CFD Analysis of Clarifier Performance With and Without Energy Dissipating Inlet

Figure 1: Energy Dissipating Inlet (LA-EDI)

Introduction

To estimate performance enhancements resulting from the use of an energy dissipating inlet (LA-EDI) in a circular clarifier a pair of computational fluid dynamics (CFD) calculations were performed. In the first simulation, the flow through a clarifier equipped with a center inlet pipe and open centerwell was calculated. In the second simulation, the center inlet pipe was replaced with an LA-EDI and the diameter of the centerwell was increased from 24 feet to 30 feet. Details regarding the development the CFD model are given in the next section.

The CFD calculations provide estimates of effluent solids concentrations, return activated sludge (RAS) concentrations, sludge blanket depth and flow distributions in the clarifiers. Performance comparisons were made on the basis of these calculated parameters.

CFD Modeling

1. Setup

The CFD models may be thought of as *glass box* models of the circular clarifiers. At the model boundaries, where flow enters and exits the clarifiers, conditions describing the influent and effluent properties are set. Within the clarifiers, the CFD models provide estimates of solids concentrations, and flow speeds throughout the modeled region. Using the *glass box*, engineers can make judgments regarding the ability of internal components (*e.g.,* centerwell baffles) to improve clarifier performance (*e.g.,* to minimize effluent suspended solids over a range of operating conditions).

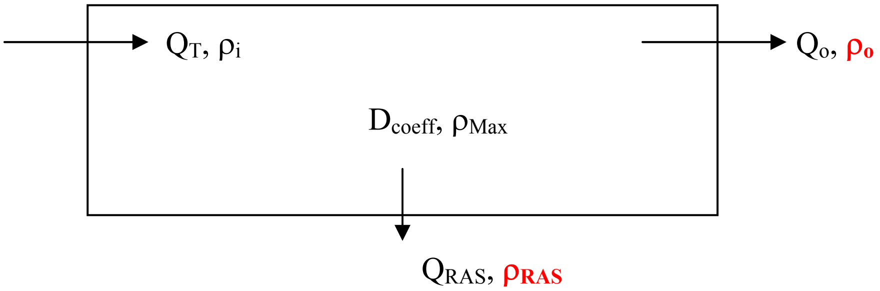
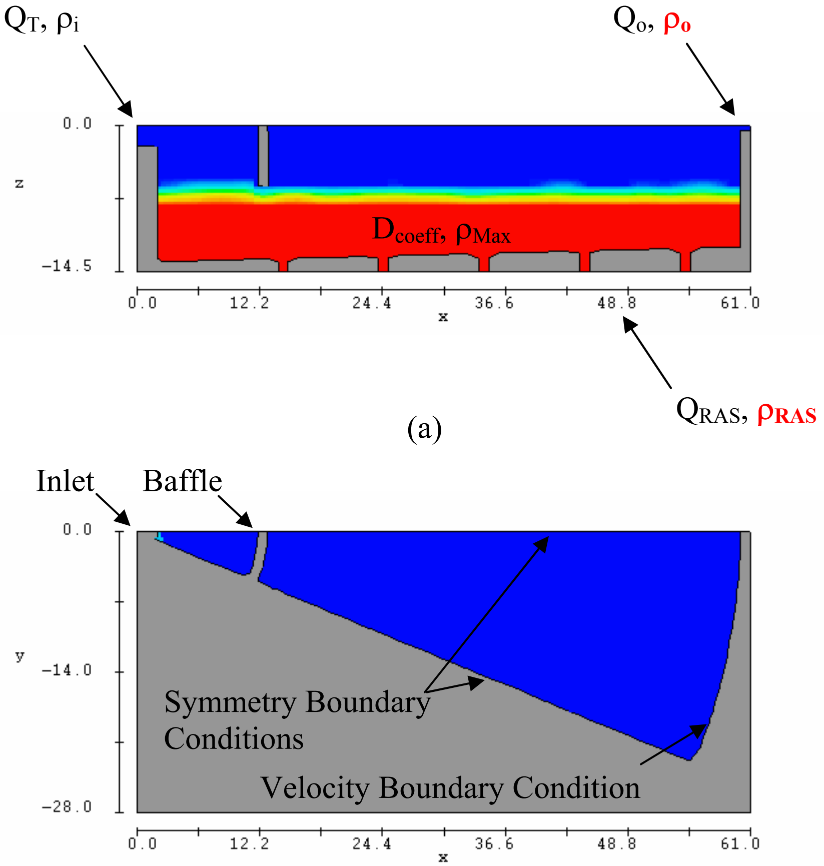


Figure 2: Schematic Diagram of Analytical Model

Figure 2 shows a schematic diagram of the clarifier model developed for this study. In all of the calculations the total flow enters the clarifiers through and inlet structure. The flow rate (Q_T) and the suspended solids concentration (expressed as an influent density, ρ_i, in these calculations) of the influent are set at the beginning of each calculation. The RAS and effluent flow rates (Q_{RAS} and Q_o respectively) are specified as well. Solids settling within the main body of the clarifier is controlled by two parameters, D_{coeff} and ρ_{Max}. These parameters control the rate of separation between the liquid and solids that comprise the mixed liquor and place a limit on the maximum density of the sludge blanket. Effluent solids concentrations and the solids concentration of the RAS flow are estimated by the model (these two parameters appear in red boldface in Figure 2).

The model requires data that are generally available to engineers working at a wastewater treatment plant. These data include: (a) dimensional drawings of the clarifiers to be modeled, (b) operating flow rates, (c) influent suspended solids concentrations, and (d) settling rates of suspended solids. Information such as: (a) sludge blanket depths, (b) effluent solids concentrations, and (c) RAS solids concentrations can be used for model calibration.

The CFD model of the clarifier equipped with a center inlet pipe and open centerwell is shown in Figure 3. To economize the calculation, only a 16th sector of the clarifier was modeled (as shown in Frame 3 [b]) and the withdrawal mechanism for the RAS was simplified. In these calculations sludge was withdrawn through five openings in the bottom of the clarifier. If the flow in the entire clarifier had been modeled, then the effect of the rotating RAS mechanism could have been included as well.



(a)

(b)

Figure 3: CFD Model
(a) elevation, (b) plan-view

2. Tank Geometry and Operating Conditions

Tank geometry and operating conditions for both clarifiers were provided by John Esler (CPE Services, Inc.). This information is summarized in Tables 1 and 2.

Table 1: Tank Geometry and Operating Conditions without EDI

Clarifier Diameter	120 feet
Side Water Depth	12 feet
Center Depth	13.5 feet
Centerwell Diameter	24 feet
Centerwell Depth	6 feet
Total Flowrate	12 mgd
RAS Flowrate	3 mgd
Effluent Flowrate	9 mgd
MLSS	2500 mg/l
SVI	110
SOR	796

Notes: (a) weirs on wall of clarifier, (b) four feed ports in center Inlet pipe – top two feet of clarifier

Table 2: Tank Geometry and Operating Conditions with EDI

Clarifier Diameter	120 feet
Side Water Depth	12 feet
Center Depth	13.5 feet
Centerwell Diameter	30 feet
Centerwell Depth	6 feet
LA-EDI Diameter	14 feet
LA-EDI Depth	3 feet
Total Flowrate	12 mgd
RAS Flowrate	3 mgd
Effluent Flowrate	9 mgd
MLSS	2500 mg/l
SVI	110
SOR	796

Notes: (a) eight opposing jet nozzles, (b) bottom of nozzles will be approximately 1.5 feet below the bottom of the EDI floor

3. Solids Settling

Solids settling, in the model domain, is controlled by two parameters D_{coeff} and ρ_{Max}. D_{coeff} controls the rate of separation between the liquid and solids that comprise the mixed liquor, and ρ_{Max} places a limit on the maximum density of the sludge blanket. The parameter value for ρ_{Max} can be determined from field data, whereas the parameter value for D_{coeff} is usually estimated from the results of a simple model calibration using available field data.

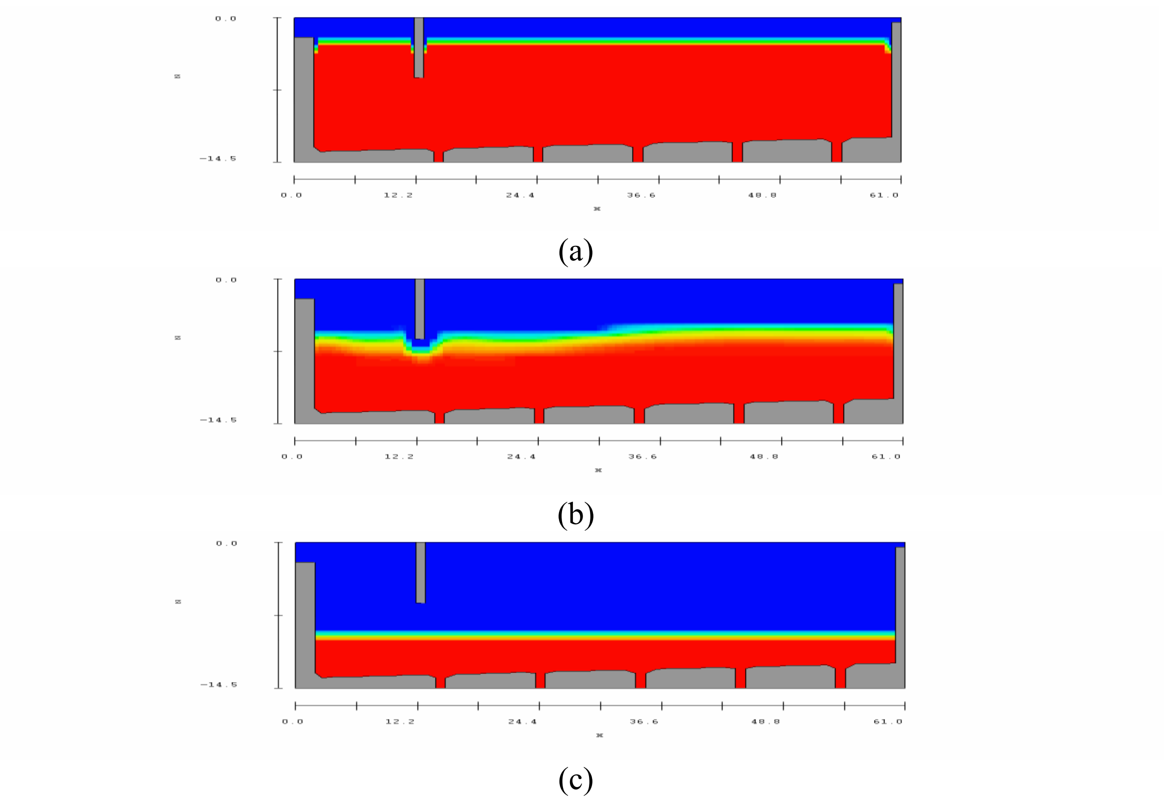


Figure 4: Model Calibration (Solids Settling, 2500 mg/l contour shown)
(a) Initial Condition, (b) after 30 Minutes, (c) after 60 Minutes

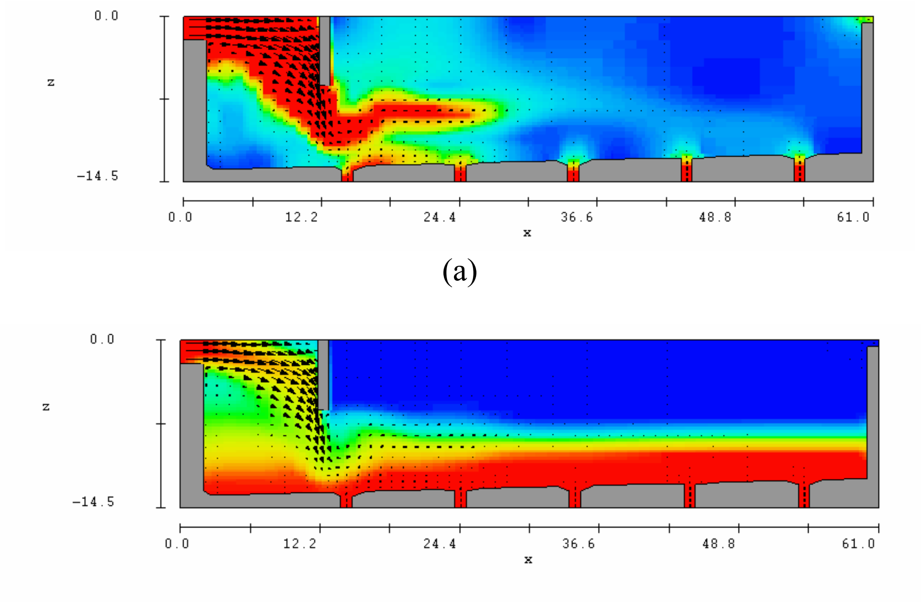
To determine the value of D_{coeff}, fluid within the clarifier is initially given a uniform density equal to that of the influent mixed liquor (Figure 4[a]). Velocities at the inlet and outlet locations are also set to zero. Solids within the tank are observed to settle in the calculation that proceeds from this initial condition (Figures 4[b] and 4[c]). In this calculation the clarifier works as a giant settling column and the movement of solids, controlled by the D_{coeff} coefficient, are matched with settling data.

Once an approximate value for the D_{coeff} coefficient is chosen additional model calibration (of D_{coeff} and ρ_{Max}) can be carried out with measurements of sludge blanket depth, the results of dye studies and the results of drogue studies. The results of this study were not compared to field data. Instead, the settling properties were chosen to approximate the behavior of a mixed liquor with an SVI equal to 110.

Results

1. Circular Clarifier without Energy Dissipating Inlet

Distributions and flow speed and solids are shown in Figure 5. The influent enters from the left-hand side of both frames, and exits from the bottom of the clarifier and through the effluent launders located at the top of the outside wall of the clarifier. Boundary conditions for this calculation are provided in Table 1.



(a)

(b)

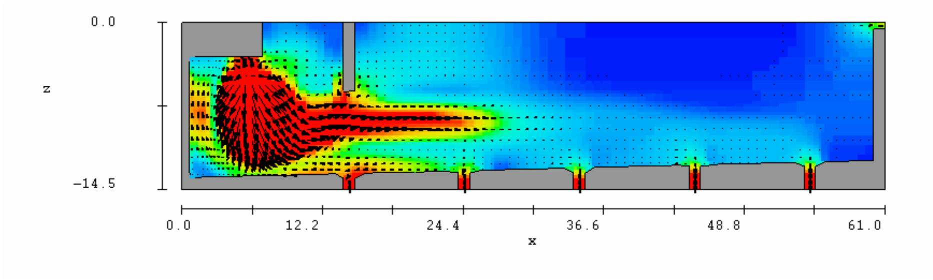
Figure 5: Model Results
(a) Flow Speed [red > 0.1 fps], (b) Solids Distribution [red > 2000 mg/l]

Table 2: Model Statistics

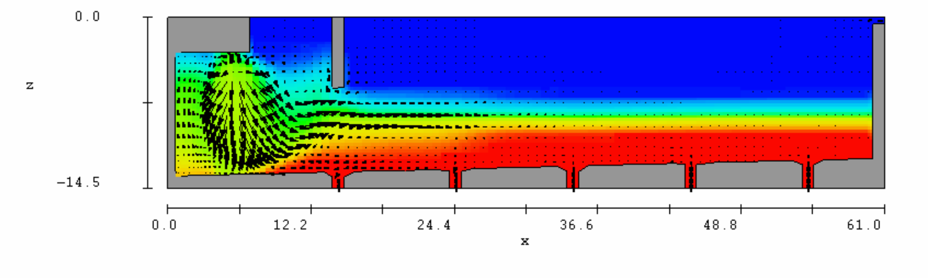
Effluent Solids Concentration	85 mg/l

2. Circular Clarifier with Energy Dissipating Inlet

Distributions and flow speed and solids are shown in Figure 6. The influent enters from the left-hand side of both frames, and exits from the bottom of the clarifier and through the effluent launders located at the top of the outside wall of the clarifier. Boundary conditions for this calculation are provided in Table 2.



(a)



(b)

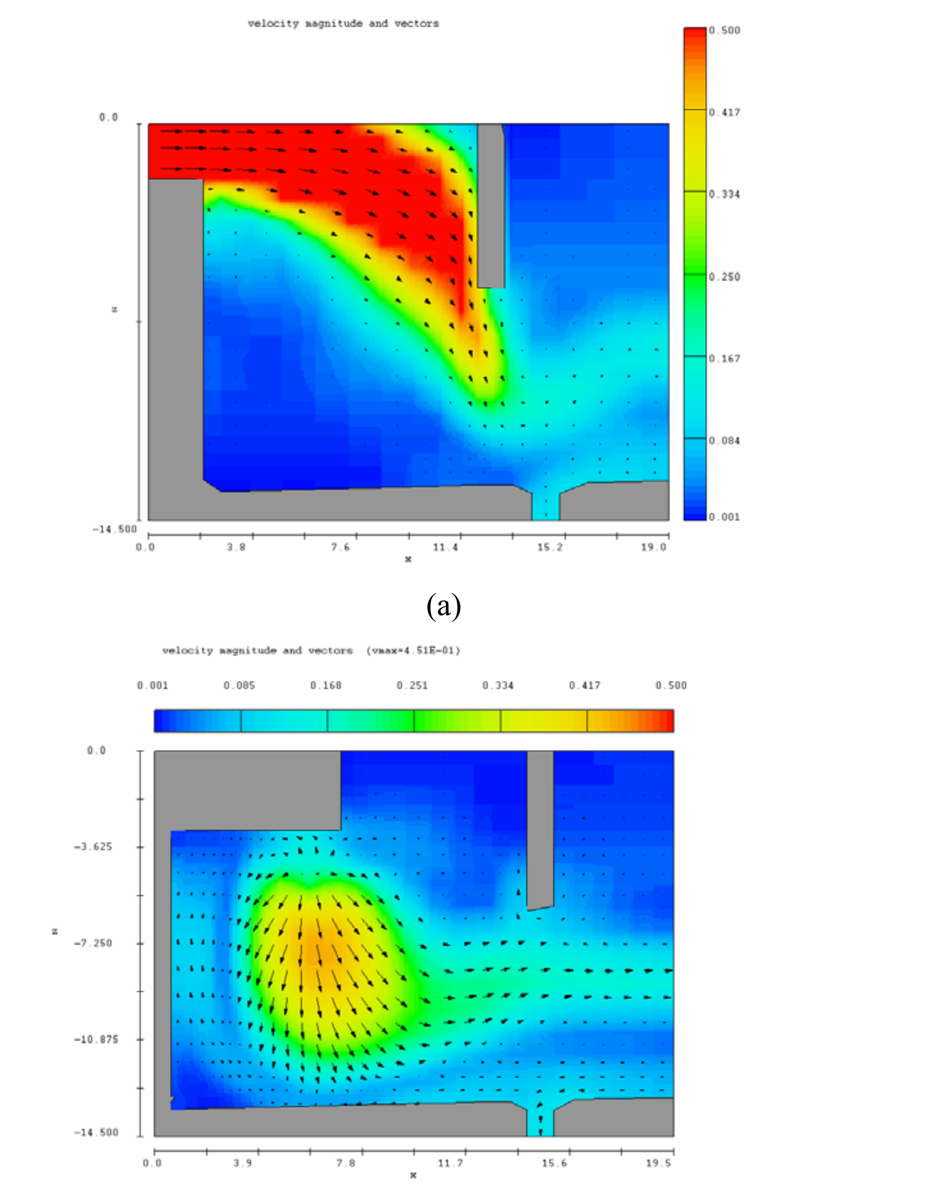
Figure 6: Model Results
(a) Flow Speed [red > 0.1 fps], (b) Solids Distribution [red > 2000 mg/l]

Table 3: Model Statistics

Effluent Solids Concentration	31 mg/l

Conclusions & Recommendations

The results of this model study show that the use of an energy dissipating baffle (LA-EDI) in a circular clarifier can improve the performance of the clarifier. In these calculations, use of the LA-EDI reduced effluent solids concentrations from 85 mg/l to 31 mg/l. The calculated improvement results from the fact that maximum inflow velocities are reduced with the LA-EDI in place and that the influent flow is not directed towards the outside wall of the clarifier (as seen in Figure 7[a] relatively high speed flow passes from the standpipe and under the centerwell without the LA-EDI, in Figure 7[b] maximum influent velocities are less and the bulk flow is not directed towards the outside wall of the clarifier).



(a)

(b)

Figure 7: Velocity Distribution near Center of Clarifier, fps
(a) without LA-EDI, (b) with LA-EDI