Optimization Stories From the Field

Marvin Gnagy, P.E., President
PMG Consulting, Inc.

NE District AWWA Canton HOF
August 17, 2017
Agenda

- Optimization practices used in the field
  - Short synopsis

- Optimization stories
  - Evaluations made
  - Technical solutions developed
  - Implementation and verification
  - Results achieved

- Questions
Optimization Practices Used in Field

- Define objectives/goals
  - Why should this project be initiated

- Develop baseline characteristics
  - Current operations and metrics

- Benchmark industry standards or best practices
  - Compare where things are to where you believe they should be

- Conduct gap analysis
  - How do I get to the goals?
  - Tools, capital, training, operating adjustments that might be needed to achieve the goals
Optimization Practices Used in Field

- **Establish Implementation strategy**
  - Capital needs
  - Tools, modeling, etc.
  - Operational changes
  - Adjustment protocols
  - Verification procedures

- **Track progress against objectives/goals**
  - Did you meet the objectives and goals?
  - Did you exceed the objectives and goals?
  - Did you improve water quality?
  - Did you improve performance?
Atlanta-Fulton County, Georgia
Atlanta-Fulton County

- 90 mgd surface water plant
  - Average daily production 44.5 mgd

- Reservoir storage from Chattahoochee River

- Coagulation/filtration plant
  - Chemical treatment
  - Solids handling
  - Disinfection and storage

- Finished water pumping to two wholesale distribution systems
  - 400,000 people
Atlanta-Fulton County

Floc Speed Adjustments Initiative
Atlanta-Fulton County

Sedimentation basins with plate settlers
Atlanta-Fulton County

- **Floc Speed Adjustments Initiative**
  - Jagged, feathery floc observed entering the sedimentation process
  - Measured drive output speeds at different VFD settings
    - Established rotational output at any VFD setting
  - Defined current $G$ values for each of four stages
    - $4 \text{ sec}^{-1}$, $4 \text{ sec}^{-1}$, $3 \text{ sec}^{-1}$, $2 \text{ sec}^{-1}$
    - Operators afraid of floc shear
  - Conducted jar testing to establish optimum $G$ values for floc development and settleability
  - Graphed floc settleability versus $G$ value to find optimum mixing characteristics
Atlanta-Fulton County

Low density floc particles observed in full-scale operations
y = 0.38399x - 0.03307
R² = 0.99695

VFD rotational speed calibration

Optimization Stories From The Field

Atlanta-Fulton County
The graph shows the relationship between Floc Drive Speed (Hz) and Shaft Rotational Speed (RPM). The linear equation is given by:

\[ y = 0.38399x - 0.03307 \]

with a coefficient of determination \( R^2 = 0.99695 \). The graph indicates that at any drive setting, the rotational speed increases linearly with the floc drive speed.
Atlanta-Fulton County

We know the rotational output

At any drive setting

\[ y = 0.38399x - 0.03307 \]

\[ R^2 = 0.99695 \]
Atlanta-Fulton County

Floc settleability curve from jars

Floc Settleability, gpm/ft²
First Stage G Value, sec⁻¹

R² = 0.9996
Atlanta-Fulton County

Floc settleability curve from jars

Current G value, 4 sec$^{-1}$

$R^2 = 0.9996$
Atlanta-Fulton County

Floc settleability curve from jars

Suggested G value 40 sec\(^{-1}\)

Current G value 4 sec\(^{-1}\)

\[ R^2 = 0.9996 \]
Atlanta-Fulton County

- Current G value 4 sec\(^{-1}\)
- Suggested G value 40 sec\(^{-1}\)
- Operating SOR = 1.14 gpm/ft\(^2\)

\[ R^2 = 0.9996 \]
Optimization Stories From The Field

Atlanta-Fulton County

- Adjusted floc drive speeds to produce suggested G values
- Tracked settled water turbidity online monitoring
- Reduced from 0.5 NTU average to 0.1 NTU average within 4 days
- Possible to reduce coagulant dosage to obtain similar settled turbidity
- **Implemented without capital costs**
Atlanta-Fulton County

- Dewatering accomplished in gravity thickeners, lime amendment to pH 12, sludge conditioning and pumping, plate and frame filter press
- Cake disposal in local landfill
- Cake typically 23% solids (another story)
Atlanta-Fulton County

- Coagulant reduction could impact other processes and costs
  - Reduced solids production
  - Reduced lime for dewatering
  - Reduced post-lime for pH adjustment/corrosion control
  - Cake disposal

- Phase 2 optimization
  - Define current operating costs
  - Develop potential costs under optimized coagulant dosing
  - Establish new settled water target values
  - Verify operating costs from annual operations
## Atlanta-Fulton County

### Initial Operating Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum, mg/L</td>
<td>15.6</td>
</tr>
<tr>
<td>Post-lime, mg/L</td>
<td>3.92</td>
</tr>
<tr>
<td>Dewatering lime, lbs/mo.</td>
<td>76,798</td>
</tr>
<tr>
<td>Filter cake, dry tons per year</td>
<td>941</td>
</tr>
<tr>
<td>Alum, lbs/MG</td>
<td>132.2</td>
</tr>
<tr>
<td>Post-lime, lbs/MG</td>
<td>33.3</td>
</tr>
<tr>
<td>Dewatering lime, tons per dry ton cake</td>
<td>1.832</td>
</tr>
</tbody>
</table>

### 2015 Operating Cost Breakdown

- **Coagulant**: $180,969
- **Post-lime**: $35,400
- **Dewatering lime**: $66,998
- **Cake disposal**: $35,400
- **Cost savings**: $87,219

**Annual operating cost**: $370,586
## Atlanta-Fulton County

<table>
<thead>
<tr>
<th>Initial Operating Metrics</th>
<th>Projected Operating Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum, mg/L</td>
<td>Alum, mg/L</td>
</tr>
<tr>
<td>15.6</td>
<td>12.5</td>
</tr>
<tr>
<td>Post-lime, mg/L</td>
<td>Post-lime, mg/L</td>
</tr>
<tr>
<td>3.92</td>
<td>3.2</td>
</tr>
<tr>
<td>Dewatering lime, lbs/mo.</td>
<td>Dewatering lime, lbs/mo.</td>
</tr>
<tr>
<td>76,798</td>
<td>57,599</td>
</tr>
<tr>
<td>Filter cake, dry tons per year</td>
<td>Filter cake, dry tons per year</td>
</tr>
<tr>
<td>941</td>
<td>752</td>
</tr>
<tr>
<td>Alum, lbs/MG</td>
<td>Alum, lbs/MG</td>
</tr>
<tr>
<td>132.2</td>
<td>105.9</td>
</tr>
<tr>
<td>Post-lime, lbs/MG</td>
<td>Post-lime, lbs/MG</td>
</tr>
<tr>
<td>33.3</td>
<td>27.2</td>
</tr>
<tr>
<td>Dewatering lime, tons per dry ton cake</td>
<td>Dewatering lime, tons per dry ton cake</td>
</tr>
<tr>
<td>1.832</td>
<td>1.832</td>
</tr>
</tbody>
</table>

**Expected 20% overall reduction in operating costs**
Atlanta-Fulton County

- Implementation and verification of annual operations
  - Month-to-month tracking and comparisons first year
  - Calculation of operating costs and actual savings
  - Adjustment of operating metrics
  - Summation of first-year operations

Dewatering lime feed
## Atlanta-Fulton County

<table>
<thead>
<tr>
<th>Initial Operating Metrics</th>
<th>Actual Operating Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum, mg/L</td>
<td>Alum, mg/L</td>
</tr>
<tr>
<td>15.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Post-lime, mg/L</td>
<td>Post-lime, mg/L</td>
</tr>
<tr>
<td>3.92</td>
<td>2.9</td>
</tr>
<tr>
<td>Dewatering lime, lbs/mo.</td>
<td>Dewatering lime, lbs/mo.</td>
</tr>
<tr>
<td>76,798</td>
<td>51,123</td>
</tr>
<tr>
<td>Filter cake, dry tons per year</td>
<td>Filter cake, dry tons per year</td>
</tr>
<tr>
<td>941</td>
<td>650</td>
</tr>
<tr>
<td>Alum, lbs/MG</td>
<td>Alum, lbs/MG</td>
</tr>
<tr>
<td>132.2</td>
<td>79.8</td>
</tr>
<tr>
<td>Post-lime, lbs/MG</td>
<td>Post-lime, lbs/MG</td>
</tr>
<tr>
<td>33.3</td>
<td>23.7</td>
</tr>
<tr>
<td>Dewatering lime, tons per dry ton cake</td>
<td>Dewatering lime, tons per dry ton cake</td>
</tr>
<tr>
<td>1.832</td>
<td>1.832</td>
</tr>
</tbody>
</table>
Atlanta-Fulton County

2015 Operating Cost Breakdown

- Coagulant: $87,219
- Post-lime: $66,998
- Dewatering lime: $35,400
- Cake disposal: $58,704

Annual operating cost $370,586

2016 Operating Cost Breakdown

- Coagulant: $142,611
- Post-lime: $100,280
- Dewatering lime: $44,599
- Cake disposal: $58,704
- Cost savings: $24,392

Annual operating cost $227,975

Actual 38% reduction in annual costs obtained

Excellent coordination between operations and engineering toward a common goal
Buffalo Water, New York
Buffalo Water

- 120 mgd surface water plant, originally 1922
  - Average daily production 71 mgd
- Direct draw from eastern basin Lake Erie
  - Just upstream of Niagara River
- Coagulation/filtration plant
  - Chemical treatment
  - Solids handling
  - Disinfection and storage
- Finished water pumping to distribution system
  - 257,00 people
Buffalo Water

Coagulant Mixing Initiative
Buffalo Water

- **SternPac coagulant used since 1990’s**
  - Raw water turbidity averages 2 NTU
  - Settled water turbidity averaged 0.85 NTU
  - Filter run times 72 hours
    - Low head loss, possible optimization initiative

- **One coagulant feed point**
  - Low service discharge header
  - Relatively poor mixing
  - Coagulant not contacting within pump flow depending on pump in operation
Buffalo Water

Discharge header

Coagulant Feed Line
Buffalo Water
Buffalo Water

Coagulant Feed Line

Discharge header
Buffalo Water

Changed feed point to each pump discharge to improve mixing
Buffalo Water

- Mixing improvement immediately led to 17% reduction in coagulant dosage
  - 9.7 mg/L to 8 mg/L

- Coagulant reduction also impacted
  - Sludge dewatering
  - Polymer conditioning
  - Cake disposal
  - Operating costs
Buffalo Water

Floc and sed basins cleaned annually, no sludge removal equipment
Buffalo Water

Sludge pumped to backwash lagoon for further processing
Buffalo Water

Lagoon contents pumped to conditioning tank for polymer addition
# Buffalo Water

## Initial Operating Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SternPac, mg/L</td>
<td>9.67</td>
</tr>
<tr>
<td>Dewatering polymer, lbs/ton</td>
<td>12.95</td>
</tr>
<tr>
<td>Cake production, dry tons/yr</td>
<td>931</td>
</tr>
<tr>
<td>Cake solids, %</td>
<td>22.6</td>
</tr>
</tbody>
</table>

## 2014 Operating Cost Breakdown

- Coagulant: $177,669
- Disposal: $48,037
- Polymer: $244,236

**Annual Operating Cost $469,941**
# Buffalo Water

<table>
<thead>
<tr>
<th>Initial Operating Metrics</th>
<th>Actual Operating Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>SternPac, mg/L</td>
<td>9.67</td>
</tr>
<tr>
<td>Dewatering polymer, lbs/ton</td>
<td>12.95</td>
</tr>
<tr>
<td>Cake production, dry tons/yr</td>
<td>931</td>
</tr>
<tr>
<td>Cake solids, %</td>
<td>22.6</td>
</tr>
</tbody>
</table>
Buffalo Water

Actual 33.5% reduction realized in annual costs
Buffalo Water

Actual 33.5% reduction realized in annual costs
Annual cost savings $157,657
Buffalo Water

- **Future optimization plans**
  - Floc speed adjustments (underway with another 12% coagulant reduction)
  - Incorporate activated carbon reactors for T&O/cyanotoxin treatment
  - Install conventional rapid mix to further reduce coagulant feed
    - Add streaming current monitors to automate coagulant feed
  - Optimize filter performance
NEMRWSD – Tupelo, MS
NEMRWSD – Tupelo, MS
NEMRWSD – Tupelo, MS

- **18 mgd surface water plant drawing from Tombigbee River**
  - Average daily production 12 mgd

- **Coagulation/filtration plant**
  - Chemical treatment
  - Solids handling
  - Disinfection and storage
    - Final chloramination

- **Finished water pumping to four wholesale distribution systems**
  - ≈70,000 people
NEMRWSD – Tupelo, MS

Disinfection Optimization Initiative
NEMRWSD – Tupelo, MS

- Filtered water disinfected using free chlorine
  - Water flows through three clearwells for CT compliance
  - Final pass ammonia added for chloramine conversion
    - High TOC in filter effluent is common
    - HAA5 formation issues existed previously
      - 2 periods greater than 60 µg/L LRAA
    - Residual monitored continuously
- Clearwells supply high service pumps
  - Six pumps and three large diameter distribution force mains to the supply district
NEMRWSD – Tupelo, MS

Average total chlorine 3.3 mg/L
NEMRWSD – Tupelo, MS

Average total chlorine 3.3 mg/L

Were not taking advantage of 48” piping contact time
NEMRWSD – Tupelo, MS

- Developed CT model to predict potential chemical feed and monitoring locations
  - Meet CT requirements according to water temperature variations
    - Water temp variations 7°C to 30°C
  - Minimize HAA5 formation in summer months
  - Produce chloramines to slow HAA5 formation
  - Install new ammonia feed and residual monitoring points as predicted

- Obtain Mississippi DOH approvals
  - Changes in feed points
  - CT monitoring and compliance
### Optimization Stories From The Field

## NEMRWSD – Tupelo, MS

### NORTHEAST MISSISSIPPI REGIONAL WATER SUPPLY DISTRICT - TUPELO, MS

#### CT CALCULATIONS MODEL

<table>
<thead>
<tr>
<th>PEAK HOURLY TREATMENT FLOW, gpm</th>
<th>HIGHEST WATER pH</th>
<th>LOWEST WATER TEMP. °C</th>
<th>LOWEST CLEARWELL OPERATING LEVEL, ft.</th>
<th>PRETREATMENT BASINS FREE CHLORINE CONC. mg/L</th>
<th>WEIR CHAMBER FREE CHLORINE CONC. mg/L</th>
<th>CLEARWELL A FREE CHLORINE CONC. mg/L</th>
<th>CLEARWELL B FREE CHLORINE CONC. mg/L</th>
<th>CLEARWELL C FREE CHLORINE CONC. mg/L</th>
<th>REQUIRED CT FROM TABLES mg/L-min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,200</td>
<td>7.00</td>
<td>8.0</td>
<td>0.80</td>
<td>2.80</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>21.9</td>
<td></td>
</tr>
</tbody>
</table>

**1 = SELECT CURRENT AMMONIA FEED POINT**

<table>
<thead>
<tr>
<th>DISINFECTION CONTACT TIMES - MINUTES</th>
<th>CUMMULATIVE MINUTES</th>
<th>CUMMULATIVE CT (mg/L-minutes)</th>
<th>CT RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRONT WEIR CHAMBER</td>
<td>PRETREATMENT</td>
<td>26.4</td>
<td>26.4</td>
</tr>
<tr>
<td>END OF WEIR CHAMBER</td>
<td>WEIR CHAMBER</td>
<td>0.6</td>
<td>27.0</td>
</tr>
<tr>
<td>END OF CLEARWELL A</td>
<td>CLEARWELL A</td>
<td>5.5</td>
<td>32.5</td>
</tr>
<tr>
<td>END OF CLEARWELL B</td>
<td>CLEARWELL B</td>
<td>22.4</td>
<td>54.9</td>
</tr>
<tr>
<td>END OF CLEARWELL C</td>
<td>CLEARWELL C</td>
<td>5.5</td>
<td>60.4</td>
</tr>
</tbody>
</table>

**CT RATIO**

1.02
NEMRWSD – Tupelo, MS

- Model suggested CT compliance through weir chamber using free chlorine
  - Ammonia feed after weir chamber to slow HAA5 formation
  - Residual monitoring downstream of feed point
  - Added multiple feed point and residual monitors to clearwell arrangements
Multiple NH₃ feed points based on water temp changes
Optimization Stories From The Field

NEMRWSD – Tupelo, MS

- Solved HAA5 issues with ammonia feed changes to slow formation
  - LRAA 38 µg/L

- Some residual maintenance issues in parts of distribution system

- Investigation into residuals suggested northern edge impacted significantly
  - Low total chlorine residuals
  - Elevated HAA5 levels
  - Some odors observed
  - Chlorine decay evaluations conducted
Tupelo, MS

- Large distribution system and multiple storage tanks
- Northern most tank area where most of low residuals occur
  - Total chlorine depleted less than 1.0 mg/L
- Chlorine decay analysis (bulk water in lab)
  - Define decay coefficient and develop computer model
  - Adjust model for piping decay along with bulk water decay
  - Predict water age in distribution system
NEMRWSD – Tupelo, MS

Raw data in graphical form

Temp = 21°C
NEMRWSD – Tupelo, MS

Exponential trend line selection and overlay

Temp = 21°C
NEMRWSD – Tupelo, MS

**Trend line equation and \( R^2 \) correlation**

\[ y = 1.800e^{-0.284x} \]

\[ R^2 = 0.999 \]

Temp = 21°C
Identified decay coefficient ($k_b$) is 0.284

$$y = 1.800e^{-0.284x}$$

$$R^2 = 0.999$$

Temp = 21°C
NEMRWSD – Tupelo, MS

- Conducted decay analysis for Tupelo water in laboratory
  - Initial residual 3.05 mg/L
- Observed total chlorine residual for 21 days
  - Residual declined below 1.9 mg/L
Optimization Stories From The Field

NEMRWSD – Tupelo, MS

- Determine decay coefficient ($\kappa$) from equation

$$C_t = C_0 e^{(-\kappa t)}$$

![Graph showing total chlorine remaining vs. decay period with equation and R² value]
NEMRWSD – Tupelo, MS

- **Determine decay coefficient** \((k)\) from equation

\[ C_t = C_0 e^{-kt} \]

Identified water decay coefficient \((k_b)\) is **0.0196**

\[ y = 2.7835e^{-0.0196x} \]

\[ R^2 = 0.9442 \]
## NE Mississippi Regional Water Supply District
### Tupelo, MS
#### Total Chlorine Decay Model

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>k</th>
<th>Days</th>
<th>Initial Total Cl₂, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.0392</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.20</td>
<td>3.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.98</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.85</td>
<td>2.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.74</td>
<td>2.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.63</td>
<td>2.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.43</td>
<td>2.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.16</td>
<td>2.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.92</td>
<td>1.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.85</td>
<td>1.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.78</td>
<td>1.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.71</td>
<td>1.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.66</td>
<td>1.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.59</td>
<td>1.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.53</td>
<td>1.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.47</td>
<td>1.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.30</td>
<td>1.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.11</td>
<td>1.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.99</td>
<td>0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.91</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.88</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.84</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.78</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.72</td>
<td>0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.67</td>
<td>0.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.62</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.57</td>
<td>0.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.52</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.48</td>
<td>0.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tupelo, MS

- Average water age less than 3 days
- Southern areas less than 2 days water age
Tupelo, MS

- **Average water age less than 3 days**
  - Southern areas less than 2 days water age
  - Northern areas increasing water age to 4.5 days
Tupelo, MS

- Average water age less than 3 days
  - Southern areas less than 2 days water age
  - Northern areas increasing water age to 4.5 days
  - Baldwyn Tank (north) water age **22 days**
- Installed PAX tank mixer to reduce water stagnation
- Within 1 day total chlorine residuals increased to 2.5 mg/L
- Reduced HAA5s 30% in Baldwyn Tank area from stagnant water
Questions

Marvin Gnagy
pmgconsulting710@gmail.com
419.450.2931