COMPUTATIONAL FLOW MODEL OF WESTFALL'S 36'3050 THREE STAGE MIXER TO BE INSTALLED IN THE PERCHLORATE BLENDING STATION FOR THE CITY OF REDLANDS, CALIFORNIA

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By

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INTRODUCTION

Alden Research Laboratory Inc. (Alden) was contracted by Westfall Manufacturing Inc. (Westfall) to evaluate the performance of a 36'3050 mixer that is to be installed at the Perchlorate Blending Station for the City of Redlands, California. The objective of this mixer is to achieve a low coefficient of variation (CoV) of the injected fluid within a short distance downstream, with as little pressure loss as possible. This report discusses the mixing capabilities of the leading tab low head mixer that is to be installed in the Perchlorate Blending Station, using the actual piping configuration over the range of expected flow rates.

COMPUTATIONAL MODEL DESCRIPTION

The model geometry was developed using the commercially available three-dimensional CAD and mesh generation software, GAMBIT V2.4.6. The computational domain generated for the model consisted of 2.0 million hexahedral and tetrahedral cells.

Numerical simulations were performed using the CFD software package FLUENT 12.1, a state-of-the-art, finite volume-based fluid flow simulation package including program modules for boundary condition specification, problem setup, and solution phases of a flow analysis. Advanced turbulence modeling techniques, improved solution convergence rates and special techniques for simulating species transport makes FLUENT particularly well suited for this study.

Alden used FLUENT to calculate the full-scale, three-dimensional, incompressible, turbulent flow through the pipe and flow conditioner. A stochastic, two-equation k-ε model was used to simulate the turbulence. Detailed descriptions of the physical models employed in each of the Fluent modules are available from Ansys/Fluent, the developer of Fluent V12.1.

MODEL BOUNDARY CONDITIONS

The piping layout for the City of Redlands Perchlorate Blending Station was modeled at full scale from the Agate Reservoir, and Agate Well #2 pipes, through the piping junction, through the static mixer, to a point 30-ft (10 pipe diameters) downstream of the mixer outlet, which is upstream of the pipe split to the gravity feed section, and the booster pumps (Figure 1, Figure 2). The line from the reservoir through to the gravity-feed/booster pump split is nominally 36'(I.D. = 35-¼'). The pipe from Agate Well #2 is nominally 16'pipe (I.D. = 15-½'), and the three 90° bends upstream of the junction are modeled, plus an additional 10 pipe diameters. The no-slip condition was applied to all pipe walls, with wall roughness set to 0.0002-ft, which is typical for steel pipe.

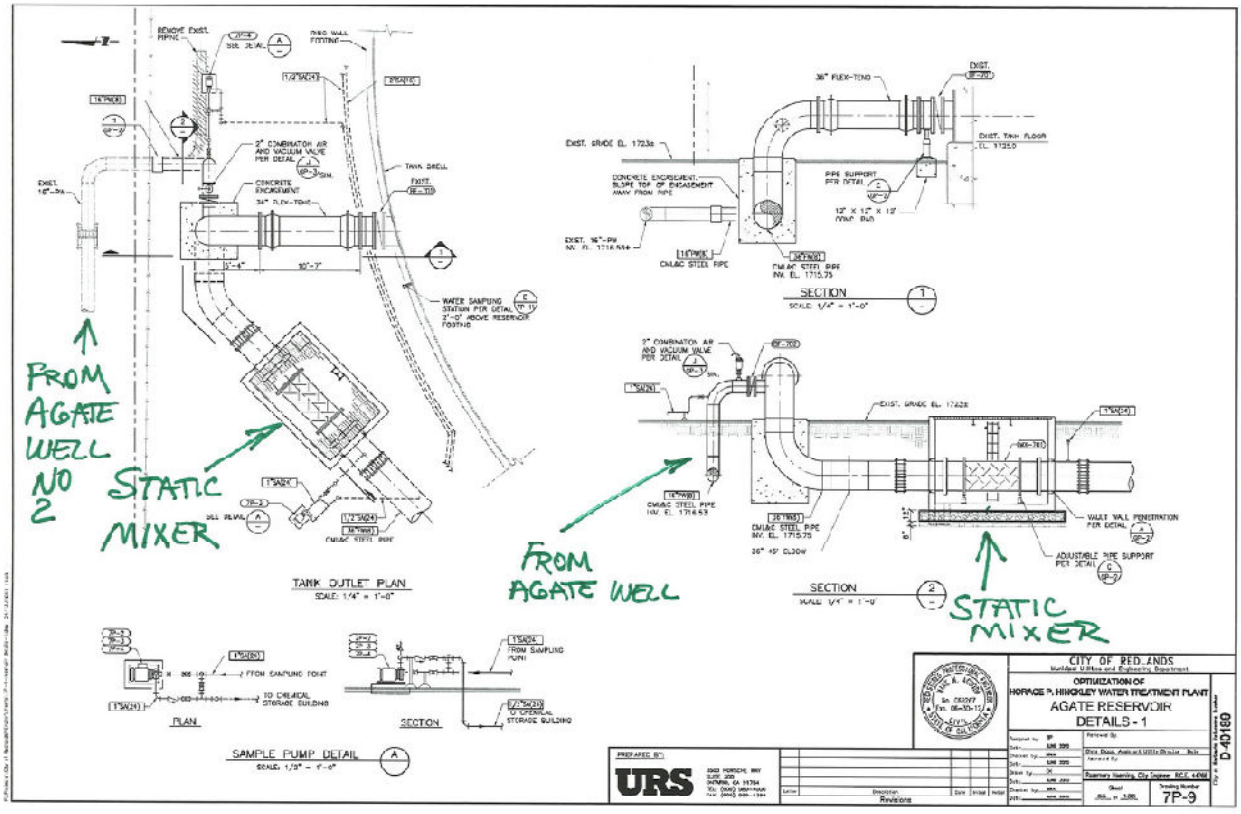

Figure 1 - Static Mixer Piping Layout

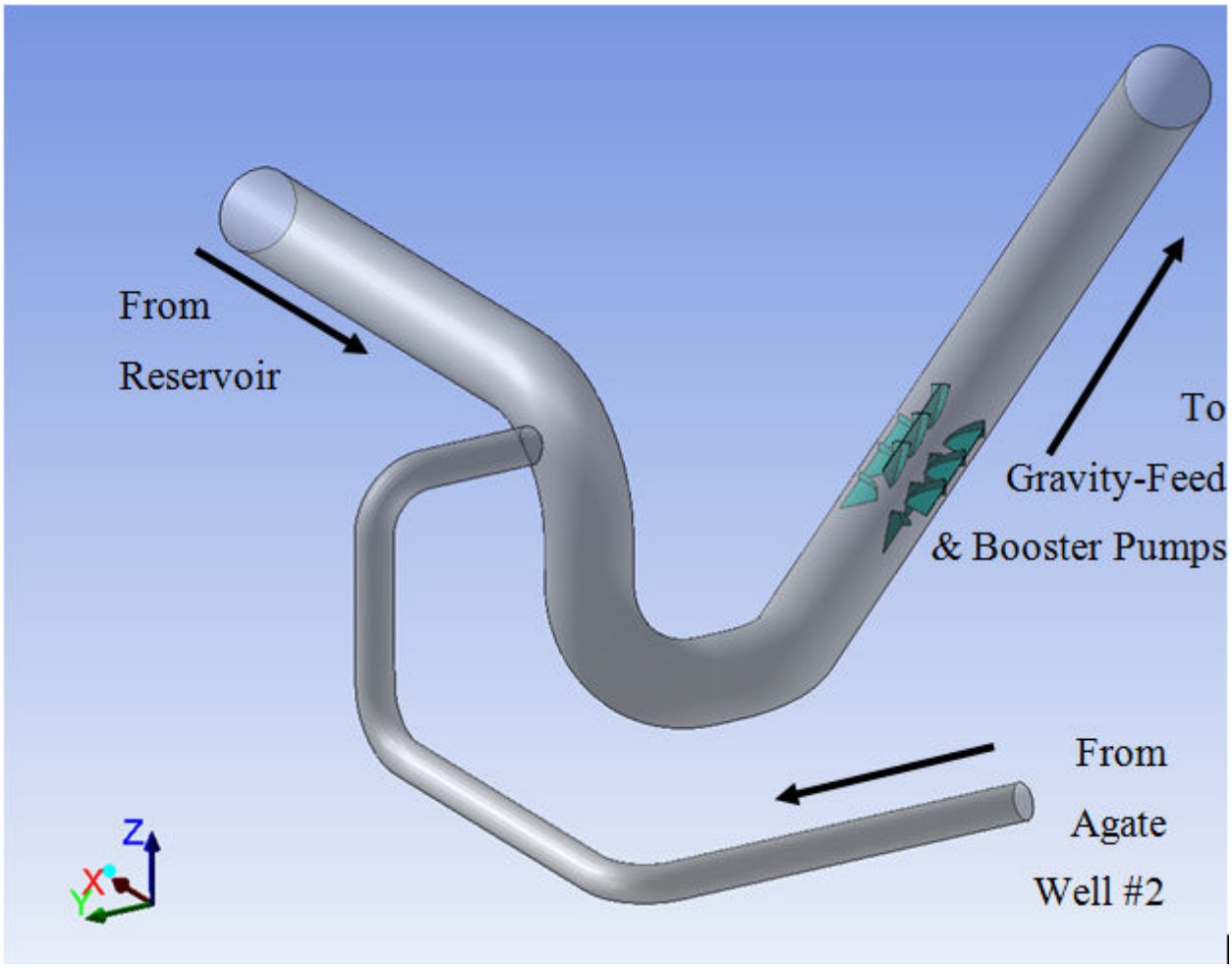

Figure 2 - CFD Model Domain, Standing at NE, Looking SW

Based on the pump curve for Agate Well #2, and the very small fluctuation in flow over the expected range of head in the reservoir (12-24 ft) a constant flow boundary was imposed at the inlet to the model from the well. This flow was set at 2,330-gpm (3.96-ft/s) for all conditions examined.

Since the system pressure loss downstream of the mixer was not directly known at the commissioning of this study, a range of expected flows were provided to simulate reservoir water heights ranging from 12-ft to 24-ft. The flows chosen were 1,970-gpm (0.65-ft/s) for low

water level, 6,270-gpm (2.06-ft/s) for medium water level, and 10,520-gpm (3.46-ft/s) for high water level. These three flow conditions correspond to the three cases examined in this report.

Table 1 - Flow Splits for Each Case Examined (gpm / fps)

(gpm)	Well	Reservoir	Total
Low	2330	1970	4300
Med	2330	6270	8600
High	2330	10520	12850

(ft/s)	Well	Reservoir	Total
Low	3.96	0.65	1.41
Med	3.96	2.06	2.83
High	3.96	3.46	4.22

The two streams were treated as separate, fully miscible fluids, both with viscosity and density consistent with water at 68°F. The fluid from the well was denoted as "well", and the blended perchlorate solution in the reservoir was denoted "reservoir". The results are presented as mass fraction of "reservoir" water, and similarly mixing is presented as coefficient of variation (CoV) of "reservoir" water, where a perfectly mixed solution would have a CoV = 0.

A uniform static pressure boundary condition was imposed at the model outlet, which was placed 10 pipe diameters downstream of the mixer outlet, which is upstream of the pipe split between the gravity feed section and the booster pumps.

RESULTS AND DISCUSSION

The goal of the 3050 mixer is to achieve a uniform concentration of the injected material in as short a downstream distance as possible, with as little pressure loss as possible. For each of the three flow conditions examined, the CoV of perchlorate solution from the reservoir is reported entering the mixer, as well as at the model outlet, 30-ft (10 pipe diameters) downstream of the mixer outlet.

Mixing of the two streams, as measured by the CoV of concentration is presented in Figure 3 and Table 2 (where a perfectly mixed stream has a CoV = 0).

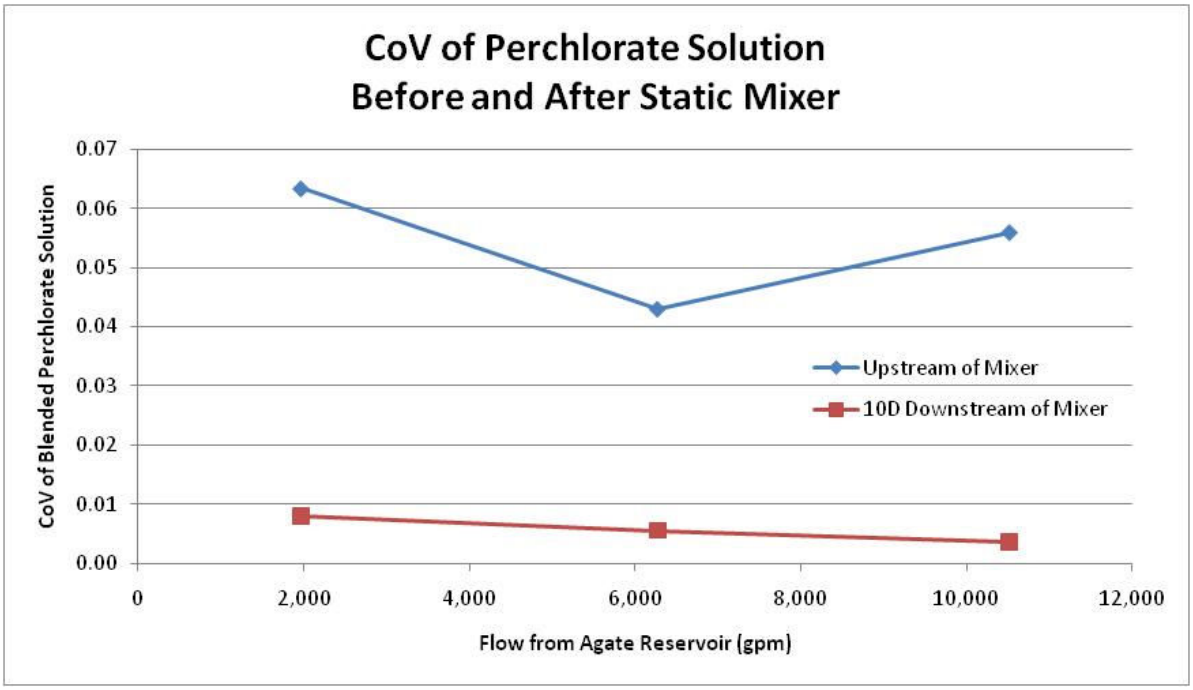

Figure 3 - CoV of Perchlorate Solution Before and After Static Mixer

Table 2 - Mixing Results for Various Reservoir Water Levels

Reservoir Water Level	Flow From Agate Reservoir (gpm)	Flow From Agate Well #2 (gpm)	Total Flow (gpm)	Mass Fraction of Reservoir Water	CoV @ Mixer Inlet	CoV @ 10D Downstream of Mixer Outlet
Low	1,970	2330	4300	45.8%	0.063	0.008
Med	6,270	2330	8600	72.9%	0.043	0.006
High	10,520	2330	12850	81.9%	0.056	0.004

Before the mixer, the perchlorate solution CoV varies between 0.043 and 0.063 based on flow condition. At first glance, it may seem counterintuitive that the CoV does not follow a monotonic trend with increasing flow rate, however the minimum CoV (best mixing upstream of mixer) at the medium flow rate is due to the comparable momentums of the two flow streams at

their confluence (momentum = $\rho V^2 A$). At lower reservoir flow rates, the well stream's momentum is greater (greater velocity), and the flow crosses the 36" pipe, and remains concentrated on the far wall. At high reservoir flow rates, the reservoir stream's momentum is greater (larger pipe area), and the well stream cannot cross the 36" pipe, and so remains concentrated on the near wall. At the middle flow rate examined, where the momentums of the two streams are roughly equal, the well flow mixes most evenly with the reservoir flow before they reach the mixer.

In any case, the CoV of the flow upstream of the mixer is higher than may be desired. In all three flow conditions, the mixer effectively reduces the CoV of perchlorate solution from the reservoir down to less than 0.01, and at the highest flow rate the CoV is as low as 0.004.

CONCLUSIONS

The 36" Westfall 3050 mixer is expected to mix the perchlorate solution from the Agate Reservoir with the water from Agate Well #2 to near uniformity (CoV < 0.01) under all expected flow conditions. Uniform mixing will be achieved before the flow reaches the split between the booster pumps and the gravity feed section.

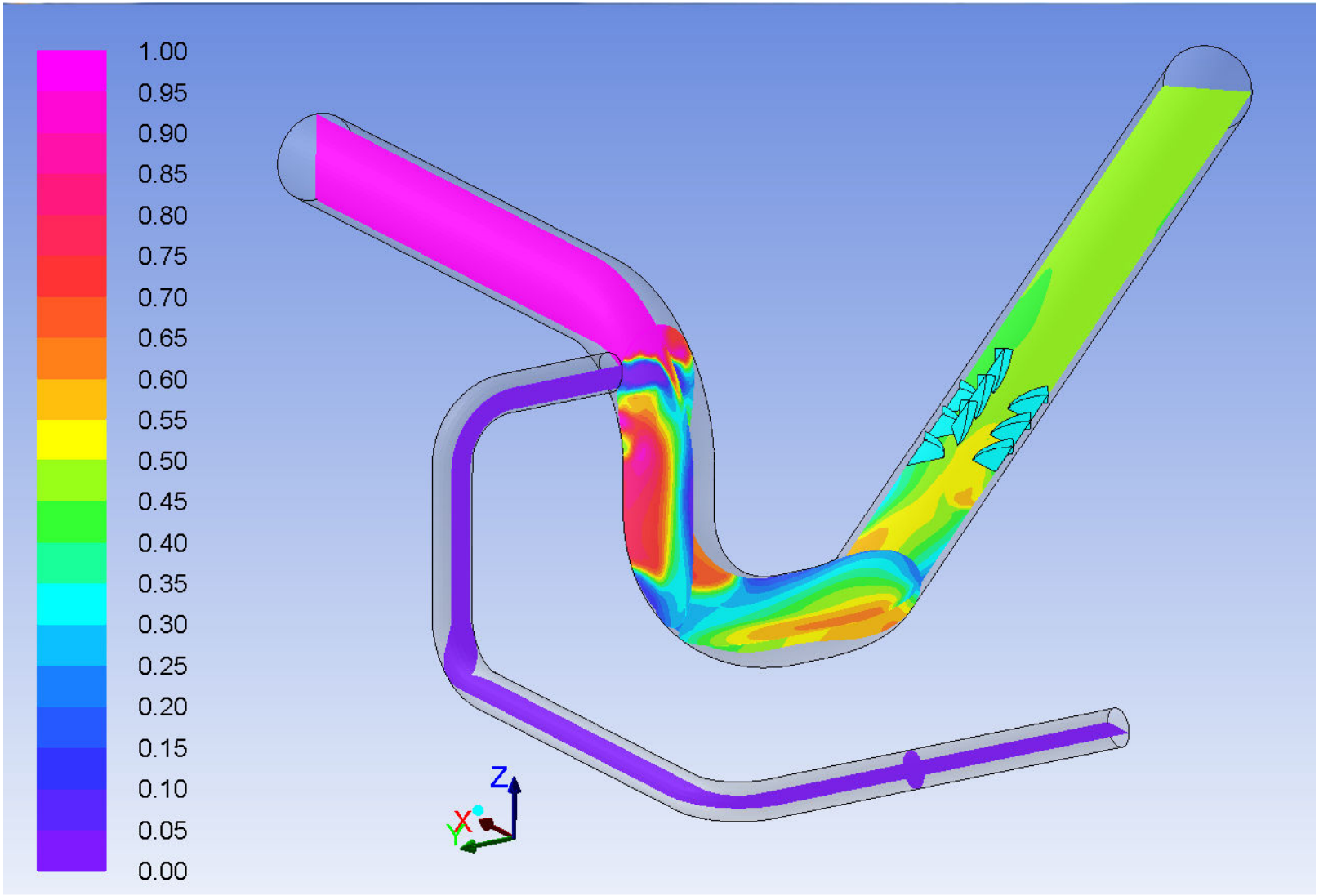

Figure 4 - Contours of Mass Fraction of Perchlorate Solution from Agate Reservoir (Low Water Level).

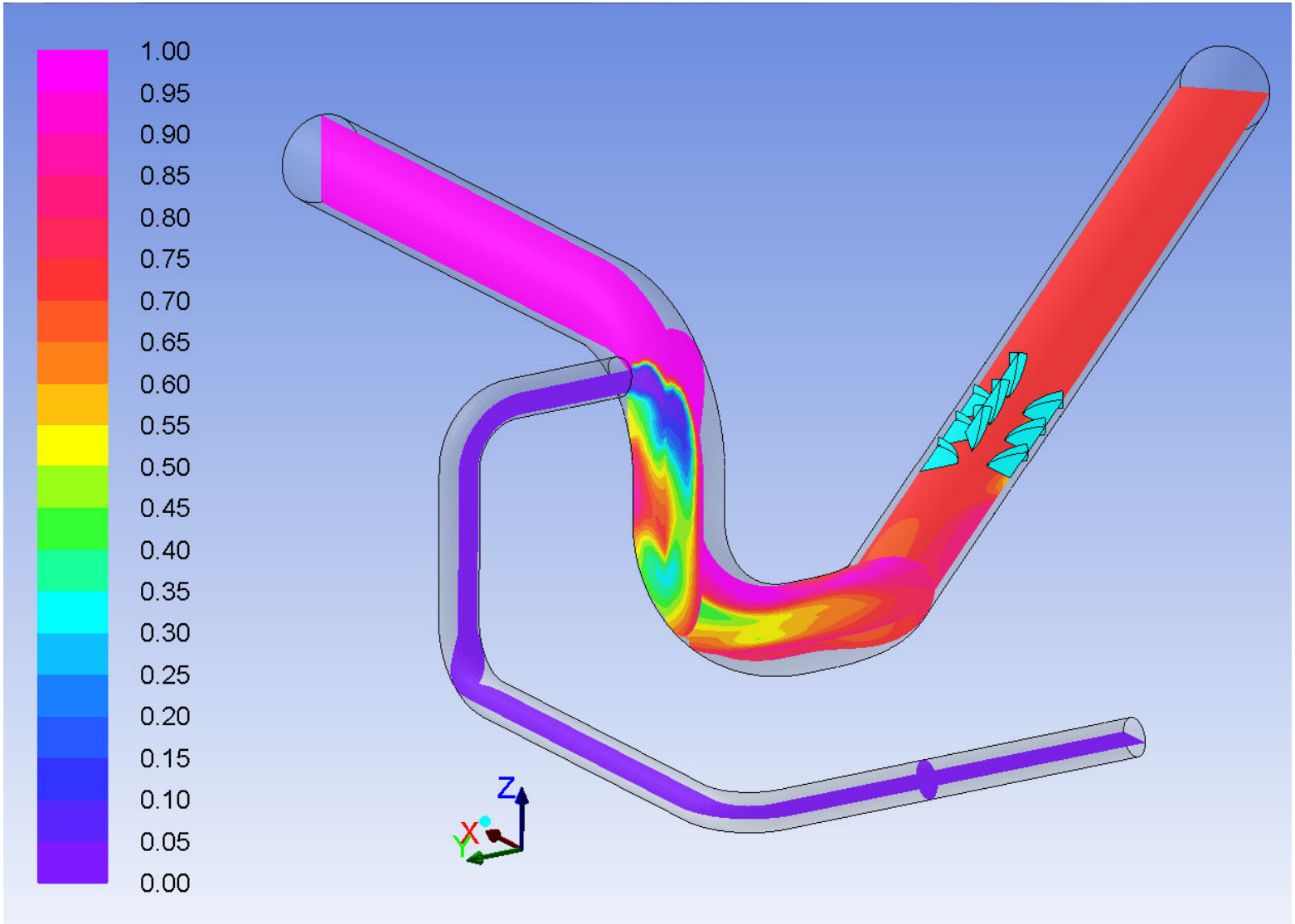

Figure 5 - Contours of Mass Fraction of Perchlorate Solution from Agate Reservoir (Medium Water Level).

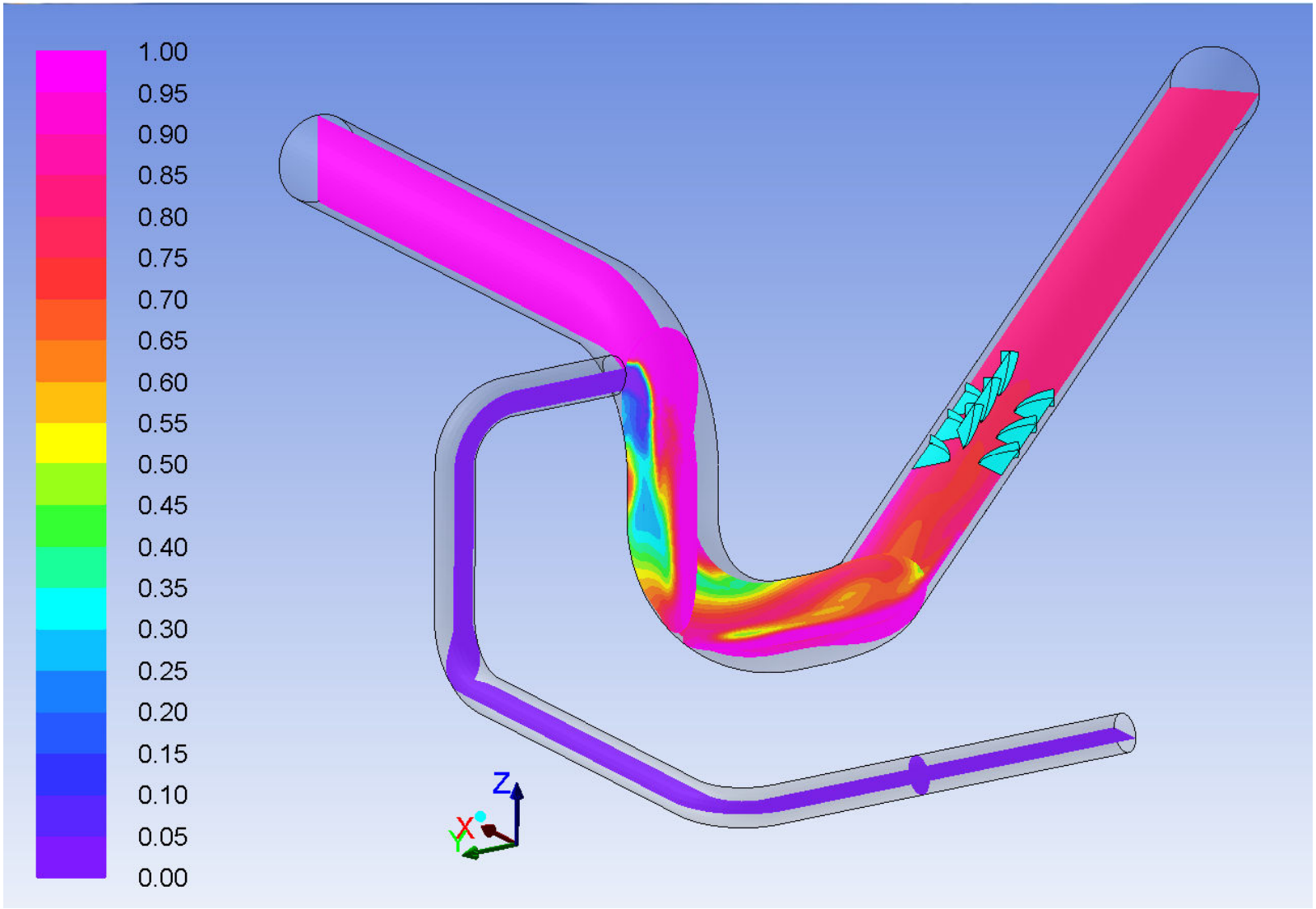

Figure 6 - Contours of Mass Fraction of Perchlorate Solution from Agate Reservoir (High Water Level).