Clearwell Efficiency - Lessons Learned from Computational Fluid Dynamics and Tracer Testing

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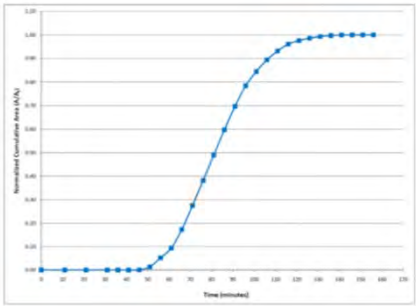
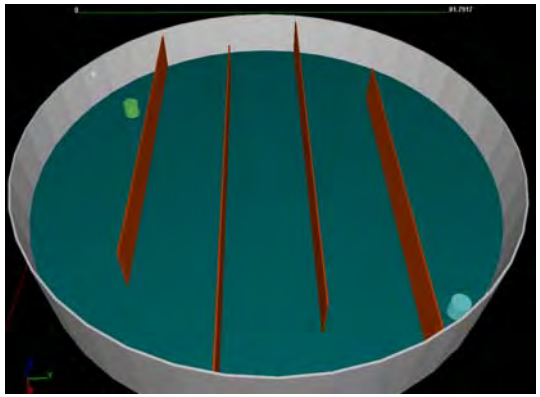
Gannett Fleming

Excellence Delivered As Promised

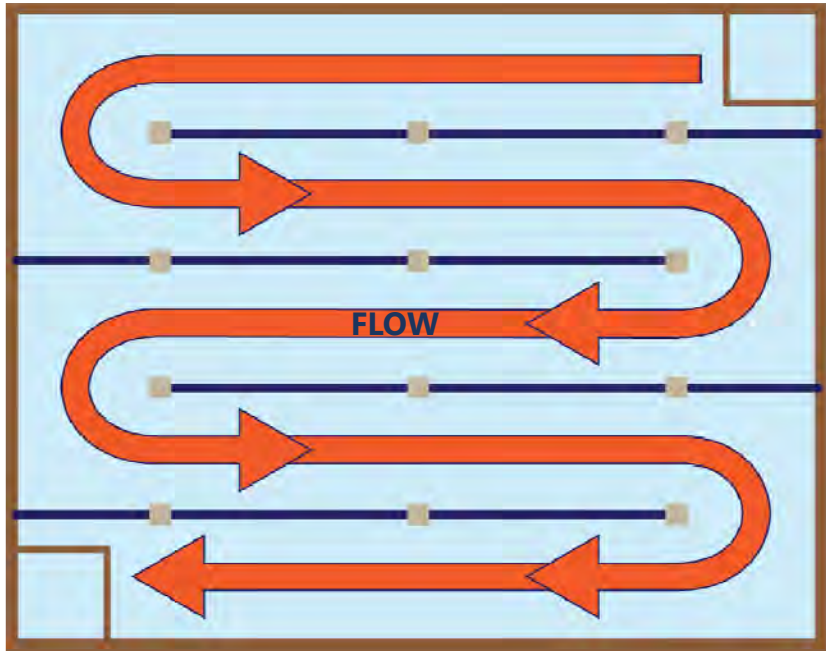
CFD and Tracer Testing Definitions

- Computational Fluid Dynamics (CFD)
- Theoretical Detention Time (T or T_D)
- Disinfection Contact Time (T_{10})
- Hydraulic Efficiency (Detention Efficiency)
- Baffle Factor
- Disinfection Credit (CT)
- Tracer Test





Typical Clearwell Design Approach is based on Empirical Data



Research Has Demonstrated the Impact of L:W Ratio on Baffle Factor

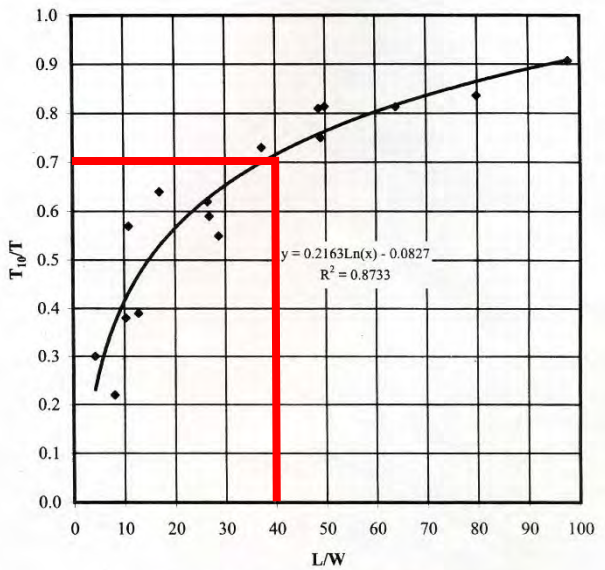
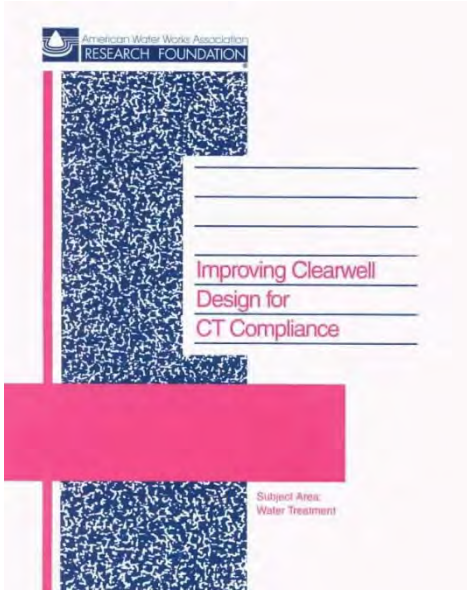
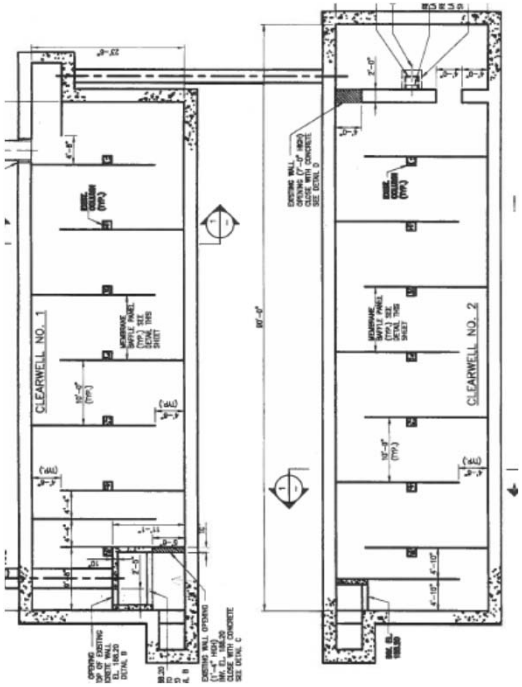
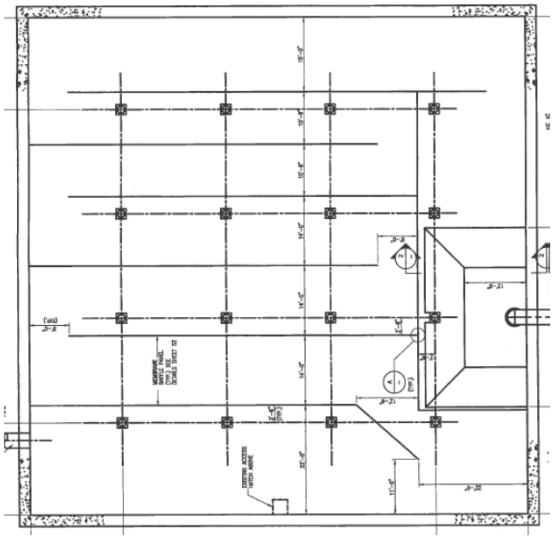


Figure ES.2 Impact of L/W on T_{10}/T ratio

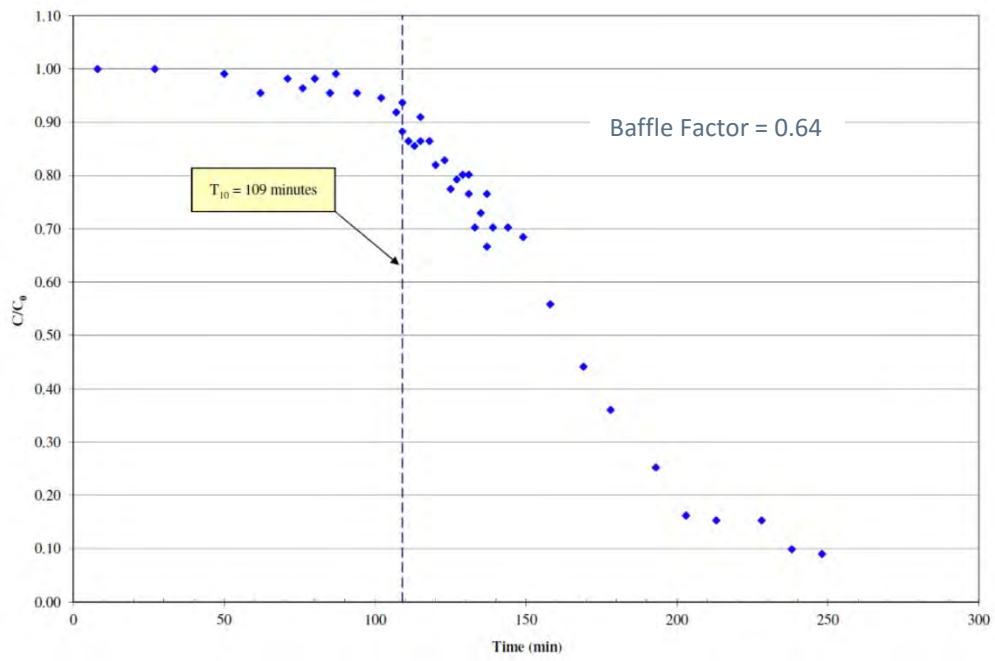


Case Study 1: Tracer Study of a Clearwell Baffle Retrofit

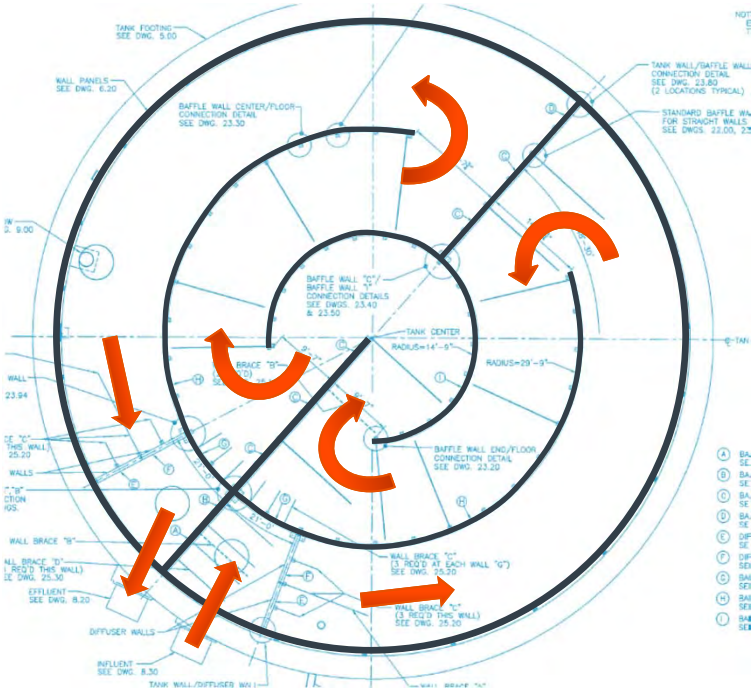




New Clearwell Baffles Improve Efficiency

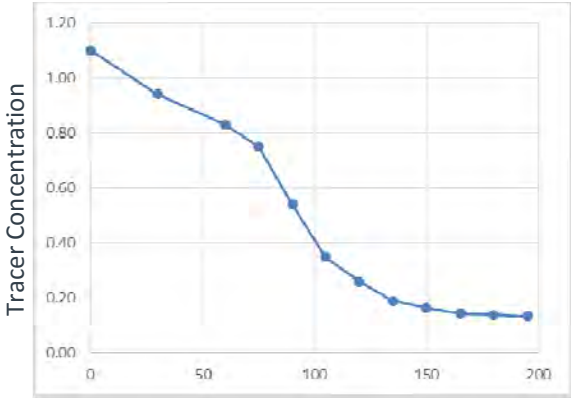


Case Study 2: Tracer Test of Well-Baffled Circular Clearwells

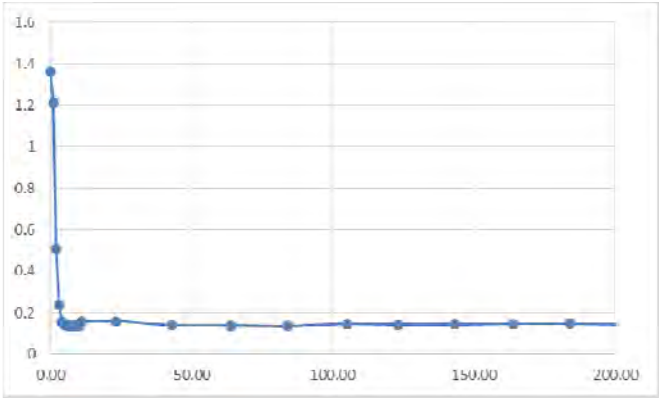


Tracer Application Details are Critical for Valid Test Results

Poor Tracer Feed Point



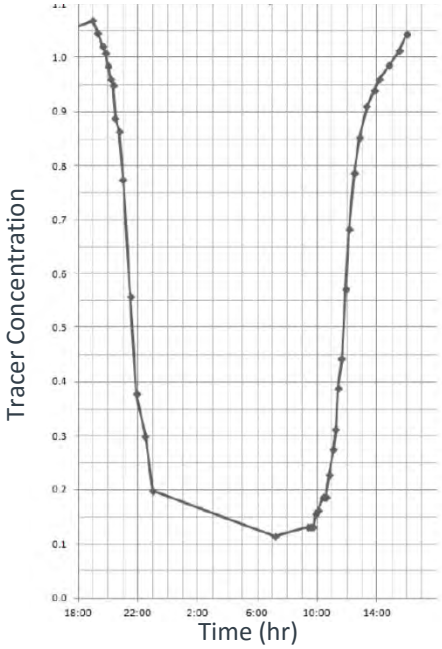
Relocated Tracer Feed Point



Clearwell Inlet Tracer Concentration

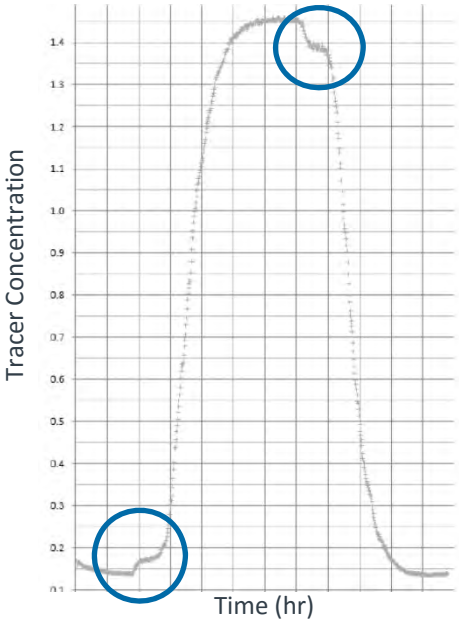
Tracer Application Details are Critical for Valid Test Results

Initial Tracer Application Point



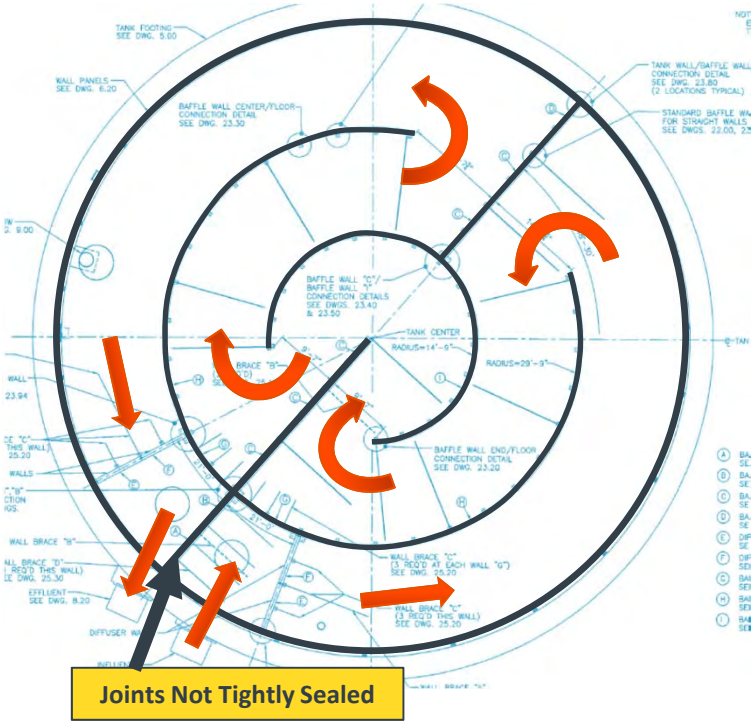
BF > 0.85

Ultimate Tracer Application Point

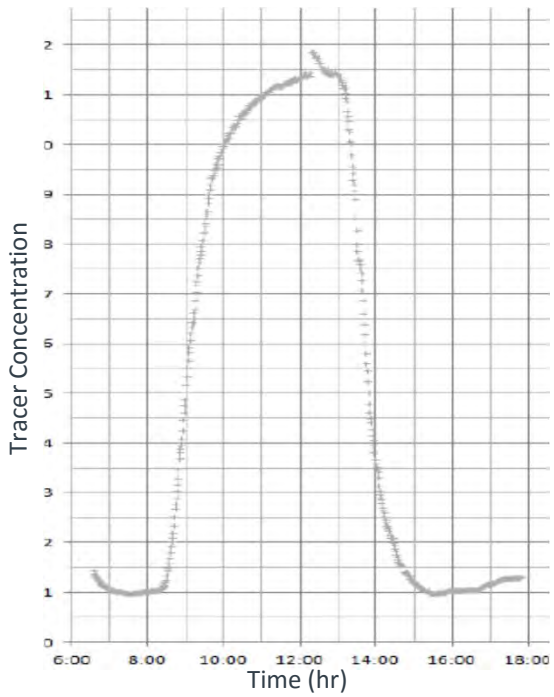


BF = 0.67

CFD Modeling and Tracer Testing Can Reveal Unexpected Issues

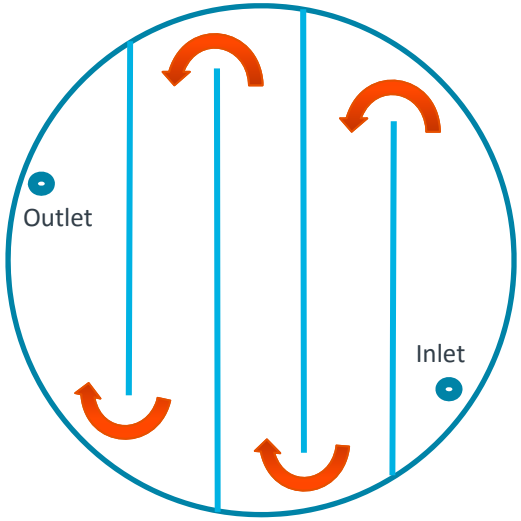


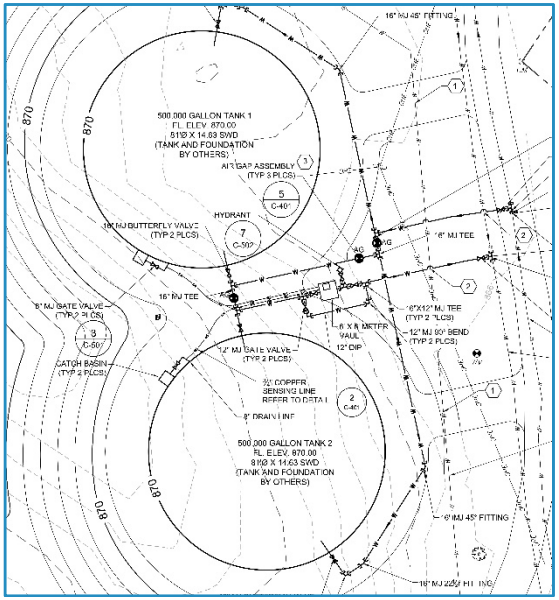
Sealed Baffle Wall Joint Achieved Clearwell Efficiency Objective



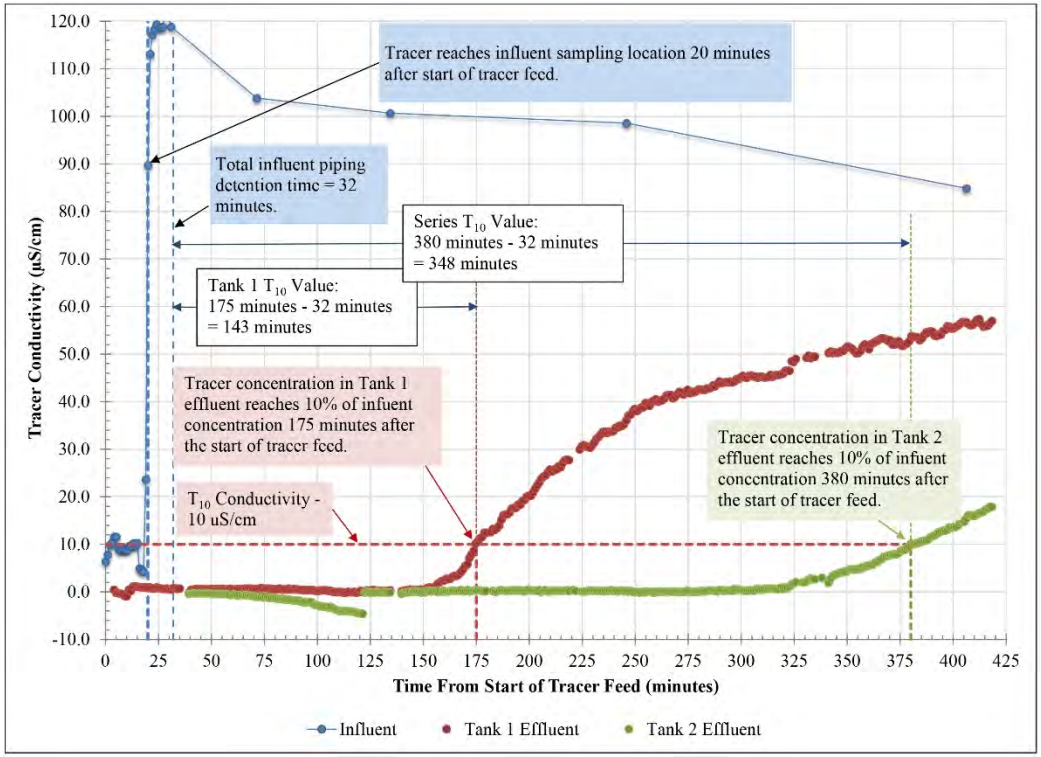
BF > 0.7

Case Study 3: Baffled Clearwell Tanks





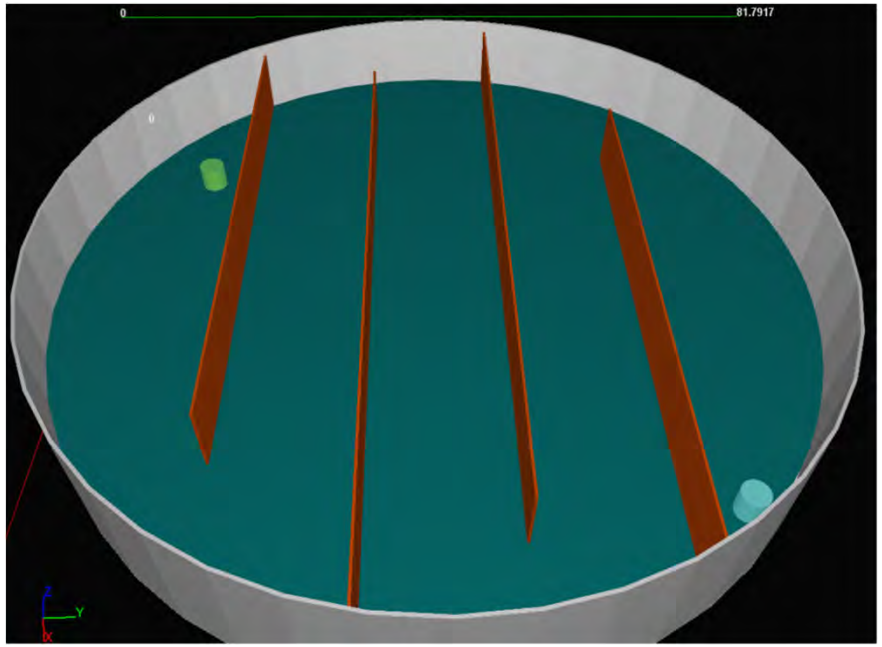
Tracer Tests Consistently Demonstrate Poor Clearwell Efficiency



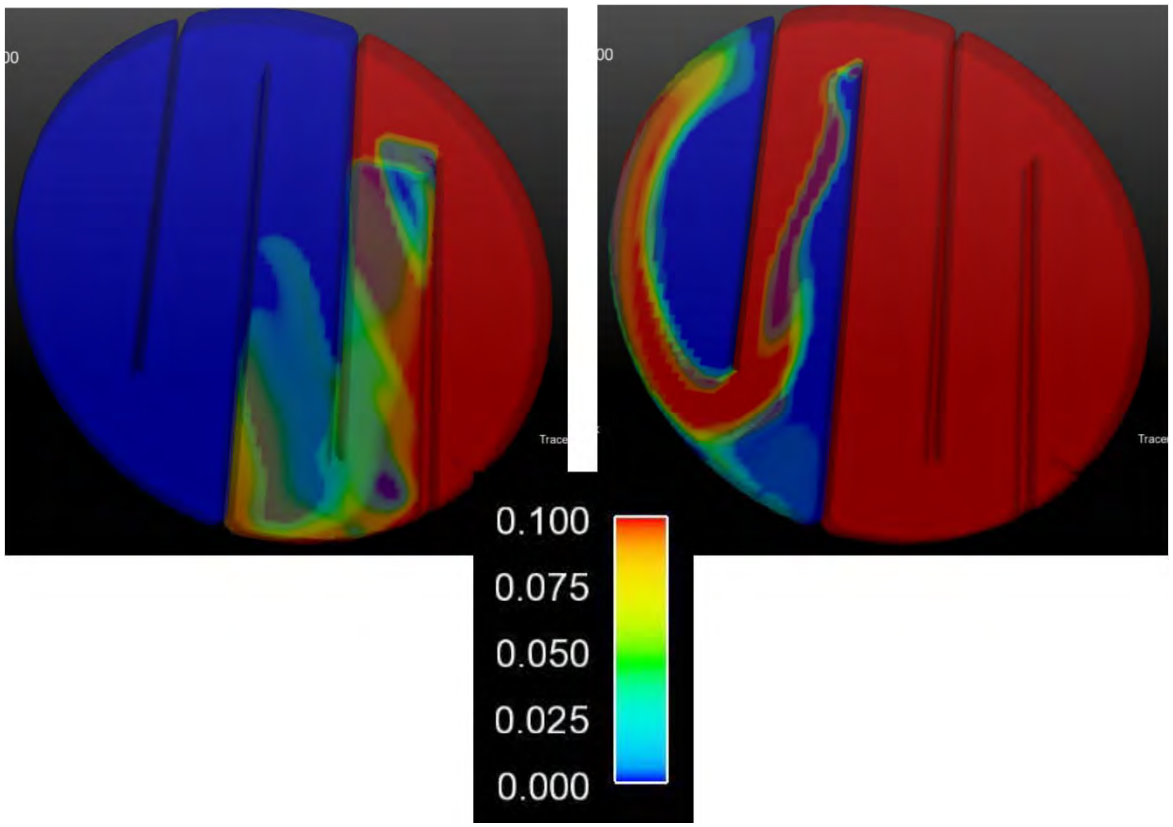
Consistently Poor Tracer Test Results – Now What?

Parameter	Parallel Flow	Series Flow	Tank 1 Series Flow	Tank 2
Average Water Depth, (ft)	6.23	6.56	8.92	6.38
System Volume during test (gal)	480,000	505,000	344,000	246,000
WTP influent to Tank(s) (gpm)	556	556	556	556
Effluent flow from Tank(s), avg. (gpm)	590	580	556	610
Theoretical Detention Time (min)	839	892	619	422
Observed influent tracer conductivity (µS/cm)	120	101	101	110
Observed T_{10} in Tank(s) (min)	173	350	143	128
Calculated Baffle Factor	0.21	0.39	0.23	0.30

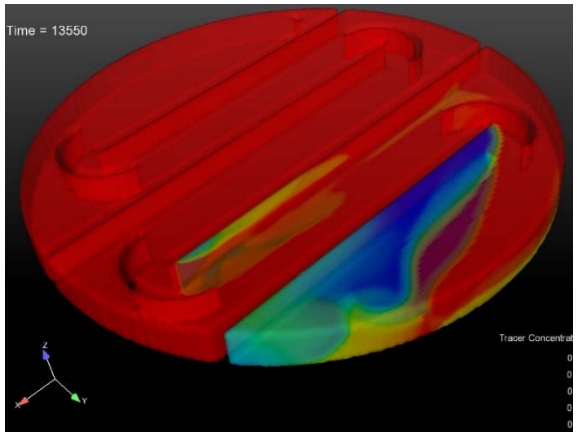
CFD Modeling Required to Understand Poor Tracer Test Results

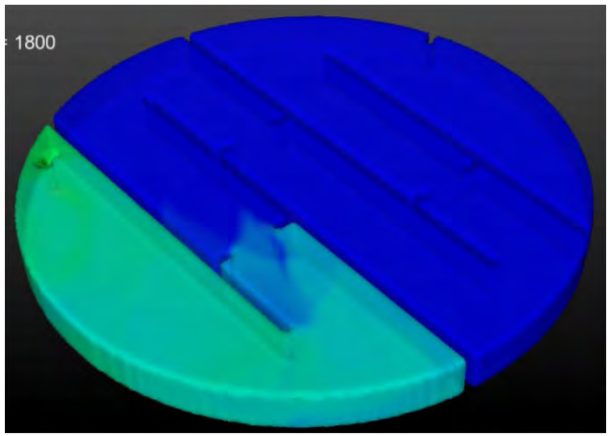


CFD Model Confirms Performance Inefficiency

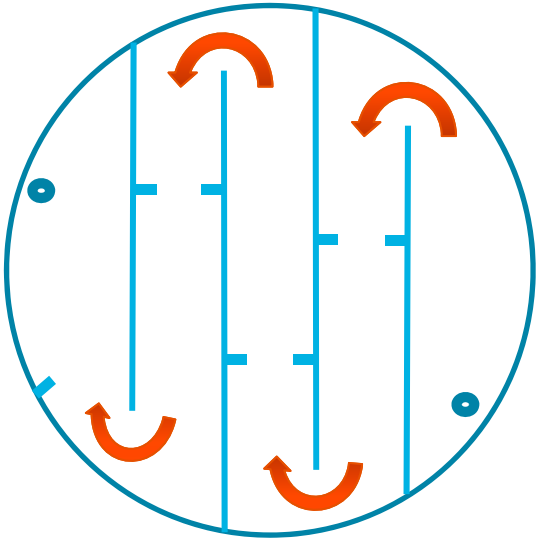


Computer Modeling Facilitates Evaluation of Improvement Alternatives

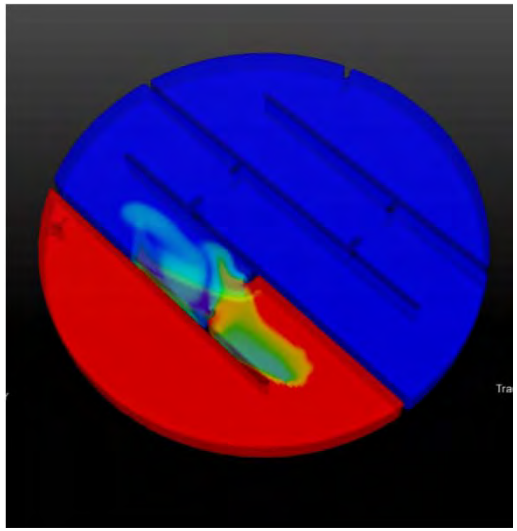


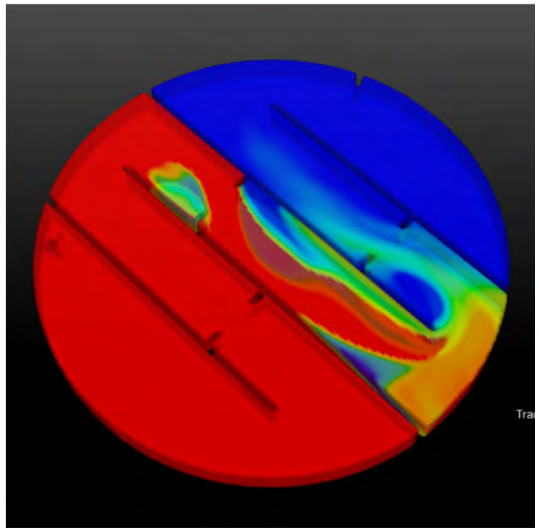


Corrective Actions Selected Based on Owner-Defined Criteria

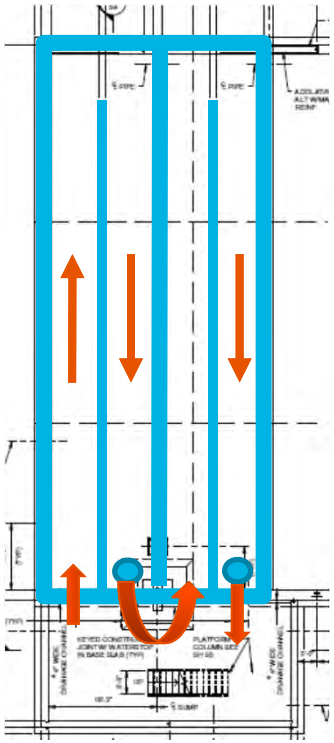


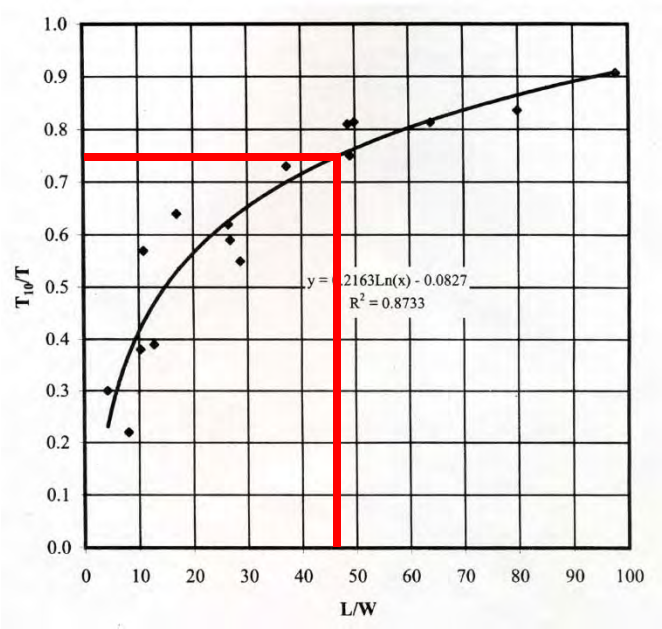
CFD Accurately Modeled Improved Clearwell Efficiency





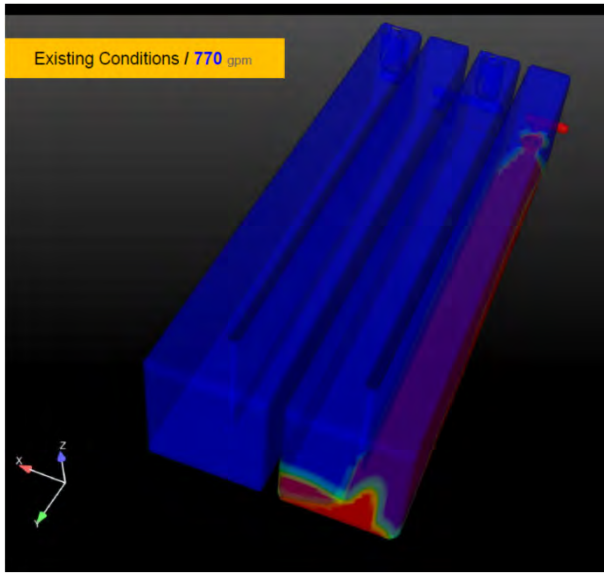
Case Study 4: Well-Baffled Rectangular Concrete Clearwell

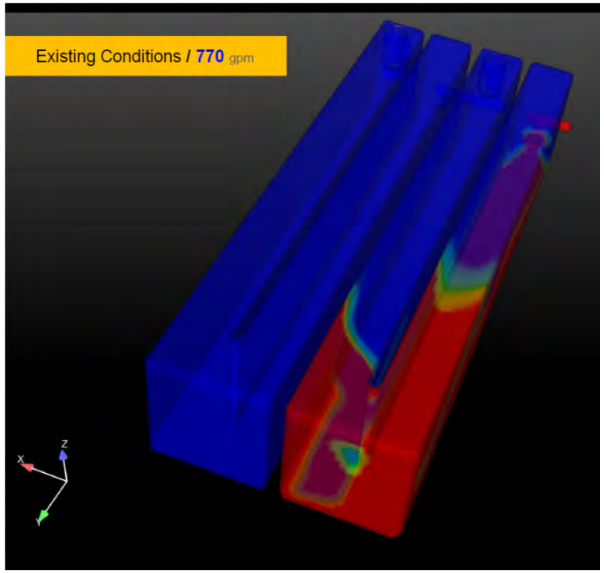




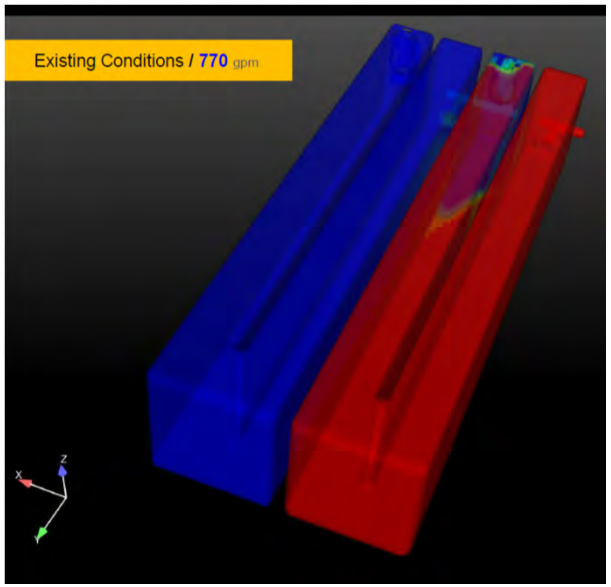
Tracer Testing BF = 0.3

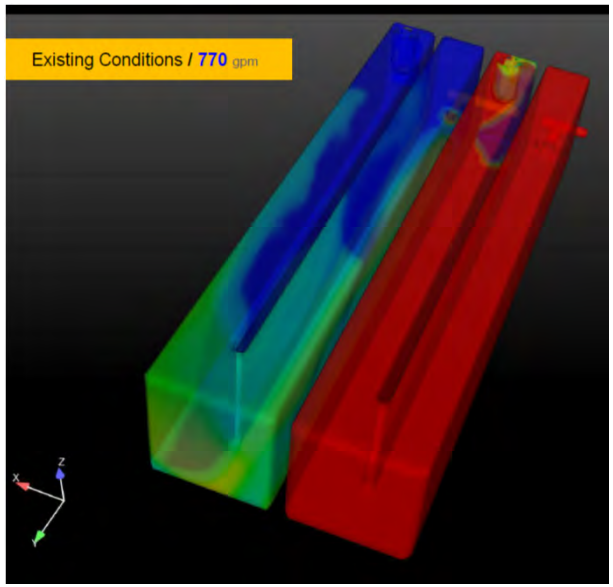
Original Design Conditions Model Reveals Sources of Inefficiency



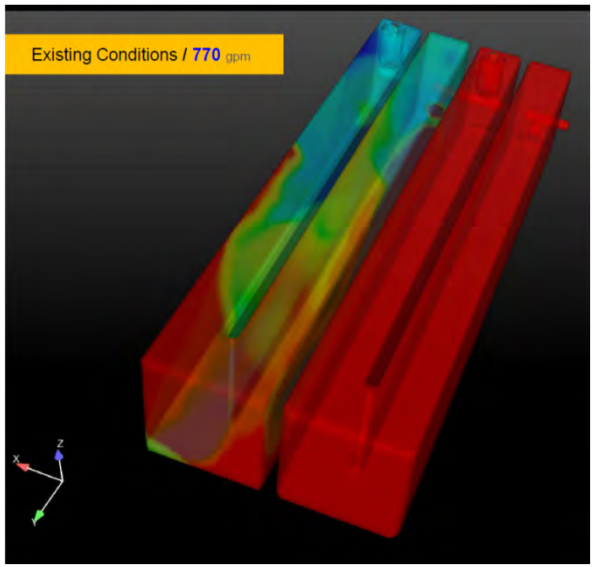


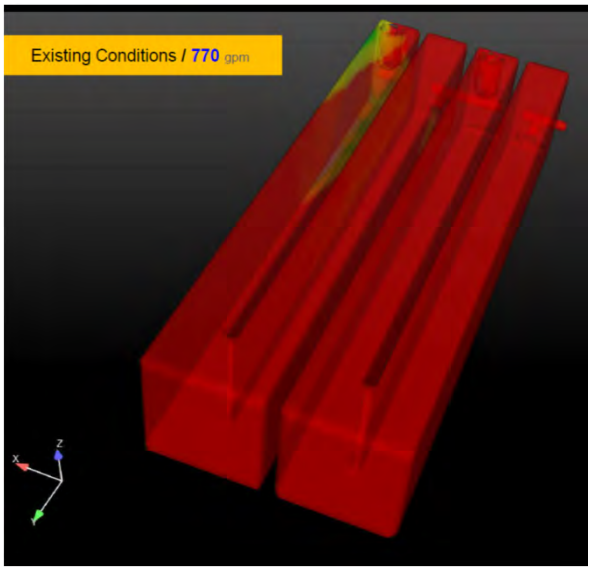
Model of Original Design Conditions Reveals Sources of Inefficiency





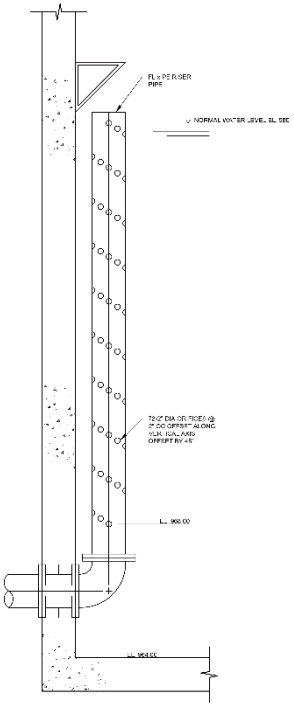
CFD Modeled Clearwell Performance Matches Tracer Results





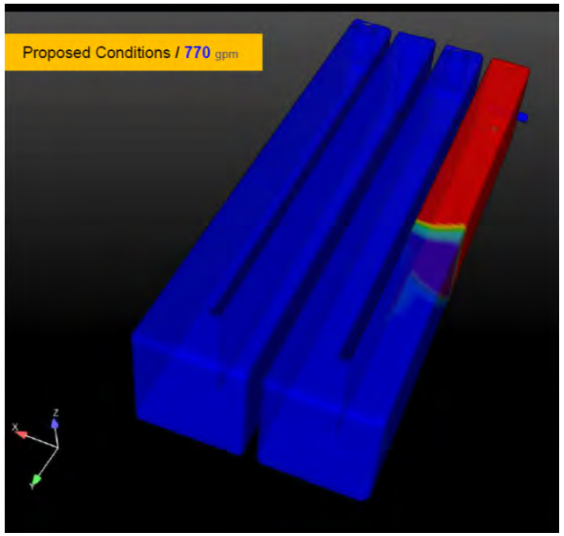
Flow Condition (gpm)	Tracer Test		Model Output	
	T_{10} (min)	BF (unitless)	T_{10} (min)	BF (unitless)
350	238	0.30	258	0.32

Simple Inlet Modifications Significantly Improve Flow Patterns

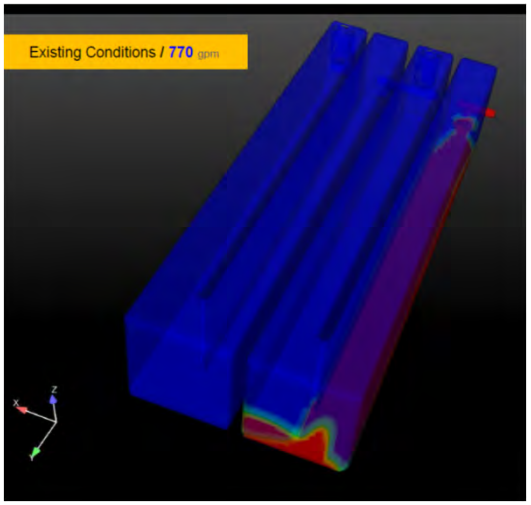


CLEARWELL INLET DIFFUSER

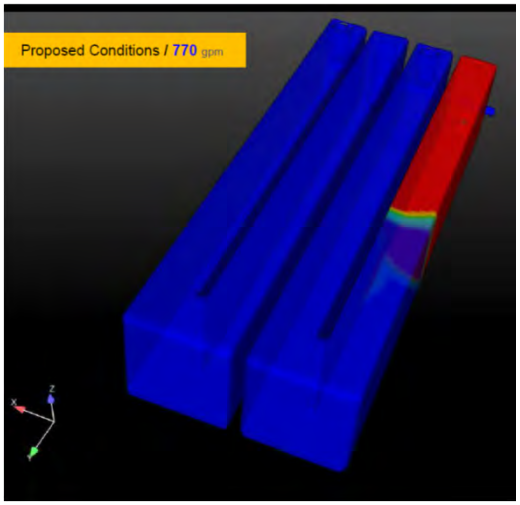
NO SCALE



Lesson-Learned: Inlet and Outlet Flow Distribution are Critical

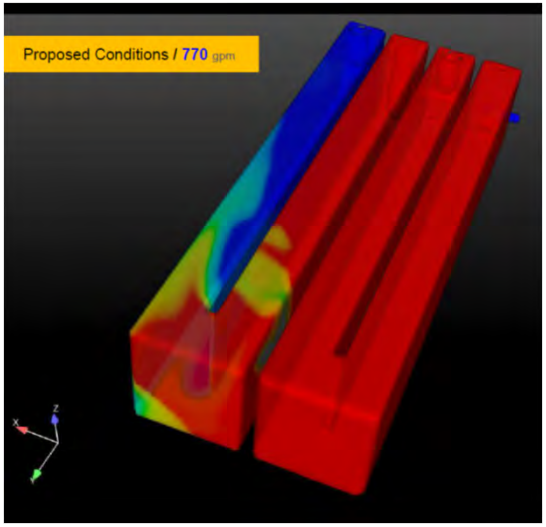


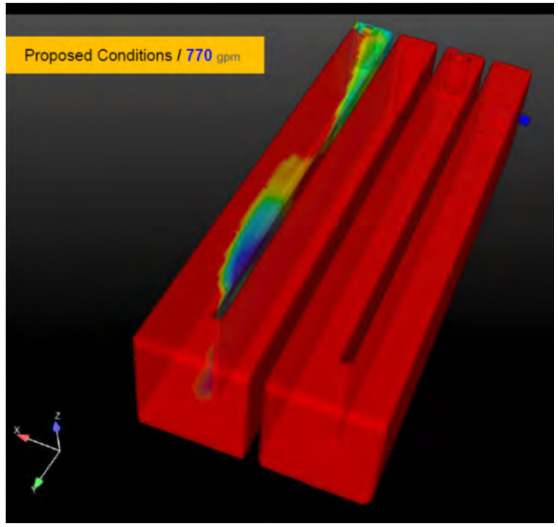
BEFORE



AFTER

Low-Cost Modifications Significantly Improved Clearwell Efficiency

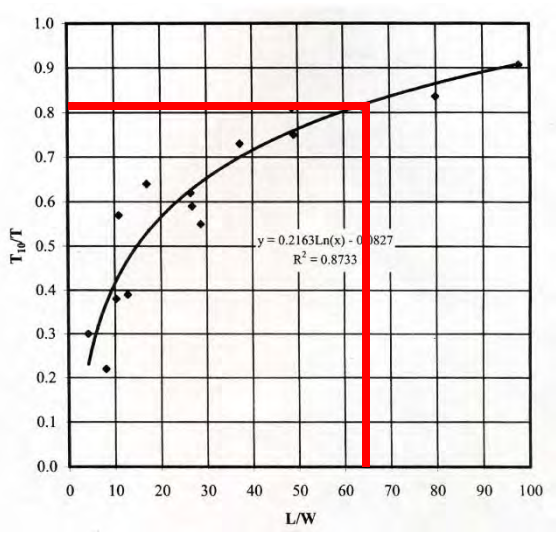


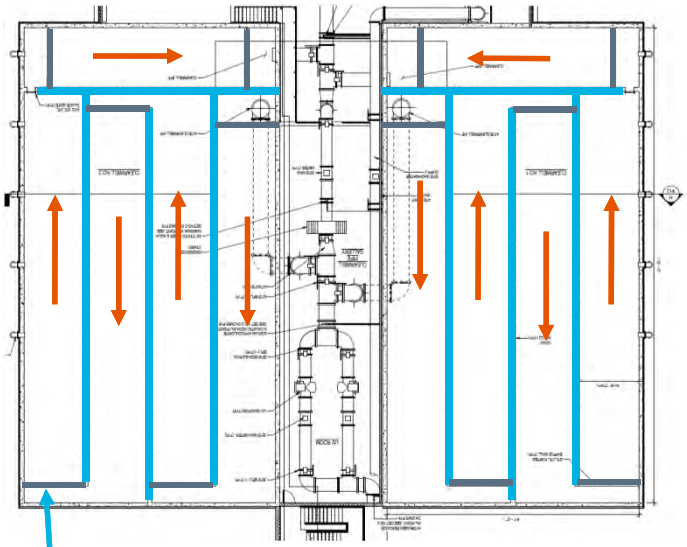


Flow Condition (gpm)	Tracer Test		Model Output	
	T_{10} (min)	BF (unitless)	T_{10} (min)	BF (unitless)
350	238	0.30	258	0.32

0.73 with Inlet Improvement

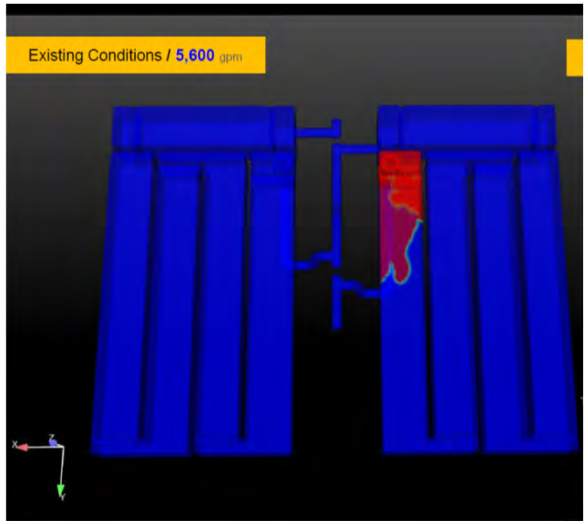
Case Study 5: Over-Designed Clearwells Can Still Under-Perform

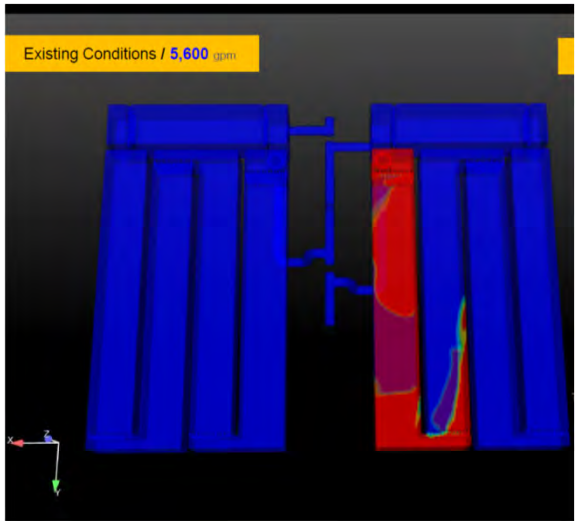




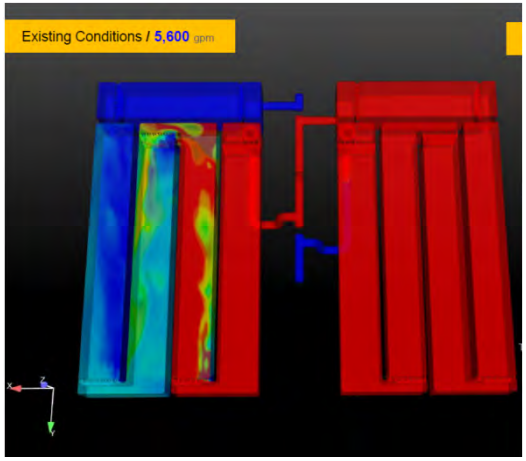
Ported Baffle Wall (typ.)

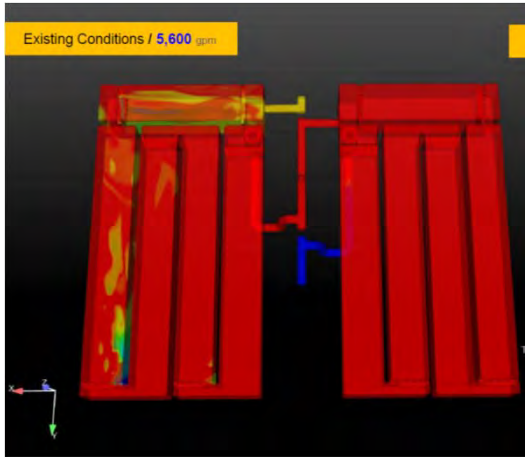
Modeling Demonstrates Inefficiencies Despite Flow Distribution Provisions





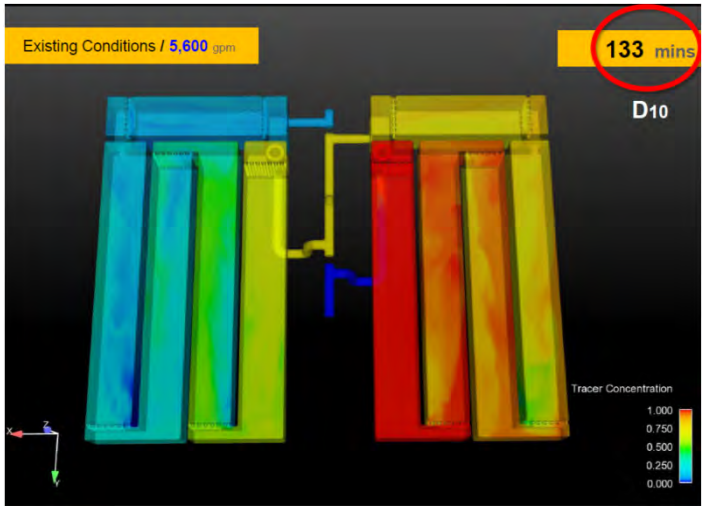
Modeling Demonstrates Inefficiencies Despite Flow Distribution Provisions



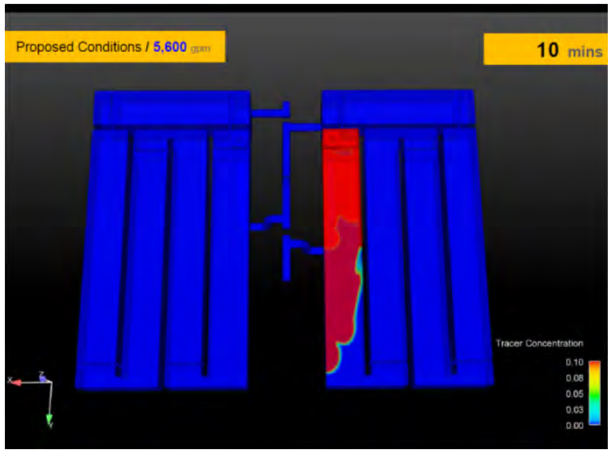


T_{10} = 133 minutes
Model-predicted BF = 0.54

Complete Tracer Concentration Gradient Shows Poor Efficiency

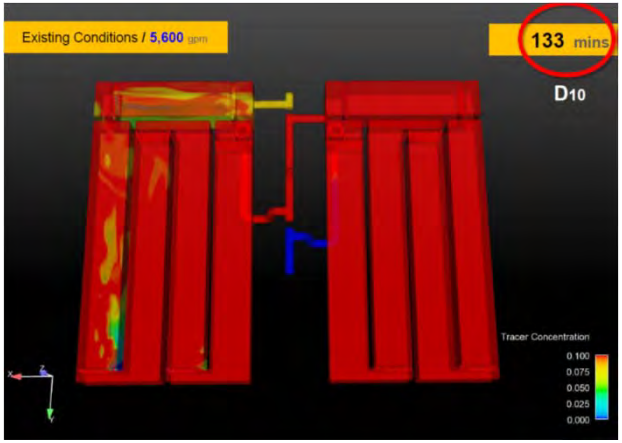


Minor Changes Can Have Major Clearwell Efficiency Impacts



Lesson-Learned: Minor Changes Can Have Major Efficiency Impacts

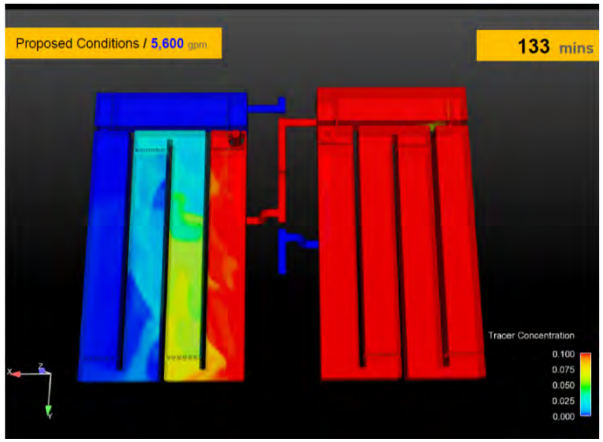
Original Design at 133 Minutes



Model-predicted BF = 0.54

BEFORE

Modified Design at 133 Minutes



Model-predicted BF > 0.8

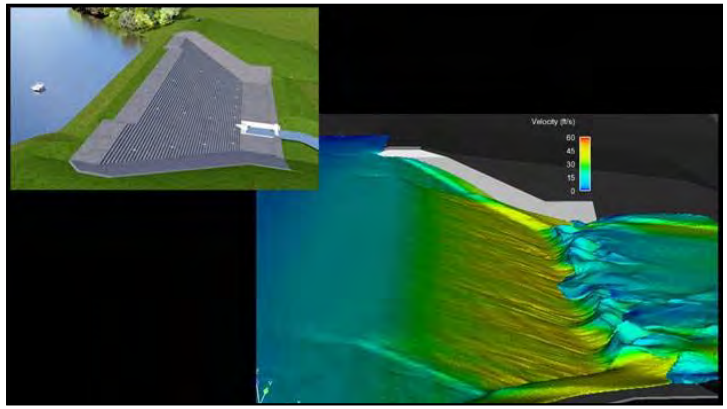
AFTER

Summary of Lessons Learned

- Tracer tests
  - Setup (feed points, sample locations) are critical to accurate test results
  - Consult with an experienced tester about protocol and data analyses
- Utilize CFD technology to design and execute projects more efficiently
  - Achieve performance efficiency objectives
  - Cost efficiency - proactive investment pays dividends
- Improve clearwell design with or without CFD
  - L:W is a good start, but it is not the only efficiency consideration
    - Vertical and horizontal distribution
      - At Inlet and Outlet
    - Control short circuiting at turns

Other Opportunities to Utilize CFD Models to Improve Hydraulic Performance

- Dam spillways
- Pump sumps
- Distribution system tanks
- Process Basins
  - Flocculation basins
  - Orifice walls
  - Flow distribution



Thank you

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Excellence Delivered As Promised