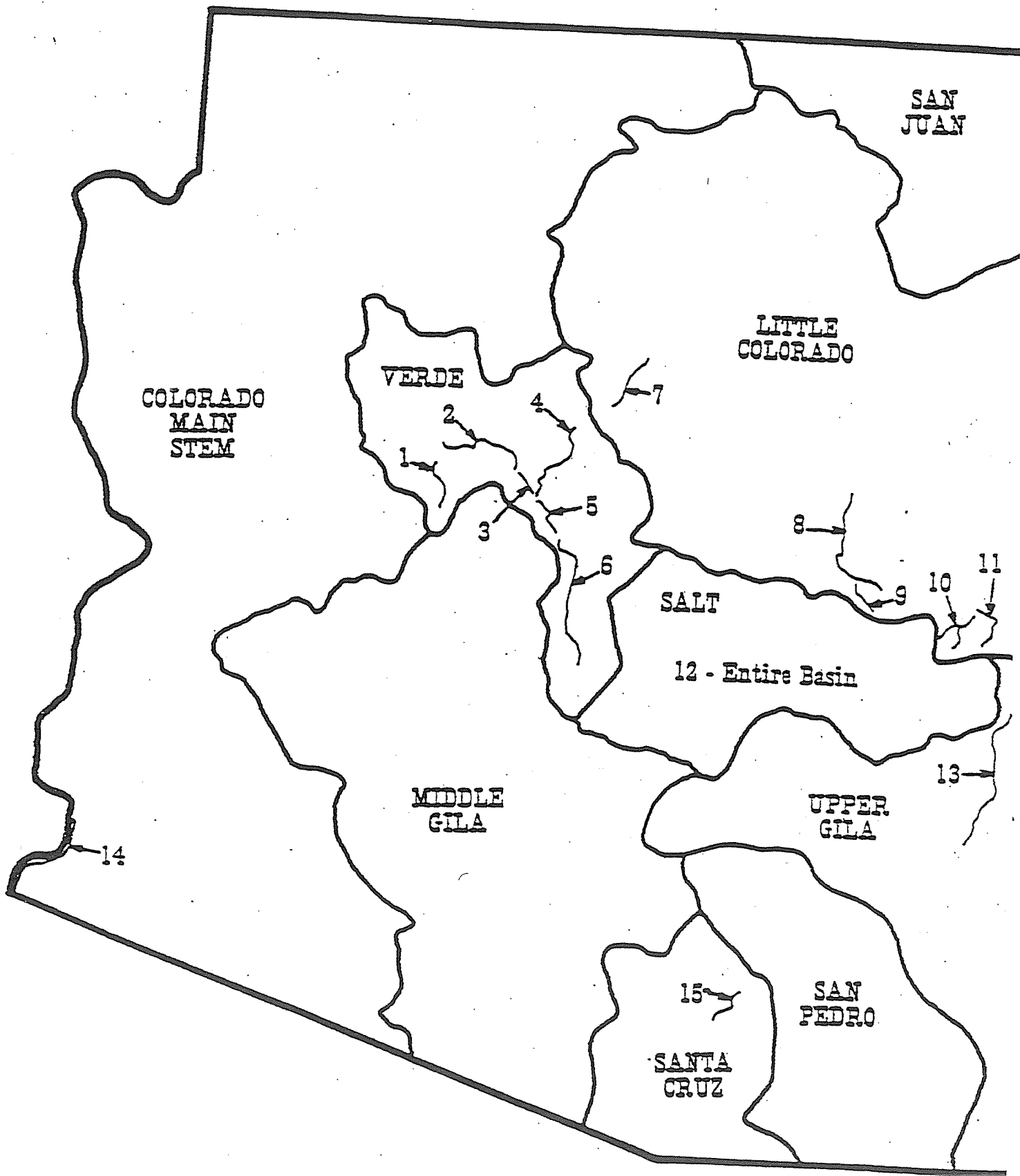


Figure II - 1

*State of Arizona Water Quality Segments
and River Basin Planning Areas.*

Water Quality Segment Description	River Basin Planning Area	COG Region
(1) Willow Creek and Tributaries	Verde	3
(2) Verde River from Sullivan Lake to Clarkdale	Verde	3
(3) Verde River Clarkdale to mouth of Oak Creek	Verde	3
(4) Oak Creek and tributaries to headwaters	Verde	3
(5) Verde River from Oak Creek to Camp Verde	Verde	3
(6) Verde River from Camp Verde to Bartlett Dam	Verde	1, 3, 5
(12) Salt River and lakes, and tributaries from Verde River to headwaters	Salt	1, 3, 5
(10) Little Colorado River and tributaries above Springerville	Little Colorado	3
(11) Nutrioso Creek	Little Colorado	3, 6
(9) Show Low Creek and tributaries to headwaters	Little Colorado	3
(8) Silver Creek	Little Colorado	3
(7) Rio De Flag	Little Colorado	3
(14) Colorado River from Imperial Dam to Southerly International Boundary	Colorado Main Stem	4
(13) San Francisco River and tributaries from headwaters to just below Luna Lake	Upper Gila	3, 6
(15) Sabino Creek	Santa Cruz	2

Table II - 1.

State of Arizona Water Quality Segments - Reference
Figure II - 1

Water	Effluent Limitation (1)			
	BOD (5 Days 20° C) mg/1	Suspended Solids mg/1	pH	Total Phosphate (as PO ₄) mg/1
1. Oak Creek and tributaries	10	10	6.5 - 8.6	3
2. Salt River Lakes (Roosevelt, Apache, Canyon, & Saguaro)	(2)	(2)	(2)	(2)
Discharges require sand filtration in addition to secondary treatment.				
3. San Francisco River and tributaries upstream (and including) Luna Lake	10	10	6.5 - 8.6	3
4. Show Low Creek and tributaries upstream (and including) Fools Hollow Lake	10	10	6.5 - 8.6	0.5
5. White River and tributaries	10	10	6.5 - 8.6	3
6. Willow Creek drainage (3)	10	10	6.5 - 8.6	3
7. Sabino Creek	10	10	6.5 - 8.6	3

(1) Standards shall be based on average of at least four weekly samples. Analytical methods shall conform to current edition of standard methods or EPA method as required for NPDES permits.

(2) No numerical standard at this time.

(3) Tertiary treatment not required if development can and will be connected to the City of Prescott waste treatment system when developed.

Table II - 2
Effluent Treatment Limitations For Surface Waters
Of Arizona

7. Other Local Conditions - Other local conditions may require more stringent effluent limitations to protect the health and welfare of the public and to minimize and/or abate adverse impact of the beneficial use of the stream accepting discharge. The Engineer shall investigate all other conditions and base his final process selection upon these findings. The Engineer shall analyze all documents and materials related to each effluent limitation entity listed above and shall select the proper process necessary to meet the most stringent limitations.

B. NON-STREAM DISCHARGE.

Effluent streams which are not discharged to the State's surface waters are generally reused or held in evaporation ponds or percolation ponds. The Department's Rules and Regulations R9-20 give effluent limitations for effluent reuse. The Regulation is summarized in Section P and Q of Chapter VII of this Bulletin. The Engineer shall make final process selection to meet these effluent limitations. In addition, precautions shall be taken to provide effluent quality which will not be detrimental to ground water quality and its present and future use.

C. MONITORING REQUIREMENTS.

The need for effluent quality standards necessitates the requirement of monitor wastewater treatment works. Each plant should monitor plant operation characteristics, as well as effluent characteristics, to assist in plant operation decisions and to assure the Department that effluent quality standards are being met. The sampling and analysis records should be kept on file at the facility for review by the Department during periodic inspections.

1. Plant Performance Monitoring.

- a. Stream Discharge - Public Law 92-500 established the requirement for plants to monitor specified effluent characteristics listed on each discharge permit issued.

Chapter VIII of this Bulletin provides information regarding the appropriate testing needed to assure compliance with EPA requirements.

- b. Non-Stream Discharge - The discharge standards previously outlined in this Chapter have been established by the State of Arizona as minimum standards. Each plant that is reusing effluent as defined in this Bulletin will be required to monitor effluent to assure compliance with these standards.

Chapter VIII of this Bulletin provides information regarding the appropriate testing needed in the monitoring process.

2. Operation and Maintenance Control Monitoring - To assure compliance with effluent standards it is recommended that an in-plant monitoring program be established. Onset of operational problems will be detected more easily and corrective actions can be taken before discharge violations occur through an in-plant monitoring program.

A plant operation and maintenance log should be set up with the parameters listed in Chapter VIII being an integral part of the log entry. In addition, hydraulic parameters of the plant process should be logged with unexpected operational interruptions or problems noted and explained as they occur.

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Chapter 3

ORIGINAL DESIGN

ARIZONA DEPARTMENT OF HEALTH SERVICES

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CHAPTER III - ORIGINAL DESIGN

A. INTRODUCTION.

Newly developed wastewater treatment processes shall be evaluated by the Department prior to issuance of Approval to Construct. In all cases, these processes will be given a temporary approval contingent upon demonstrating mathematically and with pilot plant test data that the process will operate in a manner suitable to meet discharge standards. Only one temporary approval per process may be allowed until the process proves by field performance that discharge requirements and effluent standards will be met consistently and until operation and maintenance and educational level requirements can be established.

This Chapter sets forth principles which will provide a basis for evaluation.

B. CRITERIA FOR EVALUATING DESIGN.

1. Pilot Plant Testing with Data - All requests for approval of new processes shall be accompanied with data from pilot plant studies that have been conducted over a sufficient time frame to exhibit minimal operational problems with consistent results. The data shall present results related to seasonal variations, flow variations, temperature variations, and shall include all other variations which will cause changes in treatment efficiency and characteristics. The data shall be presented in report form and shall be in sufficient detail for the Department's evaluation and analysis. Detailed descriptions of test equipment, testing procedures, and methods of chemical analysis shall be discussed in the report.

All new processes and test results will be protected by a non-disclosure agreement between the Department and the process developer.

2. Hydraulic Principles - All processes should be based upon sound hydraulic principles including but not limited to:
 - a. Principles of conservation of mass. The conservation of mass principle states that matter can neither be created nor destroyed. Hydraulically, this principle translates to a hydraulic mass balance, i.e.,
$$Q_{in} = Q_{out}$$
 - b. Principles of Conservation of Energy - The principle of conservation of energy states that energy cannot be lost, though it may be converted to other forms. In a hydraulic system, then, the sum of all energies (kinetic, pressure, and elevation) is a constant.
 - c. Principles of Impulse-Momentum - The law of momentum conservation states that momentum may not be lost in a hydraulic system, although some of it may be converted into impulse forces.
 - d. Principles of Liquid-Solid Separation - If the process involves separation of the liquid and solids, then this portion of the process will be evaluated using the following:

- 1) Gravity Process.
 - a) Stokes Law of discrete particle settling
 - b) Hindered settling principles
- 2) Pressure or Vacuum Process.
 - a) Poiseville's Law for the flow of fluids through capillary tubes or the Darcy modified scheme.
3. Physical Principles - Certain portions of newly developed processes may involve principles of physics such as sound, electromagnetic fields, heat transfer and exchange, etc. In such instances the process development report shall clearly indicate the physical principle upon which that portion is based and provide data with calculations substantiating correlation with physical laws.

4. Chemical Principles.

- a. Biochemistry - Applicable new processes shall be evaluated using principles of biochemistry. Included in the evaluation should be a mass and energy balance of the proposed process, as well as a description of the basic biochemistry.

Since biological science provides the basis of design, other factors shall be presented for evaluation which should include but not be limited to:

- 1) Reaction Kinetics - Rates of reaction of the biological process and their change with temperature. In the reaction rate temperature equation

$$\frac{K_2}{K_1} = \theta (T_2 - T_1)$$

θ shall be evaluated and substantiated.

- 2) Growth Kinetics - The substrate removal rate as a function of substrate concentration and biological growth as a function of the food to microorganism ratio, or variations thereof, shall be discussed clearly and concisely with sufficient data to substantiate process kinetics.
- b. Physical Chemistry - Portions of the process may be governed by laws or principles of physical chemistry.
 - 1) Adsorption - Adsorption equilibria should be discussed and defined in terms of Langmuir, BET, or Freudlich equations. Factors affecting the design and operation should be presented, such as pH, temperature, chemical interferences, reaction rate limitations, etc.

- 2) Ion Exchange - Ion exchange equilibria should be discussed in terms of exchange chemistry, ion selectivity, and exchange isotherms (Langmuir or Freundlich equations). Factors affecting the design and operation should be presented such as pH, temperature, chemical interferences, etc.
- 3) Membrane Processes - Membrane processes should be discussed in terms of chemical selectivity, membrane permeation, principal driving force and the principles of physical chemistry. Factors affecting the design and operation should be presented such as pH, temperature, etc.
- 4) Gas Transfer - Where portions of the process use gas transfer (O_2 , N_2 , etc.), the system shall be discussed in terms of Henry's law, Dalton's law, solubility principles, and rate of gas transfer. Temperature, pH, salinity, and other factors affecting the design and operation should be presented with data.
- 5) Chemical Oxidation - Where chemical oxidation processes are recommended, the evaluation will be based upon principles of chemistry. Stoichiometric discussions should be presented giving data showing the oxidation reduction equations, concentrations of reactants, temperature affects, role of impurities, role of pH, catalysts with dosages, retention times of reaction vessels, and other data necessary to design and operate the process.

In the preceding discussion, it is acknowledged that the principles involved in physical chemistry and biochemistry intermesh in major areas of thermodynamics, reaction kinetics, etc. However, for purposes of simplicity the evaluation criteria have been categorized as presented.

The process whose basis for evaluation has not been presented in this Chapter will be analyzed in terms of the basic applicable principles of physics and/or chemistry.

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Chapter 4

**SEWERAGE
COLLECTION
SYSTEMS**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

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CHAPTER IV - SEWERAGE COLLECTION SYSTEMS

A. INTRODUCTION.

This Chapter sets forth minimum standards for design and construction of sewer lines. The engineer should take every precaution to assure that pipe sizes and alignment will provide the necessary scouring velocities to give minimum sewer line maintenance. In addition, he is encouraged to recommend that the owner purchase, rent, or lease sewer service equipment, and that he establish a set preventive maintenance schedule.

The standards presented hereafter are established from general engineering experience and from general principles of open channel hydraulics. Imaginative designs based upon the general principles of open channel flow will be reviewed by the Department provided sufficient detailed analysis is presented to the Department in fulfillment of the requirements of Chapter I.

B. SEWERAGE COLLECTION SYSTEMS - GENERAL.

1. In general, sewer lines should be designed for the estimated population that will be contributory - present and future. Adequate allowance should be provided for infiltration, institutional, and industrial flows. Actual field flow measurements will be acceptable as a basis of design, provided that flow measurements are taken at representative points for specific areas of the system, i.e., high density industrial, commercial, low density industrial, residential, etc.
2. Pipe Selection - In selecting pipe material for sewers, consideration should be given to the chemical characteristics of the wastewater (especially in industrial waste flow areas), the possibility of septicity, exclusion of infiltration, external and internal pressures, abrasion and similar problems encountered with the established grades.

All types of pipe materials used in design shall have established ASTM, ANSI, or NSF standards of manufacture or seals of approval and shall be designated for use as sewer pipe.

3. Jointing Material - The materials used and methods proposed in making joints shall be included in the Specifications. Materials used for sewer joints shall have an established record for preventing infiltration and root entrance.

Water tightness of sewers and manholes shall be determined by one of three methods:

- a. Infiltration testing
- b. Exfiltration testing
- c. Low pressure air testing

The testing shall be performed prior to the sewers being placed in service and shall be administered on at least 20 per cent of the total project footage, unless additional tests are required by the design Engineer or the Department.

The testing shall be administered using the shortest length of line that is practical. All lines shall be cleaned before placing in service to remove extraneous material. It is also recommended that the sewers be examined by television or other methods to assure proper construction.

Suitable waterstops shall be provided at all manhole seams.

All test results shall be made available for review by the Department prior to project acceptance.

Sewer lines installed in areas where the pipe is subject to high ground water infiltration shall be tested using direct flow measurements in each specified reach of pipe.

- a. Infiltration Testing - The total infiltration shall not exceed 200 gallons per day per inch diameter per mile of pipe. If the quantity of infiltration exceeds the maximum quantity specified, immediate action shall be taken to reduce infiltration to within the specified limits.

Diameter of Sewer	Infiltration Gals/hr/100 ft.	Diameter of Sewer	Infiltration Gals/hr/100 ft.
8	1.26	54	8.51
10	1.57	60	9.45
12	1.89	66	10.39
15	2.36	72	11.34
18	2.83	78	12.29
21	3.31	84	13.23
24	3.78	90	14.17
27	4.25	96	15.12
30	4.73	102	16.07
36	5.67	108	17.01
42	6.61	114	17.95
48	7.56	120	18.90

Allowable M. H. Infiltration — 0.1 gallons per hour per vert. ft

Allowable Limits of Infiltration
200 Gal/Inch Dia/Mi/Day

- b. Low Pressure Air Testing - Low pressure air testing shall be limited to pipes less than 30 inches in diameter.

1) Test Procedure:

- a) Clean and wet the line to be tested.
- b) Plug all pipe outlets with suitable test plugs and securely brace each plug.
- c) Add air slowly to the portion of the pipe installation under test until the internal air pressure is raised to 4.0 psig.
- d) Check exposed pipe and plugs for leakage by coating with a soap solution. If any failures are observed, bleed off air and make necessary repairs.
- e) After an internal pressure of 4.0 psig is obtained, allow at least two minutes for internal air temperature to stabilize, adding only the amount of air required to maintain pressure.
- f) After the two minute period, disconnect the air supply.
- g) When the pressure decreases to 3.5 psig, start timing. Determine the time in seconds that is required for the pressure to fall from 3.5 psig to 2.5 psig. This test duration time must be equal to or greater than the minimum test duration time obtained as outlined below.

- 2) Minimum Test Duration Times - The following procedures for obtaining minimum test duration times from the nomograph, Figure IV - 1, are based on a maximum air loss of 0.003 cfm per square foot of internal cross sectional area but not more than 2 cfm for the entire length under test.

- a) For test sections of one diameter or for sections such as laterals with a few short taps.

If the length of the section under test is not greater than the length shown in Column L_A , read the minimum test duration time in seconds from Scale T_A .

If the length of section under test is greater than L_A , but within the limits of Scale L, extend a straight line from the diameter on Scale D to the length of Scale L and read the minimum test duration in seconds on Scale T_3 .

- b) For test sections consisting of more than one size pipe, and for lengths not falling within the limits of Scale L.

For test section lengths falling within the limits of Scale L, extend a straight line from the diameter read on Scale D to the corresponding length of Scale L for each size

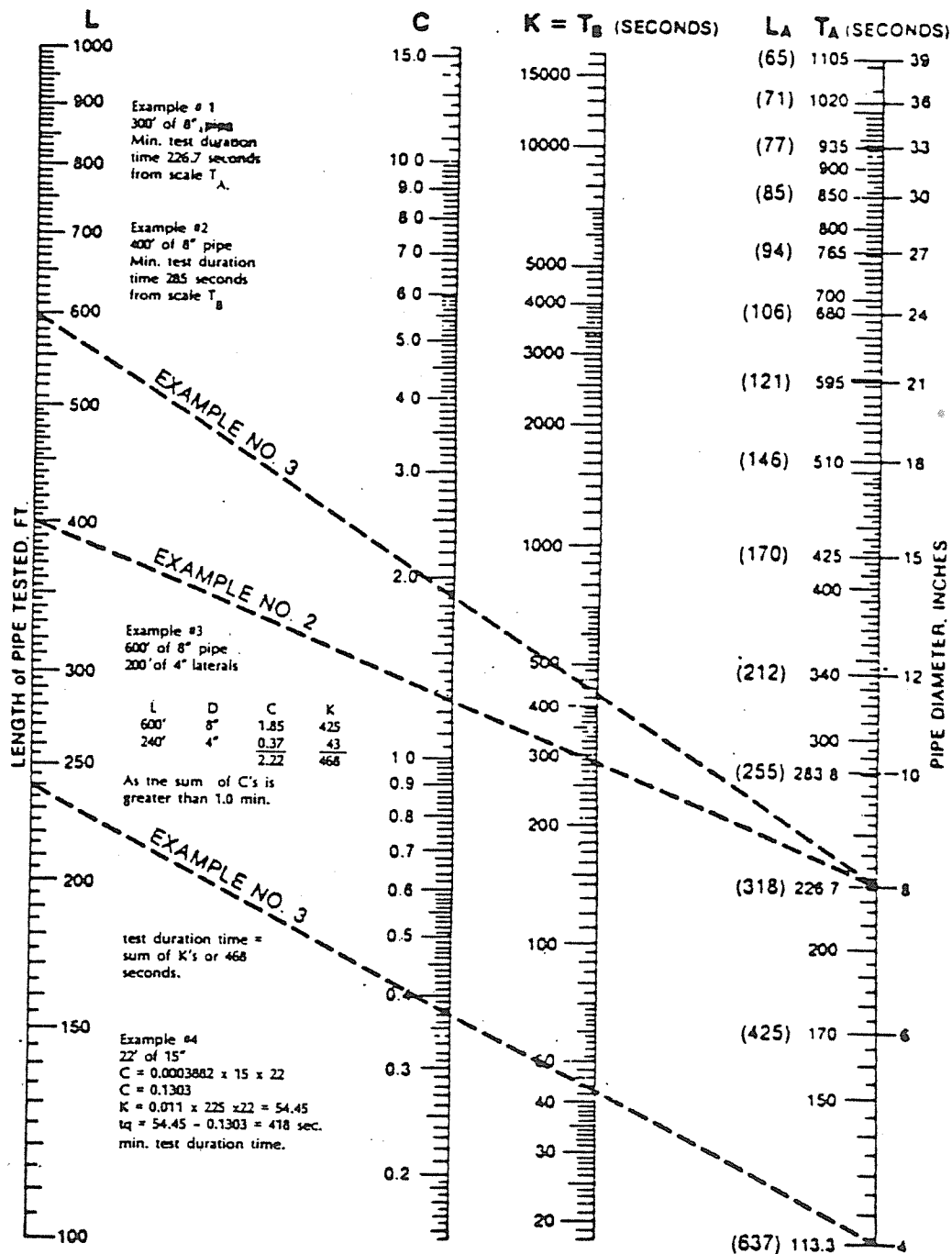


Figure IV - 1
Nomograph - Sewer Line
Air Testing

of pipe included and read values for C and K directly from the corresponding Scales.

For test section lengths not falling within the limits of Scale L, calculate C and K from the formulas at the bottom of the nomograph.

Add C's and add K's.

If the total of C's is 1.0 or greater, the sum of K's equals the minimum test duration in seconds.

If the total of C's is less than 1.0, divide the sum of K's by the sum of C's. The quotient is the minimum test duration in seconds.

- c. Exfiltration Testing - In areas where the sewer is not located in natural ground water table, exfiltration tests or low pressure air tests shall be used to give an indication of sewer tightness.

The exfiltration test should be conducted as follows:

- 1) Plug sewer at lower end of section to be tested.
- 2) Plug the highest end of the sewer to be tested. The sewer plug shall have a suitable air vent to allow trapped air removal.
- 3) Place a calibrated container at the average height of four (4) feet above the flow line of the sewer. Check the system for leaks in hoses, plugs, calibrated containers, etc. while filling through a positive shut-off valve. After filling the sewer, allow one hour for absorption of water and refill sewer line. When the water overflows the calibrated container, close the input valve and begin the test.
- 4) Record the elapsed time to empty the container of water and calculate the loss rate (gal/hr.).

Diameter of Sewer	Gals/Hr/100 ft.	Diameter of Sewer	Gals/Hr/100 ft.
8	1.26	18	2.83
10	1.57	21	3.31
12	1.89	24	3.78
15	2.36	27	4.25

Allowable Limits of Exfiltration 200 Gal/Inch Dia/Mi/Day @ (4 ft. head)

Exfiltration from manholes shall be limited to 0.1 gallons per hour per vert. foot.

4. Protecting Public Water Supply - Caution should be taken in design and construction to protect all water supplies from waste water contamination.

The Department has adopted regulations prohibiting cross connections. To minimize the potential of cross contamination, the Engineer shall design the horizontal and vertical separation of water and sewer lines as follows:

- a. Horizontal - When water lines and sewers are laid parallel to each other, the horizontal distance between them shall not be less than six (6) feet. Each line shall be laid on undisturbed or bedded material in a separate trench. Where conditions prevent the minimum horizontal separation set forth above, or where both lines are in the same trench, both the water line and sewer shall be constructed of mechanical joint cast iron pipe, or other approved pipe, which is pressure tested to assure water tightness before backfilling. In such instances, a complete description of the circumstances and details of the proposed construction shall be attached to the plans submitted to the Department.
- b. Vertical - When a sewer crosses two (2) feet or more below a water line, no extra protection is required. When a sewer crosses less than two (2) feet below a water line, the sewer shall be constructed of cast iron pipe with leaded or mechanical joints, or other approved pipe, for at least six (6) feet in both directions from the crossing, or the sewer shall be encased in concrete of 6-inch minimum thickness for the same distance. When a water line must cross under a sewer, a vertical separation of at least 18 inches between the bottom of the sewer and the top of the water line shall be maintained with support provided for the sewer to prevent settling. The sewer shall be constructed of cast iron pipe with leaded or mechanical joints, or other approved pipe at least six (6) feet in both directions from the crossing, or the sewer shall be encased in concrete of 6-inch minimum thickness for the same distance.
- c. No water pipe shall pass through or come into contact with any part of the sewer manhole.

C. CAPACITIES.

Sanitary sewers should be designed for the following existing and anticipated future flows:

- (1) Maximum rate of flow of domestic sewage for the entire service area for a specified time period.
 - (2) Infiltration that is allowed for the entire service area.
 - (3) Anticipated flow rates from commercial and industrial areas.
1. Design Period - Design periods should be chosen carefully and consider the following:

- a. Useful life of the equipment and its component structures, taking into account obsolescence and wear and tear.
- b. The ease, or difficulty, of expanding or relocating the system.
- c. The anticipated population rate increase including commercial and industrial contributions.
- d. The present rate of interest on accrued bond indebtedness.
- e. Inflation and escalation of material and labor during the period of indebtedness.
- f. The ability of the system to function properly at present flows after the expanded system is placed in operation

RECOMMENDED DESIGN PERIODS

Type of Structure	Design Period Years	Note
Laterals and submains less than 15 inches in diameter	Full Development	Requirements may change rapidly in a limited area.
Main sewers, outfalls, and interceptors	50, full development, or as specified by EPA	Difficult and expensive to enlarge

2. Design Flows - The estimates of flow of residential domestic areas can be expressed by the following equations:

$$Q_{\max}/Q_{\text{avg}} = 5.0/P^{1/6}$$

$$Q_{\min}/Q_{\text{avg}} = 0.2P^{1/6}$$

$$Q_{\max}/Q_{\min} = 25.0P^{1/3}$$

Where Q is the flow rate in gallons per day and P is the population in thousands.

Other widely used relationships of flow from moderate sized domestic sewage areas are

$$\begin{aligned} \text{Maximum daily flow} &= 2 \times \text{avg daily flow} \\ \text{Maximum hourly flow} &= 1.5 \times \text{maximum daily flow, or} \\ &= 3 \times \text{average daily flow} \\ \text{Minimum hourly flow} &= 2/3 \times \text{average daily flow, or} \\ \text{Minimum hourly flow} &= 1/2 \times \text{minimum daily flow, or} \\ &= 1/3 \times \text{average daily flow} \end{aligned}$$

In the absence of flow data new domestic sewerage systems shall be designed on the basis of an average daily flow of not less than 100 gallons per capita per day, or as specified by EPA's cost effectiveness guidelines. Lateral and submain sewers should be designed with capacities, when flowing full, of not less than 400 gallons per capita per day. Sewer mains should be designed for not less than 250 gallons per capita per day flowing full. Interceptors should be designed for maximum flows using the preceding equations.

In commercial areas the normal domestic flow should be added to that of the commercial areas. Commercial flows should be based upon known data in the design region.

Normal dry industrial flows should be based upon known data in the design region. Any residential flow should be added to these values.

Design for wet industry should be on an industry-by-industry basis.

D. DESIGN DETAILS.

1. No sewers other than house laterals shall be less than six inches in diameter. Six-inch diameter sewers will be permitted for lines under 400 feet in length in areas where the line cannot be extended, unless indicated otherwise in this Bulletin. A manhole shall be placed at the end of the six-inch line. If the six-inch diameter line is 200 feet or less in length, a cleanout at the end of the line may be used.

All other sewers shall be at least 8 inches in diameter.

2. Minimum Slope - All sewers shall be so designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second, based upon Manning's formula using an "n" value of 0.013. Use of other practical "n" values may be permitted by the plan reviewing agency if deemed justifiable on the basis of research or field data presented. Figures IV - 2 and IV - 3 are provided as a design aid.

To prevent deposition of sand and gravel, a mean velocity of 2.5 fps should be used when the circumstances permit. To prevent abrasive action of the pipe material, the maximum velocity in the sewer shall be limited to 10 fps. Where velocities exceed this maximum figure, the lines shall be constructed of ductile iron pipe or its equivalent. Manhole inverts shall also be protected.

All sewer lines shall be designed with due consideration given to sulfide production and control. Recommended references include EPA Process Design Manual for Sulfide Control in Sanitary Sewer Systems, and D. K. B. Thistlethwaite's Control of Sulphides in Sewerage Systems.

3. Alignment.

- a. Straight - Where a sewer with straight alignment is desired, the sewer shall be laid with uniform grade and straight alignment between manholes.
- b. Curvilinear - Horizontal and vertical curvilinear sewers will be accepted providing they meet the following criteria:
 - 1) The minimum velocity in the sewer flowing full is not less than 2.0 fps.
 - 2) The minimum radius of curvature shall be 200 feet or the radius calculated based upon one-half of the maximum allowable deflection per joint per pipe material, whichever is greater.

- 3) In addition to the acceptance test, the sewer line shall be cleaned to remove foreign material.
- 4) Manholes shall be placed at each end of the curve not to exceed 400 feet spacing.

4. Manholes and Cleanouts.

- a. Location - Except as itemized below, manholes shall be installed at the end of each line, at all changes of grade, pipe size, or alignment, at all sewer pipe intersections, and at distances not exceeding those shown below:

MANHOLE SPACING

Pipe Size (in.)	Max. Manhole Spacing (ft.)
8 - 15	500
18 - 30	600
36 - 60	800
Over 60	1300

Cleanouts may be used in place of manholes at the end of laterals less than 200 feet in length.

Where manholes are located in areas of flooding, consideration shall be given in design to eliminate storm water entrance.

Sewer Size		Minimum Slope to Maintain Velocity of:					
(in)	(mm)	2.0 fps (0.6 m/s)			2.5 fps (0.75 m/s)		
n		.010	.013	.015	.010	.013	.015
8	200	.0020	.0033	.0045	.0031	.0052	.0070
10	250	.0015	.0024	.0033	.0023	.0037	.0052
12	300	.0011	.0019	.0026	.0018	.0030	.0040
15	380	.00085	.0014	.0019	.0013	.0022	.0030
18	450	.00067	.0011	.0015	.0010	.0017	.0023
24	600	.00045	.00077	.0010	.00071	.0012	.0016

Table IV-1

Minimum Slope To Maintain Indicated Velocities Flowing Full
(From Manning's Formula)

- b. Drop Manholes - If the difference in invert elevations between inflow and outflow sewers exceeds 30 inches, a drop manhole shall be installed.

If the difference in invert elevations between inflow and outflow sewers is less than 30 inches, the manhole invert should be filleted to prevent solids deposition.

The Engineer should design drop manholes with due consideration given to sulfides and sulfide control. Recommended references include EPA Process Design Manual for Sulfide Control in Sanitary Sewerage Systems, and D. K. B. Thistlethwayte's Control of Sulphides in Sewerage Systems.

Elimination of drop manholes by a substitution of a vertically curved sewer into a standard manhole will be considered, provided detailed hydraulic calculations are submitted showing the vertical transition curve and its conformance with velocities and principals of open channel hydraulics.

- c. Diameter - The minimum inside diameter of manholes shall be 48 inches.

- d. Steps - Manhole steps should be installed in sewers when the depth of the manhole exceeds 48 inches. The steps shall be spaced from 15 to 18 inches apart vertically and constructed of cast iron or plastic coated cast iron.

Ladders with cast-in anchors will be an acceptable alternate to steps.

- e. Flow Channel - The flow channel through the manhole shall be steel trowel finished to conform in shape and slope to that of the sewers. The manhole shelf shall be brush or broom finished with a slope of one inch per foot.
- f. Water-Tightness - Manholes should be protected from storm drainage flooding conditions whenever possible. Where the flooding cannot be avoided, solid manhole covers shall be used to prevent infiltration. Suitable waterstops shall be provided at all manhole seams.

Manholes constructed of brick or concrete block shall be waterproofed on the exterior to prevent infiltration. Where pre-cast manholes are found to leak, the manholes shall be waterproofed on the exterior.

- 5. Depressed Sewers - The use of depressed sewers (inverted siphons) should be kept to a minimum.

To keep velocities to a maximum and clogging by sediments to a minimum and to provide easier maintenance, at least two parallel pipes should be designed with a minimum pipe diameter of six (6) inches.

A minimum velocity of 3.0 fps should be maintained in each sewer pipe. The system should be designed to provide the minimum velocity in one pipe

at minimum flows with the inlet structure arranged in such a manner as to bring additional pipes progressively into operation as the flow increases to its ultimate design flow.

Manholes shall be installed at each end of the depressed sewer to provide for cleaning and rodding.

Where circumstances warrant, a bar screen may have to be installed in a structure prior to the depressed sewer inlet. This could be especially true where 6-inch pipes are used. The design Engineer should give careful analysis and attention to potential clogging problems.

6. Depth of Sewers - Sewers shall be installed at a depth sufficient to insure adequate drainage of wastes from each service and to prevent frost damage.

All sewers shall be designed to absorb superimposed loads and back-fill overburden, without damage to the pipe material, and without adversely affecting the hydraulic characteristics of the pipe.

It is recommended that the sewer pipe be installed at a minimum depth of 3 feet (finished grade to pipe spring line). Where pipes are required to bridge ravines, washes, and caverns, the pipe shall be of high strength material and shall be supported properly to prevent settlement or washout during storm flows.

7. Easements and Rights-of-Way - No public sewer shall be installed unless the owner has in his possession evidence of his obtaining the necessary easements and rights-of-way.

Failure to produce these agreements upon request is ground for withdrawal of the Department's "Approval to Construct."

8. Special Conditions for Condominiums, Mobile Home, Travel Trailer, and Recreation Vehicle Parks - Condominiums, mobile home, travel trailer, and recreational parks shall be designed using the requirements of the uniform plumbing code, excluding the water-sewer main separation. The requirements of this Bulletin regarding water and sewer separation shall also apply to condominiums, mobile home, travel trailer, and recreational vehicle parks.

E. PLAN - DETAIL REQUIREMENTS.

In general, the engineering drawings submitted to the Department for approval shall meet the following requirements:

1. Standard Drawing Size - The engineering drawings shall be reproduced on paper not greater 24" x 36".
2. Plan View and Profile - Plans and profiles for sanitary sewers shall be submitted and shall be prepared using the following scales:

<u>Horizontal</u>	<u>Vertical</u>
1" = 20 feet	1" = 2 feet
1" = 30 feet	1" = 4 feet
1" = 40 feet	1" = 5 feet
1" = 50 feet	1" = 6 feet
1" = 60 feet	1" = 10 feet
1" = 100 feet	

The plans and profiles shall be in sufficient detail so as to provide a clear understanding of the size, invert and grade elevations and type of material used in construction.

The plans and profiles should show all utility locations, easements and rights-of-way, and other structural features of the sewer.

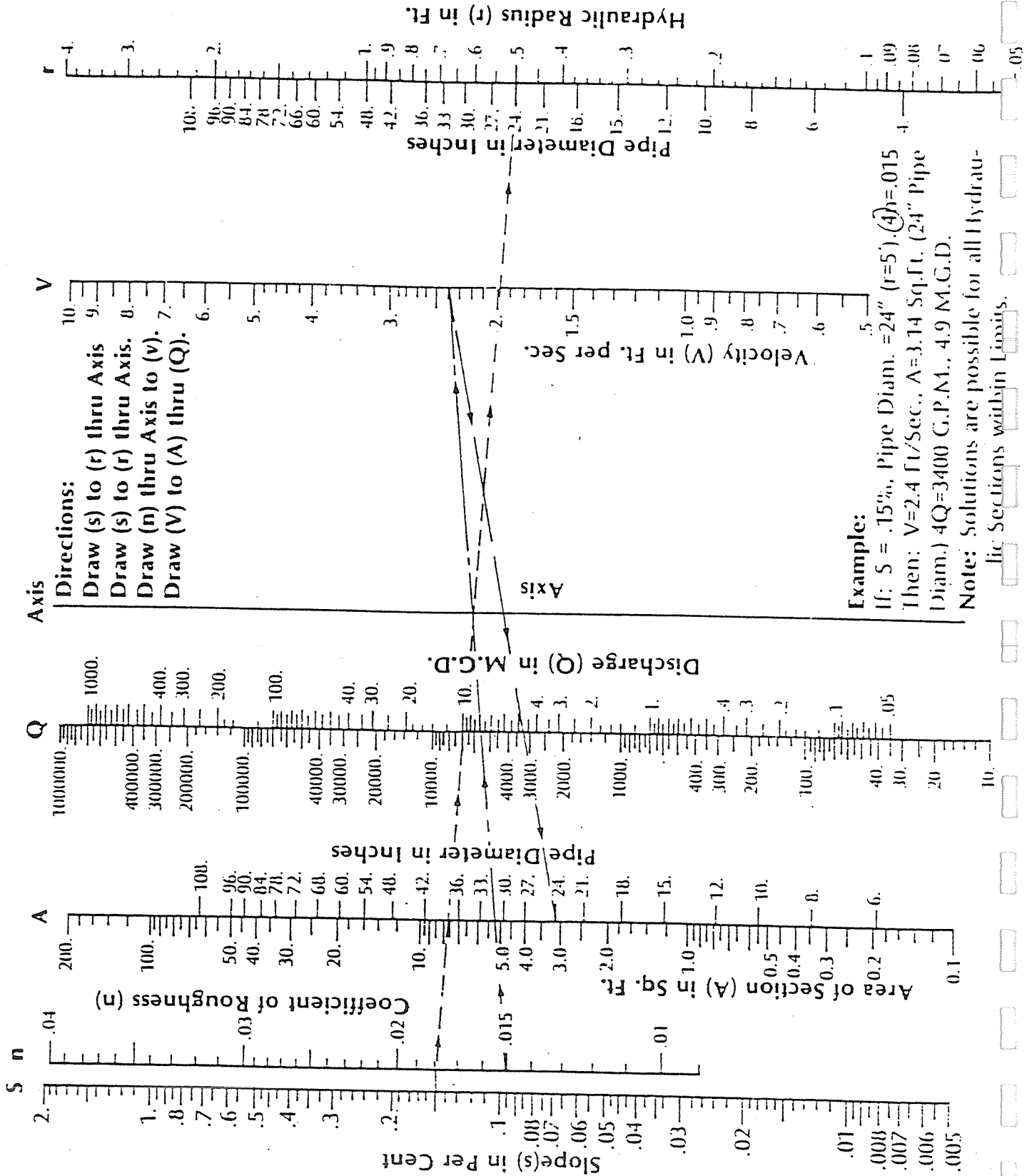
A general map, showing the vicinity of the project, area to be serviced, the location of the proposed sewers (referenced to plans and profiles), site or sites of all water and wastewater plants, wells, streets, parks, drainage areas, lakes, creeks, streams, water mains, and storm sewers, shall be included as part of the engineering drawings.

It is recommended that the general map include topographic contours at intervals of 2 feet minimum and 5 feet maximum.

Figure IV-2

Solution of Mannings Formula

$$V = \frac{1.486r^{2/3}}{n} (S)^{1/2} \text{ AND } Q = AV$$



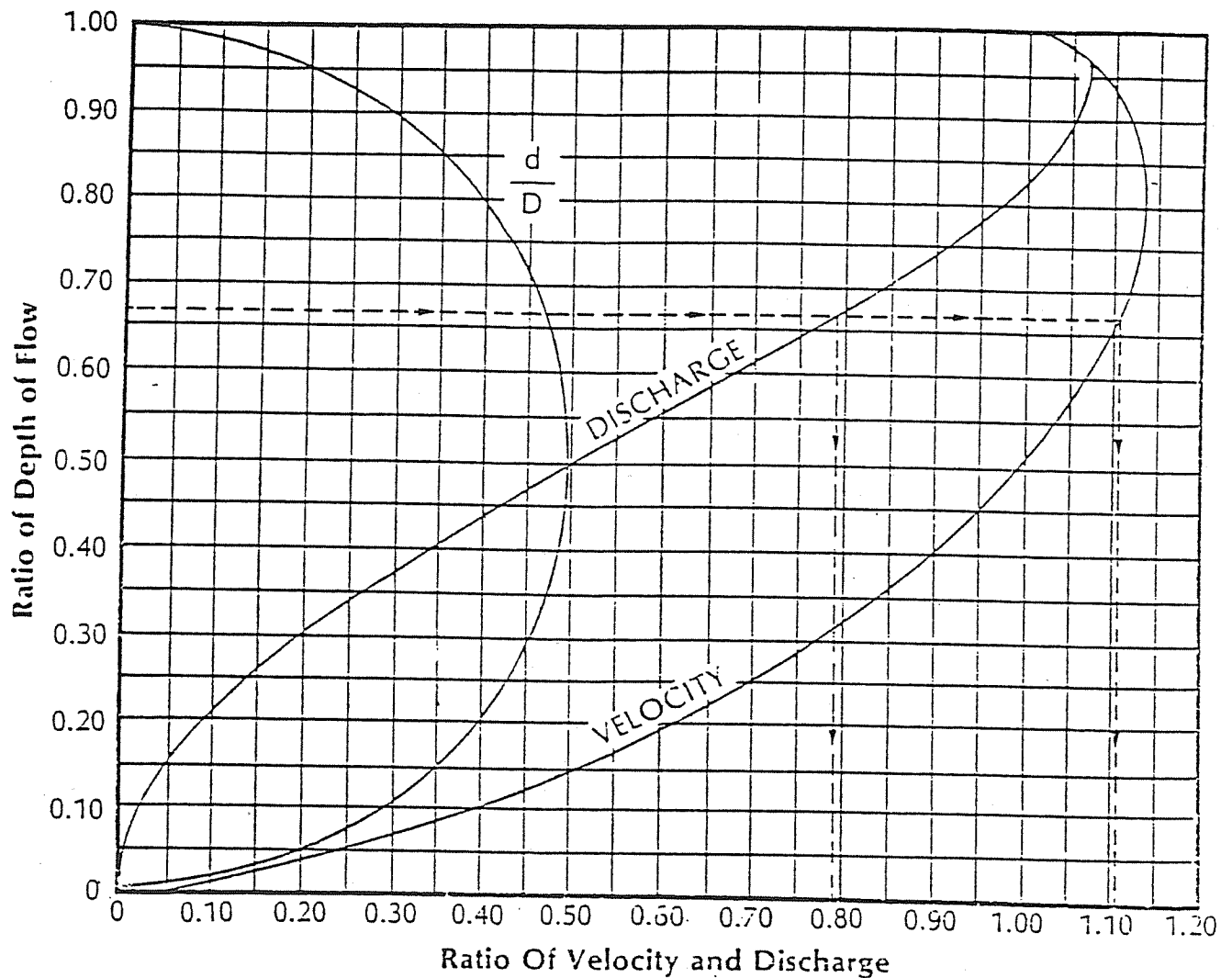


Figure IV-3
Velocity and Discharge for Partially Full Circular Sewers
 (Comparison of the filled section to the full section from Manning's Formula)

engineering bulletin no. 11

Chapter 5

**SEWAGE
PUMP STATIONS**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

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CHAPTER V - SEWAGE PUMP STATION

A. INTRODUCTION.

Chapter V provides design standards for sewage pump stations which are an integral part of the sewerage collection system. Criteria for design of in-plant sewage and sludge pumping systems are presented in Chapter VII.

1. Site Selection - In selecting a site for a sewage pumping facility, consideration should be given to:
 - a. Accessibility of site
 - b. Flooding conditions
 - c. Potential nuisance aspects
2. Location - The potential for damage or interruption of operation due to flooding shall be considered when locating sewage pump stations. The stations' structures and electrical and mechanical equipment shall be protected from physical damage by the maximum expected one hundred (100) year flood. The station shall remain fully operational during the twenty five (25) year flood if practicable; lesser flood levels may be permitted dependent on local situations, but in no case shall less than a ten (10) year flood be used.

B. DESIGN.

1. Selection of Pumping Equipment.

- a. Pumps - The selection of sewage pumps should be made after a thorough analysis of the following factors:

- 1) Design Flow - The design of the pump station will be governed by the maximum and minimum flows (present and future) contributed by the sewerage system tributary to the pumping station.

Flow patterns and quantities for the tributary contributing to the pumping station shall be established using the criteria set forth in Chapter IV of this Bulletin.

- 2) Number of Pumps - The number of pumps provided depends upon the required capacity and range of flow. The pumping station should be designed to provide a total pumping capability equal to the maximum anticipated flow with at least one of the largest pumps out of service. In no case shall less than two (2) pumps be provided in a pumping station.

Sewage pumps having suction lifts of a maximum of fifteen (15) feet will be approved only where the pumps are self-priming and adequate maintenance provisions are included in the design. Suction lifts for pumps using foot-valves on raw sewage will not be acceptable.

To minimize clogging, open impeller or non-clog type pumps, or ejectors, capable of passing a two and one-half inch sphere should be

required. For small lifts stations (40 gpm or less) grinder pumps will be acceptable.

Where special designs of pumping stations are necessary due to pump limitations, etc.; specific details of design with reasons for equipment selection shall be issued to the Department in report form for preliminary review prior to final design.

Inspection and clean-out plates on the pump bowl or a hand hole in the first fitting connected to the pump suction should be provided for clearing stoppages.

- b. Pump Controls and Alarms - Pump controls can be float-operated, electrode operated, pneumatically operated, or pressure switches.

Control mechanisms shall be located so that they will not be affected by flow currents created by the entering sewage or by pump suction.

Provision should be made to prevent floating material in the wet well from interfering with the operation of the controls.

When the controls are located in the dry well, the height of the float tube shall be such as to prevent overflow of sewage into the dry well.

All lift stations shall be equipped with an audible or visual high level alarm system. Other alarms such as pump failure, etc. should be considered in the design of lift stations.

Large lift stations should be equipped with variable speed controls to operate at varying delivery rates to permit discharging sewage from the station at approximately its rate of delivery to the pump station.

- c. Electrical Equipment - The motor starters and controls shall be located in property assembled (factory or field) control panels. Factory assembled control panels are preferred. Large stations should include a separate electrical room.

Power transformers shall be installed in an outdoor fenced enclosure, on power poles, or shall be of the lockable pad mounted type.

Unless it can be demonstrated to the Department that it is not required, all sewage lift stations shall have provision for standby power.

Lift stations which serve major flow areas shall be equipped with a standby generator, shall be supplied with power by two separate feeders from separate substations, or shall be supplied by a loop feeder on separate transformers from a common substation.

Electrical equipment in enclosed areas where gas may accumulate should comply with the National Board of Fire Underwriters and National Electrical Code for hazardous locations.

- d. Piping and Valves - Flanged pipe and fittings should be used for exposed piping in pump stations.

Each pump shall have a separate suction. It is recommended practice for the discharge pipe to be at least one pipe size larger than the discharge nozzle and for the suction pipe to be one or two sizes larger than the suction nozzle.

A concentric increaser should be installed on the pump discharge, with a full closing gate or plug valve and check valve. The pump suction should be installed with a full closing gate valve.

Where space conditions will not permit installation of rising stem valves, non-rising gate valves, check valves, and all other types of valves shall be equipped with an indicator to show open and closed positions.

Check valves should be of the swing type, preferably with outside lever and weight. The valve should be installed in the horizontal position in direct line with the pump discharge, and should be of a type permitting the unobstructed flow of sewage when in the full open position.

- e. Surge Control - The Engineer should take great care in analyzing the potential water hammer problems in force mains, the possible estimated pressure rise, and methods to reduce the maximum pressure rise to a safe limit.

Since many of the devices used to control water hammer in water pumping stations, such as surge suppressors and relief valves, are not applicable because of sewage solids, alternate solutions such as special valves with timed closures should be investigated. Hydro-pneumatic surge arrestors are also available for sewage applications.

A detailed treatise on water hammer by John Parmakian, entitled, "Waterhammer Analysis," is recommended by the Department and is available through Dover Publications, New York.

- f. Flow Monitoring - At larger pumping stations, consideration should be given to installing suitable devices for measuring sewage flows. At smaller pumping stations consideration should be given to providing a running time meter for flow monitoring.

2. Wet Well Design.

- a. Volume of Wet Well - The volume of the wet well between start and stop elevations for a single pump, a single-speed control step for variable speed, or multispeed operation is expressed as follows:

$$V_w = \frac{\phi q}{4}$$

where, V_w = required capacity, gallons

ϕ = minimum time of one pumping cycle or time between successive starts or speed increases of a pump operating over the control range, minutes

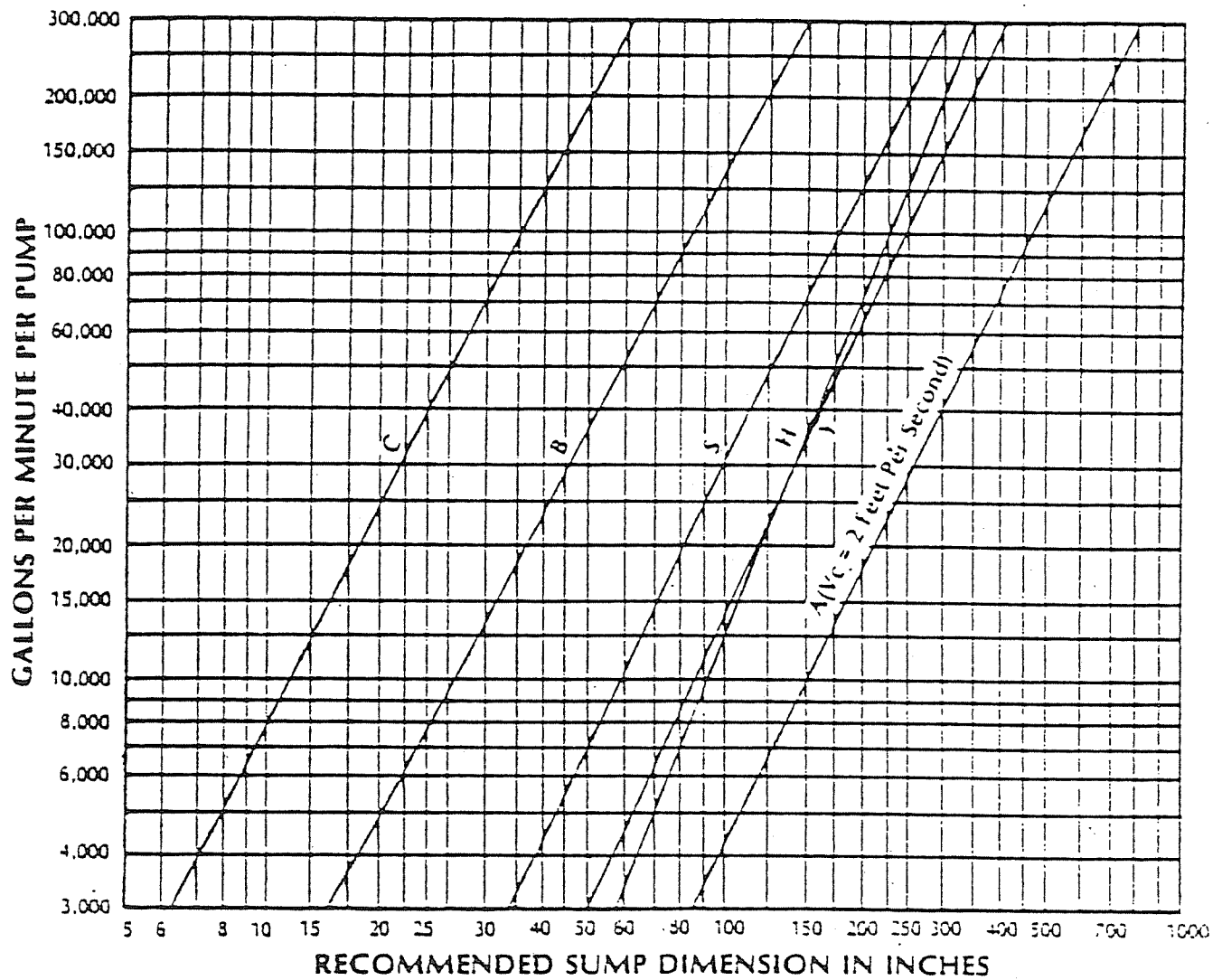
q = pump capacity, gpm, or increment in pumping capacity where one pump is operating already and a second pump is started, or where pump speed is increased.

Recommended values of ϕ for small pumps is 15 minutes (5 minutes minimum), and 20 minutes for large pumps.

- b. Floors - Floors of wet wells shall have a minimum slope of one to one to the pump intakes and shall have a smooth finish.
- c. Access - The wet well shall be designed with adequate access for maintenance purposes. It is recommended that the minimum dimension of the wet well be no less than five (5) feet.
- d. Pump Intake Protection - Pumps shall be protected from objects which will cause clogging and station malfunction. Screening devices may be used in the wet well or in an adjacent chamber to protect pumps against clogging. Manually cleaned bar racks may be used in small stations. Larger stations should use mechanically cleaned bar racks, screenings grinders, or comminutors with a manually cleaned bypass rack.
- e. Retention Time - The retention time of sewage in a wet well shall not exceed 30 minutes at average daily design flow. For areas where the retention time is greater than 30 minutes, a compressor with a diffuser bar shall be placed in the wet well to prevent the possibility of septic conditions. The compressor shall be sized at 2 scfm per 1000 gallons of storage.
- f. Ventilation - Adequate ventilation shall be provided in wet wells. Ventilation should be via blower, having sufficient capacity to provide a 2-minute air change based on the wet-well volume below grade and above the minimum sewage level. The mode of operation of the ventilation system should be at the discretion of the Engineer.
- g. Pump Intake Design - The Hydraulic Institute Standards gives recommended multiple pit layouts for centrifugal pump suction. These are shown in Figures V - 1, V - 2, and V - 3. In addition, pump suction connections to wet wells are shown in Figure V - 4.

These configurations have been established through field experience and shall be minimum standards for intake design.

- 3. Dry Well Design - The size of the dry well depends primarily on the number and type of pumps selected. The dry well shall be deep enough that the pumps are self priming at all starting levels unless self



Figures apply to sumps for clear liquid. For fluid-solids mixtures refer to the pump manufacture.

Figure V-1
Sump Dimensions Versus Flow

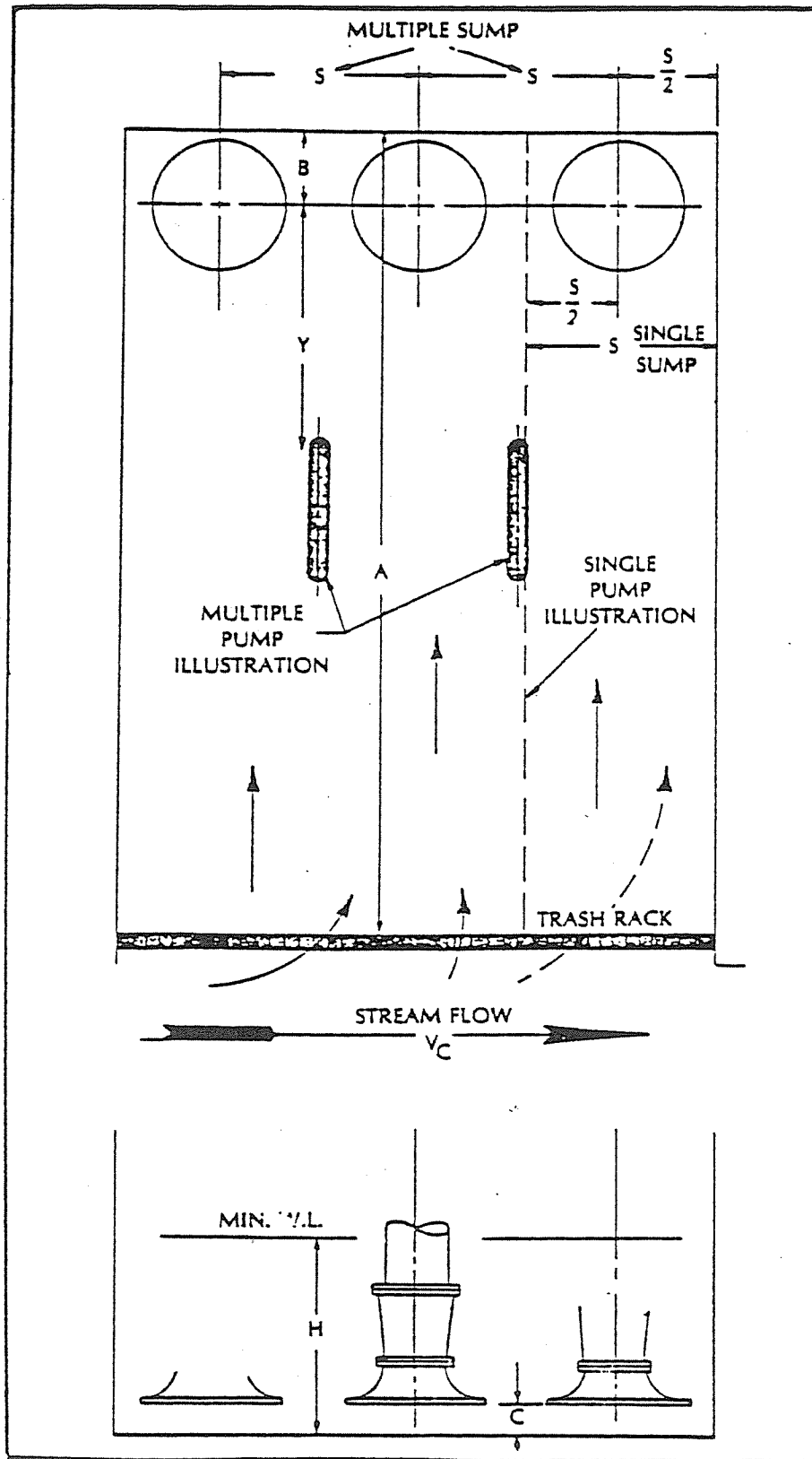
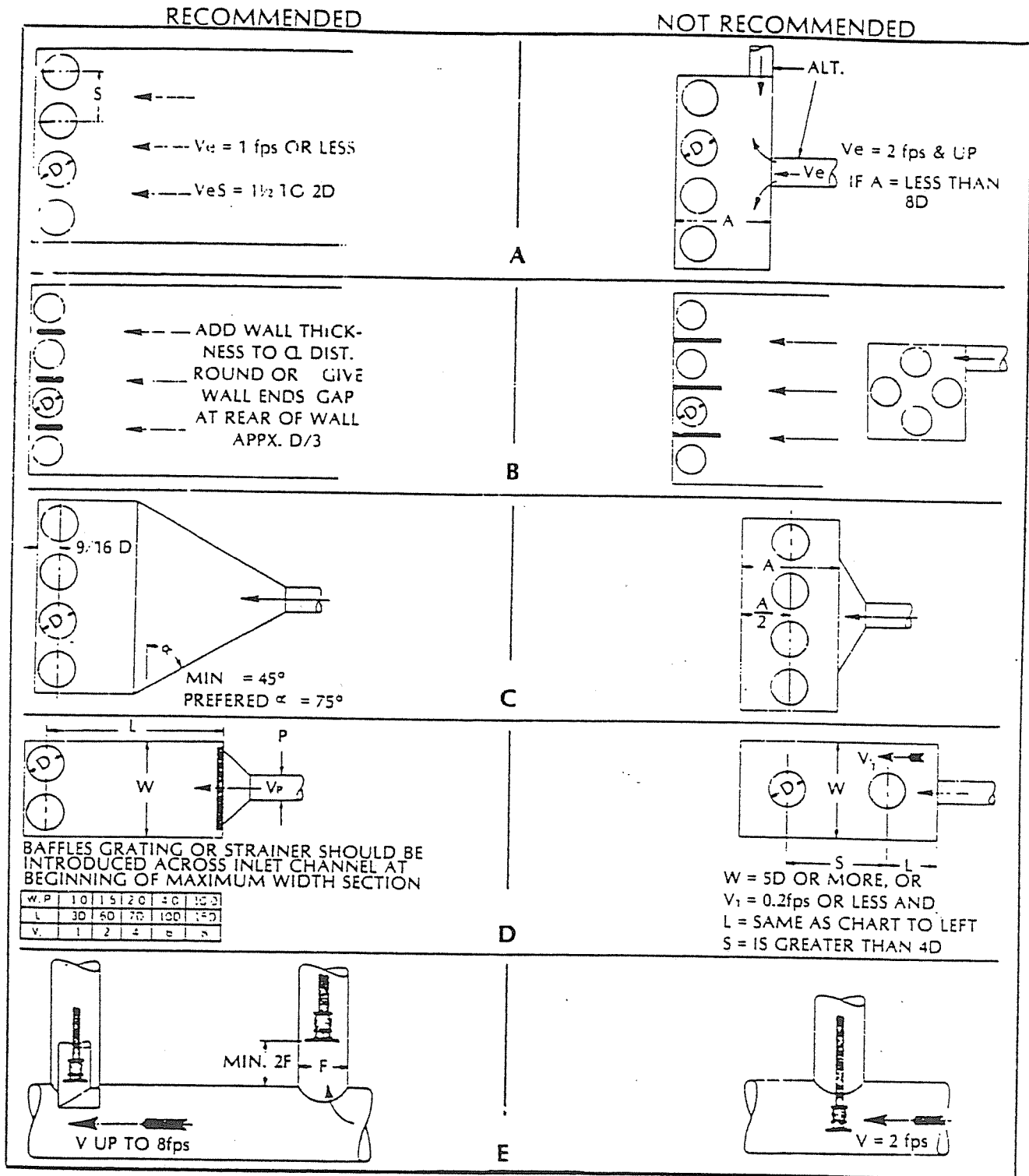


Figure V - 2
Sump Dimensions Versus Flow



NOTE: Figures apply to sumps for clear liquid. For fluid-solids mixtures refer to the pump manufacturer.

Figure V-3
Multiple Pump Pits

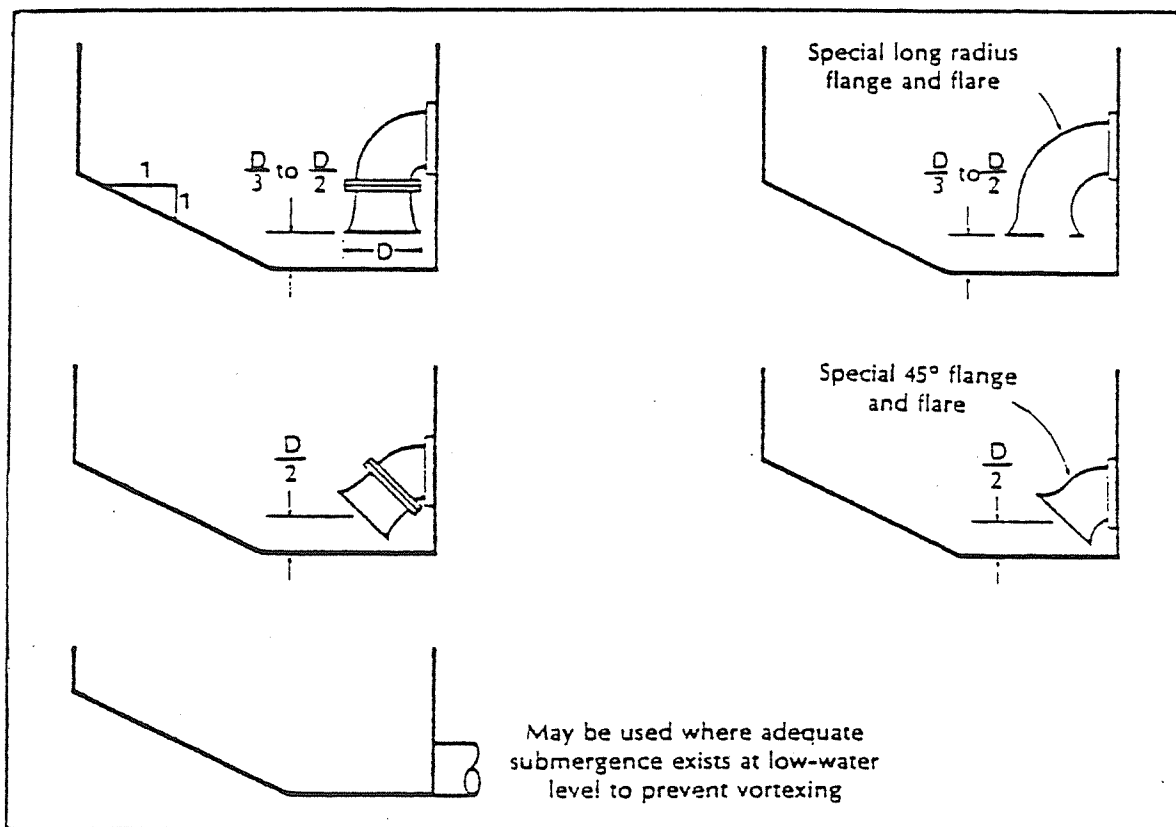


Figure V-4
Pump Suction Connections to Wet Well

priming pumps are being recommended. The pump setting shall be such that the pump's maximum suction lift is not exceeded and shall be positioned to minimize the liberation of gas.

Dry wells shall be well lighted, adequately ventilated, and provided with an automatic sump pump. The dry well shall be positively ventilated with an exhaust system which provides 30 air changes per hour based upon dry well volume below grade.

Sufficient working clearances around pumps and other machinery shall be provided to assure ease in maintenance.

Consideration shall be given to cranes or hoists for removing pumps for maintenance and replacement.

The dry well shall be separated from the wet well by a water- and gas-tight wall with separate entrances provided to each.

Stairways or access ladders shall be provided in all underground dry wells.

4. Individual Residence Lift Stations - In areas where individual residential lift stations are required to pump raw waste or effluent from individual disposal systems, the minimum design requirements are:

- a. Number of Pumps - At least one pump designed for the maximum design flow shall be provided in an enclosed sump.
- b. Controls - The lift station shall be provided with automatic "on-off" controls. A high level alarm system shall also be provided.
- c. Sump Design - The sump shall be designed in accordance with Section B.2. of this Chapter. In addition, a reserve capacity shall be provided above the high level alarm such that the total capacity of the sump equals one full day's flow volume.

5. Force Main.

- a. Velocity Requirements - The velocity of flow in the force main shall be between 3.5 and 6 fps. In no case shall a velocity less than 2 fps at minimum flow be allowed.

Although solids will not settle out at a velocity of 2.0 fps, solids in the wastewater remaining in the line when the pump stops will settle out. To assure pickup of the deposited solids, it is recommended that a design velocity of 4.0 fps be used. Pumps can be selected to give 4.0 fps minimum velocity with both pumps in operation or at peak delivery.

Figures V - 5 and V - 6 are provided for reference and as aid in designing force mains. Figure V - 5 is based upon Hazen-Williams' work and is for $C = 100$. Other values of C are presented in Table V - 1.

Type of Pipe	C
Asbestos Cement	140
Cast Iron	
New unlined	130
Old unlined	40 - 120
Cement lined	130 - 150
Bitumastic enamel lined	140 - 150
Tar-coated	115 - 135
Concrete or concrete lined	
Steel forms	140
Wooden forms	120
Centrifugally spun	135
Galvanized Iron	120
Plastic	140 - 150
Steel	
Coal-tar enamel lined	145 - 150
New unlined	140 - 150
Vitrified clay	100 - 140

Table V - 1
 Values of C
 Hazen Williams' Formula

Flow of water in pipes — Hazen - Williams formula, $C = 100$
Discharge in gallons per day

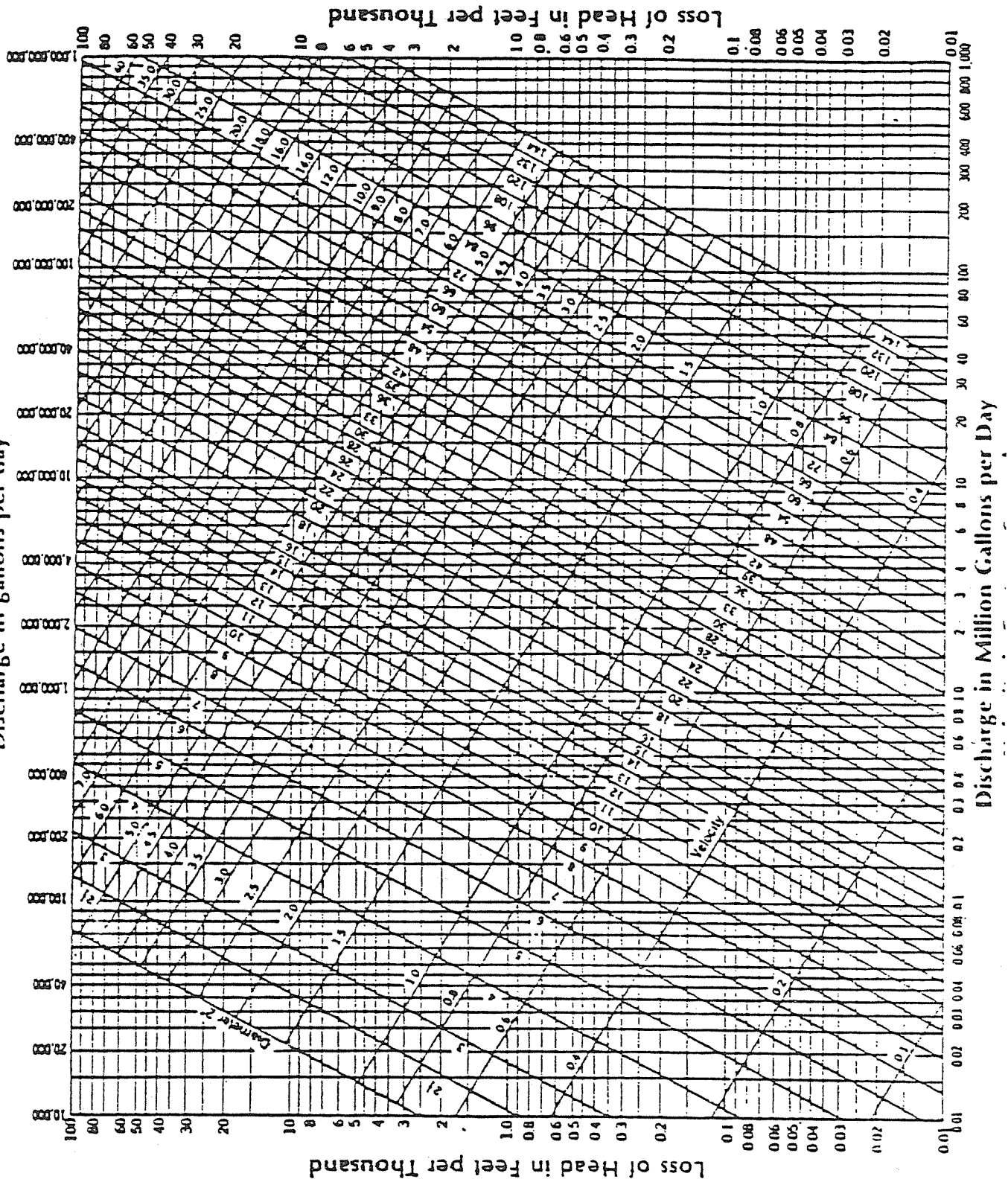
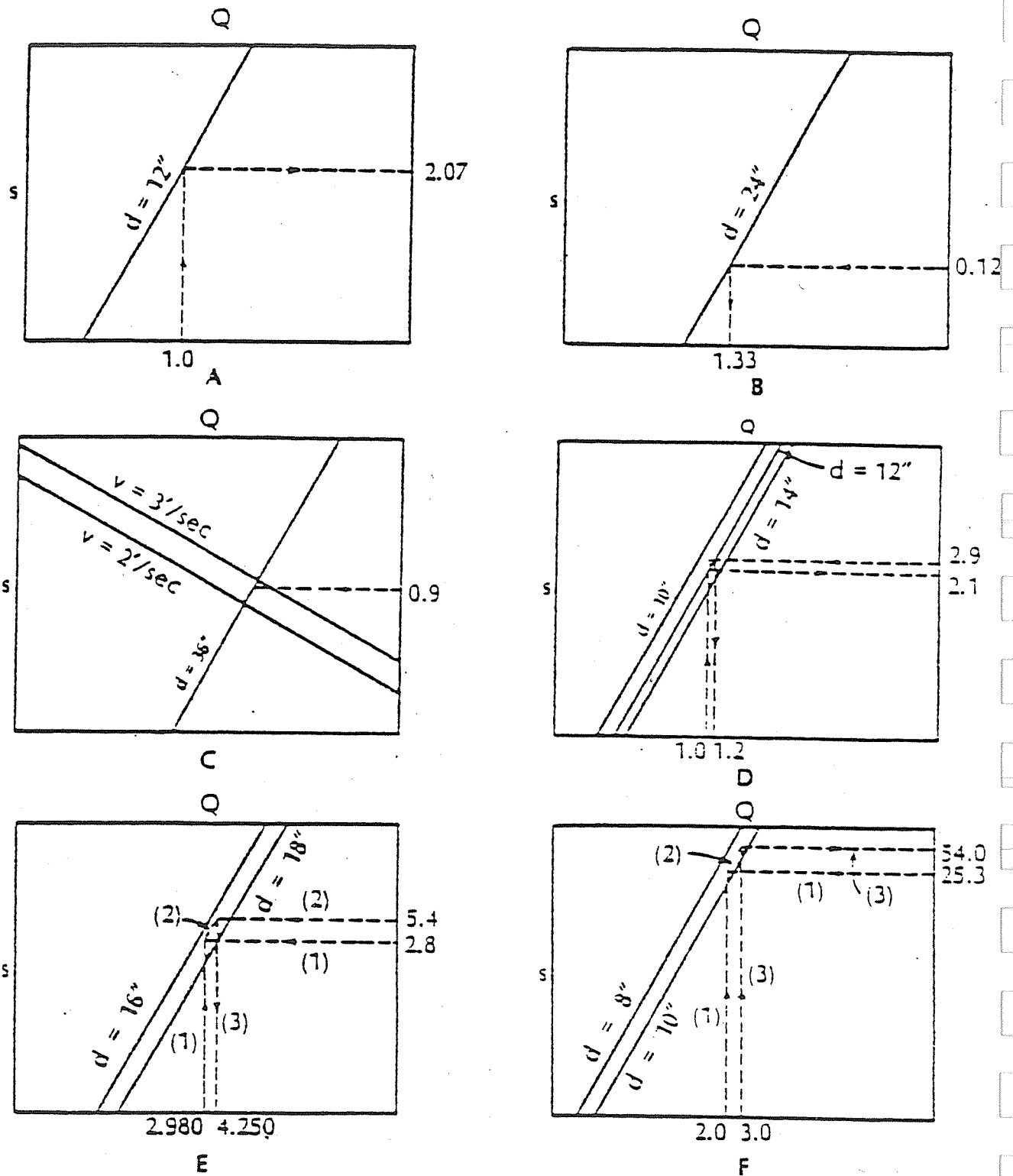


Figure V-5
Nomograph for Solution of Hazen-Williams Flow in Pipes



- Given Q and d ; to find s .
- Given d and s ; to find Q .
- Given d and s ; to find v .

- Given Q and s ; to find d .
- Given Q and h ; to find Q for different h .
- Given Q and h ; to find h for different Q .

For other than 100: (1) multiply given Q or v by $(100/c)$ to find s ; or multiply found value of Q or v by $(c/100)$ for given s .

Figure V-6
Use of Hazen-Williams Diagram

Force mains should be designed with due consideration given to minor losses in elbows, inlet and outlet structures, etc.

- b. Materials of Construction - All types of pipe materials used in design of force mains shall have established ASTM, ANSI, AWWA, and NSF standards of manufacture or seals of approval and shall be designated as pressure sewer pipe.
- c. Air Release Valves - Air release valves designed for sewage shall be provided on force mains at all peaks in elevation.
- d. Water Line Separation - Where a force main crosses a water line, the force main shall be enclosed in concrete for a distance of 10 feet each side of the water line.

The minimum separation between force mains and water lines shall be 2 feet (circumference to circumference) vertically and 6 feet horizontally. Measurements shall be from pipe circumferences.

- e. Testing - Prior to issuance of a Certificate to Operate all force mains shall be pressure tested.

Preparatory to testing, the section of the pipeline to be tested shall be filled with water and placed under a slight pressure for at least 48 hours. The pipeline shall then be brought up to 50 psi over or 125 per cent of working class pressure, whichever is greatest, and maintained on the section under test for a period of not less than 4 hours.

Accurate means shall be provided for measuring the quantity of water required to maintain full test pressure on the line for the test period, which volume shall not exceed:

$$L = \frac{JD\sqrt{P_t}}{4500}$$

where,

L = maximum allowable leakage in gallons per hour for the section of pipeline tested

J = number of joints in length tested

D = diameter of pipe in inches

P_t = test pressure in psi

- 6. Lift Stations Pumping into Treatment Facilities - Sewage pumping stations lifting wastewater into treatment plants shall be evaluated to assure that under conditions of peak flow the surface loading rates on the primary clarifiers does not exceed 1200 gpdpsf and that the secondary clarifier surface loading rate will not exceed 1000 gpdpsf.

Where preliminary analysis shows excessive clarifier loadings, consideration shall be given to flow equalization or increase in clarifier surface area.

C. PLAN DETAILS REQUIREMENTS.

Engineering drawings submitted to the Department for approval shall meet the following requirements:

1. Standard Drawing Size - The engineering drawings shall be reproduced on paper not greater than 24" x 36".
2. Drawing Scale.
 - a. Plan-Profiles - Plan-profiles of sewage force mains shall be submitted and shall be prepared using the following scales:

<u>Horizontal</u>	<u>Vertical</u>
1" = 20 feet	1" = 2 feet
1" = 30 feet	1" = 4 feet
1" = 40 feet	1" = 5 feet
1" = 50 feet	1" = 6 feet
1" = 60 feet	1" = 10 feet
1" = 100 feet	

- b. Details, Sections, Etc. - Details, site plans, and sections shall be at such scale as to indicate construction requirements in a clear understandable manner.
 3. Drawing Details - The engineering drawings shall be of sufficient detail so as to provide a clear understanding of the location of the project, site plan of each lift station, topography of the project, all utility locations, easements and rights-of-way, and other structural features of the sewer.

Lift station details shall show all invert elevations, structural elevations, existing and finished grade, control setting elevations, structural design of wet wells and dry wells, valve and piping, surge control devices, pump suction and discharge details, and any other details which will provide a clear understanding of the project.

Plans and profiles of force mains shall show size, invert and grade elevations, materials of construction, utility location, and any other details which define the force main construction requirements.

engineering bulletin no. 11

Chapter 6

**SEWAGE
TREATMENT WORKS
DESIGN
CONSIDERATIONS**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

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CHAPTER VI - SEWAGE TREATMENT WORKS DESIGN CONSIDERATIONS

A. GENERAL.

1. Treatment - The treatment plant process selection shall be such that effluent quality standards will be met under the most adverse conditions.

The treatment plant should be designed to provide for the estimated population of 15 to 25 years. In general, if the growth rate and interest rates are low, a 20 to 25 year design period is recommended. When growth and interest rates are high, a 10 to 15 year design period may be more feasible.

2. Plant Upgrading - Upgrading of sewage treatment works may be required for several reasons including the following:
 - a. Meet more stringent effluent quality standards.
 - b. Increase hydraulic and/or organic loading capacity.
 - c. Improve poor performance due to improper plant design and/or operation. It is recommended that the Engineer define the following aspects of the existing facility.
 - 1) Efficiency of treatment
 - 2) Normal operational and maintenance procedures
 - 3) Condition of structures
 - 4) Condition of equipment
 - 5) Staffing pattern and operator skill

After appropriate analysis of the existing system, a brief description of the recommended revisions should be submitted to the Department in a preliminary report for review and comment. If the Department does not have as-built drawings of the existing facility on file, the Engineer shall provide a set of as-built drawings with his final design.

Plans of the existing treatment plant and effluent disposal system should be submitted which show the location and size of structures, equipment, and piping; the hydraulic profile; and existing flow diagram in sufficient detail to determine their effects on the treatment process. A schematic of the effluent disposal piping should be submitted including approximate locations of all lines, line sizes, and inverts of major piping. All pumping stations and other special appurtenances and structures should be detailed sufficiently to determine their effects on the system.

3. Partial Construction - When it is anticipated that only a portion of the plant will be constructed presently, the Engineer shall furnish design data for the complete facility, including size, type, and location (future units shown dotted), design loads, process flow schemes, hydraulic profile, and other pertinent data which clearly defines the present and future installation.

In addition, a site plan with topographic features shown shall be submitted for review.

B. PLANT LOCATION.

The treatment works site should be selected after careful analysis and study of the following factors:

- (1) Flood potential
- (2) Noise potential
- (3) Odor potential
- (4) Direction of prevailing winds
- (5) Seasonal accessibility
- (6) Anticipated growth patterns in the vicinity of the proposed plant site
- (7) Possible elimination of sewage pump station upstream of the treatment works
- (8) Disposal of waste solids
- (9) Foundation conditions and topography

To avoid local objections, sewage treatment plants other than individual residential plants shall be located at the distances from contiguous property lines shown in Table VI - 1.

Table VI - 1

PLANT SIZE	Minimum Setback vs. Treatment Plant Size		
	Distance (Feet)		
10 ³ GPD	(1) No Controls	(2) Aesthetic, Noise & Odor Control or Signature	(3) Enclosure with Noise & Odor Con- trol or Signature
5 - 25	250	100	25
25 - 100	350	200	50
100 - 500	500	300	100
500 - 1	750	500	"
1 MGD	1000	750	"

*Will be reviewed on each individual project.

Column 1 requires the minimum setback with no controls.

Column 2 requires a minimum setback for a plant with aesthetic controls with the option of additional noise and odor control or the signatures of all property owners within the allowable setback.

Column 3 requires a minimum setback for a plant which is enclosed in a covered structure with the option of additional noise control and odor control or the signatures of all property owners within the allowable setback.

Noise control is defined as a sound level at the nearest existing property line not to exceed 50 db on the A network of a sound level meter. Aesthetic control is defined as landscaping in addition to chainlink fences or earthen berms.

In addition, the approval to operate will not be issued until an operation and maintenance manual is approved by the Department, and a certified plant operator has been employed to operate the facility.

The setback requirements listed above do not apply to lagoons or ponds. These types of treatment plants will be reviewed on an individual basis. It is recommended that wastewater treatment lagoon be located not closer than 1000 feet from the nearest property line.

C. EFFLUENT QUALITY.

Selection of the sewage treatment process shall be based upon the method of effluent disposal and the ability of the process to meet the effluent standards presented in Chapter II.

D. DESIGN.

1. Type of Treatment - The Engineer should give careful consideration of the type of treatment needed to achieve the goals outlined below before selecting the appropriate treatment process.
 - a. Discharge Standards - The quality of effluent achieved by a given process should be evaluated on the basis of consistency in meeting established effluent standards.
 - b. Operation Supervision - An optimization of manhours necessary to oversee plant operations and assure process balance and consistency in meeting effluent standards is an important part of process selection.

The type of supervision and operation each process must have to achieve the prescribed treatment level should be carefully analyzed. Each process should be evaluated based upon, but not limited to:

- 1) Operator educational level needed,
 - 2) Number of personnel required for proper operation,
 - 3) Sophistication of laboratory monitoring.
- c. Value Engineering - Value engineering is concerned with eliminating or modifying all items that contribute to the cost of a project but is not necessary for needed performance, quality, maintainability, reliability, or interchangeability. Specifically, value engineering should be a systematic creative effort directed toward an analysis of each item in the process to assure that it performs essential functions at the lowest over-all cost. The over-all cost should include, but not be limited to, costs of acquisition, construction, operation, repair, and replacement.

Value engineering should play a major role in equipment and treatment process selection.

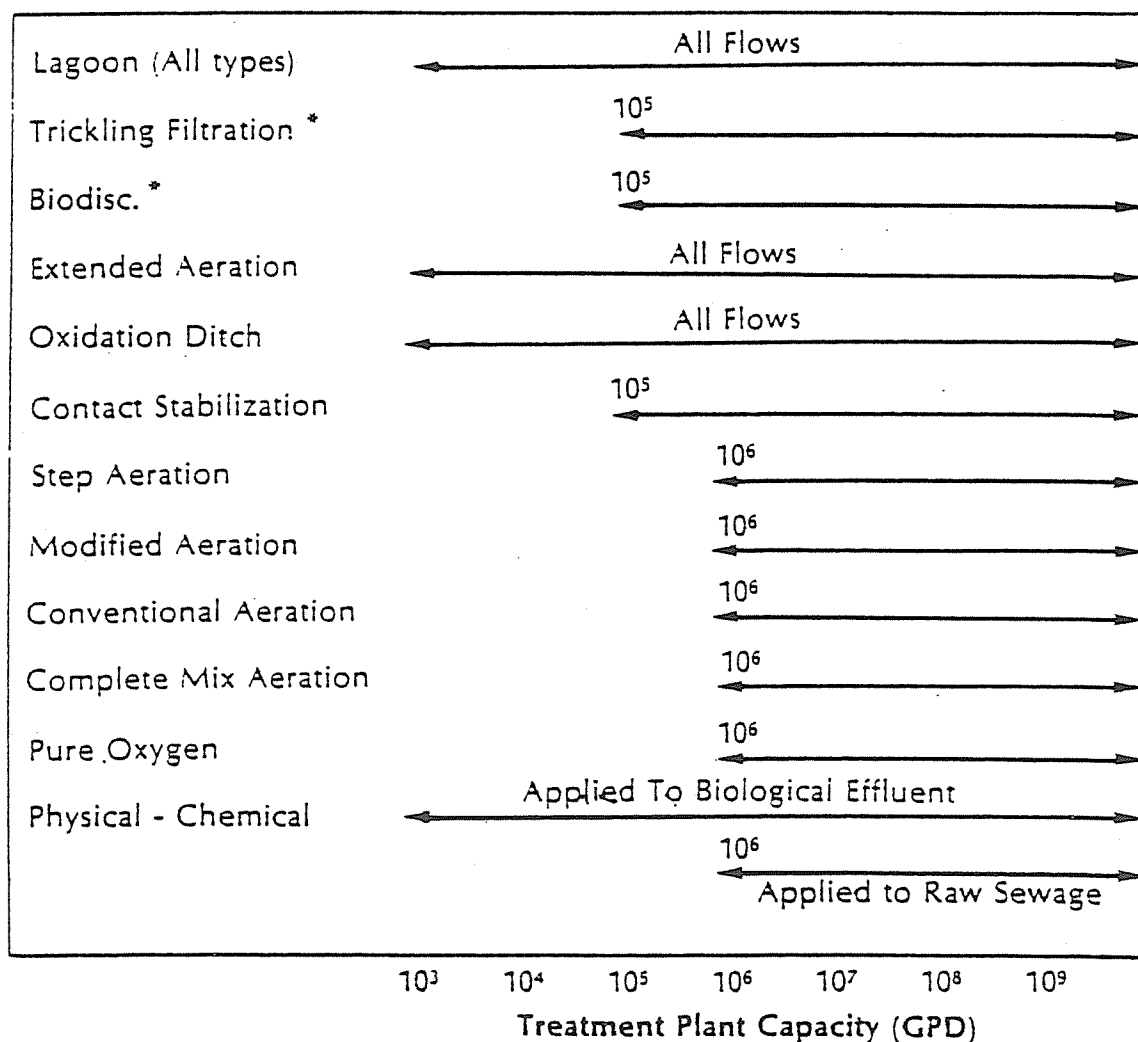


Figure VI-1
Flow Vs. Acceptible Process

* Designs at lesser flows may be considered upon consultation with the department

- d. Environmental Impact - Short- and long-term impacts of each process should be examined in terms of noise, odor, nutrient control, affects of effluent quality and/or construction on flora and fauna of the receiving reservoir, and interruption or interference of construction and/or operation on the ecosystem.

The level and degree of complexity of the environmental impact statement should be commensurate with the project scope. The latest Federal Register regarding Environmental Impact Statements should be used as a guideline.

- e. Operation and Maintenance - Consideration should be given to operation and maintenance requirements and costs. Equipment replacement and repair, chemical and electrical costs, administration costs, tools and special equipment, labor, and other pertinent items should be quantified and justified economically.
2. Industrial Waste Considerations - Industrial wastes discharged to treatment processes should be quantified as to treatability of the waste, the affect of unexpected discharges of each waste product on the process, and the affect of each type of industrial waste on the quality of the effluent.
 3. Flow vs. Treatment Process - Figure VI - 1 shows the types of processes which are considered acceptable in relation to the quantity of waste flow treated. These requirements are based upon treating domestic wastewater. Volume treated vs. process selection may be different than indicated in Figure IV - 1 for non-domestic wastewaters. The Department should be contacted to verify acceptability of process selection on non-domestic waste prior to final design.
 4. Design Loads.
 - a. Hydraulic - All units of sewage treatment works shall be designed using the hydraulic loading standards set forth in Chapter VII of this Bulletin. Careful attention shall be given to the affects of peak loads on all units.

Generally, the design of treatment units shall be based on the average rate of flow of domestic sewage per 24 hours, plus the average hourly rate of flow of industrial wastes during the maximum significant period.

Where recirculation is employed through a unit, the recirculated process stream shall be added to the flow rate.

- b. Organic - The treatment units which require sizing based upon organic characteristics shall be designed using the organic loading standards set forth in Chapter VII of this Bulletin.

Careful attention shall be given to changes in organic characteristics especially where industrial wastes are part of the waste flow.

Figure VI - 2 gives recommended values of hydraulic and organic flow characteristics from various domestic waste generating sources. Other types of wastes should be examined as to organic characteristics.

Type of Establishment
(unit basis)

Sewage Flow
(gallons per unit per day)

*Airport (passenger)	4
*Apartments, multiple family (resident)	100
1 bedroom assume 2 residents, 2 bedrooms assume 3 residents, etc.	
*Camp: Campground, overnight with flush toilets(camper)	25
Campground, overnight with flush toilets and shower (camper)	50
Construction (bed)	50
Day with no meals served (camper)	15
Luxury (camper)	100-150
Resorts, day and night, with limited plumbing (camper)	50
Tourist with central bath and toilet facilities (person)	35
*Clubs: Country (resident member)	100
Country (nonresident member)	25
*Cottages with seasonal occupancy (resident)	100
*Dwellings: Boarding of rooming houses (resident)	100
Additional kitchen requirements for nonresidents boarders	10
*Dwellings: Residential (resident)	100
*Factory (person)	25
*Highway Rest Area (contact State Hwy. Dept.)	
*Hospital (bed)	250-400
*Hotel (room)	125
*Institutions other than hospitals (person)	75-125
*Laundries, self service (machine)	400
*Mobile Home: Family (per resident)	100
Retirement (resident)	75
*Motel (room)	125
*Office (person)	25
*Picnic: With bathhouses, showers & flush toilets (picnicker)	20
With toilet facilities only (picnicker)	10
*Public Restrooms (toilet)	200
*Restaurant (seat)	30
per meal served	7
*Schools: Boarding (pupil)	100
Day with cafeteria, gymnasiums & showers (pupil)	25
Day with cafeteria, but no gymnasiums or showers (pupil)	20
Day without cafeteria, gymnasiums or showers (pupil)	15
*Service Station (bay)	1000
*Shopping Center (square foot)	1
*Swimming pool (swimmer)	10
*Theaters: Drive-In (car space)	5
Movie (seat)	5
*Trailer Park: (also see mobile home)	
Travel with no sewer connection (space)	125
Travel with sewer connection (space)	175

Organic Loading. Base All Organic Loadings on 200 mg/l BOD₅ and 210 mg/l SS.

Figure VI-2
Average Daily Sewage Flow

Variations from values shown in Figure VI - 2 will be allowed as basis for design provided substantiating data is presented giving justification for the proposed design criteria.

- c. Toxic Agent Limitations - Many constituents found in wastewater are toxic to biological organisms.

Figure VI - 3 gives the maximum allowable concentrations of chemical constituents which may be discharged to public sewers. They are based upon the limits which begin to inhibit normal biological activity of the treatment processes. These values shall be applied in the absence of more stringent applicable standards.

- 5. Arrangement of Plant Units - The Engineer should lay out the plant units in such a manner as to provide for operating convenience, flexibility, and economy. The plant configuration should allow for ease of plant expansion with minimum interruption of plant operation.

Two types of layouts should be considered.

- a. Unit Layout - The unit layout incorporates all functions into a single unit. It is often the most economical because of common walled construction; less piping and valves; and space is conserved.

The unit layout can be expanded without interference with existing structures. Disadvantages include: 1) a complete set of treatment units is required at each expansion; 2) repairs may require entire plant shut down.

- b. Functional Layout - The functional layout provides greater flexibility in operation and greater economy of construction on larger plants where each process can be sized on optimal number of units provided.

The functional design should be used where varying topography exists. It is also better suited to centralized services which is important for larger plants.

E. PLANT DETAILS.

- 1. Equipment Installation - It is recommended that the Engineer specify that the installation and initial operation of all major items of mechanical equipment be supervised by a representative of the selected manufacturer. The manufacturer's representative should be qualified to instruct the owner's operator in all phases of mechanical equipment operation.
- 2. By-Passes - By-passing of any sewage treatment works is prohibited. In larger facilities where duplicate process units are available, properly located and arranged by-pass structures shall be provided so that each unit of the plant can be removed from operation for maintenance purposes. In smaller plants where duplication of units is not possible, other suitable means of removing portions of the plant from service without discharging raw sewage in the effluent stream should be examined and proposed during design.

	ALLOWABLE DISCHARGE CONCENTRATIONS	CONCENTRATIONS INHIBITING UNIT PROCESS	
		Aerobic [mg/l]	Anaerobic
Sulphides	≤5	5	1000
Cyanide	≤1	1	-
Chromium (hexavalent)	≤1.5	1.5	100
Nickel	≤2	2	-
Zinc	≤2	2	10
Copper	≤1	1	-
Lead	≤1.5	1.5	-
Phenols	≤1	1	-
Gasoline	≤0	0	-
Fats, wax, grease, oils			
Biodegradable	≤100	100	-
Non-biodegradable	≤20		
pH	≥5.5 ≤9.0	≥5.5 ≥9.0	-
Temperature	150°F	150°F (65°C)	-

Figure VI-3

Toxic Chemicals vs. Concentration of Discharge To Public Sewers

3. Drains - Means should be provided to dewater each unit.

All floors which are subject to spills of waste, wastewater, or process chemicals should be properly drained to prevent accidents.

4. Construction Materials - Materials used in sewage treatment works should be carefully selected to resist corrosive gases, oils, and other chemical constituents frequently present in sewage. Paint systems and metallic coverings should be selected to resist these constituents and should be of sufficient thickness to prolong the service life of the equipment.
5. Pipe Identification - It is recommended that all exposed piping of larger facilities be color coded to facilitate identification. The color and marking scheme shall follow the recommendations of the American National Standards Institute, "Standard Scheme for Identification of Piping Systems."
6. Tools and Operating Equipment - The specifications and/or O & M manual should contain an outline of the necessary tools and operating equipment together with the appropriate accessories which will be required by the

operator to operate and maintain the treatment works effectively. Provisions should be made to store such tools and equipment on site. Additional storage and work space (including a laboratory) should be provided to test, service and repair equipment.

7. Grading - Final grading of the plant site should be arranged to prevent surface water from draining into any unit. Steep slopes should be avoided to prevent soil erosion.
8. Landscaping - Treatment works which are located close to residential areas should be landscaped. Concrete, asphalt, or gravel walkways should be provided to allow access to all units of the plant.

Irrigation of the plant site with plant effluent is encouraged consistent with the reuse regulations.

9. Fencing - All wastewater treatment plants, lagoons, and ponds treating and/or processing raw, partially treated, or disinfected secondary effluent shall be fenced. Ponds holding disinfected tertiary effluent are not required to be fenced. The fence shall be a minimum of six (6) feet in height and shall be of sufficient strength to exclude livestock and other animals. Material of construction shall be chain link, wood, block, or other suitable material. All gates shall be of the lockable type.

The fence should be located far enough from each unit to provide adequate access for maintenance.

In areas where freezing conditions occur, consideration should be given to enclosing process units in building enclosures.

10. Posting of Site - Each treatment works site shall be posted with signs on all sides indicating that a treatment works is located on that site and that trespassing on the premises is prohibited.
11. Flood Protection - The potential for damage or interruption of operation due to flooding shall be considered when locating treatment facilities. The structures and electrical and mechanical equipment shall be protected from physical damage by the maximum expected one hundred (100) year flood. The treatment works shall remain fully operational during a twenty-five (25) year flood, if practicable: lesser flood levels may be permitted dependent on local conditions, but in no case shall less than a ten (10) year flood be used.

Walls or berms of adequate size shall be constructed where necessary to provide protection.

12. Ground Water Table - Treatment works located in areas of high ground water shall be analyzed for buoyancy after each unit is dewatered. Units which will not withstand hydrostatic pressure shall be protected with hydrostatic relief valves in the floor of the structure.

F. ESSENTIAL FACILITIES.

1. Emergency Power - Unless it can be demonstrated to the Department that it is not required, all sewage treatment works shall have provision for standby power. A standby power source shall be provided at all sewage treatment works where a temporary power failure could allow a temporary discharge of raw or partially treated sewage which may be expected to endanger the public health, cause serious damage, or create a nuisance.

Standby power may be via a standby generator, two separate feeders from separate substations, or a loop feeder on separate transformers from a common substation.

2. Water Supply - Where water is supplied for the uses outlined in Figure VI - 4, the supply should be of sufficient pressure and quantity to assure good plant operation and maintenance.

The Engineer shall take care in design to eliminate cross-connections between potable water and wastewater (raw, partially-treated, or treated).

All non-potable water supply taps or outlets shall be painted red and shall be posted with a "Contaminated Water - Do Not Drink" sign.

3. Sanitary Facilities - Treatment works which require more than 20 man-hours per week operation and/or which are provided with a laboratory building should be provided with sanitary facilities as outlined in the Uniform Plumbing Code. At least one toilet, shower, and lavatory should be provided.
4. Laboratory Equipment and Housing - All treatment works shall include a structure for storing chemicals and analytical equipment. Consideration shall be given to providing a laboratory building. The Department may give special consideration to methods of storing chemicals and analytical equipment at an off site location for treatment plants in remote areas.

The laboratory should be equipped with the necessary items to perform the analytical testing outlined in Chapter VIII.
5. Sewage Flow Measurement - All treatment works shall be provided with flow measurement capabilities. All treatment works greater than 100,000 gpd shall be provided with the necessary equipment to indicate, record, and totalize the volume of wastewater being treated. Treatment plants under 100,000 gpd are not required to construct a totalizer-indicator recording device. However, it is recommended that they do install such a device. Acceptable flow measurement devices on plants under 100,000 gpd include weirs with flow indicators, pumping meters, Parshall flumes with indicators, or other such suitable devices.
6. Process Flow Measurement - Sewage treatment works that treat larger flows ($> 100,000$ gpd) should provide process control measurement at all strategic operational control points (i.e., return sludge, sludge waste, air volume, etc.).

Use	Potable	Disinfected Effluent
Laboratory Drinking Water	*	—
Janitorial Cleanup in Buildings	*	—
Yard Irrigation	*	*
Yard Cleanup and Washdown	*	*

* Allowed with backflow prevention device

—Not allowed

Figure VI-4
Allowable Water Supply Usage

G. OPERATION AND MAINTENANCE MANUALS.

All sewage treatment works shall be required to possess an operation and maintenance manual, written for that particular plant, in a readily accessible location at the sewage treatment plant site.

The operation and maintenance manual shall be reviewed and approved by the Department prior to issuance of a certificate to operate and shall be prepared in accordance with the requirements of Chapter XI.

H. OPERATOR CERTIFICATION.

All treatment works constructed in the State of Arizona shall employ a certified operator to operate or oversee the operation of the facility.

The Department's Rules and Regulations R9-20, Art. 5 sets forth the requirements of operator certification and classification of sewage treatment works.

I. SAFETY FEATURES.

Special emphasis should be given to safety and safety devices in the design of all treatment works.

Adequate provision should be made to protect the operator, laborers, and plant visitors from unnecessary hazards. Chapter X of this engineering Bulletin outlines safety features and devices which should be used to assure maximum safety at the plant site.

J. PLAN DETAILS.

Plans of sewage treatment works which are submitted for the Department's review and approval should be of sufficient detail and scale as to clearly identify the proposed construction.

Each set of plans shall include the following as a minimum:

1. Cover sheet - The cover sheet shall identify the project location and drawing index.
2. Site plan
3. Grading plan
4. Piping plan with flow diagram
5. Hydraulic profile
6. Plant details

The engineering drawings shall be reproduced on paper not greater than 24" x 36".

Sufficient data regarding invert and grade elevations shall be shown on all cross-sections.

engineering bulletin no. 11

Chapter 7

**UNIT PROCESSES
FOR TREATMENT
OF
DOMESTIC WASTES**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

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CHAPTER VII - UNIT PROCESSES FOR TREATMENT OF DOMESTIC WASTES

A. PRETREATMENT.

In some instances, pretreatment of incoming wastes may be required to reduce operation and maintenance difficulties. Abnormal quantities of grease, septic wastes, and flow surges may dictate that one or a combination of the following methods of pretreatment be employed in design.

1. Skimming Tanks.

- a. Use Requirements - Skimming tanks should be employed where abnormal amounts of oil, grease, or other floating debris is anticipated.
- b. Location - Skimming tanks may be a separate unit preceding grit removal; combined with grit removal; or combined with primary clarification.

c. Basin Design.

- 1) Non-Aerated - The skimming tank shall be sized to provide a 15-minute retention time. The basin effluent discharge shall be of sufficient depth to assure floating matter retention.

A positive means of continuous scum removal shall be employed in design.

The basin shall be designed to assure solids removal from the tank floor by scour or mechanical means.

Skimming tanks shall be designed so that it may be removed from service without interrupting the waste flow.

- 2) Aerated - The formation of an easily removable greasy scum can be achieved by passing the greasy sewage through a diffused air aeration tank.

The surface area of the tank may be designed using the following equation:

$$A = \frac{1,110 Q}{V_r}$$

where,

A = surface area of tank (sf)
Q = rate of flow of sewage (MGD)
 V_r = minimum rising velocity (inches per minute)

In practice, V_r is in the order of 10 (verify by laboratory testing).

Retention time will vary from 3 minutes to 15 minutes, depending upon the waste characteristics.

Air requirements vary from .03 to .10 cubic feet of air per gallon of sewage.

The length to depth ratio of the tanks should be 1.5 - 2 to 1.

Means of continuous scum removal shall be provided.

The inlet and outlet shall be placed below the scum surface to prevent entrance and exit problems.

Skimming tanks shall be designed so that it may be removed from service without interrupting the waste flow.

2. Grease Traps.

- a. Use Requirements - Grease traps are used to remove oils and greases from individual sources prior to discharge of waste to the sewer.
- b. Location - Grease traps shall be located close to the source of grease (such as, cafeterias, restaurants, schools, hospitals, manufacturing plants, garages, etc.), exterior to the facility housing.
- c. Basin Design - The basin shall be sized to provide a minimum of 30 minutes retention. The chamber velocity shall be greater than one foot per minute and not more than two feet per minute.

The tank shall be designed with a primary and secondary chamber. The outlet shall be located below the liquid surface or a scum baffle shall be provided to assure retention of floating matter.

The tank shall be designed to provide easy access for cleaning and maintenance of both chambers and shall be vented.

3. Preaeration.

- a. Use Requirements - The objectives of preaeration are: to improve treatability; to aid grease separation, odor control, grit removal and flocculation; to enhance uniform distribution of floating and suspended solids to treatment units; and to increase BOD removals.
- b. Location - Preaeration is employed preceding primary sedimentation. Aerated grit chambers may be modified to act as preaeration basins. Preaeration can be performed in aerated channels which distribute sewage to primary clarifiers.
- c. Basin Design - Retention times for preaeration range from 10 to 45 minutes. Tank depths are normally 15 feet, and air requirements range from 0.1 to 0.4 cubic feet per gallon of sewage.

The use of air in primary clarifier distribution channels ranges from 0.1 to 0.4 cubic feet per gallon of sewage.

The preaeration chamber shall be designed so that it may be removed from service without interrupting the waste flow. Each basin shall be designed with a means of draining for servicing.

4. Flocculation.

- a. Use Requirements - Flocculation of sewage by air or mechanical agitation should be considered when an increase in removal of suspended solids and BOD in the primary sedimentation tank is desirable. Flocculation may be beneficial in conditioning sewage containing certain industrial wastes.
- b. Location - Flocculation is employed preceding primary sedimentation. Preaeration and flocculation may be incorporated in the same unit.
- c. Basin Design.
 - 1) Retention Time.
 - a) Coagulation - When air or mechanical agitation with chemical addition is used to coagulate and flocculate sewage, the retention time in the basin should be 30 minutes at design flow.
 - b) BOD Reduction - When air or mechanical agitation, with or without chemical addition, is used for increasing BOD reduction in primary sedimentation, the retention time should be a minimum of 45 minutes at design flow.
 - 2) Agitation Devices.
 - a) Paddles - Paddles should have a peripheral speed of about 1.5 feet per second with variable-speed drives permitting an adjustment between 0.75 and 2.25 feet per second.
 - b) Air - The quantity of air required for air agitation ranges from 0.08 to 0.15 cubic feet per gallon for a 45-minute retention time.
 - 3) Flash Mixer - Plants utilizing chemical addition shall be equipped with flash mixers to mix the chemical with the waste stream. The retention time required in the flash-mix channel shall range from 0.5 to 3 minutes.
 - 4) General Features - Inlet and outlet devices shall be designed to insure proper distribution and to prevent short circuiting.

Each basin shall be equipped with a means of draining for servicing.

Each unit shall be designed so that it may be removed from service without affecting any settling unit.

5. Chemical Oxidation - Pretreatment using prechlorination, preozonation, hydrogen peroxide, or other liquid or gaseous oxidants shall be designed in accordance with Section O of this Chapter.

6. Raw Sewage Holding Reservoirs.

a. Equalization Basins.

- 1) Use Requirements - The primary objective of flow equalization basins for sewage treatment works is to dampen the diurnal flow variation, and thus achieve a constant or nearly constant flow rate through the downstream processes. A secondary objective is to dampen the concentration and mass flow of wastewater constituents by blending in the equalization basin.

A flow equalization basin should be considered where variations greater than 3:1 in maximum to minimum flows exist, or where a sewage pumping station will cause undesirable hydraulic loading on process units.

- 2) Location - Equalization basins should be located downstream of bar screens and grit removal units but upstream of sedimentation basins.
- 3) Design Requirements - The design of an equalization basin requires evaluation and selection of a number of features including:
 - a) In-line versus side-line basins
 - b) Basin volume
 - c) Degree of compartmentalization
 - d) Type of construction
 - e) Aeration and mixing equipment
 - f) Pumping and control concept

- 4) Basin Volume - Two methods are available for computing equalization volume requirements.

- a) Diurnal Flow Pattern - In this case, the function of the basin is to store flows in excess of the average daily flow and to discharge them at times when the flow is less than average.

The required volume can be determined graphically through construction of a hydrograph.

- b) Mass Loading Pattern - This method computes the volume required to dampen mass loading variations of a particular constituent to within a preset, acceptable range.

EPA's, "Process Manual for Upgrading Existing Wastewater Treatment Plants," and "Flow Equalization," should be consulted for a more indepth approach to the volume determination.

- 5) Basin Construction - In-line basins shall be designed to achieve complete mixing. Elongated tank basins will not be allowed. The inlet and outlet configurations shall be designed to prevent short

circuiting. The design shall allow for influent flow to discharge as close as possible to the basin mixers. The basin shall have beveled corners.

A high-water-level takeoff shall be provided for withdrawing floating material and foam. The basin shall be provided with an emergency overflow to the subsequent downstream unit process.

- 6) Air and Mixing Requirements - Mixing equipment shall be designed to blend the contents of the tank, and to prevent deposition of solids in the basin.

Mixing requirements for blending a waste having a suspended solids concentration of approximately 200 mg/l range from 0.02 to 0.04 hp per 1000 gallons of storage (mechanical aerators).

To maintain aerobic conditions, air should be supplied at a rate of 1.25 to 2 cubic feet per minute per 1000 gallons of storage.

Baffling may be required to insure proper mixing.

The aeration equipment shall be provided with low-level shut-off controls.

- 7) Pumps and Controls - Pumps used in metering the waste shall be of the non-clog type, and shall be either submersible, wet well mounted, dry pit type, or air lift.

A minimum of two pumps shall be provided (one provided as a standby). The pumps shall be provided with a low level shut off and a low level and high level alarm.

A flow measuring device should be installed downstream of the basin to monitor the equalized flow.

On larger facilities instrumentation should be provided to control the preselected equalization rate by automatic adjustment of the basin effluent pumps or flow regulating device.

b. Dump Stations.

1) Recreational Vehicles.

- a) Use Requirements - Holding reservoirs shall be required where a sewer does not exist and where tank pumping is readily available; or where metering of waste to a sewer or factory fabricated treatment plant is necessary.

- b) Location - Holding reservoirs shall be located where they are not subject to flooding and where they will not cause nuisance or odor problems.

c) Holding Basin Design.

- (1) Non-metering Type - Non-metering type holding basins shall be sized based upon the anticipated number of vehicles dumping per day, the quantity per each dump, and the desired frequency of pumping the holding reservoir.

The reservoir shall be covered and vented and provided with access manholes.

- (2) Metering Reservoirs - Holding reservoirs which are used for metering shall be sized based upon the rate at which the waste may be fed into the sewer or waste treatment facility and the time distribution of the incoming waste. The Engineer shall give careful consideration to the type of waste being metered and the effect of the metering on the waste treatment facility receiving the metered waste.

WASTE CHARACTERISTICS

TYPE OF WASTE	BOD mg/1	COD mg/1	TSS mg/1	pH	GREASE mg/1
Septage	5000 (440 - 79000)	45000 (15000 - 706000)	(15000 (310 - 93000)	6 - 9 (1.5 - 12.6)	9600 (604 - 23000)
Vault Waste	35,000 - 40,000	-	70,000 - 80,000	6 - 9	-
*Chemical Toilet Waste	20,000 - 30,000	-	40,000 - 70,000	3 - 6	-
Low Volume Flush Toilets	7000	-	15000 - 20000	6 - 9	-

*Formaldehyde or zinc sulfate range from 900 mg/1 to 1200 mg/1.

In the slug dumping mode, waste treatment plants shall not be allowed to accept the above wastes if their design capacity is less than 100,000 gpd. On a metered basis extended aeration plants can be expected to treat these wastes at approximately 0.1 per cent of the plant design capacity. Conventional activated sludge plants are able to treat these wastes at about 0.4 per cent of the plant design capacity. In all cases, the Engineer shall investigate the effects of metering these wastes into the waste treatment facility under design or modification.

If aeration of the metering station is required, sufficient air shall be provided to keep the solids in suspension and to prevent septicity.

Where dilution of the metered waste is required, a back flow prevention device shall be placed in the potable dilution water line at the metering station site.

The basin shall be covered and vented, and shall be provided with a dual pumping system with controls for high and low level shut-off and alarm system.

The reservoir shall be provided with adequate access manholes.

- d) Dump Station Design - The dump station shall be designed to avoid or minimize waste spills, and splashing. The station shall be provided with a four (4) inch diameter drain (minimum) and shall be provided with a washdown device with an approved backflow preventer. A six (6) inch diameter drain is preferable.
- 2) Marine Vehicles - The principles of design of holding reservoirs for marine vehicles should follow that of recreational vehicles. However, marine vehicle installation shall be given extra care in design to prevent potential leakage or spill of waste products into the adjacent lake or stream.

Holding reservoirs attached to boat docks shall be protected from marine vehicle collision and shall be easily accessible.

B. SCREENING DEVICES.

Screening devices in sewage treatment works are used to remove material which will damage equipment, interfere with satisfactory operation of a process or equipment, or cause other objectionable conditions in the plant or effluent disposal system.

1. Manually Cleaned Bar Screens.

- a. Use Requirements - Manually cleaned bar screens may be used where protection of pumps and other equipment is required. Manually cleaned screens should be used only in a small plant where mechanical screens cannot be justified and in unit process bypasses.
- b. Location - All manually cleaned bar screen equipment shall be located where it is readily accessible for maintenance. Bar screens should be located upstream of pumping equipment, wet wells, and grit chambers.
 - 1) In Deep Pits - Manually cleaned bar screens installed in a deep pit shall be provided with stairway access, adequate lighting, and a convenient and adequate means of removing screenings. The deep pit shall be ventilated with a blower of sufficient capacity to provide a 2-minute air change based upon the chamber volume below grade and above the sewage level.

- 2) In Buildings - Manually cleaned bar screens installed in a building where other equipment or offices are located shall be separated from the rest of the building, provided with a separate outside entrance, provided with adequate lighting, and provided with an adequate means of removing screenings. The building shall be ventilated with a blower of sufficient capacity to provide a 2-minute air change based upon the building volume.
- c. Bar Size and Spacing - Bar sizes for manually cleaned bar racks should be between 1/4 - 5/8 inches wide and 1 - 3 inches deep. Bars should be spaced a minimum of 1 inch and a maximum of 3 inches center to center. The engineer should consider using an effluent spray nozzle directed at the bar screen for self cleaning.
- d. Slope - Manually cleaned bar screens should be placed on a slope of 30 to 60 degrees with the horizontal.
- e. Approach Velocity - Manually cleaned bar screens should be designed to provide a velocity through the screen of 1 foot per second at average rate of flow. Velocities as high as 2 to 4 feet per second will be permitted.

The effective velocity shall be determined by considering a vertical projection of the screen openings from the channel invert to the flow line of the wastewater at design flow.

- f. Area.
 - 1) Total - The total cross-sectional area of the manually cleaned bar screen shall be a minimum of 200 per cent of inlet sewer cross-sectional area.
 - 2) Net Submerged Area - The net submerged area is generally 2 ft²/mgd.
- g. Allowable Head Loss - The minimum allowable head loss through a manually cleaned bar screen shall be six (6) inches. The maximum head loss with clogged screen should not exceed 2.5 ft.

Three equations are available for estimating head drops across bar screens

$$h = \frac{1}{0.7} \frac{V^2 - V_1^2}{2g} \quad (1)$$

$$h = 0.5 \frac{V^2}{2g} + \frac{V^2 - V_1^2}{2g} \quad (2)$$

$$h = \left(\frac{w}{b}\right)^{4/3} \frac{V_1^2}{2g} \quad (3)$$

where,

h = head drop across the screen, ft.

V = velocity through the clear space of the screen, fps

V₁ = upstream velocity, fps

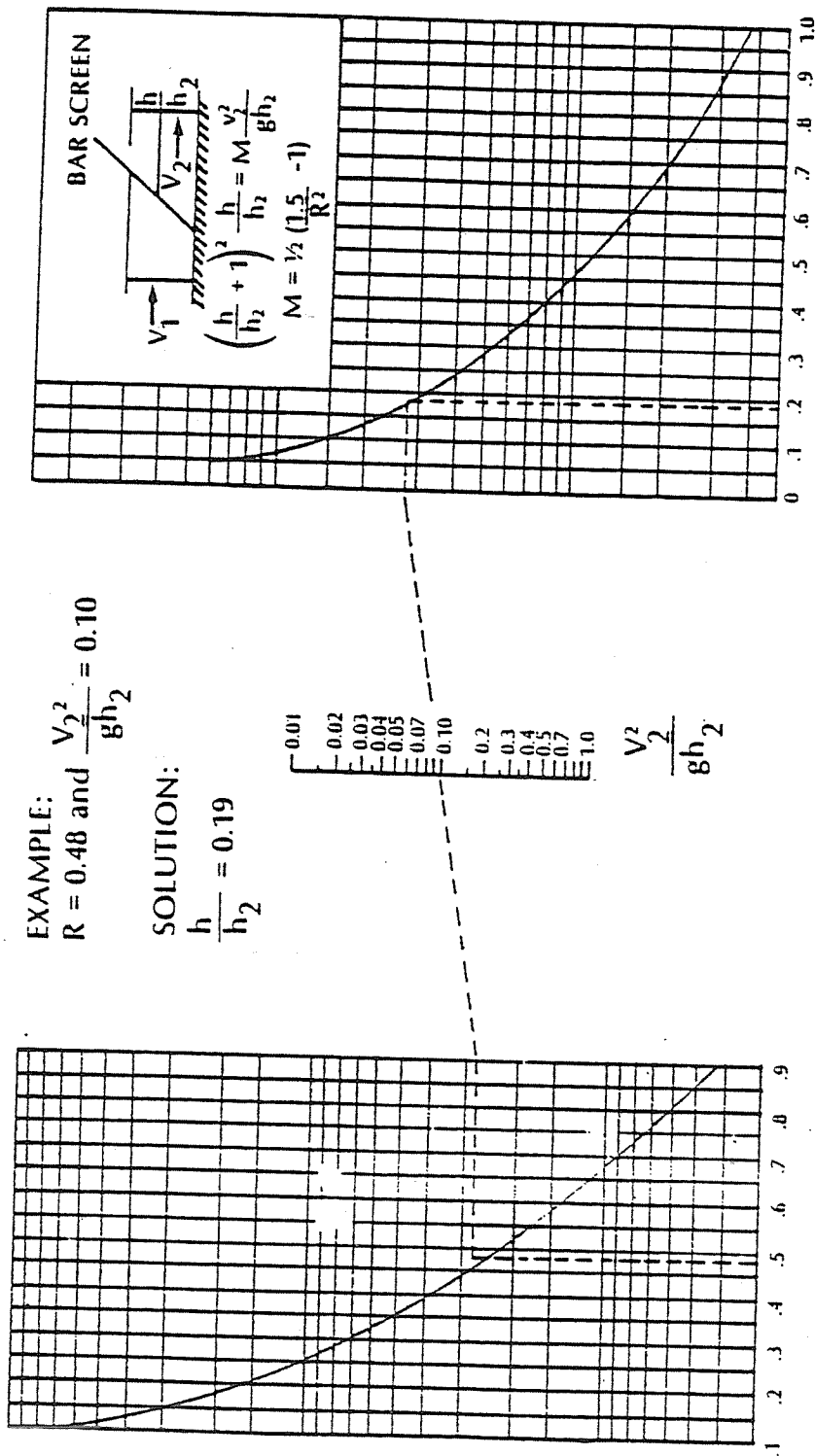


Figure VII-1
 Nomograph for Calculating Head Drops Across Bar Screens

Bar Shape	β
Sharp-edged rectangular bar	2.42
Rectangular bar with semi-circular upstream face	1.83
Circular bars	1.79
Rectangular bars with semi-circular upstream and downstream	1.67
Tapering "tear-drop"	0.76

Table VII-1

Shape vs β

g = gravitational constant, 32.2 fpsps
 w = maximum width of bars facing the flow, inch
 b = minimum width of the opening, inch
 β = a shape factor (Table VII - 1)

Equation (2) is the best practical engineering application. Yao has developed a nomograph (Figure VII - 1) for estimating head drop based upon the bar screen opening, total bar screen area, and the downstream depth (based upon requirements and principles of open channel hydraulics).

- h. Channel Construction - A straight approach channel upstream of the screen shall be required to insure good velocity distribution across the screen.

The channel preceding and following the screen shall be filleted to prevent stranding and sedimentation of solids.

A minimum freeboard of 1 foot shall be provided above the upstream flowline during clogging conditions.

- i. Quantity of Screenings - The total amount of screenings to be removed in a period of time, although difficult to estimate, is an important design consideration.

Figure VII - 2 shows approximate volumes of screenings that can be used for estimating methods of screenings disposal. These values should be varified at similar plants prior to final design.

Screenings vary in moisture content from 80 - 90 per cent by weight. Screenings density varies from 40 - 60 lb/ft³.

j. Handling of Screenings.

- 1) Platform - Manually cleaned screening facilities shall include an amply-sized, accessible platform from which the operator may rake screenings easily and safely.
- 2) Drainage - Suitable drainage facilities shall be provided for the platform and screening storage area.
- 3) Storage - Temporary storage facilities shall be provided at all manually cleaned bar screens. The containers shall be sized to hold one day's screenings and shall be supplied with a tight fitting lid.
- 4) Disposal - An incinerator or a burial area for screenings shall be provided to assure satisfactory, safe disposal of all screenings. Transporting to a sanitary landfill is considered an acceptable means of disposal provided the screenings are transported in a leakproof container.

2. Mechanically Cleaned Bar Screens.

- a. Use Requirements - Mechanically cleaned bar screens are preferred over manually cleaned bar screens. They may be used where protection of pumps and other equipment is required.
- b. Location - All mechanically cleaned bar screen equipment shall be located where it is readily accessible for maintenance. Bar screens should be located upstream of pumping equipment, wet wells, and grit chambers.
 - 1) In Deep Pits - Mechanically cleaned bar screens installed in a deep pit shall be provided with stairway access, adequate lighting, and a convenient and adequate means of removing screenings. The deep pit shall be ventilated with a blower of sufficient capacity to provide a 2-minute air change based upon the chamber volume below grade and above the sewage level.
 - 2) In Buildings - Manually cleaned bar screens installed in a building where other equipment or offices are located shall be separated from the rest of the building, provided with a separate outside entrance, provided with adequate lighting, and provided with an adequate means of removing screenings. The building shall be ventilated with a blower of sufficient capacity to provide a 2-minute air change based upon the building volume.
- c. Bar Size and Spacing - Bar sizes for mechanically cleaned bar screens should be between $1/4$ - $5/8$ inches wide and 1 - 3 inches deep. Bars should be spaced a minimum of $5/8$ inches clear opening.
- d. Slope - Mechanically cleaned bar screens should be placed on a slope of 60 to 90 degrees with the horizontal.

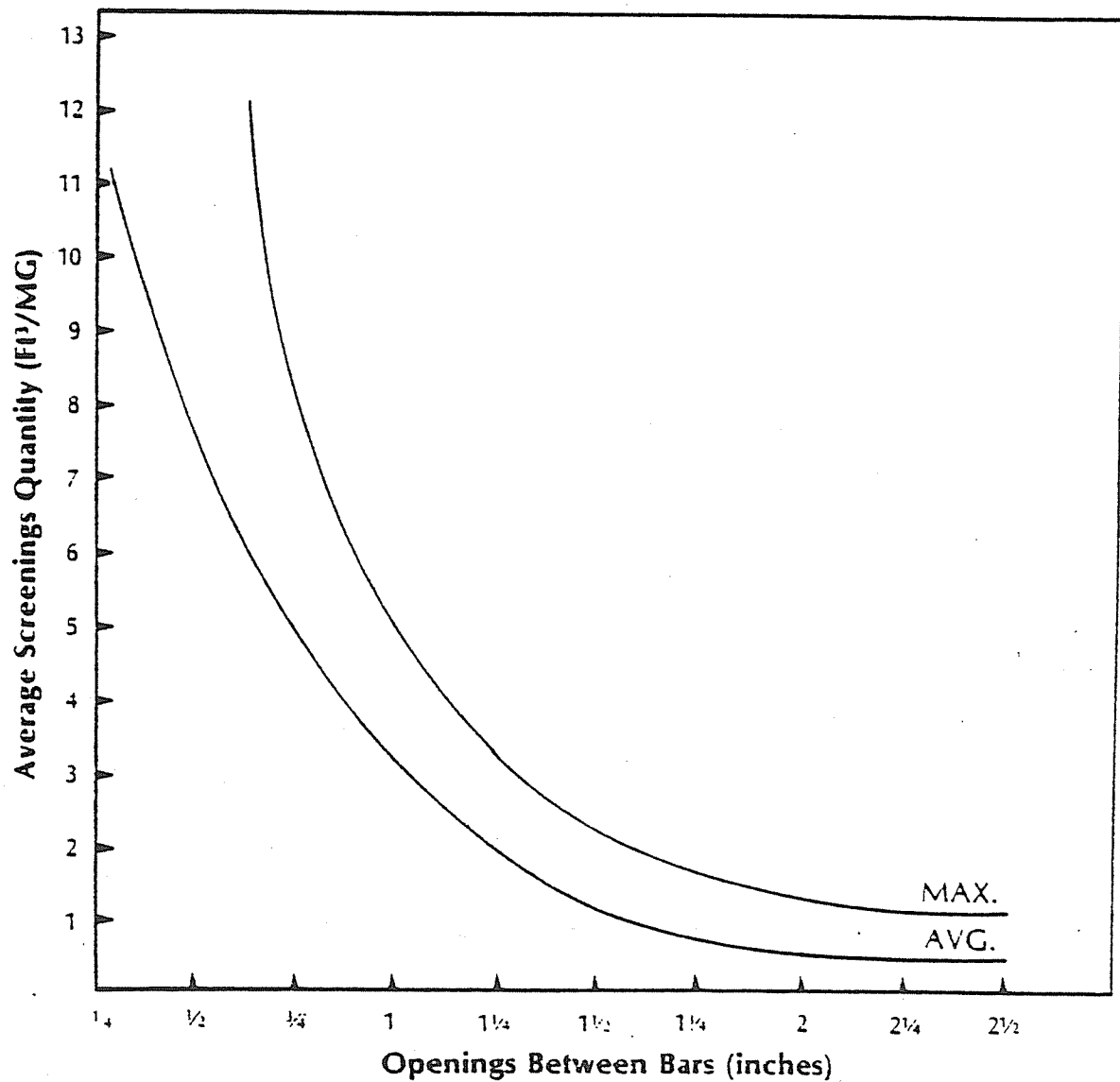


Figure VII-2
Mechanically Cleaned Bar Screen: Cubic Feet of
Screenings Per Million Gallons of Sewage

- e. Approach Velocity - Mechanically cleaned bar screens should be designed to provide a velocity through the screen of 1.5 feet per second at average flow rate. Maximum velocities during wet weather periods should not exceed 2.5 feet per second.

The effective velocity shall be determined by considering a vertical projection of the screen openings from the channel invert to the flow line of the wastewater at design flow.

- f. Area.

- 1) Total - The total cross-sectional area of the mechanically cleaned bar screen shall be a minimum of 200 per cent of the inlet sewer cross-sectional area.
- 2) Net Submerged Area - The net submerged area is generally $2 \text{ ft}^2/\text{mgd}$.

- g. Allowable Head Loss - The minimum allowable head loss of the mechanically cleaned bar screen shall be six (6) inches.

Figure VII - 1 can be used to estimate the head-drop requirement of mechanically cleaned bar screens.

- h. Channel Construction - A straight approach channel upstream of the screen shall be required to insure good velocity distribution across the screen.

Where mechanically cleaned bar screens are employed, a manually cleaned screen shall be installed in a bypass channel to provide standby service while servicing the mechanical device.

The channel preceding and following the screen shall be filleted to prevent stranding and sedimentation of solids.

A minimum freeboard of 1 foot shall be provided above the upstream flowline during clogging conditions.

- i. Quantity of Screenings - Figure VII - 2 shows anticipated average and maximum cubic feet of screenings removed by a mechanically cleaned bar screen per million gallons of sewage.

- j. Handling of Screenings.

- 1) Platform - Mechanically cleaned screening facilities shall include an amply sized, access platform from which the operator may maintain and operate the screen easily and safely.
- 2) Drainage - Suitable drainage facilities shall be provided for the platform and the screenings storage area.

- 3) Storage - Temporary storage facilities shall be provided at the screening area. The storage container should be arranged so that the screenings empty by gravity into the container. The container shall be sized to hold one day's screenings. Screening areas where ultimate disposal is via incineration shall be equipped with suitable transport facilities (conveyor, bucket elevator, etc.) to provide minimum housekeeping.
 - 4) Disposal - An incinerator or a burial area for screenings shall be provided to assure satisfactory, safe disposal of all screenings. Transporting to a sanitary landfill is considered an acceptable means of disposal provided the screenings are transported in a leakproof container.
 - k. Safety Devices, Auxiliary Controls and Alarms - All mechanical units should be operated on a "hand-off-automatic" control using a time clock. Auxiliary controls shall include a float control which will initiate the operation of the cleaning mechanism at a predetermined high water elevation. This function shall be independent of the normal operating cycle.
3. Comminutors/Barminutors.

- a. Use Requirements - Comminutors and barminutors may be used in lieu of manually or mechanically cleaned bar screens. They may be installed in the wet well of a pumping station to protect the pumps from rags and large objects.
- b. Location - Comminutors are generally placed, when used, between grit chambers and primary clarifiers. A smaller installation, where a low quantity of grit is anticipated, will not require grit removal, so the comminutor may be used as a pretreatment device prior to aeration.

Consideration should be given to using comminutors in lieu of other devices where the removal of screenings would be difficult (very deep pits).

- c. Channel Construction - The design of approach channels shall provide gates or similar devices to stop or divert flow from any one comminutor or barminutor without interrupting the flow to other units.

In smaller installations a bypass channel shall be provided with a manually cleaned bar screen so that the comminutor or barminutor may be serviced without interrupting flow.

- d. Allowable Head Loss - Manufacturers' data should be consulted to determine head-drops through comminutors or barminutors. A free-board of 1 foot at peak design flow shall be provided for the channel depth.
- e. Auxiliary Controls - Comminutors and barminutors should be provided with reversing switches to maximize operating cycles and comminutor downtime.

4. Fine Screens.

- a. Use Requirements - Fine screens may be of the fixed or rotating sieve type. These devices may be used in lieu of 1) bar screens, comminutors, or barminutors; 2) bar screens and grit chambers, comminutors and grit chambers, or barminutors and grit chambers; or 3) bar screens, grit chambers, and primary clarifiers, or comminutors, grit chambers, and primary clarifiers, or barminutors, grit chamber, and primary clarifier.
- b. Location - The fine screens may be located at the head of the process scheme, after the grit chamber, or preceding aeration.
- c. Size Openings - Fixed sieve screens are available in various wiring spaces from 0.005" to 0.100".

Rotating sieve screens are available in various wiring spaces from 0.010" to 0.100".

- d. Head Loss Requirements - Manufacturers' data should be consulted for head-drop requirements, and inlet and effluent flow requirements.
- e. Construction Details - Since fine screening devices are generally top fed, coarse bar screens should be used preceding the units to remove large objects which might damage or clog the system.

Effluent channels shall be designed to maintain one foot per second velocity to the following treatment unit.

Rotating and fixed sieves shall be installed with a minimum of two (2) units. Means shall be provided for diverting flow to each unit in such a manner that any unit may be serviced without interrupting flow.

- f. Screenings Disposal - An incinerator, or a burial area for screenings, shall be provided to assure satisfactory safe disposal of all screenings. Transporting to a sanitary landfill is considered an acceptable means of disposal provided the screenings are transported in a leakproof container.

C. GRIT CHAMBER.

Grit chambers are installed to remove grit, consisting of sand, gravel, cinders, or other heavy solid materials that have specific gravities substantially greater than those of the organic solids in wastewater. They are used to provide protection of moving mechanical equipment from abrasion and abnormal wear; to reduce formation of heavy deposits in pipelines, channels, and conduits; and to reduce the frequency of digester cleaning through reduction of excessive accumulation of grit in such units.

1. Horizontal Flow Grit Chamber.

- a. Use Requirements - Horizontal grit chambers should be considered at any sewage treatment works where grit is known to be present or where grit may be anticipated. Consideration should be given to grit quantities which may enter from street wash at the manholes, from garage floors or washing racks, and through joints with infiltration. Smaller sewage treatment works may not need grit removal.
- b. Location - Grit chambers should be located ahead of all other units in a sewage treatment works where removal of grit would facilitate operation.

Horizontal grit chambers should be constructed preceding pumps and comminutors or barminutors. Mechanically cleaned grit chambers should, in this case, be protected by coarse bar racks.

- c. Number of Units - Grit chambers shall have duplicate manually cleaned units or a single mechanically cleaned unit with a bypass.
- d. Velocity Requirements - The velocity flowing through a grit chamber shall be not less than 0.8 fps nor more than 1.3 fps and as close to 1.0 fps as is practical.
- e. Velocity Control - Velocity shall be controlled by design of a suitable control structure such as a proportional weir, suture weir, or Parshall flume.

The control structure shall be designed to minimize deposition of organic matter. The Velocity control shall be based upon retaining a 0.2 mm diameter particle of assumed specific gravity of 2.65. Consideration will be given to other specified diameter providing justification is given for the different design criteria.

- f. Retention Time - The retention time should be based upon peak flow and should be between 30 seconds and 1 minute.
- g. Channel Construction - The grit chamber structure shall be designed to provide minimum inlet turbulence. The channel shall provide a straight approach to insure good velocity distribution across the channels.

The floor of each channel shall slope to the point of grit removal.

Each channel shall be provided with a drain.

h. Quantity of Grit - The quantity of grit depends upon:

- 1) extent of building,
- 2) extent of garbage disposal use,
- 3) extent of paved streets,
- 4) infiltration potential,
- 5) extent of industrial discharges.

The quantity of grit varies from .5 - 10 ft³/MG where infiltration exists and between .3 - 5 ft³/MG where the infiltration potential is minimal.

i. Grit Removal - Horizontal manually cleaned grit chambers should be constructed as shallow as possible to facilitate grit removal.

Where deep pit grit chambers are required, manually cleaned units shall be equipped with hoisting lifts to transport grit to ground level. The deep pit facility shall be provided with an access and adequate lighting. Ventilation shall be provided with a blower of sufficient capacity to provide a 2-minute air change based upon the chamber volume below grade and above the sewage level.

j. Grit Washing - It is recommended that installation of grit washing equipment be considered prior to grit disposal.

k. Grit Disposal - Acceptable alternatives for disposing of grit include on-site burial or transporting to landfill.

2. Aerated Grit Chamber.

a. Use Requirements - Aerated grit chambers offer the following advantages over conventional grit chambers:

- 1) The sewage may be freshened by the air.
- 2) Low hydraulic head loss is required in the design.
- 3) The controllable air-induced water velocity enhances the removal of grit having a low organic content.
- 4) Grit larger than a desired size can be preferentially removed, assuming a constant specific gravity for all the grit involved.
- 5) The grit removal efficiency can be maintained over a larger flow range.

Aerated grit chambers may be used in lieu of manually cleaned or mechanically cleaned grit chambers. In addition, the aerated grit chamber may be incorporated with preaeration units to provide grit removal and sewage freshening.

- b. Location - Grit chambers should be located ahead of all other units in a sewage treatment works where removal of grit will facilitate operation.

Aerated grit chambers shall be preceded by coarse bar screens.

- c. Number of Units - Aerated grit chambers shall be designed so that one (1) chamber can be removed from operation for servicing without disturbing the plant flow.
- d. Velocity Requirements - The Cross-sectional area of the chamber shall be such that the nominal flow through velocity is no greater than 0.5 fps.
- e. Air Requirements - The amount of air fed to the chamber will be a function of the maximum particle size allowed to flow through the grit chamber and its settling characteristics.

General practice varies from 3 - 8 scfm/ft of chamber length. Means of adjusting the quantity of air flow shall be provided for operational flexibility.

- f. Retention Time - The aerated grit chamber shall be designed so that the retention time does not exceed 3 minutes at maximum rate of flow.
- g. Quantity of Grit - The quantity of grit removed by an aerated grit chamber generally varies from 1 to 12 cu ft/MG. The average quantity is 4 cu ft/MG.
- h. Channel Construction - Aerated grit chambers should be designed using the following criteria:

Width to depth ratio - 1:1
Length to width - 2:1 to 4:1

The chamber shall be designed with a grit hopper (approximately 3 feet deep) of near vertical sides located under the air diffusers.

Air diffusers should be located 18 - 24 inches above the normal plane of the chamber bottom.

The entrance channel should be designed to introduce flow in the direction of the roll.

The chamber bottom shall be constructed so that it slopes in the direction of the grit hopper and with the velocity vector of the liquid medium at the tank bottom.

- i. Grit Removal - Grit removal may be provided by grab buckets, screw conveyors, jet pumps, chain and bucket conveyors or air lifts.
 - j. Grit Washing - Provisions should be made for washing the grit prior to ultimate grit disposal.
 - k. Grit Disposal - Acceptable alternatives for disposing of grit include on-site burial and transporting to landfill.
3. Mechanical.
- a. Use Requirements - Mechanical grit chambers may be used in lieu of manually cleaned or aerated grit chambers.
 - b. Location - Mechanical grit chambers should be located ahead of all other units in a sewage treatment works where removal of grit would facilitate operation.
 - c. Number of Units - One mechanically cleaned grit chamber is required. The unit shall be designed with a bypass to facilitate maintenance without interrupting plant flow.
 - d. Velocity Requirements - Mechanically cleaned grit chambers should be designed for approximately 1 fps velocity at maximum flow.
 - e. Retention Time - The retention time of the mechanically cleaned grit chamber ranges from 30 seconds to 1 minute.
 - f. Quantity of grit - The quantity of grit removed by a mechanically cleaned grit chamber varies from 1 to 12 cu ft/MG with an average of 4.0 cu ft/MG.
 - g. Channel Construction - Mechanically cleaned grit chambers are generally square construction.

The tank bottom should be flat and must be provided with a grit hopper at the side of the tank contiguous to the grit removal mechanism. The center mounted rotating mechanism should be provided with an access platform for drive maintenance.

The inlet structure should extend the length of one side with the outlet structure extending the length of the side opposite the inlet.

The inlet shall be provided with baffles to prevent short circuiting in the basin.

- h. Grit Removal - Grit removal may be maintained using a reciprocating rake, screw conveyor, or air lift pumps.

- i. Grit Washing - Provisions should be made for grit washing prior to ultimate grit disposal.
- j. Grit Disposal - Acceptable methods of grit disposal include burial or landfill.

4. Cyclonic-Degritters.

- a. Use Requirements - Cyclonic-degritters may be used in lieu of mechanical, manually cleaned, or aerated grit chambers.
- b. Location - Cyclonic-degritters should be located ahead of all other units in a sewage treatment works where removal of grit would facilitate operation.
- c. Number of Units - One cyclonic-degritter is required as minimum. The unit shall be designed with a bypass to facilitate maintenance without interrupting plant flow.
- d. Sizing Degritters - Generally, the following information is required for sizing the cyclone degritter:
 - 1) plant flow, MGD
 - 2) cubic feet of grit per MG
 - 3) weight of grit per cubic foot
 - 4) per cent solids in flow.

Since cyclonic-degritters are a manufactured product, the Engineer should work with the manufacturer in sizing each unit to assure achievement of maximum grit and minimum organic removal.

- e. Equipment - Cyclonic-degritters are composed of two units, 1) the cyclone, 2) the classifier.

The cyclone separates coarse and fine grit from the light weight organics. The cyclone should be designed to prevent entry-to-over-flow short circuiting and should be provided with an adjustable apex and quick disconnect assembly at the apex housing to remove oversized objects.

The classifier acts as a final grit washing and dewatering device. It should be designed with an adjustable weir which regulates the depth of liquid.

- f. Grit Disposal - Acceptable methods of grit disposal include burial or landfill.

D. SEDIMENTATION/CLARIFICATION.

The objective of treatment by sedimentation is to remove settleable solids and floating matter economically and, thereby, reduce the suspended solids content of the liquid-solids medium.

1. Mechanical - Rectangular and Circular.

- a. Use Requirements - Sedimentation basins are installed as primary solids separation units, intermediate solids separation units (in some instances), and as a final solids separation unit.
- b. Location - Primary basins are located between grit removal units and aeration.

Intermediate basins are located between separate aeration compartments such as in the trickling filtration application.

Final basins are located between aeration units and disinfection.

Variations in location in the flow scheme exist depending upon the particular selected process.

- c. Number of Basins - Multiple basins should be considered on larger installations. Consideration should also be given to more than one basin when removal of a single unit from service for a short period would result in objectionable conditions. Provisions shall be made to bypass each unit for servicing without interrupting the plant flow.
- d. Design Loadings - Table VII - 2 itemizes the recommended sedimentation basin design loadings.

In addition, Figure VII - 3 and Figure VII - 4 are graphical presentations of the maximum allowable surface loading rate and weir loading rate for the extended aeration and the contact stabilization process. Under no circumstance shall the surface loading rate exceed 1200 gpdpsf for primary sedimentation or 1000 gpdpsf for secondary sedimentation.

e. Basin Design.

- 1) Inlet - The inlets shall be designed to dissipate the inlet velocity, to distribute the flow equally, and to prevent short circuiting.

Inlet channels or pipes shall be designed to maintain a velocity of at least 1 foot per second at one-half design flow.

Corner pockets and dead ends shall be eliminated by use of corner fillets and proper channeling.

Flow through velocities in rectangular basins shall not exceed 100 feet per hour.

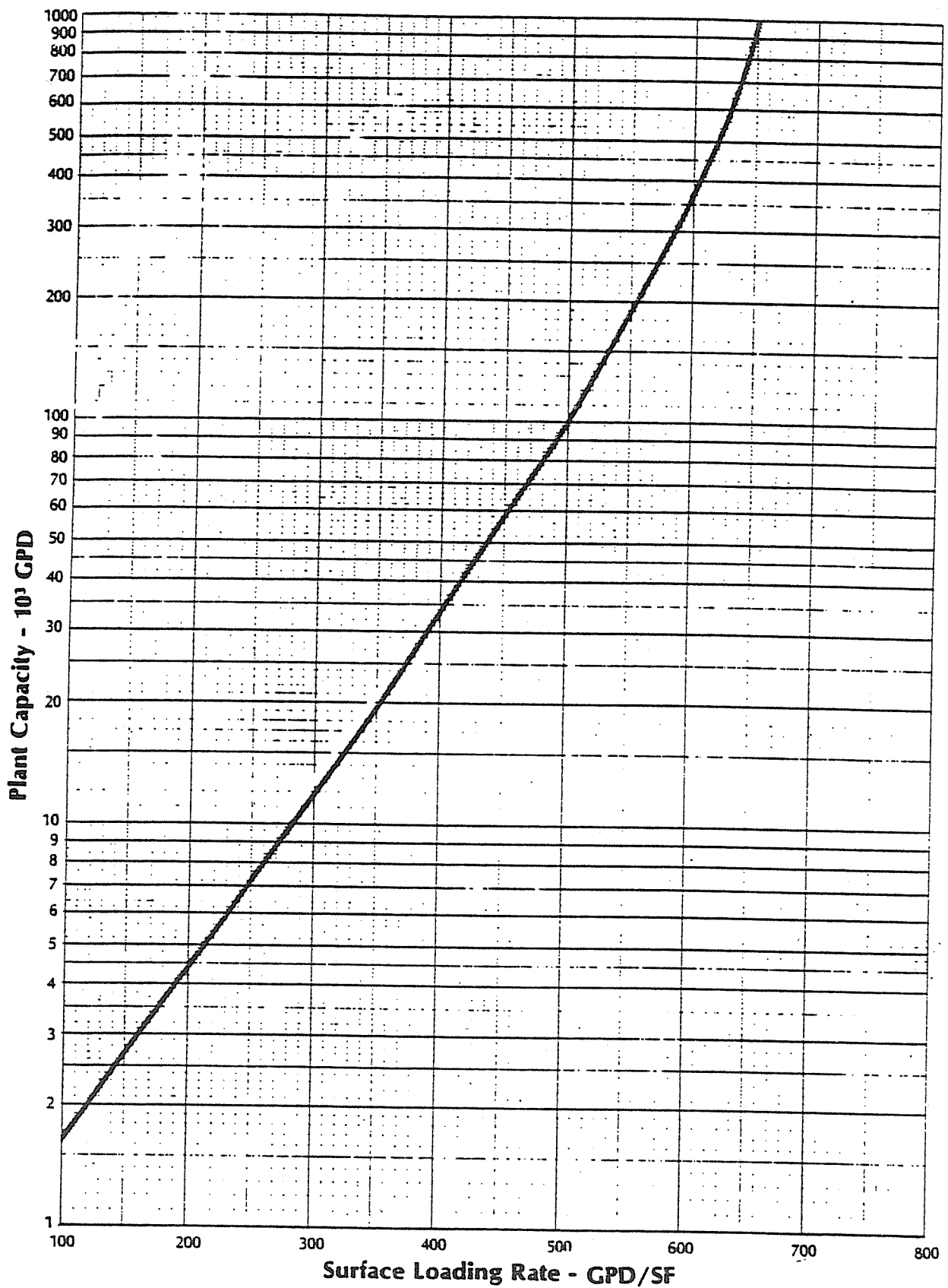


Figure VII-3
Maximum Clarifier Surface Loading Rate
vs
Plant Average Daily Flow
for
Extended Aeration and Contact Stabilization

Clarification Application	Average Design Flow	Surface Loading Rate GPD/SF	Weir Loading Rate GPD/LIN. FT.	Retention Time Hrs.	Anticipated Underflow Concentration % Wt.
PRIMARY	To 1.0 MGD Above 1.0 MGD	600 800 (700 - 1000) *	15,000 (15,000 - 15,000) *	2.5 2.0 (1.75 - 4)	3 - 5
SECONDARY					
1. Conventional, complete mixed, modified, and step aeration					
a. Air	To 0.5 0.5 - 1.5 Above 1.5	600 700 800	10,000 (8,000 - 15,000) *	3.0 2.5 2.0	0.5 - 1.0
b. Pure O ₂	To 0.5 0.5 - 1.5 Above 1.5	600 700 800	10,000 (8,000 - 15,000) *	3.0 2.5 2.0	2 - 3
2. Trickling filter, biofilter					
a. Standard	All	1000	15,000	2.0	3 - 5
b. High rate	All	800	10,000	2.0	3 - 5
c. Intermediate	All	1000	15,000	2.0	3 - 5
3. Contact stabilization	To 0.5 0.5 - 1.0 1.0 - 1.5 Above 1.5 MGD	See Figure VII - 3 700 800	See Figure VII - 4	3.6 3.0 3.0 2.5	0.5 - 1.0
4. Extended aeration	To 0.05 0.05 - 0.15 Above 0.15 MGD	See Figure VII - 3	See Figure VII - 4	4.0 4.0 3.6	0.5 - 1.0
5. Physical - Chemical					
a. Primary, secondary, and tertiary					
1) Alum	↑ All ↓	450 (500 - 600) *	8,000	3.0	0.5 - 1.0
2) Iron	↑ All ↓	600 (700-800) *	10,000	2.5	0.5 - 1.0
3) Lime	↑ All ↓	1000 (1400 - 1600) *	15,000	2.0	3 - 5

* Higher values are for peak loading only —

Table VII — 2
Recommended Clarifier Loadings

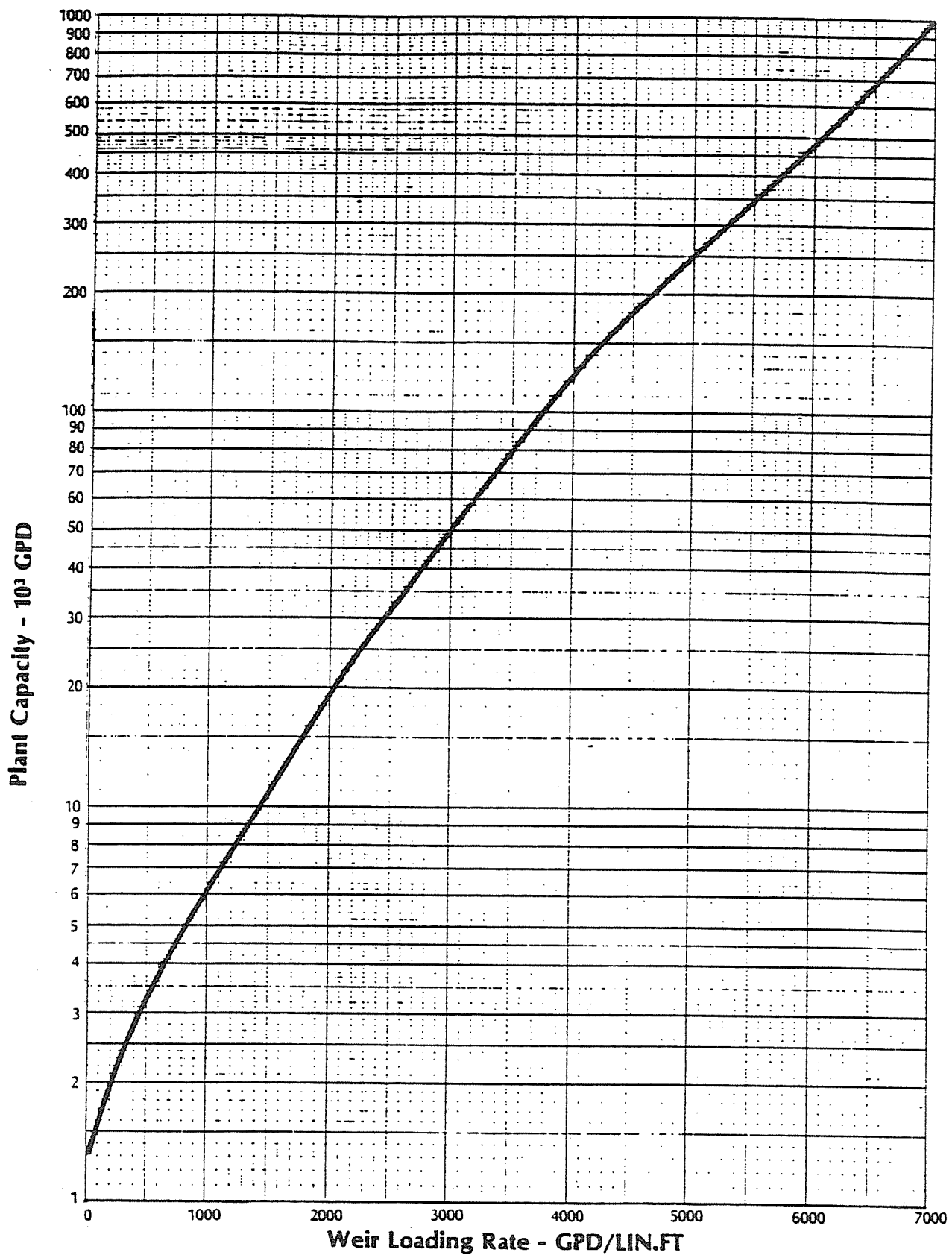


Figure VII-4
Maximum Clarifier Weir Loading Rate
vs
Plant Average Daily Flow
for
Extended Aeration and Contact Stabilization

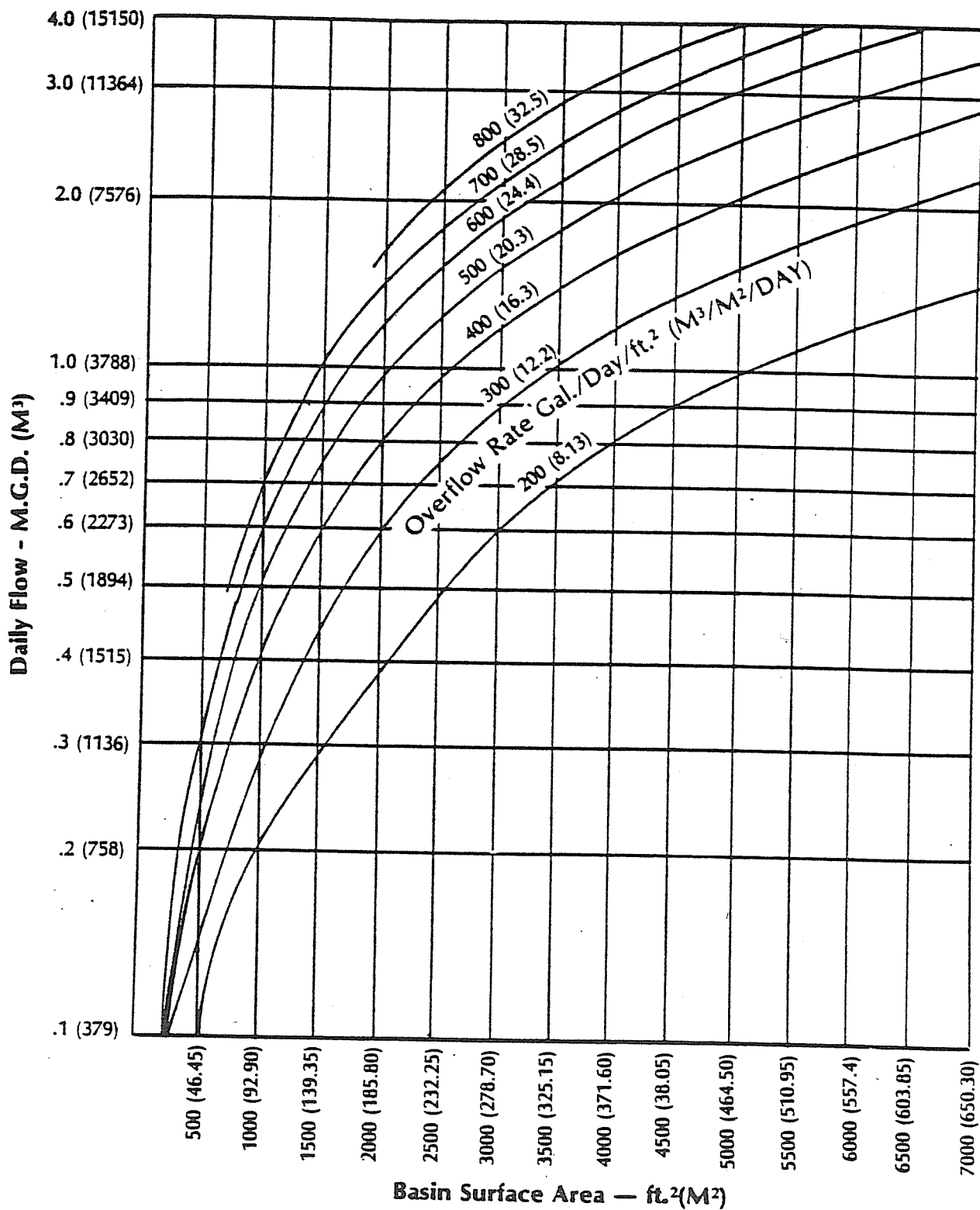


Figure VII-5
Overflow Rate
Basin Surface Area - ft.²(m²)

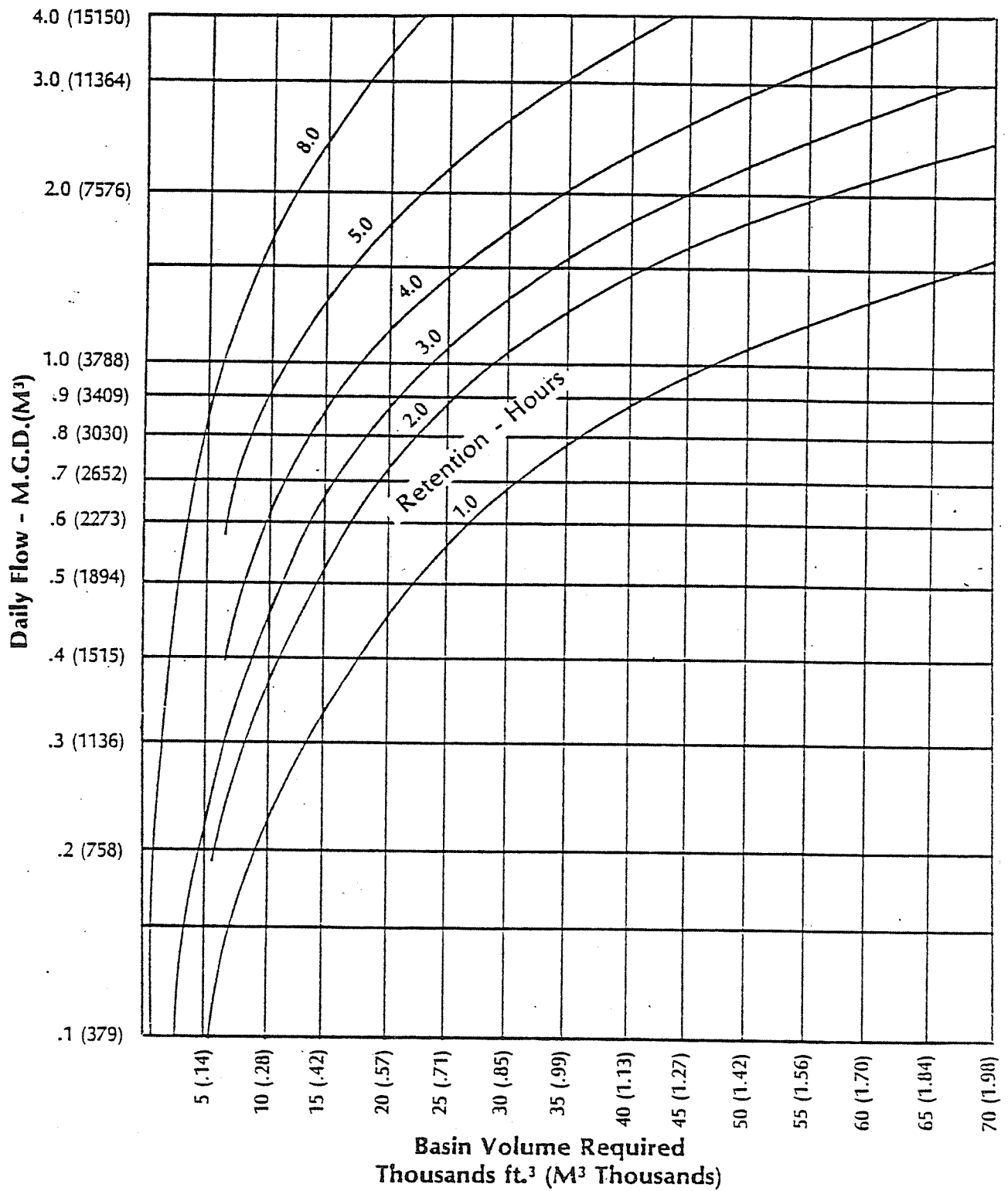


Figure VII-6
Retention Time
Basin Volume Required

- 2) Length/Width - Rectangular - Length to width ratios of rectangular basins range from 4:1 to 5:1.
- 3) Weirs - Overflow weirs shall be adjustable. Weir plates with 90° V-notches for low flows or launders with multiple weirs are preferred. The upflow velocity in the immediate vicinity of the weir should be limited to between 12 and 24 fph.
- 4) Scum Baffles - Effective scum baffles shall be provided ahead of the outlet weirs on all sedimentation basins.
- 5) Sludge Removal - Provisions shall be made to permit continuous sludge removal from final sedimentation basins when the sludge is returned to primary sedimentation basins.

Each sludge hopper shall have an individually valved sludge withdrawal line at least six (6) inches in diameter. Head available for withdrawal of sludge shall be at least 30 inches. Sludge hoppers shall be accessible for maintenance from the operating level. The minimum slope of the side walls of sludge hoppers shall be 1.7 vertical to 1 horizontal. Clearance between the end of the sludge draw-off pipe and the hopper walls shall be sufficient to prevent "bridging" of solids. Hopper bottoms shall have a maximum dimension of 2 feet.

- 6) Skimming Requirements and Controls - Effective scum collection and removal facilities shall be provided ahead of the outlet weirs on all sedimentation basins. The equipment should be automatic or provide for easy scum removal, and shall discharge to a sludge well for pumping to sludge disposal.
- 7) Mechanical Equipment - Sedimentation basin equipment is either of the scraper type or suction type (final sedimentation only). Peripheral speeds of scraper mechanisms is generally 5 - 8 fps. Suction type mechanisms travel between 4 - 12 fpm.

Sludge withdrawal is generally controlled by telescoping valves which may be varied to match sludge pumping rates.

8. Safety Controls - All sedimentation basins shall be provided with easy access for maintenance. Operator safety shall be assured by installation of stairways, walkways, handrails, etc.

The sedimentation mechanism shall be provided with adequate safety mechanisms to prevent drive failure or overloading.

9. Sampling facilities - Appropriate equipment shall be provided for viewing and sampling and return sludge from the final sedimentation basin.

2. Non-Mechanical.

- a. Use Requirements - Non-mechanical basins shall be restricted to combined aerator-clarifier units which are less than 100,000 gpd capacity.
- b. Location - Non-mechanical sedimentation basins are located at the effluent side of extended aeration or contact stabilization aeration basins.
- c. Design Loadings - Figure VII - 3 and Figure VII - 4 provide a graphical presentation of the maximum allowable surface loading rate and weir overflow rate. Table VII - 2 gives the recommended retention times for these basins.
- d. Basin Design.
 - 1) Inlet Structure - The inlet structure from the aeration basin may be by pipe, elbow, tee, or other such means which will distribute the sludge adequately and will prevent short circuiting or clarifier turbulence. The inlet velocity to the sedimentation basin shall not exceed 1 fpm at design flow. Flow through velocities shall not exceed 100 feet per hour.
 - 2) Width to Length Ratios - Non-mechanical sedimentation basins are generally provided with a length to width ratio of 1:2.
 - 3) Weirs - Overflow weirs shall be adjustable. Weir plates of 90° V-notches for low flows or launders with multiple weirs are preferred. The upflow velocity in the immediate vicinity of the weir should be limited to between 12 and 24 fph.
 - 4) Scum Baffles - Effective scum baffles shall be provided ahead of the outlet weirs on all sedimentation basins.
 - 5) Sludge Removal - Sludge removal shall be continuous, via air lift or sludge pumps. Sludge hoppers shall have a minimum slope of 1.7 vertical to 1.0 horizontal to reduce "bridging" of solids.
- e. Skimming Requirements and Controls - Effective scum collection facilities should be provided ahead of the outlet weirs on all sedimentation basins. The equipment should be automatic or provide for easy scum removal, and should be designed to discharge to a sludge well for pumping to sludge disposal, or for smaller plants return the scum to the aeration basin.
- f. Pumping Capacities and Pumping Rate Controls - Return sludge pumping capacities should be provided which will allow a variable control range of 0.5 to 1.5 times the average daily flow.

- g. Safety Controls - All sedimentation basins shall be provided with easy access for maintenance. Operator safety should be assured by installation of walkways, handrails, etc.
 - h. Sampling Facilities - Appropriate equipment shall be provided for viewing and sampling the return sludge from the final sedimentation basin.
3. Tube Settlers.
- a. Use requirements - Tube settlers are used in secondary sedimentation of biological and physical chemical process schemes. The advantage in using tube settlers is the achievement of a higher surface loading rate as compared to sedimentation basins without settlers. The higher loading rates will result in smaller basin dimensions and, thus, reduce construction costs.
 - b. Design Loadings - Table VII - 3 gives the recommended allowable design loads to be used in designing sedimentation basins using tube settlers.

Clarifier Type	Maximum Design gpm/ft ²	Maximum Peak gpm/ft ²
Suction	0.7	1.8
Scraper and non-mechanical	0.5	1.5

Table VII -3
Recommended Allowable
Design Loading Using Tubular Settlers

NOTE: The rates given above are for liquid temperatures of 70°F. For liquid temperatures of 40°F, the rates shall be reduced by a factor of 2. Rates for temperatures between 40°F and 70°F shall be reduced proportionately. Design loadings shall be for the minimum liquid temperature at the clarifier inlet for the plant locality.

The solids loading rate on the basin shall not exceed 40 lb/sf/da.

$$\begin{aligned}\text{Solids loading (psf/day)} &= \frac{(\text{MLSS}) (2Q) (8.34)}{A} \\ &= \frac{16.68 (\text{MLSS})Q}{A}\end{aligned}$$

MLSS - Concentration mixed liquor suspended solids - mg/l
Q - Design flow - MGD
A - Total basin surface area (square feet)

- c. Basin Depth - The recommended side water depth in a circular basin with center feed is 10 feet minimum. In rectangular basins, the recommended minimum depth is 12 feet. These limits are based upon satisfying thickening requirements of the activated sludge solids. Shallower basins may be used depending upon circumstances of design.
- d. Chemical Feed System - The treatment facility should have the capability of feeding chemicals to the influent of the clarifier during periodic minor upsets in the process. The purpose of the chemical feed system is to enable the operator to exert control over flocculation of the activated sludge solids.

Chemical feed systems shall include provisions for feeding metallic salts (alum or ferric chloride) and polyelectrolyte. The metallic salts should be fed to either the primary or aeration system. The polyelectrolyte should be fed to the influent of the secondary sedimentation basin. Anticipated chemical dosages are:

Alum - 100 - 150 mg/l as $\text{Al}_2 (\text{SO}_4) - \text{H}_2\text{O}$

FeCl_3 - 45 - 90 mg/l as FeCl_3

Polyelectrolyte - 0.5 to 1.0 mg/l

- e. Return Sludge Capability - The return sludge pumping capacity shall be equal to 100 per cent of the design basin flow rate.
- f. Skimming Requirements - A suitable means of skimming shall be provided for removing floating materials in the area ahead of the tubes. Baffling ahead of the tube settlers may be required with certain clarification equipment.

Provisions for skimming the area above the tubes shall be provided (manual or automatic) to prevent dislodged materials from passing into the final effluent.

The weirs and launders shall be provided with scum baffles ahead of the weirs.

- g. Tube Cleaning - A tube cleaning system consisting of air wash shall be provided.
- h. Non-mechanical Clarifiers - The bottom slopes of non-mechanical clarifiers shall be a minimum of 1 to 1.

E. TRICKLING FILTERS

1. Introduction - A trickling filter is a biological treatment process which uses surface growth of organisms on a media as compared to dispersed growth in the activated sludge process.

In a manner analagous to the activated sludge process (using plug flow), the BOD removal is related to the biological surface available and time of interface contact between the wastewater and the biological surface. In a trickling filter, the mean time of contact is expressed as

$$t = \frac{CD}{Q_h^n} \quad (1)$$

where,

C, n = constants which vary depending upon the specific surface and the particular configuration of media packing employed

D = media depth (ft)

Q_h = hydraulic loading (gpm/sf)

The BOD removal rate in the biological process is proportional to the amount of BOD remaining as expressed in the following equation:

$$\frac{L_e}{L_o} = e^{-k t} \quad (2)$$

where,

L_e = BOD remaining (mg/l)

L_o = BOD feed (mg/l)

k = coefficient incorporating the surface area of active film per unit volume

t = contact time (days)

A generalized relationship may be derived from the above equations where the constants (k and C) combined:

$$\frac{L_e}{L_o} = e^{-K_T D / Q_h^n} \quad (3)$$

The value of K_T varies with temperature as expressed by the following equation:

$$K_T = K_{20}(1.035)^{T-20} \quad (4)$$

where,

K_T = BOD removal rate constant at design temperature

K_{20} = BOD removal rate constant at 20°C (See Table VII - 4.)

T = design temperature (°C)

Eckenfelder modified equation (3) to a retardant form in describing overall removal since all components of the organic waste are not removed at the same rate. The modification is expressed as:

$$\frac{L_e}{L_o} = \frac{100}{1 + \frac{CD(1-m)}{Q_h^n}} \quad (5)$$

Statistical analysis of dates from rock filters treating domestic wastes yields the equation:

$$\frac{L_e}{L_o} = \frac{100}{1 + \frac{2.5D^{0.67}}{Q_h^{0.50}}} \quad (6)$$

When recirculation is used, the rock filter performance can be estimated by the equation

$$\frac{L_e}{L_a} = \frac{1}{(1+N) \left(1 + \frac{2.5D^{0.67}}{Q_h^{0.5}}\right) - N} \quad (7)$$

where,

L_a = influent sewage BOD_5 , mg/l

N = recirculation ratio

L_o = admixture of recirculated flow $BOD = \frac{L_a + NL_e}{N + 1}$

Eckenfelder derived an equation to include the effect of recirculation on the removal capabilities of plastic media towers. That equation is expressed as

$$\frac{L_e}{L_a} = \frac{1}{(1+N)e^{\frac{K_1 D}{Q_h} \left(\frac{1}{1+N}\right)} - N}$$

Figures VII - 7, 8, and 9 give graphical solutions to equation (3) for plastic media (after B. F. Goodrich Corporation).

Detailed discussions of process design may be found in Eckenfelder's works and Metcalf and Eddy's "Wastewater Engineering."

2. Use Requirements - Trickling filters may be used as "roughing" filters to reduce organic loads on other biological process units or may be used as the prime source of biological treatment.

3. Types and Design Loadings - Trickling filters are classified as standard rate filters and high rate filters.

Table VII - 4 gives general features and recommended loading criteria for trickling filters.

4. Distribution Equipment.

- a. Distribution - The sewage may be distributed over the filter by rotary distributors, horizontal or traveling distributors, or other suitable devices which provide the required continuity and uniformity of distribution. At average design flow, the deviation from a calculated uniformly distributed volume per square foot of the filter surface shall not exceed plus or minus 10 per cent at any point.
- b. Dosing - 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 shall be such that the time interval between applications does not exceed 5 minutes at design flows.
- c. Hydraulics - All hydraulic factors, including recirculation, which involve proper distribution of the sewage on the filters should be carefully calculated. For reaction type distributors, a minimum head of 24 inches between low water level in the siphon chamber and center of the distributor arms is good design practice.
- d. Clearance - A minimum clearance of 6 inches between the media and distributor arms shall be provided. Greater clearance will be required where icing occurs.

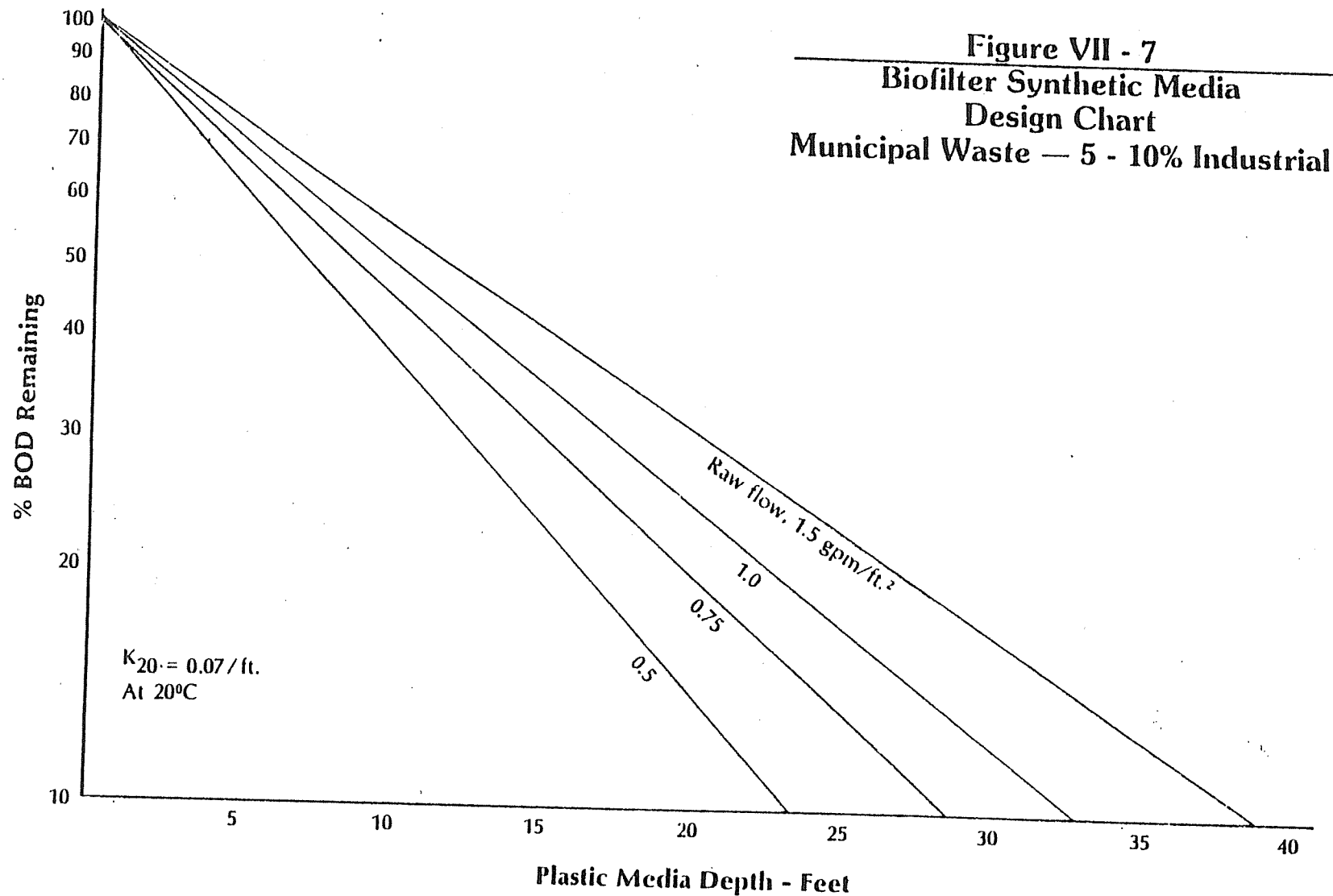
5. Media.

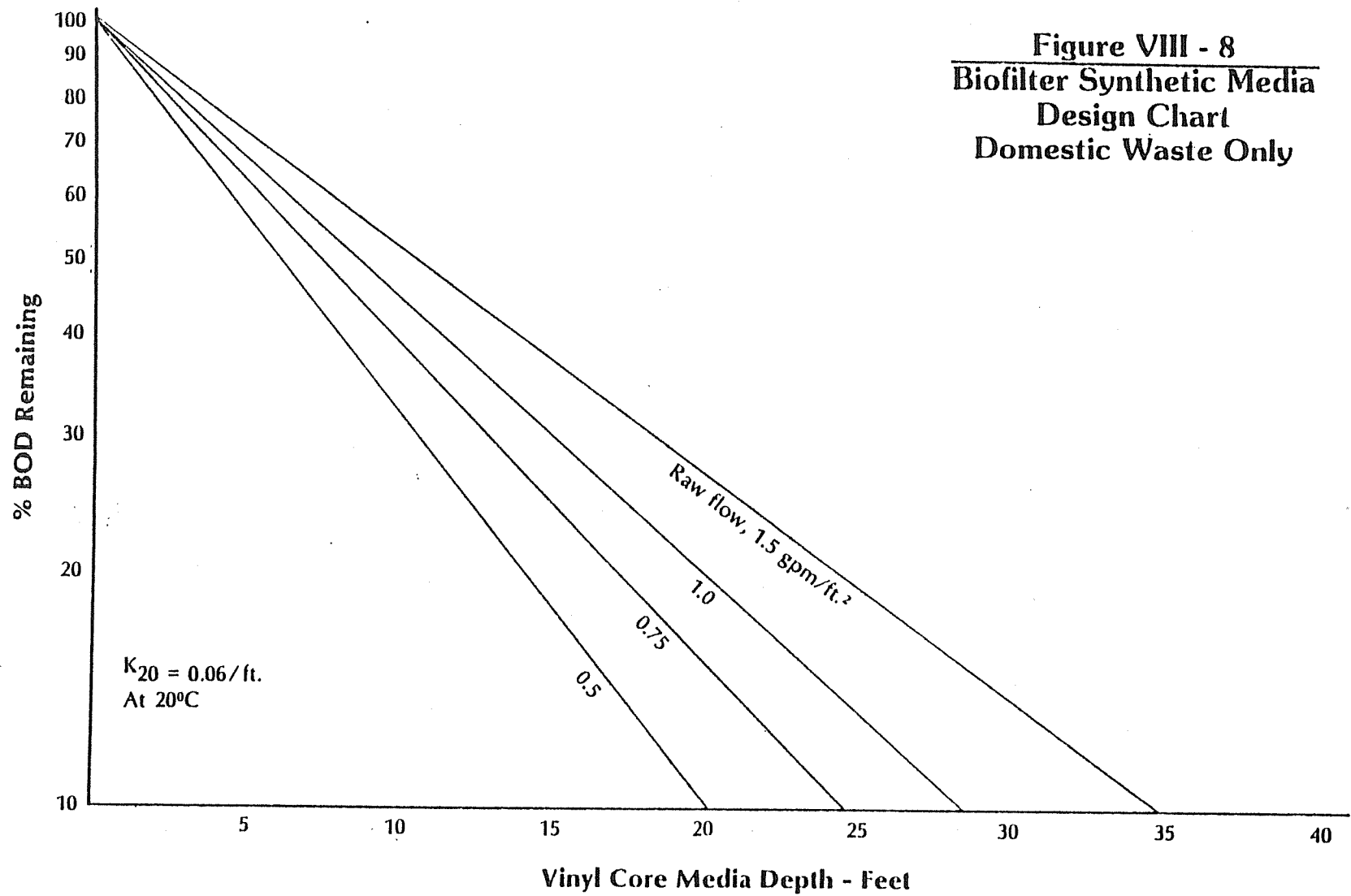
- a. Quality - The filter media may be crushed rock, slag, or specially manufactured material. The media shall be durable, resistant to spalling or flaking, and shall be insoluble in sewage. The top 18 inches shall have a loss by the 20-cycle, sodium sulfate soundness test of not more than 10 per cent, as prescribed by ASCE Manual of Engineering Practice, Number 13, the balance to pass a 10-cycle test using the same criteria. Slag media shall be free from iron and sulphur. Manufactured media shall be structurally stable and chemically and biologically inert.
- b. Depth - Crushed rock and slag media shall have a minimum depth of 5 feet above the underdrains and shall not exceed 7 feet in depth except where special construction is justified to the Department.

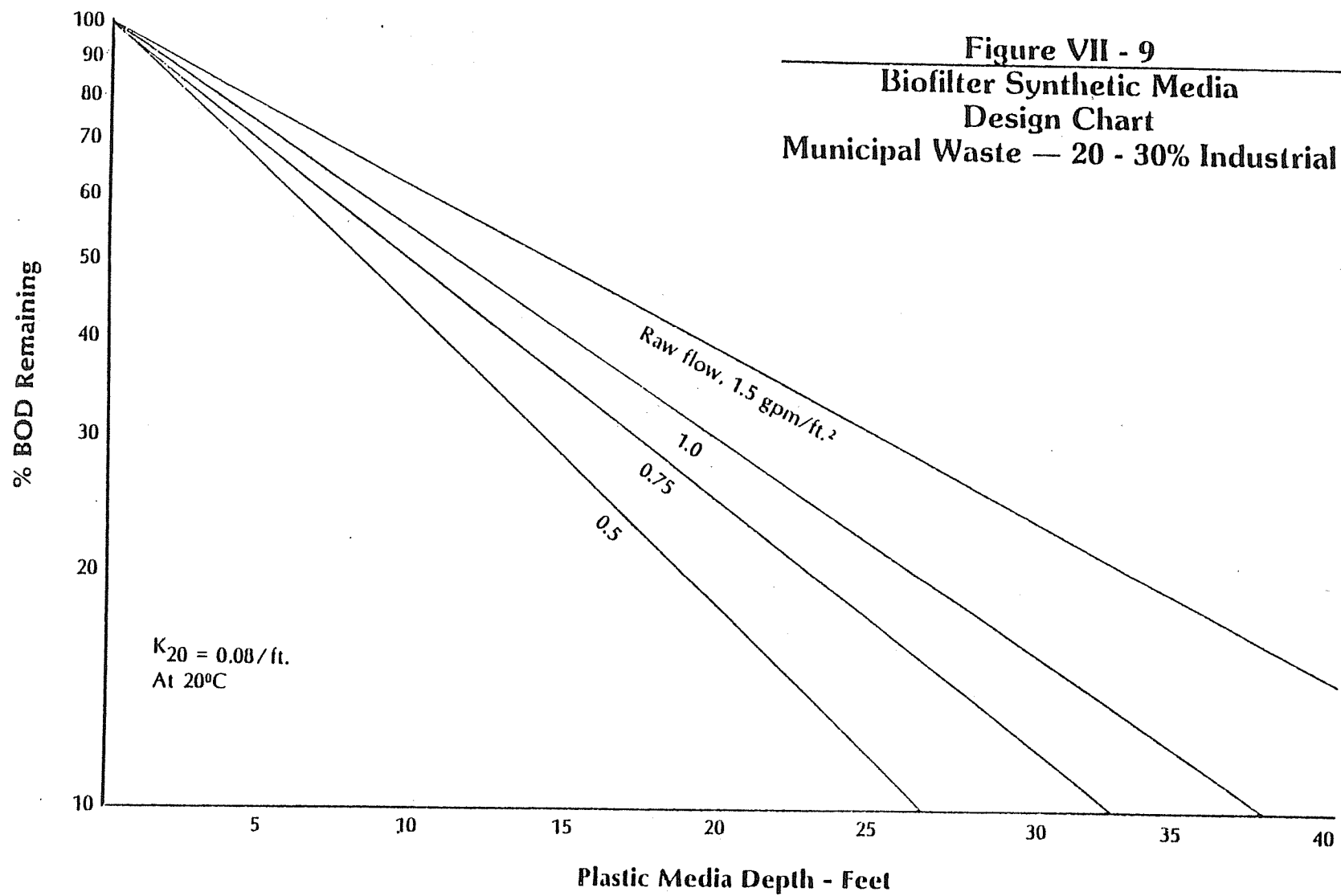
Manufactured media shall have a minimum depth of 5 feet above the underdrains and should not exceed 20 feet in depth except where special construction is justified to the Department.

	Hydraulic Loading (MGAD)	Organic Loading (lb BOD/acre/ ft/day)	Depth ft	n	K ₂₀	Recirculation
Standard Rate						
Rock, etc.	2 - 5	400 (200 - 1100)	6 (5 - 10)	0.50	.33	None
Manufactured Media						
Rings	10 - 150	-	21 (14 - 28)	.39	.46	None
Sheet-type	10 - 150	-	21 (14 - 28)	.5	.33 - .40	None
High Rate						
a. Single Stage						
Rock, etc.	16 (10 - 30)	2000 (1300 - 3900)	4 (3 - 6)	0.50	.33	0.5 - 3.0
Manufactured Media						
Rings	30 - 500	-	21 (14 - 28)	.39	0.46	0.5 - 3.0
Sheet-type	30 - 500	-	21 (14 - 28)		.33 - .40	0.5 - 3.0
b. Two Stage						
Rock, etc.	16 (10 - 30)	2500 (2000 - 3000)	4 (3 - 6)	0.50	.33	0.5 - 4.0
Manufactured Media						
Rings	30 - 500	-	21 (14 - 28)	.39	0.46	0.5 - 4.0
Sheet-type	30 - 500	-	21 (14 - 28)	.5	.33 - .40	0.5 - 4.0

Table VII - 4
Recommended Trickling Filter Design Criteria







c. Size and Grading of Media.

- 1) Rock, Slag, and Similar Media - Rock, slag and similar media shall not contain more than 5 per cent by weight of pieces whose longest dimension is 3 times the least dimension. They shall be free from thin elongated and flat pieces, dust, clay, sand, or fine material and shall conform to the following size and grading when mechanically graded over vibrating screen with square openings:

Passing 4 1/2 inch screen - 100% by weight
Retained on 3 inch screen - 95% - 100% by weight
Passing 2 inch screen - 0 - 2% by weight
Passing 1 inch screen - 0 - 1% by weight

- 2) Hand Packed Field Stone:

Maximum dimension of stone - 5 inches
Minimum dimension of stone - 3 inches

- d. Handling and Placing of Media - Material delivered to the project site shall be stored on wood planked or other approved clean hard surfaced areas. All material shall be rehandled at the filter site and no material shall be dumped directly into the filter. Crushed rock, slag, and similar media shall be rescreened or forked at the filter site to remove all fines. Such material shall be placed by hand to a depth of 12 inches above the tile underdrains and all material shall be carefully placed so as to not damage the underdrains. The remainder of the material may be placed by means of belt conveyors or equally effective methods.

Manufactured media shall be handled and placed as recommended by the manufacturer and as approved by the Engineer.

Trucks, tractors, or other heavy equipment shall not be driven over the filter during or after construction.

6. Under-Drainage System.

- a. Arrangement - Underdrains with semicircular inverts or equivalent should be provided. The underdrainage system shall cover the entire floor of the filter. Inlet openings into the underdrains shall have an unsubmerged gross combined area equal to at least 15 per cent of the surface area of the filter.
- b. Bottom Slope - The underdrains shall have a minimum slope of 1 per cent. Effluent channels shall be designed to produce a minimum velocity of 2 feet per second at average daily rate of application to the filter.
- c. Flushing - Provisions shall be made for flushing the underdrains. 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 underdrain 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 per cent of their cross sectional area will be submerged under the design hydraulic loading. Where standard rate filters are to be provided, consideration should be given to the design of the effluent channels for eventual conversion to high rate operation.
7. Control Devices - Flow measurement devices shall be provided to permit measurement of flow to the filter. Flow measurement should be installed to record dosing feed and recirculation quantities.
8. Maintenance Considerations - All distribution devices, underdrains, channels and pipes shall be installed so that they may be properly maintained, flushed, or drained.
9. Freezing Protection and Odor Control - Consideration shall be given to protecting the filter from freezing when the climate and other conditions are expected to require freezing protection.

Where odor control is necessary, consideration should be given to covering each unit.

F. ACTIVATED SLUDGE.

The activated sludge process uses a dispersed growth phase for reduction of organics in the waste stream as compared to the surface growth of the trickling filter process.

The works of Michaelis-Menton and Monod in relating organic removal rate as a function of organic feed concentrations and biological growth rates as a function of food microorganism ratios have been the foundation for designing the activated sludge process. Chapter 10 of Metcalf and Eddy's "Wastewater Engineering" presents in-depth discussions of growth kinetics as they apply to sewage treatment.

1. Design Parameters - Table VII - 5 is a compilation of recommended design parameters for activated sludge processes. Designs using values other than those shown in Table VII - 5 shall be submitted with justification for variance.
2. Return Sludge Requirements.
 - a. Sludge Pumps - The return sludge pumps shall be of such capacity as is required for returning sludge as governed by Table VII - 5. The pumps shall be designed to provide variable delivery. A standby pumping unit shall be provided equal in capacity to the largest single pump.
 - b. Pipe Velocity - The velocity range of flow in the return sludge lines shall be between 2 fps and 8 fps.

Parameter Process	Aeration Period hrs	% Recycle	BOD Design Load		LB O2	Cu Ft Air	MLSS mg/l	Sludge Age- Days	Lb Solids	Primary Treatment Required			
			Lbs 1000 CF	Lbs Lb mlss	Lb bod Removed	Lb bod Removed			Lb bod Removed				
Conventional	4 - 8	25 - 50	35 (20-40)	0.25 - 0.50	0.8 - 1.0	700 - 1000	1500 - 3000	3.7 - 7.0	0.5	yes			
Step - Feed	2 - 4	25 - 75	50 (40 - 60)	0.25 0.50	0.8 - 1.0	500 - 700	200 - 3500	3.5 - 7.0	0.5	yes			
Complete-Mix	3 - 5	25 - 100	50 - 120	0.5 - 0.75	0.8 - 1.0		3000 - 6000	3.5 - 7.0	0.5	yes			
Kraus	4 - 8	50 - 100	40 - 100	0.3 - 0.8		800	2000 - 4000		0.5	yes			
High Rate	.5 - 2	100 - 500	100 - 1000	0.4 - 1.5	0.65 - 0.80		4000 - 10,000	0.5 - 2.0	0.6 - 0.7	yes			
Modified Aeration	1.5 - 3	5 - 20	100 (75 - 150)	1.5 - 5.0	0.65 - 0.80	400 - 600	200 - 500	0.5 - 2.0	0.6 - 0.7	no			
Pure Oxygen	1 - 3	25 - 50	100 - 250	0.25 - 1.0	0.8 - 1.5		6000 - 8000	1.0 - 2.0	0.3 - 0.7	yes			
Deep Shaft Aeration **	1.0 - 3.0	100		0.8 - 1.1	*		4000 - 6000	4.0 - 5.0	0.25 - 0.5	no			
Contact Stabilization To 0.5 MGD	Contact Basin 3.0	25 - 100	30	0.2 - 0.5	0.8 - 1.0		Contact - 1000 - 3000	3.5 - 7.0	0.5	no			
0.5 to 1.5 MGD	3.0 - 2.0		30 to 50				Reaeration - 4000 - 10,000						
1.5 MGD up	1.5 - 2.0		50										
Extended Aeration	24	75 - 150	12.5 (10 - 20)	0.05 - 0.15		2100	2000 - 4000	10 or more		no			

* consult manufacturer

** design governed by Chapter III

***Contact Basin - 30 to 35 percent of total aeration capacity. Reaeration Basin comprises the balance of the aeration capacity.

Note: All other activated sludge processes shall be governed by chapter III

Table VII - 5
Recommended Design Criteria For Activated Sludge Process

- c. Sludge Wasting - Provisions shall be provided on the return sludge piping for wasting sludge to the primary sedimentation unit or to other sludge handling facilities.

3. Basin Configuration.

- a. General - The dimensions of each independent aeration tank shall be such as to maintain effective mixing and utilization of air.
 - 1) Diffused Aeration - Liquid depths should not be less than 10 feet, nor more than 15 feet. Length to width ratios are generally 4:1 to 5:1, while width to depth ratios vary from 1:1 to 2.2:1. The liquid depth may be less for small plants or those with special configurations.
 - 2) Mechanical Aeration - Liquid depths of basins employing mechanical aeration equipment vary with the size of the mechanical aerator. Figure VII - 10 gives recommended liquid depths using mechanical aeration devices.

The shape of the tank and installation of aeration equipment shall provide for positive control of short-circuiting through the tank.

- b. Inlets and Outlets.

- 1) Controls - Inlets and outlets for each aeration tank unit shall be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit flow control to any unit and to maintain a reasonably constant liquid level.
 - 2) Conduits - Channels and pipes carrying liquids with solids in suspension shall be designed to maintain self-cleaning velocities or shall be agitated to keep such solids in suspension at all rates of flow within the design limits.
- c. Freeboard - All aeration basins shall have a freeboard of not less than 6 inches. Greater heights are desirable. Consideration should be given to providing positive means of froth and foam control.

- 4. Aeration Equipment - Aeration equipment shall be capable of maintaining a minimum of 2.0 mg/l of dissolved oxygen in the mixed liquor at all times and shall provide thorough mixing of the mixed liquor. Diffused aeration generally requires 20 to 30 scfm/1000 cf of tank volume to insure good mixing. Typical power requirements vary from 0.5 to 1.0 hp/1000 cf of tank volume for mechanical aeration.

- a. Diffused Aeration.

- 1) Diffusers and Piping - The air diffuser system, including piping, should be capable of delivering 200 per cent of the average air requirements. The diffuser units shall be designed with individual control valves. These valves shall be of the type that will permit throttling.

A pressure relief valve and pressure gauge shall be provided on the main air supply pipe.

The diffuser units shall be designed to be removed from service for inspection and cleaning without dewatering the aeration basin.

2) Blowers and Compressors.

- a) Capacity of blowers of air compressors shall be designed for air intake temperatures of 120°F and shall be designed with compensation for pressure changes with altitude variation.
- b) Dual Units - The blowers shall be installed in multiple units. The capacity of each shall be such that the maximum air demand will be met with the single largest unit out of service.
- c) Air Filters - Air filters shall be provided in numbers, arrangements, and capacities to furnish an air supply having dust content of not more than 0.5 mg per 1000 cubic feet in all air delivered to diffusers.
- d) Noise Level - Blowers and compressors shall be selected to meet OSHA noise level standards. Suitable mufflers, silencers, etc. shall be employed to provide a noise level acceptable to OSHA.

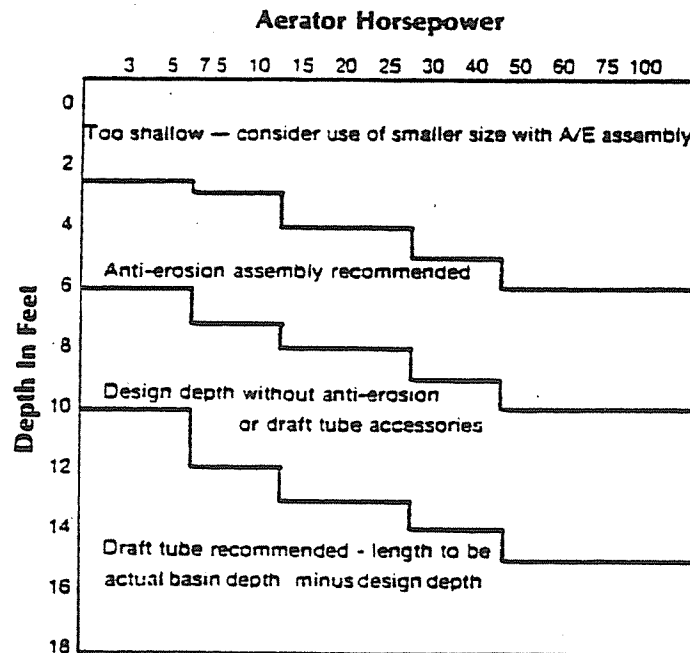


Figure VII - 10
Recommended Depth of Basin
vs Mechanical Aerator Application

- e) Control of Air Supply - The blowers and compressors shall be designed to provide for variation in the volume of air delivered either through throttling valves, variable pitch pulley arrangements, or other suitable methods.
- b. Mechanical Aeration - Mechanical aerators are available in floating or fixed systems.
 - 1) Floating Aerators - Floating aerators may be used in water depths varying from 3 to 20 feet. Figure VII - 10 shows application methods using various size aerators at specified depths.

Antierosion devices shall be required in relatively shallow basin depths. Aerated lagoons shall be constructed with riprap or a concrete pad under each aerator covering a minimum area of 1.5 times the impeller diameter.

The use of draft tubes will be required in deeper basins. Caution shall be used when the depth is more than 1.5 times the length of the shortest side wall. Anti-vortexing devices may be required under these conditions.

Floating aerators shall be provided with corrosion resistant tie-down hardware.

- 2) Fixed Aerators - Fixed aerators may be used in water depths up to 30 feet.

The same precautions as outlined for the floating aerators apply and require investigation.

Fixed aerators shall be mounted on easily accessible platforms with walkways and suitable guardrailing.

Suitable equipment should be provided for removing the aerators from the platform. Adequate working space shall be provided for maintenance.

- 3) Design Factors - Items requiring investigation when applying mechanical aerators include:

- a) depth of tank
- b) aerator spacing
- c) tank geometry
- d) type of activated sludge process
- e) use of baffles
- f) impeller freeboard
- g) zone of aerator influence.

Aerator manufacturers should be consulted to assure proper equipment application in all areas above.

- 4) Field Transfer Requirements - The design Engineer should give consideration to requiring oxygen transfer field testing on units greater than 50 hp. to assure sufficient oxygen is being transferred and proper mixing occurs.
5. Waste Sludge Disposal - Waste activated sludge disposal may include anaerobic digestion and aerobic digestion with any of the means outlined in Section M.

Installations not employing sludge drying beds or other acceptable means of sludge disposal shall be equipped with an aerated sludge holding tank. The sludge holding tank volume shall be at least 10 per cent of the average daily flow with minimum 100 gallons capacity allowable.

The sludge holding tank shall be designed with provisions for decanting supernatant and shall be provided with means of draining and desludging.

6. Sludge Reaeration.

- a. Use Requirements - Sludge reaeration should be considered in design when a temporary means is sought to increase the capacity of an overloaded waste treatment plant.

- b. Design Criteria.

- 1) Organic Loading - Organic loading of the sludge reaeration ranges from 2 to 6# BOD per 1000 cu ft of aeration volume.
- 2) Oxygen Requirements - Sludge reaeration oxygen generally requires 1.25# O₂/lb. BOD removed.
- 3) Retention Time - The aeration time in the sludge reaeration basin shall be between 3 to 6 hours.
- 4) Mixed Liquor Suspended Solids - MLSS concentrations generally vary from 4000 to 10,000 mg/l.
- 5) Mixing Requirements - Mixing requirements for the basin should be 20 to 30 scfm/1000 cu ft of tank volume for diffused aeration and 0.5 to 1.0 hp/1000 cu ft of tank volume for mechanical aerators.
- 6) Basin Design - The basin design should parallel the concepts presented in Section L.

7. Special Considerations for Factory Built Treatment Plants.

- a. Hydraulic Requirements - The design Engineer should carefully review the hydraulic characteristics of all factory built treatment plants before finalizing design.

Clarifiers shall be designed to prevent short circuiting, vortexing, uneven distribution of solids loading or other hydraulic problems which will cause solid washout.

For rectangular tanks, horizontal flow - though velocities based on the maximum mixed liquor flow - shall not exceed 100 fph.

- b. Time Clock Control - All factory built waste treatment plants shall be provided with time clock controls for the aeration equipment capable of 15 minute interval adjustments. Alternators for blowers shall be provided.
- c. Blower Housing - All factory built waste treatment plants shall be furnished with aeration equipment in a lockable, well-ventilated housing to protect the blowers and electrical controls.
- d. Grit Tanks - Preaeration grit tanks will not be allowed on factory built waste treatment systems.
- e. Flow Equalization - Flow equalization shall be considered where:
 - 1) High fluctuations ($>3:1$ peak to average flow) of flow occur,
 - 2) The clarifier loading exceeds normal storage requirements,
 - 3) A sewage pumping station precedes the waste treatment facility.

Design of the equalization basin shall follow the requirements established in Section A.

8. Sampling and Measuring Devices.

- a. Sampling Devices - Sampling ports shall be placed at the following locations:
 - 1) aeration basin inlet
 - 2) aeration basin outlet
 - 3) return sludge line
 - 4) waste sludge line.
- b. Flow Measurement Devices - Flow meters should be placed at the following locations:
 - 1) air supply line to aeration basin
 - 2) return sludge line
 - 3) waste sludge line
 - 4) at locations where the waste flow is split.

Metering may be of the recording type, time clock pump control or other suitable means.

9. Individual Home Aerobic Systems.

- a. Use Requirements - Individual aerobic systems may be used where a central sewer system is not feasible and where the soil conditions will allow subsurface irrigation and/or percolation.

b. Design Criteria.

- 1) Hydraulic - The clarifier shall be designed for a maximum surface loading of 92 gpdpsf.
- 2) Organic - The aeration basin shall be designed for an organic loading of 12# BOD₅/1000 cf volume.
- 3) Retention Times - The aeration basin shall be designed for a minimum retention time of 24 hours.

The clarifier shall be designed for a minimum retention time of six hours.

- 4) Air Requirements - The aeration system shall be designed to provide complete basin mixing and maintain a 2.0 mg/l dissolved oxygen level in the liquid.

Aerators shall be sized using 2100 scf/#BOD per day or 1.5 lb O₂ per lb BOD per day.

Mixing requirements shall be at least 15 scfm/1000 cf of aeration volume.

- c. Effluent Disposal - Acceptable effluent disposal methods for individual aerobic systems include percolation, evapotranspiration and sub-surface irrigation.

Percolation systems shall be designed in accordance with Engineering Bulletin No. 12. Other forms of effluent disposal shall be designed in accordance with Sections P and Q.

G. FLOTATION THICKENERS.

1. Use Requirements - Flotation thickeners are used primarily with waste activated sludge. Applications of combinations of primary clarifiers and flotation thickeners may be warranted where excessive amounts of grease, oils, etc., are found in raw wastewater. Flotation thickening may also be used to thicken mixtures of primary and secondary sludges.
2. Design Requirements - Proper sizing requires knowledge of the following:
 - (1) pounds of sludge available to thicken
 - (2) operational cycle
 - (3) solids loading
 - (4) hydraulic loading
 - (5) air to solids ratio.

Activated sludge can be thickened by flotation, but solids concentrations in the influent to the flotation thickener should not exceed 15,000 ppm (1.5%) for effective flotation.

Type of Sludge	Recommended Design Loading lb/sf/hr
Waste Activated Sludge	1.5 (1.2 - 2.5)
50% Primary + 50% Waste Activated	3.5 (2.5 - 4.5)
Primary Only	To 6.5

Table VII - 6
Solids Loading Dissolved Air Flotation

a. Operation Cycle.

Plants less than 2.0 MGD - 40 hrs/wk
 Plants 2.0 - 5.0 MGD - 80 hrs/wk
 Plants greater than 5.0 MGD - 100 - 168 hrs/wk

b. Solids Loading - Table VII - 6 gives recommended design solids loading for flotation thickening.

Where possible, pilot plant studies should be used in sizing flotation thickeners.

c. Hydraulic Loading - The hydraulic loading of the flotation thickener is of secondary importance. However, it should be the controlling factor if waste activated sludge is less than 3,000 mg/l (0.3%) solids.

The hydraulic loading should never exceed 2.0 gpm/sq ft and should be in the 1.25 - 1.75 gpm/sf range. Reducing overflow rates below 1.0 gpm/sf does not improve removal.

d. Air to Solids Ratio - Air to solids ratio should be designed at 0.02 pounds per pound of dry solids. This is approximately equal to 0.30 cubic feet of air per pound of dry solids.

e. Recycle Ratio: For an air to solids ratio of 0.02 lbs/lb, the recycle flow is generally equal to 2 or 2.5 times the influent flow. The pressure system flow will normally be equal to 1/3 or 1/2 of the raw waste flow.

Primary tank effluent or plant effluent is recommended as the source of air charged water.

H. GRAVITY THICKENERS.

1. Use Requirements - Gravity thickening is the most economical means of thickening sewage treatment works sludges. It is used primarily for concentrating sludge to reduce the quantity of water which would have to be pumped to digesters, holding tanks, drying beds, and/or sludge facilities.
2. Location - Sludge thickeners should be located between primary and/or final sedimentation basins, and sludge digestion or sludge dewatering facilities.
3. Design Parameters - When designing a gravity sludge thickener, consideration should be given to the following:
 - a. Thickening of mixed sludges (primary and secondary) should be considered at each plant. Secondary sludges normally release their bound water slowly, but mixtures of secondary and primary and/or digested sludge respond well to thickening.
 - b. The liquid displacement period in gravity thickeners is of secondary importance for all sludges. However, a retention time of 4 hours and surface loading rates of 400 to 900 gpd/sf are recommended.

When thickening a combination of primary and waste activated sludge, the curve shown in Figure VII - 11 can be used to predict the sludge concentration expected in the underflow solids based upon the per cent (by weight) of the activated sludge in the mixture.

This curve follows the following equation:

$$\% \text{ solids} = \frac{6.43(\text{PAS})^2 - 11.93(\text{PAS}) + 8}{100}$$

where,

$$\begin{aligned} \text{PAS} &= \text{fraction of total solids that is due to the waste} \\ &\quad \text{activated sludge} \\ &= \frac{\text{pounds of waste activated sludge}}{\text{total pounds dry solids}} \end{aligned}$$

Table VII - 7 gives recommended design loading rates and the expected underflow concentrations for gravity thickeners.

When thickening a combination of primary and waste activated sludge, the curve shown in Figure VII - 12 can be used to predict the sludge loading rate (lbs/sf/day) based upon the per cent (by weight) of the activated sludge in the mixture.

The curve is defined by the equation:

$$\text{SLR} = \frac{1}{\frac{\text{PAS}}{5} + \frac{(1 - \text{PAS})}{22}}$$

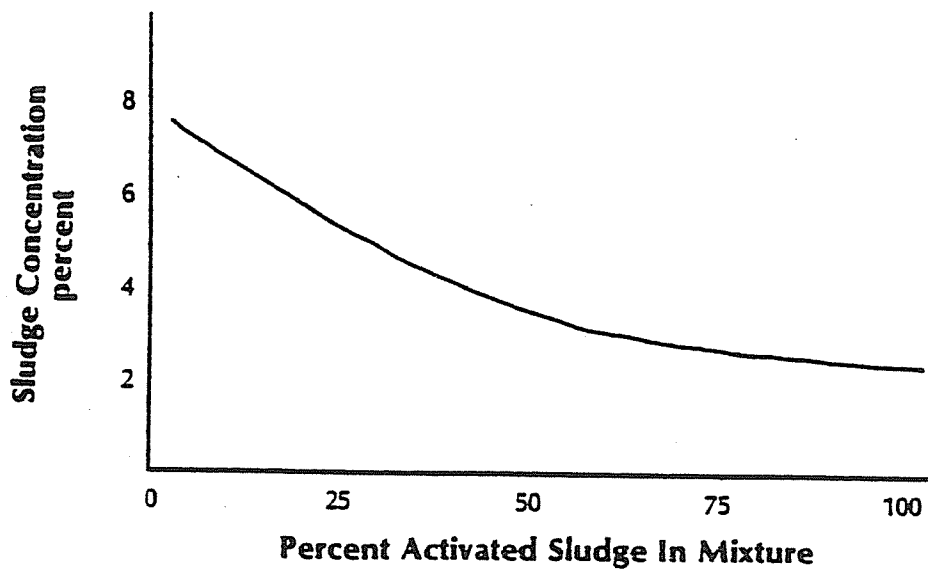


Figure VII - 11
Gravity Thickener - Underflow Sludge Concentration
vs Percent Activated Sludge Mixture

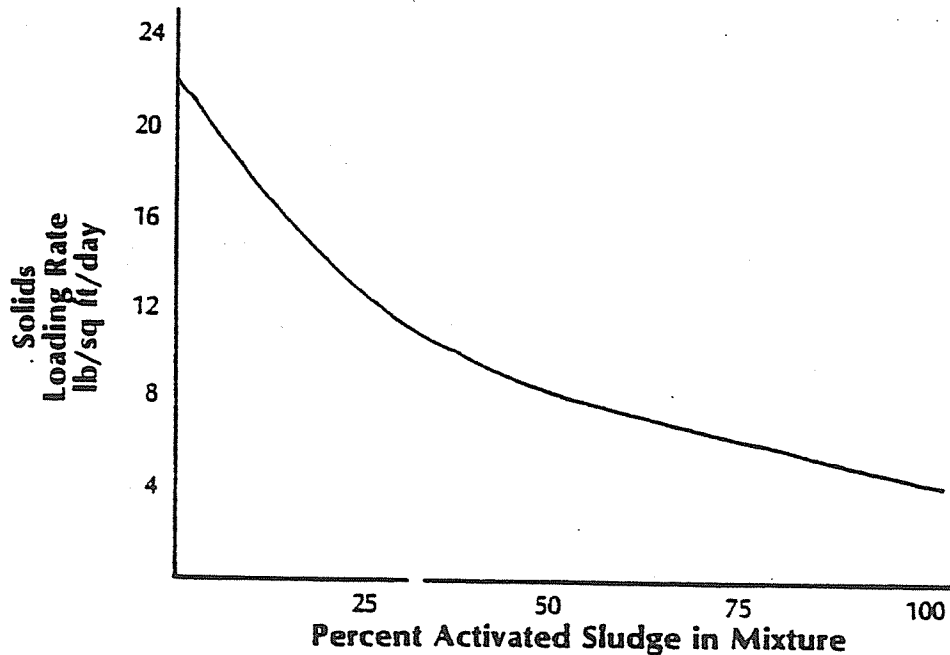


Figure VII - 12
Gravity Thickener Solids Loading Rate
vs Per Cent Activated Sludge Mixture

Sludge Type	Loading lbs/sq ft/day	% Solids in Underflow
Primary	22 (20 - 30)	10 (8 - 10)
Trickling Filter	9 (8 - 10)	8 (7 - 9)
Waste Activated Sludge	4	2
a. Air	(4 - 12)	(2 - 3.5)
b. Pure Oxygen	5	4
Primary + Trickling Filter	15 (12 - 20)	8 (7 - 9)
Primary + Waste Activated	10 (8 - 16)	5 (4.5 - 9)
Activated Physical - Chemical		
a. Lime	30	15
b. Alum	5	1.5
c. Iron	10	3

Table VII - 7
Recommended Solids Loading
Rates for Gravity Thickeners

where,

SLR = Solids loading rate (lbs/sf/day)

PAS = $\frac{\text{pounds of waste activated sludge}}{\text{total pounds of dry solids}}$

4. Basin Design.

- a. Inlet - The inlet shall be designed to dissipate the inlet velocity, to distribute the flow equally, and to prevent short circuiting.
- b. Weirs - The basin shall be provided with adjustable weir plates.
- c. Scum Baffles - Effective scum baffles shall be provided ahead of the overflow weirs.
- d. Sludge Removal - Provisions shall be made to permit continuous sludge removal or to provide sufficient sludge storage for intermittent sludge removal.

- e. Skimming Requirements and Controls - Effective scum collection and removal facilities shall be provided ahead of the outlet weirs on all thickeners.

The equipment shall be automatic and shall discharge to a sludge well for pumping to sludge disposal.

- f. Mechanical Equipment - Thickener equipment is either of the scraper type or suction type. Thickener mechanisms with pickets are preferred over mechanisms without pickets. Tip speeds should not exceed 7 fpm.
- g. Safety Controls - All thickener basins shall be provided with easy access for maintenance. Operator safety shall be assured by installation of stairways, walkways, handrails, etc.

The thickener mechanism shall be provided with adequate safety mechanisms to prevent drive failure or overloading.

- h. Depth - Thickeners should be designed with a minimum side water depth of 10 feet. A side water depth of 14 feet is preferred.

I. PHYSICAL CHEMICAL TREATMENT.

Physical chemical treatment is employed where the effluent stream requires a limitation of nutrients (phosphorous and nitrogen) and, thus, requires a reduction of the constituents prior to final effluent discharge.

The major advantages of physical chemical treatment include:

- (1) The physical chemical treatment systems have the capability of producing treatment efficiencies well in excess of those of biological systems.
- (2) The present suggested physical and chemical processes are generally controllable and lend themselves to automation.
- (3) The physical chemical treatment systems are not typically subject to process failure due to unexpected waste loads of biologically toxic materials.
- (4) The physical chemical treatment systems require less land area than biological systems.

Disadvantages of physical chemical treatment include:

- (1) The quantity of sludge produced is much greater than with conventional processes.
- (2) Processes employing iron and/or alum result in large amounts of ions being (chloride or sulfates) added to the wastewater.
- (3) The physical chemical treatment process is limited in its ability to remove colloidal and nonadsorbable organics, and soluble organic phosphorous and nitrogen.

1. Nutrient Removal.

- a. **Phosphorous Removal** - Phosphorous removal can be accomplished by addition of lime or mineral salts at various locations in the treatment facility. Locations of chemical addition are shown in Table VII - 8.

- 1) **Basic Design Considerations** - The quantity of phosphorous in domestic sewage is approximately equivalent to 3.5 pounds P per capita per year. The average total phosphorous concentration in domestic raw wastewater is found to be about 10 mg/l expressed as elemental phosphorous (P). These figures are rough guides to Engineers and should not be used as a basis of design. Sampling of the wastewater and analyses for phosphorous are recommended in all cases.

Economic analyses should be performed regarding the use of flow equalization techniques to dampen diurnal flow variation. The possibility of reduction of downstream costs and increased efficiencies may justify using flow equalization.

2) Design Criteria.

- a) **Mineral Salts** - Determination of mineral salt dosage requirements must be performed in the laboratory or in field pilot work to assure effective phosphorous removal. Table VII - 9 tabulates anticipated ranges of metallic salt on a mole of chemical per mole of phosphorous basis.

The values in Table VII - 9 should provide a residual phosphorous < 1 mg/liter.

Unit Process	Iron	Chemical Alum	Lime
1. Primary Clarification	x	x	x
2. Trickling Filter Process			
a. Primary Clarification	x	x	—
b. Trickling Filter		Not recommended	
c. Secondary Clarification	x	x	—
3. Activated Sludge			
a. Aeration Basin	x	x	—
4. Secondary Effluent	x	x	x

Table VII - 8
Points of Chemical Addition, Phosphorous Removal

Chemical	Moles of Chemical per Mole of Phosphorous
Alum [Al (III)]	1.5 - 3.0
Iron [Fe (II)]	1.8 - 2.6
Iron [Fe (III)]	1.8 - 2.2

Table VII - 9
Dose Range of Alum and Iron Salt for Phosphorous Removal

- b) Lime - The amount of lime required for phosphorous removal is independent of the amount of phosphorous present. It is a function of the wastewater alkalinity and hardness.

Two basic schemes are employed when applying lime for phosphorous removal at primary clarification.

- (1) Low Lime Treatment - Low lime treatment involves addition of lime to the primary influent sufficient to increase the flow stream pH to 9.5 - 10.0. The biological process serves as the recarbonation stage and additional phosphorous removal will occur in aeration.

The low lime process would be more attractive where low alkalinity of the raw sewage exists.

- (2) High Lime Treatment - High lime treatment involves the addition of sufficient lime in the primary influent to achieve pH 11. Recarbonation will be required to adjust the pH before biological treatment.

High lime treatment is applicable when effluent standards require softening, low levels of soluble metallic compounds, increased virus removal, or consistent effluent phosphorous concentrations below 1.0 mg/l.

Two lime treatment systems are employed with phosphorous removal of secondary effluents: (a) single stage, (b) two stage.

- (a) Single Stage - In single stage, lime is mixed with water to raise the pH to the desired value which is dependent upon the required phosphorous removal (generally, 9.5 - 11.0). After clarification, the effluent stream is recarbonated to prevent post precipitation of CaCO_3 prior to discharge.

- (b) Two Stage - In two stage treatment, sufficient lime is added to the feed water in the first stage to raise the pH to 11, where precipitation of hydroxyapatite, CaCO_3 , and $\text{Mg}(\text{OH})_2$ occurs. After first stage clarification, carbon dioxide is used to adjust to pH 10 where CaCO_3 precipitation results. The CaCO_3 is removed by clarification and the effluent is discharged.

Table VII - 10 gives anticipated values of lime required for phosphorous removal. These values are general ranges. Determination of lime dose requirements must be performed in the laboratory or in field pilot work to assure effective phosphorous removal.

Process Scheme	Lime Dose (mg/l)
Primary	
a. Low Lime	150 - 250
b. High lime	300 - 500
Secondary Effluent	250 - 350

Table VII - 10
Dose Range of Lime for Phosphorous Removal

3). Equipment Requirements.

- a) Coagulant Mixing - The coagulants, mineral salts or lime shall be thoroughly mixed with the waste stream prior to the flocculation chamber. Acceptable means include flash mixers, high velocity pipe lines, or other methods demonstrating good mixing capabilities.

Flash mixers shall be designed for a retention time of 20 to 60 seconds.

- b) Flocculator - The flocculation basin (clarifier or aeration basin) shall be designed to provide sufficient time for chemical precipitation of the phosphorous compounds. Five minutes is generally sufficient to assure floc formation.

The design shall assure a gentle delivery of the flocculated wastewater to the clarification basin.

- c) Recarbonation - Addition of CO_2 to the waste stream for pH adjustment may be performed by on-site generation or by gas CO_2 systems.
- d) Chemical Equipment and Handling - The EPA Process Design Manual for Phosphorous Removal, as well as chemical feed equipment manufacturers and chemical companies, should be consulted when designing chemical feed systems.

All necessary precautions should be taken to assure operator safety in handling and operating chemical storage and feed systems.

- b. **Nitrification Facilities** - The nitrification facility is comprised of additional aeration tanks with clarification following the activated sludge or trickling filter process.
- 1) **Design Criteria** - Table VII - 11 gives tabulated criteria for design of nitrification systems based upon actual pilot plant studies. It is recommended that pilot plant testing be performed to varify these loadings for the specific plant design.
 - 2) **Basin Configuration** - The basin configuration and physical features shall follow the guidelines established in Section F.

Tanks may be designed for either diffused-air or mechanical aeration systems.

- a) **pH Control** - Consideration should be given to providing facilities for pH adjustment. Continuous pH monitoring shall be provided at the effluent port of each aeration basin.

Figure VII - 13 shows the permissible volumetric loading of the nitrification tank at pH 8.4 and at various temperatures and MLVSS concentrations. Figure VII - 14 shows the corrections that must be applied to the permissible loadings when the pH is different than 8.4.

Parameter	Value Range
Basin Influent BOD (mg/l)	50
Size	See Figure VII - 14
MLVSS (mg/l)	1500 - 2500
pH	8.3 - 8.7
D.O. (mg/l) Avg. flow	3.0
Peak flow	1.0
Clarification Basin	
Hydraulic Loading (gpd/sf)	400 - 600
Side Water Depth (ft)	12 - 15

Table VII - 11
Nitrification System Design Criteria

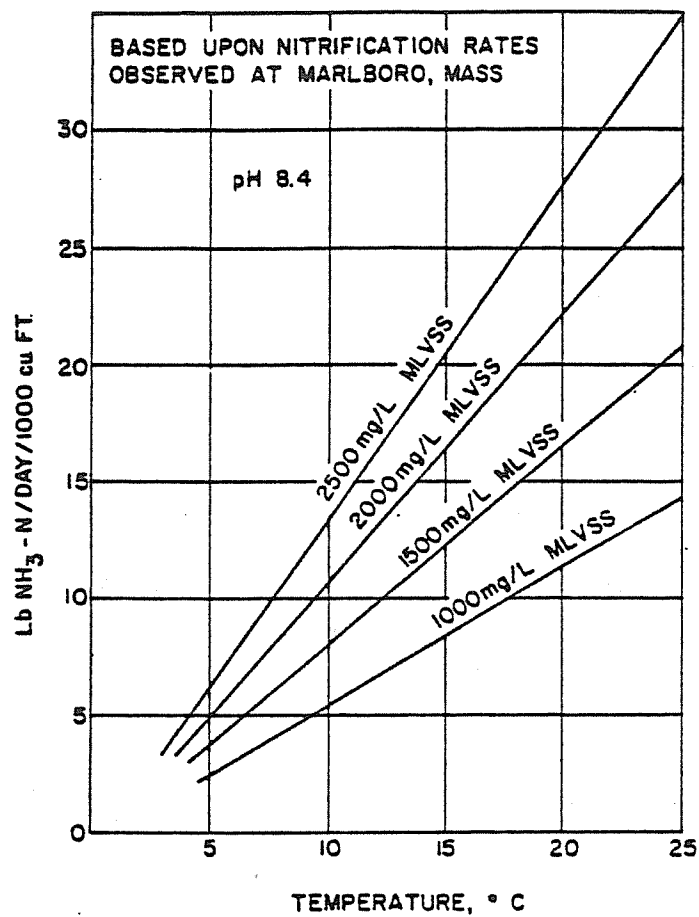


Figure VII - 13
Permissible nitrification-tank loadings.

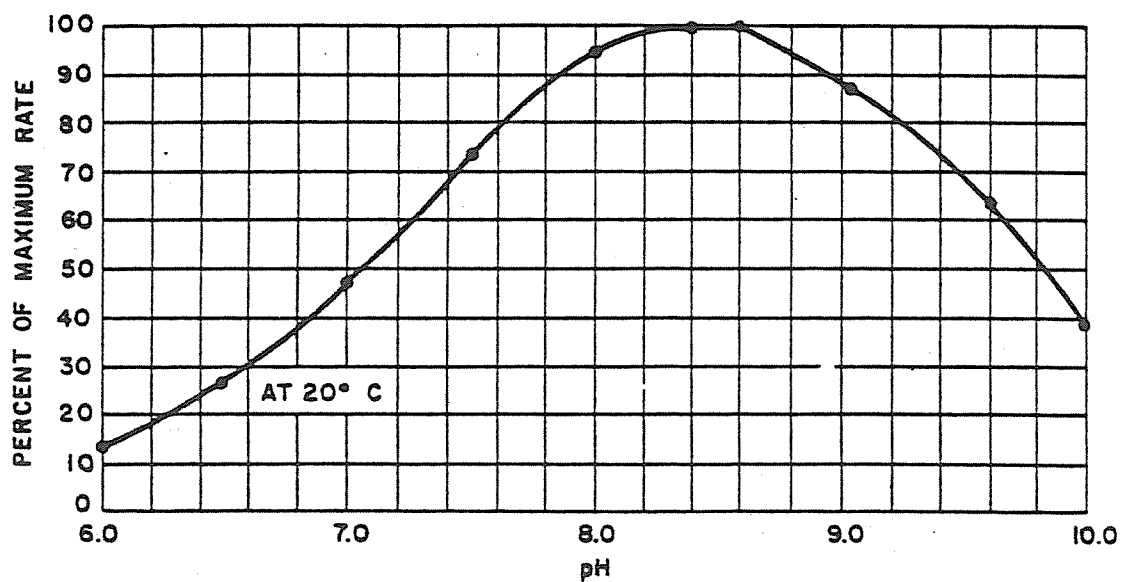


Figure VII - 14
Percent of maximum rate of nitrification
at constant temperature versus pH.

- 3) Oxygen Requirements - Stoichiometrically, each pound of ammonia nitrogen requires 4.6 pounds of oxygen.

An additional allowance should be made for carbonaceous BOD that escapes from the preceding secondary treatment process.

The total oxygen requirement shall be corrected to meet actual operating conditions of

- a) temperature
 - b) minimum D.O.
 - c) coefficient of wastewater oxygen-uptake rate (alpha)
 - d) coefficient of wastewater D.O. saturation (beta)
 - e) altitude of plant.
- 4) Sludge Recycle and Wasting - Provisions shall be made to adjust the return sludge rate between 50 and 100 per cent of the average daily flow.

Sludge wasting will be required periodically. Provisions shall be made to dispose of the waste nitrification sludge with the waste sludge from the carbonaceous treatment process.

- 5) Foam Control - Foam spray systems shall be provided on basins where MLSS concentrations will be greater than 2000 mg/l.
- 6) Inhibiting Factors - The following substances have been found to inhibit the nitrification process in concentrations greater than those indicated:

Substance	Concentration (mg/l)
Halogen substituted phenolic compounds (mg/l)	0
Thiourea and thiourea derivatives (mg/l)	0
Halogenated solvents (mg/l)	0
Heavy metals, (mg/l)	10
Phenol and Creasol, (mg/l)	20
Cyanides (mg/l)	20

- c. Denitrification - The denitrification process consists of contacting the nitrified waste stream with methyl alcohol in a reaction vessel followed by short term aeration prior to clarification.
- 1) Design Criteria - Table VII - 12 gives tabulated criteria for the design of denitrification systems. Pilot plant testing should be performed to verify these loadings for the specific project.
 - 2) Basin Configuration - The basin configuration and physical features shall follow the guidelines established in Section F. Basins should be plug flow designed to minimize short circuiting.

Parameter	Value Range
Basin	
Size	See Figure VII. 17
MLVSS mg/l	1000 - 3000
pH	6.5 - 7.5
Methanol to Nitrate Nitrogen Ratio	3 - 4
Clarification Basin	
*Hydraulic Loading (gpd/sf)	1200
Side Water Depth (feet)	12 - 15

* at peak load conditions

Table VII - 12 Denitrification System Design Criteria

Figure VII - 17 shows the permissible volumetric loading of the denitrification basin as related to MLVSS concentrations and operating temperatures. Figure VII - 16 shows the correction that must be applied to the permissible loading when the pH is not in the optimum range.

- a) pH Control - Consideration should be given to providing facilities for pH adjustment. Continuous pH monitoring shall be provided at the effluent port of each basin channel.
- b) Basin Mixing - The contents of the denitrification tank shall be mixed with underwater mixers comparable to those used in flocculation basins in water treatment tanks. The mixing shall be designed to keep the MLSS in suspension without pickup of atmospheric oxygen.

Power requirements generally range from .25 to .5 hp per thousand cubic feet for proper mixing.

- 3) Aeration - Prior to clarification, degasification via aeration shall be required to prevent nitrogen gas bubbles from interfering with sludge settling. The aeration basin shall be designed to provide 5 to 10 minutes detention at peak flow.

Either diffused or mechanical aeration will be acceptable for degasification. Aeration and mixing capabilities of the aeration equipment shall be in compliance with the regulations in Section F.

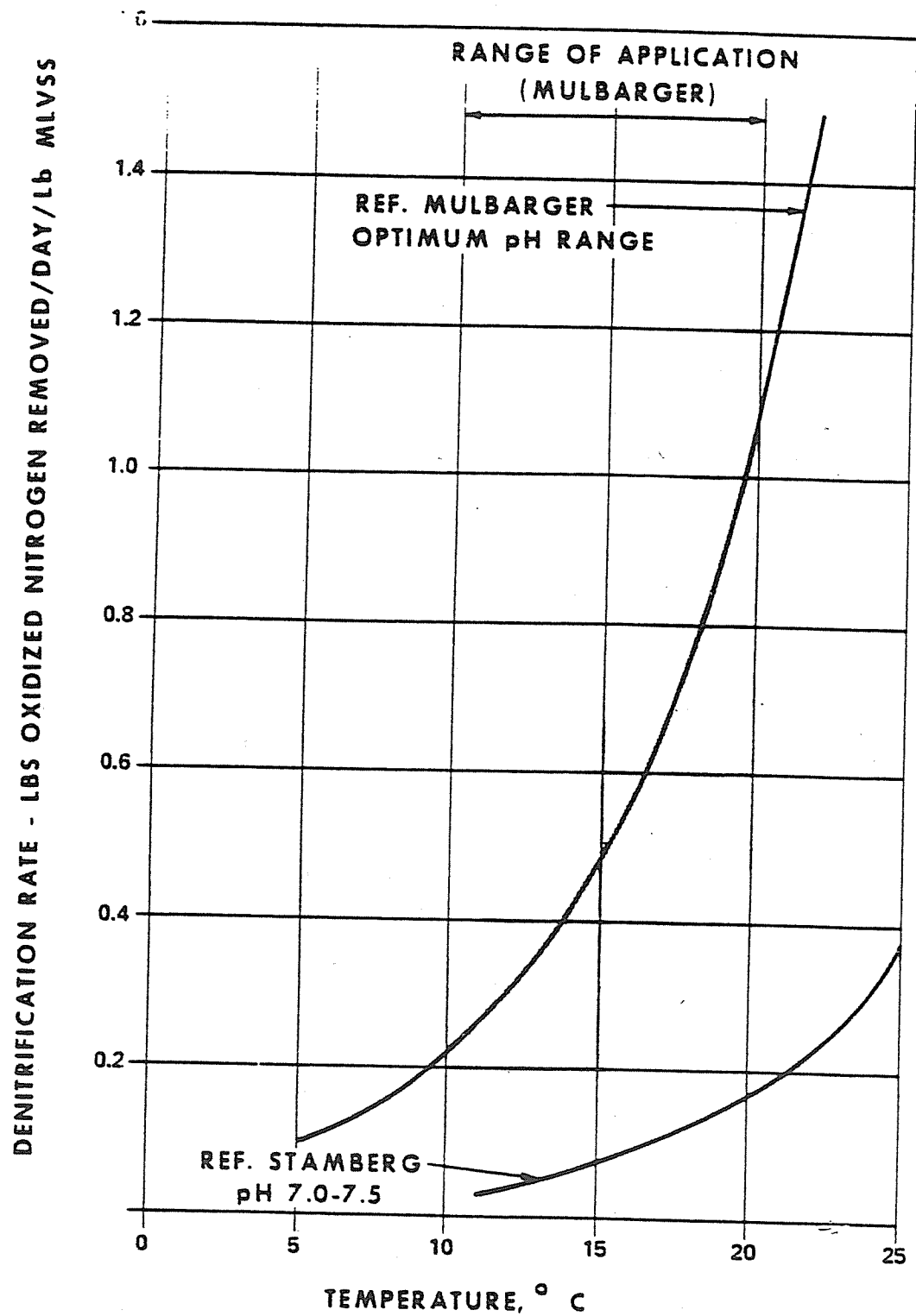


Figure VII - 15
Effect of Temperature on Rate of Denitrification.

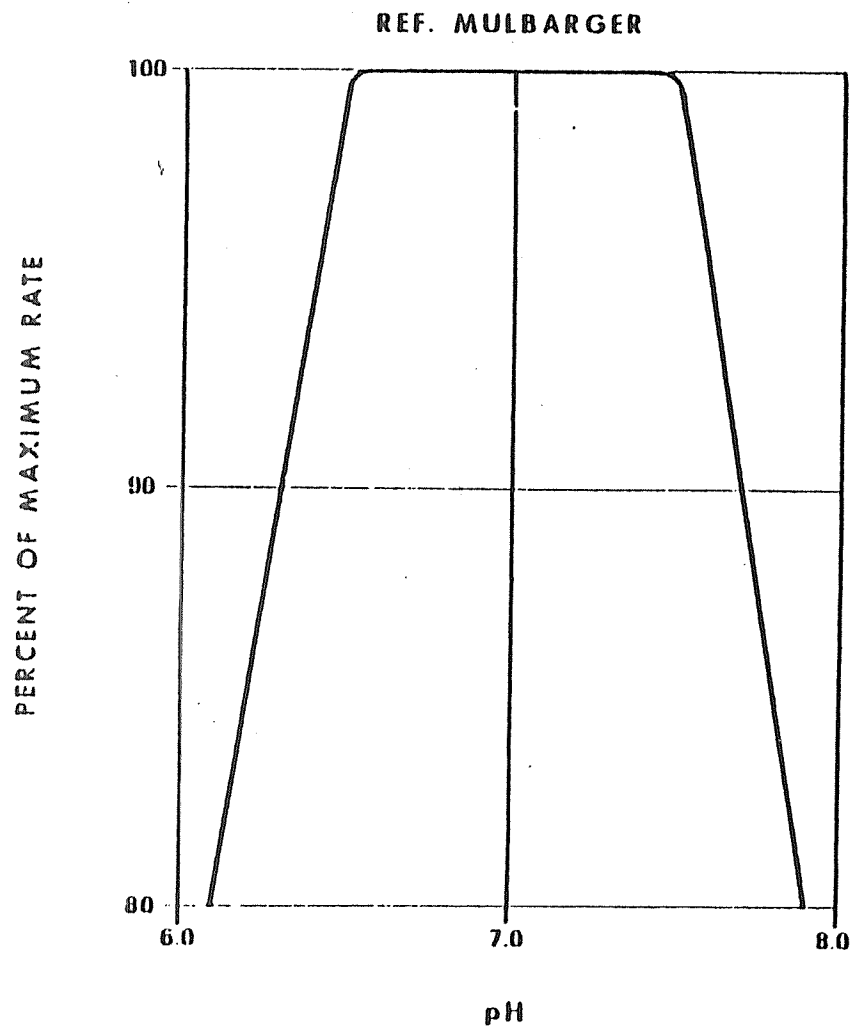


Figure VII - 16

Percent of maximum rate
of denitrification versus pH.

BASED ON DENITRIFICATION RATES
OBSERVED AT MANASSAS, VA.
(REF: MULBARGER)

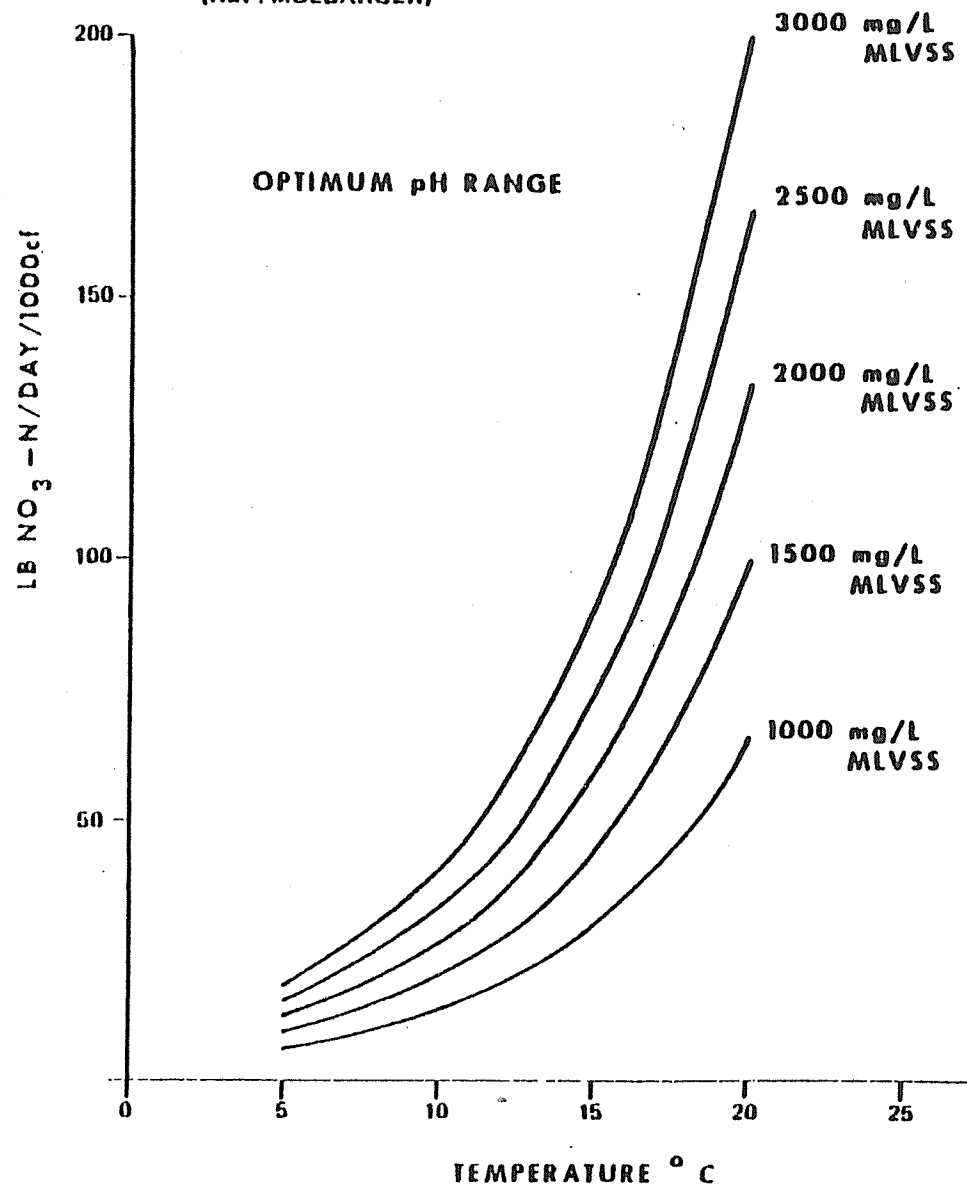


Figure VII - 17

Permissible denitrification-tank loadings.

- 4) Sludge Return and Wasting - Provisions shall be made to vary the return sludge rate between 50 and 100 per cent of the average daily flow.

Sludge wasting will be required periodically. Provisions shall be made for wasting sludge to the carbonaceous sludge scheme. The waste sludge line should also be designed to transport sludge to the nitrification basin when desired.

d. Ammonia Removal.

1) Air Stripping.

a) General - Ammonia stripping consists of a process which

- (1) raises the pH of the effluent to values in the range of 10.8 to 11.5.
- (2) allowing formation and reformation of water droplets in a stripping tower.
- (3) providing air-liquid contact and droplet agitation by high volume air circulation through the tower.

b) Design Criteria - Typical design criteria for ammonia removal using the air stripping tower is given in Table VII - 13.

c) Equipment Requirements.

- (1) Tower - Two basic types of stripping towers may be used in the ammonia removal process.
 - (a) countercurrent
 - (b) cross flow

Parameter	Value
Hydraulic Loading	1 - 3 gpm/ft ²
Air-to-water ratio	300 - 500 ft ³ /min per gpm
Air pressure drop	0.5 to 1.25 inches water
Fan tip speed	9000 to 12000 fpm
Packing depth	20 - 25 ft.
Packing spacing	2 - 4 inches horizontal and vertical
Packing material	Wood, plastic

Table VII - 13
Recommended Design Criteria
Ammonia Removal Air Stripping Towers

- (2) Air-Liquid Distribution - The tower shall be designed to provide uniform distribution of liquid and air over the tower area.
- (3) pH Elevation - Adequate chemical feed systems shall be provided to raise the influent stream to the tower to pH 11.0. The Engineer shall provide complete analysis of buffer capacities, alkalinity, and other pertinent waste characteristics as part of the design report.
- (4) Access - Access shall be provided to the tower packing for cleaning and descaling. High pressure cleaning equipment shall be provided to assist in descaling operation.

2. Organic Removal.

a. Carbon Adsorption.

- 1) Use Requirements - There are currently two approaches for the use of granular activated carbon in wastewater treatment.
 - a) Activated carbon may be employed in a "tertiary" treatment sequence following conventional primary and biological treatment. Tertiary treatment processes using carbon range from secondary effluent treatment with activated carbon only to systems employing chemical clarification, nutrient removal, filtration, carbon adsorption and disinfection.
 - b) Activated carbon may be employed in a "physical-chemical" treatment process in which raw wastewater is treated in a primary sedimentation unit with chemicals prior to carbon adsorption.
- 2) Design Criteria - Table VII - 14 presents general design criteria which should be used in designing carbon adsorption columns using granular activated carbon.

In-depth discussion of carbon adsorption design is found in the EPA Technology Transfer publication, "Process Design Manual for Carbon Adsorption."

- 3) General Structural Requirements.
 - a) Number of Columns - A minimum of two columns (or pairs of columns) shall be provided to assure adequate treatment with one column (or pair of columns) out of service for repairs.
 - b) Gravity vs. Pressure - Either gravity or pressure carbon columns will be acceptable.
 - c) Flow Distribution and Collection Requirements - The columns shall be designed to assure good distribution and collection of the water at the inlet and outlet of the carbon column.

Parameter	Downflow	Upflow
<u>Flow rate/column (GPM/SF)</u>		
Average	3 - 9	3 - 6
2-hour peak	8	5 - 15
<u>Retention Time (Total Treatment)</u> (minutes)		
Low quality (COD 20 mg/1)	30	7.5 - 30
High quality (COD 20 mg./1)	30	
Bed Depth (feet)	8 - 10	5 - 20
Carbon Size (mesh size granules)	8 x 30, or 12 x 40	12 x 40
<u>Backwash Frequency</u>		
Headloss (feet)	6	
Minimum	once daily	
<u>Air Backwash</u>		
Rate (scfm/sf)	3	3 - 5
Duration Time (minutes)	5 - 10	5
Water Backwash (gpm/sf)	14 - 18	15 - 20
	15 - 20	15 - 20
<u>Carbon Capacity (lb COD/lb Carbon)</u>		
High quality effluent	0.5 lb	1.0
Low quality effluent	1.0	
Tertiary system	0.5	

Table VII - 14
Recommended Carbon Adsorption Design
Criteria

In open columns of design similar to gravity filters, the backwash collection troughs shall be covered with a screen to prevent loss of carbon during backwash.

- d) Depth to Diameter Ratio - With good design of the flow distribution and collection system, the depth to diameter ratio is not critical but should not be less than 1:1.

Columns using the media as a means of flow distribution should be designed with a depth to diameter ratio greater than 4:1 to prevent short circuiting.

- 4) Carbon Regeneration - Since organic saturation of carbon beds occurs, the Engineer should investigate the feasibility of carbon regeneration. The best means of restoring the adsorptive capacity of carbon is by thermal regeneration. By heating the carbon in a multiple hearth incinerator at temperatures of 1650° to 1750°F and providing a low oxygen steam atmosphere, carbon can be restored to near virgin adsorptive capacity with only 10 - 15 per cent burning and attrition loss. The Engineer should design these systems with the aid of the multiple hearth incinerator manufacturers.

J. FILTRATION.

There are a number of different types of filters using sand and other media that can be used to improve the quality of the sewage treatment plant effluent. The size of the waste treatment facility and the quantity of flow to be filtered will dictate which type would be most suitable.

Filtration devices are generally gravity fed or pressure fed vessels.

1. Gravity Filters.

- a. Use Requirements - Gravity filters are classified as intermittent slow filters and rapid filters.

Intermittent filtration is generally used in smaller plants for effluent polishing. Rapid filtration is generally used in intermediate to large facilities for suspended solids removal and effluent polishing.

- b. Number of Units - Intermittent gravity filters shall be designed in duplicate to provide for maintenance and continuous treatment while one unit is out of service.

The rapid rate filter systems shall be designed to provide a total filtration capacity equal to the maximum anticipated flow with at least one of the largest filters out of service. In no case shall less than two (2) filters be provided. Consideration will be given to automatic backwash systems on plants less than 250,000 gpd capacity which briefly (<15 minutes) interrupt the filter operation during backwash.

c. Intermittent Sand Filtration.

- 1) Design Loading - The surface loading rate of biologically treated effluents shall not exceed 800,000 gpd per acre.
- 2) Media - The media shall consist of sand and gravel which is clean graded. The media shall be placed in a minimum of 3 layers of gravel, topped with a layer of sand, as required by Table VII - 15.

The layer of gravel around the underdrains shall be placed to a depth of at least 6 inches over the top of the underdrains.

Layer	Media Size	Depth
Bottom (Layer 1)	$\frac{3}{4}$ " - $1\frac{1}{4}$ "	12"
Layer #2	$\frac{1}{4}$ " - $\frac{3}{4}$ "	6"
Layer #3	$\frac{1}{8}$ " - $\frac{1}{4}$ "	6"
Sand	E.S. - .3 to .6 mm U.C. - less than 3.5	24"

Table VII - 15
Intermittent Sand Filter Media
Requirements

- 3) Dosing.
 - a) Volume - A dosing tank shall be provided such that the filter bed will be covered to a depth of 2 to 4 inches by each dose.
 - b) Siphon - The siphon shall have a discharge capacity, at minimum head, at least 100 per cent in excess of the maximum rate of inflow to the dosing tank and, at average head, at least 1 cubic foot per second per 5000 square feet of each filter bed.
 - c) Siphon Discharge Lines - The siphon discharge lines to the beds shall have sufficient capacity to permit the full rated discharge of the siphons through the drawing head range.
- 4) Distribution and Underdrains.
 - a) Arrangement - Troughs or piping used for distribution of the secondary effluent over the filter surface should be so located that the maximum lateral travel is not more than 20 feet. Provisions should be made at each discharge port for adjustment of the flow.
 - b) Splash Slabs - Splash slabs are required at each point of discharge.

- c) Drain - A drain opening from troughs or discharge piping shall be required.
- d) Underdrains - Open jointed or perforated vitrified clay, concrete, or PVC pipe may be used for the underdrains. The piping shall be sloped to the outlet and shall be spaced not more than 10 feet between centers.

The soil base of the filters shall be sloped to the underdrain trenches. Asphalt or other impervious materials are acceptable base alternatives and may be required to protect the ground water quality.

d. Rapid Rate Filtration.

- 1) Design Loading - Table VII - 16 gives the tabulation of recommended design criteria for the rapid rate gravity filter as related to media employed.
- 2) Basin Configuration.
 - a) Length, Width, and Depth - The rapid filters are usually rectangular in shape with a length to width ratio of 1.25 to 1.0.

The depth of the filter unit should be as shallow as possible and be controlled by the minimum permissible distance from filter bottom to freeboard required above the wash water trough or by the maximum operating head of the filter. The overall depth of a filter unit is generally in excess of 8 feet.

- b) Wash Water Troughs - Wash water troughs shall be arranged so that the horizontal flow distance is less than 3 feet for any one gutter. The edge-to-edge distances of parallel gutters should therefore not exceed 6 feet.

All troughs shall be set at the same elevation with overflow weirs along gutter edges by level.

The trough weir shall be located so that loss of sand during backwash will be minimized. The bottom of the wash water trough shall be at least 12 inches above the unexpanded bed.

- c) Filter Underdrainage - Filter underdrains shall be placed in a manner such that the rate of removal of filtered water be uniform over the entire filter bottom and that the backwash water be distributed uniformly.
- d) Rate Controllers - All filtration units shall be equipped with suitable rate control devices for providing a constant rate or variable declining rate to the unit.

Table VII - 16
Recommended Design Criteria
Rapid Rate Gravity Filter

Characteristic	Value	
	Range	Typical
Single-Media		
Sand:		
Depth, in.	10 - 36	24
Effective Size, mm.	0.5 - 0.6	0.5
Uniformity Coefficient	1.2 - 1.8	1.6
Filtration Rate, gpm/sf	12 - 5	3
Water Backwash Rate, gpm/sf (minimum 50% Bed Expansion)	12 - 18	15
Air Backwash Rate, scfm/sf	3 - 5	3
Dual-Medium		
Anthracite:		
Depth, in.	8 - 24	18
Effective Size, mm.	0.8 - 2.0	1.2
Uniformity Coefficient	1.4 - 1.8	1.5
Sand:		
Depth, in.	10 - 24	12
Effective Size, mm.	0.3 - 0.8	0.5
Uniformity Coefficient	1.2 - 1.6	1.4
Filtration Rate, gpm/sf	2 - 10	6
Water Backwash Rate, gpm/sf	13 - 18	15
Air Backwash Rate, scfm/sf	3 - 5	3

Multi-Medium		
Anthracite		
Depth, in.	8 - 20	15
Effective Size, mm.	1.0 - 2.0	1.4
Uniformity Coefficient	1.4 - 1.8	1.5
Sand:		
Depth, in.	8 - 16	12
Effective Size, mm.	0.4 - 0.8	0.6
Uniformity Coefficient	1.2 - 1.6	1.4
Gannet:		
Depth, in.	2 - 4	3
Effective Size, mm.	0.2 - 0.6	0.3
Uniformity Coefficient		1.0
Filtration Rate, gpm/sf	2 - 12	6
Water Backwash Rate, gpm/sf	13 - 20	15
Air Backwash Rate, scfm/sf	3 - 5	3

Filter Pipe	Velocity (fps)	
	Min.	Max.
Influent	1.25	2.5
Effluent	2.1	4.2
Rewash	8.0	10.0
Backwash	8.0	12.0
Surface Wash	8.0	12.0
Backwash Waste	4.0	6.0

Table VII - 17
Recommended Velocities for Filtration Piping

- e) Back Wash Water System - All rapid filtration units shall be equipped with an air scour or mechanical scour method for filter cleaning at 50 per cent bed expansion.
- f) Recommended Pipe Velocities - Average and maximum flow velocity guides for sizing piping on filter plants are tabulated in Table VII - 17.
- g) Sampling - The filter shall be equipped with sampling ports or taps at the inlet and discharge.
- 3) Chlorination - Consideration should be given to the addition of chlorine to the filters.
- 4) Disposal of Wash Water - Dirty wash water generated during backwash shall be collected in a storage basin and shall be metered to the headworks of the waste treatment facility or sludge stabilization process.

The return rate to the headworks shall not exceed 15 per cent of the average design flow and shall be considered as part of the hydraulic and organic plant loading.

2. Pressure Filtration.

- a. Use Requirements - Pressure filters are generally used on facilities where high terminal headlosses are expected (15 - 20 ft) or where the additional head will permit flow to pass through downstream units without repumping. They are most commonly used in small-to-medium sized treatment plants where premanufactured units are economical.
- b. Design Criteria - The design criteria for pressure filters follows the recommended criteria set forth in Table VII - 16.

- c. Basin Configurations - Pressure filters are generally premanufactured items. Basin sizes and appurtenant structures should be as recommended by the equipment manufacturer.

The basic operation of the pressure system will follow the sequence of the rapid rate system. Cleaning and backwashing requirements are also similar.

- d. Chlorination - Consideration should be given to chlorinating the filters.
- e. Disposal of Wash Water - Dirty wash water generated during backwash shall be collected in a storage basin and shall be metered to the headworks of the waste treatment facility.

The return rate to the headworks shall not exceed 15 per cent of the average design flow and shall be considered as part of the hydraulic and organic plant loading.

- f. Controls - The pressure filters shall be provided with the necessary controls to provide automatic operation, including a 50 per cent bed expansion backwash. The controls may be based upon pressure differential or time clock. The piping inlet and outlet shall be provided with a pressure gauge.
- g. Sampling - The filter shall be equipped with sampling ports or taps at the inlet and discharge.

K. WASTEWATER LAGOONS AND PONDS.

A lagoon is defined as a discharging reservoir used for stabilizing or treating raw or partially treated wastewater by natural biological processes. A pond is defined as a reservoir used for holding, storing, and/or treating and disposing of wastewater and/or wastewater effluent.

1. Lagoons.

- a. Use Requirements - Waste treatment lagoons can be divided into three basic types: 1) aerobic, 2) aerobic-anaerobic, 3) anaerobic.

Table VII - 18 itemizes the use requirements of each type and the estimated effluent characteristics from flow-through lagoons expressed in terms of effluent suspended solids and influent BOD₅. The Table shows a range of values because the effluent composition will vary with lagoon locality and mode of operation.

- b. Design Parameter vs. Lagoon Type - Table VII - 19 gives recommended design limits for lagoon systems by lagoon type.

Types of Lagoons and Lagoon Systems	Application	Effluent Characteristics			
		Suspended solids, mg/liter*			BOD ₅ , mg/liter†
		Algae (BOD ₅) _i	Micro- organisms (BOD ₅) _i	Other (SS) _i	Soluble (BOD ₅) _e Suspended (SS) _e
Aerobic (6-18 in. deep)	Nutrient removal, treatment of soluble organic wastes, production of algal cell tissue	0.5-1.2	0.2-0.5	Low	0.02-0.1 0.3-1.2
Aerobic (up to 60 in. deep)		0.4-1.0	0.2-0.5	Low	0.02-0.1 0.3-1.0
Aerobic-anaerobic (oxygen source: algae)	Treatment of untreated screened or primary settled wastewater and industrial wastes	0.2-0.8	0.2-0.5	0.1-0.4	0.02-0.1 0.3-1.0
Aerobic-anaerobic with and without effluent recirculation (oxygen source: surface aerators)	Treatment of untreated screened or primary settled wastewater and industrial wastes	0.02-0.1	0.2-0.5	0.1-0.4	0.02-0.1 0.3-0.8
Anaerobic	Treatment of domestic and industrial wastes	...	0.1-0.3	0.3-0.5	0.05-0.2 0.3-0.8
Anaerobic + aerobic- anaerobic with recircu- lation from aerobic- anaerobic to anaerobic	Complete treatment of wastewater and industrial wastes	...	0.2-0.5	0.05-0.15	0.05-0.1 0.3-0.8
Anaerobic + aerobic- anaerobic + aerobic pond system with recirculation from aerobic to anaerobic	Complete treatment of wastewater and industrial wastes with high bacterial removals	0.05-0.1	0.02-0.05	0.03-0.1	0.02-0.1 0.3-1.0

* Effluent suspended solids are composed of algae and other microorganisms, which are estimated in terms of influent (BOD₅)_i and a fraction of the influent suspended solids (SS)_i.

† Effluent BOD₅ is composed of a fraction of the soluble influent BOD₅ (BOD₅)_i plus a contribution from the effluent suspended solids (SS)_e.

Table VII - 18
Application and Effluent Characteristics
of Various Types of Stabilization Lagoons
and Lagoon Systems

Parameter	Aerobic		Aerobic - Anaerobic		Anaerobic
	High rate	Facultative			
Lagoon Cell Size, Acres (Max.)	10	10	10	10	2.0
Operation	Series or Parallel	Series or Parallel	Series or Parallel	Series or Parallel	Series
Detention time, days	---	10 - 40	7 - 30	7 - 20	20 - 50
Depth, ft.	1 - 1.5	3 - 4	3 - 6	3 - 15	8 - 15
pH	6.5 - 10.5	6.5 - 10.5	6.5 - 9.0	6.5 - 8.5	6.8 - 7.2
Temperature range, °C	0 - 40	0 - 50	0 - 50	0 - 50	6 - 50
Optimum temperature, °C	20	20	20	20	30
BOD ₅ Loading, lb/acre/day	30 - 200	15 - 120	15 - 50	30 - 100	200 - 500
BOD ₅ Conversion	80 - 95	80 - 95	80 - 95	80 - 95	50 - 85
Recirculation	yes	yes	yes	yes	---
Principal Conversion Products	Algae, CO ₂ , bacterial cell tissue	Algae, CO ₂ , bacterial cell tissue	Algae, CO ₂ , CH ₄ , bacterial cell tissue	CO ₂ , CH ₄ , bacterial cell tissue	CO ₂ , CH ₄ , bacterial cell tissue
Algal Concentration, mg/l		80 - 200	40 - 160	10 - 40	---
Primary Oxygen Source	Algae	Algae	Algae	Mechanical or Diffused Aeration	---

Table VII - 19
Design Criteria - Wastewater Lagoons

- 1) Aerobic Lagoon Design - The design of an aerobic lagoon requires that the oxygen resources of the pond be equated to the applied organic loading. The principal source of oxygen in the aerobic lagoon is photosynthesis which is governed by solar energy.

The yield of oxygen can be estimated with the following equation:

$$Y_{O_2} = 0.25FS_{avg}$$

where,

Y_{O_2} = oxygen yield, lb O_2 /acre/day

F = oxygenation factor

S_{avg} = solar radiation, cal/cm²-day (varies with latitude) -
See Table VII - 20.

The oxygenation factor is a representation of the ratio of the oxygen produced to the BOD that will be satisfied in the pond. The use of F of 1.6 will assure BOD removals of from 85 to 90 per cent.

The organic surface loading expressed in lb. BOD/acre/day can be obtained through the following equation:

$$L'_O = C' \left(\frac{d'}{t} \right) BOD_L$$

where,

L'_O = organic loading, lb. BOD/acre/day

C' = conversion factor, 0.226

d' = pond depth, inches

t = retention time, days

BOD_L = ultimate BOD, mg/l

By equating oxygen yield to organic loading, the following equation results, which can be used in the design of aerobic lagoons:

$$\frac{d'}{t} = 1.1 \frac{FS_{avg}}{BOD_L}$$

Values of S may be found from Table VII - 20.

For any worst winter and/or summer month in Arizona, a P = 75 should be used for design.

The design procedure shall be to:

Latitude deg. N.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 Max.	136	176	218	261	290	296	289	271	231	192	148	126
Min.	76	96	135	151	184	163	178	166	147	113	90	70
32 Max.	124	166	211	245	289	296	289	268	226	184	137	114
Min.	66	87	126	145	178	165	177	162	140	104	81	21
34 Max.	113	157	203	229	288	297	289	265	220	176	127	102
Min.	57	79	119	140	174	167	175	158	133	96	71	22
36 Max.	102	148	195	213	287	297	288	263	214	168	116	90
Min.	48	69	111	135	170	169	174	154	126	88	61	22
38 Max.	91	139	188	197	286	298	288	260	208	160	105	78
Min.	39	61	103	130	166	171	173	150	119	80	51	23
40 Max.	80	130	181	181	286	298	288	258	203	152	95	66
Min.	30	53	95	125	162	173	172	147	112	72	42	24

Savg = Smin + P(Smax - Smin)

where P = total hours sunshine divided by total possible hours sunshine

Table VII - 20
Probable Values of Visible Solar Energy as a Function of
Latitude and Month

- a) Determine average minimum and maximum solar radiation.
 - b) Determine retention times during winter and summer.
 - c) Determine lagoon surface area requirements.
 - d) Determine organic surface loading.
- 2) Aerobic-Anaerobic Lagoon Design - Proper design of aerobic-anaerobic lagoons requires consideration of:
- a) BOD removal characteristics
 - b) biological oxygen requirements
 - c) oxygen transfer
 - d) basin geometry
 - e) sludge production

The design of the aerobic-anaerobic lagoon is based upon the principle of the BOD mass balance for a lagoon operating at steady state conditions.

$$1b \text{ BOD removal/day} = 1b \text{ BOD}_{in}/\text{day} - 1b \text{ BOD}_{out}/\text{day}$$

Assuming that loss or gain of water in evaporation, percolation, and precipitation is small and can be neglected, the mass balance equation can be written mathematically as

$$MV' = C_i Q - C_e Q$$

where,

M = BOD removal rate, pounds per day

V' = lagoon volume, gallons

Q = flow rate of sewage, MGD

C_i = BOD_{in}, pounds

C_e = BOD_{out}, pounds

All BOD is 5-day, 20°C.

The power required to surface mix the aerobic-anaerobic lagoon may be from atmospheric conditions or mechanical aeration. In either case the efficiency of BOD removal based upon first-order kinetics is:

$$\% \text{ removal} = \frac{C_e}{C_i} = 100 - \frac{100}{1 + K_t t}$$

where,

K_T = BOD removal rate coefficient at temperature T (°C)

t = retention time, days

Since the designer generally knows the percentage of removal desired and wishes to solve for the retention time necessary to achieve this removal, the equation is rearranged:

$$t = \frac{\% \text{ removed}}{(100 - \% \text{ removed})K_T}$$

A K_T value of 0.25^{-1} at 20°C (K_{20}) should be used for design of lagoons treating domestic wastes.

Since K_T varies with temperature, the reaction rate must be converted to the rate constant of the system under design according to the equation:

$$K_T = K_{20} \theta^{(T - 20)}$$

where,

$$K_{20} = 0.25 \text{ day}^{-1} \text{ (domestic waste only)}$$

$$\theta = 1.058$$

T = temperature ($^\circ\text{C}$) of designed system

K_T = rate constant at $T^\circ\text{C}$

The lagoon system must also be designed as a reactor with axial dispersion, first-order kinetics, and arbitrary entrance and conditions.

Figure VII - 18 shows a plot of BOD removal for axial dispersion factors varying from zero (0) for an ideal plug-flow reactor to infinity (∞) for a complete-mix reactor. Lagoons should be designed using dispersion factors of 0.1 to 2.0. It is recommended that a $d = 1.0$ be used for atmospheric oxygen transfer at shallow depths (3.0 feet) and that a $d = 0.5$ be used in the design of mechanically aerated lagoons of depths in the order of 6 feet. Lagoons deeper than 10 feet should use a $d = 0.0625$.

The design procedure shall be to:

- a) based upon the lagoon depth and loading characteristics, select the dispersion factor.
- b) from Figure VII - 18, determine the value of $K_T t$ for the selected dispersion factor and the desired efficiency.
- c) determine the winter and summer reaction rate constants.
- d) determine the winter and summer retention times.
- e) determine the lagoon volume and surface area requirements, summer and winter.
- f) Determine the horsepower requirements for surface aeration. Check the horsepower input to determine if complete mixing will occur. Note: Complete mixing should not occur in a properly designed aerobic-anaerobic lagoon.

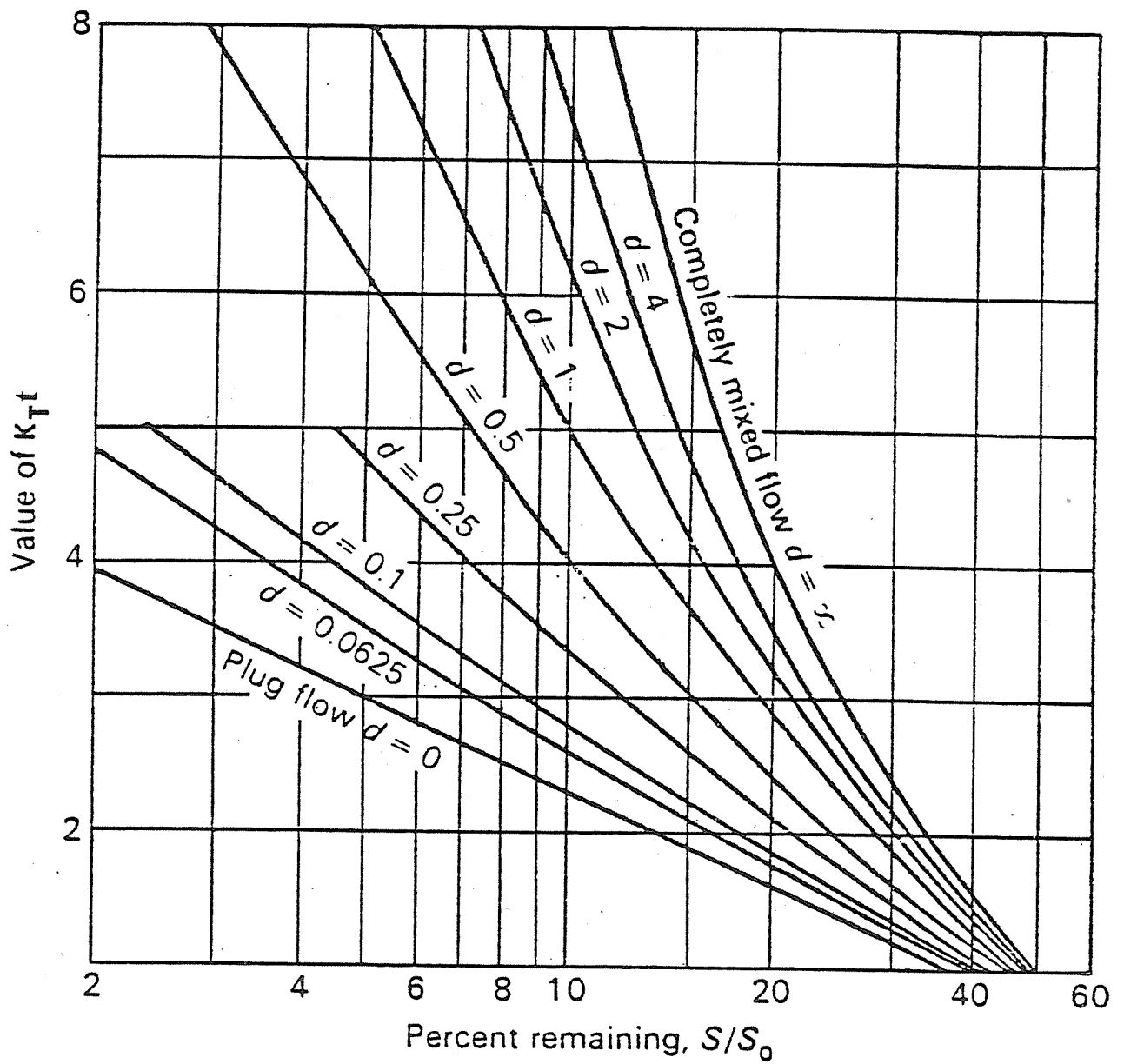


Fig. VII - 18
Values of $K_T t$ vs. % Remaining
For Various Dispersion Factors
In Lagoon Design

- 3) Anaerobic Lagoon Design - Anaerobic lagoon should be designed using the basic principles of anaerobic digestion. The anaerobic lagoon is essentially a large unheated unmixed digester; therefore, the basic design should follow that found in the anaerobic digestion design criteria in Section L.
- c. Industrial Wastes - Due consideration shall be given to the type and affects of industrial wastes on the treatment process.
- d. General Design Features.
 - 1) Multiple Units - Multiple cells designed to permit both series and parallel operation are required for all installations. This flexibility is desirable when loadings are light or when a community is installing a new sewer system, since in the period preceding substantial connections, the entire discharge can be put into a single cell, thus facilitating the maintenance of satisfactory water levels. In addition, when a low algae content in the effluent is desired, the cells may be advantageously operated in parallel during fall, winter, and spring when algae development is less intensive and in series during the summer months. Series operation is also beneficial where a high level of BOD or coliform removal is important.

Where a greater degree of treatment is necessary or desirable, or more cells in series may be added to the primary cell. The primary cell, when designed for series operation, should be designed to handle the maximum loading.

- 2) Lagoon Shape - The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular cells with a length not exceeding 3 times the width are considered most desirable. Dikes should be rounded at corners to minimize accumulations of floating materials.
- 3) Lagoon Construction Details.
 - a) Embankments and Dikes - Embankments and dikes shall be constructed of relatively impervious materials and compacted sufficiently to form a stable structure. Soils with a permeability coefficient ranging from 10^{-2} to 10^{-4} cm/sec are considered to be relatively impervious. Vegetation should be removed from the area upon which the embankment is to be placed.

The minimum embankment top width shall be 8 feet to permit access of maintenance vehicles. Lesser top widths will be considered for berms where vehicles will not enter.

Inside and outside embankment slopes shall not be steeper than 3 horizontal to 1 vertical unless sufficient erosion protection is given embankments.

Embankment slopes should not be flatter than:

- (1) Inner - 4 horizontal to 1 vertical. Flatter slopes are sometimes specified for larger installations because of wave action but have the disadvantage of added shallow areas conducive to emergent vegetation.
 - (2) Outer - sufficient to prevent significant volumes of surface water from entering the lagoons.
- b) Freeboard - Minimum freeboard shall be 3 feet.
- c) Depth - Minimum and maximum depths shall be as allowed in Table VII - 19.
- d) Seeding - Embankments shall be seeded from the exterior berm toe to 1 foot above the lagoon high water line measured on the dike slope. Perennial type, low growing, spreading grasses that withstand erosion and can be kept mowed are most satisfactory for seeding of embankments. In general, alfalfa and other long-rooted crops should not be used in seeding, since the roots of this type plant are apt to impair the water holding efficiency of the dikes. Additional protection for embankments (riprap) may be necessary where the dikes are subject to erosion due to flooding of an adjacent watercourse or internal wave action.
- e) Vegetation Control - A method shall be specified which will prevent vegetation growth over the bottom of the lagoon and up to 1 foot above the water line on the dikes.
- f) Embankment Compaction - Embankment of earth material shall be placed in horizontal layers not exceeding 8 inches in loose measurement and compacted as follows:
 - (1) Where embankments 5 feet or less in height are to be constructed, the top 6 inches of the ground on which the embankment material is to be placed shall be compacted to a density of not less than 90 per cent of the maximum density.
 - (2) Embankment material shall be compacted to a density of not less than 95 per cent of maximum density.
- 4) Lagoon Bottom - The lagoon bottom shall be as level as possible except at the discharge of the inlet. Finished elevations should not be more than 3 inches from the average elevation of the bottom. Shallow or feathering fringe areas usually result in locally unsatisfactory conditions.

The bottom shall be cleared of vegetation and debris. Organic material thus removed shall not be used in the dike core construction. However, suitable topsoil relatively free of debris may be used as cover material on the outer slopes of the embankment.

The soil formation or structure of the bottom should be relatively tight to avoid excessive liquid loss due to percolation or seepage. Soil borings and tests to determine the characteristics of surface soil and subsoil shall be made a part of preliminary surveys to select lagoon sites. Gravel and limestone areas may be used only where the lagoon system is properly lined.

The ability to maintain a satisfactory water level in the lagoons is one of the most important aspects of design. Removal of porous topsoil and proper compaction of subsoil improves the waterholding characteristics of the bottom. Removal of porous areas, such as gravel or sandy pockets, and replacement with well-compacted clay or other suitable material may be required.

When the wastewater contains toxic substances; where the possibility of ground water contamination exists; or where the soil percolation rate is less than 60 minutes per inch, sealing of the lagoon bottom with a clay blanket, bentonite, or other sealing material shall be required.

Supplementary field survey data including soil borings, and percolation testing shall be submitted to the Department with the final design report for approval.

- 5) Influent Lines - All types of pipe used in design shall have established ASTM, ANSI, or NSF standards of manufacture.

Influent lines should be located along the bottom of the lagoon so that the top of the pipe is just below the average elevation of the lagoon bottom. This line can be placed at zero grade.

The discharge point of the influent line to a single celled lagoon shall be placed and positioned to minimize short circuiting of the raw wastewater. Each cell of a multiple celled lagoon operated in parallel should have its own near center inlet, but this does not apply to those cells following the primary cell when series operation alone is used. Influent lines or interconnecting piping to secondary cells of multiple celled lagoons operated in series may consist of pipes through the separating dikes. Influent lines to rectangular lagoons should terminate at approximately the third point farthest from the outlet structure. The effluent piping should be located to minimize short-circuiting within the lagoon.

The inlet line shall discharge horizontally into a shallow, saucer-shaped depression. The depth of the depression shall be not more than the diameter of the influent pipe plus 1 foot.

The end of the discharge line should rest on a suitable concrete apron with a minimum size of 2 feet square.

- 6) Manholes - A manhole shall be installed at the terminus of the outfall line or force main and shall be located as close to the dike as topography permits, and its invert should be at least 6 inches above the maximum operating level of the lagoon to provide sufficient hydraulic head without surcharging the manhole.

Manholes which accept flow from force mains should provide proper energy dissipation of the incoming waste.

- 7) Overflow Structures and Interconnecting Piping - Interconnecting piping and overflows should be of cast iron pipe or corrugated metal pipe of ample size. Plastic pipe will not be allowed due to solar radiation deterioration of material.

Overflow structures should consist of a manhole or box equipped with multiple-valved lagoon drawoff lines or an adjustable overflow device so that the liquid level of the lagoon can be adjusted to permit operational flexibility. The drawoff lines or overflow devices shall be designed to operate at maximum of 1 foot intervals. The lowest of the drawoff lines of such structure should be 12 inches off the bottom to control eroding velocities and to avoid pickup of bottom deposits. The overflow from the lagoon shall be taken 6 inches below the water surface to release the best effluent and insure retention of floating solids. The structure should also have provisions for draining the lagoons.

When possible, the outlet structure should be located on the windward side to prevent short circuiting. Consideration must be given in the design of all structures to protect against freezing or ice damage under winter conditions. All overflow structures shall have access platforms as required.

- 8) Interconnecting Piping - Interconnecting piping for multiple unit installations operated in series shall be valved or provided with other arrangements to regulate flow between structures and permit flexible depth control. The interconnecting pipe to the secondary cell should discharge horizontally near the lagoon bottom to minimize need for erosion control measures and should be located as near the dividing dike as construction permits.
- 9) Flow Measurement - Provisions for flow measurement shall be provided on the inlet and outlet.
- 10) Depth Control - The Engineer shall make provision for depth control of the lagoon system.

Optimum liquid depth is influenced to a degree by lagoon area since circulation in larger installations permits greater liquid depths. The basic plan of operation may also influence depth.

Facilities to permit operation at selected depths between the limits shown in Table VII - 19 are required for operational flexibility. Where winter operation is desirable, the operating level can be lowered before ice formation and gradually increased to its maximum depth by retention of winter flows. In the spring, the level can be lowered to any desired depth at the time surface runoff and dilution water are generally at a maximum. Shallow operation can be maintained during the spring with generally increased depths to discourage emergent vegetation. In the fall, the levels can be lowered and again be ready for retention of winter storage.

- e. Lagoon Recirculation - Lagoon recirculation involves interlagoon and intralagoon recirculation as opposed to mechanical mixing in the lagoon cell. The effluents from lagoon cells are mixed with the influent to the cells. In intralagoon recirculation, effluent from a single cell is returned to the influent to that cell. In interlagoon recirculation, effluent from another is returned and mixed with influent to the lagoon.

Both methods return active algal cells to the feed area to provide photosynthetic oxygen for satisfaction of the organic load. Intralagoon recirculation allows the lagoon to gain some of the advantages that a completely mixed environment would provide if it were possible in a lagoon. It helps prevent odors and anaerobic conditions in the feed zone of the lagoon.

One objective of recirculation in the series arrangement is to decrease the organic loading in the first cell of the series. While the loading per unit surface is not reduced by this configuration, the retention time of the liquid is reduced. The method attempts to flush the influent through the lagoon faster than it would travel without recirculation. The hydraulic retention time of the influent and recycled liquid in the first, most heavily loaded lagoon in the series system is:

$$t = \frac{V_c}{(1 + r)F'}$$

where V_c is the volume of lagoon cell; F' is the influent flow rate; r , or cR/F' , is the recycle ratio; and R is the recycle flow rate. R generally varies from 0.5 to 2.0 F'_{avg} .

Another advantage of recirculation in the series configuration is that the BOD_5 in the mixture entering the lagoon is reduced, and is given by the expression:

$$S_m = \frac{S_{in}}{1 + r} = \left(\frac{r}{1 + r}\right) S_3$$

where S_m is the BOD_5 of the mixture, S_3 is the effluent BOD_5 from the third cell, and S_{in} is the influent BOD_5 . Thus, S_m would be only 20 per cent of S_{in} with a 4:1 recycle ratio, as S_3 would be negligible in almost all cases. Thus, the application of organic load in the lagoon

is spread more evenly throughout the lagoons, and organic loading and odor generation near the feed points are less. Recirculation in the series mode has been used to reduce odors in those cases where the first lagoon is anaerobic.

The parallel configuration more effectively reduces lagoon loadings than does the series configuration, because the mixture of influent is spread evenly across all lagoons instead of the first cell in a series. Recirculation has the same benefits in both configurations.

Recirculation usually is accomplished with high-volume, low-head propeller pumps. Design of the pumping system shall be in accordance with the requirements in Section N. Siphon breaks shall be provided to insure positive backflow protection.

Lagoon configuration should allow full use of the wetted cell area. Transfer inlets and outlets should be located to eliminate dead spots and short circuiting that may be detrimental to photosynthetic processes. Wind directions should be studied, and transfer outlets located to prevent dead pockets where scum will tend to accumulate.

- f. Algae Removal - Specific attention shall be given to removing algae from wastewater lagoon effluents. Acceptable methods for achieving algae removal include:
 - 1) Dissolved Air Flotation - Dissolved air flotation is a feasible alternative when coagulating chemicals are employed with the operation. Alum is the primary coagulant used at doses ranging from 125 to 300 mg/l. Overflow rates vary from 1.3 to 4.0 gallons per minute per square foot, while retention times vary from 8 to 17 minutes. Pressurized recycle ranges from 25 to 100 per cent at pressures between 35 and 70 psig. Air to solids ratio generally ranges from 0.05 to 0.10.
 - 2) Centrifugation - Successful algae removal has been achieved by using the centrifugation operation without coagulants. 80 - 90 per cent removal can be achieved on effluent SS of 200 mg/l.
 - 3) Coagulation-Flocculation-Sedimentation - High efficiency of algae removal can be achieved using the coagulation-flocculation-clarification operation. Alum is generally used as the primary coagulant. Doses range from 45 to 500 mg/l. Overflow rates for the sedimentation basins range from 0.2 to 0.8 gpm/ft². Tubular settlers have allowed the loading rate to increase to 2.0 - 2.5 gpm/sf. Hydraulic retention times range from 3 to 4 hours for conventional clarification. The flocculation tank design will require retention times of 25 minutes with a G value of 36 to 51 per second. Underflows from the clarifier are generally 1.0 to 1.5 per cent by weight.

- 4) Coagulation-Clarification Followed by Filtration - The application of polishing clarification effluent will result in effluent solids less than 10 mg/l. Loading rates of rapid sand or multi-media filters will range from 2.0 gpm/ft² to 5.5 gpm/ft².
- 5) Intermittent Sand Filtration - Intermittent sand filtration is also an acceptable algae removal alternative. Feed SS concentrations of 72 mg/l have been reduced to 4 mg/l with loading rates ranging from 4.6 to 9.2 gpdpsf.
- 6) Slow Rock Filter - The upflow submerged rock filter has been found to be an effective means of algae removal. A 24-hour hydraulic retention time at a surface loading rate of 0.008 gpm/ft² has been used. The unit may be sized using 27 ft³ of filter volume for 100 gpcpd. River run gravel between 1/2 to 2 inches and crushed rock between 2 - 3 inches may be used as the filter media. The system may be designed to provide a hydraulic flow range between 3 to 7 gallons per day per cubic feet of submerged filter volume.
- 7) Other Methods - Other methods such as fill-draw ponds, etc. will be considered in accordance with the requirements of Chapter III.

In all cases, it is recommended that pilot studies be employed to establish design criteria for the facility under design.

2. Ponds.

- a. Use Requirements and Classification - Ponds are classified into three categories:

- 1) evaporation
- 2) percolation
- 3) effluent holding

The evaporation pond may be used for raw sewage or sewage effluent. The percolation and effluent holding pond shall only be applied to wastewater effluent.

- b. Design Parameters vs. Pond Type.

- 1) Evaporation Ponds - Evaporation ponds shall be designed using the evaporation data established by Figure VII - 19 and Figure VII - 20. Since localized conditions are not shown in Figure VII - 20, the Engineer shall make necessary adjustments based upon elevation. The pond shall be designed such that periods of high evaporation can be maintained in one basin with subsequent basins in series which will absorb the flow in periods of low evaporation.

Evaporation ponds shall be designed using the principles of mass balance.

$$Q_{in} = Q_{out}$$

$$Q_{in} = Q_{evaporation} - Q_{precipitation}$$

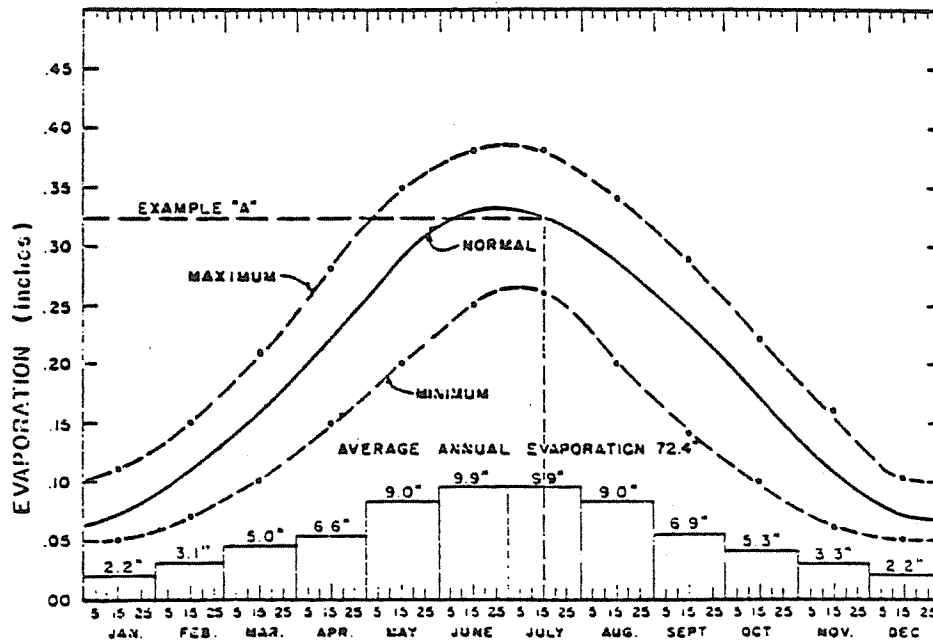


Figure VII - 19

**Maximum, Normal and Minimum
Daily Evaporation and Average Monthly
Evaporation From Open Water Surfaces
(Adjustment Factor = 1.00)**

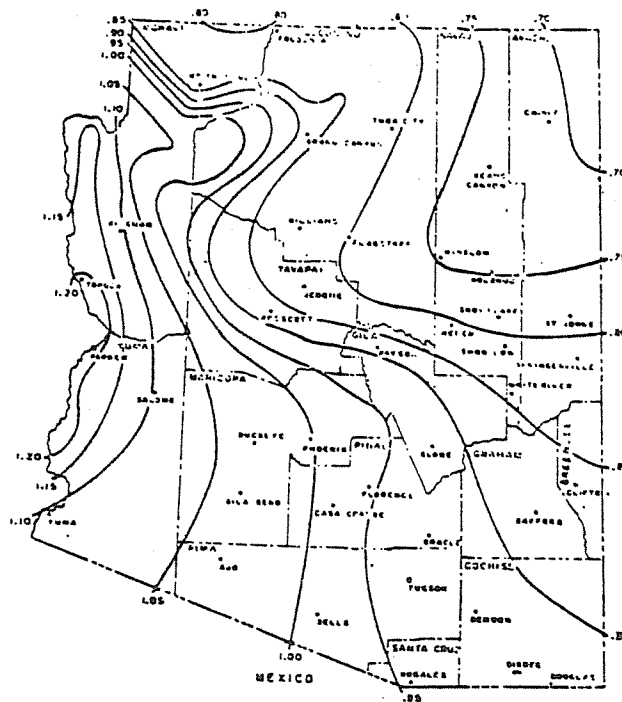


Figure VII - 20

Evaporation Adjustment Factors for Arizona

Since evaporation ponds are designed based upon surface area requirements, the depth of the pond is unimportant. The evaporation ponds shall be sealed with pond liners, soil cement, asphaltic material, clay compounds, or other approved sealing methods.

- 2) Percolation Ponds - Percolation ponds shall not be used for effluent disposal where the possibility of ground water contamination exists. The Engineer shall submit data showing the impact on the ground water using the percolation method.

The percolation pond shall be designed, using principles of mass balance.

$$Q_{in} = Q_{evaporation} - Q_{precipitation} + Q_{percolation}$$

The Engineer shall provide percolation data at the elevation of the pond floor to substantiate design criteria. The percolation data shall be established in a manner which uses only the bottom area of the test hole. The Engineer shall provide the proper number of percolation tests and boring logs, the detailed boring logs, and data regarding location of ground water table as specified in Engineering Bulletin No. 19.

Special attention shall be given to the existing soil conditions and soil chemistry related to the increase of salinity concentration and its affect on the soil and its ability to provide stable percolation.

Provisions shall be made in pond construction to temporarily drain one cell to scarify and renew the bottom surface area without interrupting operation of the pond system.

- 3) Effluent Holding Basins - Effluent holding basins shall be designed for the full retention intended and shall be provided with an emergency overflow. The basin may be earthen (sealed or unsealed), concrete or constructed of other suitable materials of construction.

When the wastewater contains toxic substances; where the possibility of ground water contamination exists; or where the soil percolation rate is less than 60 minutes per inch, sealing of the lagoon bottom with a clay blanket, bentonite, or other sealing material shall be required.

c. General Features.

- 1) Pond-Dike Construction.

- a) Pond Dikes shall be constructed with a maximum 3:1 slope unless indicated otherwise in this Bulletin.

Pond Type	Minimum Depth	Maximum Depth
Evaporation		
1. Effluent	3	8
2. Raw Waste	3	5
Percolation	3	8
Effluent Holding	3	15

Table VII - 21
Recommended Pond Operating Depths

The dikes shall be protected against wave action erosion from at least 1 foot below the minimum water surface to at least 1 foot above the maximum water surface.

- b) The top of the dike shall be at least 8 feet in width.
- c) Minimum freeboard shall be 3 feet.
- 2) Pond Depth - The minimum and maximum depths recommended for each type pond is tabulated in Table VII - 21.
- 3) Multiple Units - Consideration should be given to assuring operational flexibility by providing multiple pond cells connected in parallel and series. The design shall be such that any unit may be removed from operation without interrupting treatment.
- 4) Pond Shape - The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular ponds with a length not exceeding 3 times the width are considered most desirable. Dikes should be rounded at corners to minimize accumulations of floating materials.
- 5) Influent Lines - Any generally accepted material for underground sewer construction shall be used for the influent line to the pond. The material selected should be adapted to local conditions.

A manhole shall be installed at the terminus of the outfall line or the force main and shall be located as close to the dike as topography permits, and 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.

Influent lines should be located along the bottom of the pond so that the top of the pipe is just below the average elevation of the pond bottom. This line can be placed at zero grade.

The inlet line of raw waste evaporative ponds shall discharge horizontally into a shallow, saucer-shaped depression. The depth of the depression shall be not more than the diameter of the influent pipe, plus 1 foot.

The end of the discharge line should rest on a suitable concrete apron with a minimum size of 2 feet square.

- 6) Flow Measurement - Provisions for flow measurement should be provided on the inlet.

3. Other Requirements.

- a. Pond or Lagoon Sealing - Ponds or lagoons may be sealed by chemical or geological means such as soil cement, asphaltic products, special chemicals which seal the pond or lagoon, or by bentonite clay/soil mixture.

In some cases, these methods should only be employed where a constant level in the pond or lagoon will be maintained.

The Engineer should consult the manufacturer of the product and/or a soils engineering laboratory for the proper soil/cement ratio, chemical/soil ratio, or clay/soil ratio in each particular application.

The side slope requirement shall be 3:1 ratio maximum in all cases where chemical or geological sealants are employed.

- b. Pond Lining - Where plastic or rubber liners are employed to seal ponds or lagoons, the liner shall be not less than 20 mils in thickness, and should preferably be 40 mils. Exposed liner materials shall be selected to provide minimum deterioration.

The liners shall extend over the freeboard of the ponds or lagoons, and a positive seal shall be provided at all points requiring a break in the pond lining.

The use of pond liners may enable the Engineer to provide a side slope of greater than 3:1 depending upon soil conditions. In such cases, soils reports shall be submitted to the Department verifying the ability of the soil to maintain such a slope.

A positive means of tiedown of the liner around the top periphery shall be included in the design of the liner application.

L. SLUDGE STABILIZATION.

Digestion, either aerobic or anaerobic, is a means of stabilizing waste solids by long term retention, thereby reducing the BOD and destroying volatile solids.

1. Anaerobic Digestion.

a. Design Criteria - Recommended loadings and retention times for heated digesters are tabulated in Table VII - 22.

b. General Structural Requirements.

- 1) Multiple Units - Multiple tanks are recommended. Where a single digestion tank is used, it is desirable to have a lagoon or storage tank for emergency use so that the tank may be taken out of service without unduly interrupting plant operations.

Provision for sludge storage and supernatant separation in an additional unit may be required, depending on raw sludge concentration and disposal methods for sludge and supernatant.

- 2) Depth - The proportion of depth to diameter should be such as to allow for the formation of a reasonable depth of supernatant liquor. Depths normally range from 15 to 30 feet side water depth.
- 3) Maintenance Provisions - To facilitate emptying, cleaning, and maintenance, the following features are desirable:
 - a) Slope - The tank bottom shall slope to drain toward the withdrawal pipe. Generally, the bottom slopes are 1 vertical to 6 or more horizontal.

	Conventional Single Stage (Unmixed)	First Stage High-Rate (Complete Mixing)
Loading (lb VS destroyed/ft ³ day)	0.02 - 0.05	0.1 - 0.2
Retention Time (days)	30 - 90	10 - 15
Volatile Solids Reduction (%)	50 - 70	50

Table VII - 22
Recommended Anaerobic Digestion
Design Criteria

- b) Access Manholes - At least 2 access manholes shall be provided in the top of the tank in addition to the gas dome. One opening should preferably be large enough to permit the use of mechanical equipment to remove grit and sand. A separate side wall manhole shall be provided.
 - c) Cleanouts - Cleanouts shall be provided on the sludge inlets and outlets, sludge recirculation lines, and other piping which may be subject to plugging.
- 4) Sludge Inlet and Outlets - Multiple sludge inlets and draw-offs and, where used, multiple recirculation suction and discharge points to facilitate flexible operation and effective mixing of the digester contents shall be provided 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 discharge points shall be so located as to minimize short circuiting to the supernatant draw-off.
- 5) Tank Capacity - In recent years, a number of modifications to the conventional anaerobic sludge digestion process have been developed, especially in the area commonly known as "high rate digestion". Design standards, operating data and experience are not well established for some of these modifications. This should be considered in the selection and design of the process modification.

The total digestion tank capacity should be determined by rational calculations based upon such factors as volume of sludge added, its per cent solids and character, the temperature to be maintained in the digesters, the degree or extent of mixing to be obtained, the degree of volatile solids reduction required, and the size of the installation with appropriate allowances for sludge and supernatant storage.

When such calculations are not submitted to justify the design based on the above factors, the minimum combined digestion tank capacity shall be as follows:

- a) Completely Mixed Systems - The system shall be loaded not to exceed 80# VS/1000 cf/day in the active digestion units.
- b) Moderately Mixed Systems - The system shall be loaded not to exceed 40 lb VS/1000 cf/day in the active digestion units.

Such requirements assume that the raw sludge is derived from ordinary domestic wastewater, a digestion temperature is to be maintained in the range of 85° to 95°F, 40 to 50 per cent volatile matter in the digested sludge, and that the digested sludge will be removed frequently from the process.

- c. Gas Collection, Piping, and Appurtenances - 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 pressure. All enclosed areas where any gas leakage might occur shall be adequately ventilated.
- 1) 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 shut-off valves, are essential. Water seal equipment shall not be installed.
 - 2) 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.
 - 3) Gas Utilization Equipment - Gas burning boilers, engines, etc. should be located at ground level and in well ventilated rooms. Gas lines to these units shall be provided with suitable flame traps.
 - 4) Electrical Systems - Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, control circuits, etc.) in enclosed or partially enclosed spaces where volatile flammable liquids or flammable gases are handled, processed or used but in which the hazardous liquids, vapors or gases normally will be confined within closed containers or closed systems should comply with the National Electrical Code requirements for Class I Division 2 locations.
 - 5) Waste Gas - Waste gas burners shall be readily accessible and should be located at least 25 feet away from any plant structure if placed at ground level, or may be located on the roof of the control building if sufficiently removed from the tank. In remote locations, it may be permissible to discharge the gas to the atmosphere through a return-bend screened vent terminating at least 10 feet above the walking surface provided the assembly incorporates a flame trap.
 - 6) Ventilation - Any underground enclosure connecting with digestion tanks or containing sludge or gas piping or equipment shall be provided with forced ventilation. Ventilation may be either continuous or intermittent. Continuous ventilation should provide at least 6 complete air changes per hour. Intermittent ventilation shall provide at least 30 complete air changes per hour.

All intermittently operated ventilating equipment should be interconnected with the respective lighting system. Consideration should be given also to automatic controls where intermittent operation is used. Switches for operation of ventilation equipment should be marked and conveniently located. Tightly fitting self-closing doors should be provided at connecting passageways and tunnels to minimize the spread of gas.

- 7) Meter - A gas meter with by-pass should be provided to meter total gas production.

d. Digestion Tank Heating.

- 1) Insulation - Wherever possible, digestion tanks should be constructed above ground water level and should be suitably insulated to minimize heat loss.
- 2) Heating Facilities - Sludge may be heated by circulating the sludge through external heaters or by units located inside the digestion tank.
 - a) External Heating - Piping shall be designed to provide for the preheating of feed sludge before introduction to the digesters. Provisions shall 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.
 - b) Internal Coils - Hot water coils for heating digestion tanks should be at least 2 inches in diameter and the coils, as well as the support brackets and all fastenings, should be of corrosion resistant materials. The use of dissimilar materials should be avoided to minimize galvanic action. The high point in the coils should be vented to avoid air lock.

Other types of heating facilities will also be considered on their own merits.

- 3) Heating Capacity - Sufficient heating capacity shall be provided to maintain a constant design sludge temperature. Where digestion tank gas is used for other purposes, an auxiliary fuel may be required.
- 4) Hot Water Internal Heating Controls.
 - a) Mixing Valves - A suitable automatic mixing valve shall 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 at which caking will be accentuated. Manual control should also be provided by suitable by-pass valves.
 - b) Boiler Controls - The boiler shall be provided with suitable automatic controls to maintain the boiler temperature at approximately 180°F to minimize corrosion and to shut off the main gas supply in the event of pilot burner or electrical failure, low boiler water level, or excessive temperature.

- c) Thermometers - Thermometers shall be provided to show temperatures of the sludge, hot water feed, hot water return, and boiler water.
- 5) External Heater Operating Controls - All controls necessary to insure effective and safe operation are required.
- 6) Digester 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.
- e. Supernatant Withdrawal.
 - 1) Piping Size - Supernatant piping should not be less than 6 inches in diameter.
 - 2) Withdrawal Arrangements.
 - a) Withdrawal Levels - Piping shall be arranged so that withdrawal can be made from 3 or more levels in the tank. A positive unvalved vented overflow shall be provided.
 - b) 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.
 - c) Supernatant Selector - If a supernatant selector is provided, provisions shall be made for at least 1 other draw-off level located in the supernatant zone of the tank, in addition to the unvalved emergency supernatant draw-off pipe. High pressure back-wash facilities shall be provided.
 - 3) Sampling - Provision shall be made for sampling at each supernatant draw-off level. Sampling pipes should be at least 1 1/2 inches in diameter.
 - 4) Alternate Supernatant Disposal - An alternate disposal method for the supernatant liquor such as a lagoon, an additional sand bed or hauling from the plant site should be provided for use in case supernatant is not suitable or other conditions make it advisable not to return it to the plant headworks. Consideration should be given to supernatant conditioning, where appropriate, in relation to its effect on plant performance and effluent quality.

2. Aerobic Digestion.

- a. Design Criteria - Table VII - 23 gives recommended design criteria for aerobic digestion.

Parameter	Value
<u>Hydraulic retention time, (day @ 20°C)</u>	
Activated sludge only	12 - 16
Activated sludge from plant, operated without primary settling	16 - 18
Primary plus activated or trickling filter	18 - 22
Solids loading, lb. VS/ft ³ /day	0.1 - 0.2
<u>Oxygen requirements (lb/lb)</u>	
Cell tissue	2
BOD in primary sludge	1.7 - 1.9
<u>Mixing requirements</u>	
Mechanical aerators, hp/1000 ft ³	0.5 - 1.0
Diffused air mixing, scfm/1000 ft ³	20 - 30
Dissolved Oxygen level in liquid, mg/l	1 - 2

Table VII - 23
Recommended Design Criteria for Aerobic Digesters

- d. General Structural Requirements - Aerobic sludge digestion is accomplished in a tank or tanks designed to provide effective air mixing, reduction of the organic matter, supernatant separation, and sludge concentration under controlled conditions.

- 1) Number of Tanks - Multiple tanks are recommended. A single sludge digestion tank may be used in the case of small treatment plants. The design of the facility should be such that the single tank will not adversely affect normal plant operations.

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 per cent solids and character, the degree of volatile solids reduction required, the size of installation with appropriate allowance for sludge and supernatant storage.

- 2) Mixing - Aerobic sludge digestion tanks shall be designed for effective mixing by satisfactory aeration equipment. If diffusers are used, they shall be non-clogging and shall be designed to permit removal for inspection, maintenance, and replacement without dewatering the tanks.

3) Supernatant Separation - Facilities shall be provided for effective separation or decantation of supernatant.

c. Sampling Devices - Provision shall be made for sampling the supernatant draw-off, incoming feed, and stabilized sludge withdrawal.

M. SLUDGE HANDLING AND DISPOSAL.

Sludge handling and disposal techniques employed in waste treatment are a function of the type, size, and location of the treatment plant, unit operations used in treatment, and the method of ultimate solids disposal.

The basic unit operations may include sludge conditioning, sludge beds or mechanical dewatering, incineration, or some other drying operation, and ultimate sludge disposal via sanitary landfill or spreading of sludge on agricultural land.

1. Sludge Conditioning.

a. Use Requirements - Sludge conditioning involves addition of any material to the sludge or any physical process to which the sludge is subjected prior to dewatering, for the purpose of increasing production rate, increasing cake solids content, and improving solids capture.

Heat treatment or chemical oxidation of sludges generally will eliminate the need for chemical conditioning, and will also provide a stable, sterilized sludge.

The Engineer should perform field testing to determine the most feasible means of sludge conditioning prior to dewatering and/or sludge disposal.

b. Chemical Dose Requirements - The most commonly used chemicals employed in sludge conditioning are ferric chloride, ferrous chloride, aluminum sulfate, lime, and polyelectrolytes.

At times, combinations of chemicals may be required to achieve the best dewatering capability. For instance, combinations generally are ferric or ferrous chloride and lime, aluminum sulfate and lime, or ferric chloride and polymer.

The criteria presented under the specific method of dewatering includes general ranges of required chemical doses. Chemical requirements should be confirmed in the laboratory or by pilot testing prior to design and definitely before equipment startup.

1) Chemical Feed Equipment.

a) Chemical Mix Tanks - Chemical mix tanks should be designed to hold one shift's supply of conditioning chemicals. They are generally mixed at 20 per cent by weight for ferric

chloride and lime. The polyelectrolyte mix concentrations should be at the recommendation of the polymer manufacturer.

The chemical tanks shall be provided with a mixer of sufficient horsepower to assure complete dispersion and mixing of the chemicals.

The tanks shall be adequately protected from chemical corrosiveness. Fiberglass or rubber-lined tanks are generally employed.

- b) Chemical Feed Pumps - The chemical feed pumps shall be of the variable delivery type suitable for the chemical service required. Lime feed pumps are generally of the plunger type. Ferric chloride or polyelectrolyte pumps usually of the noncorrosive diaphragm type.
- 2) Chemical Conditioning Tank - Prior to transport to the selected method of dewatering the sludge shall be pumped through a conditioning tank where the chemicals are mixed with the sludge. The tank shall be equipped with a variable slow speed agitation device (propeller or paddle mixer, or rotating drum).

The tank shall be provided with slide gates to adjust retention time of the sludge flow through.

It is standard practice in centrifugation dewatering to add the chemicals at the centrifuge feed entrance.

- c. Heat Treatment - Sludge conditioning by heat treatment is accomplished by breaking down the affinity of the sludge particle for water so that the majority of the liquid in the sludge can be easily separated from the solids.

The conditioning is generally accomplished by pumping the sludge from a storage basin through a grinder pump into a heat exchanger. The method of primary heat exchange may be either water to sludge or sludge to sludge. Temperature elevation through the heat exchanger is generally from 60°F to approximately 350°F.

The sludge is then pumped to a reaction vessel with a retention time of between 30 and 60 minutes. Reactor temperature is increased through steam injection at 120 - 350 psig to between 350° to 450°F. Sludge is then run through another heat exchanger to reduce the temperature to about 120°F. The sludge is then stored for dewatering equipment or transported to sludge beds.

1) Equipment Requirements.

- a) Sludge Grinders - Prior to pumping to the heat exchangers, the sludge shall be ground or macerated to reduce plugging of exchanger tubing.

- b) Heat Exchanger - The heat exchanger may be of the water to sludge type or the sludge to sludge type.

They should be designed to meet all requirements of A.S.M.E.

Sludge velocities in the heat exchanger shall be limited to 4 - 6 pfs.

- c) Reactor - The steam injected reaction vessel shall be designed and constructed to meet all requirements of A.S.M.E.
 - d) Off-Gas Control - Any off-gas from the system shall be controlled by providing a completely enclosed system or through an after-burner-scrubber system.
 - e) Access - All portions of the equipment shall have ready access for maintenance, repair, degreasing, and descaling.
- 2) Other Design Considerations - Close attention should be given to the characteristics of the liquor after heat treatment.

Generally, the return liquor that is transported to the head of the plant will have a 4000 mg/l BOD₅. Suspended solids will be approximately 200 mg/l. COD will be approximately 12,000 mg/l. This is accumulated from decant liquor, dewatering filtrate or centrate, and sludge thickening tank overflow. pH will be from 0.5 to 4.0 units less than the feed pH depending upon the manufacturer's product.

- 3) Sizing Criteria - Since each manufacturer may use varying criteria, sizing of the system should be performed using the manufacturer's recommendations.

2. Sludge Dewatering.

- a. Sludge Drying Beds - Sludge drying beds may be one of two basic types.

- 1) evaporation beds
- 2) combination evaporation-percolation beds

The combination evaporation-percolation beds (commonly called sand beds) should only be employed in regions of a soft water municipal supply. Hard waters result in sludge crystallization with mineral salt (CaCO₃) deposits which cause solidification of the sand and decrease drainage substantially.

Evaporation beds should be used in lieu of combined evaporation-percolation beds where water hardness is high. The mineral salt deposits will seal the bed bottom and result in drying by evaporation.

1) Design Criteria.

- a) Evaporation Beds - Solids loading rates should range between 2.2 to 2.4 lb DS/yr/cf of bed capacity.
- b) Combined Percolation-Evaporation Beds - Solids loading rates for combined beds is shown in Table VII - 24.

2) Basin Requirements.

a) Evaporation Beds.

- (1) Number of Beds - Not less than 2 beds shall be provided, arranged so as to facilitate sludge removal.
- (2) Sludge Influent - The influent sludge pipe to each bed cell shall terminate at least 12 inches above the surface and be so arranged that it will drain. Concrete splash pads shall be provided at sludge discharge points.
- (3) Depth - The depth of the sludge shall not exceed 24 inches.
- (4) Dike Construction - The dikes shall be constructed to prevent surface water from entering the bed. Interior dikes may be sloped approximately 1:1. The exterior dike shall be 8 feet wide at the top so that vehicles may drive around the bed.
- (5) Liquor Decanting - The sludge beds shall be provided with a suitable means of decanting the liquor. The decanting device shall be adjustable. The decanted liquor should be returned to the plant headworks or

Type of Sludge	Sludge Loading Dry Solids (lb/sf/yr)
Primary, Digested	27.5
Primary and Trickling Filter, Digested	22.0
Primary and Activated, Digested	15.0
Activated, Digested	10.0
Chemically Precipitated	22.0

Table VII - 24

**Criteria for Design of Combined Evaporation
Percolation Sludge Drying Beds**

other suitable means of disposal. Conditioning of the decant liquor may be required to reduce biological impact on other unit processes of the plant.

b) Combined Evaporation-Percolation Beds.

- (1) Number of Beds - Not less than 2 beds shall be provided properly arranged so as to facilitate sludge removal.
- (2) Sludge Influent - The sludge pipe to the beds shall terminate at least 12 inches above the surface and be so arranged that it will drain. Concrete splash plates shall be provided at sludge discharge points.
- (3) Bed Construction.
 - (a) Media.
 - [1] Gravel - Properly graded gravel to a depth of 12 inches shall be provided, extending at least 6 inches above the top of the underdrains. The top 3 inches shall consist of gravel 1/3 to 1/4 inch in size.
 - [2] Sand - The top course shall consist of at least 6 - 9 inches of clean coarse sand. The finished sand surface should be level.
 - (b) Underdrains - Underdrains shall be sewer pipe at least 6 inches in diameter laid with open joints spaced not more than 10 feet apart.
 - (c) Walls - Walls shall be water-tight and extend 15 - 18 inches above and at least 6 inches below the sand surface. Outer walls should be curbed to prevent soil from washing on the beds.
 - (d) Drainage Disposal - Drainage from beds should be returned to the raw or settled sewage, if possible. Where chlorination is required, the filtrate shall be returned to a point preceding the chlorination process.
- 3) The Engineer shall thoroughly investigate soil characteristics and potential ground water problems in applying sludge drying beds. Certain conditions may require lining or scaling of the bed bottom and should be acknowledged.

b. Vacuum Filtration.

- 1) Design Criteria - Table VII - 25 tabulates recommended design criteria for vacuum filtration of sewage sludges. This Table is

Type of Sludge	Feed (2) Wt. % DS	Multiplier	Rate (2) lb/DS/hr./sq	% Moisture		% FeCl ₃ of DS	% CaO of DS
Primary, Raw	8.0	1.20	9.6	54-80	67	1.5	7.0
Primary, Digested	6.0	0.88	5.25	65-80	75	3.0	10.0
Primary, Digested and Elutriated	5.0	0.80	4.0	75-80	78	2.5	4.0 ¹
Primary and Trickling Filter, Raw	7.0	1.10	8.0	58-82	70	1.5	8.0
Primary and Trickling Filter, Digested	7.0	1.00	7.0	67-80	75	3.0	8.5
Primary and Trickling Filter, Digested and Elutriated	6.0	0.80	4.8	68-80	75	2.5	4.0 ¹
Activated (Conventional), Raw (3)	2.5	0.68	1.7	83-85	84	5.5	
Contact Stabilization or Extended Aeration	2.6	0.60	1.6	75-85	80	4.0	8.0
Primary and Waste Activated, Raw 3:1 P to A	4.0	0.88	3.5	72-87	79	4.0	8.0
Primary and Waste Activated Digested 3:1	4.5	0.75	3.4	72-80	78	4.0	12.0
Primary and Waste Activated, Digested and Elutriated	4.0	0.75	3.0	72-80	78	5.0	5.0 ¹
Heat Treated:							
Primary Raw	10-12		18		60		
Primary and Waste Activated, Raw	8		10		65		
Waste Activated, Raw	6		6		70		
Physical Chemical:							
Lime (5)	10		8-10	60-70	65		
Alum	2		1		80		
Ferric Chloride	2		1		80		

NOTES

- (1) Lime can be used in many cases to produce higher filtration rates, lower cake moisture and to control pH.
- (2) Average for most treatment plants. However, feed solids content will affect filtration rates directly. Use the multiplier shown to obtain design or assume rate for calculations. Example: If design rate for a project is 7% (raw) primary sludge solids, filtration rate is $1.20 \times 7.0 = 8.4$ lb. DS/hr./sq. ft. Variations in particular or anticipated sludge should be considered and the multiplier adjusted accordingly.
- (3) Concentrated (thickened) waste activated sludge. Filtration should not be considered at any lower feed solids concentration. It is strongly recommended that a higher concentration be obtained by flotation or gravity thickening, if possible.
- (4) The average cake moisture and chemical figures listed should be used only as guides.
- (5) Addition of 1% polyelectrolyte to dewatering.

Table VII - 25
Recommended Sewage Sludge Vacuum Filtration Design Criteria

for systems using ferric chloride and lime as conditioning chemicals. Rates and dosages of polyelectrolyte conditioned sludge is shown in Table VII - 26.

- 2) Equipment Requirements - The basic equipment requirements of the vacuum filter station include the vacuum filter, vacuum pump, sludge conveyor, filtrate receiver, filtrate pump, and sludge pump.
 - a) Vacuum Pump - As a general rule of thumb, vacuum pumps are selected for an air flow of 1.8 - 2.0 scfm per sq. foot of filter area on conventional sewage sludge applications. Heat treated sludge dewatering applications require 3.0 scfm per square foot or greater.
 - b) Sludge Pumps - Sludge pumps feeding vacuum filters are generally of the reciprocating plunger or progressive cavity type which are capable of pumping high solids material. See Section N for pump system design recommendations.

Duplicate sludge pumps shall be required for standby purposes.

- c) Controls - Vacuum filters shall be equipped with level controls in the filter vat which interlock to the chemical conditioning equipment and the sludge pump for operational control.
- d) Sludge Conveyance - Sludge conveyance systems may be tubular or belt conveyors. Discharge hoppers with breakers should be considered to contain the filter cake and prevent cake bridging.

Type of Sludge	Rate lb DS/hr/sq. ft.	% Moisture	% Polymer of DS
Primary (Raw)	8 - 10	65 - 75	0.2 - 1.2
Primary, Digested	7 - 8	68 - 75	0.2 - 1.5
Primary and Trickling Filter, Raw	4 - 6	70 - 80	0.4 - 1.8
Primary and Activated Sludge, Raw	4 - 6	75 - 82	0.5 - 2.0
Primary and Activated Sludge, Digested	3.5 - 6	78 - 85	0.5 - 2.3

Table VII - 26
Vacuum Filtration Design Criteria for
Polymer Conditioned Sludge

Wastewater Sludge Type	Sludge Solids (%)	Cake Solids Recovery (%)	Characteristic Chemical Addition
Raw or digested primary	28 - 35	70 - 90	no
Raw or digested primary, plus trickling filter humus	20-30	80-95 60-75	yes no
Raw or digested primary, plus activated sludge	15-30	80-95 50-65	yes no

Table VII - 27

Sludge Dewatering in Solid Bowl and Basket Centrifuge

c. Centrifugation.

- 1) Design Criteria - Selection of centrifuges for solids dewatering is dependent upon the equipment manufacturer's rating and performance information. Since wastewater sludges differ from location to location, pilot plant tests should be run before final design decisions are made.

Table VII - 27 and Table VII - 28 give typical performance data for solid bowl and basket centrifuges.

- 2) Equipment Requirements.

- a) Sludge Pumps - The sludge feed pumps should be a constant uniform rate pump such as a progressive cavity pump. The pumps shall be duplicate for standby service and shall be variable delivery. See Section N for pump system design recommendations.
- b) Sludge Conveyance - Sludge conveyance systems may be tubular or belt conveyor. Discharge hoppers with breakers should be considered to contain the centrifuge discharge and to prevent hopper bridging.

d. Filter Press.

- 1) Design Criteria - Pressure filters should be designed under the guidance of the equipment manufacturer. Table VII - 29 gives a tabulation of results from typical filter press installations.

The values given in Table VII - 29 are based upon operating experiences. Pilot plant testing should be performed before selecting and sizing the equipment.

Centrifuge Type	Feed Solids Concentration (% by wt)		Feed Rate (gpm)		Solids Capture (%)		Cake Concentration (% solids by wt.)		Polymer Addition (lb/ton dry solids)	
	Oxygen	Conventional	Oxygen	Conventional	Oxygen	Conventional	Oxygen	Conventional	Oxygen	Conventional
Solid Bowl										
Raw wastewater	2-3	1.5-2.5	50-60	45-55	85-90	80-85	10-13	9-11	3	6-10
Primary effluent	2-3	0.7-1.3	90-100	55-65	90-95	80-85	8-10	8-9	3	6-10
Basket										
Raw wastewater	2-3	1.5-2.5	35-40	20-35	92-96	90-95	9-12	9-11	0	0
Primary effluent	2-3	0.7-1.3	35-45	35-45	92-97	90-95	10-14	9-11	0	0

Table VII - 28
Dewatering of Oxygen Activated Sludges
in Solid Bowl and Basket Centrifuges (37)

Sludge Type	Suspended (%)	Conditioning of Dry Solids (%)		Cake Solids (%)	Time Cycle (hr)
Raw Primary	5 - 10	Ash	100	50	1.5
		FeCl ₃	5		
		Lime	10	45	2.0
Raw Primary with less than 50% EAS	3 - 6	Ash	150	50	2.0
		FeCl ₃	5		
		Lime	10	45	2.5
Raw Primary with more than 50% EAS	1 - 4	Ash	200	50	2.0
		FeCl ₃	6		
		Lime	12	50	2.5
Digested and Digested with less than 50% EAS	6 - 10	Ash	100	50	1.5
		FeCl ₃	5		
		Lime	10	45	2.0
Digested with more than 50% EAS	2 - 6	Ash	200	50	1.5
		FeCl ₃	7.5		
		Lime	15	45	2.5
EAS	Up to 5	Ash	250	50	2.0
		FeCl ₃	7.5		
		Lime	15	45	2.5

Table VII - 29
Typical Filter Press Production Data

- 2) Equipment Requirements - The basic filter press flow scheme includes a sludge storage tank, sludge conditioning tank, conditioning chemical makeup and feed equipment, high pressure sludge pumps, filter press, and cake hopper.
 - a) Sludge Conditioning Tank - The sludge conditioning tank shall be designed to hold and adequately mix the sludge and conditioning chemicals for each press batch.
 - b) Sludge Pumps - Dual high-pressure, continuous feed pumps shall be designed to provide a pressure of up to 250 psig. One pump shall be standby.
 - c) Controls - The filter press shall be provided with the necessary controls to semi-automatically operate the system excluding the press dump at each cycle's end.

At the end of the press time, the press shall open and remain so until the operator manually closes the press.

Suitable controls shall be supplied to shut the system down so the operator can complete removal of the sludge cake prior to the next batch.

- d) Sludge Conveyance - Sludge conveyance is generally by conveyor and sludge hopper. The hopper should be provided with breaker bars to break the sludge cake prior to transport.

3. Sludge Drying and Incineration.

- a. Use Requirements - Heat drying by the flash drying or rotary kiln method is employed for the purpose of removing sludge moisture so that it can be incinerated efficiently or processed into fertilizer.

Incineration is employed as a method of sludge volume reduction.

- b. Flash Drying.

- 1) Design Criteria - Flash drying is the most frequently used method of heat drying of sludge. It involves pulverizing the sludge in a mill or by an atomized suspension process in the presence of hot gases. The hot gases and sludge are mixed achieving an 8 per cent weight solids. The solids are captured in a cyclone separator. Drying temperatures are approximately 700°F.

The Engineer should design this type system with the assistance of the manufacturer.

- 2) Air Pollution Control - The Engineer shall provide evidence that the system will operate within air discharge quality standards established by the Arizona Department of Health Services, Bureau of Air Quality Control.

- c. Rotary Dryers.

- 1) Design Criteria - Rotary kiln dryers may provide direct or indirect heat through the passing of hot gases counter current to the movement of the sludge in the kiln. The kiln temperature is approximately 700°F. The wet sludge is fed in one end of the slowly rotating drum. The gases vaporize moisture from the sludge. Dried sludge emerges at the opposite end. The emergent gases flow through a cyclone or scrubber for fine particle classification.

The Engineer should design this type system with the assistance of the manufacturer.

- 2) Air Pollution Control - The Engineer shall provide evidence that the system will operate within air discharge quality standards established by the Arizona Department of Health Services, Bureau of Air Quality Control.

Material	Wet Feed		Heat Value Btu/lb. combustibles
	% Solids	% Combustible	
Scum	40 - 50	85 - 95	14,000 - 16,500
Grit	40 - 60	30 - 60	10,000 - 11,000
Screening	30 - 40	80 - 95	7,500 - 8,500
Primary, Raw	25 - 32	60 - 75	10,500 - 12,000
Primary & T.F., Raw	23 - 25	60 - 75	10,000 - 11,000
(1) Primary & Act., Raw	20 - 24	60 - 75	9,500 - 10,500
Primary, Digested	23 - 26	40 - 55	9,500 - 10,500
Primary & T.F., Digested	20 - 25	40 - 55	9,500 - 10,500
(2) Primary & Act., Digested	18 - 25	40 - 55	9,000 - 10,000
Waste Act., Digested	15 - 18	40 - 55	8,500 - 9,500

Notes

- (1) Centrifuge cake if mixture of 60% primary and 40% activated will contain 17% - 20% dry solids.
- (2) Centrifuge cake will contain 13% - 15% dry solids.

Table VII - 30
Typical Sludge Feed Characteristics

d. Multiple Hearth Incinerator.

- 1) Design Criteria - The actual determination of the furnace size is made on the basis of the processing rate of wet feed per square foot of furnace area.

Table VII - 30 tabulates typical sludge feed characteristics for design of incinerators.

Furnace sludge feed rates vary with the dry solids content of the sludge. Table VII - 31 shows representative feed rates to incinerator versus per cent dry solids of feed.

The Engineer should consult the incinerator manufacturer for assistance in design.

- 2) Air Pollution Control - The Engineer shall provide evidence that the system will operate within air discharge quality standards established by the Arizona Department of Health Services, Bureau of Air Quality Control.
4. Sludge Disposal - Two generally accepted methods of sludge disposal are landfill and soil spreading or injection.
- a. Landfill - The sanitary landfill may be used for disposal of raw or stabilized sludge, septage, chemical vault sludge, sludge from drying beds, drying lagoons, mechanically dewatered sludge, and ash from mechanical drying or incineration.

% Dry Solids in Feed	Wetcake lb/sf-hr
25	7 - 12
18 - 22	6 - 11
14 - 17	5 - 9

Table VII - 31
Sludge Feed Rates to Incinerators

All sludges shall be disposed at designated sites in each county and must be in accordance with the State solid waste management program.

The Engineer shall provide the Department with details regarding the size, method of operation, location, etc. of the landfill where the sludge will be disposed. Assurance must be given that the sanitary landfill is managed such that wastes are systematically deposited and covered with sufficient soil to control environmental impacts within defined areas. The leachate and runoff from a sanitary landfill should be minimized and, when necessary, collected and suitably treated to prevent pollution of ground and surface waters.

- b. Soil Spreading and Injection - Stabilized sewage sludge, drying bed sludge, drying lagoon sludge, mechanically dewatered sludge, or ash from mechanical drying or incineration may be disposed of by either soil spreading or soil injection of a land farm, crop land or non-dairy cattle grazing land.

Raw sewage sludge, septage, chemical vault sludge, and other raw waste sludge may be disposed only by injection.

The Engineer shall be required to provide the Department with the size, method of operation, location, etc. of the soil spreading or injection operation, including information on runoff control, erosion, and leachate control.

- 1) Types of Crops - All sewage sludge may only be applied to crop lands used for growing field corn, wheat, and forage crops. In addition, forest land may be a feasible alternative to improve soil fertility and increase tree growth.

In no case will sewage sludge be applied to root crops or crops intended for human consumption.

Relative Soil Conditions	Application Rate (Tons dry solids per acre per year)
Slight Limitations	10 - 30
Moderate Limitations	10

Table VII - 32
Application Rates to Crop Land

For advice concerning crops which can be satisfactorily grown in sludge enriched soils, the local representatives of the U. S. Department of Agriculture, or the Agricultural Departments of University of Arizona or Arizona State University should be consulted.

- 2) **Application Rates** - Application rates depend on sludge composition, soil characteristics, climate, vegetation, and cropping practices. Applying sludge at a rate to support the nitrogen needs of the selected crop avoids overloading the soil with problem constituents. A rough guide for applying acceptable sludge to soils is given in Table VII - 32. The sludge application rates should be justified in accordance with the nitrogen and heavy metal content of the sludge.
- 3) **Monitoring Requirements** - Specific points which must be continuously considered and/or monitored during sludge utilization are:
 - a) The trace element composition of sludge, soil, and crops.
 - b) The nitrogen content of sludge, soil, and crops and potential nitrate contamination of the ground waters.
 - c) Hydraulic overloading of the soil.
 - d) Ultimate land use.
 - e) Practice to control runoff and erosion. The leachate and runoff should be minimized and, when necessary, collected and suitably treated to prevent pollution of ground and surface waters.
- 4) **Sludge Conveyance Systems** - In designing a sludge application system, the method of conveying sludge from the plant to the cropland should carefully consider:
 - a) sludge characteristics
 - b) distance to transport
 - c) sludge volume
 - d) elevation differences
 - e) land availability.

Conveyance may be accomplished by tank truck, rail, or pipeline.

Retention basins at the treatment plant or near the land application site should be considered for storage when land spreading is not feasible.

- 5) Methods of Application - Dilute sludge may be applied by ridge and furrow irrigation, spray sprinkler irrigation systems, or tank trucks with surface spray systems. More concentrated sludges may use sludge spreader trucks or other suitable surface application systems.
- 6) Other Design Considerations - The Engineer should investigate toxic constituent levels of the sludge, soil composition, soil pH, drainability, permeability, ground water level, and the affects each will have on crops, soils, and ground water.

N. IN-PLANT SEWAGE AND SLUDGE PUMPING STATIONS.

1. Pump Requirements.

- a. Sewage - The pump most commonly used for raw sewage service in the single end-suction volute-type centrifugal with an overhung impeller of either the radial non-clog or mixed-flow type.
- b. Sludge - Sludge pumps are generally of three types: plunger, centrifugal, and progressing cavity.
- c. Capacity - Pump capacities shall be of adequate size to meet the flow variation requirements. Provisions for varying pump delivery is desirable.
- d. Duplicate Units - Duplicate pumps shall be provided where failure of 1 unit will seriously hamper plant operation.
- e. Materials of Construction - All raw sewage and sludge pumps should be manufactured of abrasion resistant material.

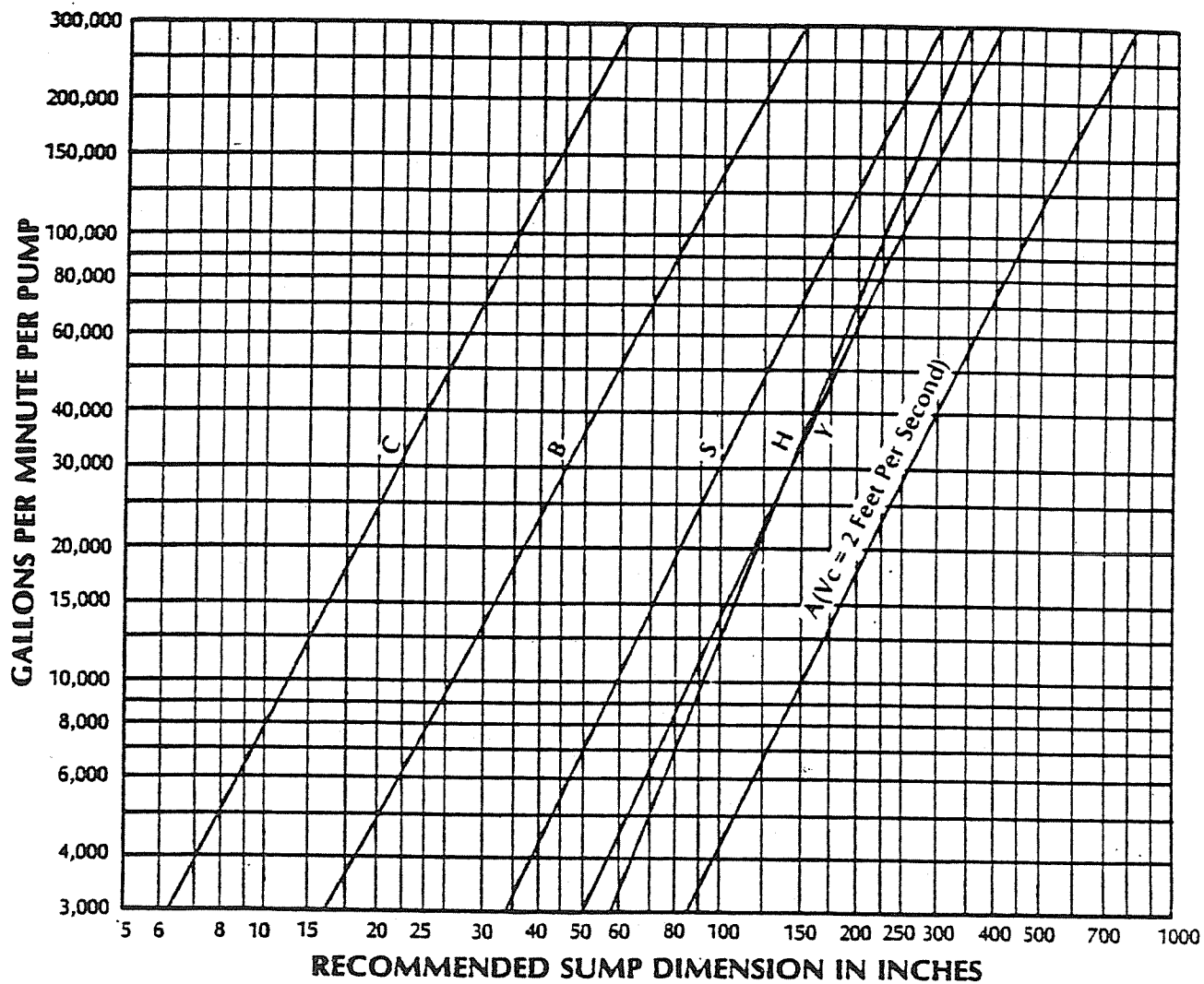
All pumps should be corrosion resistant.

- f. Sampling Facilities - All pumps shall be equipped with quick closing sampling valves unless sampling facilities of the flow stream are otherwise provided. The size of valve and piping should be at least 1 1/2 inches.

2. General Structural Details.

a. Wet Well Design.

- 1) Wet Well Capacity - The wet well capacity may be sized using the recommendations of Figures VII - 21, 22, 23, and 24. However, there is no method applicable to all conditions. Care should be taken in using the sump capacity graph.



Figures apply to sumps for clear liquid. For fluid-solids mixtures refer to the pump manufacture.

Figure VII-21
Sump Dimensions Versus Flow

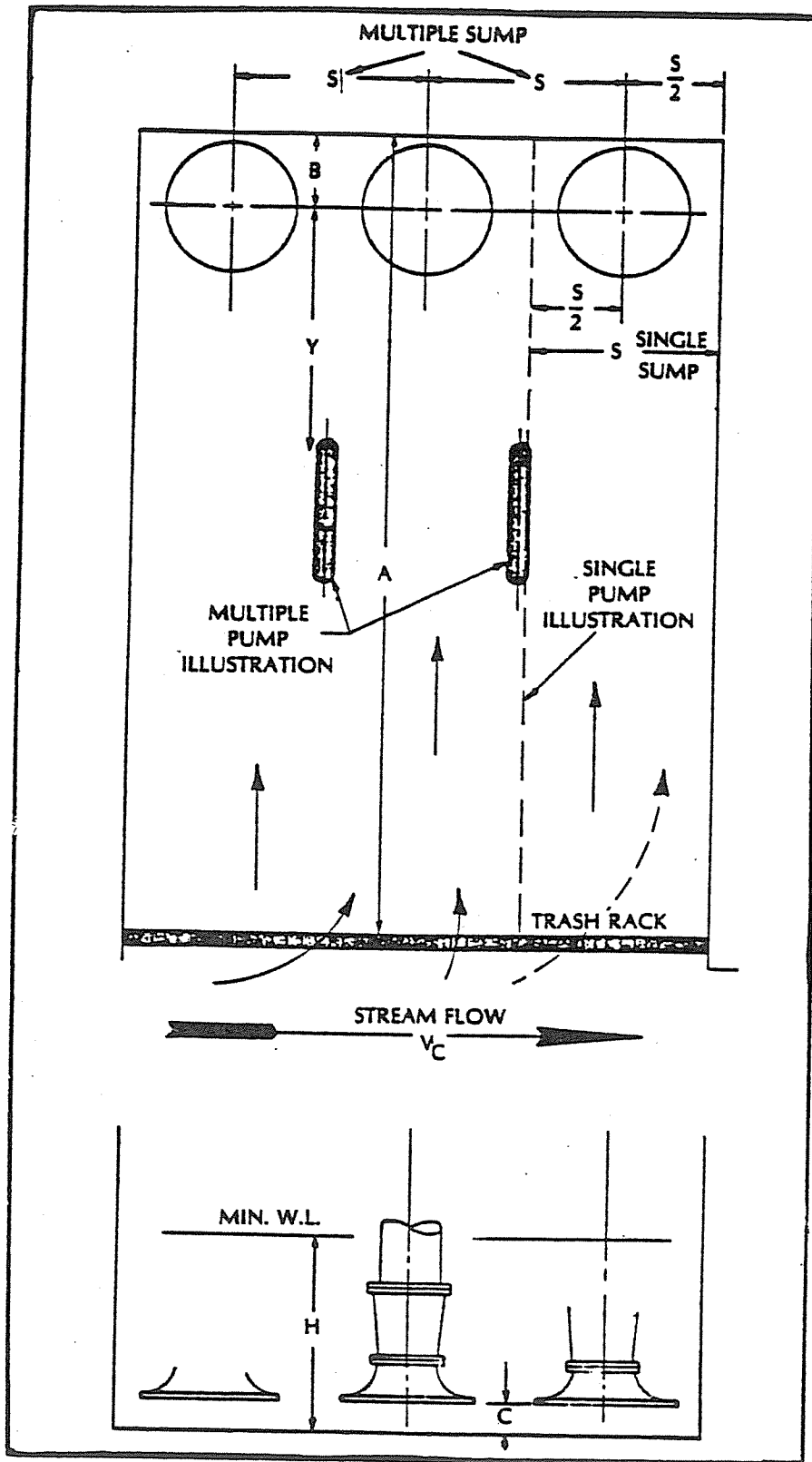
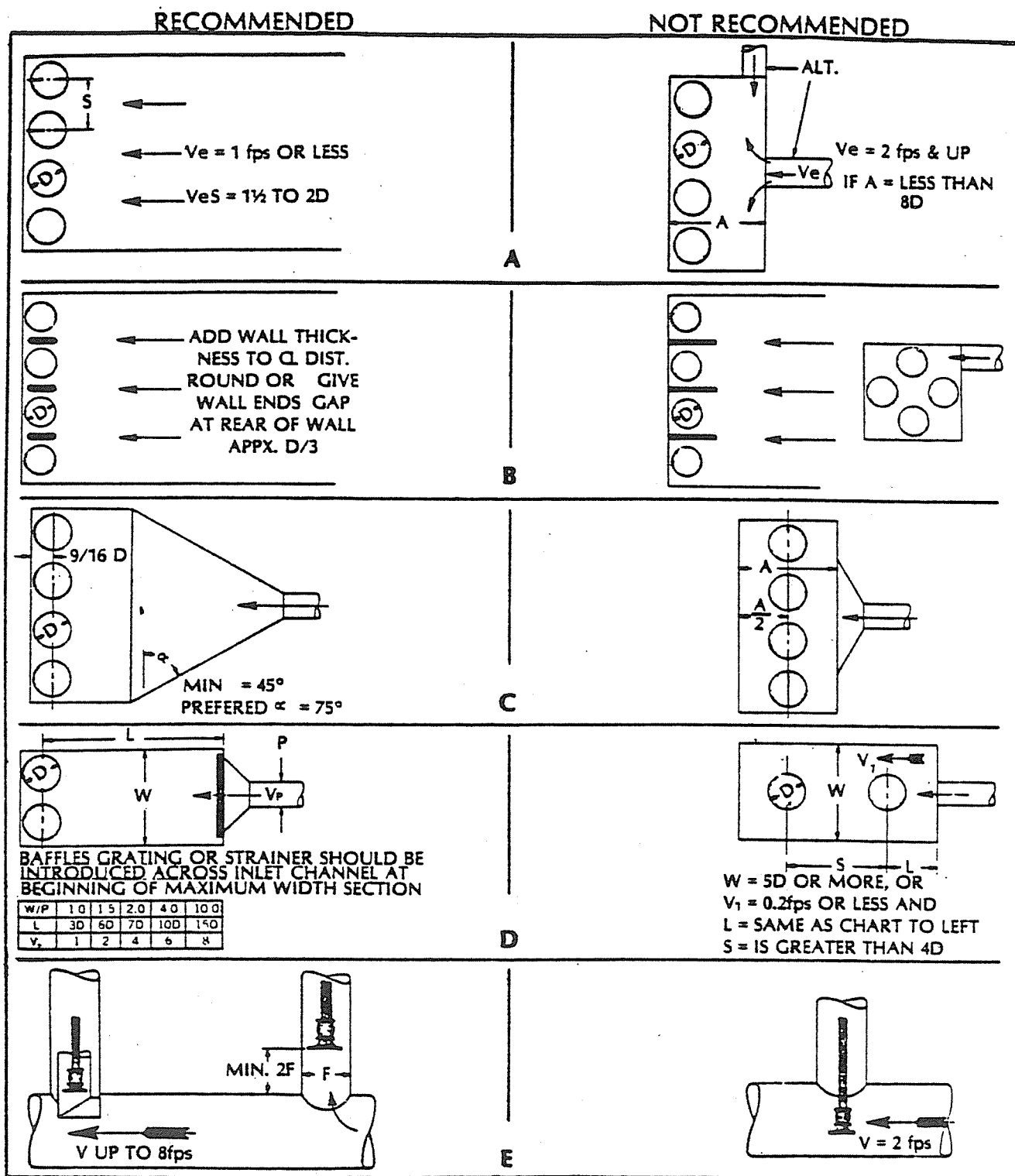


Figure VII-22
Sump Dimensions Versus Flow



NOTE: Figures apply to sumps for clear liquid. For fluid-solids mixtures refer to the pump manufacturer.

Figure VII-23
Multiple Pump Pits

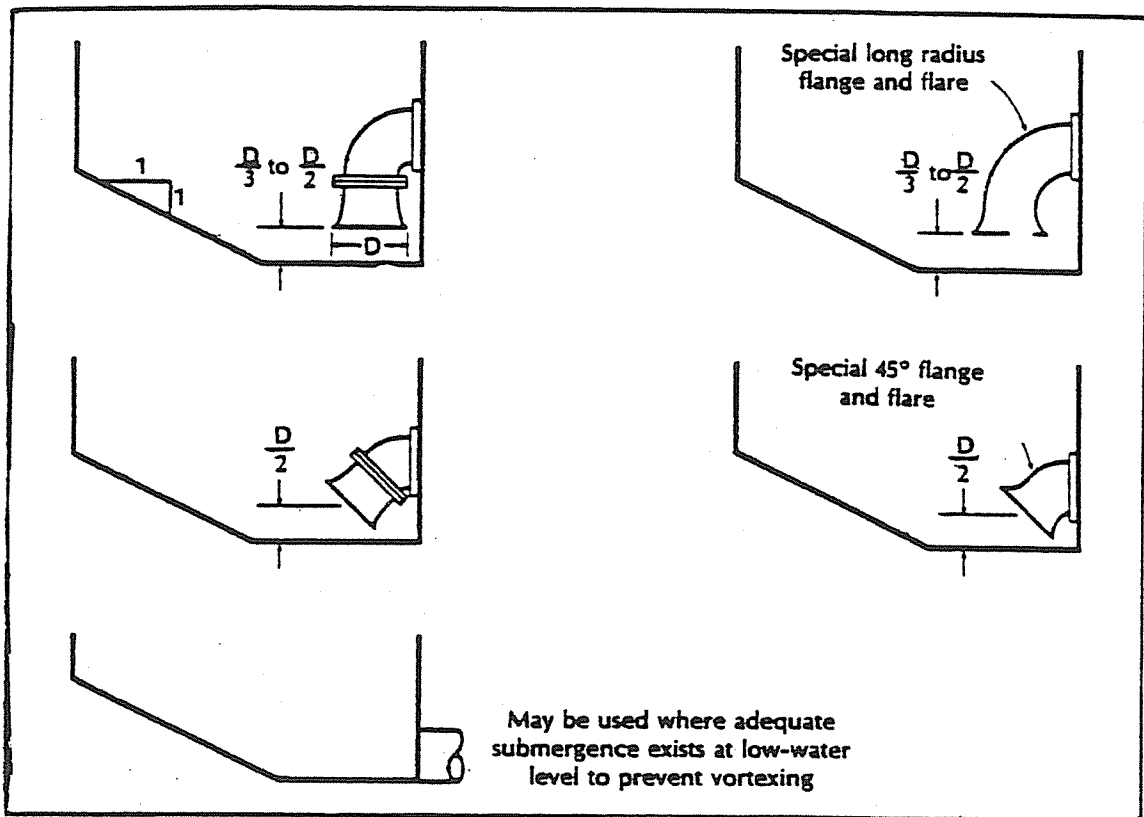


Figure VII-24
Pump Suction Connections to Wet Well

- 2) Floor - Floors of wet wells shall have a minimum slope of one to one to the pump intakes and shall have a smooth finish.
 - 3) Access - The wet well shall be designed with adequate access for maintenance purposes. Access shall be provided from the exterior of the building only.
 - 4) Ventilation - Ventilation shall be provided in all wet wells. Ventilation should be via blower, having sufficient capacity to provide a 2-minute air change based on the wet well volume below grade and above the minimum sewage level.
 - 5) Pump Intake Design - The Hydraulic Institute standards gives recommended multiple pit layouts for centrifugal pump suction. These are shown in Figures VII - 21, 22, and 23. In addition, pump suction connections to wet wells are shown in Figure VII - 24.
- b. Dry Well Design - The size of the dry well depends primarily on the number and type of pumps selected. The dry well shall be deep enough that the pumps are self-priming at all starting levels unless self-priming pumps are being recommended. The pump setting shall be such that the pump's maximum suction lift is not exceeded.

Dry wells shall be well lighted and adequately ventilated. The dry well shall be positively ventilated with an exhaust system which provides 30 air changes per hour based upon dry well volume below grade.

The ventilation system may be continuous operated or intermittently operated. All intermittently operated ventilating equipment should be interconnected with the respective lighting system. Consideration should also be given to automatic controls where intermittent operation is used. Switches for operation of ventilation equipment should be marked and conveniently located.

Sufficient working clearances around pumps and other machinery shall be provided to assure ease in maintenance.

Consideration shall be given to cranes or hoists for removing pumps for maintenance and replacement.

The dry well shall be separated from the wet well by a water- and gas-tight wall with separate entrances provided to each.

Stairways or access ladders shall be provided in all underground dry wells.

A separate sump pump shall be provided in the dry wells to remove leakage or drainage. All floor and walkway surfaces shall have an adequate slope to a point of discharge.

3. Controls.

- a. Electrical Equipment - Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, control circuits, etc.) in enclosed or partially enclosed spaces where flammable mixtures or gases occasionally may be present should comply to the National Electrical Code and OSHA requirements.
4. Pipe Velocities - The velocities of fluids generated by pumps shall be between 4 and 6 fps. In no case shall a velocity less than 2 fps at minimum flow be allowed.
5. Valves - Suitable shutoff valves shall be placed in suction and discharge lines of each pump. A check valve shall be placed on each discharge line, between the shutoff valve and the pump.
6. Flow Measurement - Suitable devices for measuring sewage flow should be provided at all pumping stations.
7. Cleanouts - Cleanouts should be located at strategic points in the piping system to allow line cleaning and system maintenance.
8. Sampling Taps - Sampling taps should be located at strategic points in the piping system for ease in acquiring samples for laboratory analysis.

O. DISINFECTION AND ODOR CONTROL.

1. Disinfection - All sewage treatment effluents which discharge in areas subject to public contact shall be disinfected by chlorination, ozonation, or other suitable means.

a. Chlorination.

- 1) Dose Requirements - The capacity of the chlorination equipment shall be of sufficient size to produce a total residual of 2.0 ppm in the final effluent. Table VII - 33 gives recommended chlorine dosages versus type of treatment.

Type of Treatment	Dosage (Based on average design flow)
Trickling Filter Effluent	15 ppm
Activated Sludge Effluent	8 ppm
Physical Chemical Effluent	10 ppm
Sand Filter Effluent	6 ppm

Table VII - 33
Recommended Chlorine Design Dosage vs. Type of Treatment

The chlorination equipment shall have a capacity greater than the highest expected dosage to be applied at any time. It shall be capable of operation under every prevailing hydraulic condition.

2) Feed Equipment.

- a) Type - The use of equipment designed to feed chlorine gas in solution is recommended. Hypo-chlorinators will be acceptable on smaller installations.
 - b) Standby Equipment - Standby equipment of sufficient capacity should be available to replace the largest unit during shut-downs. Spare parts shall be available for all chlorinators to replace parts which are subject to wear and breakage.
 - c) Water Supply - An ample supply of water (potable or filtered effluent) shall be available for operating the chlorination equipment. Where a booster pump is required, consideration should be given to providing a standby pump.
- 3) Piping and Connections - Piping systems should be as simple as possible, especially selected and manufactured to be suitable for chlorine service with a minimum number of joints. Piping shall be well supported and protected against extreme temperature variations.

The standard weight and thickness of steel or wrought iron is suitable for use with DRY chlorine liquid or gas. Low pressure lines made of hard rubber, sarran-lined, rubber-lined, polyethylene, PVC, or Uscolite materials are satisfactory for wet chlorine or aqueous solutions of chlorine.

To prevent corrosion, all lines designed to handle dry chlorine shall be protected from the entrance of water or air containing water.

4) Housing.

- a) Separation - If gas chlorination equipment and chlorine cylinders are to be in a building used for other purposes, a gas-tight 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 shall be at ground level, and should permit easy access to all equipment. Storage area should be separated from the feed area.
- b) Inspection Window - A clear glass, gas-tight 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.

- c) Heat - Chlorinator rooms should be provided with a means of heating so that a temperature of at least 60°F can be maintained, but the room should be protected from excess heat. Cylinders should be kept at room temperature.
- d) Exhaust Ventilation - Sufficient ventilation shall be provided to allow one complete air change in the chlorination room, every two minutes. The exhaust duct shall be located within 6 inches of the floor level. A louvered fresh air intake must be provided to serve as a make-up air supply when the exhaust fan is operating. This intake should be located in the ceiling or near ceiling level. The exhaust fan shall be wired to automatically activate when the light is turned to the "on" position. The light switch shall be located outside the room. As an additional safety factor, a pressure type switch should be located in the door to the chlorination room which will activate the exhaust fan automatically when the door is opened, in case the operator fails to turn on the light switch. The point of discharge shall be so located as not to contaminate the air inlet to any building or inhabited area.

On chlorination equipment which is wall or cylinder mounted, the vent hose shall be screened and shall discharge to the outside atmosphere and above grade.

- e) Electrical Controls - The controls for the fans and lights shall be such that they will automatically operate when the door is opened and can also be manually operated from the outside without opening the door. All other electrical equipment shall be located outside the chlorine room. All switches should be properly identified.
- 5) Chlorine Supply.
- a) Cylinders - The use of one-ton containers should be considered where the average daily chlorine consumption is over 150 lbs.
 - b) Tank Cars - At large installations consideration should be given to the use of tank cars, generally accompanied by gas evaporators.
 - c) Scales - Scales shall be provided at all plants using chlorine gas for weighing cylinders. Automatic switchover systems may be accepted as an alternative to weighing scales on smaller plants. At large plants, scales of the indicating and recording type are recommended. At least a platform scale shall be provided. Scales shall be of corrosion-resistant material.

- d) Evaporators - Where manifolding of several cylinders will be required to evaporate sufficient chlorine, consideration should be given to the installation of gas evaporators.
 - e) Leak Detection and Controls - A bottle of ammonium hydroxide solution shall be available for detecting chlorine leaks. Consideration should also be given to the provision of caustic soda solution reaction tanks for absorbing the contents of leaking one-ton cylinders where such cylinders are in use. At large installations consideration should be given to the installation of automatic gas detection and related alarm equipment.
 - f) Safety Chains - Safety chains shall be provided at all gas chlorination installations where chlorination bottles are employed. The chains shall be installed to hold the bottles securely upright, both on the scales and in storage areas.
 - g) Leak Repair Kit - An emergency repair kit should be provided with the particular chlorine container to be used. Kits are available for all types: 100 lb. bottles, 150 lb. bottles, ton cylinders, and tank cars.
 - h) Posting - A poster giving chlorine handling instructions and precautions should be posted in a conspicuous place in the chlorination room. Detailed chlorine manuals are available from the various manufacturers and should be available for reference.
 - i) Outside Cover - Chlorination equipment located outside buildings shall be protected from the sun.
- 6) Gas Masks - At least 1 self-contained breathing apparatus in good operating condition of a type conforming to OSHA standards shall be available at all installations where chlorine gas is handled and shall be located outside and adjacent to any room where chlorine is used or stored. Instructions for using, testing, and replacing mask parts, including canisters shall be posted.
 - 7) Dechlorination - Attention should be given to design of suitable dechlorination methods where aquatic life protection is required.
- b. Ozonation.
- 1) Dose Requirements - The capacity of the ozonation equipment shall be of sufficient size to assure proper coliform discharge requirements.

Table VII - 34 gives recommended ozone dosage versus type of treatment.

Type of Treatment	Dosage (Based upon average design flow)
Activated Sludge Effluent	10 ppm
Sand Filter Effluent	7 ppm
Advanced Waste Treatment Effluent	7 ppm

Table VII - 34
Recommended Ozone Design Dosage vs.
Type of Treatment

2) Equipment Requirements.

- a) Ozone Generation Equipment - Ozone must be produced from air or oxygen by the reaction of an oxygen-containing feed gas in an electric discharge. Ozone generation shall be on-site with immediate application of the ozone to the waste stream.

The ozone generator may be of the plate or tube type. The equipment shall be equipped with adequate cooling water systems to dissipate heat produced during ozone generation.

- b) Piping and Piping Appurtenances - All piping from the generator to the diffuser system shall be of an approved material which is corrosion resistant to ozone.
- c) Dissolution System - Since the purpose of ozonation is to achieve a maximum oxidizing effect with minimum dose, a dissolution system shall be provided to divide the gas into fine bubbles as it mixes with the effluent. Acceptable methods include porous diffusers, venturi injectors, and emulsion turbines.
- d) Handling of Process Off-Gases - Handling of off-gases from the ozone contact chamber should be a major design consideration.

Ozone produced by using oxygen as feed gas may contain more than 90 per cent oxygen in the off-gases released from the contact chamber. A suitable means of covering the chamber and recycling the oxygen to the ozonator may be economically feasible. The possibility of nitrogen build-up in the off-gases should be acknowledged and a suitable nitrogen gas removal system shall be included in the design.

- c. Other Methods - Other methods of disinfection, such as iodination, x-radiation, γ -radiation, etc., may be proposed. Prior to use, sufficient data as to the technical feasibility and application shall be submitted to the Department for review and approval.

2. Contact Basin Design.

a. Design Criteria - Table VII - 35 gives recommended design criteria for the design of chlorine and ozone contact chambers.

b. General Structural Requirements.

- 1) Chemical Addition - The design of the contact tank should provide for the disinfectant solution through a diffuser which will uniformly distribute the solution into the path of flow of sewage or by flow directly into a rapid mix propeller for instantaneous and complete diffusion.

Mixing for at least 30 seconds should be maintained if mechanical mixing is not used.

- 2) Basin Channels - Basin channels may be under-over type or around-the-end serpentine type which shall be designed to prevent short circuiting and shall assure at least 80 to 90 per cent of the wastewater is retained in the basin for the specified retention time.

- 3) Dewatering and Desludging - Drains shall be provided in the tank for dewatering the contact basin and for removal of sludge by flushing or manual operation.

3. Odor Control.

a. Use Requirements - Several methods may be employed for odor control. In selection of the most feasible method, consideration should be given to using equipment employed elsewhere in the process, such as aeration, chlorination, etc.

b. Methods and Doses.

- 1) Chlorination - Chlorine is used in up-sewer, ahead of odor producing points in the plant. The design of chlorination odor control should be based upon 20 ppm chlorine dosage.

Parameter	Chlorine	Ozone
Retention Time (minutes at peak hourly flow or max. rate of pumpage)	15	5
Channel Velocity (fpm)	5 - 15	5 - 15

Table VII - 35
Recommended Design Criteria
Chlorine or Ozone Contact Chamber

Equipment design shall conform to the requirements of Section 0.1.a.

- 2) Ozonation - Ozone is used primarily at in-plant points since on-site ozone generation is required. In addition to applications in the waste stream, ozone may be mixed with off-gases from digesters and holding basins for odor control.

Dosages range from 15 ppm to 25 ppm and should be designed for the maximum dose requirements.

- 3) Aeration - Aeration at points upstream of odor production may be a feasible means of odor control. Retention times range from 10 to 45 minutes with air requirements ranging from 0.1 to 0.4 cubic feet per gallon of wastewater.
- 4) Chemical Addition - Deodorizing chemicals may be employed in areas where it is difficult to arrange aeration, chlorination, or ozonation. Chemicals may be employed directly in the waste stream or aspirated and sprayed over areas of odor production.
- 5) Lime Application - The use of lime in odor control is generally used on open sludge beds. Dose requirements depend upon digester operation and control, pH, alkalinity and volatile acids in the sludge.
- 6) Hydrogen Peroxide - Hydrogen peroxide is used primarily in up-sewer and ahead of odor producing points in the plant. The dose requirements range from 5 to 40 mg/l depending upon the location of the odor and the temperature of the waste.

It is recommended that no greater than 50 per cent hydrogen peroxide solution be used as feed. Where the Engineer is contemplating using 70 per cent solution, care should be taken to safely house the equipment and meet local fire codes.

P. EFFLUENT REUSE SYSTEMS.

Reuse of treated sewage effluents is encouraged. However, the potential public hazard caused by reusing effluents must be weighed carefully in the study of reuse methods. Additional treatment of the effluent may be required prior to reuse.

1. Domestic Irrigation - Domestic irrigation includes watering of playgrounds, parks, lawns, or other areas where the public may congregate and/or where children may play.
 - a. Effluent Storage - Since wastewater flows at a continuous non-uniform rate and the frequency of irrigation and quantity of water used for irrigation vary, effluent storage should be provided.

The requirements for effluent storage pond design are outlined in Section K of this Chapter.

- b. Effluent Quality Requirements - The Department's Rules and Regulations R9-20-400 place restrictions on the quality of effluent which may be used for domestic irrigation. Under this regulation, all waste effluents used for domestic irrigation shall contain not more than 10 mg/l BOD, 10 mg/l suspended solids, and 200 fecal coliform per 100 ml, based upon the arithmetic mean of 5 analyses over a 15-day period.

To achieve this quality of effluent, a form of tertiary treatment will most likely be required.

- c. Water Demand - The water demand for domestic irrigation varies seasonally. As a rule of thumb, water demands range from 10,000 gpad in the summer to 1000 gpad in the winter.
 - d. Distribution Systems - The distribution system for domestic irrigation shall be by spray irrigation. The nozzles should be of the non-clog type, if possible, and should be designed for easy maintenance.

The spray nozzle shall be spaced so that the spray pattern is overlapping.

Areas of potential puddling will not be permitted.

- e. Consideration should be given to providing buffer zones to allow for wind transport of the effluent aerosols.
 - f. Monitoring Requirements - Plants employing effluent reuse systems shall monitor the effluent to assure compliance with Regulation R9-20-400. Monthly reports showing the effluent quality shall be sent to the Department.

- g. Sprinkler Head Posting - Signs shall be posted on the irrigation area with the following statement: "Sprinklers Spraying Contaminated Water - Do Not Drink."
- 2. Agricultural Irrigation - The design and operation of an effluent reuse system via agricultural irrigation requires investigation of the following:
 - a. Effluent Storage - Since wastewater flows at a continuous non-uniform rate and crop demand varies with season, the Engineer should give due consideration to effluent storage requirements. The requirements for storage pond design are outlined in Section K of this Chapter.
 - b. Clogging of Soils and Irrigation Distribution Systems - Most of the suspended solids in raw wastewater are removed by proper treatment. However, effective filtration methods should be investigated to assure that soils and sprinklers or trickle irrigation systems will not plug.

In heavy soils, organic matter may clog the capillary pores in the upper layer which will decrease infiltration. Deeper soil plugging will result in anaerobic conditions which will reduce soil permeability. In these cases, a regular means of breaking the surface crust and plowing the deeper layers may be required as standard operational procedure to improve and maintain soil permeability.

- c. Crop Demands - The amount of water required by the crop and the frequency of application will be the major criteria in designing the irrigation system. Technical Bulletin No. 169, "Consumptive Use of Water by Crops in Arizona," is recommended as reference for design of agricultural irrigation systems.
- d. Toxic Constituents - Wastewater effluents may contain soluble constituents at concentrations toxic to plants. The following chemical constituents should be investigated and correlated with crop toxicity.

1) chloride	7) nickel
2) sodium	8) lead
3) zinc	9) mercury
4) manganese	10) organic acids
5) hexavalent chromium	11) phenols
6) cadmium	12) boron

If such constituents exceed the recommended toxic limits for crops in question, suitable means shall be designed to dilute or reduce the concentration of the toxic constituent.

- e. Coliform Restrictions - The Department's Rules and Regulations R9-20-400 place restrictions on the quality of effluent which may be used for agricultural irrigation.

Irrigated Constituent	Maximum Allowable Coliform Count #/100 ml	
	Coliform Group	Fecal Coliform
Fibrous a forage crop not for human consumption	No limit	No limit
Orchard crop (indirect application) of effluent	No limit	No limit
Processed food crop	Single sample	Single sample
	Monthly arithmetic average 5,000	Monthly arithmetic average 1,000
Orchard crops (direct application) of effluent	Single Sample	Single Sample
	20,000	4,000
	Monthly arithmetic average 5,000	Monthly arithmetic average 1,000
Food crops unprocessed	—	Arithmetic average of 5 samples over 15 days — 200

Table VII - 36
Maximum Coliform Concentrations for Agricultural Irrigation

Irrigated Constituent	Type of Treatment	Effluent Quality	
		BOD ₅ mg/l	SSmg/l
Fibrous or forage crops not for human consumption	Secondary	30	30
Orchard crops (indirect application) of effluent	Secondary	30	30
Processed food crop	Secondary and disinfection	30	30
Orchard Crops (direct application) of effluent	Secondary and disinfection	30	30
Unprocessed food crop	Secondary, Tertiary, and disinfection	10	10

TABLE VII - 37
Effluent Quality Requirements for Agricultural Irrigation

Table VII - 36 summarizes the coliform requirements of the regulations.

- f. Effluent Quality - R9-20-400 also gives effluent quality and monitoring requirements for agricultural irrigation. Table VII - 37 summarizes the type of waste treatment required and the effluent quality restrictions.
- g. General Features.
 - 1) Conveyance System - Conveyance of effluent to the irrigation should preferably be by gravity. Only when topography is unfavorable or where long conveyance distances are required should pumping be considered.

The storage pond shall be considered as an integral part of the conveyance system.

The requirements established in Section Q - Land Treatment also apply to agricultural irrigation.

Animal	Water Consumed (gpd)
Beef cattle, per head	7 - 12
Dairy cattle, per head	10 - 16
Horses, per head	8 - 10
Swine	3 - 5
Sheep and goats, per head	1 - 4
Chickens, per 100 birds	8 - 10
Turkeys, per 100 birds	10 - 15

Table VII - 38
Water Consumption by Livestock

- 2) Fence - The effluent storage pond shall be fenced to prevent public access. The fence shall be a minimum of 6 feet in height and shall be of sufficient strength to exclude livestock and other animals. Material of construction shall be chain link, wood, or block. All gates shall be of the lockable type.
3. Stock Watering - Stock and wildlife consume water in varying amounts, depending upon climate, type of diet, degree of exercise, and the salinity of the water available. Table VII - 38 tabulates some appropriate ranges of water consumption by livestock. Animals can tolerate higher salinities than man. Table VII - 39 shows the proposed safe limits of salinity for livestock.

When reusing sewage effluent for stock watering, the Engineer shall give careful consideration to the quality of the effluent, its affect upon the animals, and the potential for disease or chemical contamination of humans through animal consumption.

The Department's Rules and Regulations R9-20-400 requires minimum of secondary treatment for watering of farm animals other than producing dairy animals.

Animal	Threshold Salinity Concentrations (TDS, mg/1)
Poultry	2860
Swine	4290
Horses	6435
Dairy cattle	7150
Beef cattle	10000
Sheep (adult)	12000

Table VII - 39
Proposed Safe Limits of Salinity for Livestock

Watering of producing dairy animals requires secondary treatment and disinfection. The maximum monthly arithmetic average coliform count shall not exceed 5000/100 mg, and the maximum monthly arithmetic average fecal coliform count shall not exceed 1000/100 ml. Single sample limitations are 20,000/100 ml for coliform, and 4000/100 ml for fecal coliform.

4. Golf Course Irrigation - The use of effluent for golf course irrigation requires investigation of the following:
 - a. Effluent Storage - Since wastewater flows at a continuous non-uniform rate and golf course irrigation pumping systems operate during daily or weekly intervals, storage ponds shall be required (in the form of lake systems) to provide for the periodic operation. The requirements for effluent pond design are outlined in Section K of this Chapter.
 - b. Water Demand - The water demand for a golf course varies seasonally. As a rule of thumb, water demands range from 10,000 gpad in the summer to 1,000 gpad (once per week) in the winter, depending upon elevations and climatological conditions.
 - c. Effluent Quality and Monitoring Requirements - The Department's Rules and Regulations R9-20-400 require a minimum of secondary treatment and disinfection for effluents used on golf courses in non-residential areas, and tertiary treatment and disinfection for effluents used on golf courses in residential areas.

For residential areas, fenced golf courses which prevent children from playing on the links may be used as an alternative to tertiary treatment.

Consideration should be given to providing buffer zones to allow for wind transport of the effluent aerosols.

- d. Posting - Signs shall be posted on the golf course with the following statement: "Sprinklers Spraying Contaminated Water - Do Not Drink."
5. Industrial Reuse - The quality of effluent required for industrial reuse varies from industry to industry and from process water to process water.

"Water Quality Criteria," by McKee & Wolf is an excellent reference to use in designing industrial reuse systems.

6. Wetlands Marsh - Formation of a wetland marsh for the reuse of effluent incorporates physical, chemical, and biological principles in a common environment to yield a balanced ecosystem. The effluent marsh is stocked with fish and aquatic organisms, is a resting place and breeding area for fowl; and, provided with the proper land and vegetation balance, attracts a wildlife habitat.

a. Effluent Quality Requirements.

- 1) Bacteriological Quality - The fecal coliform content shall not exceed a geometric mean of 1000/100 ml nor shall more than 10 per cent of the samples during a 30-day period exceed 200/100 ml, based on a minimum of five samples during such periods.
- 2) pH - The pH shall remain within the limits of 6.5 and 8.6 at all times. The maximum change permitted as a result of the waste discharge shall not exceed 0.5 pH units.
- 3) Dissolved Oxygen - The discharge of wastes shall not lower the dissolved oxygen content below 4 mg/l in the receiving body.
- 4) Temperature - The temperature of wastes discharged shall not interfere with wildlife use or aesthetic values.
- 5) Toxicity - The following limits shall not be exceeded for the listed substances.

Substance	Limiting Concentration mg/l
Arsenic	0.05
Barium	0.5
Cadmium	0.01
Chromium (Hexavalent)	0.05
Copper	0.05
Cyanide	0.10
Lead	0.05
Mercury	0.005
Phenol	0.001
Selenium	0.01
Silver	0.05
Zinc	0.5

- b. Ground Water Protection - Care shall be taken to assure that bacterial contamination, tastes, odors, turbidity, color, foaming, or a significant increase of mineral water quality of the underlying aquifers which are used for public supply does not occur. Ground water monitoring may be required.
- c. Physical/Biological Requirements - The marsh should be designed to meet the following requirements to allow optimum management and success of purpose:
 - 1) The effluent source must not contain significant quantities of any harmful materials. (Discharge requirements discussed above provide for this need.)

- 2) Optimum waterfowl habitat conditions must be provided, i.e., sufficient nesting cover for upland and over-water nesters, adequate brood cover, minimum access for predators and sufficient loafing sites.
- 3) Water level manipulation must be timed so as not to affect nesting birds.
- 4) The effluent discharge to the marsh area should be disinfected, either by natural means, chlorination, or other acceptable methods.
- 5) Storage facilities may have to be provided in those situations where mechanical plants are discharging continuously, since it is not recommended that the marshes receive water during the winter.
- 6) Marsh may be a natural or artificial basin and it may be operated as a closed system (with all water loss through evaporation) or an open system, allowing periodic discharge into a natural water course.
- 7) If efficient nutrient removal is to take place in such a system, care must be taken to avoid creating a marsh with a large central area of open water. Depending upon the morphometry of the basin, various internal works such as cross dikes may have to be constructed to obtain relatively shallow water throughout the system, and thereby provide the maximum contact of water with the nutrient absorbing aquatic plants. The nutrient-rich water should result in prolific growth of aquatic plants and invertebrates; as a result, food will not be a limiting factor to water fowl production. In order to avoid other factors (e.g., nesting and loafing sites) limiting production, it is strongly recommended that internal work (loafing bars and islands) be included in the design.
- 8) About 25 per cent of the marsh area should be open water at a depth of 4 to 5 feet. Islands for upland nesting and loafing would cover approximately 10 per cent of the marsh area. Some 50 to 60 per cent of the area would consist of shallow water and emergent vegetation for brood cover and nesting habitat for over-water nesters. Maximum security from nest predation is provided by surrounding the complex with a continuous zone of water two feet deep and approximately 300 feet wide.
- 9) Annual discharge and reflooding in early spring is desirable to insure maximum uptake of nutrients during the growing season and provide as little disruption to nesting water fowl as possible.
- 10) Some method of detritus removal, either by conventional harvest methods, burning or some form of dredging should be considered to prevent "fill in" of the marsh area.

- d. Other Engineering Requirements - There are several requirements which the Engineer should consider during design.
- 1) Protection against discharge or escape of reclaimed water from the marsh site should be considered. Sufficient water surface area must be provided so that the entire output of the treatment plant is taken up by evaporation during the months of maximum production of reclaimed water. Storage or alternate methods of disposal should be provided for use during months of low evaporation, if necessary.
 - 2) The marsh land should be segmented, so that sections can be closed off for rehabilitation or other work under the management program. Additional surface area should be allowed for in the design of the marsh to compensate for such periodic closures or, as an alternative, reclaimed water storage facilities should be incorporated into the design of the marsh.
 - 3) The wetlands should be located in an area of low soil permeability having a minimum soil mantle of three feet.
 - 4) The site should be level to minimize earthwork and to a low simulation of natural conditions as closely as possible.
 - 5) The site should be protected from natural inflow of waters to increase its capacity for utilization of reclaimed water. In addition, the site must be safe from flooding by storms up to the 100-year frequency.
 - 6) Facilities for delivery of reclaimed water to the wetlands marsh and for initial distribution into the marsh must be designed as all-weather components, capable of functioning during periods of freeze, as well as during normal weather.
 - 7) The initial distribution system at the marsh area should be designed to permit operating personnel to select the area of the marsh to which the water will be delivered.
 - 8) If it is found that the marsh land program cannot consumptively use all of the reclaimed water produced, either on an annual or a seasonal basis, alternative supplemental means of disposal/reclamation must be sought.
 - 9) Soils and geological investigation should be undertaken to define unusual geology, faults, dikes, etc. which would govern site location.
 - 10) Tabulation of existing wells that use the underlying aquifer and their water quality should be defined for background on future monitoring. Other ground water monitoring may be required.

- 11) Investigation of the effects of the system relative to proximity of inhabited areas should be considered.

Q. LAND TREATMENT.

The treatment of wastewater by land application can be applied to raw pretreated wastewater or effluents from secondary treatment processes.

There are three basic methods of applying raw waste or secondary effluents to land:

- (1) slow rate (irrigation)
- (2) rapid infiltration (infiltration-percolation)
- (3) overland flow.

1. Design Criteria - Tables VII - 40 and VII - 41 show the recommended design criteria for the three basic methods of land treatment. More detailed design information and examples are given in the EPA Process Design Manual for Land Treatment of Municipal Wastewater.

Preliminary investigative soils work shall be performed and submitted in report form evaluating the items listed in Table VII - 42.

2. Distribution - Distribution of the wastewater or effluent may be by fixed or moving sprinkling systems, ridge and furrow surface spreading, or border-strip irrigation.
3. Containment - All land disposal areas shall be designed to contain the effluent within the desired area.

If overland flow is used, the system used to collect the effluent discharge shall be suitable to assure confined transport to the point of final disposal.

4. Buffer Zones - Consideration shall be given to providing buffer zones on the land area to absorb unusual flow variations.
5. Monitoring Requirements - The effluent stream should be monitored, especially when the land treatment area is used in conjunction with agricultural production.

Ground water monitoring may be required and will be designated as required when the Department feels monitoring is necessary.

R. OTHER PROCESSES.

There are other processes which have application as advanced waste treatment processes and are generally applied to treated effluents.

1. Ion Exchange - Ion exchange is generally used in the advanced waste treatment field to remove organic nutrients, specially nitrogen and phosphorous compounds.

Feature	Principal processes		
	Slow rate	Rapid infiltration	Overland flow
Application techniques	Sprinkler or surface ^a	Usually surface	Sprinkler or surface
Annual application rate, ft	2 to 20	20 to 560	10 to 70
Field area required, acres ^b	56 to 560	2 to 56	16 to 110
Typical weekly application rate, in.	0.5 to 4	4 to 120	2.5 to 5 ^c 6 to 16 ^d
Minimum preapplication treatment provided in United States	Primary sedimentation ^e	Primary sedimentation	Screening and grit removal
Disposition of applied wastewater	Evapotranspiration and percolation	Mainly percolation	Surface runoff and evapotranspiration with some percolation
Need for vegetation	Required	Optional	Required

a. Includes ridge-and-furrow and border strip.

b. Field area in acres not including buffer area, roads, or ditches for 1 Mgal/d (43.8 L/s) flow.

c. Range for application of screened wastewater.

d. Range for application of lagoon and secondary effluent.

e. Depends on the use of the effluent and the type of crop.

Table VII - 40

Comparison of Design Features for Land Treatment Processes

Characteristics	Principal processes		
	Slow rate	Rapid infiltration	Overland flow
Slope	Less than 20% on cultivated land; less than 40% on noncultivated land	Not critical; excessive slopes require much earthwork	Finish slopes 2 to 8%
Soil permeability	Moderately slow to moderately rapid	Rapid (sands, loamy sands)	Slow (clays, silts, and soils with impermeable barriers)
Depth to groundwater	2 to 3 ft (minimum)	10 ft (lesser depths are acceptable where underdrainage is provided)	Not critical
Climatic restrictions	Storage often needed for cold weather and precipitation	None (possibly modify operation in cold weather)	Storage often needed for cold weather

Table XII - 41

Comparison of Site Characteristics for Land Treatment Processes

Wastewater Characteristics	Climate	Geology	Soils	Plant Cover	Topography	Application
Flow Consistent load	Precipitation Evapotranspiration Temperature Growing season Occurrence and depth of frozen ground Storage requirements Wind velocity and direction	Groundwater Seasonal depth Quality Points of discharge Bedrock Type Depth Permeability	Type Gradation Infiltration/ permeability Type and quantity of clay Cation-exchange capacity Phosphorus adsorption potential Heavy metal adsorption potential pH Organic matter	Indigenous to region Nutrient-removal capability Toxicity levels Moisture and shade tolerance Marketability	Slope Aspect of slope Erosion hazard Crop and farm management	Method Type of equipment Application rate Types of drainage

Table VII - 42
General Design Considerations For Land-Treatment Systems

In the general application, the ion exchange process should be preceded by carbon adsorption to reduce the organic load to the ex-changers and decrease organic fouling of the resin beds.

- a. Ammonia Removal - Ammonia removal may be accomplished using a porous cationic resin with the feed applied at approximately 3 gpm/ft². Regeneration is accomplished using a 10 per cent NaCl solution.

Selective ion exchange has been used which employs a natural zeolite, which is selective in the presence of sodium, magnesium, and calcium ions. Hydraulic loading rates of 6 - 8 gpm/ft² of bed area is the normal operating procedure. Regeneration of the exhausted resin is accomplished with a lime slurry which reacts with the ammonium ions to give an alkaline aqueous ammonia solution. The ammonium solution is then taken to an airstripping tower and the regenerant is recycled to the zeolite bed.

- b. Phosphate Removal - Typical organic resins used for anion exchange may be used for phosphate removal.

In addition, consideration should be given to using activated alumina. Application rates are generally in the range of 3 - 4 gpm/ft². Regeneration is accomplished using 2.0 M NaOH solution for backwash.

In all cases, it is recommended that pilot studies be administered to define design criteria and potential problem areas prior to final design.

2. Oxidation - Chemical oxidation in the advanced waste treatment process has application to:

- (1) remove ammonia in the effluent stream,
- (2) reduce the concentration of residual organics,
- (3) reduce the bacterial and viral content of the effluent. (See Section O.)

- a. Chlorine - Chlorination has proven to be operationally dependable in removing ammonia nitrogen in the wastewater effluent.

Theoretically, approximately 6.3 mg/l Cl₂ are required to remove 1.0 mg/l of ammonia. Actual experience shows requirements of 10 mg/l or greater of Cl₂ to remove 1.0 mg/l of ammonia. Best results occur with a reaction time of 2 hours, a temperature of 45 - 48°F, and a pH 7 - 9.

Chlorination is also a dependable means of reducing organic concentration (BOD₅, COD) in the effluent. Dosages required for organic reduction can only be determined in the laboratory. Therefore, pilot testing should be undertaken to size the chlorination system.

- b. Ozone - Ozone may be used in reducing the organic concentrations in wastewater treatment effluents. Since the reaction rate of ozone with organics is dependent upon the rate of ozone decomposition, which in turn varies with pH, pilot testing should be performed in designing ozonation systems used for oxidation of organics.
- 3. Reverse Osmosis - The reverse osmosis process may be used for inorganic and organic reduction in wastewater effluent streams prior to water reuse.

To assure an extended membrane service it will be necessary to pre-treat the effluent prior to application of the reverse osmosis system. In addition, facilities should be provided for periodic cleaning of the membrane units.

- a. Pretreatment - Since the principal cause of flux-decline of a reverse osmosis unit is generally attributed to organic or heavy metal fouling of the membrane, membrane hydrolysis, and membrane compaction, pretreatment is a necessity prior to reverse osmosis. The most frequently used pretreatment methods for wastewater effluents include:

- 1) pH Adjustment - Acidification of the feed stream reduces the rate of flux-decline by increasing the solubility of inorganic precipitates such as CaCO_3 , Mg(OH)_2 , or CaSO_4 , and minimizes the hydrolysis of the reverse osmosis membranes. It is general practice to keep the pH of the feed below 7.5. In addition, it is important to control the temperature of the feed to between 70 - 80°F for reduction in membrane hydrolysis.

In any case, the manufacturers' recommendation should be considered for operating conditions related to pH and temperature.

- 2) Turbidity Control - Removal of excess turbidity may be achieved by clarification with chemical coagulants absorption. In all cases, the feed stream should not exhibit a turbidity greater than 1 and, preferably, less than .75 JTU.

Disinfection prior to the reverse osmosis following pretreatment is necessary to prevent slime growths on the membrane and/or prevent contamination of the equipment.

- b. Membrane Cleaning - Table VII - 43 lists the methods of membrane cleaning that have been used and which may be considered to prolong membrane service.
- c. Post Treatment - Post treatment of the permeate water may be necessary and may involve pH adjustment, degasification to remove carbon dioxide, and disinfection.

Technique	Method	Description
Physical	Mechanical	Foam-ball swabbing
	Hydrodynamical Reverse flow	Tangential velocity variation Turbulence promoters Depressure and use forced or osmotic reverse flow of product
Chemical	Air/water flushing	Daily 15 min depressurized flush
	Sonication	Regular ultrasonic cleaning with wetting agent
	Additives to feed	pH control to reduce hydrolysis and scale deposit 5 mg/gal of 5% sodium hyperchlorite at pH = 5 Friction-reducing additives (poly-etheleneglycol) soil dispersants (sodium silicate)
	Flushing with additives at low pressure	Complexing agents (EDTA, Sodium hexametaphosphate) Oxidizing agents (citric acid) Detergents (1% BIZ) Precoat (diatomaceous earth, Activated carbon, and surface-active agent) High concentraton of NaCl (18%)
	Membrane replacement - Inorganic membranes - Active insoluble enzymes attached to membrane Proyelectrolyte membranes	<i>In situ</i> membrane replacement Encourage biogrowth to consume fouling film Degradation of fouling film Composite membranes or dynamic layer technique

Table VII - 43
Membrane Cleaning Techniques for Reverse Osmosis

The design of reverse osmosis system should be undertaken in conjunction with a reputable reverse osmosis manufacturer which has had prior experience in wastewater treatment applications. It is recommended that pilot studies be performed on pretreatment as well as reverse osmosis applications prior to final design.

4. Evapotranspiration - Evapotranspiration systems have application in effluent disposal of small waste treatment facilities. They generally provide a means of wastewater disposal in localities where site conditions preclude soil absorption, although they may be used in conjunction with soil absorption systems.
 - a. Design Criteria - The surface area of the evapotranspiration bed shall be sized on a hydraulic loading rate shown in Figure VII - 25. Since localized conditions are not shown in Figure VII - 25, the Engineer shall make necessary adjustments based upon similar elevations.

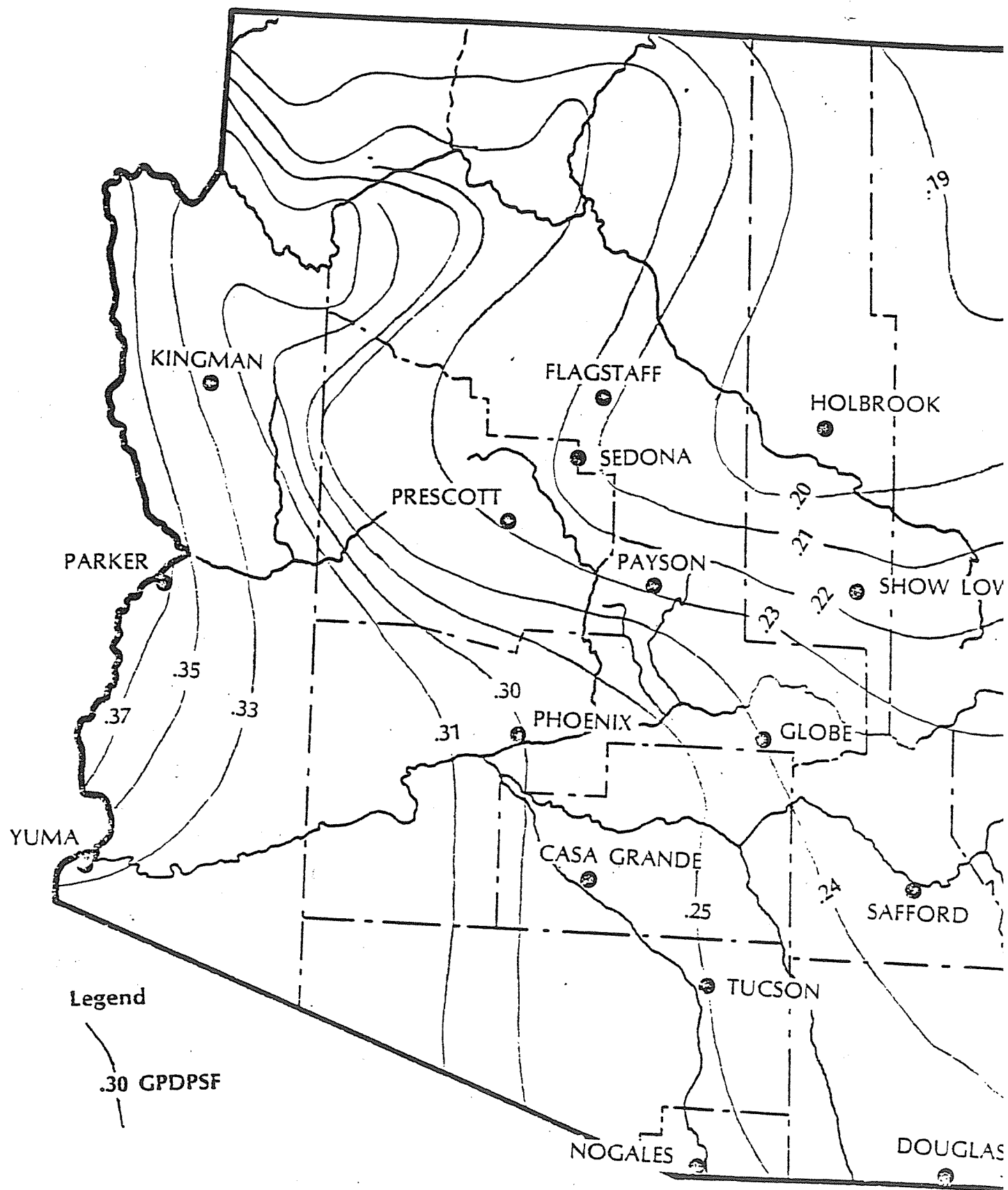


Figure VII - 25
Evapotranspiration Bed Application Criteria

	Minimum Distance, ft.
Well - Public Water Supply	100
- Private	50
Water Line	10
*Live Stream	100
Dry Wash	50
**Property Line	6
Building Foundation	10
Swimming Pools	10
Walks, Driveways	5

* 200 feet on water supply water sheds.

** Lots with individual wells require setbacks of 50 feet.

Table VII-44

Setback Requirements for Evapotranspiration Systems

- b. Setbacks - The minimum setbacks allowed shall be as outlined in Table VII - 44.
- c. Bed Construction.
 - 1) The bed surface shall be slightly crowned to exclude rain water. Adjacent drainage shall be diverted around and away from the evapotranspiration bed.
 - 2) The bed depth shall be between 3 feet and 5 feet, but not less than twice the maximum frost depth.
 - 3) The media shall be placed as follows:
 - a) Bottom half shall be 3/4 - 4 inch diameter gravel. Perforated drain tiles shall lay level on the top of the gravel.
 - b) Pea gravel shall be placed on top of the gravel to within 15 inches of the bed surface.
 - c) Coarse sand shall be placed on top of the pea gravel to within 2 inches of the bed surface.
 - d) The bed shall be topped with 2 inches of top soil.
 - 4) The distribution drain lines shall be perforated and shall be spaced no greater than 10 feet apart distributed across the bed area.

- 5) Serial or parallel loading of the drain lines is permitted.
- 6) The area may be planted with trees, flowers, or grass. However, vegetation should be selected to maximize evapotranspiration. The State Universities or the U. S. Department of Agriculture should be contacted for guidance.
- 7) Where evapotranspiration beds are placed on hillsides, concrete retaining walls or other suitable construction shall be installed to a depth of 2 feet below the bed bottom to prevent effluent from surfacing.
- 8) In areas where blasting is necessary, the soil and rock conditions and construction techniques may dictate use of bottom and/or side sealing.
- 9) Where sealing of the evapotranspiration bed is required, it is recommended that 20 mil minimum Hypalon or PVC liner be installed.
- 10) An evapotranspiration bed area equal to 100 per cent of the initial area shall be available for bed expansion. This space shall not be used for permanent structures.

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Chapter 8

**LABORATORY
EQUIPMENT
AND CONTROL**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

CHAPTER VIII - LABORATORY EQUIPMENT AND CONTROL

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CHAPTER VIII - LABORATORY EQUIPMENT AND CONTROL

A. INTRODUCTION.

This Chapter presents guidelines for laboratory control and testing of sewage treatment works. It is recommended that each laboratory use the following publications in performing all testing:

1. Standard Methods of the Examination of Water and Wastewater, latest edition, American Public Health Association, Inc., 1790 Broadway, New York, 10019.
2. Manual of Methods for Chemical Analysis of Water and Wastes, U. S. Environmental Protection Agency, Office of Technology Transfer, Washington, D. C., 20460.
3. Handbook for Analytical Quality Control in Water and Wastewater Laboratories, U. S. Environmental Protection Agency, Office of Technology Transfer, Washington, D. C., 20460.

Operators of smaller facilities may not be equipped to perform some of the recommended testing. In these instances, an accredited, independent, commercial laboratory or a regional sewage treatment works laboratory should be used.

B. OPERATION AND MAINTENANCE - ROUTINE CONTROLS.

The size of the laboratory necessary to support the operator in maintaining process balance is dependent upon the size and sophistication of the plant process. In smaller facilities the plant operator may be required to perform his or her own testing. The larger facilities require an independent staff to perform test work and advise the operator.

Table VIII - 1 is a list of recommended routine tests which should be performed at appropriate intervals to provide the operator with sufficient data to operate and maintain the treatment process.

In addition to the routine testing, special analysis may be required for heavy metals, pesticides, and other chemical constituents which could cause operational problems.

Residual chlorine in the plant effluent should be determined as a standard practice.

C. PLANT PERFORMANCE.

Laboratory testing needed to determine plant performance as measured by overall efficiency will vary from plant to plant based upon the assigned effluent quality standards and the NPDES discharge permit.

As a minimum, each plant shall be prepared to evaluate the following effluent constituents. Other constituents may be required in the NPDES permit.

1. pH
2. BOD
3. TSS
4. Suspended Solids
5. Temperature
6. Coliform
7. Dissolved Oxygen
8. Chlorine Residual

D. LABORATORY DESIGN.

The three key words to any well-planned wastewater treatment plant laboratory are:

- (1) Flexibility, which provides for changes in use requirements.
- (2) Adaptability, for changes in occupancy requirements, and
- (3) Expandability, for changes in space requirements.

The design of the laboratory facility should be performed with expectations of meeting future laboratory certification requirements. Smaller sewage treatment plants may not be able to support such a facility nor will it be necessary. As the size of the facility increases (above 100,000 gallons per day) careful design is encouraged to facilitate updating of the existing laboratory as laboratory certification requirements become mandatory.

1. Location - The laboratory should be located on ground level, easily accessible to all sampling points. In site selection, environmental control is an important consideration. It should be located away from vibrating machinery or equipment which might have adverse effects on the performance of laboratory instruments or the analyst. Optimum utilization of the laboratory is related to a pleasant, comfortable environment.
2. Equipment - Each laboratory should be equipped with the necessary equipment to perform the recommended laboratory analysis given in Table VIII - 1.

Glassware, chemicals, and other miscellaneous appurtenances should be housed in lockable cabinets.

Table VIII-1
Process vs. Routine Control Tests

	pH	Temperature	iOD	COD	Dissolved Oxygen	Suspended Solids	Total Dissolved Solids	Grease	Settleable Solids	Volatile Solids	Sludge Volume Index	Alkalinity
Influent	•	•	•			•	•	•		•		
Primary Clarification												
a. Influent			•	•		•			•			
b. Effluent			•	•		•						
c. Underflow						•				•		
Aeration (Including Trickling Filter)	•	•		•	•	•	•		•	•	•	
Secondary Clarification												
a. Influent	•	•				•				•		
b. Effluent			•	•	•	•	•		•			
c. Underflow						•				•		
Thickeners												
a. Gravity												
1. Influent						•						
2. Effluent			•	•		•						
3. Underflow						•		•		•		
b. Flotation												
1. Influent						•						
2. Effluent			•	•		•						
3. Underflow						•		•		•		
Digesters *												
a. Anaerobic												
1. Influent	•	•		•				•		•		•
2. Supernatant	•	•		•								•
3. Sludge						•				•		•
b. Aerobic												
1. Influent						•				•		
2. Supernatant			•		•	•				•		
3. Sludge						•				•		•
Sludge Dewatering												
a. Influent	•					•		•				•
b. Supernatant (Filtrate or centrate)	•		•	•		•	•					
c. Dewatered sludge						•		•		•		

* Volatile acids should be included in anaerobic digestion analysis

Table VIII-1, continued.

	pH	Temperature	BOD	COD	Dissolved Oxygen	Suspended Solids	Total Dissolved Solids	Grease	Settleable Solids	Volatile Solids	Sludge Volume Index	Alkalinity
Sludge Incineration												
1. Influent						●		●		●		
Lagoon												
1. Influent	●	●	●			●	●	●	●			
2. Pond Content	●	●			●				●			●
3. Effluent	●	●	●		●	●	●		●			

Table VIII-1, continued.

Advanced Waste Treatment	pH	Temperature	BOD	COD	Suspended Solids	Total Dissolved Solids	NH ₃	Organic Nitrogen	NO ₃	PO ₄
1. On Effluent from Biolog- ical treatment										
a. Ammonia air stripping										
1. Influent	●						●			
2. Effluent							●			
b. Filtration										
1. Influent			●	●	●		●		●	
2. Effluent			●	●	●		●		●	
3. Backwash					●					
c. Distillation										
1. Influent	●	●	●	●	●	●		●	●	●
2. Effluent			●	●	●	●		●	●	●
d. Flotation										
1. Influent	●		●				●		●	
2. Effluent					●		●		●	
3. Sludge			●		●					
e. Foam Fractionation										
1. Influent	●	●	●	●	●					
2. Effluent			●	●	●					
f. Reverse Osmosis										
1. Influent	●	●	●	●	●	●	●	●	●	●
2. Effluent			●	●	●	●	●	●	●	●
g. Carbon Adsorption										
1. Influent	●	●	●	●	●			●		
2. Effluent			●	●	●			●		
h. Ion Exchange										
1. Influent	●	●	●	●			●	●	●	●
2. Effluent			●	●						
i. Electrodialysis										
1. Influent	●	●				●	●		●	●
2. Effluent						●	●		●	●
j. Chemical Precipitation										
1. Influent	●	●	●	●	●	●	●	●	●	●
2. Effluent			●	●	●	●	●	●	●	●
3. Sludge					●					
k. Nitrification Denitrification										
1. Influent	●	●					●	●	●	
2. Effluent							●	●	●	

Table VIII-1, continued.

Advanced Waste Treatment	pH	Temperature	BOD	COD	Suspended Solids	Total Solids	Dissolved Solids	NH ₄	Organic Nitrogen	NO ₃	PO ₄
2. Physical Chemical - Secondary Treatment											
a. Coagulation											
1. Influent	●	●	●	●	●		●	●	●	●	●
b. Sedimentation											
1. Influent	●	●			●						
2. Effluent			●	●	●		●	●	●	●	●
3. Sludge*					●						
c. Filtration											
1. Influent	●	●	●	●	●			●	●	●	●
2. Effluent			●	●	●			●	●	●	●
3. Backwash					●						
d. Carbon Adsorption											
1. Influent	●	●	●	●	●			●	●	●	●
2. Effluent			●	●	●			●			●

*Volatile solids should be included in sludge analysis.

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Chapter 9

**INDUSTRIAL AND
AGRICULTURAL
WASTES**

ARIZONA DEPARTMENT OF HEALTH SERVICES

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CHAPTER IX - INDUSTRIAL AND AGRICULTURAL WASTES

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CHAPTER IX - INDUSTRIAL AND AGRICULTURAL WASTES

A. INTRODUCTION ~

1. Discharge to Surface Waters - Wastewaters from industrial and agricultural operations which discharge into any waters of the State shall not degrade the water quality of the surface waters beyond the limits prescribed by the Water Quality Standards as set forth in the Department's Rules and Regulation R9-21 and shall require a Discharge Permit.
2. No Discharge - Wastewaters from industrial and agricultural operations which do not discharge to the State's surface waters and are generally disposed of by leachfield, injection, evaporation, percolation, or other such feasible methods shall not be detrimental to ground water quality and its present and potential use.

Groundwaters which are used or have the potential of being used for drinking water supplies shall meet the standards for chemical quality as outlined in the Safe Drinking Water Act or any other applicable regulations. Effluent from land application which will degrade the quality of these water supplies must be treated to remove the potential of ground water quality degradation.

3. Discharge to Public Sewers - Wastewaters from industrial and agricultural operations which discharge into a public sewer shall be of such quality as to not cause toxicity to the public wastewater treatment process and to not degrade the water quality (surface or ground water) of the effluent receiving reservoir.

In certain instances, public systems are protected by local ordinances which limit quantity and quality of industrial and agricultural wastewaters.

4. Reuse - Wastewaters from industrial and agricultural operations which are candidates for reuse shall be considered on an individual basis in accordance with the Department's Regulation R9-20-408.

Industrial and agricultural wastes which recycle the total effluent stream as process water is not of concern to the Department provided the reuse does not create a health hazard.

Each wastewater should be evaluated for its reuse acceptability based upon, but not limited to:

- a. The degree of public contact with reclaimed wastes and the effect of the water quality upon public health and welfare.
- b. The degree of potential contamination of the products or by-products being produced or handled in the industrial or agricultural operation.

B. APPROVING AUTHORITY.

All treatment works proposed or designed to treat industrial and agricultural wastewaters shall be reviewed and approved by the appropriate approving authority prior to commencement of construction.

1. Environmental Protection Agency - All industrial and agricultural operations requiring a Discharge Permit shall submit the necessary reports, plans, and specifications to EPA for review and approval.

Operations requiring pretreatment prior to discharge to a public sewer may require review and approval by EPA. The owner or his representative should contact the Environmental Protection Agency regarding the requirements of such submittal.

2. State of Arizona - The Arizona Revised Statute 36-132 requires an application for approval to construct treatment works with engineering reports, plans, specifications, and all necessary information prior to construction of all waste treatment works and reclamation systems.

Four (4) copies of the plan documents shall be submitted to the Department at least 30 days prior to the date upon which Department approval is desired.

3. County - Certain counties act as the review and enforcement arm of the Department. The Department should be contacted for a current listing of its delegated agencies.
4. Municipality or Sanitary District - In certain instances, especially where discharges to public sewers occur, a municipality or sanitary district may require review and approval of industrial and agricultural treatment works. The owner or his representative should contact the local agencies regarding requirements for submittal.

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Chapter 10

SAFETY

ARIZONA DEPARTMENT OF HEALTH SERVICES

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CHAPTER X - SAFETY

A. INTRODUCTION.

Adequate provision must be made to protect operators and visitors of sewerage systems from hazards. The Engineer should design treatment facilities and sewer systems with maximum consideration of accident prevention and should refer to the appropriate OSHA requirements and the WPCF Manual of Practice No. 8.

B. SYSTEM PROTECTION.

Sewage treatment plants, manhole covers, sewage pumping stations, and other appurtenances of the sewerage system which are accessible to the public shall be protected from public entrance by fencing, a lockable enclosure, or other suitable means to assure a "closed" entrance to unauthorized individuals.

C. PROCESS WATER.

All process water taps shall be painted red and marked with a visible sign - "Contaminated Water - Do Not Drink."

D. IN-PLANT SAFETY.

All details pertaining to mechanical equipment, structural features, etc. of the sewage treatment plant shall be designed using the Arizona Occupational Health and Safety Standards as adopted by the Industrial Commission of Arizona, Division of Occupational Safety and Health. Such items which should be examined are belt guards, moving part guards, stairway protection, walkway design, handrail requirements, grating requirements, and color coding.

Other items which should be considered are:

1. Non-Slip Floors - In areas where water will stand or where freezing conditions may occur, suitable provision shall be made to assure proper safety by providing non-slip floors or suitable means of safety assurance.
2. Pipe Color Coding - All exposed pipe of larger facilities are to be color coded to facilitate identification. The color scheme shall follow the recommendations of the American National Standards Institute, "Standard Scheme for the Identification of Piping Systems."
3. Manhole Step Spacing - Maximum manhole step spacing shall be between 12 to 18 inches. The manhole step shall be manufactured of non-corrosive material and shall be knurled to prevent slippage.
4. Safety Equipment - All safety equipment, such as body straps, shoes, hard hats, etc. shall conform to OSHA standards.
5. Masks, Cannisters, and Respirators - All breathing devices shall conform to OSHA standards.

6. Gas Chlorination Facilities - The chlorination facilities shall conform to the safety design principles outlined in Chapter VII, Section O.
7. Anaerobic Digestion Facilities.
 - a. Gas Collection, Piping, and Appurtenances.
 - 1) General - All portions of the gas system, including space above the tank liquid, storage facilities and piping must be so designed that under all normal operating conditions, including sludge withdrawal, the gas will be maintained under pressure. All enclosed areas where any gas leakage might occur should be adequately ventilated.
 - 2) 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 shut-off valves, are essential.
 - 3) Gas Pipe and Condensate - Gas pipe shall be of adequate diameter and should slope to condensation traps at low points. The use of float control condensate traps is not permitted.
 - 4) Gas Utilization Equipment - Gas burning boilers, engines, etc. should be located at ground level and in well-ventilated rooms. Gas lines to these units must be provided with suitable flame traps.
 - b. Boiler or Heat Exchanger Controls - The automatic controls provided shall automatically shut off the main gas supply in the event of pilot burner or electrical failure.
 - c. Waste Gas Burner - This burner shall be located at least 25 feet away from any plant structure, if placed at ground level, or may be located on the roof of the control building, if sufficiently removed from the tanks.
 - d. Electrical Fixtures - Electrical fixtures in enclosed places where gas may accumulate, should comply with the National Board of Fire Underwriters' specifications for hazardous conditions.
 - e. Ventilation - Any underground enclosures connecting with digestion tanks or containing sludge, gas piping or gas equipment, shall be provided with forced ventilation.
 - 1) Wet Wells - Ventilation should be continuous and should provide at least 12 complete air changes per hour. For intermittent operation, at least 30 complete air changes per hour should be provided. Such ventilation shall be accomplished by introduction of fresh air into the wet well by mechanical means.
 - 2) Dry Wells - Ventilation may be either continuous or intermittent. For continuous operation, at least 6 complete air changes per hour should be provided. For intermittent operation, at least 30 air changes per hour should be provided.

- f. Maintenance Provisions - Non-sparking tools, rubber soled shoes, safety harnesses, gas detectors for inflammable and toxic gases, and gas masks which conform to OSHA standards shall be provided.
- 8. Maintenance Signs - Equipment lockout signs and devices shall be provided at all facilities for use by maintenance crews.

E. ELECTRICAL.

Electrical design should conform to the National Electrical Code and local codes. Non-sparking equipment should be used where explosion hazards exist. The equipment should bear the seal of the National Underwriters.

Adequate lighting shall be provided in the buildings as well as on the ground and especially around units serviced by personnel during hours of darkness.

F. OVERHEAD CLEARANCE.

Overhead clearances of moving equipment and stationary structures shall be sufficient to eliminate potential hazards.

G. LABORATORY SAFETY.

All laboratories shall be provided with the necessary safety equipment (conforming to OSHA standards) to assure laboratory safety. Table X - 1 serves as a minimum guideline of items needed to assure laboratory safety.

Table X - 2 is a general design check list which will be helpful in checking design features for laboratory safety.

H. FIRST AID KITS.

A well-stocked first aid kit shall be placed in strategic places throughout the plant. All vehicles used in the sewerage system should be equipped with a well-stocked first aid kit.

I. FIRE EXTINGUISHERS.

Suitable fire extinguishers shall be provided at strategic locations throughout the plant and shall be attached in a manner such that quick and easy access is provided.

J. SEWER MAINTENANCE.

- 1. Portable Ventilators - Portable ventilators should be provided for each sewer maintenance crew. The ventilator should be used to reduce air contamination in manholes or wet wells to a safe environment for sewer maintenance crews.

I. Eye and Face Protection	
Hazards	Protective Equipment
Splashing and spills Toxic fumes and gases Ruptures and explosions	Safety glasses, goggles Face shields Ventilating exhaust hoods Protective shields of shatterproof glass or plastic
II. Hand and Arm Protection	
Hazards	Protective Equipment
Glass Burns Splashing Spilling	Protective shields Gloves: Asbestos - for handling hot objects Leather - for working with glass Heavy rubber - for corrosive chemicals Light rubber - where finger dexterity is required Cotton Canvas - for general light duty Moleskin mitts - for heavy duty; with sodium hydrocarbons Plastic-coated - for handling organic solvents and chlorinated hydrocarbons
III. Respiratory Protection	
Treat every chemical as toxic. Odor is not a dependable guide.	
Hazards	Protective Equipment
Gaseous Fumes generated by reaction Harmful dust	Gaseous chemicals Chemical-cartridge respirators Self-contained breathing apparatus Filter respirators Gas masks Supplied-air respirators
IV. Body Protection	
Hazards	Protective Equipment
Explosion Fumes and gases Splashes and spills	Protective shields Ventilating exhaust hoods Aprons, coats, coveralls Rubber, plastic, coated glass fiber for water, moisture, mild acids and alkalis Natural rubber, plastic for strong acids and alkalis Synthetic rubber, plastic, coated glass fiber for solvents Asbestos, fire-resistant duck, insulated glass fiber for flame

Table X - 1
Laboratory - Personal Protection Checklist

I. Laboratory Layout

1. Adequate exits, aisles, stairways, etc.
2. Properly designed doors
3. Exhaust hoods
4. Ventilators
5. Lighting
6. Furniture arrangement
7. Storage facilities

II. Safety Equipment

1. Safety showers and eye baths
2. Fire extinguishing equipment
3. Personal protective equipment, safety glasses, face masks, gloves, aprons, respiratory equipment, etc.

III. Emergency Facilities

1. First Aid Kits and posted first Aid procedures for poisoning, burns, bleeding, unconsciousness, etc.
2. Posted phone number of physician and ambulance
3. Posted phone number of fire department
4. Posted charts of antidotes for poisoning
5. Stretchers

Table X - 2

A Checklist for General Laboratory Safety

2. Barricades - Barricades shall be provided at each manhole where a maintenance crew is at work for protection from traffic. The barricades should be easily visible from a distance of two hundred (200) feet.
3. Safety Equipment - The maintenance crews should be provided with the following minimum safety equipment:
 - a. Safety shoes
 - b. Gas detector
 - c. Hard hat
 - d. Body saddles attached to rope (in conformance with OSHA requirements)
 - e. Gloves

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Chapter 11

**OPERATION AND
MAINTENANCE
MANUAL**

ARIZONA DEPARTMENT OF HEALTH SERVICES

JULY 1978

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CHAPTER XI - OPERATION AND MAINTENANCE MANUAL

A. INTRODUCTION.

Proper operation of new or modified sewerage works and improved operation of existing facilities are essential if effluent quality standards are to be met. In an effort to increase the probability of meeting effluent quality standards, it is mandatory that each sewerage works operator have access to an operation and maintenance manual which will act as a guide in all aspects related to the system operation and maintenance.

Therefore, the design Engineer shall submit four (4) copies of an operation and maintenance manual to the Department for review and approval prior to the issuance of a certificate to operate. Upon final acceptance of the manual by the Department, the Engineer shall furnish four (4) copies of the corrected manual to the Owner.

The Owner shall locate the operation and maintenance manual in a place accessible to the operator on the site of the sewage treatment works.

B. GENERAL REQUIREMENTS.

The operation and maintenance manual shall be designed for use by the operator. It should, therefore, be written on a reading level appropriate for the grade of operator necessary for the particular plant. Readability should be increased by use of short sentences, simplified vocabulary, etc. Use of illustrations is encouraged, especially where they can supplement involved instructions.

It is recommended that all manuals be in looseleaf form for expansion and updating purposes. If the manual is large, it is recommended that it be produced in at least two volumes. Manufacturers' manuals should be grouped together and should be cross-referenced to the main text, as appropriate. The manuals should be indexed and tabbed to simplify usage.

C. FORMAT REQUIREMENTS.

The operation and maintenance manual of all sewerage works shall contain, but not be limited to, the following sections.

1. Lift Stations - Each unit of the lift station shall be related to its function. Schematic diagrams shall be used to show the location of all valves, pumps, controls, etc. and how they relate to the overall station operation. Items which should be considered are:
 - a. Pumps
 - b. Level controls
 - c. Valves and piping
 - d. Ventilation equipment
 - e. Dehumidifiers
 - f. Sumps
 - g. Bar screens or baskets

2. Plant Layout and Flow Pattern - The plant type and a description of the basic process will be required. Each unit of the plant shall be related to its function and to the other units included in the process. Schematic diagrams shall be used to show the location of all valves, pumps, controls, etc., and how they relate to the over-all operation. Additional diagrams shall contain enlarged details of the complicated piping areas.

Items which should be considered are:

- a. Pumping
 - b. Pretreatment systems
 - c. Screening and comminution
 - d. Grit removal
 - e. Primary clarification
 - f. Aeration and re-aeration
 - g. Secondary sedimentation
 - h. Trickling filters
 - i. Sand filters
 - j. Sludge digestion
 - k. Sludge conditioning
 - l. Sludge disposal
 - m. Sludge drying beds
 - n. Gas control and use
 - o. Disinfection
 - p. Effluent reuse systems
 - q. Wastewater lagoons
 - r. Odor control systems
 - s. Chemical addition
 - t. Effluent polishing systems
 - u. Other processes
3. Expected Efficiency of the System and the Principal Design Criteria - A detailed outline of the expected treatment efficiency in removing the required discharge constituents shall be presented. Principal design criteria shall be given with unit sizes, retention times, loading rates, etc., for each part of the sewerage system.
 4. Detailed Operational and Control Procedures - Routine procedures of operation and control shall be detailed as well as alternate methods and emergency procedures. The pipelines, valves, and controls should be clearly marked as referenced in the detailed operation procedures.

A description of the various controls with recommended settings shall be given as related to:

- a. Manual controls
- b. Automatic controls
- c. Physical controls
- d. Chemical controls
- e. Biological controls
- f. Industrial waste monitoring
- g. Safety features

Pump calibration curves, chemical makeup charts and other graphical aids which assist the operator shall be included.

5. Laboratory Controls - A brief discussion of required laboratory tests, why these tests are required, interpretation of the test results, and sampling procedures shall be presented as applied to:
 - a. Each unit of the process
 - b. Monitoring of effluent and receiving waters
 - c. Water quality standards

Recommended laboratory testing manuals or books should be referenced with names and addresses of publishers.

6. Records - The operation and maintenance manual shall stress the importance of record keeping and graphing test results. Sample forms shall be enclosed which apply to:
 - a. Process operations
 - b. Laboratory analysis
 - c. Reports required by the regulatory agencies
 - d. Maintenance
7. Maintenance - The manual shall contain a detailed recommended maintenance schedule for all facets of sewerage system maintenance. These schedules shall be for:
 - a. Normal equipment maintenance schedules as per manufacturer's recommendations
 - b. Preventive maintenance summary schedules
 - c. Special tools and equipment
 - d. Housekeeping schedules, such as weed control, etc.
8. Trouble Shooting Guide - A trouble shooting guide shall be provided for each system unit (biological and mechanical) with a ready reference chart describing short-term and long-term solutions, and a brief description of the cause.
9. Safety Procedures - The operation and maintenance manual shall discuss safety procedures as related to:
 - a. Sewers
 - b. Electrical equipment
 - c. Mechanical equipment
 - d. Explosion and fire hazards
 - e. Health Hazards
 - f. Handling of chlorine and other hazardous chemicals
 - g. Open tank hazards

A list of recommended safety equipment shall be an integral part of the manual. It is recommended that the WPCF Manual of Practice No. 8 be used in conjunction with OSHA in addressing safety procedures.

10. Emergency Operating Plans and Procedures - The operation and maintenance manual for lift stations and treatment plants shall describe the effective automatic response for probable emergency situations which may be caused by the following:

a. Power Failure.

- 1) entire plant
- 2) treatment process
- 3) pumping stations
- 4) false alarms

- b. Flood, hurricane, earthquake, fire, windstorms, freezing, explosions
- c. Contamination of potable water supply
- d. Hydraulic overloading, ruptures, and stoppages
- e. By-passing
- f. Equipment breakdowns and process failures
- g. Failure of emergency warning equipment
- h. Labor strikes
- i. Spills of oils, toxic or hazardous materials into sewers or at treatment works
- j. Personnel injury
- k. Other types of emergency situations

A general response pattern shall be established for each type of emergency and should follow the general response actions of:

- a. Early warning report
- b. Investigation
- c. Assess severity of the situation (including threat to public health, water supplies, etc.)
- d. Determine response course of action and implement appropriate emergency plan.
- e. Follow appropriate notification schedule (local-State-Federal) depending on type of emergency.

The operation and maintenance manual shall also contain an emergency readiness program. The manual shall describe the appropriate program for maintaining readiness by addressing the following:

- a. Equipment and parts inventory and chemical supplies necessary to handle emergency.
 - b. Personnel training on emergency operating procedures.
 - c. Charts on location of facilities
- 1) sewers
 - 2) pump stations
 - 3) sewer overflow points
 - 4) flow regulators, valves, and controls
 - 5) wastewater storage

- d. Alert and response system for each type of emergency
 - e. Early warning systems where applicable to warn downstream water users of spills, etc.
 - f. Industrial waste monitoring and warning system within sewer networks to alert plant operators of spills and changes in waste consistency or hydraulic conditions that may adversely affect waste treatment.
11. Utilities - A map of all utilities showing key shut-off points shall be included in the manual for
- a. Electrical
 - b. Gas
 - c. Water
 - d. Heat
12. Manufacturer's Equipment Data - Each manual shall contain data from equipment suppliers which contains
- a. Parts lists
 - b. Assembly drawings
 - c. Equipment trouble shooting guides
 - d. List of recommended spare parts and instructions for ordering equipment.
13. Appendix - The appendix of the manual shall contain.
- a. Schematics
 - b. Valve indices
 - c. Sample forms
 - d. List of chemicals used in the plant and handling procedures
 - e. List of chemicals used in the laboratory
 - f. Effluent discharge permit and standards
 - g. Detailed design criteria
 - h. List of equipment suppliers with addresses and telephone numbers
 - i. Suppliers' manuals
 - j. Local ordinances
 - k. Operator certification and staffing requirements
 - l. Details for reporting spills

LIST OF SYMBOLS

CHAPTER I - None

CHAPTER II - None

CHAPTER III

K_2, K_1 = reaction rate constants

Q = flow, MGD

T_2, T_1 = system temperatures, °C

θ = constants

CHAPTER IV

n = Manning's coefficient

P = population (thousands)

Q = capita flow, gpd

CHAPTER V

A, B, S, H, C, W = sump dimensions, inches

α = sump side wall entrance angle, degrees

c = Hazen-Williams' coefficient

D, d = pipe diameter, inches

\emptyset = cycle time, minutes

F = diameter of pipe with pump intake, inches

J = number of joints in test pipe

L = maximum allowable leakage, gph

P_t = test pressure, psi

Q = flow, MGD

q = pump capacity, gpm

s = pipe head loss, ft/1000 ft

V_1 = velocity past intake, fps

V_e = sump entrance velocity, fps

V_c = stream flow velocity, fps

V_p = pipe velocity, fps

V_w = wet well capacity, gallons

v = velocity of pipe flow, fps

CHAPTER VI - None

CHAPTER VII

- A = surface area of tank or basin, sf
- BOD_L = ultimate BOD
- β = minimum width of bar screen opening, inches
- b = minimum width of bar screen opening, inches
- C' = conversion factor
- C_i = influent BOD, pounds
- C_e = effluent BOD, pounds
- D = media depth, ft
- d = dispersion factor
- d' = pond depth, ft
- F = oxygenation factor
- F' = influent flow rate, gpm
- g = gravitational constant, 32.2 fpsps
- h = head drop across bar screen, ft
- K_T = removal rate constant, day⁻¹
- L_a = BOD settled sewage, mg/l
- L_o = BOD influent, mg/l
- L_e = BOD effluent, mg/l
- L'_o = organic loading, lb BOD/acre/day
- M = BOD removal rate, lb/day
- MLSS = mixed liquor suspended solids concentration, mg/l
- N = recirculation ratio
- P = ratio of total hours of sunshine to total possible hours of sunshine
- PAS = fraction of total solids due to WAS
- Q = flow rate of sewage, MGD
- Q_h = hydraulic loading, gpm/sf
- R = recycle flow rate
- r = recirculation ratio
- S_{avg} = solar radiation, cal/cm² - day
- S_{in} = influent BOD, mg/l
- S_m = BOD of mixture, mg/l
- S₃ = BOD effluent from third cell, mg/l

CHAPTER VII (Contd.)

SLR = solids loading rate, lb/sf/day

T = design temperature, °C

t = retention time, days

V = velocity through clear space of bar screen, fps

V_1 = upstream velocity, fps

V_c = volume lagoon cell, gallons

V' = lagoon volume, gallons

V_r = minimum rising velocity, inches per minute

w = maximum width of bars facing the flow, inches

Y_{O_2} = oxygenation factor

C, m, n, k = constants

CHAPTER VIII - None

CHAPTER IX - None

CHAPTER X - None

CHAPTER XI - None

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