Sedimentation Tank Hydraulics *

January 3, 2012

Abstract

The goal of this research is to evaluate sedimentation tank bottom geometry, jet location, and the design requirements for a floc hopper in an AguaClara sedimentation tank. Inlet jet geometry along the bottom of the sedimentation tank is critical in the resuspension of flocs. The inlet end of the sedimentation tank needs to be redesigned to re suspend flocs. A floc weir will be needed to set the upper limit of the floc blanket level and a floc hopper will be needed to consolidate the wasted flocs.

students	4
skills	fabrication, experimentation, fluids, process controller

1 Sedimentation tank geometry

AguaClara sedimentation tanks have evolved rapidly from

1. flat bottom with 3 large pipe inlets (Ojojona)
2. sloped bottom with 3 large pipe inlets (Marcala 1 and Tamara)
3. sloped bottom with inlet ducts under the sloped bottom (Cuatro Comunidades)
4. sloped bottom with simple inlet manifold with orifices (Agalteca)
5. sloped bottom with inlet manifold with diffuser drop tubes (Marcala 2)
6. sloped bottom with small radius jet reverser and line source jet (proposed design for Atima)

The design for the diffusers on the inlet manifold was modified in August of 2011 to improve the ability of AguaClara plants to form floc blankets. This new design is going to be built in Atima, Santa Barbara, Honduras. The conceptual design for the diffuser has been created. We now need a method to fabricate

Figure 1: Spring 2011 version of the sedimentation tank inlet manifold and diffusers. These diffusers do not provide the continuous line source that is required to suspend all flocs that slide down the slopes of the sedimentation tank. In addition, the flat sludge drain cover does not provide the geometry for a jet reverser that can easily suspend the settled flocs.

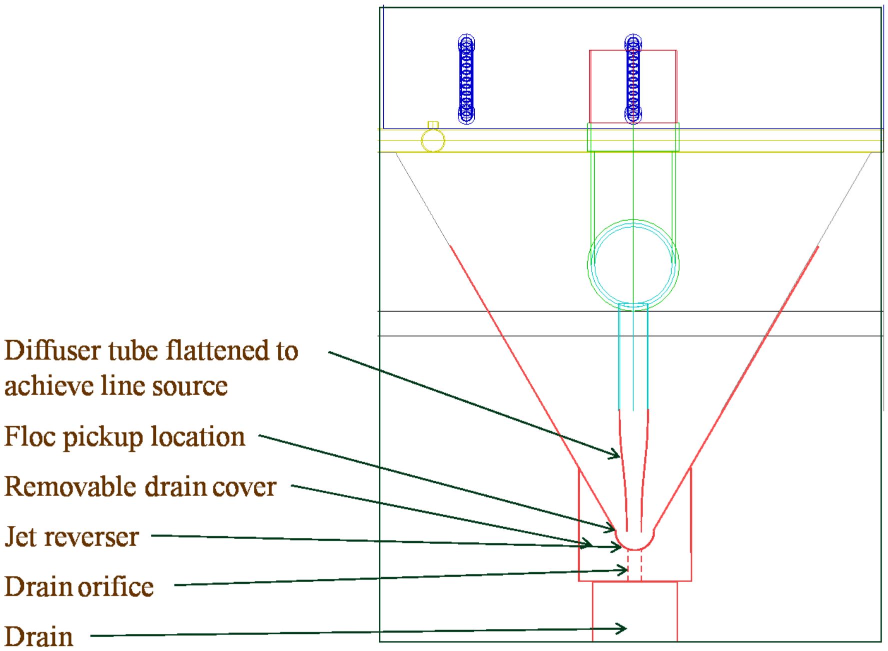

Figure 2: Preliminary sketch of the inlet manifold with diffuser tubes and jet reverser.

the inlet manifold system. We will build on the technology used to fabricate the diffusers at Marcala (figure 1).

The preliminary design for the Atima, Santa Barbara plant calls for a 6 inch diameter manifold, 4.4 cm diameter ports every 12.1 cm, diffusers that are 3 inches in diameter and approximately 60 cm long. The diffusers pipes will be heated, reshaped, and stretched by 20% into a rectangle that is 3.2 cm wide and 12.1 cm long. The rectangular section should extend as long as possible so that there is a long distance for the fluid to approach uniform flow. A preliminary cross section of the design is shown in figure 2.

The evolution of the sedimentation tank design continues as we learn more about what is required to produce floc blankets and as we improve how we handle the sludge. The focus of our current research is to carefully design the interaction between the flocs that settle on the bottom slopes as they return to the central valley of the sedimentation tank and the jets produced by the diffuser drop tubes. The design of the interaction between the settled flocs and the inlet jets is critical because it is the jets that re-suspend the settled flocs and thus create the floc blanket. As we improve tank geometry to reliably create floc blankets it will necessary to also control the depth of the floc blanket (with

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[*] This team has potential for the EPA P3 competition and should consider a submission in the fall of 2011

a floc blanket weir) and use a floc hopper to provide time for the wasted flocs to consolidate or dewater to reduce the amount of water that must be wasted with the resulting sludge.

The manifold currently doesn't have diffuser drop tubes below and behind the elbow in the inlet manifold. It may be critical for rapid floc blanket formation to develop a method of fabricating an inlet manifold with diffuser pipes that extend all the way to the end of the tank or it may be possible to add a slope to return flocs to the first drop tube. We need a method to assess which approach should be used and we should implement these changes in the design tool as soon as possible.

We have preliminary evidence that floc blanket formation and performance is negatively influenced by any consolidation of the flocs before resuspension by the jet. It would be useful to confirm this observation with overall performance data for a sedimentation tank including residual turbidity after plate (or tube) settlers. This will require setting up the tube settlers on the 2D sedimentation tank apparatus (Figure 3 and 4). The tube settler effluent turbidity should be compared for different bottom and jet geometries to see if tank geometry has a significant influence on overall performance. We are particularly interested in comparing bottom geometries that cause floc consolidation prior to resuspension and bottom geometries that resuspended flocs without floc consolidation. If floc consolidation is shown to negatively influence performance then the AguaClara sedimentation tank bottom geometry should be redesigned. The experimental conditions could be 100 NTU raw water and 1 mm/s up flow velocity in the sedimentation tank. The coagulant should be PACl and the appropriate dose can be supplied by the Tube Floc team.

During the summer of 2011 we developed the following hypotheses based on reviewing the floc blanket videos. Some of these hypotheses can be evaluated by both experimental and theoretical approaches. All of these hypotheses can be tested

1. Jet stability is important and can be increased by decreasing the distance between the flow splitter and the diffuser.
   (a) if the jet moves off center due to pressure from sludge on one side, then it loses its ability to lift flocs on one side and the sediment build up on that side becomes stable (the floc blanket fails)
   (b) The jet discharge point should be very close to the flow splitter to prevent jet drift
2. Jet dissipation rate (depends on degree of contraction and velocity at discharge) will control size of flocs after interaction with jet
   (a) We should experiment with a range of energy dissipation rates to see how this influences blanket formation and residual turbidity
   (b) Jet velocity is directly tied to dissipation rate and will determine ability of the jet to suspend the flow of flocs

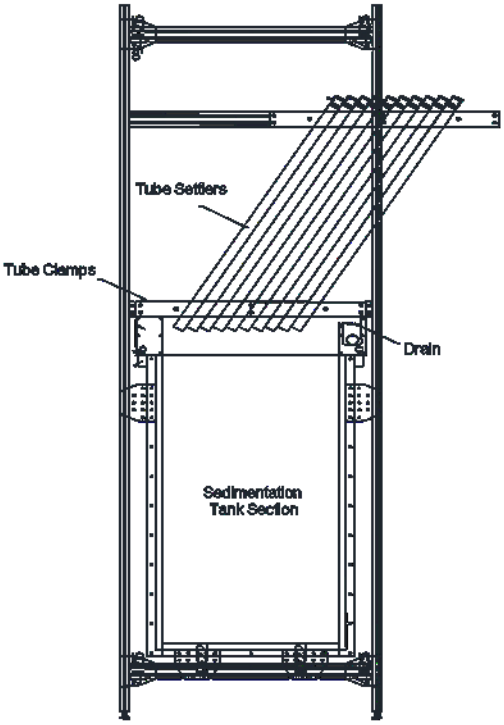

Figure 3: 2D sedimentation tank apparatus

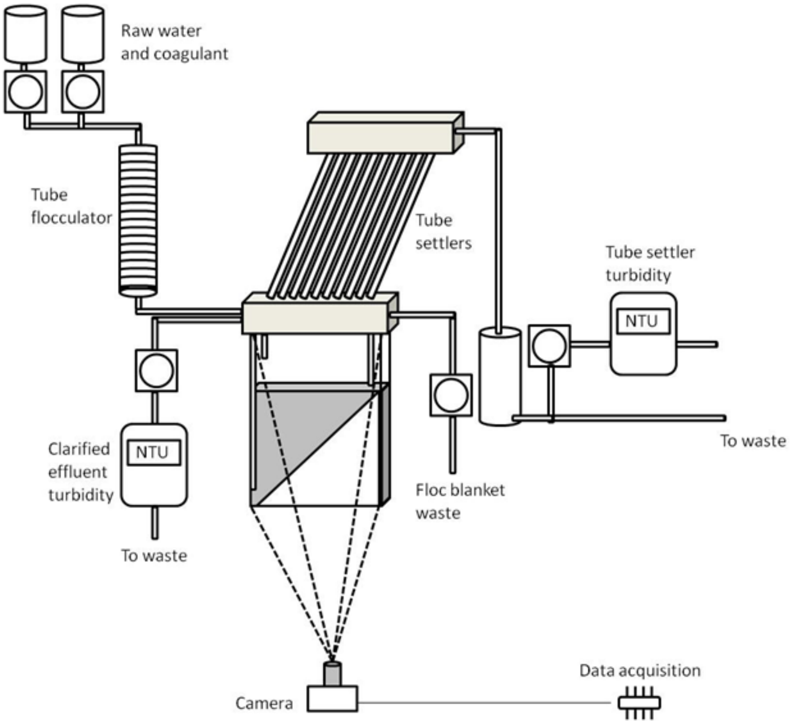

Figure 4: Schematic of apparatus including turbidimeters, camera, source water, flocculator, and sedimentation tank.

3. Angle of jet interaction with flocs strongly influences the ability of the jet to suspend flocs
    (a) Vertical flow is better than horizontal flow for suspended flocs
    (b) Would it be even more stable if the jet was flowing underneath the falling flocs (60 degrees from the horizontal instead of 90 degrees from the horizontal)? This might reduce failure due to flocs falling into the boundary layer because gravity would pull the flocs into the higher velocity fluid.
4. Jet reverser radius of curvature
    (a) 10 cm radius fails and 5 cm works (must be related to boundary layer development along the wall of the jet reverser and the ability of the settled flocs to drop into that boundary layer)
    (b) Smaller radius of curvature needs to be investigated
    (c) At minimum the radius of curvature must be equal to the width of the jet where it discharges from the diffuser
    (d) The flow regime of the jet reverser is similar to the flow around a baffle in a flocculator

Jet reverser with flow splitter geometry might have some advantages. A few tests should be conducted with a jet reverser that is made from two halves of a pipe.

2 Floc hopper geometry

The parameters of interest are the ratio of the plan view area of the floc hopper to the plan view area of the rest of the sedimentation tank, the volume of the floc hopper, and possible the angle of the bottom of the hopper. We are also interested in knowing how the geometry of the floc hopper influences the required sludge flow rate. The depth of flow and flow rate over the floc hopper weir is also of interest. The depth of flow over the floc hopper weir is not expected to be significant design constraint.

The critical design constraint is expected to be during high turbidity events when the floc volume fraction is high and hence the flow of flocs into the floc hopper will be the greatest. The fractal flocculation model predicts that at 500 NTU the floc volume fraction is 0.08. Thus the flow over the weir would be $0.08Q_{SedBay}$. The floc volume fraction is proportional to the turbidity for high turbidities and thus at 1000 NTU the floc volume fraction is 0.16. Without consolidation of the flocs it would be necessary to waste 16% of the flow during a 1000 NTU event. AguaClara plants have already treated water in excess of 700 NTU and so it would be reasonable to design the floc hopper to handle a 1000 NTU event.

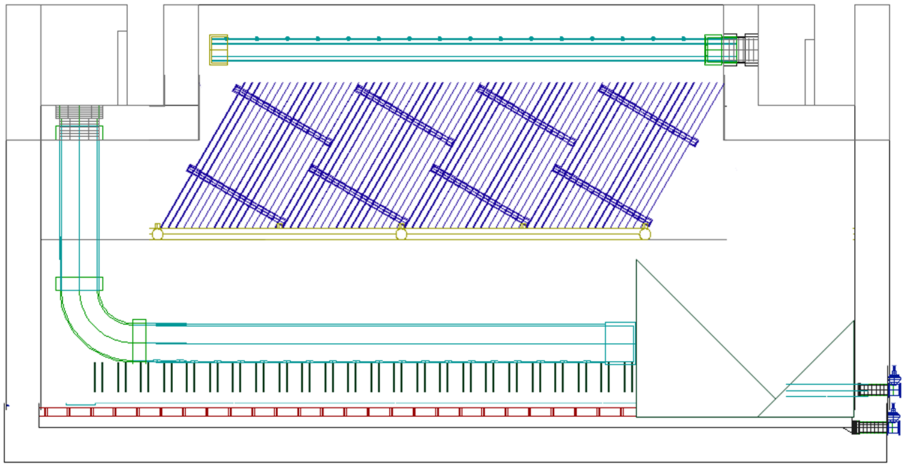

Figure 5: Preliminary sketch of a floc hopper with a double bottom slope.

A floc hopper can be installed in the 2d sedimentation apparatus (Figure 4). You could start with a floc hopper that occupies 15% of the plan view area of the sedimentation tank. The bottom slope could be very steep so that the sludge hopper extends all the way to the bottom of the sedimentation tank. A peristaltic pump can be used to remove sludge from the very bottom of the floc hopper. The flow rate of the pump can be slowly varied and the depth of the flocs in the floc hopper can be measured. This will give a relationship between the required plan view area of the floc hopper and the corresponding required sludge wasting rate. The steady state depth of sludge in the floc hopper will increase as the sludge wasting rate decreases. There may be problems with this experimental method because the sludge may consolidate so well that the pump won't be able to remove it.

The plan view area and time required for floc consolidation is not easily estimated. The fractal flocculation model predicts that at 1000 NTU the floc volume fraction is 0.16. Thus the flow over the weir would be $0.16Q_{SedBay}$. Does this mean that the area of the floc hopper should be about 16% of the sedimentation tank area? We need some modeling work here to understand what controls this consolidation process. A literature review would be useful and experimental work is needed. Images of this floc weir in action and the consolidation would be very useful in understanding how these processes work.

The goal is to develop an understanding of how floc consolidation works and to determine the top width of the floc hopper.

1. Z.SedFlochopperWeir - The height of the top of the floc hopper weir that will then set the depth of the floc blanket. It is probably best if the floc blanket doesn't reach the bottom of the plate settlers and thus we may want to set the top of the floc hopper weir to be approximately 10 cm below the bottom of the plate settlers.

2. AN.SedFlochopper - The angle of the floc hopper could be 60° or perhaps as low as 45°. The goal is to be able to have the sludge slide down the incline easily. It may be best to make this 60° to reduce the risk that sludge will accumulate and not slide into the drain.
3. ND.SedFlochopperValve - Ten state standards suggests that the minimum diameter for any sludge valve should be 3 inches. That seems rather large given what this valve has to handle. I believe we have used 2 inch valves on sedimentation tanks and they performed well. The flow rate for this valve will be very low. We should estimate the sludge flow rate. My intuition is that the valve should be at least 1 inch in diameter so that it won't clog too easily. In normal operation the plant operator may leave the valve open slightly with a low continuous flow rate discharging the sludge as it accumulates and consolidates in the floc hopper.
4. L.SedFlochopper - distance between the drain end wall of the sedimentation tank and the floc hopper weir. This would be estimated based on the floc hopper plan view area required to consolidate the flocs.