CHAPTER 6: SETTLING

6.1 APPLICABILITY AND SCOPE

This chapter is applicable to the construction, installation, or modification of any disposal system required to obtain a construction permit from the department under Iowa Code section 455B.183 and rule 567—60.2(455B). Specifically, this chapter details the design criteria for settling tanks (also known as sedimentation tanks or clarifiers) used to remove settleable solids, grease and scum from wastewater following pretreatment or to separate biomass and scum from the biological process effluent. Design criteria for different types of settling tanks are included in this chapter including primary, intermediate and secondary units following both attached growth and activated sludge processes.

6.2 GENERAL CONSIDERATIONS

6.2.1 Number of Units

Multiple units capable of independent operation are desirable and shall be provided in all plants except those specified in IWFDS Section 4.5.

6.2.2 Flow Distribution

Flow splitting devices and control appurtenances (i.e., valves, gates, splitter boxes) shall be provided to permit proper proportioning of flow to each unit in accordance with IWFDS Subsection 4.4.9.3.

6.3 DESIGN CONSIDERATIONS

6.3.1 ~~Dimensions~~Side Water Depth

The side water depth for ~~primary~~ settling tanks shall ~~not~~ be ~~less than seven feet~~as set forth in Table 1 below:~~.~~ ~~Settling tanks following the activated sludge process shall have side water depths of at least 12 feet to provide an adequate separation zone between the sludge blanket and the overflow weirs. Settling tanks following the activated sludge process may have 10-foot side water depths provided that less than 340 lbs/day of BOD_5 is treated and provided the clarifier is followed by a five-day pond. Intermediate settling tanks following first stage fixed film reactors shall have side water depths of at least seven feet. Final settling tanks following fixed film reactors shall have side water depth of at least 10 feet.~~

Table 1. Settling Tank Side Water Depths

Type of Settling Tank	Minimum Side Water Depth (ft)
Primary	10
Secondary - Activated Sludge[a,b]	12
Secondary - Attached Growth[b]	10

[a] Greater side water depths are recommended for secondary settling tanks in excess of 4,000 square feet of surface area.

[b] Side water depths less than 12 feet may be permitted for plants with an AWW design flow of 40,000 gallons per day or less. Settling tanks following integrated fixed-film activated sludge processes incorporating both attached growth and activated sludge in a single reactor are considered activated sludge for the purposes of this table.

6.3.2 Surface Overflow and Solids Loading Rates

6.3.2.1 General

1. ~~Settling~~ Surface overflow and solids loading rates in this section are based on typical clarifier designs for domestic wastewaters without additions of chemical settling aids. If chemical coagulants are added to aid settling, overflow rates may be increased based on pilot studies or similar facilities already in operation.
2. The flows used in the following sections are designated by the abbreviations used in IWFDS Subsection 4.4.5.2 for municipal treatment plants. The corresponding flow designations for AWW and PHWW flows for industrial wastewater treatment facilities would be the average rated flows and the peak hour flows.

6.3.2.2 Primary Settling Tanks

1. Surface overflow rates for primary settling tanks should not exceed the rates set forth in Table 2 below:~~1,000 gpd/ft^2 at AWW flows or 1,500 gpd/ft^2 for PHWW flows. Clarifier sizing shall be calculated for both flow conditions, and the larger surface area determined should be used. At these rates, primary settling of normal domestic sewage can be expected to remove 30-35% of the influent BOD_5. The overflow rates may be increased, but lower removal rates shall be assumed unless adequate chemical addition is provided.~~

Table 2. Primary Settling Tank Surface Overflow Rates[a,b]

Type of Primary Settling Tank	Surface Overflow Rate at AWW Flow, gpd/ft²	Surface Overflow Rate at PHWW Flow, gpd/ft²
Tanks not receiving waste activated sludge	1,000	1,500
Tanks receiving waste activated sludge	700	1,200

[a] Clarifier sizing shall be calculated for both flow conditions, and when appropriate, use the larger surface area determined. Primary settling of typical domestic wastewater in settling tanks not receiving waste activated sludge can be expected to remove approximately one-third (1/3) of the influent BOD_5 when operating at an overflow rate of 1,000 gpd/ft².

[b] Greater BOD_5 removal for typical domestic wastewater at the recommended overflow rates or anticipated BOD_5 removal for higher overflow rates, chemically enhanced primary settling, or sewage containing appreciable quantities of industrial wastes should be verified by laboratory tests, actual settling data, and consideration of the quantity and character of the wastes.

~~1.~~

~~2. Anticipated BOD_5 removal for sewage containing appreciable quantities of industrial wastes should be determined by laboratory tests, actual settling data, and consideration of the quantity and character of the wastes.~~

6.3.2.3 Intermediate Settling Tanks

~~1.~~ Surface ~~settling~~ overflow rates for intermediate settling tanks shall not exceed the ~~following~~rates set forth in Table 3 below: ~~the carbonaceous stage of a separate stage nitrification activated sludge process shall not exceed 900 gpd/ft² at AWW flows or 1,200 gpd/ft² for PHWW flows. Higher surface settling rates may be permitted if such rates are shown to have no adverse effects on subsequent treatment units.~~

1.

~~Surface settling rates for intermediate settling tanks following other treatment units shall not exceed 1,500 gpd/ft² based on PHWW flows.~~

Table 3. Intermediate Settling Tank Surface Overflow Rates

Type of Intermediate Settling Tank	Surface Overflow Rate at AWW Flow, gpd/ft²	Surface Overflow Rate at PHWW Flow, gpd/ft²
Settling Tank Following the Carbonaceous Stage of Separate-Stage Nitrification Activated Sludge[a]	900	1,200
All Others	-	1,500

[a] Higher surface overflow rates may be permitted if such rates are shown to have no adverse effects on subsequent treatment units.

~~2.~~

6.3.2.4 Final Settling Tanks

1. Final Settling Tanks ~~– Fixed Film Biological Reactors~~General

~~1.~~ Settling tanks shall be designed to meet thickening and solids separation requirements. Surface overflow and solids loading rates shall be low enough to minimize problems with excessive solids loadings, density currents, inlet hydraulic turbulence, and occasional poor sludge settleability.

~~a. Surface overflow rates for settling tanks following trickling filters or RBCs treating domestic wastewater shall not exceed 1,200 gpd/ft² for PHWW flows.~~

~~b. The allowable surface overflow rates may be increased if chemical addition is provided. This determination shall be based on data from pilot studies, similar systems already in operation, or the literature.~~

2. Final Settling Tanks ~~– Activated Sludge~~Domestic Wastewater

~~2.~~ The surface overflow and solids loading rates for facilities treating domestic wastewater shall not exceed the rates set forth in Table 4 below:

~~a. To perform properly while producing a concentrated return flow, activated sludge settling tanks shall be designed to meet thickening and solid separation requirements. Since the rate of recirculation of return sludge from the final settling tanks to the aeration or reaeration tanks is quite high in activated sludge processes, surface overflow rates shall below enough to minimize problems with high solids loadings, density currents, inlet hydraulic turbulence, and occasional poor sludge settleability. The surface settling rates of final settling tanks following the activated sludge processes shall be based on PHWW flow. The hydraulic loadings for facilities treating domestic wastewater shall not exceed the following:~~

~~Process Type~~	~~Hydraulic Loading at PHWW Flow, gpd/ft²~~
~~All (except as listed below)~~	~~1,200~~
~~Contact Stabilization~~	~~1,200~~
~~Extended Aeration~~	~~1,000~~
~~Separate Nitrification~~	~~800~~
~~High-Purity Oxygen with Primary Settling~~	~~1,200~~

Table 4. Final Settling Tank Surface Overflow and Solids Loading Rates[a]

Treatment Process	Surface Overflow Rate at PHWW Flow, gpd/ft²	Solids Loading Rate at AWW Flow, lbs/day/ft²	Solids Loading Rate at PHWW Flow, lbs/day/ft²
Activated Sludge (except as listed below)	1,200	30[b]	50[b]
Extended Aeration	1,000		
Nitrification Stage of Separate-Stage Nitrification	800		
Attached Growth[c]	1,200	-	-

[a] The allowable surface overflow and solids loading rates may be increased if chemical addition, baffling or other measures to allow increased rates while maintaining adequate settling performance are provided. This determination shall be based on data from pilot studies or similar systems already in operation.

[b] The solids loading rate shall be calculated using the design maximum return sludge rate and the design MLSS concentration. Settling tank sizing shall be calculated for the surface overflow rate and both solids loading conditions and shall use the largest surface area determined.

[c] Settling tanks following integrated fixed-film activated sludge processes incorporating both attached growth and activated sludge in a single reactor are considered activated sludge for the purposes of this table.

~~b. The final settling tank solids loading for all activated sludge processes shall not exceed 30 lbs/day/ft² of solids at AWW flow or 50 lbs/day/ft² of solids at PHWW flow. Settling tank sizing shall be calculated for both flows and both solids loading conditions and shall use the largest surface area determined.~~

~~c. The allowable surface overflow rates may be increased if chemical addition is provided. This determination shall be based on data from pilot studies, similar systems already in operation, or literature data.~~

3. Final Settling Tanks - Industrial Waste

~~3.~~

a. For industrial waste treatment facilities and domestic waste treatment facilities with significant industrial contributions, surface overflow rates ~~shall~~ may be based on pilot studies, representative water analyses and jar test studies, data from similar systems already in operation, or literature data. The surface overflow rates shall not exceed those allowed in Subsection~~s 6.3.2.4.1 and~~ 6.3.2.4.2.

b. When the department has actual operating experience with ~~two~~ similar facilities, it may require lower settling rates or additional solids removal capability.

~~6.3.3~~ Inlet Structures

~~6.3.3.1~~**6.3.3** ~~**When the department has actual operating experience with two similar facilities, it may require lower settling rates or additional solids removal capability.**~~

~~6.3.3.2~~ Inlet structures shall be designed to dissipate the inlet velocity, to distribute the flow equally both horizontally and vertically, and to prevent short circuiting. Channels shall be designed to maintain a velocity of at least one fps at one-half the AWW flow. Corner pockets and dead ends shall not be allowed and corner fillets or channeling shall be used where necessary. Provisions shall be made for elimination or removal of floating materials in the inlet structures.

6.3.4 Weirs

6.3.4.1 General - Overflow weirs shall be readily adjustable for leveling. The range of adjustment shall consider uneven settling over the life of the structure. Overflow weirs shall be serrated with V-Notches or similar notches.

6.3.4.2 Location - Overflow weirs shall be located to optimize actual hydraulic detention time, ~~and~~ minimize short circuiting and provide~~. Peripheral weirs should be placed at least one foot away from the clarifier wall or baffles should be provided to minimize wall effects. Interior weirs are permissible if accompanied by~~ effective means of scum removal.

6.3.4.3 Design Rates - Weir loadings shall not exceed 10,000 gpd/lineal ft for plants designed for AWW flows of 1.0 mgd or less. Higher weir loadings may be used for plants designed for larger AWW flows, but should not exceed 15,000 gpd/lineal ft. If pumping to the settling tanks is required, weir loading should be related to pump delivery rates to avoid short circuiting. Avoid ~~P~~pumping ~~should not be intermittent, but as nearly continuous as possible, and pumping~~ into a final clarifier ~~should be avoided~~, but if necessary provide pumping that is as continuous as possible.

6.3.4.4 Weir Troughs - Weir troughs shall be designed to prevent submergence at PHWW flow with the largest tank out of service, and to maintain a velocity of at least one fps at ½ the AWW flow.

6.3.4.5 Unit Dewatering and Bypassing - Unit dewatering features shall conform to IWFDS Subsection 4.4.8.2. Unit bypass design shall also provide for proportional redistribution of the plant flow to the remaining units.

6.3.4.6 Freeboard - Walls of settling tanks shall extend at least six inches above the surrounding ground surface and shall provide not less than 12 inches freeboard. Additional freeboard or the use of wind screens is recommended where large settling tanks are subject to high winds that would cause tank surface waves and inhibit effective scum removal.

6.4 SLUDGE AND SCUM REMOVAL

6.4.1 Scum Removal

Scum collection and removal facilities, including baffling, shall be provided for all primary and final settling tanks. Characteristics of certain treatment process scum (i.e., nitrification, industrial wastewater) which may adversely affect pumping, piping, sludge handling, or disposal, shall be recognized in the design.

6.4.2 Sludge Removal

Sludge collection and withdrawal facilities shall be designed to assure rapid removal of ~~the~~ sludge and facilitate accurate measurement and control of the sludge withdrawal rate from each individual clarifier. Consider ~~S~~suction withdrawal ~~should be provided~~ for activated sludge settling tanks.

6.4.2.1 Sludge Hopper - The minimum slope of the side walls shall be 1.7 vertical to 1 horizontal. Hopper wall surfaces shall be made smooth with rounded corners to aid in sludge removal. Hopper bottoms shall have a maximum plan dimension of two feet. Extra depth sludge hoppers for sludge thickening are not acceptable.

6.4.2.2 Cross-Collectors - Cross-collectors serving one or more settling tanks may be useful in place of multiple sludge hoppers.

6.4.2.3 Sludge Removal Piping - Each hopper shall have an individual sludge withdrawal line at least six inches in diameter with a valve. The static head available for sludge withdrawal shall be 30 inches or greater, as necessary to maintain a three fps velocity in the withdrawal pipe. Provide sufficient ~~C~~clearance between the end of the withdrawal line and the hopper walls ~~should be sufficient~~ to prevent "bridging" of the sludge. Provisions shall be made for rodding or back flushing individual pipe runs. Piping may also be provided to return waste sludge to primary clarifiers.

6.4.2.4 Sludge Removal Control - Sludge wells equipped with telescoping valves or other appropriate equipment should be provided for viewing, sampling, and controlling the rate of sludge withdrawal. The use of easily maintained sight glass, sampling valves, and sludge density meters may be appropriate. A means of measuring the sludge removal rate shall be provided. Air lift type of sludge removal will not be approved for removal of primary sludges. Sludge pump ~~motor~~ control systems should include variable frequency drives or time clocks and valve ~~activators~~ actuators for regulating the duration and sequencing of sludge removal.

6.5 PROTECTIVE AND SERVICE FACILITIES

6.5.1 Operat~~or~~ion Protection

Equip ~~A~~all settling tanks with safety features to protect operators that may include ~~should be equipped to enhance safety for operators. Such features should appropriately include~~ machinery covers, life lines, stairways, walkways, handrails, confined space signage, and slip resistant surfaces.

6.5.2 Mechanical Maintenances Access

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

6.5.3 Electrical Fixtures and Controls

~~The~~ Locate fixtures and controls ~~should be located~~ so as to provide convenient and safe access for operation and maintenance. Provide ~~A~~adequate area lighting ~~should be provided~~ (see IWFDS Section 4.8). Appropriate pump controls should be located near sludge and scum viewing points.

6.5.4 Cold Weather Protection

~~The design should P~~provide measures for cold weather protection that may include~~such as~~ the use of wind screens, protective walls, or other means, as appropriate, to alleviate the problems of freezing.

CHAPTER 8B: ACTIVATED SLUDGE BIOLOGICAL TREATMENT

8B.1 APPLICABILITY AND SCOPE

This chapter is applicable to the construction, installation, or modification of any disposal system required to obtain a construction permit from the department under Iowa Code section 455B.183 and rule 567—60.2(455B). Specifically, this chapter applies to the activated sludge process, which uses aeration tanks containing suspended biomass and a means of sludge retention to reduce oxygen demand and/or oxidize ammonia to nitrate following pretreatment or primary settling. Variations of the activated sludge process employing anoxic and/or anaerobic basins, zones or cycles may also be used for biological nutrient removal.

8B.2 PROCESS SELECTION

8B.2.1 Applicability

The activated sludge process and its various modifications may be used to treat wastewater amenable to biological treatment.

8B.2.2 Operational Requirements

The activated sludge process requires close attention and competent operating supervision. Facilities and appurtenances for routine control and testing, including suitable laboratory apparatus, shall be provided at all activated sludge plants.

8B.2.3 Specific Process Selection

The activated sludge process and its modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of carbonaceous and nitrogenous oxygen demand. Choice of the most applicable process will be influenced by the proposed plant size, type of waste to be treated, treatability of waste, degree and consistency of treatment required, and local factors. All designs shall provide for flexibility in operation. All plants with a design ~~over 1 MGD at~~ AWW flow over 1 mgd should be designed to be operable in more than one mode. Seasonal organic loadings and significant wet weather flow increases are factors that affect mode of operation.

8B.3 PRETREATMENT

When primary settling tanks are not used, effective removal or exclusion of grit, debris, and excessive oil or grease, and comminution/grinding or screening of solids shall be accomplished prior to the activated sludge process. Where primary settling is used, it may be desirable to include provisions for discharge of raw wastewater directly to the aeration tanks to facilitate plant startup and initial operation.

8B.4 AERATION

8B.4.1 Design Basis

In addition to the requirements of IWFDS Chapter 1, the design basis for an activated sludge process shall be prepared by the owner's representative ~~an~~ engineer (as indicated in Schedule A) and included in the engineering report or facilities plan or submitted under separate cover for review and approval. The design basis shall include a discussion of all of the following:

- All design parameters used in sizing the activated sludge treatment facilities;
- Mode of operation, including discussion of process flexibility;
- Influent wastewater characteristics and flows, including the ADW, AWW, MWW, and PHWW flows;
- Wastewater temperature range, including estimates of temperature losses through the treatment plant and subsequent effect on removal efficiencies;
- Pretreatment of the waste;
- Effects of variable hydraulic and organic loadings applied to the aeration basins and secondary clarifiers, particularly variations resulting from infiltration/inflow to the system;
- Anticipated MLSS concentration to be maintained in the aeration basin;
- Aeration time;
- Oxygen transfer and mixing requirements at the ADW, AWW, and MWW flows;
- Where nitrification is required, evaluation of process alkalinity requirements;
- Sludge recirculation and wasting (ranges and average values), including proposed method of control and anticipated typical operating mode; and

- Design calculations for oxygen requirements, blower or aerator capacity, aeration basin and clarifier sizing, clarifier solids loading, and treatment efficiency.

8B.4.2 Capacities and Permissible Loadings

8B.4.2.1 General - Aeration tank size shall be determined by full scale experience, pilot plant studies, and/or rational calculations based on food to microorganism ratio, solids retention time, and MLSS levels. Other factors, such as treatment plant size, diurnal load variations, and degree of treatment required shall also be considered.

~~8B.4.2.1~~8B.4.2.2 Typical Design Parameters - Table 1 represents typical design parameters for domestic wastewater. Design parameters differing substantially from those in Table 1 may be allowed if applicable references are submitted demonstrating their use and long-term effectiveness. These may include but are not limited to data from actual operating plants, pilot plant studies, standard textbooks or current technical literature. Table 1 applies to plants receiving peak to average diurnal organic load ratios ranging from approximately 2:1 to 4:1. The department may approve organic loading rates that exceed those specified in Table 1 if flow equalization is provided to reduce the diurnal peak organic load.

~~8B.4.2.2 Table 1 represents typical design parameters for domestic wastewater. Design parameters differing from those in Table 1 shall reference actual operating plants or pilot plant studies. Table 1 applies to plants receiving peak to average diurnal organic load ratios ranging from approximately 2:1 to 4:1. The department may approve organic loading rates that exceed those specified in Table 1 if flow equalization is provided to reduce the diurnal peak organic load.~~

~~8B.4.2.3 The single stage of a two-stage activated sludge system designed to remove ammonia shall maintain adequate alkalinity concentrations and a pH level between 7.2 and 8.4. Chemical feed equipment shall be provided if necessary. Flow equalization shall be considered where necessary to limit TKN peaks resulting from industrial wastes. For two stage systems, $CBOD_5$ concentration to the second stage should be limited to 20 - 50 mg/L. A bypass around the first stage shall be provided to allow discharge of raw or primary settled wastewater to the second stage aeration tank as needed for process control.~~

~~8B.4.2.4 Due to the dilute nature of some design load concentrations, a minimum hydraulic detention time may be required to ensure that the colloidal, finely suspended, and dissolved organics are adsorbed by the activated sludge. The minimum hydraulic detention time shall be based on the AWW flow plus the return sludge flow and shall not be less than 60 minutes.~~

~~**8B.4.3** Aeration Tanks~~

~~8B.4.3.1 Multiple Units Multiple units shall be provided in accordance with IWFDS Chapter 4. Tanks shall be designed so that each tank may be dewatered and operated independently.~~

Table 1. Typical Aeration Tank Loadings and Design Parameters

Process	Aerobic Solids Retention~~*~~ Time-Days	Maximum Aeration Tank Organic Loading~~*~~[a] lbs BOD_5/1,000 ft^3/day	F/M Ratio~~*~~[a] lbs BOD_5/lbs MLVSS/day	MLSS[b] mg/L
Conventional, Step Aeration~~,~~ and Complete ~~m~~Mix ~~and Conventional~~ (Without Nitrification)	~~6~~3-~~15~~10	~~40~~50	0.2-0.5	1,000-3,000
Cont~~r~~act Stabilization (Without Nitrification)	~~6~~5-~~15~~10~~****~~[c]	~~50~~65~~*~~[c]~~***~~	0.2-0.6~~*~~[c]~~***~~	1,000-3,000
Extended Aeration (Provides Nitrification)	>15~~20-30~~	~~15~~20	0.05-0.1	3,000-5,000
Single-Stage Nitrification (Combined Carbon Oxidation~~-~~ and Nitrification)	~~15-25~~>10	~~15~~25	0.~~08~~1-0.~~16~~2	2,000-5,000
Carbonaceous Stage of Separate~~-~~-Stage Nitrification	3-10	70	0.3-0.8	1,000-2,500
Nitrification Stage of Separate~~-~~-Stage Nitrification	15-25	10~~*~~[d]~~*~~	0.05-0.20~~*~~[e]~~**~~	1,000-3,000

[a] Based on the influent organic load to the aeration tank(s) at the maximum 30-d BOD_5 design load. The influent organic load to the aeration tank(s) may consider BOD_5 reductions from preceding treatment units or zones that meet the reliability criteria of IWFDS Section 4.5. Excludes BOD_5 attributable to supplemental carbon sources used to sustain biological nutrient removal processes.

[b] For systems incorporating biological nutrient removal meeting the reliability criteria of IWFDS Section 4.5, MLVSS and MLSS concentrations may be determined using anaerobic and anoxic as well as aerobic mixed volumes. The MLVSS mass in the F/M Ratio is the mass in the aeration tank(s) only.

[c] Total aeration capacity includes both contact and reaeration capacities.

Process	Aerobic Solids Retention* Time-Days	Maximum Aeration Tank Organic Loading*[a] lbs BOD_5/1,000 ft^3/day	F/M Ratio*[a] lbs BOD_5/lbs MLVSS/day	MLSS[b] mg/L
[d] lbs NH_3-N/1,000 ft^3/d [e] lbs NH_3-N/lbs MLVSS/d				

~~*Maximum - 30 day BOD_5 loading~~
~~**lbs NH_3-N/1,000 ft^3/day~~
~~***lbs NH_3-N/lbs MLVSS/day~~
~~****Total aeration capacity includes both contact and reaeration capacities.~~

8B.4.3 Aeration Tanks

8B.4.3.1 Multiple Units - Multiple units shall be provided in accordance with IWFDS Chapter 4. Tanks shall be designed so that each tank may be dewatered and operated independently.

8B.4.3.2 Tank Geometry - Tank dimensions shall not inhibit effective mixing or utilization of air. Liquid depths typically range between ~~should not be less than~~ 10 ft and ~~or more than~~ 30 ft. The shape of the tank and the installation of aeration equipment shall provide for positive control of short-circuiting through the tank.

8B.4.3.3 Freeboard and Froth Control - All aeration tanks shall have a minimum freeboard of 18 inches. Suitable froth and foam control such as water spray systems or other approved means ~~of froth and foam control~~ shall be ~~provided~~evaluated ~~if excessive foaming is anticipated. Otherwise, provisions~~ for current or future installation ~~of froth or foam control should be considered~~.

8B.4.3.4 Inlet and Outlet Control - Inlets and outlets for each aeration tank unit shall be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit balancing, proportioning, and splitting of the flow to and from any unit, and to maintain reasonably constant liquid level. The hydraulic elements of the system shall permit the peak hydraulic load to be carried with any single aeration tank out of service. This shall be done in accordance with IWFDS Subsection 4.4.9.3.

8B.4.3.5 Conduits - Channels and pipes carrying liquids with solids in suspension shall be designed to maintain self-cleansing velocities or shall be agitated to keep such solids in suspension at all design rates of flow. ~~Provisions should be made to drain segments of channels w~~When not in use, consider provisions to drain segments of channels.

8B.4.3.6 Winter Protection - Protection against freezing, including maximum utilization of earthen bank insulation shall be considered to ensure continuity of operation and performance in cold weather. ~~Maximum utilization of earthen bank insulation should be considered to minimize heat losses.~~

8B.4.4 Aeration Equipment

8B.4.4.1 General

1. Aeration requirements depend upon mixing energy, BOD_5 and nitrogen loading, degree of treatment, oxygen uptake rate, MLSS concentration, and sludge age. Required oxygen delivery shall be determined using a minimum dissolved oxygen concentration of 2 mg/L in aerobic basins or zones. ~~Aeration equipment shall be capable of maintaining a DO concentration of 2.0 mg/L in the aeration tanks at all times.~~ Energy transfer shall be sufficient to maintain the mixed liquor solids in suspension.
2. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes (with the exception of the extended aeration process) shall be 1.1 lbs oxygen/lb BOD_5/day ~~at the MWW flow, plus 50% of the difference between the MWW flow and four-hour peak above that rate~~based on the maximum 30-day BOD_5 loading applied to the aeration tanks. For the extended aeration process, the design oxygen requirements shall be 1.~~8~~5 lbs oxygen/lb ~~peak 12-hour~~maximum 30-d BOD_5.
3. For nitrification, the oxygen requirement for oxidizing ammonia must be added to the above requirement for $CBOD_5$ removal. The nitrogenous oxygen demand (NOD) shall be 4.6 times the ~~daily TKN content of the influent at MWW flow~~maximum day TKN loading.

~~3.~~4. An allowance for oxygen recovery through denitrification may be considered where denitrification unit processes and equipment meet the reliability criteria of IWFDS Section 4.5.

~~4.~~5. Additional oxygen shall be supplied to meet the oxygen demands due to recycle flows, including, but not limited to, ~~anaerobic~~ digester, thickener or sludge storage facilities supernatant and sludge dewatering ~~, belt press~~ centrate/filtrate~~, and elutriates~~.

~~5.~~6. Carefully consider~~ation should be given to~~ maximizing oxygen utilization per unit power input. ~~Unless~~

~~flow equalization is provided, consideration should be given to designing the aeration system to match the diurnal organic load variations while economizing power input.~~

8B.4.4.2 Diffused Air System

1. Design calculations for diffused air systems shall consider:
   a. Tank depth;
   b. Alpha factor of wastes (considering aeration device characteristics and tank geometry);
   ~~b.~~c. Fouling factor;
   ~~c.~~d. Beta factor of waste;
   ~~d.~~e. Certified aeration device transfer efficiency;
   ~~e.~~f. Minimum aeration tank DO concentrations;
   ~~f.~~g. Critical wastewater temperature; and
   ~~g.~~h. Altitude of the plant.

   In the absence of experimentally determined alpha, fouling and beta factors, wastewater field oxygen transfer efficiency shall be assumed to be not greater than 50 percent of clean water oxygen transfer efficiency for plants treating primarily (90 percent or greater) domestic wastewater. Treatment plants where the wastewater contains higher percentages of industrial wastes shall consider lower field transfer efficiencies due to the presence of wastes that may result in diminished oxygen transfer capability.~~10% or more of the waste is industrial waste shall experimentally determine the alpha and beta factors and shall submit test result calculations to justify the factors. The design basis shall include detailed computations for all diffused air systems and account for the factors listed above.~~
2. Consider design of ~~B~~blowers or air compressor capacity to take into account~~design should consider~~ that the air intake temperature may reach 104°F (40°C) or higher and that the barometric pressure may be less than normal.
3. Consider design of ~~M~~motor drive capacity taking into account~~design should consider~~ that the intake air temperature may reach ~~-~~-22°F (-30°C) or lower, which may require motor oversizing as a means of reducing the rate of air delivery to prevent overheating or damage.
4. Multiple blowers shall be provided. Blowers shall be arranged ~~and~~ in such capacities as to meet the maximum total air demand with the single largest unit out of service. Blower design shall provide for the ability to adjust air flow in proportion to the load demand of the plant. Aeration equipment shall be easily adjustable in increments and maintain solids suspension within the limits.
5. Design air piping systems to reduce total headloss from blower outlet to the diffuser inlet. Typical designs for total headloss do not exceed 0.5 pounds per square inch at average operating conditions.~~The air diffusion piping and diffuser system shall be capable of delivering air without excessive head loss with all available blowers on. Air diffusion piping includes all of the piping from the blower to the aeration basin. Diffusers shall be spaced to meet the oxygenation requirements throughout the length of the channel or tank and should be designed to facilitate spacing adjustments without major revision to air header piping.~~ Diffusers in any single assembly shall have substantially uniform pressure loss.
6. Individual diffuser assembly units shall be equipped with control valves, preferably with indicator markings for throttling and for complete shut off. For aeration basin configurations that do not meet Unit Process Reliability Criteria B or C (IWFDS Section 4.5.2)~~T~~the diffuser arrangement shall permit unit removal for inspection, maintenance, and replacement without dewatering the tank and without shutting off the air supply in the tank.~~, unless the dewatering basins are 50% or less of the total aeration basin capacity.~~
7. Air filters shall be provided in such numbers, arrangement, and capacities as to furnish at all times an air supply sufficiently free from dust to prevent clogging of the diffuser system. Air filters will not be required where coarse bubble diffusers are used.

8B.4.4.3 Mechanical Aeration Systems

1. Oxygen Transfer Performance - The mechanisms and drive unit shall be designed for the expected conditions in the aeration tank in terms of the power performance. Certified testing ~~shall~~ should be provided to verify mechanical aerator performance. Refer to applicable provisions of Section 8B.4.4.2. In the absence of specific design information, the oxygen transfer capability shall be calculated using a clean water transfer rate not to exceed 2 pounds of oxygen per horsepower per hour under standard test conditions. Design transfer efficiencies shall be included in the specifications.

2. Design Requirements - The mechanical aeration system shall:
   a. Determine oxygen delivery using a minimum dissolved oxygen concentration of 2 mg/L in aerobic basins or zones~~Maintain a minimum of 2.0 mg/L of DO in the mixed liquor at all times throughout the tank or basin~~;
   b. Provide a liquid waste turnover time such that a minimum velocity of 1.0 fps is maintained at all points in the basin to provide adequate mixing and to prevent solids deposition;
   c. Be protected from excessive ice coating in inclement weather; and
   d. Include multiple unit installation designed to meet the maximum oxygen demand with the largest unit out of service and provide for rapid replacement.
3. Consider provisions for flexibility in design to ~~The design should also~~ provide for varying the amount of oxygen transferred in proportion to the load demand on the plant. If depth of submersion is an important criterion, the aeration system shall be adjustable or the basin levels shall be readily controllable with regard to depth. Spray protection in the form of mist shields or high walls around tanks should be considered.

8B.5 RETURN SLUDGE EQUIPMENT

8B.5.1 Return Sludge Rate

The minimum permissible return sludge rate of withdrawal from a settling tank is a function of the concentration of suspended solids in the mixed liquor entering the tank, the sludge volume index of the solids, and the length of time the solids in the final settling tanks may be deleterious to the aeration and sedimentation phases of the activated sludge process. The rate of sludge return expressed as a percentage of the AWW design flow shall be variable between ~~limits of 25 - 100%. This requirement shall apply to all activated sludge processes except extended aeration, single stage nitrification, and the nitrification stage of separate stage nitrification, for which the return sludge rate shall be variable from 50 - 150%~~the values set forth in Table 2 below:~~.~~

Table 2. Return Sludge Rates

Type of Process	% of Design AWW Flow Lower[a]	% of Design AWW Flow Upper[a]
Conventional, Step Aeration, Complete Mix, or Carbon Oxidation Stage of Separate-Stage Nitrification	10	67
Contact Stabilization, Single-Stage Nitrification (Combined Carbon Oxidation and Nitrification) or Extended Aeration	33	100
Nitrification Stage of Separate-Stage Nitrification	33	133

[a] Minimum rates below the lower values or maximum rates above the upper values, i.e. wider ranges, are acceptable.

8B.5.2 Return Sludge Pumps

8B.5.2.1 If motor driven return sludge pumps are used, the maximum return sludge capacity shall be obtained with the largest pump out of service. The rate of sludge return shall be varied by means of variable speed motors or drives or other suitable means. Consider provisions for ~~A~~a positive head or other means to ensure proper operation ~~should be provided~~ on pump suctions. ~~Pumps shall have at least three-inch suction and discharge openings.~~

8B.5.2.2 If air lift pumps are used for returning sludge from each settling tank, no standby unit shall be required provided that the air lifts are designed to facilitate rapid and easy cleaning. Typical ~~A~~air lift~~s~~ designs ~~should be~~ are at least three inches in diameter.

8B.5.3 Return Sludge Piping

8B.5.3.1 Typical ~~S~~suction and discharge~~ing~~ pipe~~ing sizing is should be~~ at least four inches in diameter and ~~should be~~ designed to maintain a velocity of not less than 1.0 fps when return sludge facilities are operating at ~~normal~~ return sludge rates within the ranges of IWFDS Section 8B.5.1.~~(25% - 150%).~~

8B.5.3.2 Independent ~~D~~devices for observing, measuring, sampling and controlling return activated sludge flow

from each settling tank shall be provided, as outlined in IWFDS Section 6.4.2.4.

8B.5.4 Waste Sludge Control

8B.5.4.1 Consider ~~W~~waste sludge control facilities ~~should~~ sizing based on the expected maximum sludge production rates and minimum sludge concentrations. Although continuous wasting is preferred, for non-continuous wasting the capacity of pumps and pipelines should be designed to handle the expected wasting rates.~~have a maximum capacity of not less than 25% of the AWW flow and function satisfactorily at rates of 0.5% of ADW flow or a minimum of 10 gallons/minute, whichever is larger.~~

8B.5.4.2 Means for observing, measuring, sampling and controlling waste activated sludge flow shall be provided. It is desirable to have separate waste sludge equipment so that sludge return is not interrupted.

8B.6 SEQUENCING BATCH REACTORS

Batch fill-and-draw or continuous inflow batch draw variants of the activated sludge process may be approved on a case-by-case basis. The design shall meet applicable requirements of Chapters 4, 6 and 8B, except as modified in this Section. Reliability of treatment equal to that of the continuous flow-through modes of the activated sludge process shall be provided.

8B.6.1 Design Requirements

8B.6.1.1 Design F/M ratios in the range of 0.05 to 0.1 pounds of BOD_5 per day per pound of MLVSS are permissible. The aeration tank organic loading shall not exceed 15 pounds BOD_5 per 1,000 cubic feet per day. Calculate the reactor MLSS and MLVSS concentrations and aeration tank organic loading at the low-water level.

8B.6.1.2 Typical designs provide more than two (2) tanks. Two tanks may be acceptable where in-line flow equalization is provided in addition to the decantable volume.

8B.6.1.3 Designs employing fewer than 4 basins shall provide a decantable volume of at least four (4) hours with the largest tank out of service based on 100 percent of the design MWW. In-line flow equalization capacity may be considered in determining the decantable volume.

8B.6.1.4 System reliability with any single aeration tank unit out of service and the instantaneous delivery of flow shall be evaluated in the design of decanter weirs and approach velocities.

8.B.6.1.5 Solids-excluding decanters are required.

8B.6.1.6 Scum removal shall be provided in order for the treated effluent from each reactor to be free of scum with a typical design suspended solids concentration no greater than 30 mg/L at any time. An adequate zone of separation between the sludge blanket and the decanter(s) shall be maintained throughout the decant phase.

8.B.6.1.7 Decanters that draw the treated effluent from near the water surface throughout the decant phase are recommended.

8B.6.1.8 Solids management to accommodate tank dewatering shall be considered. See IWFDS Section 4.4.8.2.

8B.6.1.9 The blowers shall be provided in multiple units, so arranged and in such capacities as to meet the maximum air demand in the oxic portions of the fill and react phases of the cycle with the single largest unit out of service. See IWFDS Section 8B.4.4.

8B.6.1.10 Consider mechanical mixing independent of aeration for all systems where biological nitrogen and/or enhanced biological phosphorus removal is required. When used, mixing equipment shall be sized to thoroughly mix the entire tank from a settled condition within five (5) minutes without aeration.

8B.6.1.11 Typical designs include flow-paced 24-hour effluent quality composite samples for monitoring process operations and samples collected at the beginning and end of each decant phase. Continuous turbidity monitoring to separately monitor the effluent quality from each tank is recommended.

8B.6.1.12 A programmable logic controller (PLC) shall be provided with consideration of multiple PLCs as necessary to ensure rapid process recovery and minimize the deterioration of effluent quality from the failure of a single controller. An uninterruptible power supply with electrical surge protection shall be provided for each PLC to retain program memory through a power loss. A hard-wired back-up for manual override shall be provided in addition to automatic process control. Both automatic and manual controls shall allow independent operation of each tank.

8B.6.2 Additional Considerations

As necessary, consideration shall be given to pretreatment, positive flow division control, measures for creating uniform waste loadings to each tank, diffusers suitable for cyclic aeration, type of decanter, emergency overflow, effect of peak discharge flow rates on downstream process units, sludge transfer and sludge wasting.

8B.7 BIOLOGICAL NUTRIENT REMOVAL

Biological Nutrient Removal (BNR) processes may be approved on a case-by-case basis with consideration of applicable design information derived from data from actual operating plants, pilot plant studies, standard textbooks or current technical literature. For BNR processes that are not well established see IWFDS Section 4.4.3. The design shall meet applicable requirements under IWFDS Chapters 4, 6 and 8B except as modified in this Section.

Consideration shall be given to wastewater composition, type of BNR treatment process, peak wastewater flow rates, actual nutrient loading relative to the plant design capacity (with all recycle flows excluded), effluent requirements, presence of biological inhibitors or toxic constituents, initial low flow conditions, anticipated treatment efficiency, side stream recycle flows (e.g., digester, thickener, or sludge storage facilities supernatant, sludge dewatering centrate/filtrate, wet oxidation return stream, etc.), internal recycle flows (e.g., mixed liquor, RAS), chemical usage, process control and maintenance requirements, and optimum operation for water quality protection.

All designs shall provide for flexibility in operation including operation in various BNR modes, if feasible. Unit process reliability for BNR facilities (e.g., anaerobic or anoxic basins) in accordance with IWFDS Section 4.5 is required where BNR is proposed to meet effluent limits established by Iowa Water Quality Standards or an EPA-approved Water Quality Improvement Plan (Total Maximum Daily Load) and recommended for other BNR applications. Provisions for chemical phosphorus removal may be considered in lieu of unit process reliability for EBPR processes. Sufficient numbers of installed vital components for mixed liquor recycle or mechanical mixing to maintain design capacity with the largest unit(s) offline are recommended.

8B.7.1 Biological Nitrogen Reduction

Biological nitrogen removal is typically accomplished by biological oxidation of ammonia to nitrate (nitrification) followed by biological denitrification of nitrate to nitrogen gas.

8B.7.1.1 Nitrification - Biological nitrification is used to convert ammonia to nitrate to meet effluent requirements or as the first step in nitrogen removal. Ammonia is oxidized to nitrite and then to nitrate by nitrifying bacteria in an aerobic environment. Nitrification consumes alkalinity.

Nitrification can be achieved with either a single-stage nitrification process (combined carbon oxidation and nitrification) or with a separate-stage nitrification process. In each case, suspended growth, attached growth or hybrid systems can be used. See Sections 8B.4 and 8B.5.

For plants subject to high wet weather flows, often also associated with low temperatures, flexibility in design and operation to periodically aerate additional zones (i.e., swing zones) should be provided as necessary to ensure that nitrification is consistently achieved and maintained as part of the BNR process. Swing zones are zones in a biological reactor than can be operated in multiple modes such as anaerobic, anoxic, or aerobic conditions, depending on the operational strategy.

8B.7.1.2 Denitrification - Denitrification is the biological process where facultative bacteria (i.e., most heterotrophs and some autotrophs) convert nitrate to nitrogen gas under anoxic conditions. The process generates alkalinity and therefore restores up to half the alkalinity consumed during nitrification.

A soluble, biodegradable organic carbon source is required to drive the denitrification process. The carbon requirements for denitrification may be provided by influent wastewater, sludge fermentation, or by an external source such as methanol, ethanol, acetate or glycerin. For BNR processes that have both a pre-anoxic zone before the nitrification zone and a post-anoxic zone, denitrification in the post-anoxic zone is driven by either carbon from endogenous activity or an external carbon source that may be added to accelerate the denitrification rate in that zone. An aerobic zone typically follows the post-anoxic zone.

The anoxic zone(s) of a BNR process may be divided into two (2) or more cells, one of which can be equipped with both mixers and aerators designed to operate independently, to allow for operation in either anoxic or oxic mode (i.e., sing zone), as necessary. Provide flexibility in operation to adequately address potential fouling of aeration devices during extended periods of anoxic operation. Consider baffling to maintain zone integrity and prevent any short-circuiting or back-mixing.

8B.7.2 Enhanced Biological Phosphorus Removal

A number of process configurations for enhanced biological phosphorus removal (EBPR) have been developed as alternatives to phosphorus removal by chemical treatment (see IWFDS Section 9.2). Phosphorus accumulating organisms (PAOs) in EBPR process biological solids incorporate phosphorus into their cell mass in excess of their metabolic requirements, allowing them to achieve enhanced removal of phosphorus from wastewater. Exposure of activated sludge microorganisms to alternating anaerobic and aerobic conditions allows PAOs to proliferate in numbers sufficient to remove phosphorus.

The design shall ensure that readily biodegradable organic matter in sufficient quantities is available in an anaerobic environment to promote the proliferation of PAOs, which is reflected by the release of ortho-phosphate in the anaerobic zone of the EBPR process. The amount of readily biodegradable organic matter can be increased by fermentation of wastewater sludge, or a fermentable supplemental carbon source, or by the addition of supplemental volatile fatty acids such as acetic acid.

The volume of the anaerobic zone should be large enough to accommodate EBPR without switching off mechanical mixers. Typical design anaerobic mass fraction is no less than 12 percent, with 20 to 25 percent being desirable. The anaerobic mass fraction is the amount of sludge subjected to anaerobic conditions relative to the total mass of sludge in all of the BNR reactor zones. Typical designs include providing timers and/or VFDs for mechanical mixers where necessary to allow for process optimization. Consider baffling to maintain zone integrity and prevent any short-circuiting or back-mixing.

To create truly anaerobic conditions, both dissolved oxygen and combined oxygen (e.g., nitrate) shall be excluded. Many EBPR process configurations include the denitrification process to limit the nitrate concentration in the anaerobic zone.

Intermittent mixing in the mainstream anaerobic zone for settling and fermentation of MLSS or the alternative of a side stream anaerobic fermentation tank(s) for RAS may be desirable in cases where the readily biodegradable organic content in the influent wastewater is low (i.e. low readily biodegradable chemical oxygen demand relative to total phosphorus, or rbCOD to TP ratio).

EBPR process sludge containing the excess accumulated phosphorus can be wasted, or the excess phosphorus can be removed and recovered from the waste sludge by a side stream sludge treatment process. The EBPR process may require chemical treatment as a back-up system or for polishing to achieve very low effluent phosphorus levels. The EBPR process is often combined with nitrification and denitrification processes.

8B.7.3 Combined Biological Nitrogen and Phosphorus Removal

A number of BNR processes have been developed for the combined biological removal of nitrogen and phosphorus. Combinations of anaerobic, anoxic and aerobic zones or compartments are designed to accomplish biological nitrogen and phosphorus removal.

8B.7.4 BNR Monitoring

Monitoring equipment to routinely measure ortho-phosphate, nitrate, nitrite, dissolved oxygen and ammonia in all zones (i.e., anaerobic, anoxic and aerobic) is recommended at appropriate locations. Oxidation-reduction potential (ORP) monitoring may also be beneficial for process control.