Sedimentation and Clarification

Sedimentation is the next step in conventional filtration plants. (Direct filtration plants omit this step.) The purpose of sedimentation is to enhance the filtration process by removing particulates. Sedimentation is the process by which suspended particles are removed from the water by means of gravity or separation. In the sedimentation process, the water passes through a relatively quiet and still basin. In these conditions, the floc particles settle to the bottom of the basin, while "clear" water passes out of the basin over an effluent baffle or weir. Figure 7-5 illustrates a typical rectangular sedimentation basin. The solids collect on the basin bottom and are removed by a mechanical "sludge collection" device. As shown in Figure 7-6, the sludge collection device scrapes the solids (sludge) to a collection point within the basin from which it is pumped to disposal or to a sludge treatment process. Sedimentation involves one or more basins, called "clarifiers." Clarifiers are relatively large open tanks that are either circular or rectangular in shape. In properly designed clarifiers, the velocity of the water is reduced so that gravity is the predominant force acting on the water/solids suspension. The key factor in this process is speed. The rate at which a floc particle drops out of the water has to be faster than the rate at which the water flows from the tank's inlet or slow mix end to its outlet or filtration end. The difference in specific gravity between the water and the particles causes the particles to settle to the bottom of the basin. Some plants have added baffles or weirs in their sedimentation basins to limit short-circuiting through the basins, promoting better settling.

Other forms of sedimentation used in the water industry are:

1. Tube and plate settlers;
2. Solids contact clarifiers, sludge blanket clarifiers, and contact clarifiers; and,
3. Dissolved air flotation.

These forms of sedimentation typically allow for higher loading rates and/or improved particle removal than the basins illustrated in Figures 7-5 and 7-6. More information on these sedimentation processes is presented in the following sections.

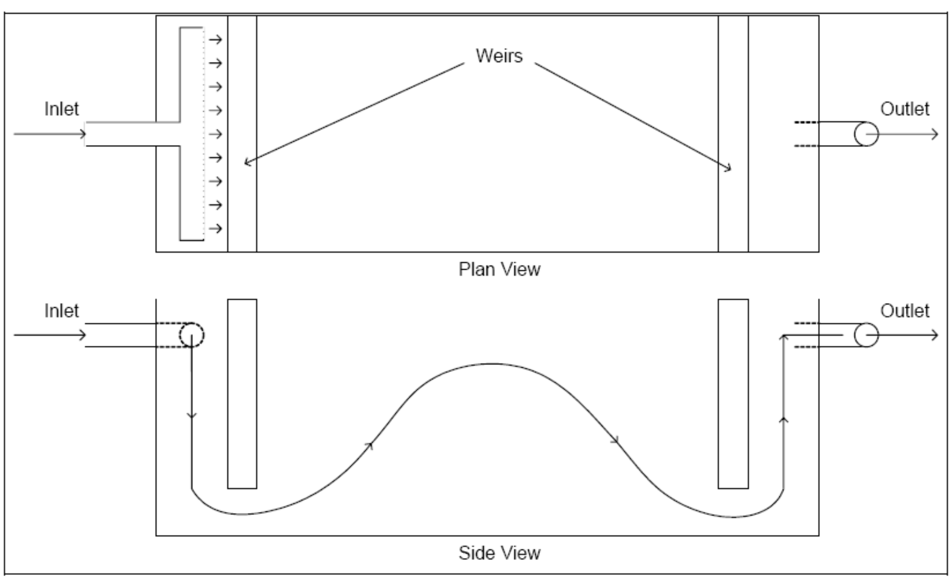
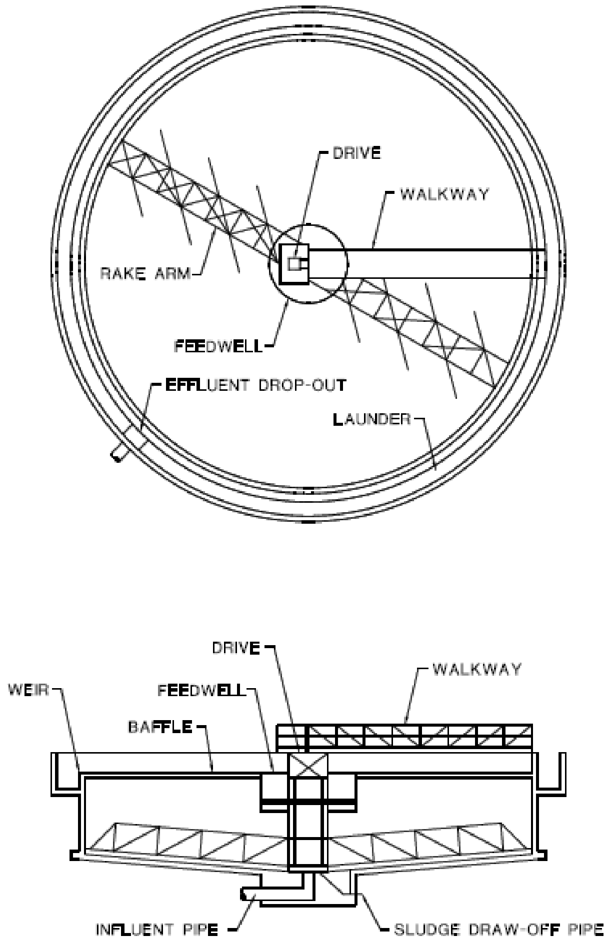


Figure 7-5. Rectangular Sedimentation Basin



Source: AWWA and ASCE, 1990.

Figure 7-6. Circular Radial-Flow Clarifier

Circular Radial Flow Clarifier

Pre-Sedimentation

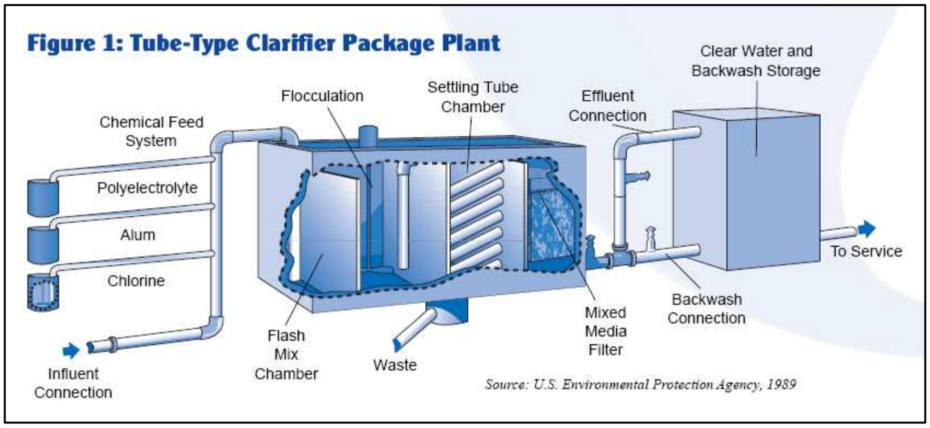
Not all systems use pre-sedimentation, but pre-sedimentation is often used when raw water turbidity is high or highly variable. Pre-sedimentation basins range in size, depending on the flow, and the water is sometimes pre-treated with a coagulant and/or a polymer prior to entering the pre-sedimentation basin (AWWA, 1999). The addition of coagulants and/or polymers at this point in the treatment process could be helpful if a system needs to reduce the natural organic matter entering the plant. Natural organic matter is a disinfection byproduct precursor, and if a system has high organic matter (measured as total organic carbon, or TOC), then pre-sedimentation could be beneficial for system compliance.

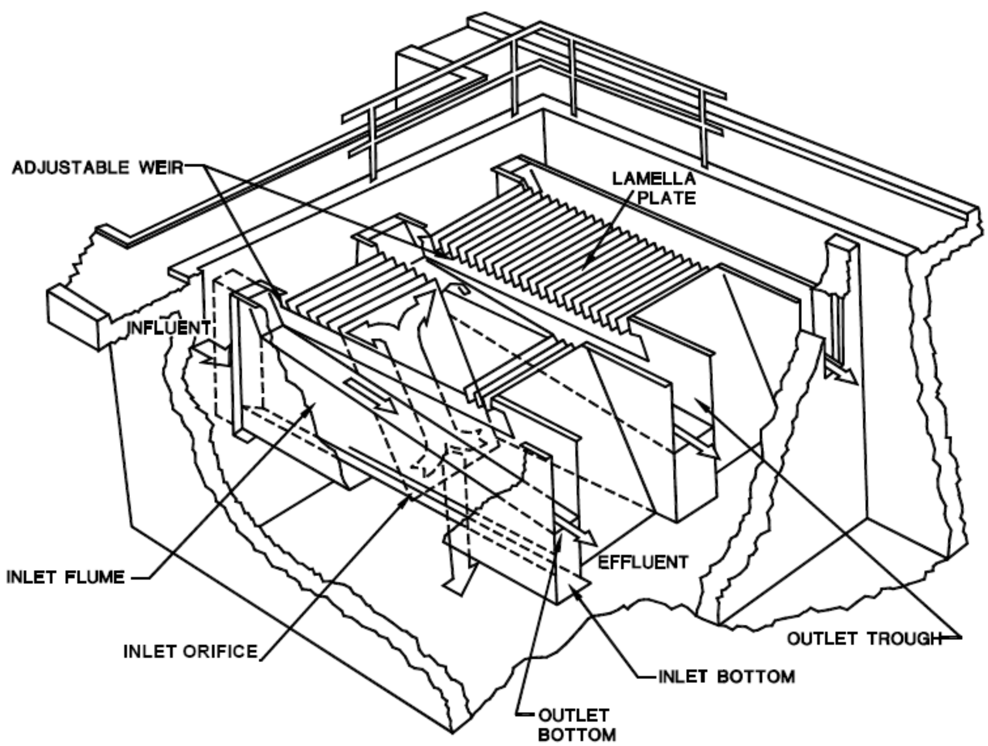
Effect on Turbidity

Sedimentation may remove suspended solids and reduce turbidity by about 50 to 90 percent, depending on the nature of the solids, the level of pretreatment provided, and the design of the clarifiers. Common values are in the 60 to 80 percent range (Hudson, 1981).

Tube and Plate Settlers

Inclined tubes and plates can be used in sedimentation basins to allow greater loading rates. This technology relies on the theory of reduced-depth sedimentation: particles need only settle to the surface of the tube or plate below for removal from the process flow. Generally, a space of two inches is provided between tube walls or plates to maximize settling efficiency. The typical angle of inclination is about 60 degrees, so that settled solids slide down to the bottom of the basin. Figure 7-7 illustrates a plate settler used for high-rate sedimentation.





Source: AWWA and ASCE, 1998.

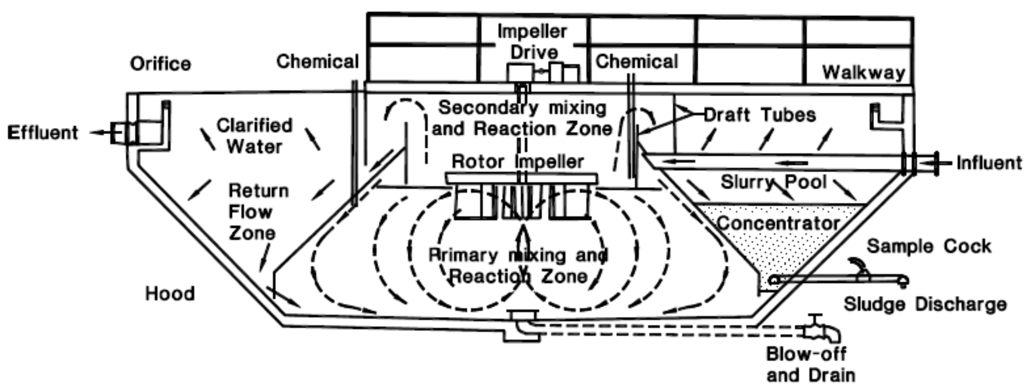
Figure 7-7. Plate Settlers Used for High-Rate Sedimentation

Solids Contact Clarifiers, Sludge Blanket Clarifiers, and Contact Clarifiers

Solids contact clarifiers represent an entirely different approach to high-rate clarification. They consist of a basin similar to that used for a conventional clarifier, but with a sludge recycle system to promote development of a dense sludge blanket that captures floc. There are numerous types of solids contact units on the market in the United States. These units are all similar in design in that they combine solids contact mixing, flocculation, solids-water-separation, and continuous removal of sludge in a single package-type basin. The recirculation rate of water and solids in solids contact units is critical to the units' effective operation. Too high a recirculation rate will cause the sludge blanket to lift and create increased loading to the filters.

Accelator®

An Accelator® solids contact clarifier is shown in Figure 7-8. Raw water enters the primary mixing and reaction zone, where it receives the coagulant chemical. Coagulation and flocculation begin in this chamber in the presence of previously formed floc particles. These particles provide the nucleus of new floc particles. The resulting solids precipitant is pumped up into a secondary mixing and reaction zone. More gentle mix energy in this chamber allows completion of the flocculation process and separation of the solids. The mixture of solids and water flows down a draft tube. The downward flow starts the solids particles on a path down the hood to the sludge blanket at the bottom of the basin. Clear water flows up at a constantly reducing velocity that allows small particles to settle out. Other manufacturers of solids contact units may have flow patterns different than the Accelator® flow pattern.



Source: AWWA and ASCE, 1998.

Figure 7-8. Accelator® Solids Contact Unit

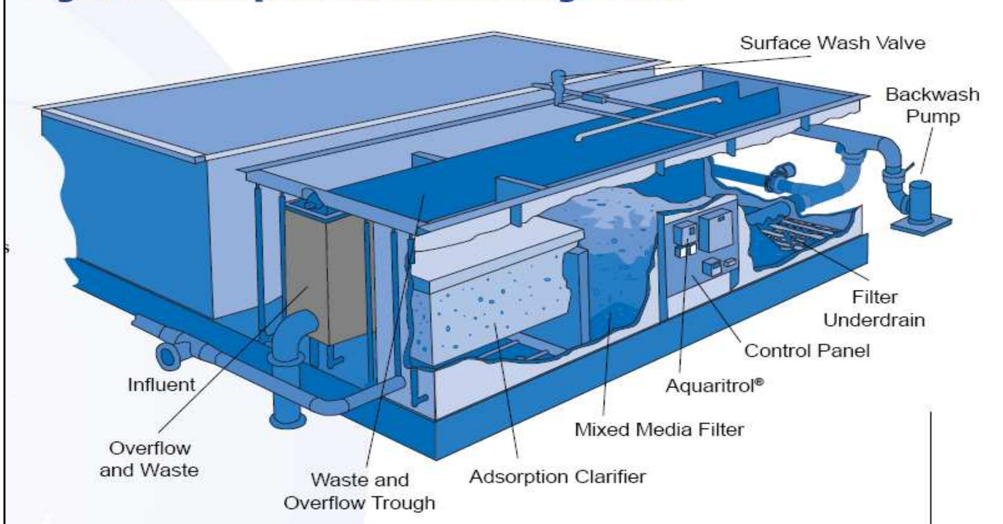
Sludge Blanket Clarifiers

Sludge blanket clarifiers are a variation of solids contact units in which coagulated water flows up through a blanket of previously formed solids. As the small, coagulated particles enter the sludge blanket, contact with other particles in the blanket causes flocculation to occur. The floc grows in size and becomes part of the blanket. A blanket depth of several feet is required for efficient clarification (AWWA and ASCE, 1998).

Contact Clarifiers

Contact clarifiers (sometimes referred to as contact adsorption clarifiers) are designed to provide flocculation and clarification in a single process. These clarifiers consist of a basin filled with adsorption media, generally plastic or rock about the size of pea gravel. As water passes through the media, hydraulic mixing promotes flocculation and the flocculated particles adhere to the surface of the media particles. The media is cleaned periodically using an air, or air and water, backwash process to remove the solids.

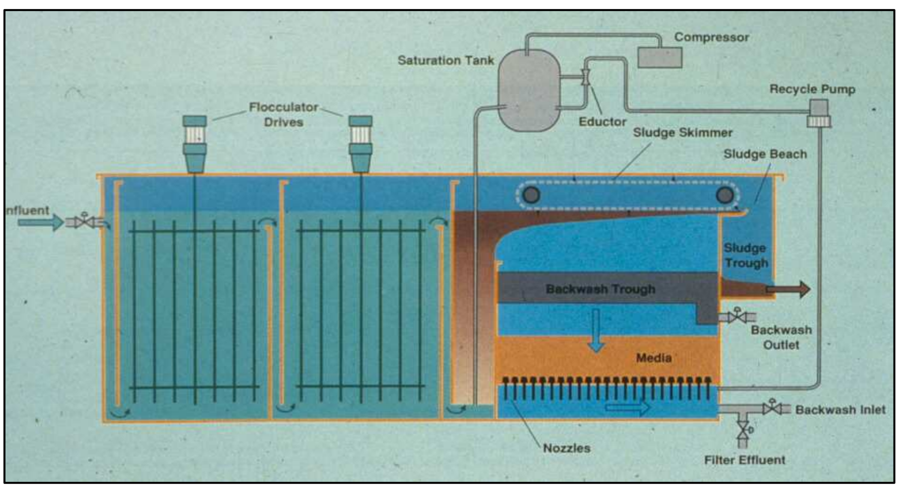
Figure 2: Adsorption Clarifier Package Plant



Source: U.S. Environmental Protection Agency, 1989

Dissolved Air Flotation

Dissolved air flotation clarifiers bubble air into the flocculated water and cause the floc particles to float to the surface. Dissolved air flotation clarification allows for loading rates up to 10 times that of conventional clarifiers (AWWA and ASCE, 1998). Dissolved air flotation consists of saturating a sidestream with air at high pressure and then injecting it into a flotation tank to mix with incoming water. As the side-stream enters the flotation tank, the pressure drop releases the dissolved air. The air bubbles then rise, attaching to floc particles and creating a layer of sludge at the surface of the tank. The clarified water is collected near the bottom of the tank.



Optimization of the Sedimentation and Clarification Process

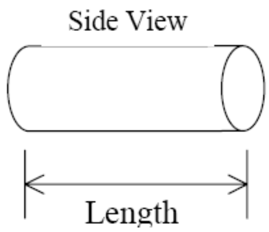
Optimization of the clarification process will minimize solids loading on the filters and will contribute to enhanced filter performance and better overall treated water quality.A water system should consider the following items when evaluating sedimentation basins:

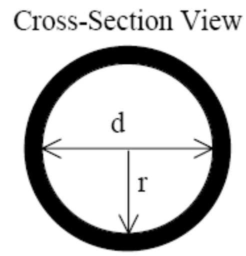
1. Conducting a tracer study in the sedimentation basin. Often, very simple design changes can be made to improve sedimentation basin performance. For information on tracer studies, see the *LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual* (EPA, 2003).
2. Is sludge collection and removal adequate? Inadequate sludge collection and removal can cause particles to become re-suspended in water or upset circulation. Systems should disrupt the sludge blanket as little as possible. Sludge draw-off rates can affect the sludge blanket. Sludge draw-off procedures should be checked periodically, making sure sludge levels are low and sludge should be wasted if necessary. Sludge pumping lines should be inspected routinely to ensure that they are not becoming plugged. These lines should also be flushed occasionally to prevent the buildup of solids.
3. Do basin inlet and outlet conditions prevent the breakup of formed floc particles? Settling basin inlets are often responsible for creating turbulence that can break up floc. Improperly designed outlets are also often responsible for the breakup of floc. Finger launders (small troughs with V–notch weir openings that collect water uniformly over a large area of a basin) can be used to decrease the chance of floc breakup.
4. Is the floc the correct size and density? Poorly formed floc is characterized by small or loosely held particles that do not settle properly and are carried out of the settling basin. Such floc may be the result of inadequate rapid mixing, improper coagulant dosages, or improper flocculation. Systems should look to previous steps in the treatment train to solve this problem.
5. Is the basin subject to short-circuiting? If the basin is not properly designed, water bypasses the normal flow path through the basin and reaches the outlet in less than the normal detention time. Causes of shortcircuiting may include poor influent baffling or improperly placed collection troughs. If the influent enters the basin and hits a solid baffle, strong currents may result. A perforated baffle may distribute inlet water without causing strong currents. Tube or plate settlers may also improve efficiency, especially if flows have increased beyond original design conditions. The installation of tube settlers can sometimes double a basin's original settling capacity.
6. Are basins located outside and subject to windy conditions? Wind can create currents in open basins that can cause short-circuiting or disturb the floc. If wind poses a problem, installing barriers may reduce the effect and keep debris out of the unit.
7. Are basins subject to algal growth? Although primarily a problem in open, outdoor basins, algae can also grow as a result of window placement around indoor basins. Algae should be removed regularly to avoid buildup.
8. Is the sludge blanket in SCUs maintained properly? Operators should be able to measure the sludge depth and percent solids to ensure the sludge blanket is within the manufacturer's recommendations. A timing device to ensure consistent blanket quality characteristics should control sludge removal rates and schedule.
9. Is the recirculation rate for SCUs within the manufacturer's recommendations? Various designs have different recirculation rates and flow patterns. Systems should refer to the manufacturer's operation manual.

Equations for Determining Basin Volumes

VOLUME EQUATIONS

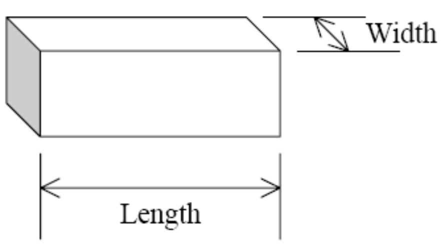
Water Pipe (raw or treated):
Fluid Volume = Length x Cross-Sectional Area

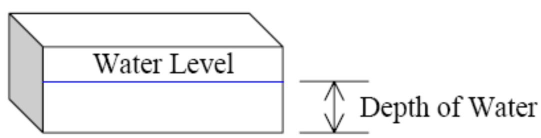




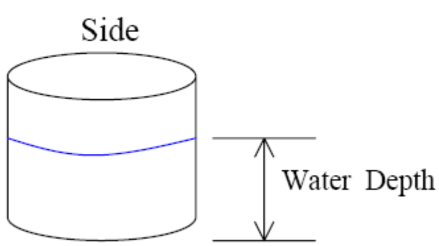
Cross-Sectional Area = 3.1416 * r^2
r = inner radius = d / 2
d = inner diameter

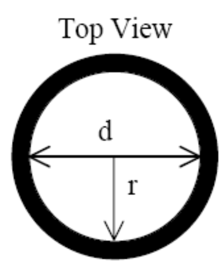
Rectangular Basins:
Fluid Volume = Length x Width x Depth of Water





Cylindrical Basins:
Fluid Volume = Water Depth x Cross-Sectional Area





Cross-Sectional Area = 3.1416 * r^2
r = inner radius = d / 2
d = inner diameter