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ASSESSMENT OF DESIGN TRADEOFFS WHEN USING INTRACHANNEL CLARIFIERS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

ASSESSMENT OF DESIGN TRADEOFFS

WHEN USING

INTRACHANNEL CLARIFIERS

by

Jon H. Bender
Wastewater Research Division
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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INTRODUCTION

A conventional oxidation ditch system, shown in figure 1, is a type of activated sludge process where the mixed liquor continuously circulates around a channel used as the aeration basin. Achieving adequate performance from this system as with any activated sludge wastewater treatment system requires the effective separation of the activated sludge from the treated wastewater. After separation, the activated sludge must return to the aeration basin. Secondary clarifiers, usually located adjacent to the oxidation ditch, allow for the gravity separation of the solids. These clarifiers then mechanically collect and remove the separated sludge sending it to another system that pumps the sludge back to the oxidation ditch.

Intrachannel clarifiers, also shown in figure 1, represent a relatively new alternative to conventional secondary clarifiers for oxidation ditch processes. These devices allow the solids/liquids separation and sludge return to occur within the aeration channel. This eliminates the need for an external secondary clarifier, its associated equipment and a sludge return system. Using intrachannel clarifiers, therefore, could reduce the capital and operation costs over a conventional oxidation ditch system.

Eight different manufacturers currently market intrachannel clarifiers, though others may have entered the market during preparation of this paper. Each of these proprietary devices operates based upon a different concept to achieve solids/liquids separation in the aeration channel. Some may argue that all of these devices are not truly intrachannel clarifiers. For this paper, however, the author has chosen to include all of the devices in the market without making such distinctions.

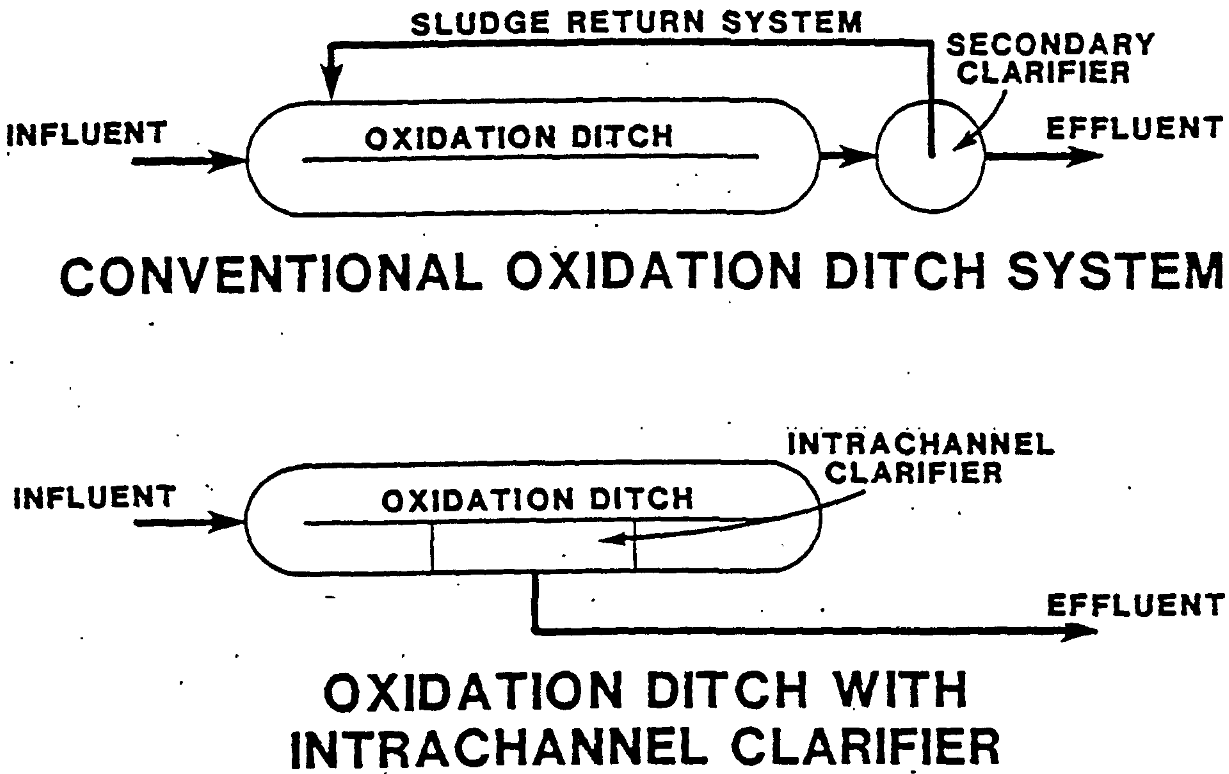


Figure 1. Comparison of a Conventional Oxidation Ditch System With One With an Intrachannel Clarifier.

All of these devices, however, have not reached the same stage of development. Some are operating in full-scale facilities, others are included in facilities being designed or under construction, while others are concepts with or without pilot testing. Currently, 80 municipal wastewater treatment facilities throughout the United States are using or will be using intrachannel clarifiers (1).

A complete independent assessment of all these intrachannel clarifiers or the process in general has not been completed. Data on the design, performance capabilities, energy requirements and costs of these systems have been collected only by the manufacturers for their respective devices. These data show that intrachannel clarifiers are a valid concept and can achieve acceptable levels of solids/liquids separation. Zirschky (1) summarizes these data and indicates that one can expect an effluent of 20 or 30 mg/L of biochemical oxygen demand (BOD) and total suspended solids (TSS). He also reports that these systems have produced higher effluent qualities but does not believe that sufficient data are available to show that they can consistently achieve these levels.

This paper contains no new data on these systems and, therefore, falls short of being the complete independent assessment needed. Instead it presents the various intrachannel clarification concepts and discusses the different tradeoffs a designer must consider in selecting any of these devices.

Specific advantages claimed by the manufacturers, discussions of their stage of development or other information that would possibly lead a designer to choose one device over another have been purposely excluded from this paper. The author believes that, [redacted]
For any specific application, the designer may find any of the devices

more appropriate. For this reason, this paper will discuss intrachannel clarifiers in generic terms expecting that the designer will select the best device for his or her particular application after discussions with the different manufacturers.

DIFFERENT TYPES OF INTRACHANNEL CLARIFIERS

The following discussions present only the basic concepts of operation for the different intrachannel clarification devices. Detailed design information regarding structural requirements, scum handling, piping and appurtenances will have to be obtained from the respective manufacturers. Each device is presented below in alphabetical order by manufacturer's name.

Advanced Environmental Enterprises BMTS (2)

Figure 2 shows a schematic of the BMTS. AEE locates the dividing wall of the aeration channel off-center making the aeration channel wider on the side with the clarifier than on the side where aeration occurs. The clarifier spans the entire width of the aeration channel with the end walls forcing the circulating mixed liquor flow beneath it. Baffles form the bottom of the clarifier. Spaces between the baffles allow the mixed liquor displaced by the raw wastewater flow to enter the clarifier and the separated sludge to return to the aeration channel. Submerged orifice pipes collect the clarified effluent and remove it from the system.

EIMCO Process Equipment Co. Carrousel Intraclarifier (3)

Figure 3 shows a schematic of the EIMCO Carrousel Intraclarifer. EIMCO uses its intrachannel clarifier in conjunction with its Carrousel oxidation ditch system. The clarifier spans the entire width of one side of the aeration channel. It uses a sloped solid floor as a bottom with the circulating mixed liquor flow forced beneath it. Mixed liquor displaced by the raw wastewater flow enters the front of the clarifier through inlet control gates. Inlet baffles reduce the effects of turbulence at the inlet on clarifier performance. Effluent launders located

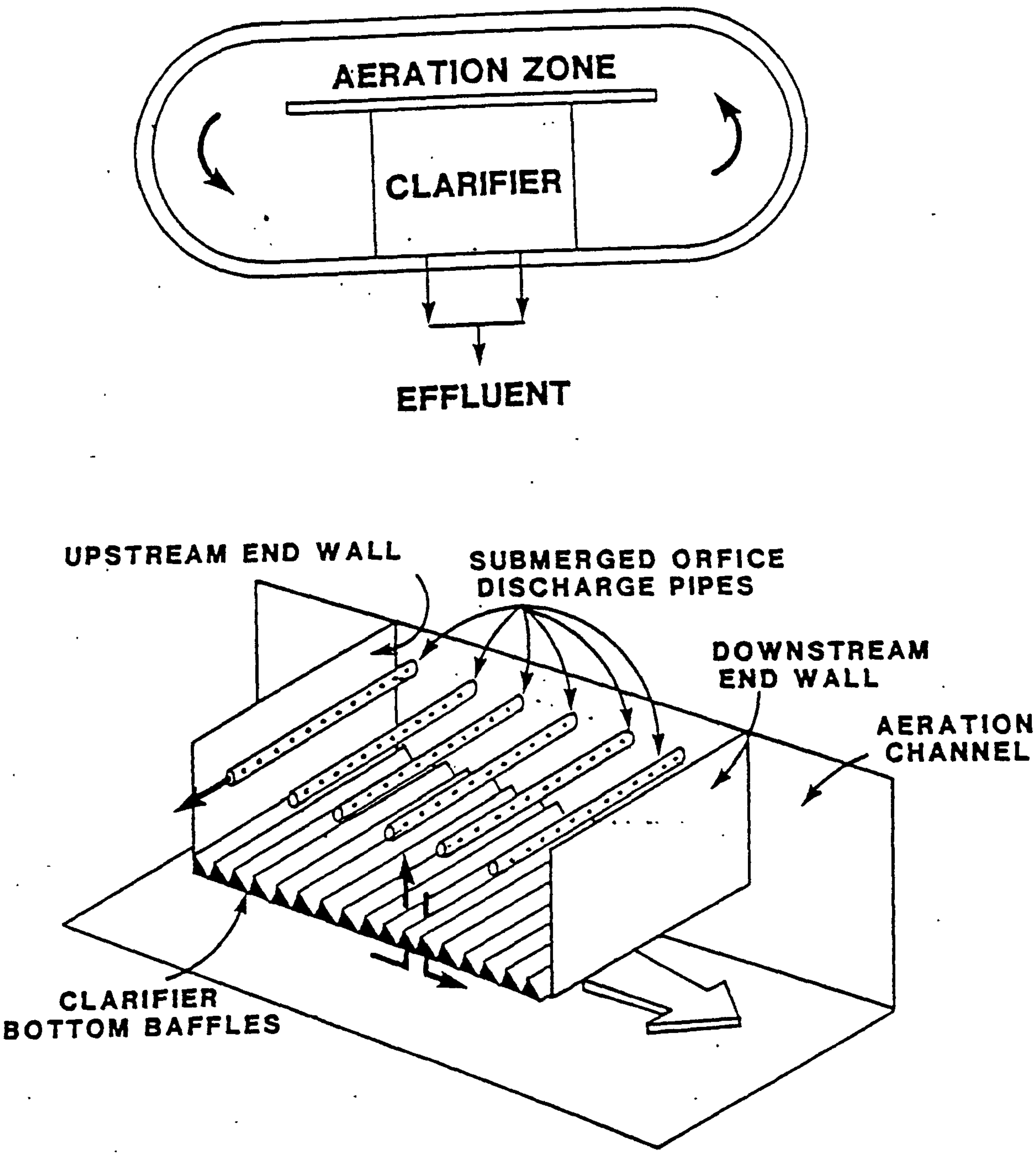


Figure 2. Advanced Environmental Enterprises BMTS (2).

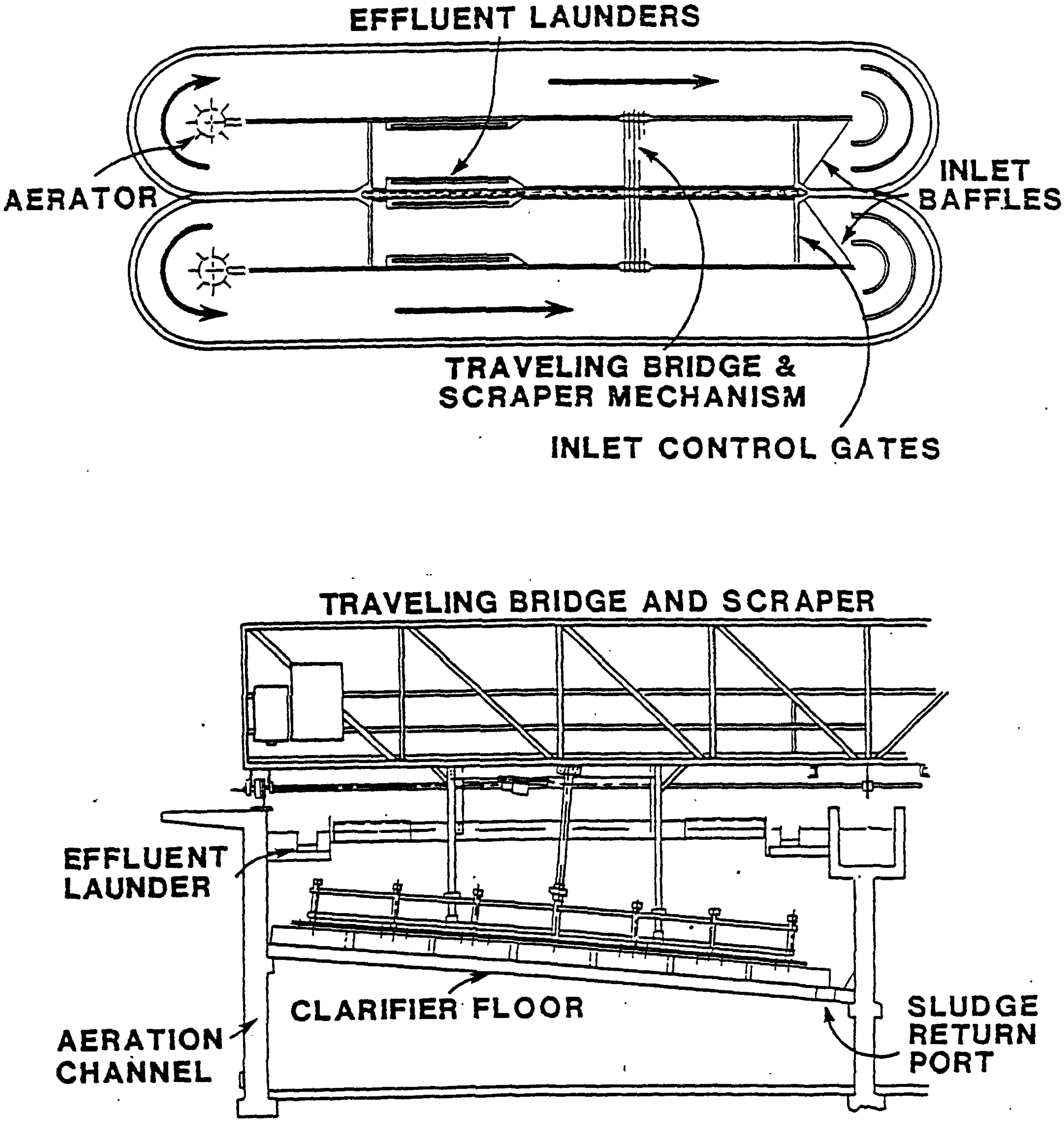


Figure 3. EIMCO Process Equipment Co. Carrousel Intraclarifier (3).

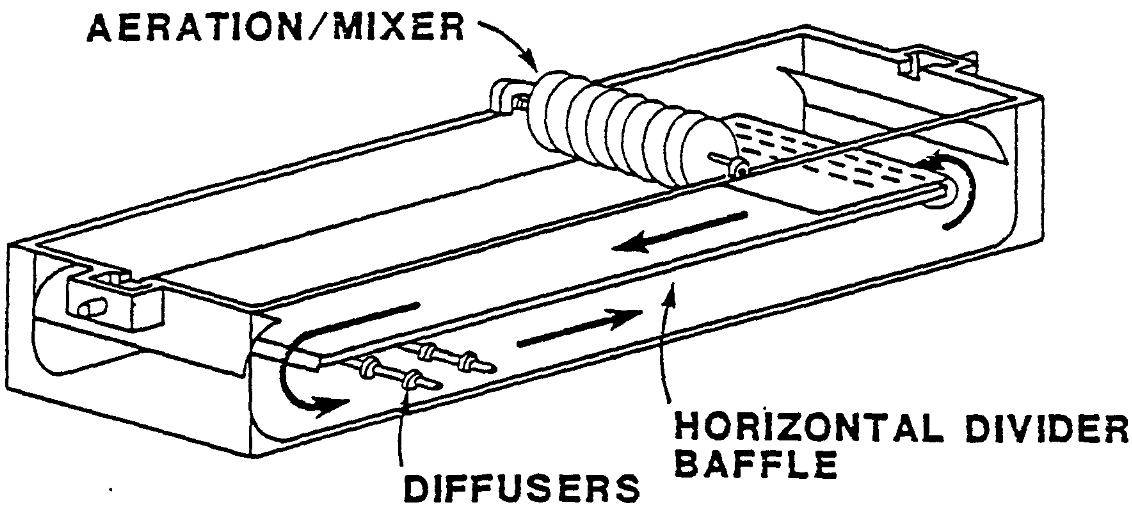
at the back of the clarifier collect and remove treated wastewater from the system. Separated sludge returns to the aeration channel through ports located at the side of the sloped bottom. A traveling bridge and scraper mechanism provides positive sludge removal. If necessary, multiple clarifiers are typically located adjacent to each other so that they can use a common traveling bridge and scraper mechanism.

Envirex, Inc. Side-Channel Clarifier (4)

Figure 4 shows a schematic of the Side-Channel Clarifier that Envirex markets along with their Vertical Loop Reactor system. A Vertical Loop Reactor consists of a rectangular aeration basin with a horizontal divider baffle that creates two compartments in the basin. Mixed liquor continuously circulates similar to that in an oxidation ditch, but between the upper and lower compartments of the aeration basin. Aeration consists of diffusers in the bottom compartment and a mixer/aeration device that circulates the mixed liquor. The Side-Channel Clarifiers are built into the sides of the Vertical Loop Reactor. Mixed liquor displaced by the wastewater flow enters the slots at the bottom of the clarifiers. Recirculation ports provide for separated sludge return to the aeration basin. Clarified effluent is withdrawn at the top of the clarifier.

INNOVA-TECH, Inc. Pumpless Integral Clarifier (5)

Figure 5 shows a schematic of the Pumpless Integral Clarifier that INNOVA-TECH markets along with its Total Barrier oxidation ditch system. The Total Barrier oxidation ditch uses a draft tube aeration system. INNOVA-TECH markets two clarifier configurations; the in-channel and side-channel. The in-channel configuration forms the barrier in the oxidation ditch with an extended draft tube running underneath it. In the side-channel configuration, the clarifier is located adjacent to the aeration



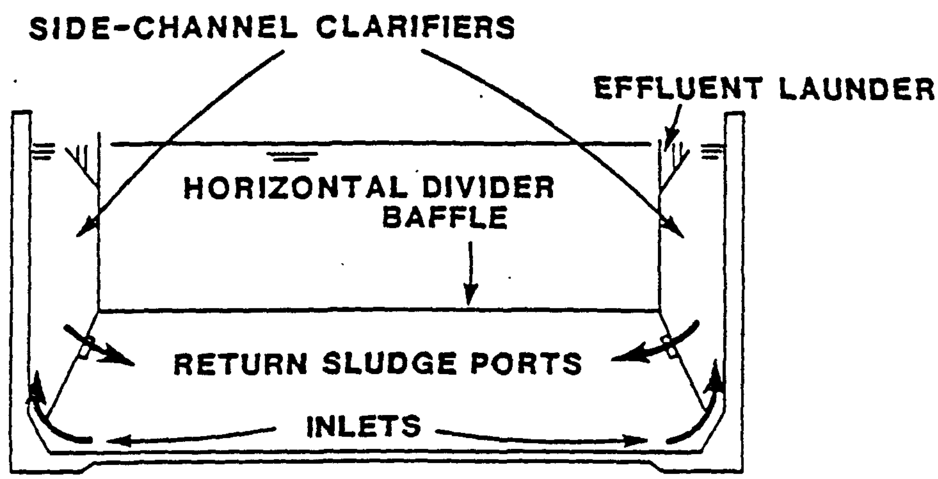


Figure 4. Envirex, Inc. Side-Channel Clarifier in a Vertical Loop Reactor (4).

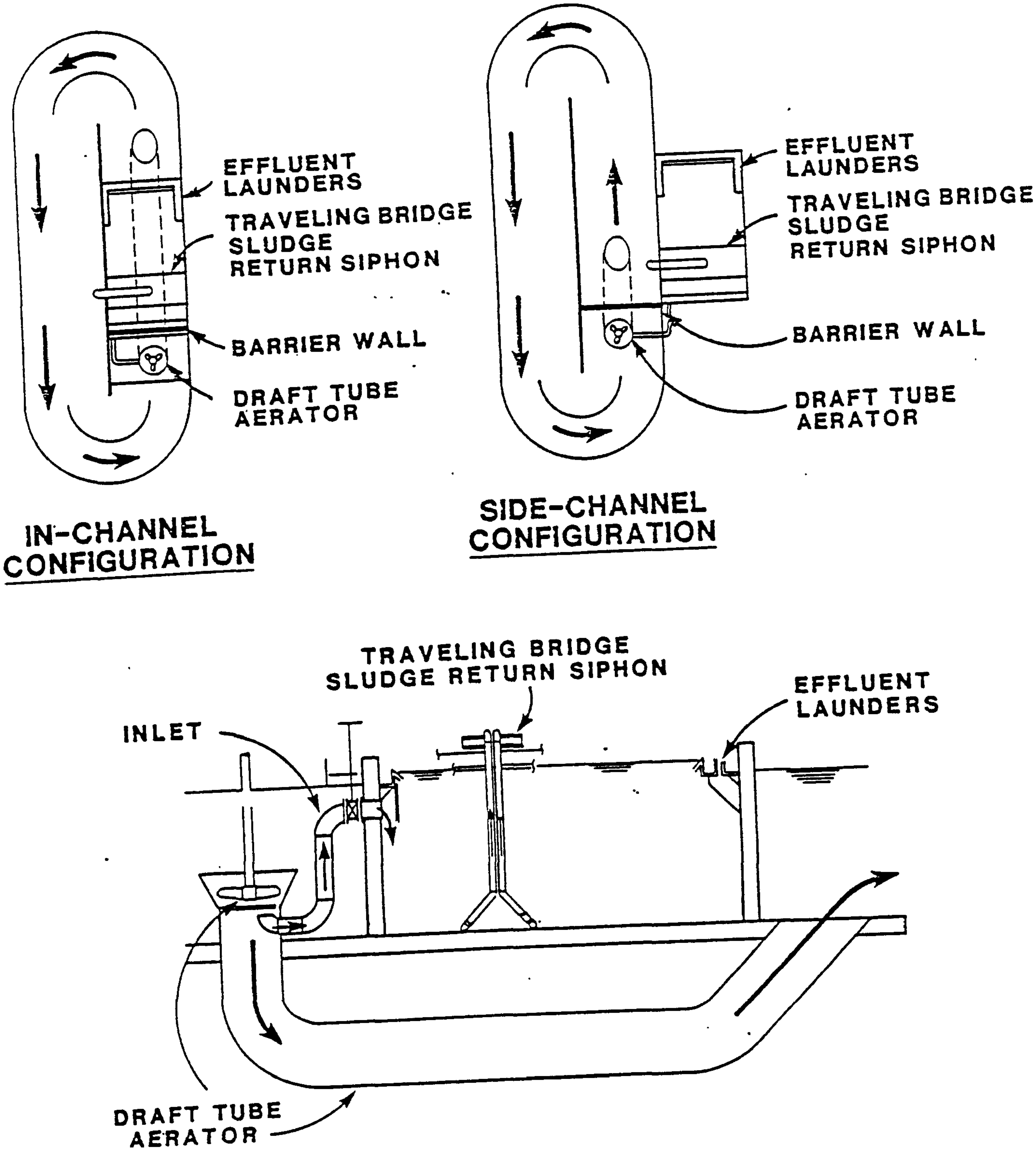


Figure 5. INNOVA-TECH, Inc. Pumpless Integral Clarifier (5).

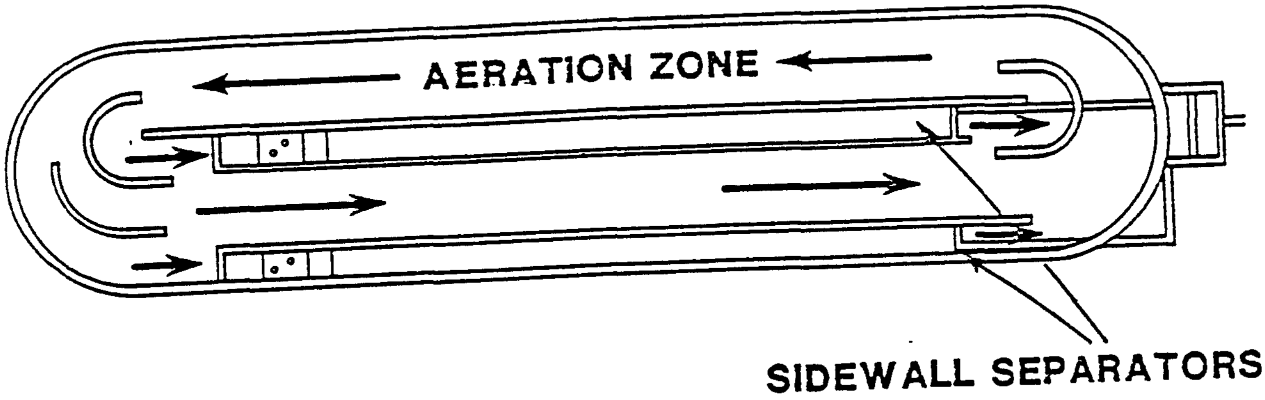
channel and uses a standard draft tube aerator. Both configurations rely on the draft tube aerator to create a head differential between the clarifier and the aeration channel. This head differential permits a traveling bridge sludge siphon mechanism to return separated sludge to the aeration channel. Effluent launders collect and remove the treated wastewater from the system.

Lakeside Equipment Corporation - Sidewall Separator (6)

Figure 6 shows a schematic of a Sidewall Separator which Lakeside uses in conjunction with their oxidation ditch equipment. The divider wall in the aeration channel is located off center. Each Sidewall Separator projects out from the wall of the aeration channel and extends its full depth. Most of the circulating mixed liquor flows between the separators while a portion of it enters the inlet. Inside the separator mixed liquor, displaced by the raw wastewater flow, moves through inclined baffles. A submerged orifice pipe collects and removes the clarified liquid. Separated sludge moves down through the baffles and is returned to the mixed liquor flowing underneath the baffles before it flows out the back end of the separator.

Mixing Equipment Company Lightnin Integral Clarifier (7)

Figure 7 shows a schematic of the Lightnin Integral Clarifier that Mixing Equipment Company uses in conjunction with its barrier oxidation ditch system and draft tube aerator. The clarifier is located adjacent to the oxidation ditch. Mixed liquor displaced by the raw wastewater flow enters the clarifier through inlet slots in the common wall between the aeration channel and the clarifier. Once in the clarifier, the flow encounters a "chimney baffle" intended to minimize short circuiting in the clarifier. Effluent launders at the far side of the clarifier collect and remove treated wastewater from the system. Separated sludge returns



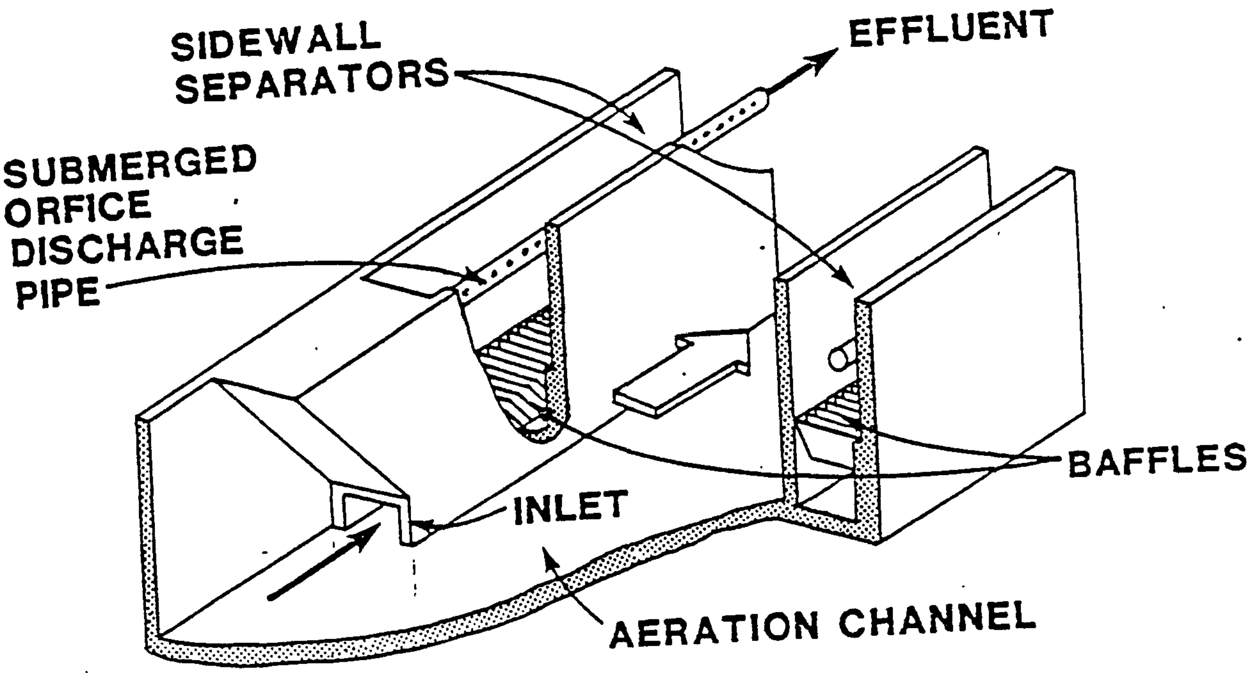
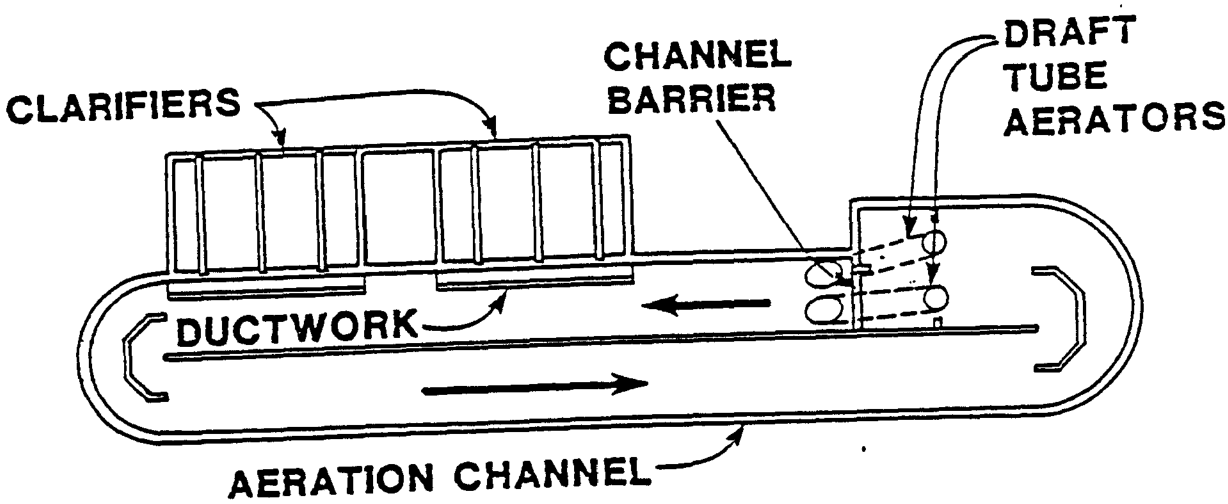


Figure 6. Lakeside Equipment Corp. Sidewall Separator (6).



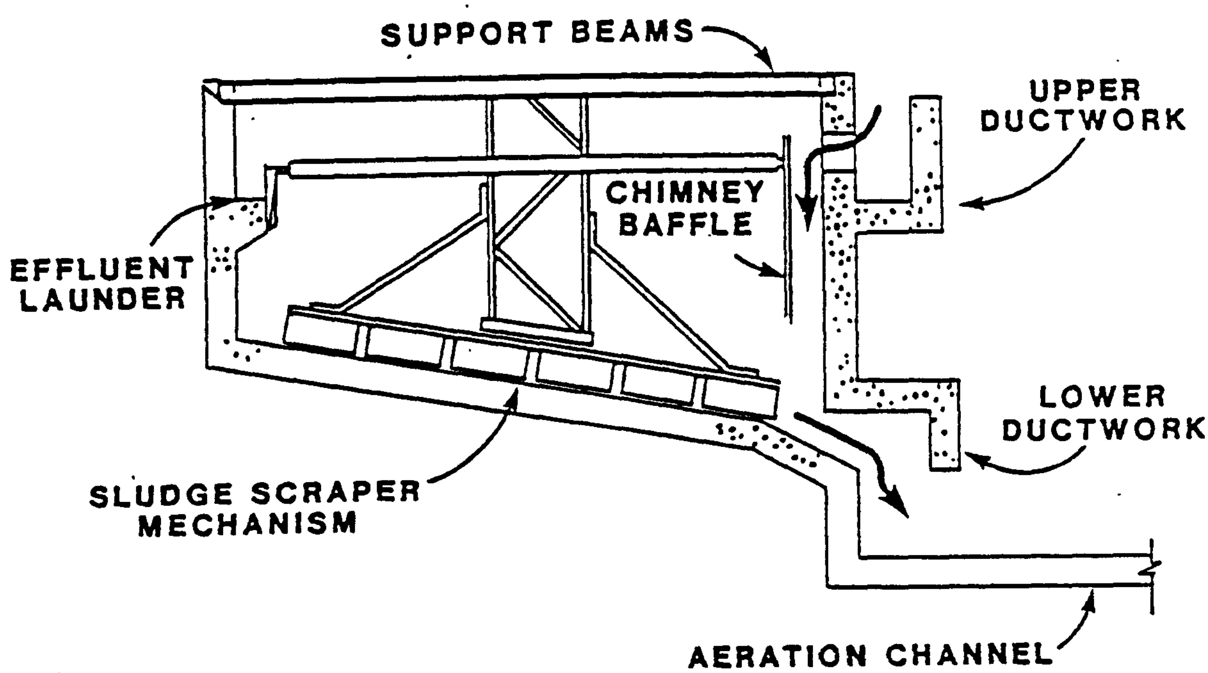


Figure 7. Mixing Equipment Co. Lightnin Integral Clarifier (7).

to the aeration basin through bottom slots in the common wall. A sludge scraper mechanism assists in positive sludge removal from the clarifier. Structures called "ductwork", located at the inlet and sludge return slots, protrude into the aeration channel.

SYDLO, Inc. Integral Clarifier/Oxidation Ditch System (8)

Figure 8 shows a schematic of the Integral Clarifier which SYDLO incorporates into a standard oxidation ditch. The clarifier spans the entire side of the oxidation ditch with standard tube settler modules located across the entire width. Mixed liquor displaced by the influent wastewater flow proceeds upward through the tube settler modules. Clarified liquid is removed at the surface while separated sludge flows downward through the tube settler modules returning to the mixed liquor flowing beneath the clarifier. Aeration channel flow beneath the clarifier is increased by the raised section on the floor of the aeration channel.

United Industries Boat Clarifier (9)

Figure 9 shows a schematic of the Boat Clarifier that United Industries uses in conjunction with standard oxidation ditch systems. The Boat Clarifier is placed in one side of the aeration channel where the circulating mixed liquor flows around and underneath it. Mixed liquor, displaced by the influent wastewater flow, enters at the downstream end or back of the clarifier. Clarified effluent enters the front of the clarifier over a weir before its removal from the system. Separated sludge returns to the aeration channels through a large number of sludge return ports that cover the entire bottom of the clarifier. Each port has its own separate hopper. By design, the Boat Clarifier restricts the flow in the aeration channel creating a head differential between the clarifier and aeration channel that assists sludge removal through the ports.

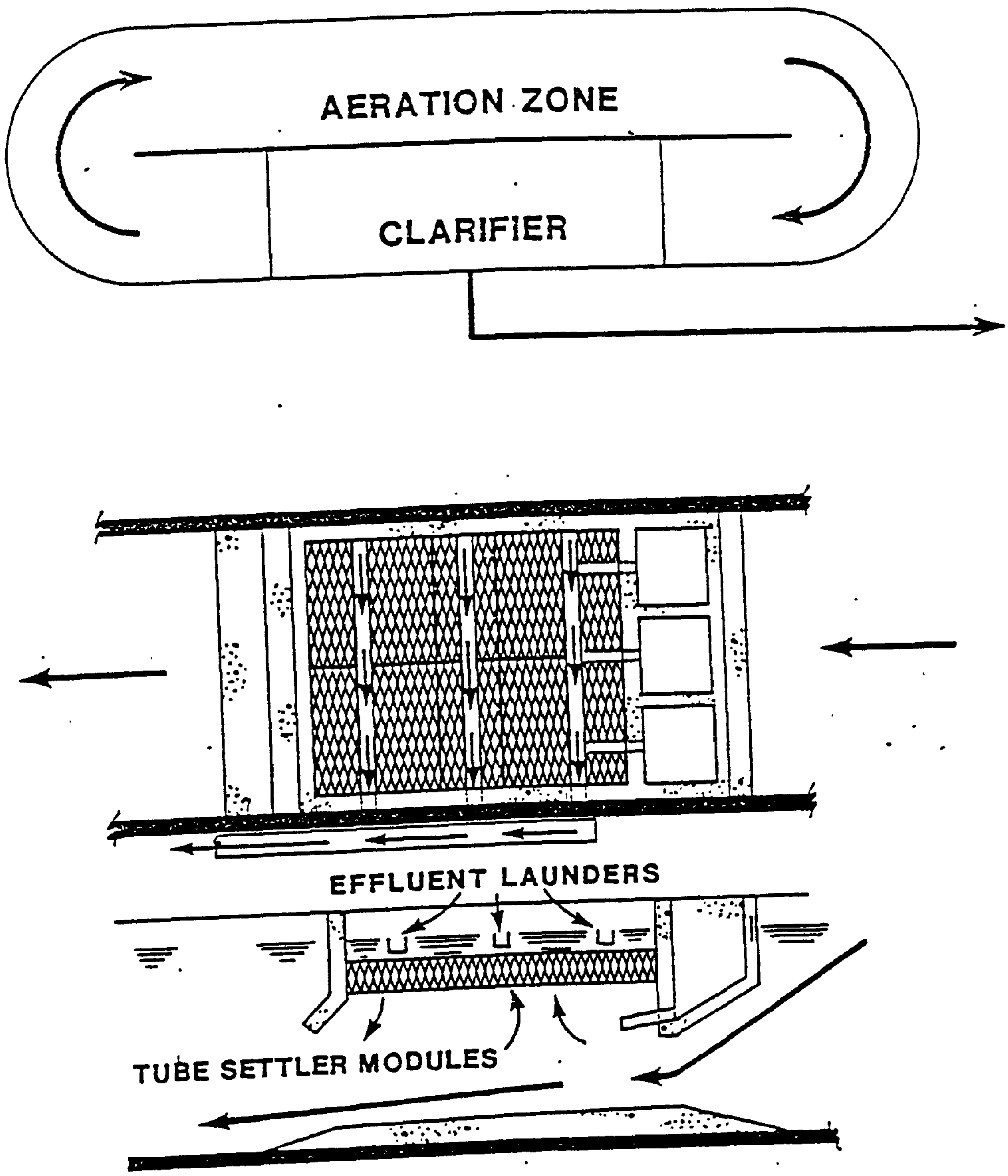


Figure 8. SYDLO, Inc. Integral Clarifier/Oxidation Ditch System (8).

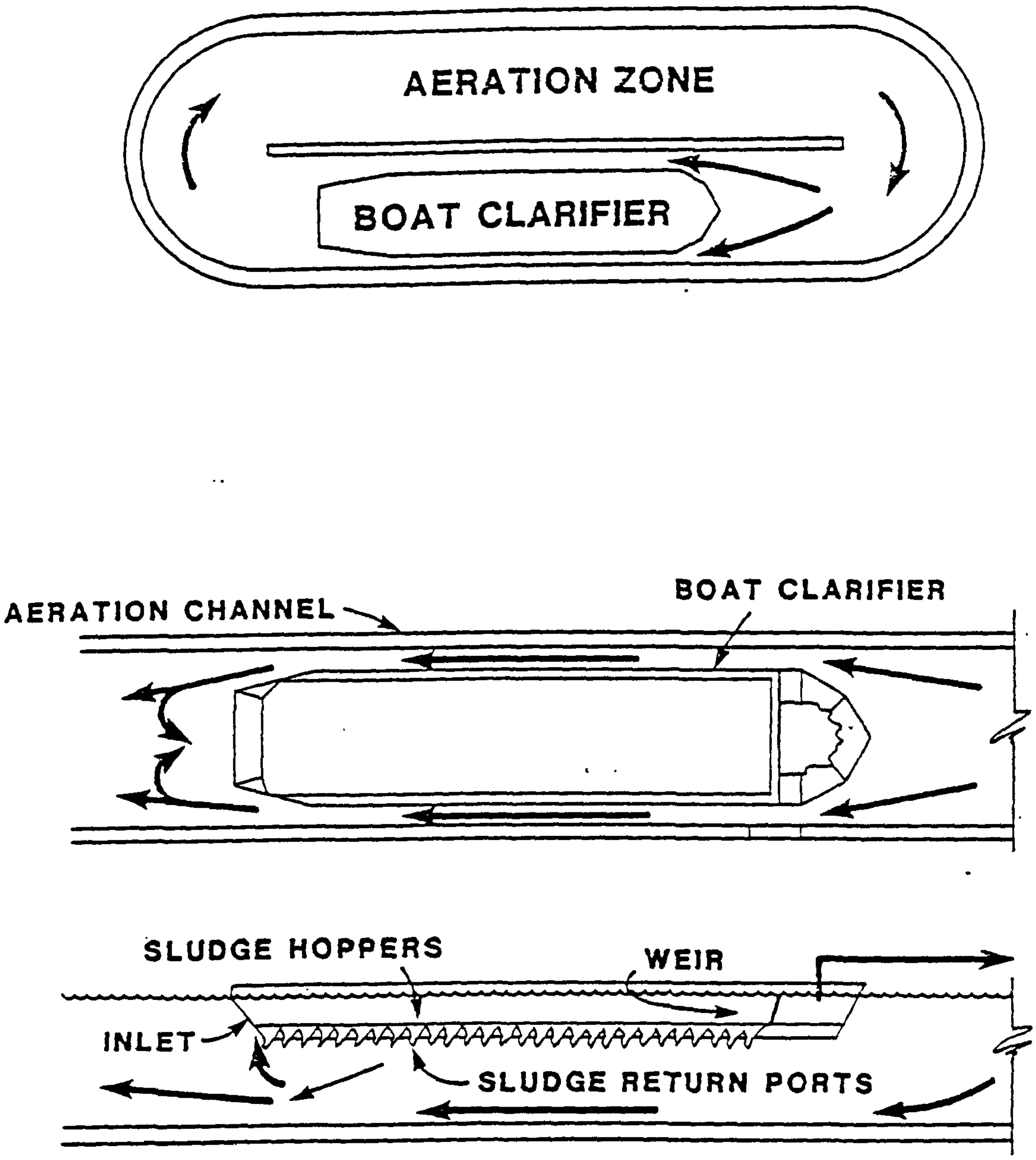


Figure 9. United Industries Boat Clarifier (9).

DESIGN TRADEOFFS WHEN CONSIDERING INTRACHANNEL CLARIFIERS

Elimination of the separate secondary clarifier and sludge return system by using an intrachannel clarifier in an oxidation ditch at first appears to offer many advantages. Using any of these devices, however, has several implications relative to the design and operation of the facility that the designer must consider. The following sections discuss these various design tradeoffs.

Thickening Capabilities and Impact on Size of Sludge Handling Facilities

Conventional oxidation ditch systems with separate secondary clarifiers usually waste the required excess sludge from the underflow of the secondary clarifier. A properly designed and operated secondary clarifier will typically concentrate the separated sludge to 2-4 times the concentration of the mixed liquor depending on the recycle rate and operating strategy.

Oxidation ditch systems with intrachannel clarifiers, however, must waste sludge from either the aeration channel or the intrachannel clarifier. Wasting mixed liquor directly from the aeration channel means that the plant's sludge handling facilities will have to handle higher volumes of a more diluted waste sludge than a conventional oxidation ditch system. Some concentration of the sludge, however, may be possible within the intrachannel clarifier depending on the particular configuration chosen. This would lower the volume of sludge wasted.

When a wastewater treatment plant designer chooses an intrachannel clarifier the anticipated waste sludge concentration from the system must be estimated and its impact on the size of the plant's sludge handling facilities considered. Any cost savings associated with the intrachannel clarifier must be weighed against any increased sludge handling costs over those of a conventional oxidation ditch plant.

Wastewater treatment plant designers have numerous alternatives available for sludge handling systems. They must select the most cost-effective alternative based on the particular conditions at their plant. Examining the impact of feed sludge concentration on each of these alternatives is definitely beyond the scope of this paper. The following example shows the effect that wasting a thinner sludge could have on the size of the sludge handling system at a plant using an intrachannel clarifier.

In this example the plant will use a gravity thickener for the waste activated sludge, to concentrate the feed sludge to the sludge handling facilities. Gravity thickeners are sized based on the minimum surface area that meets both hydraulic surface leading and solids loading require ments (10,11).

Figure 10 shows the impact of feed sludge concentrations on the required thickener surface area for a hypothetical 18,900 m^3/d (5.0 mgd) treatment facility at the hydraulic and solids loading indicated (11). The mass of sludge wasted would control the thickener solids loading and this loading would not change with lower waste sludge concentrations. Hydraulic loadings, however, increase with lower waste sludge concentrations. In this analysis when the waste sludge concentration drops below about 5000 mg/L, additional thickener size is required to meet the surface hydraulic loading requirements.

Other sludge handling alternatives may be affected to a greater or lesser degree by having to waste a more dilute sludge from a facility with an intrachannel clarifier. Generalizations regarding appropriate technologies for sludge handling or their cost-effectiveness for various sizes of facilites using intrachannel clarifiers, however, can not be made.

IMPACT OF WASTE SLUDGE CONCENTRATION ON REQUIRED THICKENER SURFACE AREA

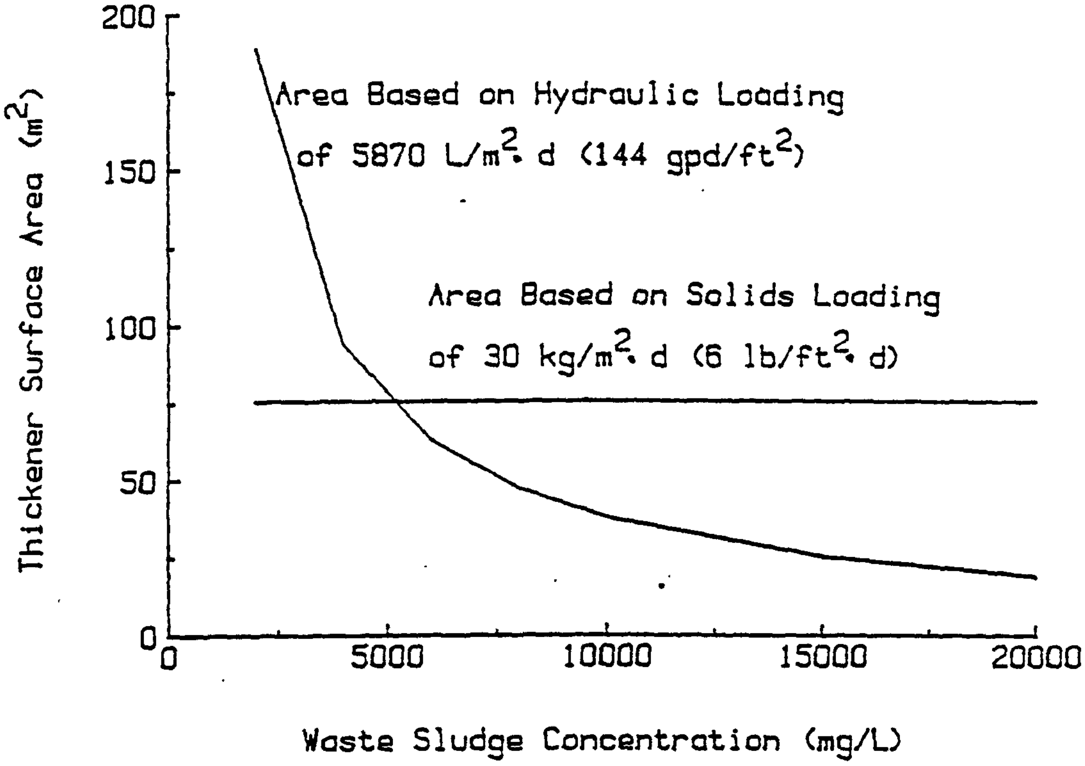


Figure 10. Impact of Waste Sludge Concentration on Size of Sludge Handling Facilities for Example Plant.

Restriction of Aeration Channel Flow by Intrachannel Clarifiers

Conventional oxidation ditch systems are designed to maintain the mixed liquor in the aeration basin at a velocity of 0.30 m/s (1.0 fps) to prevent solids deposition. This value represents an industry standard that has been used for decades in the design of oxidation ditch systems (12). Aeration devices specially designed for these systems provide sufficient energy to maintain this velocity and meet process oxygen requirements.

To a certain degree, all intrachannel clarifiers restrict the circulating flow of the mixed liquor in the aeration channel. The aeration equipment must overcome these restrictions to maintain adequate velocities throughout the aeration channel. Zirschky (1) reports that inadequate aeration and mixing are the most predominant and significant problems of the intrachannel clarification systems in operation.

Designers of systems using any of the intrachannel clarifiers must make sure that the aeration device they provide adequately mixes and aerates the oxidation ditch. The capability of the aeration device to overcome the increased headloss in the channel because of the intrachannel clarifier must also be considered.

Aeration Channel and Clarifier Maintenance

Conventional oxidation ditch systems with separate secondary clarifiers typically have multiple units with provisions that allow the plant to continue treating wastewater with a unit out of service for maintenance. For instance, in a plant with two aeration channels and two separate secondary clarifiers, shutting down one of the aeration channels will allow the two clarifiers to continue to operate at the same hydraulic and solids loadings as before. The operational aeration channel, however, will receive an increased hydraulic and organic loading which may affect its performance. Removing one of the clarifiers from service would not affect aeration capacity, but the increased hydraulic and solids loading to the operational clarifier may affect its performance.

When the same oxidation ditch plant, provided with two aeration channels and intrachannel clarifiers, must remove either an aeration channel or clarifier from service for maintenance, both processes must be removed together. Neither of the processes, though potentially operational, could work in conjunction with the others to provide additional treatment capacity. Severe performance problems could exist during maintenance.

Designers must consider how the oxidation ditch facility using an intrachannel clarifier will maintain adequate treatment performance when either the aeration channel or clarifier must be taken out of service.

Operational Flexibility

One of the claimed advantages of using an intrachannel clarifier is the elimination of the sludge return system. Elimination of the slúdge return system saves its capital cost and the need to operate and maintain the system but also eliminates the capability to monitor or adjust return sludge flows.

In a conventional oxidation ditch system the operations staff must periodically monitor and adjust the return sludge flows. When problems with sludge settling characteristics begin to affect performance, one strategy calls for reducing return sludge flows to lower the solids loading to the clarifier (13). A second strategy temporarily treats the return sludges chemically, to oxidize and remove the problem organisms from the sludge.

None of the options would be available to an operator of a facility with an intrachannel clarifier. At this time, however, there has not been sufficient operational experience with these systems to determine whether giving up control of the return sludge will impact the long term performance capabilities of these systems.

SUMMARY

Intrachannel clarifiers represent a relatively new alternative to conventional separate secondary clarifiers for the oxidation ditch process by providing solids/liquids separation and sludge return within the aeration channel. Eight different manufacturers supply intrachannel clarifiers each having a different principle of operation. Eighty different wastewater treatment facilities throughout the United States are using or will be using intrachannel clarifiers.

Intrachannel clarification appears to be a valid concept and units have produced effluents that have met secondary treatment standards. At this time, however, no one has completed an independent assessment of the long term performance capabilities, energy requirements and costs of these systems. Virtually all of the data on these systems has been collected by the manufacturers for their respective devices. This paper has not provided any additional data on these systems.

Eliminating the conventional secondary clarifier, its associated equipment, and the sludge return system may appear to automatically improve the cost-effectiveness of oxidation ditch systems. Designers considering using intrachannel clarifiers, however, must make sure that they evaluate the impact of the anticipated waste sludge concentrations on the size of the sludge handling facilities. They must also determine if the aeration equipment can provide adequate amounts of oxygen and maintain adequate channel velocities when used in conjunction with a particular intrachannel clarifier. Other considerations include the ability to maintain treatment during maintenance and the impact of losing return sludge control. Each of these factors may reduce the cost-effectiveness of oxidation ditch systems using intrachannel clarifiers.

DISCLAIMER

"This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication."

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16. ABSTRACT

Intrachannel clarifiers replace secondary clarifiers in the oxidation ditch process by providing solids/liquids separation and sludge return within the aeration channel. Eight different manufacturers supply intrachannel clarifiers each having a different principle of operation. Intrachannel clarification appears to be a valid concept based on data collected by the manufacturers. Sufficient data are not available for a complete assessment of the long term performance capabilities, energy requirements and costs of these systems. This paper presents the principles of operation for the eight different intrachannel clarifiers and discusses design tradeoffs that facility designers must consider when selecting any of these devices.

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