PNWS-AWWA 2012 Annual Conference
May 2 -5, 2012 Yakima, Washington

Reservoir Water Quality

Modeling and Mixing Improvements

Presented by:
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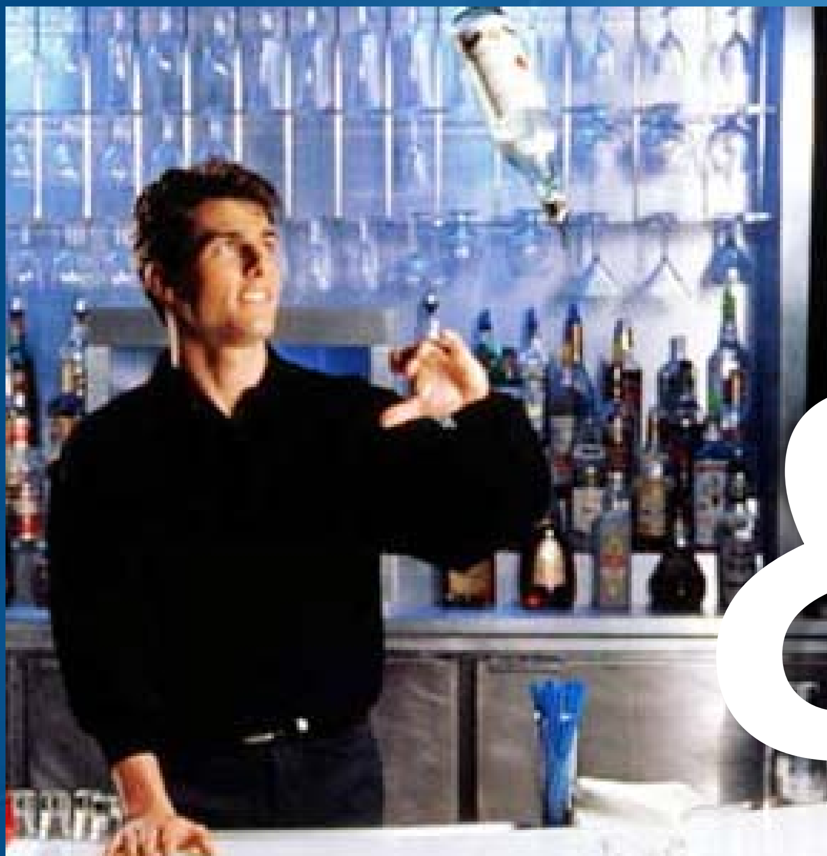
David Stangel, P.E.

Murray, Smith & Associates, Inc.
Engineers/Planners

MODELING



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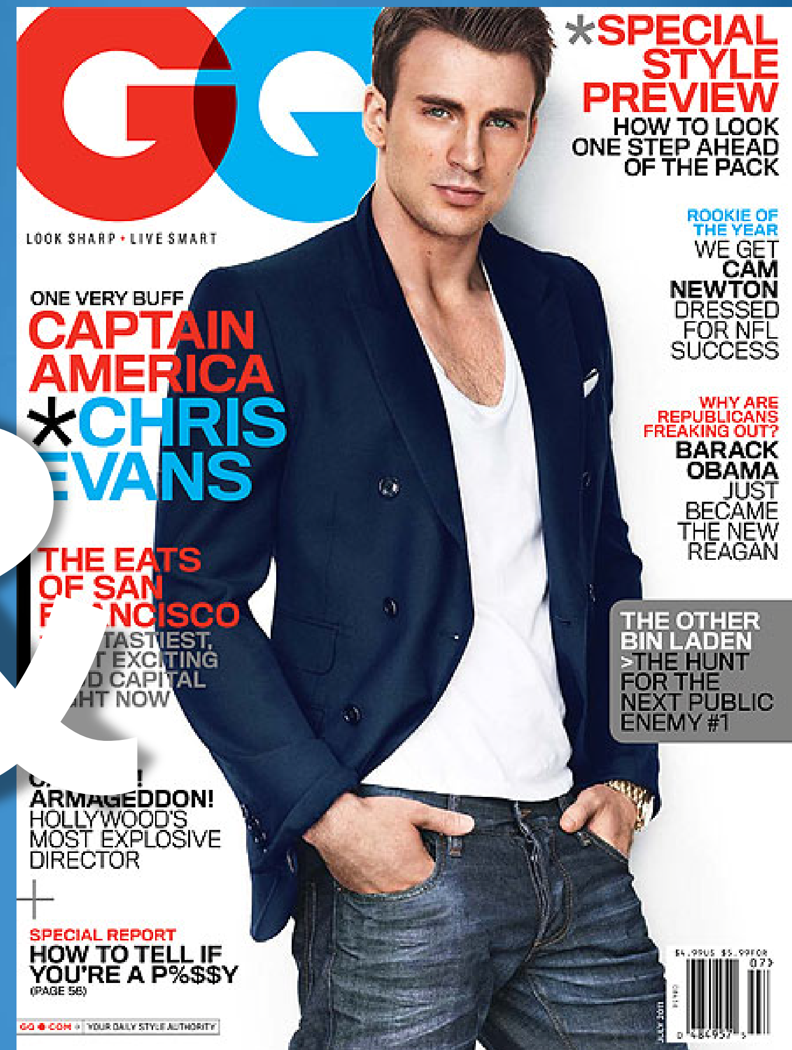


MIXING

Presentation Outline

- Importance of reservoir water quality
- Causes of water quality issues
- Case study – City of Albany Broadway Reservoir
  - ✓ Methods for evaluating water quality parameters
  - ✓ Water age analysis
  - ✓ Water system hydraulic modeling and system operations evaluation
  - ✓ Computational fluid dynamics modeling
  - ✓ Design and construction of improvements
- Question and answers

Why is Water Quality in Reservoirs Important?

- Low disinfectant residuals
- Poor water quality in distribution system
- Failing to meet new more stringent water quality rules
- Disinfected by products (DPB)
- Biological growth
- Algae growth
- Biofilm growth
- Taste and odor problems

What Causes Water Quality Issues in Reservoirs?

- Reservoir Size
  - ✓ Future growth
  - ✓ Fire and emergency storage
  - ✓ Increased water age
  - ✓ Low turnover
- Operations
  - ✓ WTP/water supply operations
  - ✓ Day time supplies system not the reservoir
  - ✓ Night time no demand to drain reservoir
  - ✓ Inadequate flow rate into the reservoir to promote mixing

What Causes Water Quality Issues in Reservoirs?

- Reservoir Piping Configurations
  - ✓ Low inlet velocities
  - ✓ Single inlet/outlet pipe
  - ✓ Short circuiting (last in – first out)
  - ✓ Inadequate vertical flow vector component
  - ✓ Dead zone

- System piping configurations and capacity
  - ✓ Reservoir filled through distribution piping
  - ✓ Transmission piping inadequate capacity

What Causes Water Quality Issues in Reservoirs?

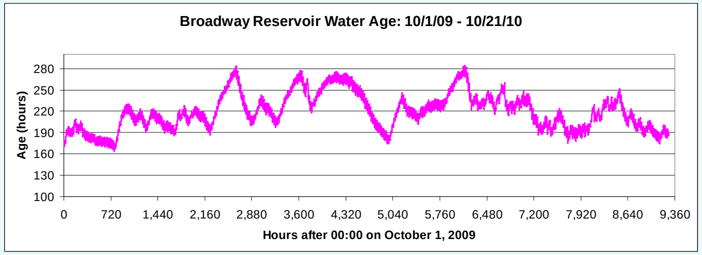
- Reservoir location in the system
  - ✓ At the end of the system
    - Low flows into the reservoir
    - Little turnover/little demand
    - Floats on another reservoir
  - ✓ Wrong elevation
- Thermal Stratification
  - ✓ Cooler water entering the reservoir
  - ✓ Warm water on top
  - ✓ Critical times of year
- Bad Turnover

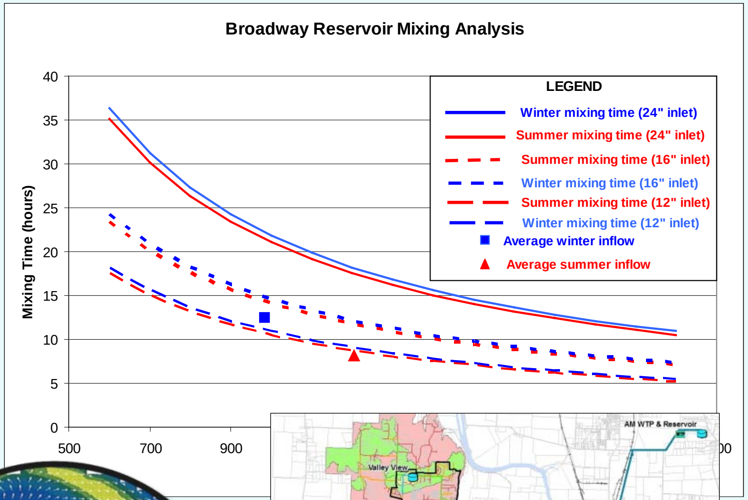
How are Water Quality Issues in Reservoirs Addressed?

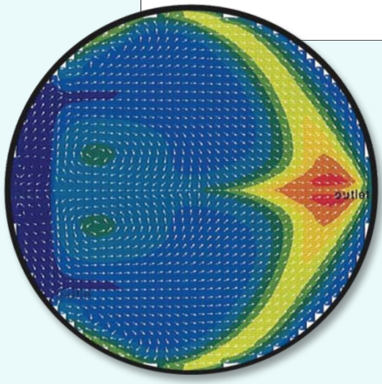
- Demolish tank and build smaller one
- Move reservoir
- Construct dedicated transmission line
- Change operations
- Mixing improvements
- The overall system should be evaluated
- Case study

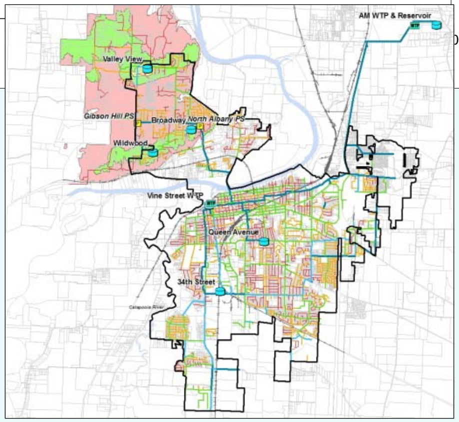
City of Albany 8.0 MG Broadway Reservoir Water Age and Mixing Analysis – Case Study

- Four main elements
- Preliminary water age analysis
- Water system hydraulic modeling
- CFD modeling
- Design and construction of mixing improvements









Project Team

- **City of Albany** – owner
- **MSA** – project manager, hydraulic modeling and final designs
- **Confluence Engineering Group** – water quality and water age analysis
- **Walter Grayman, PhD. Consulting Engineer** – preliminary water age analysis and mixing evaluations
- **Flow Science, Inc.** – CFD modeling
- **Red Valve** – Tide Flex valve supplier/technical data

Red Valve Company, Inc.

Background

- 8.0 MG prestressed concrete reservoir
- Constructed in 1992
- Serves the main low service zone
- City’s largest reservoir
- 39 feet tall and 189 feet in diameter
- 24-inch diameter single inlet/outlet pipe
- Inlet is 24-inch diameter with a ductile iron flap

Water Quality History

- Historically, the City struggled to fill and drain reservoir due to transmission main limitations
- Recent evaluations
  - ✓ Raised concerns regarding ability to maintain chlorine residuals in the tank
  - ✓ There is suspected long residence time
  - ✓ There is suspected poor mixing

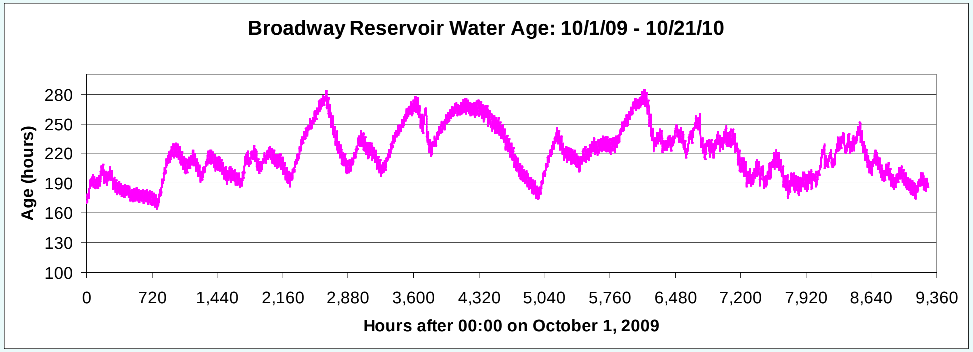
Current Operations and Planned Improvements

- Operated in a simple fill/draw manner
- Previous studies show residence time as 10 to 20 days
- Average inflow rate of 280 to 560 gpm
- City planning transmission main improvements to reduce residence time to 4 to 7 days
- Mixing improvements needed

Water Age Analysis

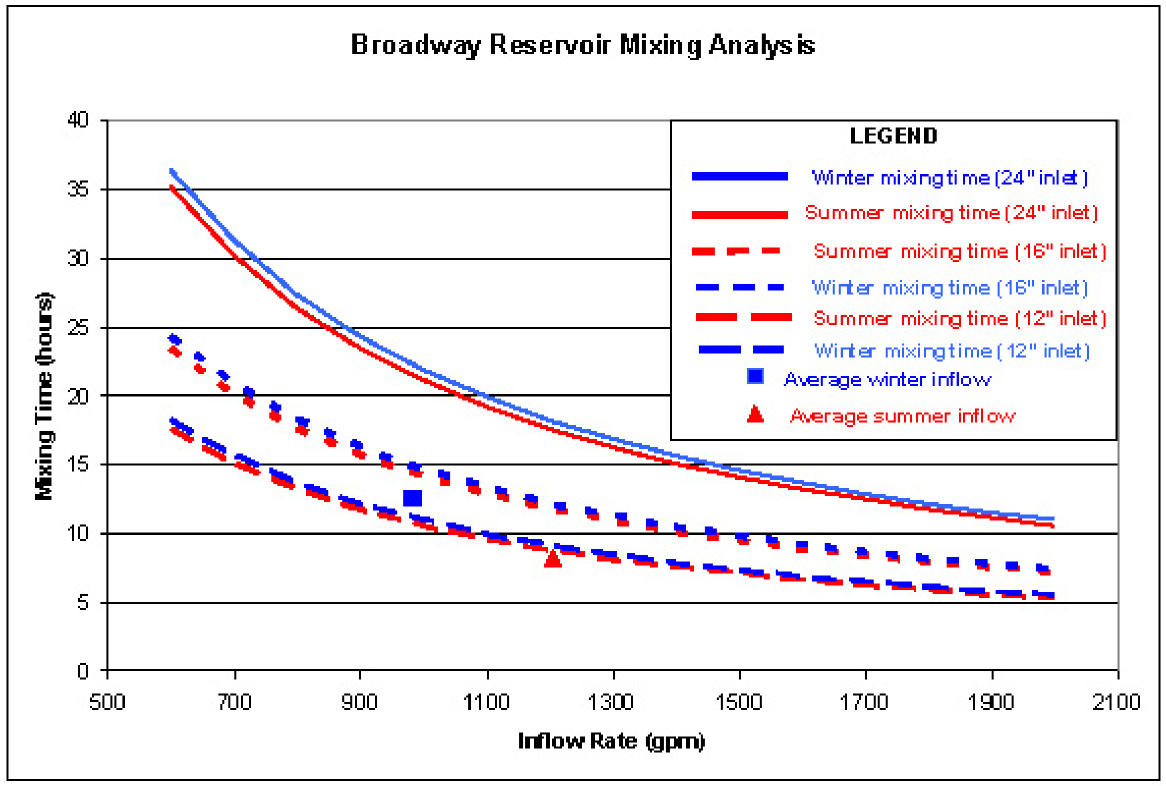
- Objective
  - ✓ Determine baseline water age
  - ✓ Compare to proposed modifications

- Initial evaluations
  - ✓ Approx. nine days based on completely mixed tank
  - ✓ Water likely much older in portions of the tank
  - ✓ Mixing time equation
    - Approximates time to fully mix during a fill cycle
      - i. Inlet diameter
      - ii. Inflow rate
      - iii. Tank dimensions
    - 3 – 5 days rule of thumb



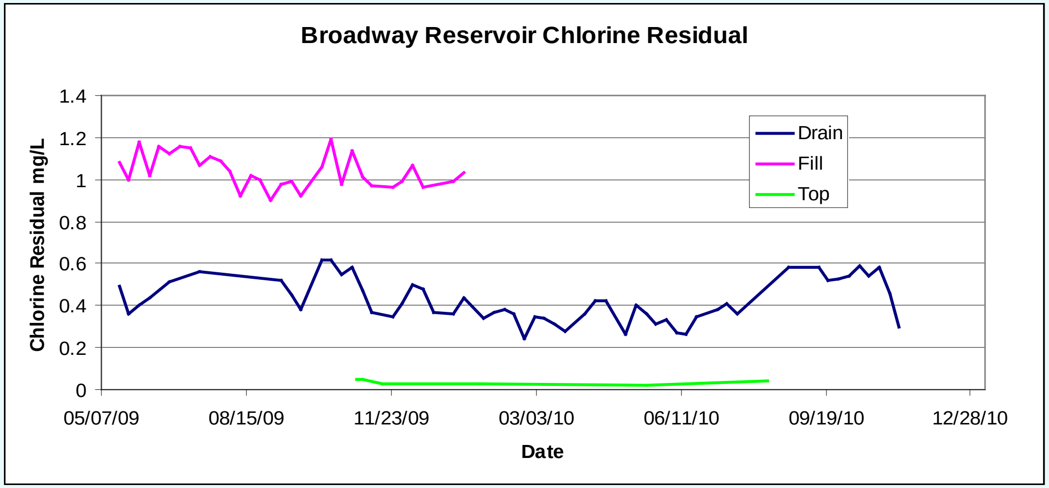
Water Age Analysis

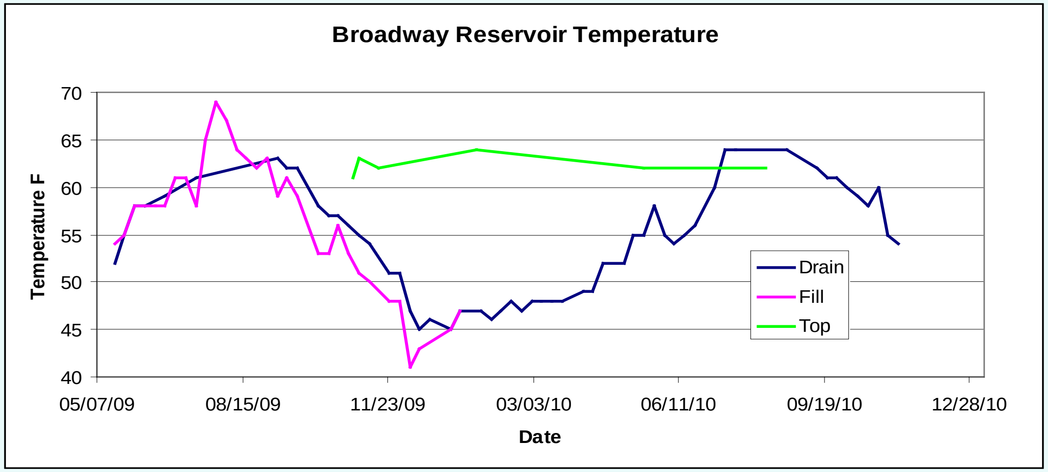
- Tank Operation Data Review and mixing evaluation
  - ✓ One year of tank levels from Oct ’09 to Oct ’10
  - ✓ Mixing time exceeds the typical fill cycle
  - ✓ Evaluated various conditions
    - Reduced inlet diameter
    - Increased flow rate



Water Age Analysis

- Chlorine Residual and Temperature Analysis
  - ✓ City provided chlorine residual and temperature data
  - ✓ Low chlorine residual
  - ✓ Thermal stratification
  - ✓ Fall time conditions were critical

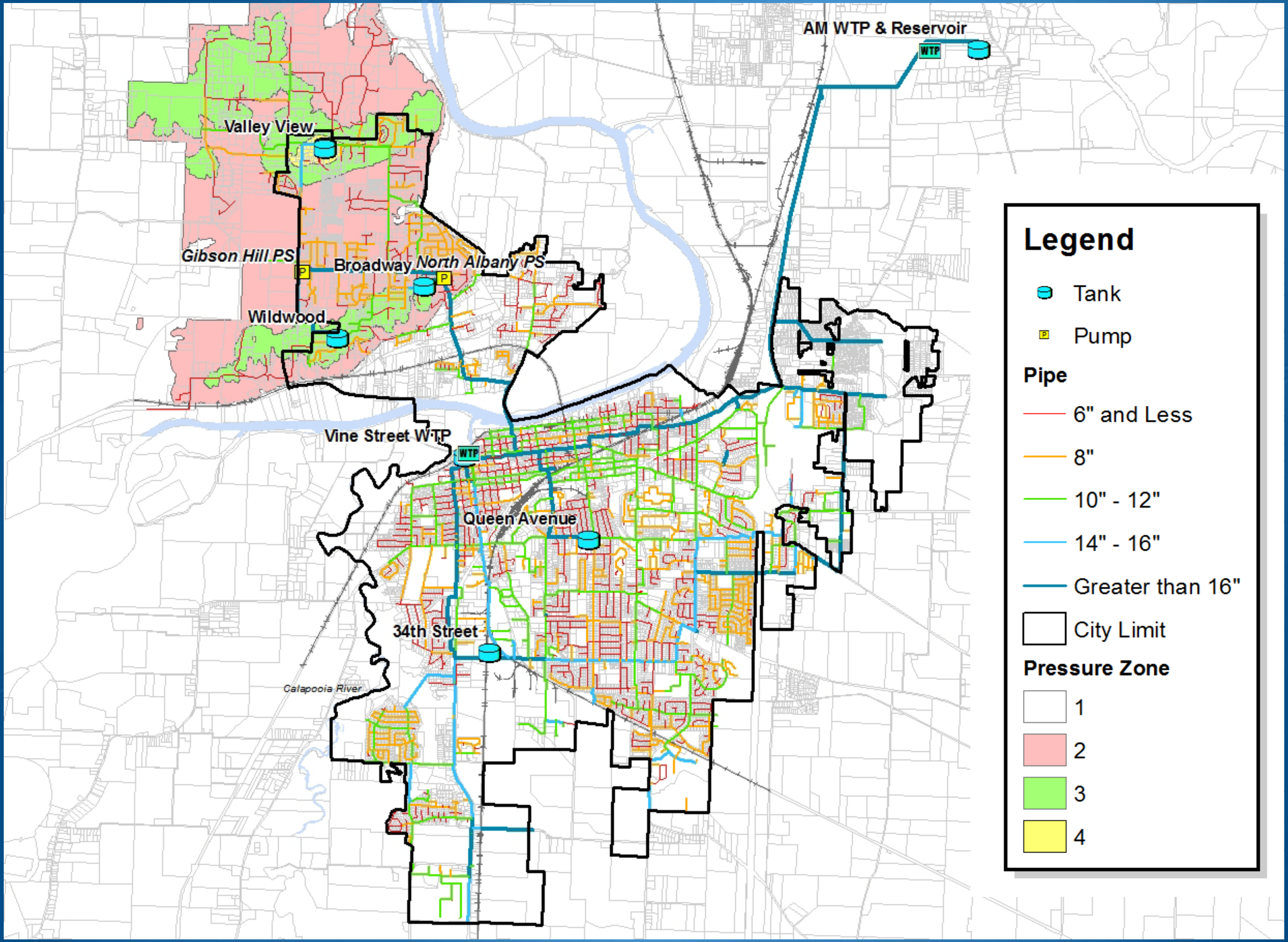




Water System Hydraulic Modeling

- Utilize City's hydraulic model to identify existing and future reservoir flow rates

City System


AM WTP & Reservoir
WTP
Valley View
Gibson Hill PS
Broadway
North Albany PS
Wildwood
Vine Street WTP
WTP
Queen Avenue
34th Street
Calapooia River
Legend
Tank
Pump
Pipe
6" and Less
8"
10" - 12"
14" - 16"
Greater than 16"
City Limit
Pressure Zone
1
2
3
4

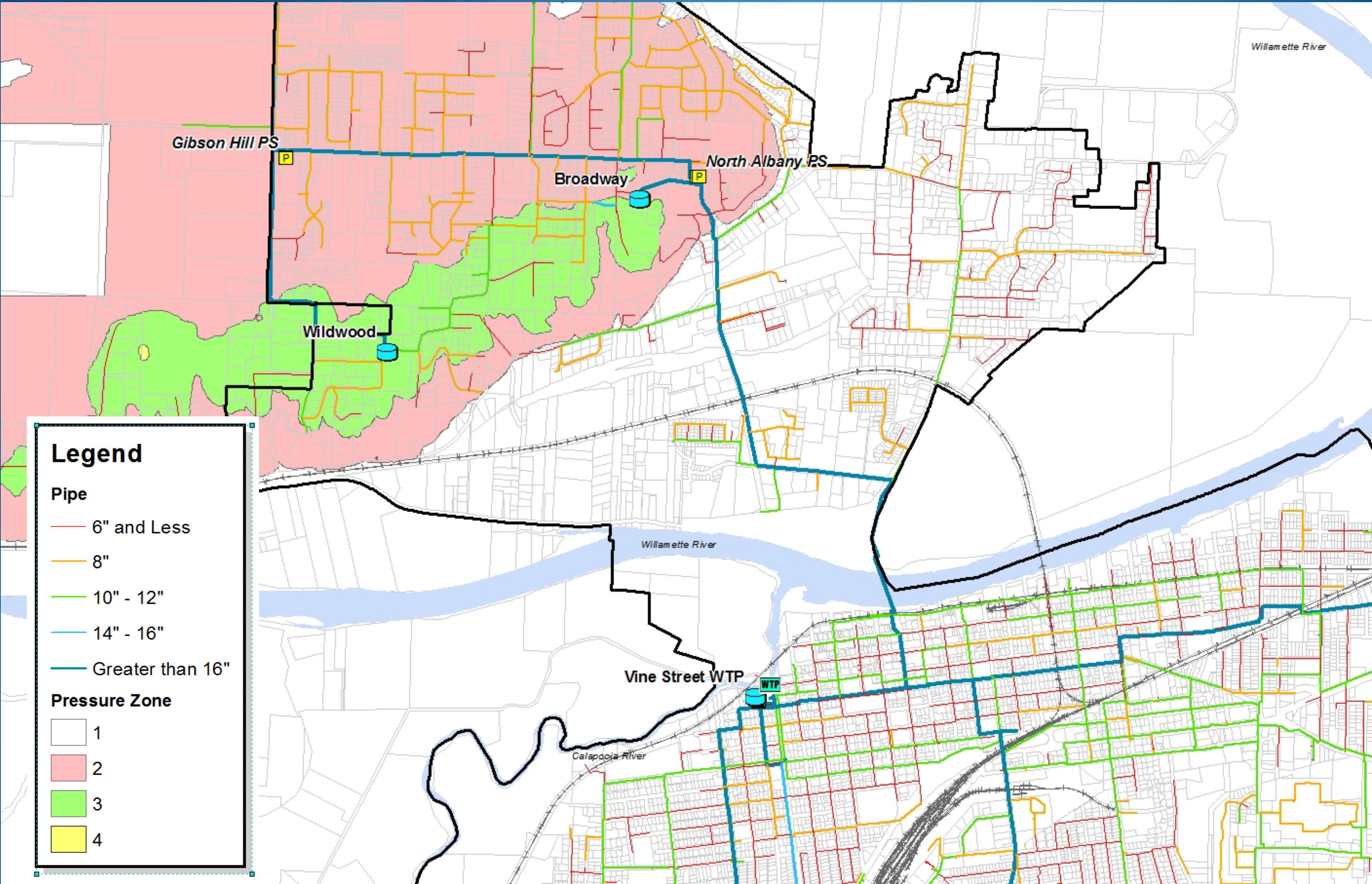
Existing System

- Supply provided by two water treatment plants
  - ✓ Albany-Millersburg
    - Operated as primary WTP
    - Supply to system through a PRV
  - ✓ Vine Street
    - Operated manually during summer based on demand
- Four Pressure Zones
  - ✓ Main zone primarily east of Willamette River
  - ✓ Three smaller zones west of river (North Albany)
- Broadway reservoir “floats” on main zone and is located west of Willamette River

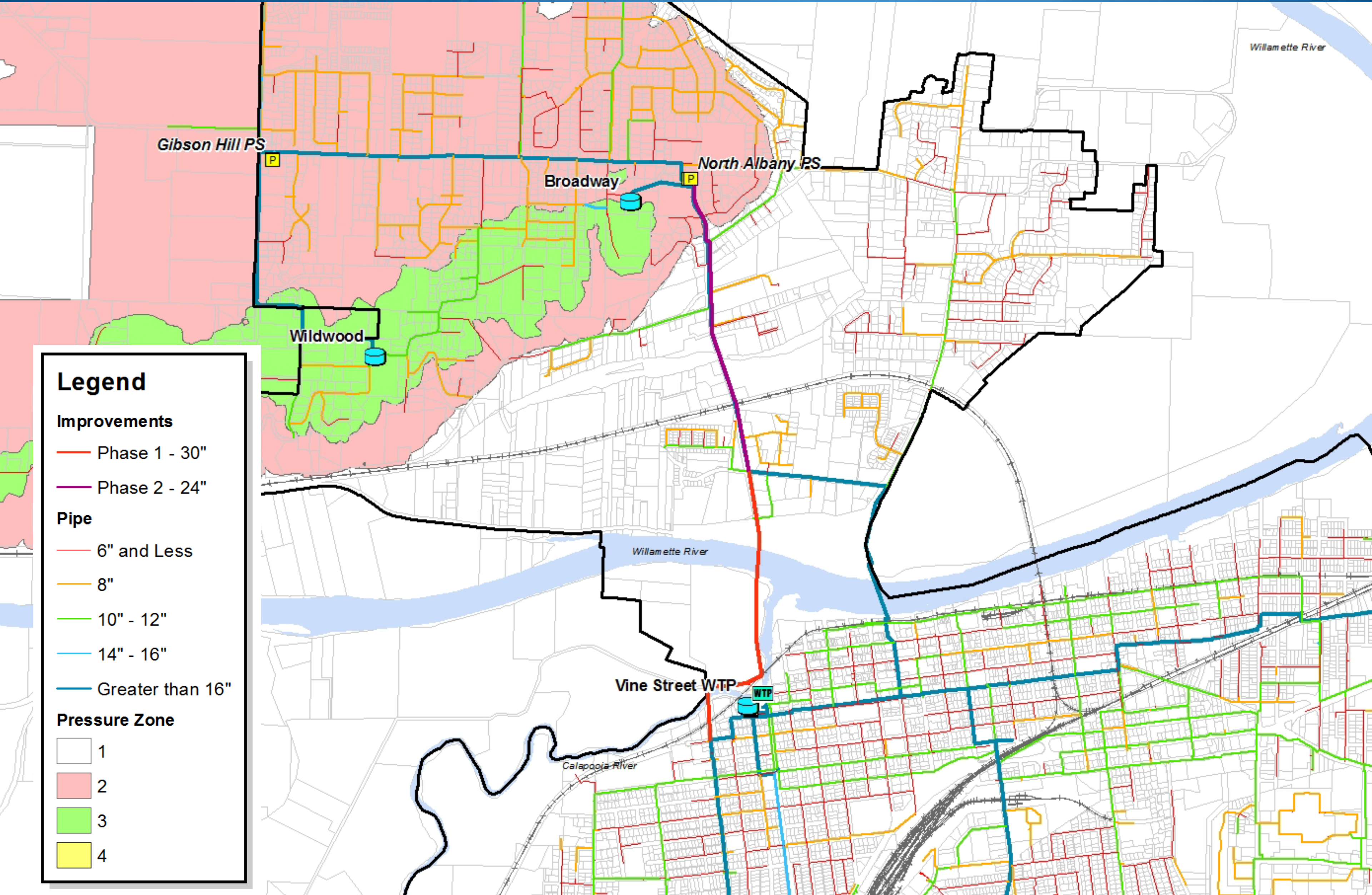
Specific Modeling

- Low turnover occurring in Broadway Tank, particularly under fall conditions
- Vine Street WTP has been manually operated during peak summer conditions only
- Single pipe across the Willamette causes some hydraulic limitations
- Second river crossing planned
- Two phases

Existing System



Improvements



Modeling Approach

- Utilize model to evaluate specific system variables to identify the flow in/out of the Broadway Reservoir
  - ✓ Demand
  - ✓ Supply
  - ✓ Tank Level
  - ✓ Pipe Improvements
- Specifically identify a supply and improvement combination that allows the tank to fill at approximately 1500 gpm

Existing Modeling Results

Run #	Demand (gpm)		Broadway Tank Level (ft)		Phase 1 Installed	Phase 2 Installed	North Albany PS Flow (gpm)	Broadway Tank Inflow (gpm)
1	Ave	3,745	Ave	35.9	Yes	No	1,200	1,860
2	Ave	3,745	Ave	35.9	Yes	Yes	1,200	2,630
3	Ave	3,745	High	38.9	Yes	No	1,200	1,530
4	Ave	3,745	High	38.9	Yes	Yes	1,200	2,220
5	Ave	3,745	Low	32.8	Yes	No	1,200	2,180
6	Ave	3,745	Low	32.8	Yes	Yes	1,200	3,030
7	High	5,635	Ave	35.9	Yes	No	1,200	910
8	High	5,635	Ave	35.9	Yes	Yes	1,200	1,340
9	High	5,635	High	38.9	Yes	No	1,200	560
10	High	5,635	High	38.9	Yes	Yes	1,200	920
11	High	5,635	Low	32.8	Yes	No	1,200	1,250
12	High	5,635	Low	32.8	Yes	Yes	1,200	1,760
13	Low	1,854	Ave	35.9	Yes	No	1,200	2,680
14	Low	1,854	Ave	35.9	Yes	Yes	1,200	3,830
15	Low	1,854	High	38.9	Yes	No	1,200	2,360
16	Low	1,854	High	38.9	Yes	Yes	1,200	3,430
17	Low	1,854	Low	32.8	Yes	No	1,200	2,990
18	Low	1,854	Low	32.8	Yes	Yes	1,200	4,220

Existing Conclusions

- Assumptions:
  - ✓ Vine Street WTP not operating
  - ✓ Second river crossing is constructed (phase 1)
  - ✓ North Albany PS is operating
  - ✓ Tide-Flex is installed at Broadway Tank
- Results
  - ✓ Most combinations result in a net inflow of approximately 1500 gpm
  - ✓ Becomes challenging to fill tank under higher demand conditions

Future Modeling Results

- Assumptions:
  - ✓ Demands increase to 9000 gpm - average day
  - ✓ Both River Crossing Improvements are constructed
  - ✓ Vine Street WTP provides 3500 gpm on average and is <u>controlled by tank level</u>
  - ✓ Other conditions remain the same
- Conclusions:
  - ✓ Approximately 1500 gpm can be conveyed into the tank

Results

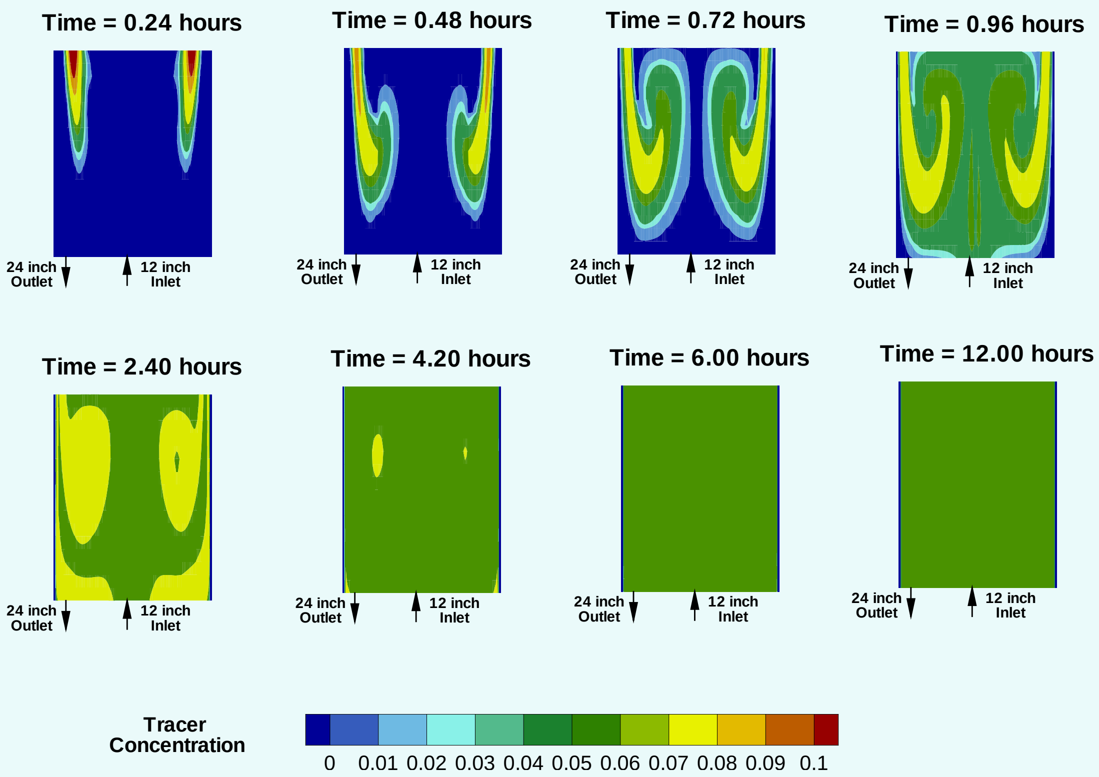
- Phase 1 of river crossing required
- Draw the reservoir down to 33 feet before refilling
  - ✓ Cycle tank by approximately 5 feet
- Utilize Vine Street WTP under fall conditions
- Control Vine Street WTP on Broadway level
- Evaluate connecting the suction of the North Albany BS to the Broadway Reservoir
  - ✓ Would increase average daily turnover by 300 gpm

Further Modeling

- Once the Vine Street WTP is being operated on Broadway tank level:
  - Calibrate an Extended Period Simulation (EPS) model under those operating conditions
  - Utilize the EPS model to simulate long term tank turnover and water age
  - Use the model as a predictive operations tool by modifying system control as dictated by tank turnover rates and water age

Computational Fluid Dynamics Modeling

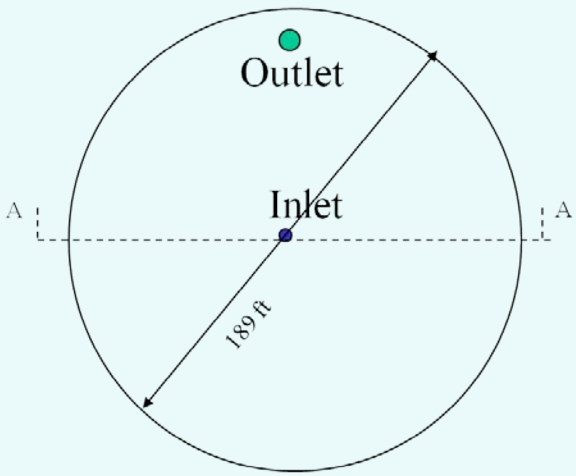
- Three-dimensional hydraulic model
  - ✓ Size and shape of the reservoir
  - ✓ Inlet/outlet piping configuration
  - ✓ Inlet flow rates
  - ✓ Reservoir water levels at fill and draw cycles
  - ✓ Temperature gradients in the reservoir



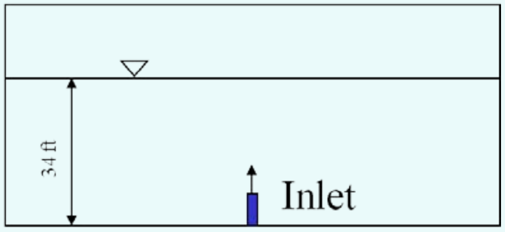
- Models flow patterns and mixing characteristics

Analysis

- Base case
  - ✓ 12” diameter inlet at center of reservoir
  - ✓ Fill rate 1500 gpm
  - ✓ Fill cycle 12 hours, draw cycle 12 hours
  - ✓ Temperature gradient (50 deg at bottom, 54 deg at top)
  - ✓ Fall is critical operating conditions



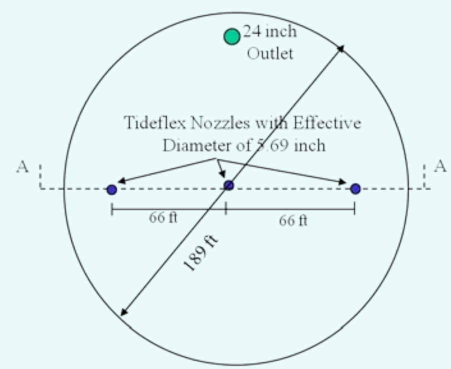
Plan View



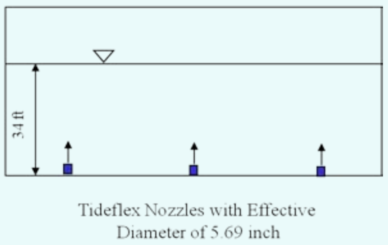
Side View

Results

- Configuration and operating parameters mix the tank
- Does not address lower flow conditions
- To achieve mixing over a broader range of conditions
  - ✓ TideFlex duckbill valves
  - ✓ 3 vertically oriented valves
  - ✓ Flow range 750 gpm to 3000 gpm
- Recommended Operating Conditions
  - ✓ Avg flow rate = 1457 gpm
  - ✓ Fill/draw cycle = 12 hrs
  - ✓ Initial water elevation = 34 feet
  - ✓ Water level variation = 5 feet

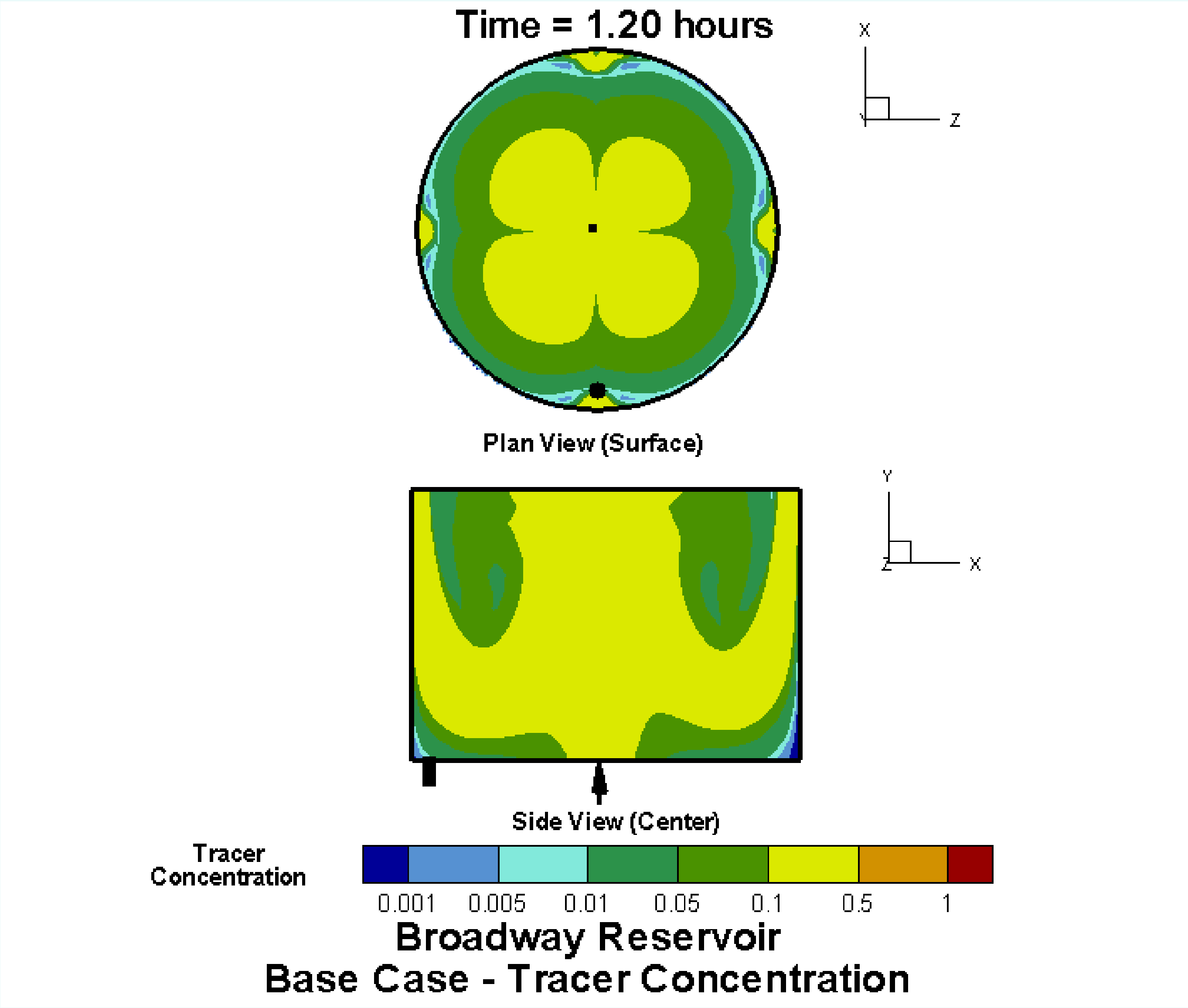


Plan View



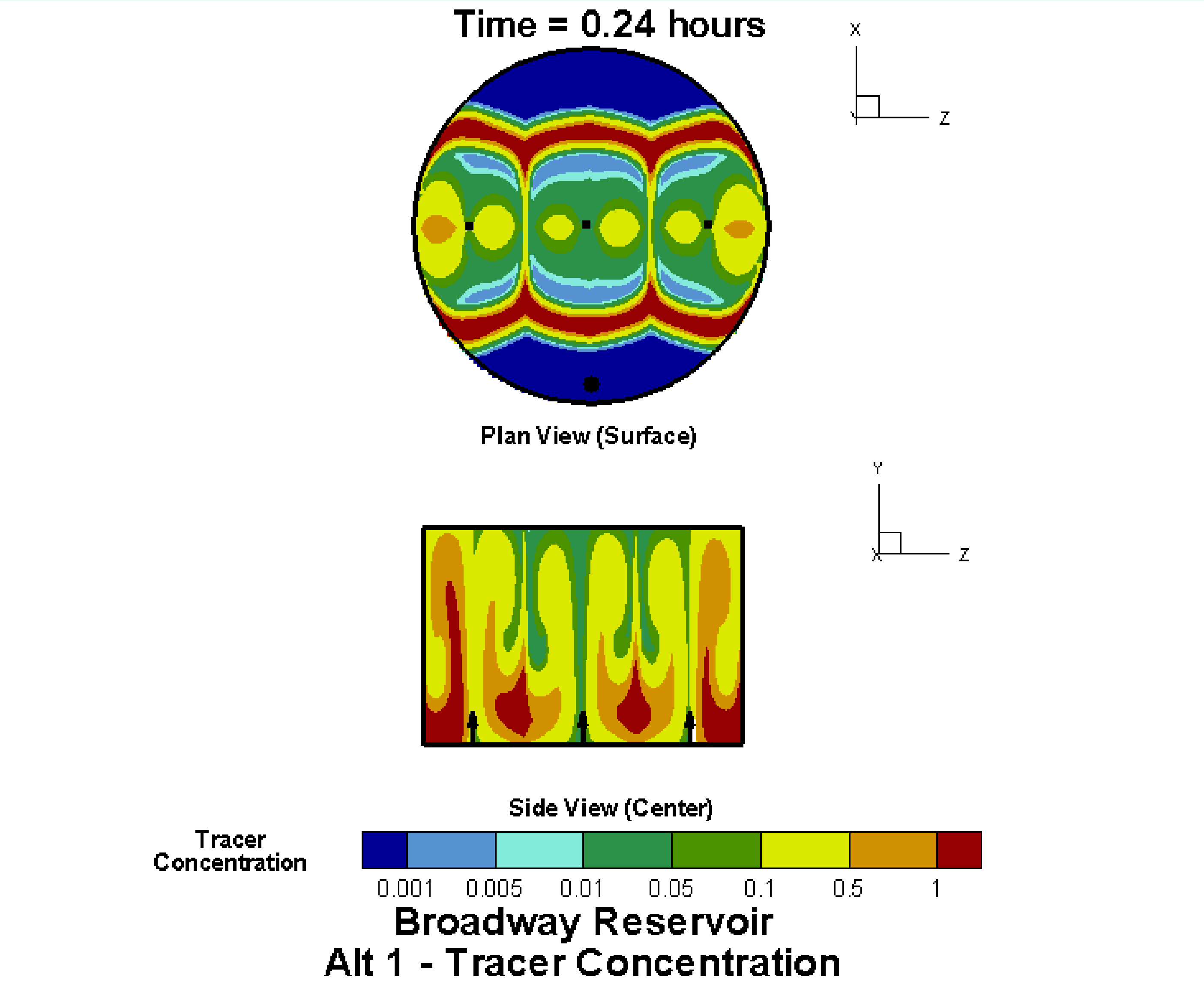
Side View

Results



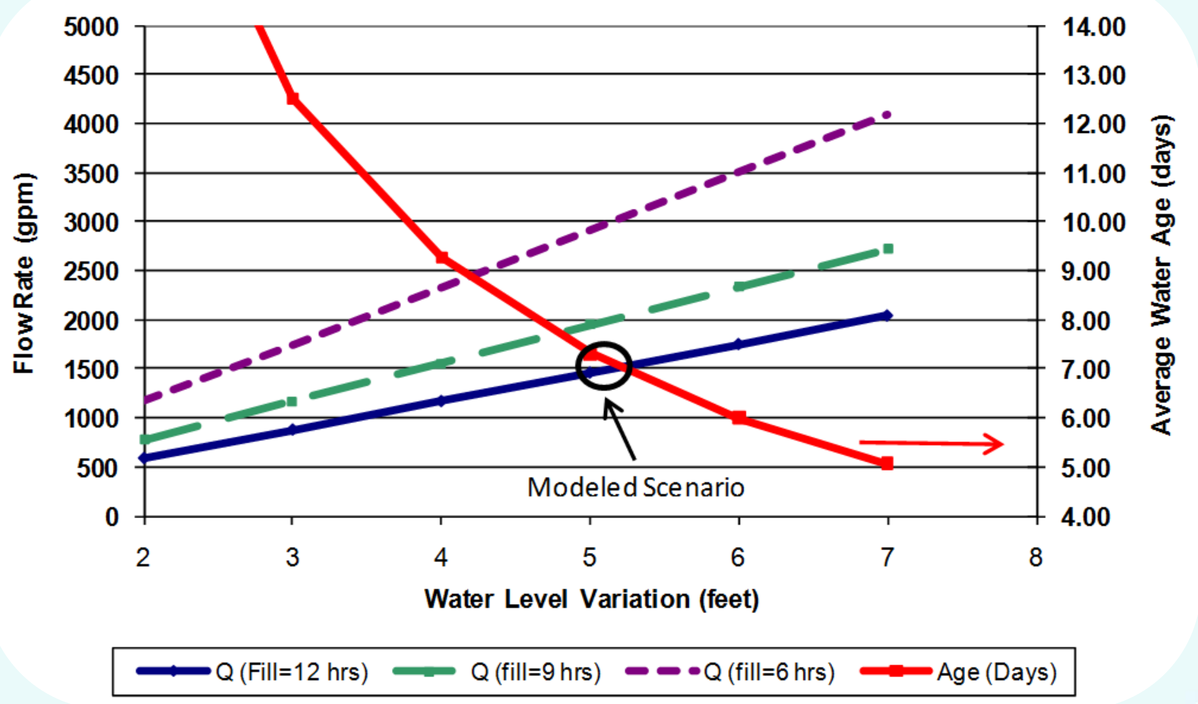
Time = 1.20 hours
X
Z
Y
Plan View (Surface)
Y
X
Z
Side View (Center)
Tracer Concentration
0.001
0.005
0.01
0.05
0.1
0.5
1
Broadway Reservoir
Base Case - Tracer Concentration

Results


Time = 0.24 hours
X
Y
Z
Plan View (Surface)
Y
X
Z
Side View (Center)
Tracer
Concentration
0.001
0.005
0.01
0.05
0.1
0.5
1
Broadway Reservoir
Alt 1 - Tracer Concentration

Recommended Operational Improvements

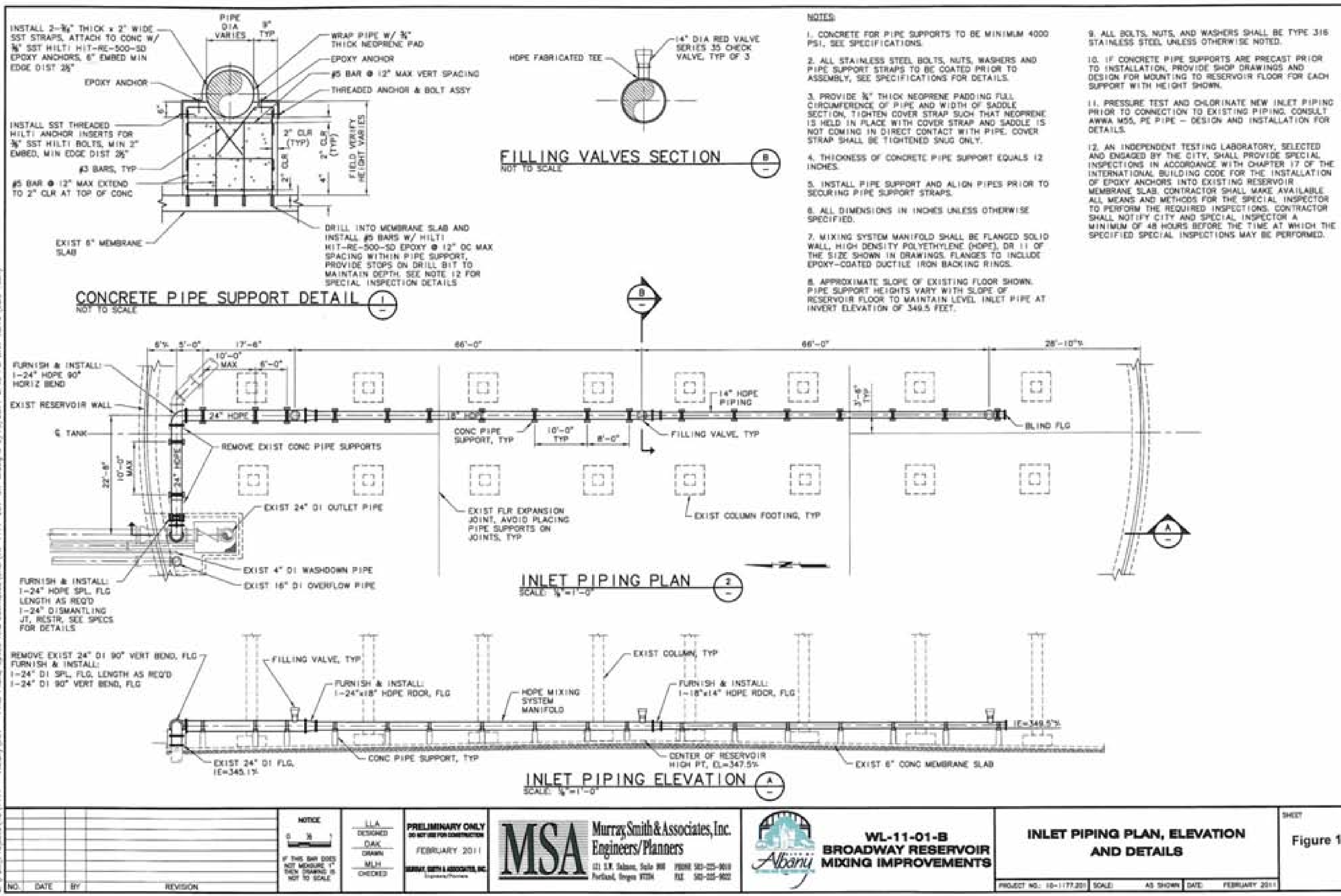
- Run WTPs at night or 24 hrs/day
- Control Vine Street WTP based on Broadway Reservoir levels
- Avoid need to add chlorine



Recommended Improvements

- Remove existing 24-inch diameter horizontal inlet
- Install HDPE pipe on concrete supports
- 3 Tide-Flex Valves

Recommended Improvements



Operational System Improvements

- City running WTP at night and day
- Constructing transmission main improvements
- Changed reservoir operating levels

Summary and Conclusion

- Maintaining water quality in reservoirs is important
  - ✓ Overall system water quality
  - ✓ Meet more stringent water quality regulations
  - ✓ Avoid taste and odor problems
  - ✓ Causes are numerous
- Evaluate overall system
  - ✓ Evaluations can include water age analysis, hydraulic modeling and CFD modeling
  - ✓ Determine cost-effective improvements for improving water quality
  - ✓ Improvements can include operational, system piping, reservoir piping, mechanical mixing
  - ✓ Post-improvements evaluation

Questions & Answers

"If something is hard to do, then it's not worth doing!"

Don't be a Homer!

Aquifer Storage & Recovery Impacts on Distribution and Treatment

Ronan V. Igloria, PE

PNWS-AWWA May 2012

HDR

Outline of Presentation

- Overview of ASR
- Opportunities and challenges for a utility
- Impacts to distribution system planning
- Reduced storage needs
- Impacts on WTP operations
- Conclusions

Aquifer Storage and Recovery – Sustainable and Cost-effective

- ASR is a water resources management technique for actively storing water underground during wet periods for recovery when needed, usually during dry periods. The timeframe can range from months to decades.

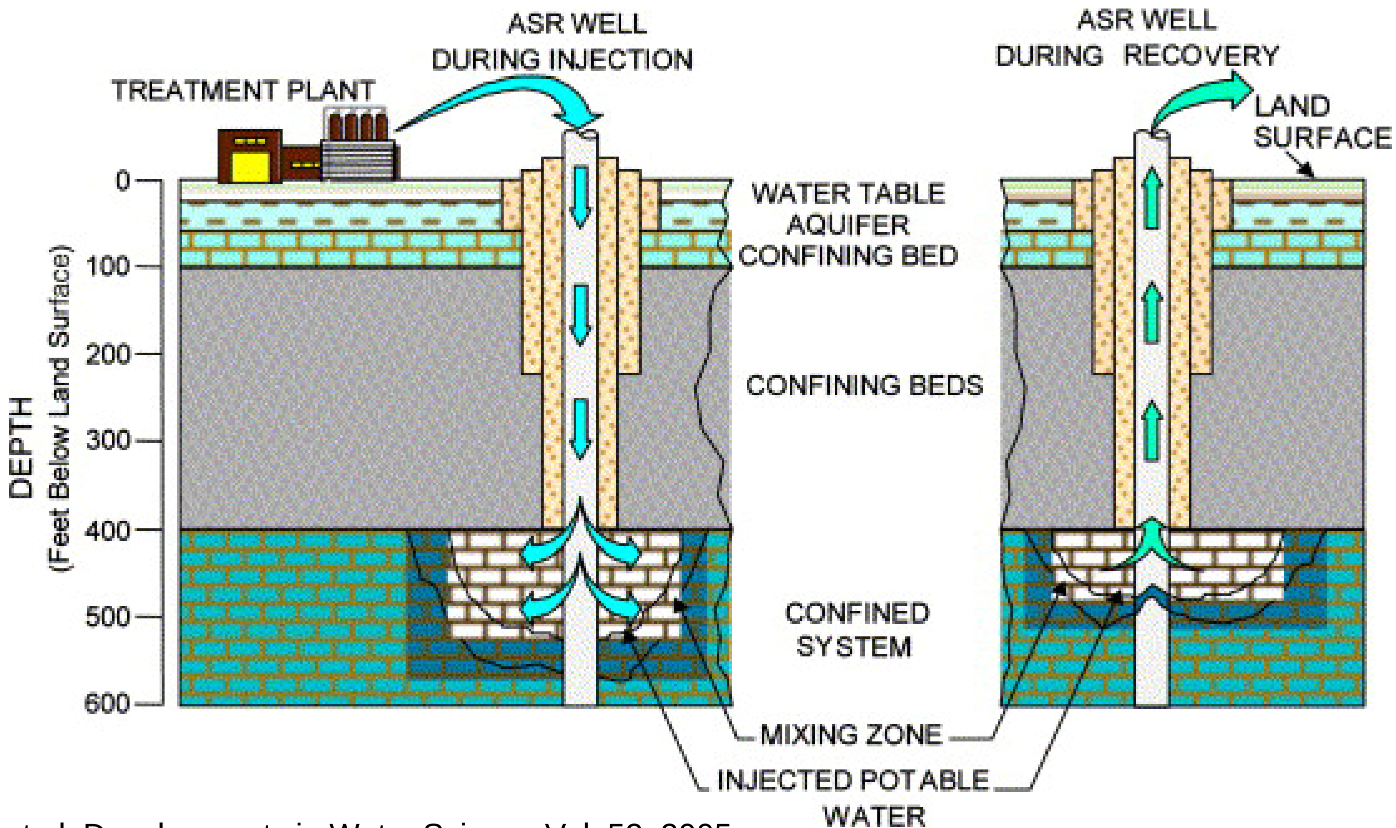


Image from Muniz et al, Developments in Water Science Vol. 52, 2005

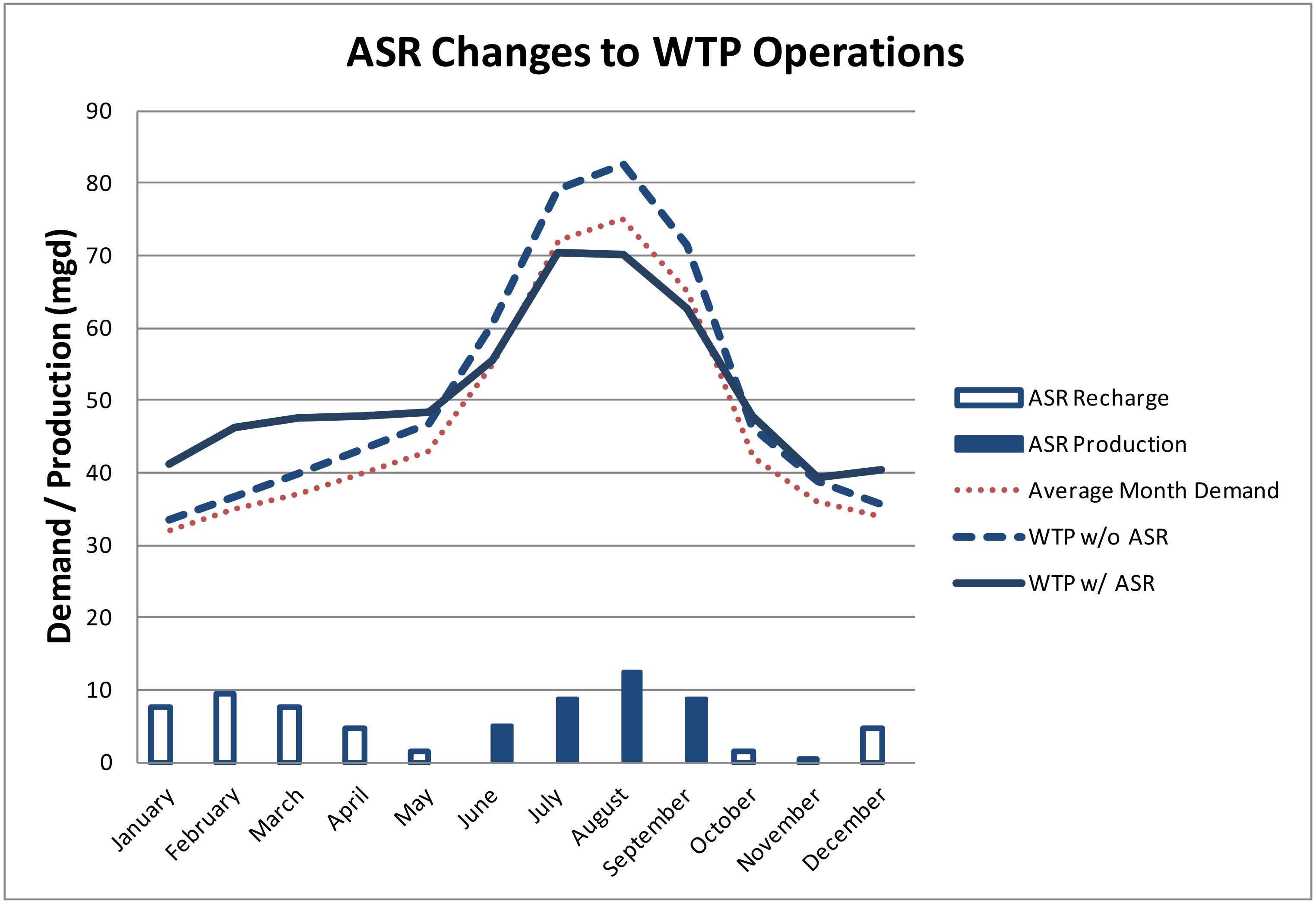
Key Benefits of ASR

- Lower capital costs
  - Defer expansion of treatment
  - New above-ground storage
- Optimize use of existing facilities
- Enhance reliability and supplement yield
- Reduce supply vulnerability
- Reduce water losses (seepage, ET)
- Minimize environmental impacts

Unique Aspects to ASR Affecting Fundamental Planning Assumptions

- Large stored volume, but only available at a limited rate
- Source of supply that is not on year round, but is always somewhat available
- Source that acts as a demand in the winter during recharge period (typically around 2/3 of production rate)

Example Supply Curve for ASR Operations



Distribution System Operational/Planning Considerations

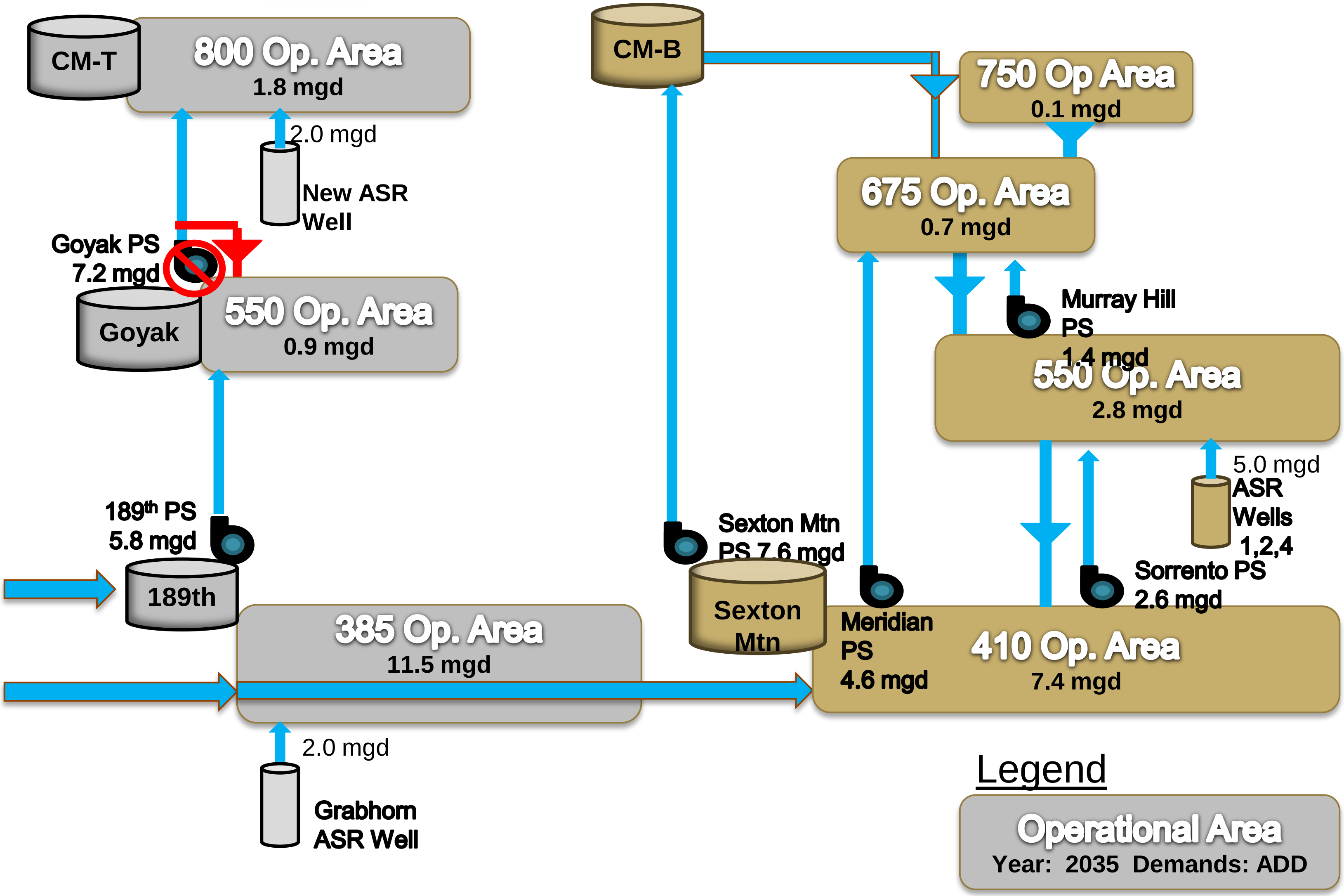
- Understand which demands are being served
- Use hydraulic modeling to optimize operations to control flows for recharge
  - Maintain flow directions
  - Account for higher velocities
- Additional O&M costs when pumping recharge water
- Improvements to existing distribution system
  - Pumping capacity to recharge
  - PRVs to distribute water

Pumping Capacity Evaluation with ASR

- Traditionally pumping capacity based on (summer):
  - Firm capacity to meet MDD
  - Firm capacity to meet PHD (with no reservoir)
  - MDD with largest source out of service
- With ASR need to evaluate summer and winter
  - Winter capacity > summer capacity for large ASR systems
  - Winter: use peak capacity instead of firm capacity (since recharge can be shut off)

HDR

Infrastructure Considerations



Potential for *Reduced* Storage Needs

- Typical Storage Design Criteria (e.g. WA)
  - Operational = volume supplying system when supply is off
  - Equalization = (PHD – Q_s)(150 min)
  - Fire suppression = (FF)(t_m)
  - Standby = (2 days)(ADD)(ERUs) – t_m(Q_s-Q_L)
- Other Storage definitions (e.g. OR)
  - 3xADD
  - 2xADD + FSS + 0.25xMDD
  - Multiple sources addressed subjectively

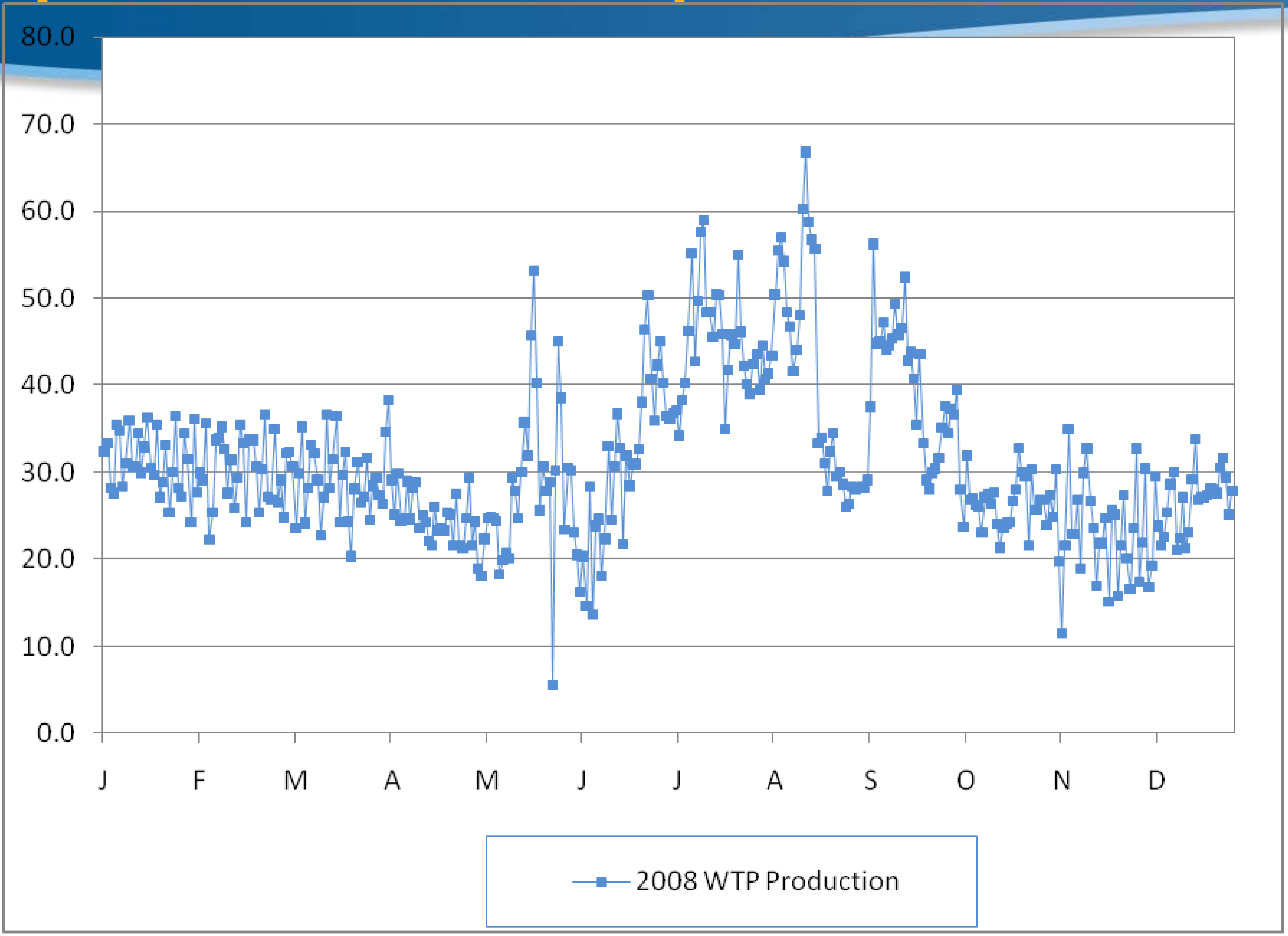
Reducing storage requirements through ASR

- ASR benefits emergency storage
- Consider ASR as part of a multiple source system
  - Provide auxiliary power (auto-start)
- Level-of-service analysis
  - Community expectations to reduce standby from 2 days to 1 day volume
  - Production capacity could be affected by time during recovery period

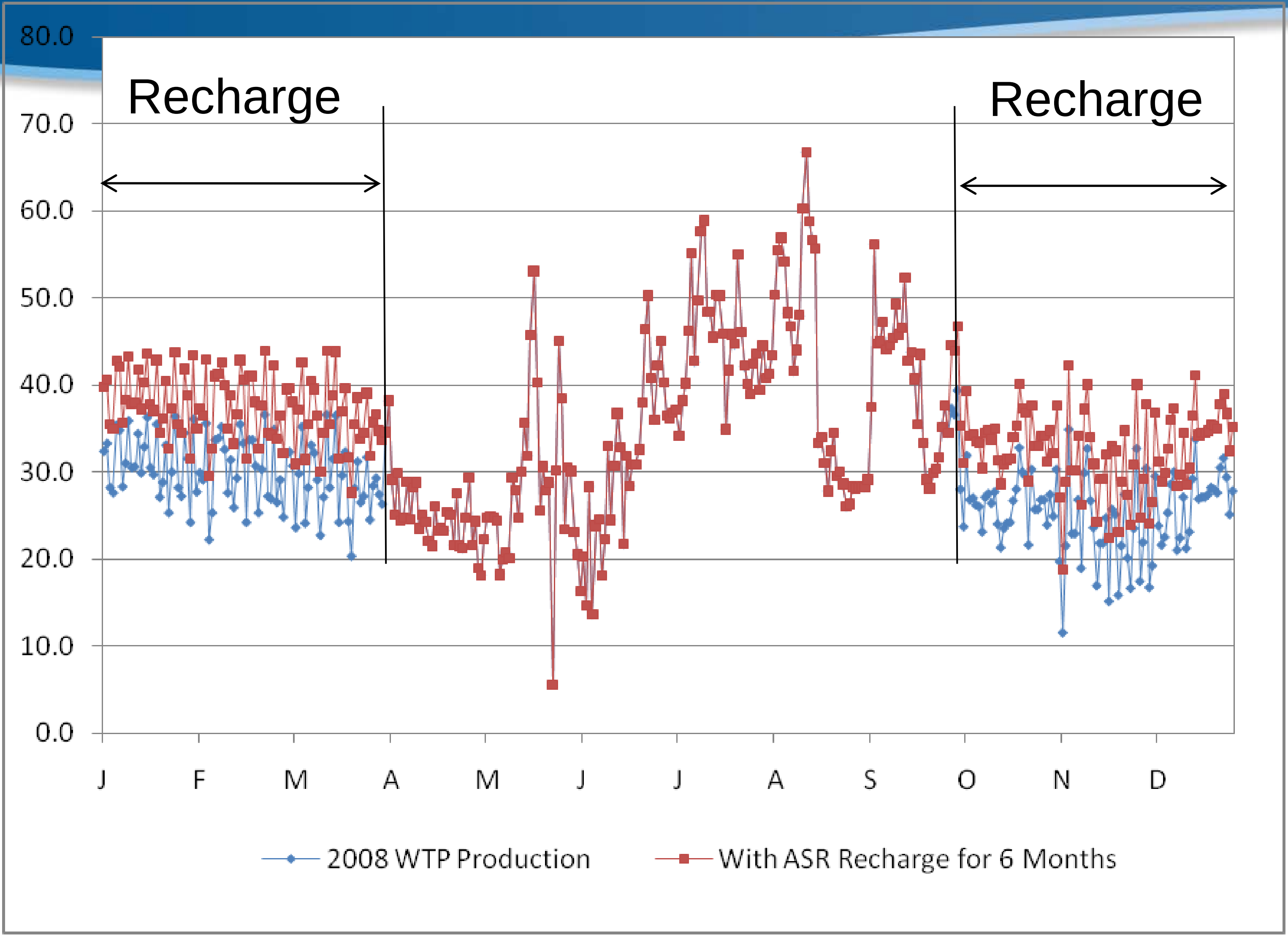
Impacts on WTP Operations

- ASR increases use of WTP during winter season and could reduce use during summer season
  - *Could see significant flattening of production curve*
- Winter capacity of the plant could determine the level of ASR that can be supported

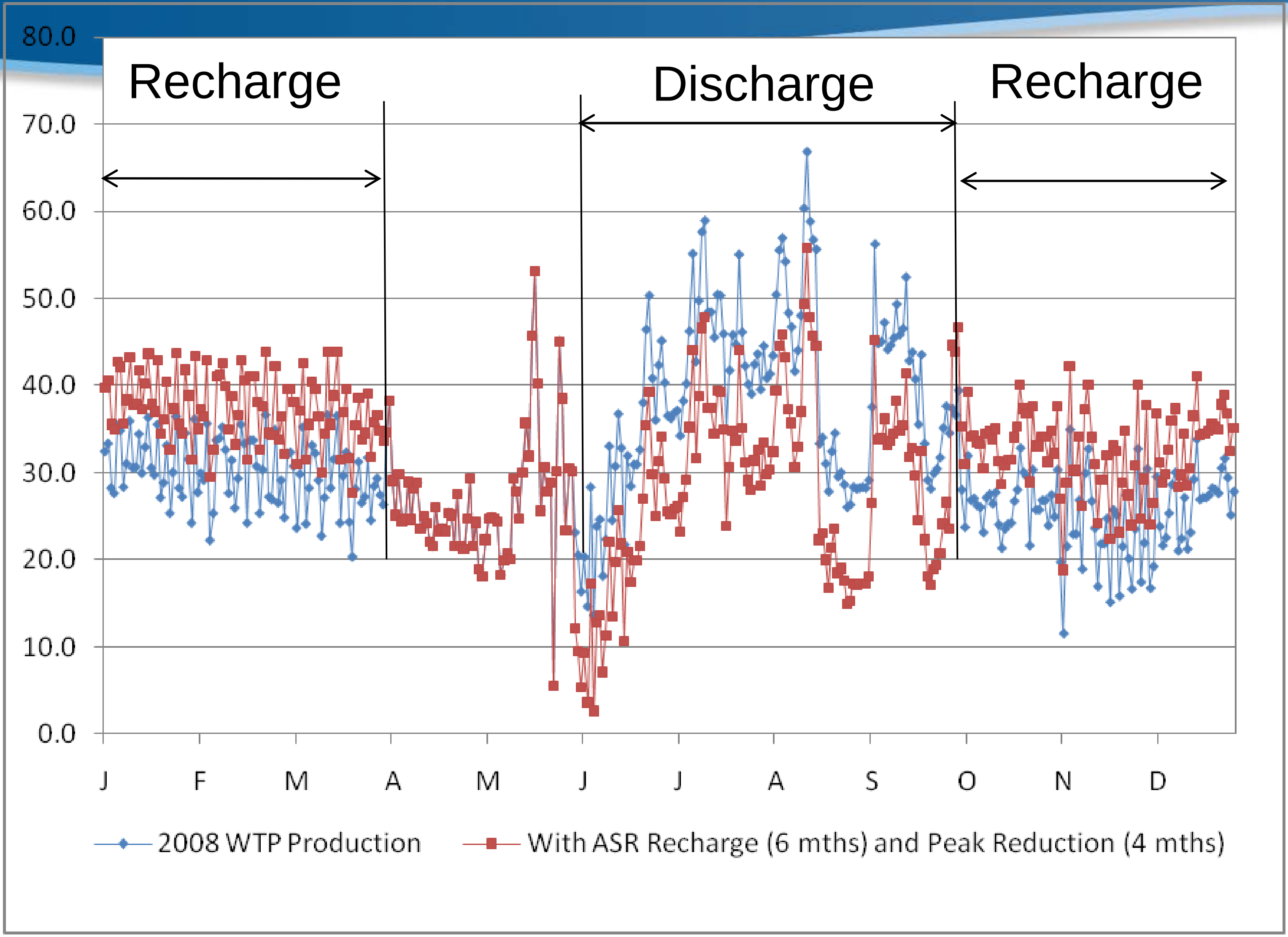
Step 1: Start with WTP production data



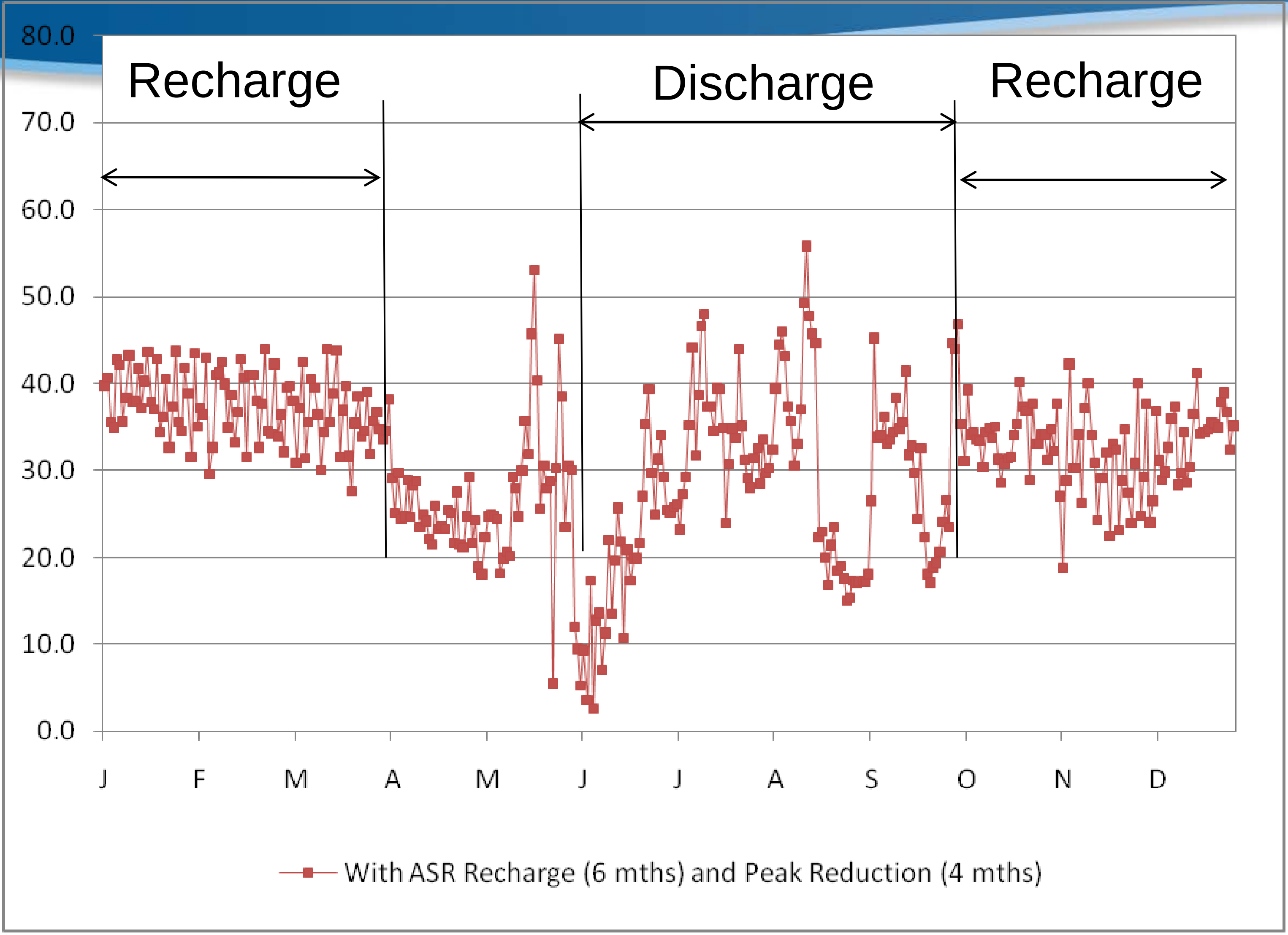
Step 2: Add ASR recharge waters



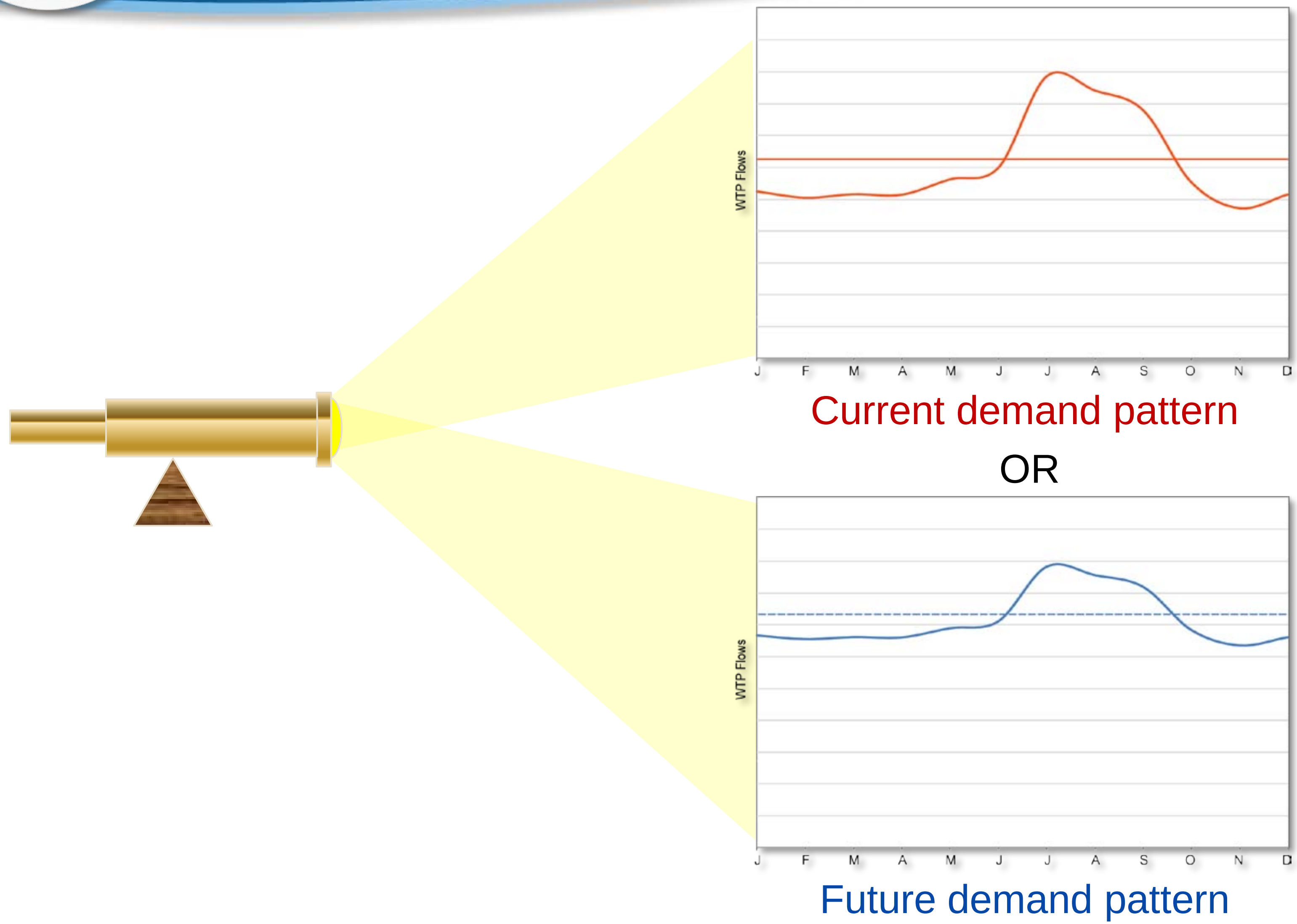
Step 3: Add ASR peak season supply



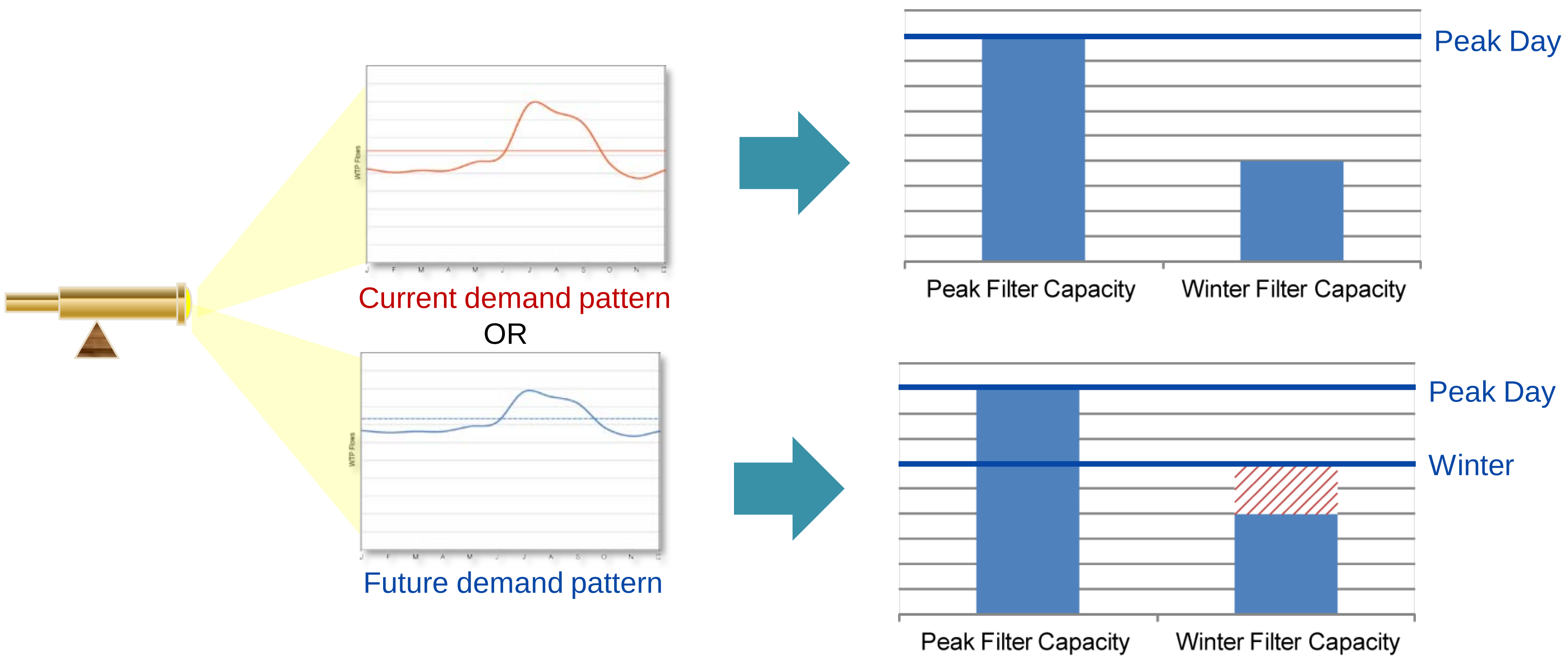
Step 3: Add ASR peak season supply



To hit the target, you have to know what you're shooting at



Defining level of service goals now will avoid surprises later



Plant hydraulics and process capacity to support ASR

Summary and Conclusions

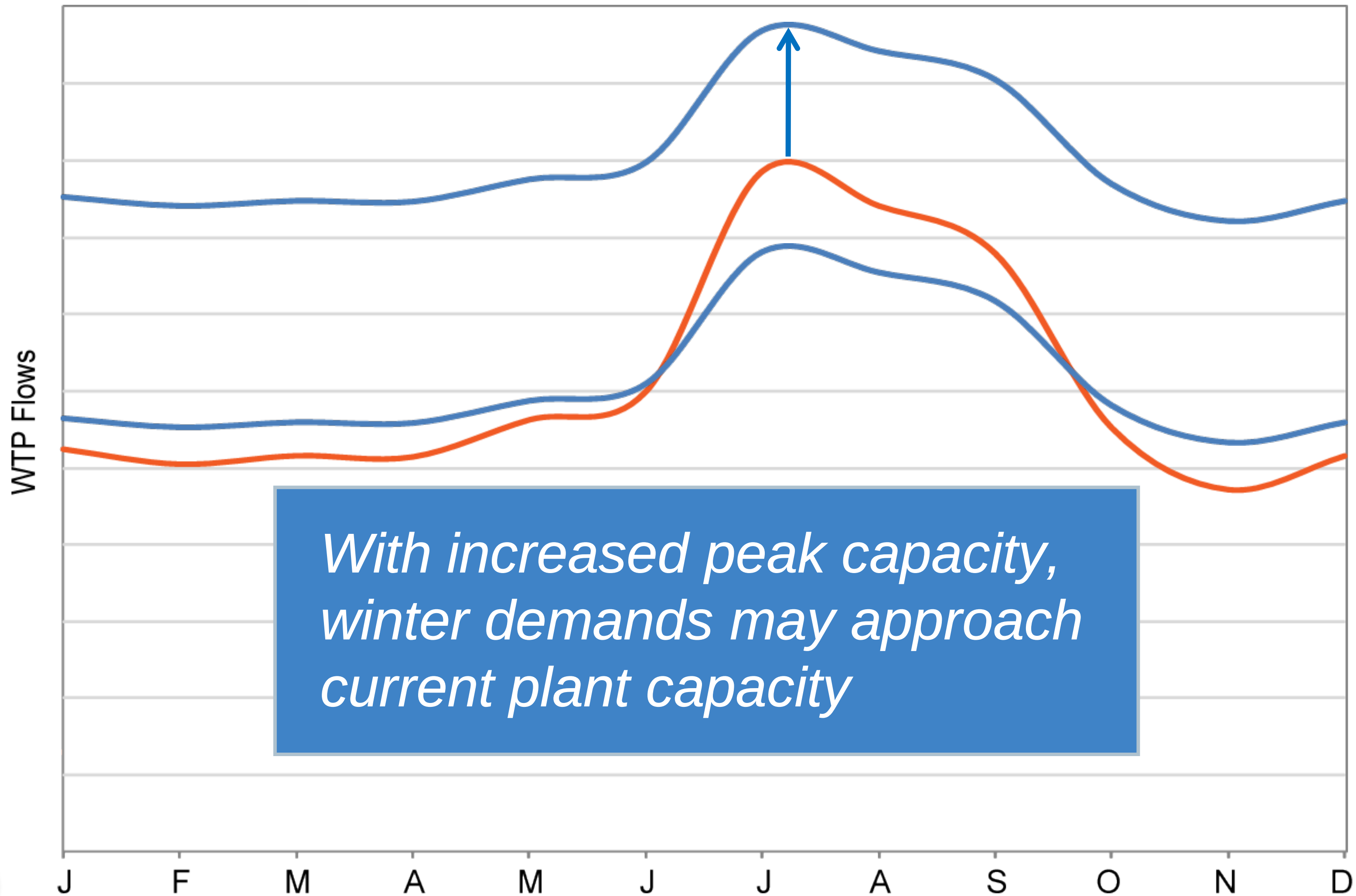
- ASR is a sustainable and cost-effective supply approach
- Expanding applications for integrated water resource management
- Water treatment and distribution system operations and planning also need attention for long-term success

Questions?

Thank you!

Ronan V. Igloria, PE
Ronan.Igloria@hdrinc.com

Overall water supply strategies will affect demand patterns at the WTP



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2012 PNWS • YAKIMA, WA

Disinfection Byproduct Control and Optimization

Presented to:
Spring Conference 2012, Yakima, Washington
Pacific Northwest Section American Water Works Association

Kim Ervin, P.E.
Regional Drinking Water Practice Leader
Kim.Ervin@ch2m.com

Two Systems Working for Compliance with DBP Rule

- Filtered System: Raymond, Washington
  - Direct Filtration Plant
  - Cationic polymer, without coagulant
  - Pre-chlorination at head of plant
  - High formation of haloacetic acids in distribution system
- Unfiltered System: Ketchikan Public Utilities
  - Chlorine CT only for disinfection
  - High formation of haloacetic acids in distribution system
  - Need to comply both with disinfection byproduct limits and Cryptosporidium inactivation

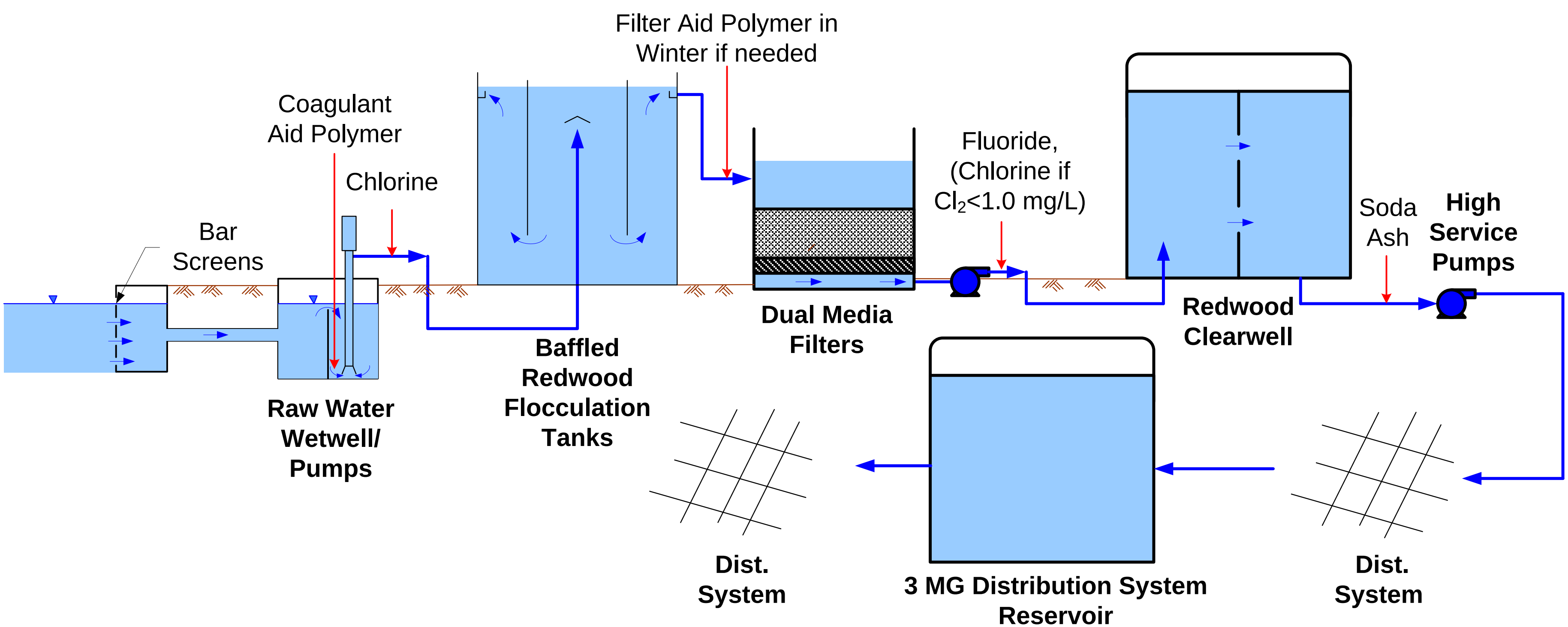
Filtered Source Compliance with Disinfection Byproduct Rule

Raymond, Washington

Raymond, Washington

- Population: 3,000
- Average Precipitation: 85 inches
- Temperatures:
  - Winter 32 to 46 F
  - Summer 50 to 70 F
- Water Treatment Plant
  - Built in 1972
  - Direct filtration with chlorine disinfection
  - Capacity: 1400 gpm
  - Average Demand: 375 gpm
  - Peak filter loading rate: 5 gpm/sf
  - Plant operates on/off to fill distribution system tank.

Existing Treatment Train



Existing Treatment Plant

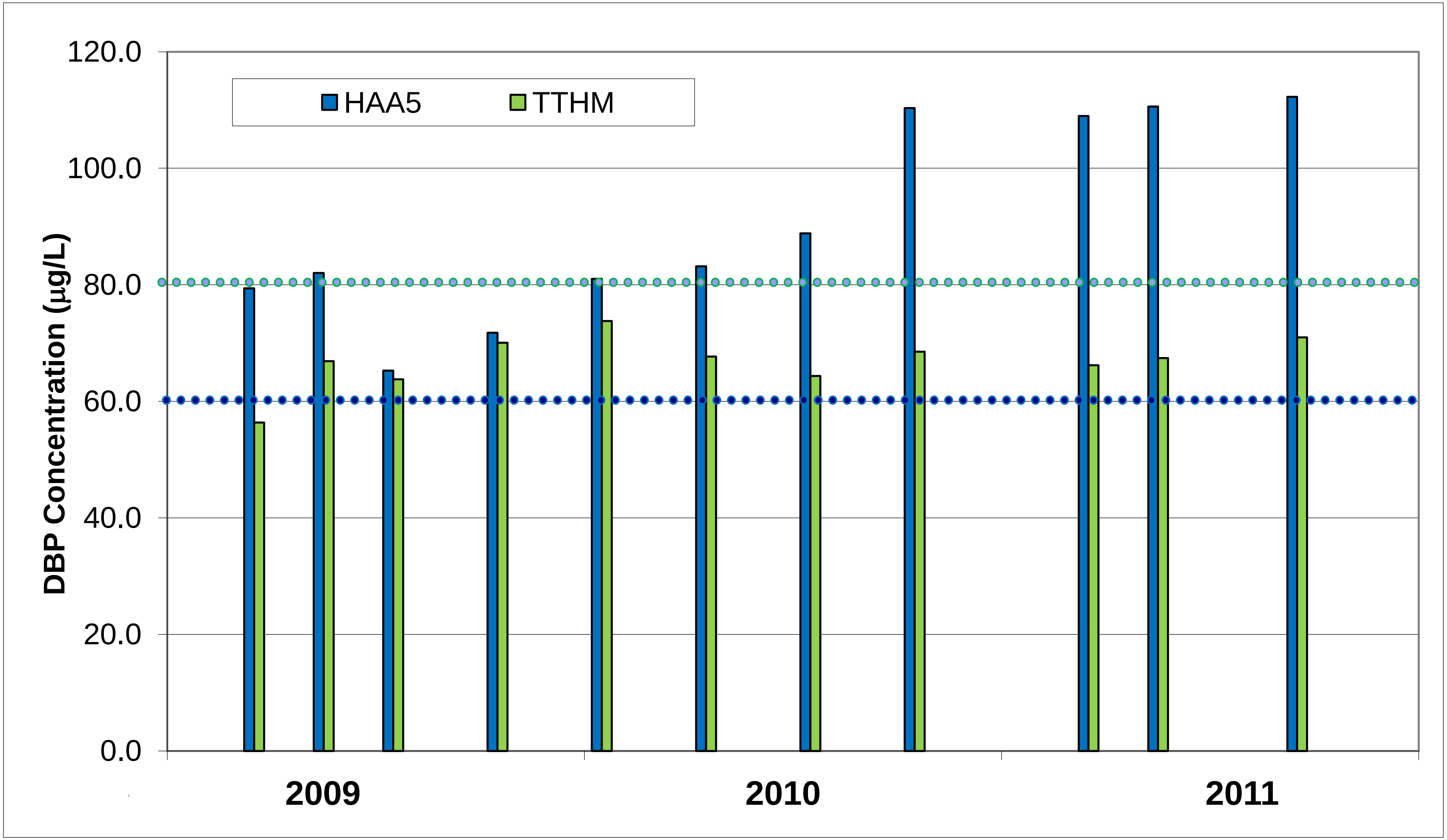
Clarifier

Filter

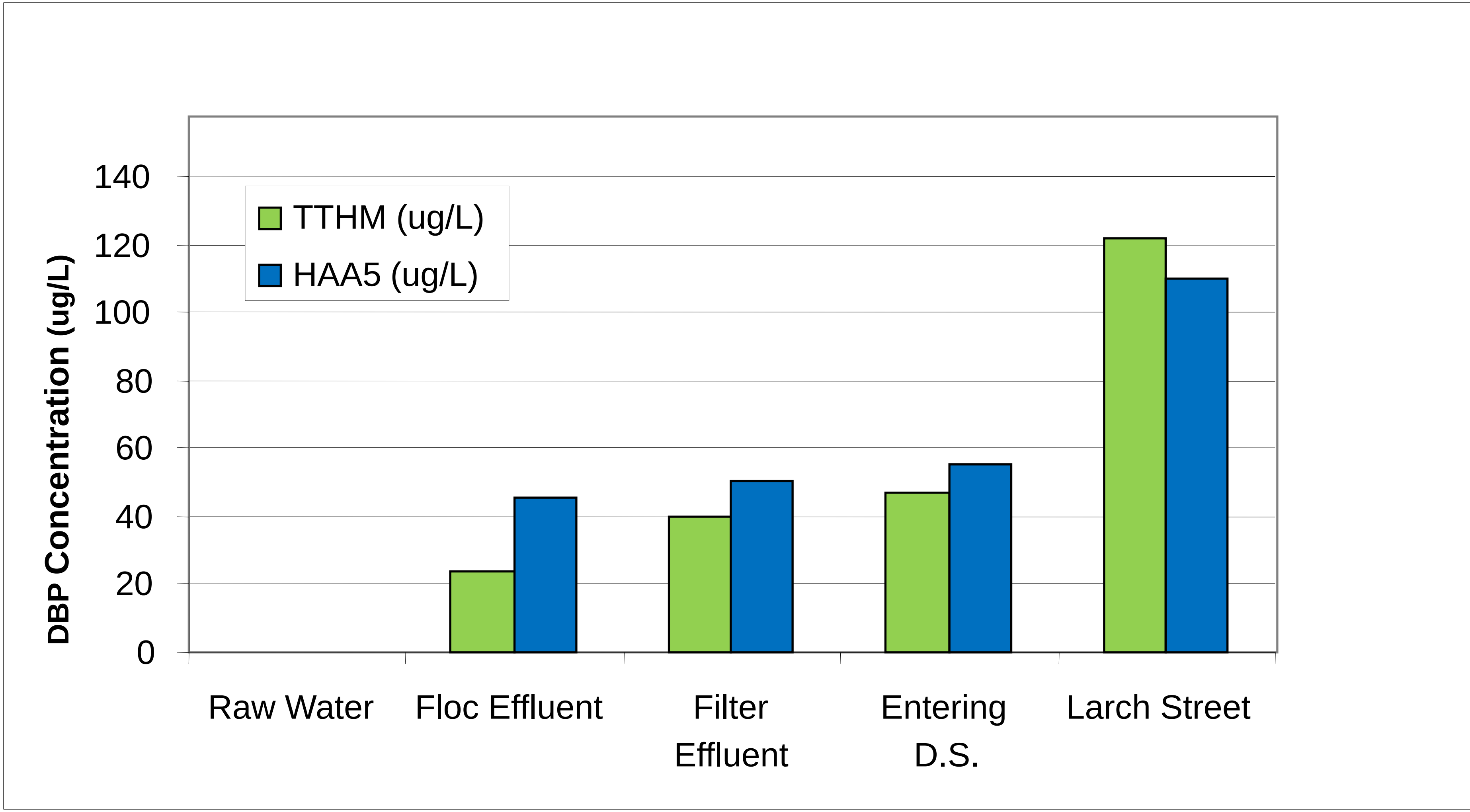
Typical Raw Water Quality

Sample Information				
Project Name		Raymond WTP	Raymond WTP	Raymond WTP
Sample Description		Raw Water	Raw Water	Raw Water
Sample Collection Date		8/17/2011	11/22/2011	2/22/2012
General Chemistry Analysis				
pH	Units	7.71	7.17	7.45
Turbidity	NTU	1.58	31.3	73.7
TOC	mg/L	1.21	2.8	3.2
DOC	mg/L	1.16	2.5	2.3
UV_{254}	abs $*cm^{-1}$	0.0400	0.1505	0.1225
SUVA w/DOC	L/mg-m	3.45	6.09	5.28
Alkalinity	mg/L as $CaCO_3$	25.9	16.8	9.2
Ammonia	mg/L as N	0.048	<0.10	<0.10

Disinfection Byproduct Level
Maximum Locational Running Annual Average



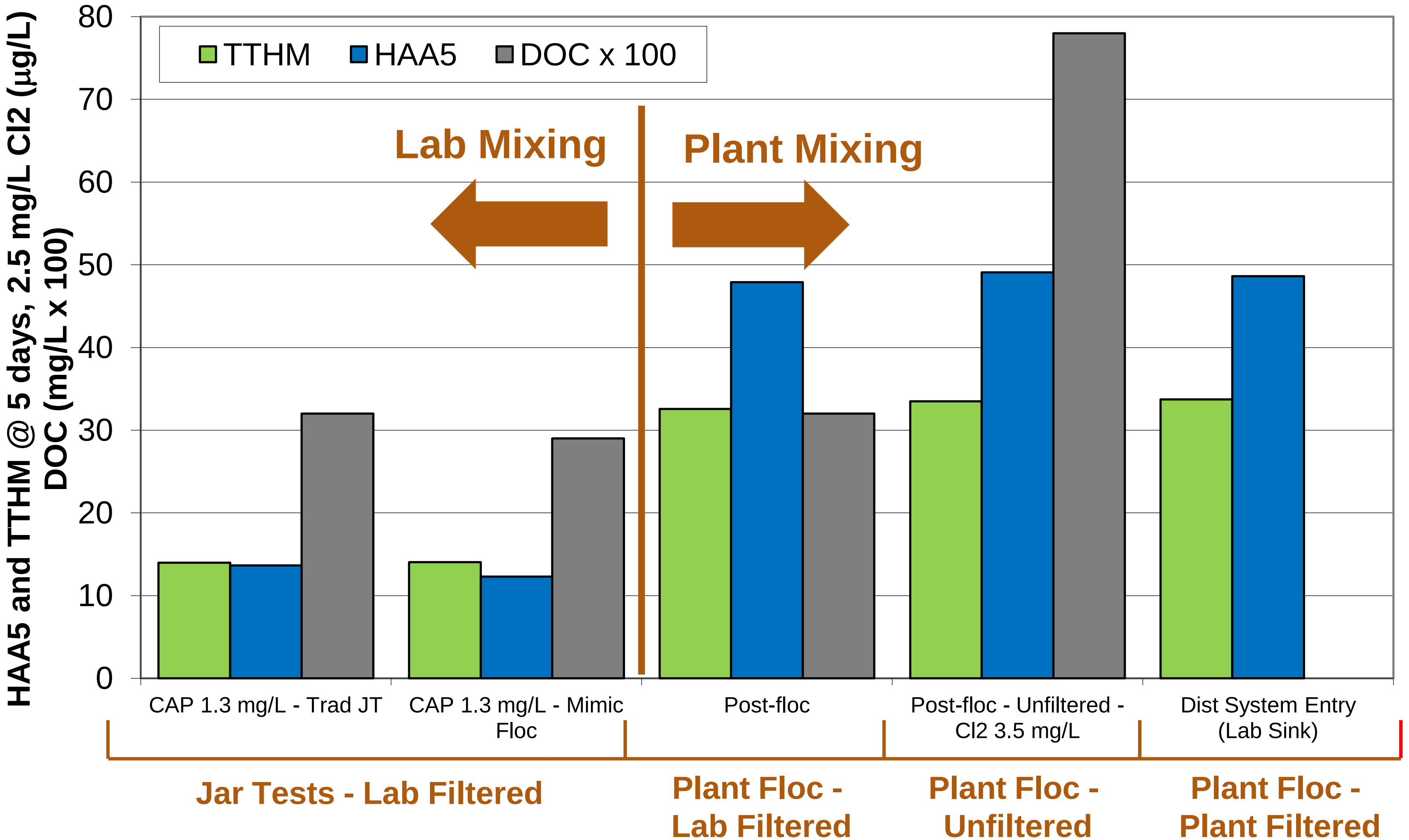
DBP Profile through the Plant



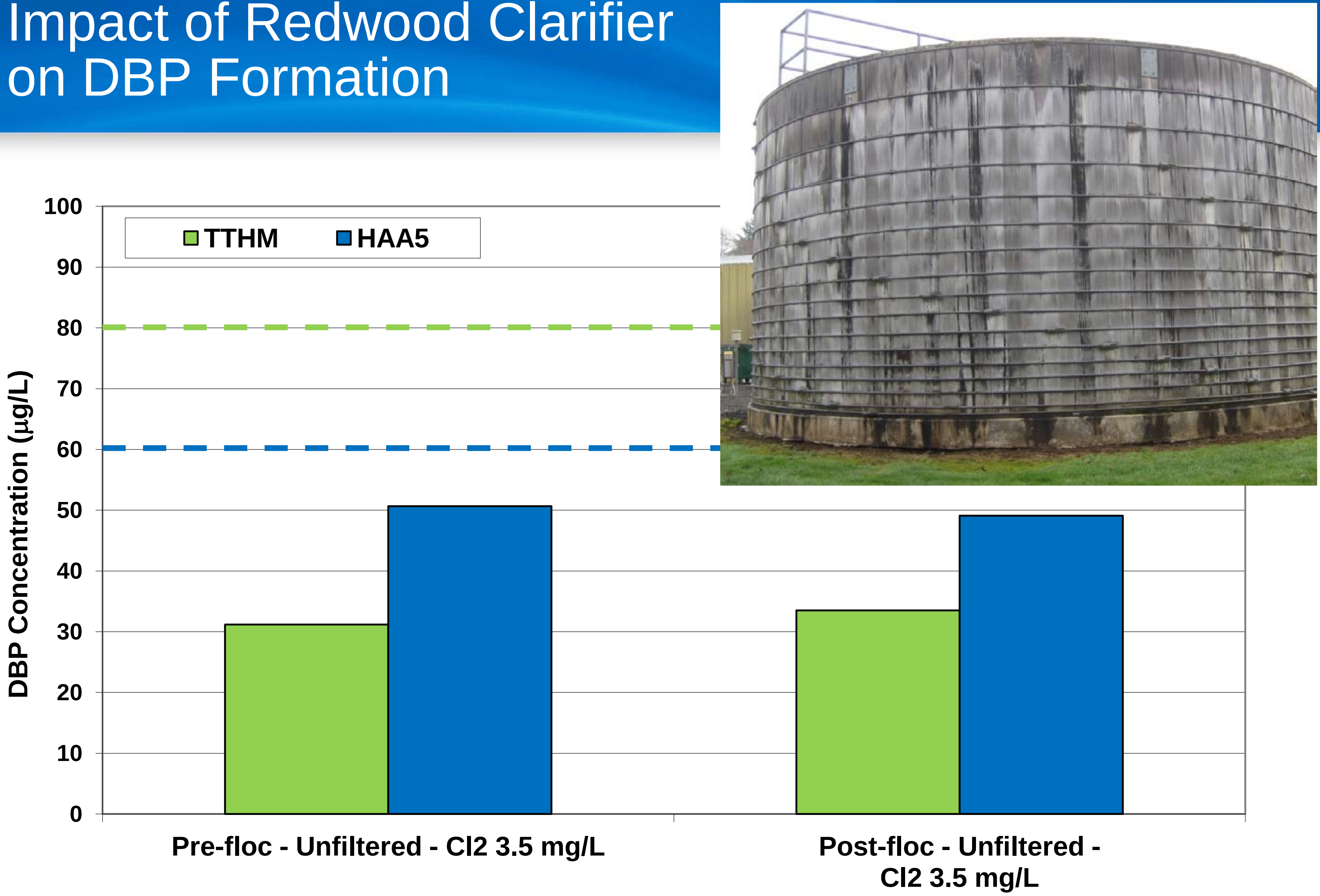
Treatment Approach

- Add sedimentation step to increase log removal credit and decrease CT requirement for chlorine.
- Optimize coagulant addition for removal of DBP precursors.
  - *Raymond historically used alum but found that it blinded the filters during higher turbidity events. Switched to cationic polymer only.*
- Improve rapid mix and flocculation of coagulants.
- Relocate chlorine injection downstream of filtration.

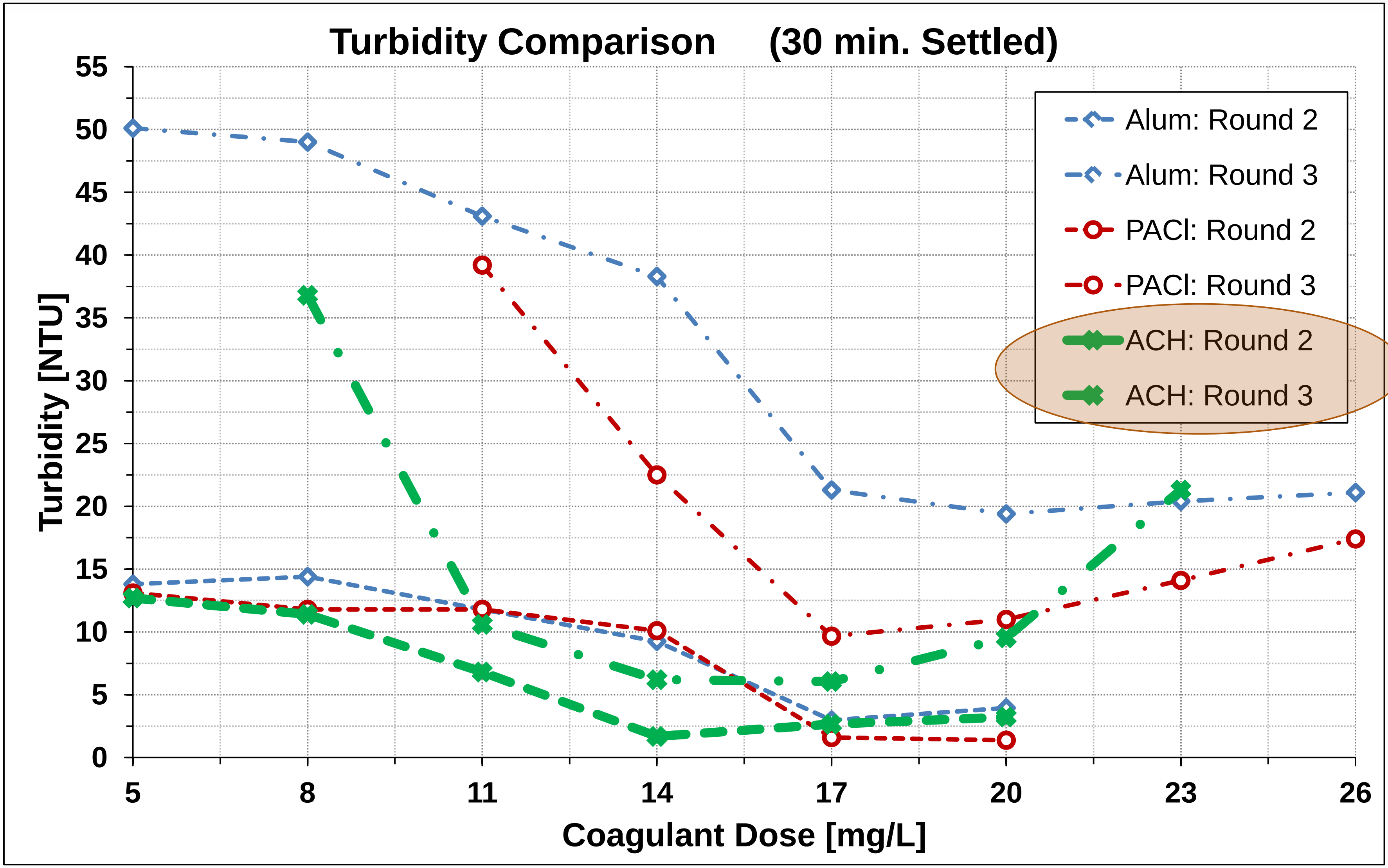
The Importance of Mixing



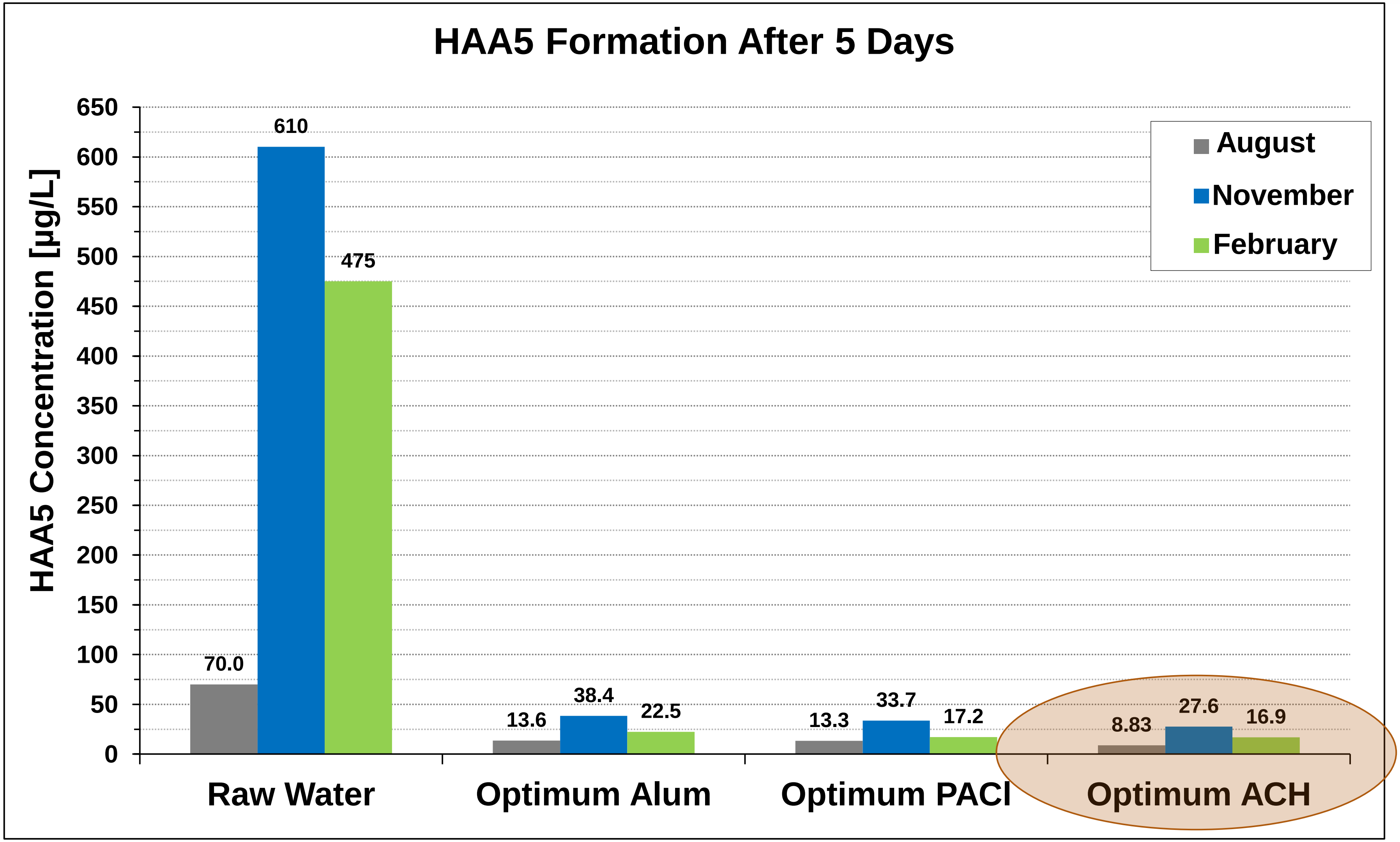
Impact of Redwood Clarifier on DBP Formation



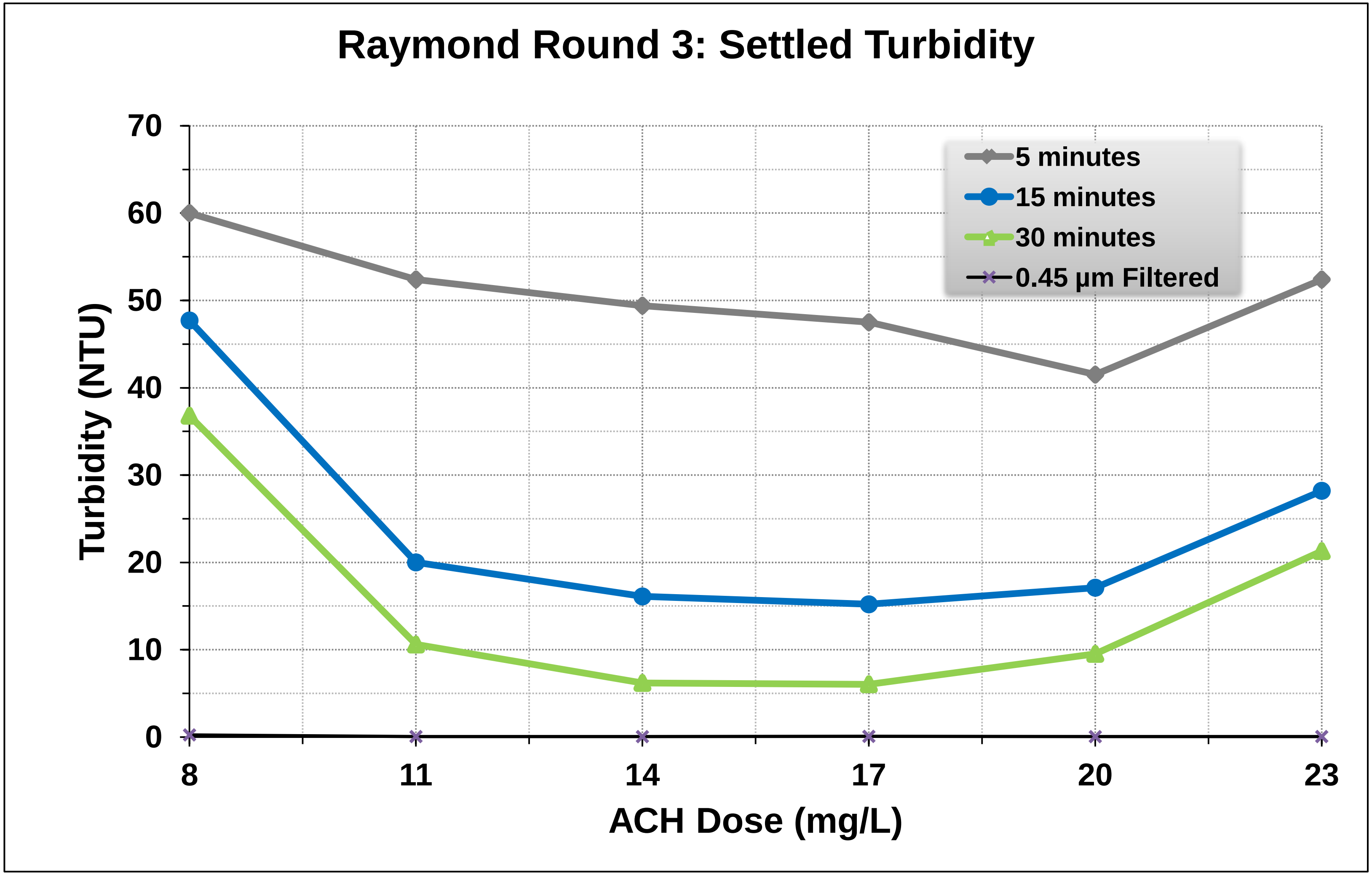
Optimizing the Coagulant: Turbidity



Optimizing the Coagulant: DBPs



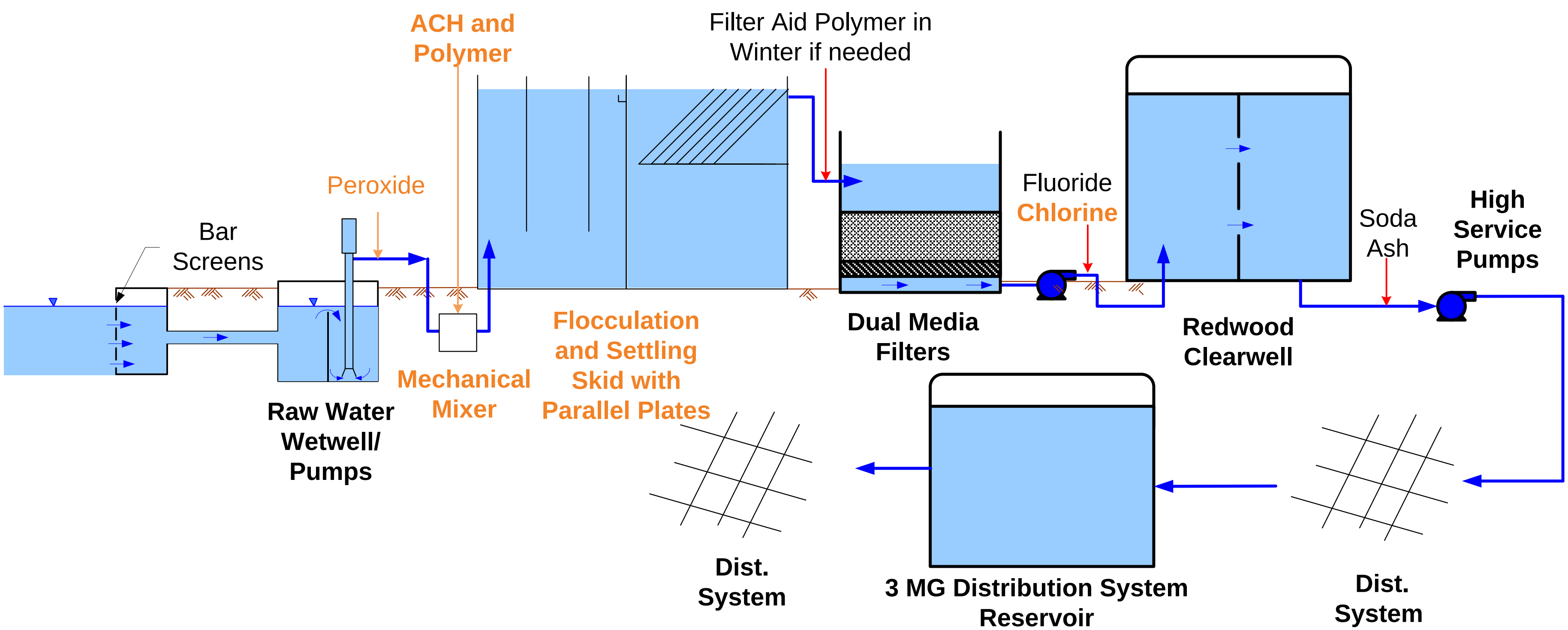
Optimizing Flocculation Time



Treatment Process Changes

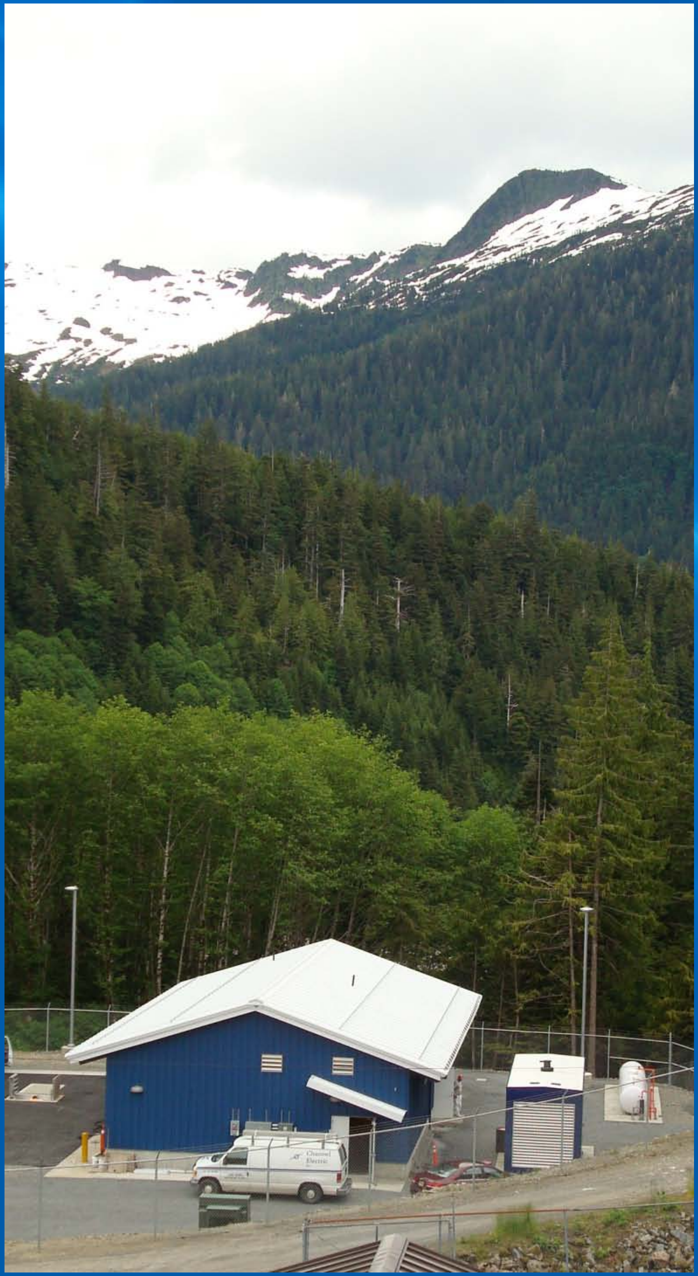
- Convert to Conventional Filtration by adding solids removal step.
- Add rapid mechanical mixer and improve flocculation.
- Add ACH as coagulant and keep the coagulant aid polymer.
- Add AFDs to reduce plant flow and lower filter loading rate.
- Relocate point of chlorine addition.

Process Flow Diagram with Improvements



Unfiltered Source Compliance with Disinfection Byproduct Rule

Ketchikan, Alaska

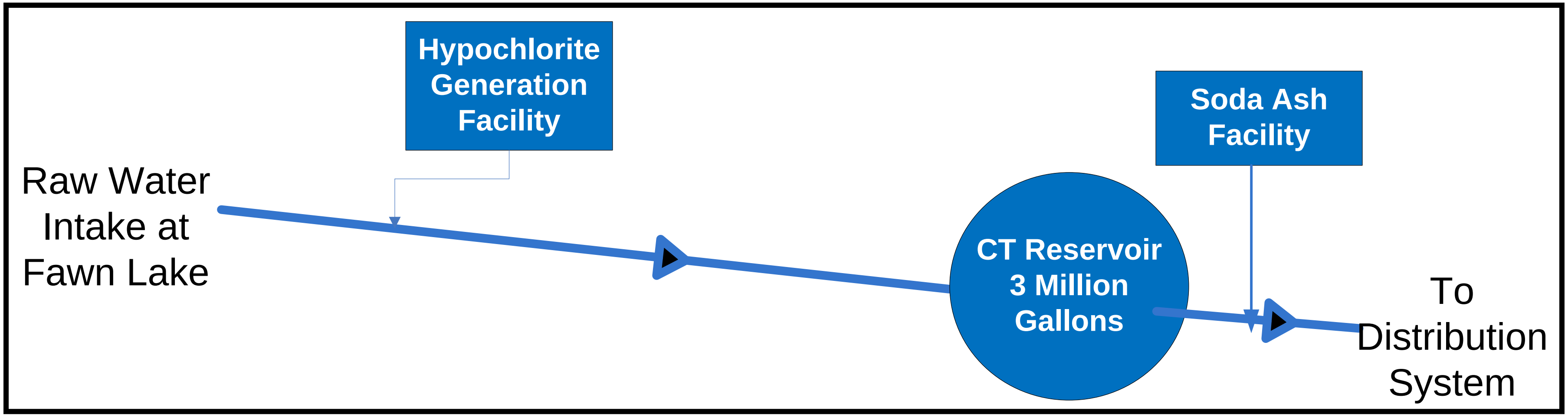


Ketchikan, Alaska

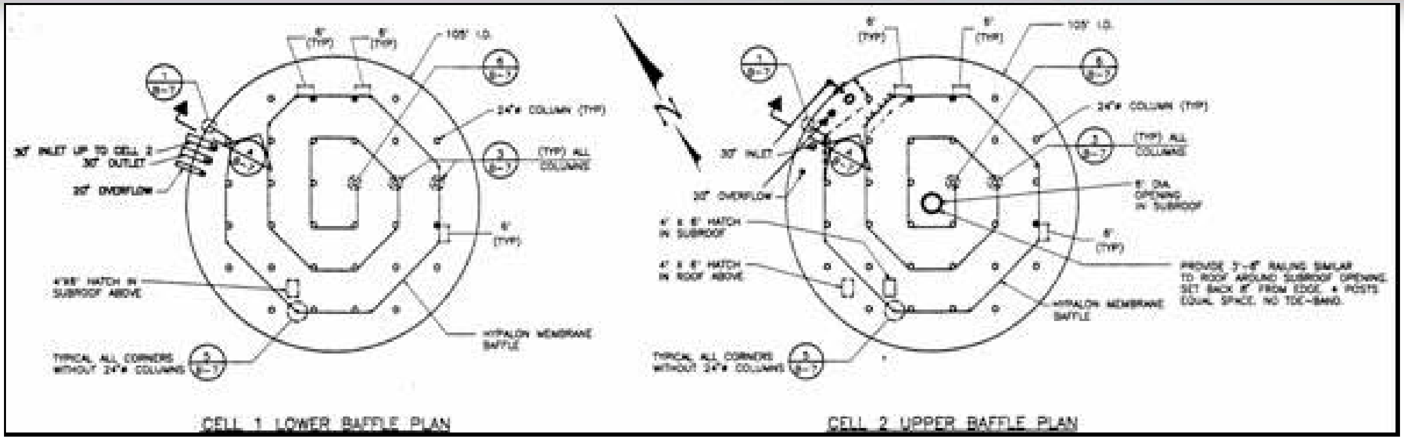
- Population: 7,500
- Southernmost "large" city in Alaska (5th largest)
  - Distance from Seattle = 668 miles
  - Distance from Anchorage = 771 miles
- Average Rainfall:
  - Ketchikan=152 in (>12.5 ft)
  - Seattle=37 in
- Average Temperature
  - Summer High = 57F
  - Winter Low=28F

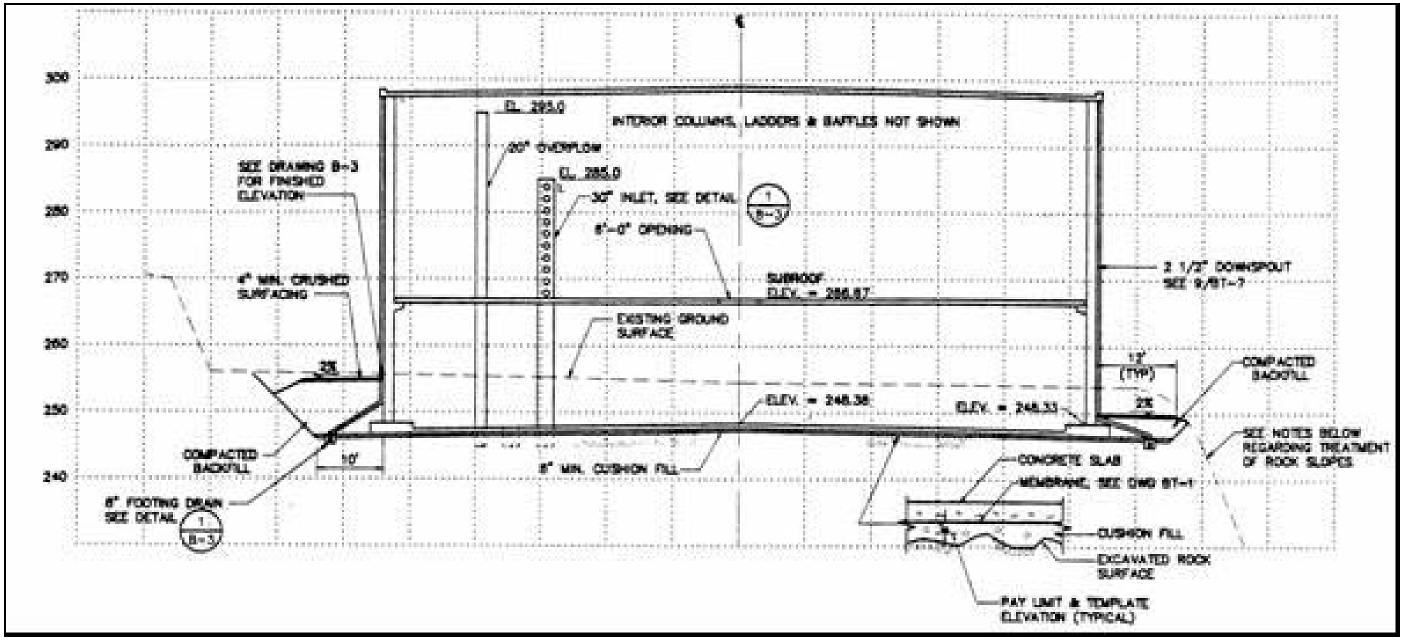
Ketchikan's Original Water Treatment Facilities

- Unfiltered System - Provides only Chlorination
- Wide range of flows due to two major seasonal industries (2 to 15 mgd)
  - Cruise ships
  - Fish processing



Bear Valley CT Reservoir





Ketchikan Project Drivers

- Meet requirements of LT2ESWTR (Crypto)
- Achieve 'simultaneous compliance' with LT2ESWTR and Stage 2 DBP Rule (HAA5)
- Minimize formation of HAAs and TTHMs by adding ammonia to form monochloramine as residual disinfectant

Raw Water Quality

Parameter	Average Value	Range
Water Temp (°C)	8.7	2.5 - 19.4
Turbidity (NTU)	0.20	0.12 - 1.99
UV Transmittance (%/cm)	86	69 - 98
pH	6.1	5.8 - 6.3
TOC (mg/L)	1.52	0.5 - 1.9
DOC (mg/L)	1.44	0.5 - 1.8
Hardness (mg/L as $CaCO_3$)	2.6	2.3 - 3.4
Bromide (mg/L)	0.03	NA
Iron (ug/L).	ND	ND
Manganese (ug/L)	ND	ND

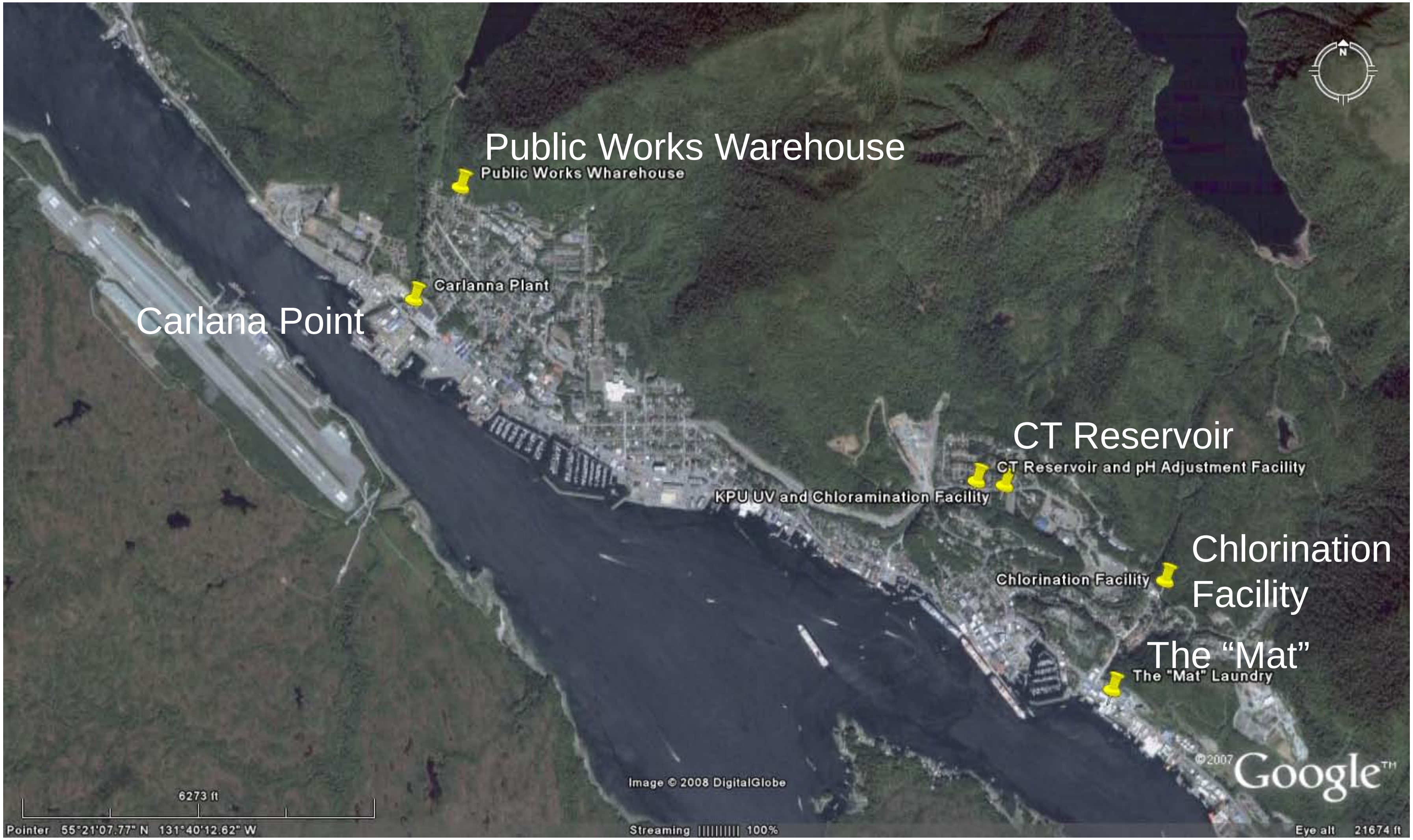
DBP Formation Indicators

Historical Raw Water Quality Data

Date	UV254	UVT (%/cm)	TOC (mg/L)	DOC (mg/l)	SUVA*
9/15/2003	0.083	82.4	1.63	1.51	5.5
10/7/2003	0.082	82.8	1.54	1.43	5.8
11/3/2003	0.084	82.4	1.90	1.76	4.8
12/1/2003	0.069	85.4	1.54	1.43	4.8
1/20/2004	0.076	83.9	1.45	1.34	5.7
1/28/2004	0.068	85.4	1.69	1.56	4.4
3/2/2004	0.067	85.6	1.37	1.27	5.3
5/3/2004	0.089	81.5	1.67	1.55	5.8
8/30/2004	0.048	89.6	1.47	1.36	3.5
10/5/2011	0.083	82.7	1.48	1.37	6.0

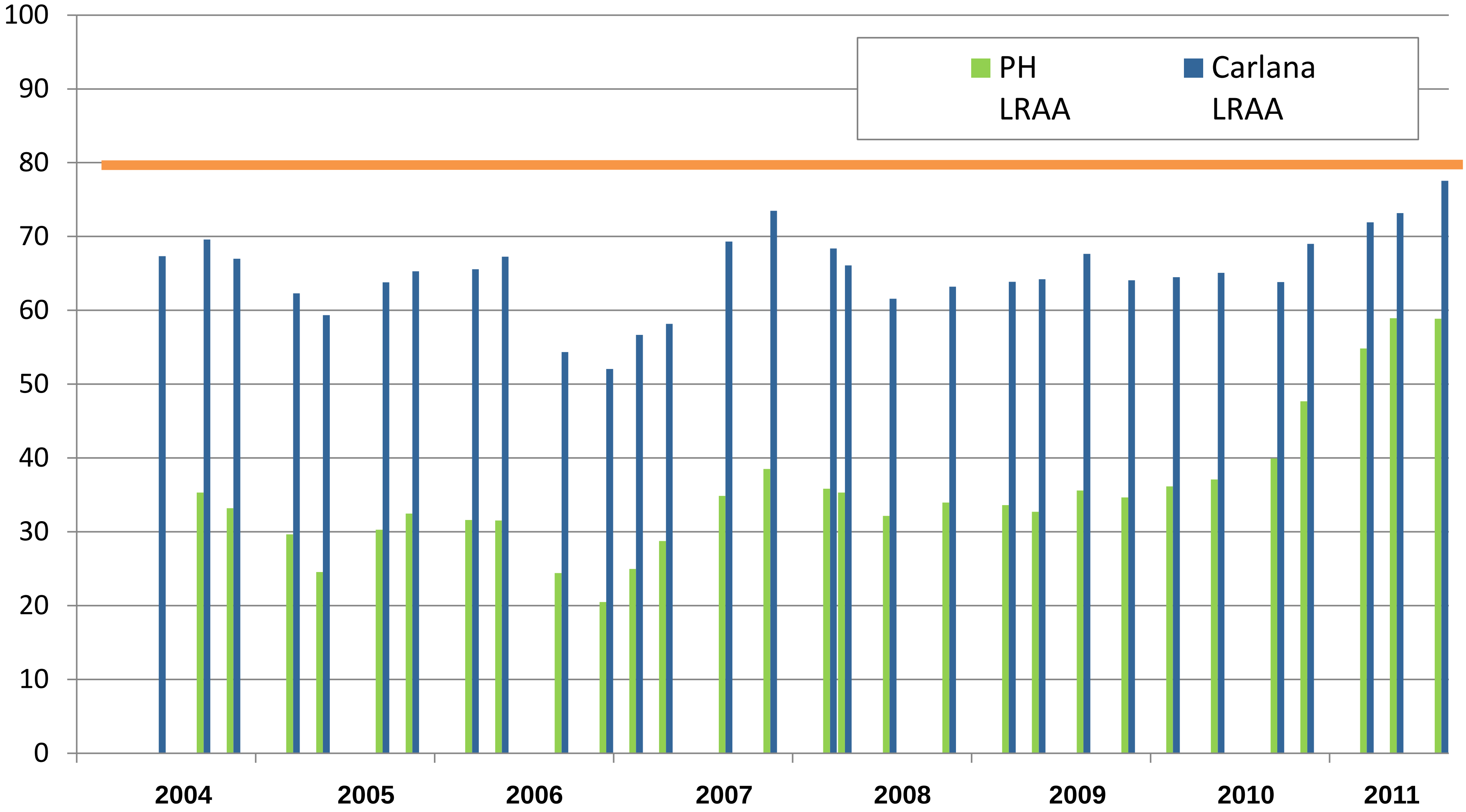
* SUVA is the ratio of UVA*100/DOC

Ketchikan DBP Sample Sites

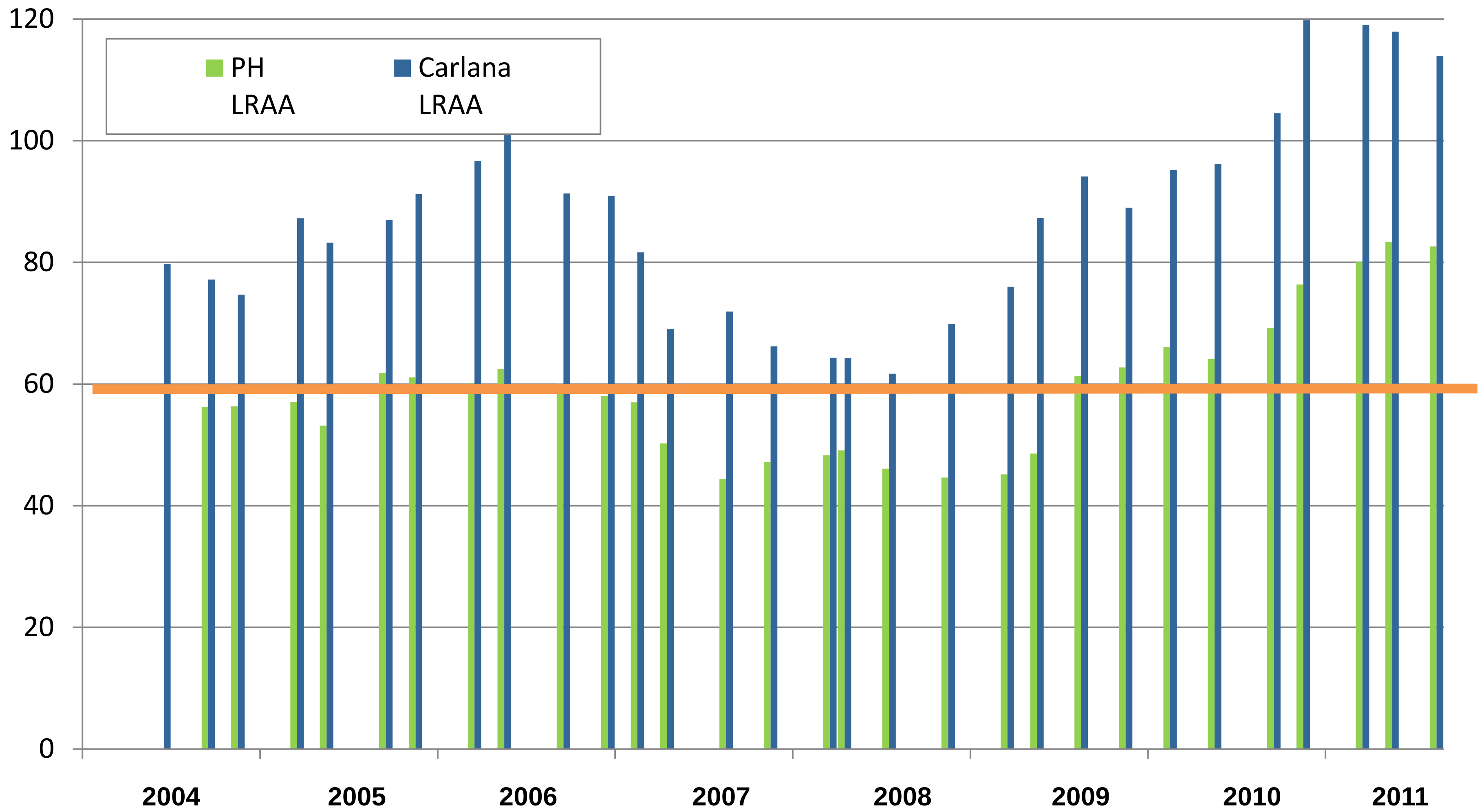


CH2MHILL.

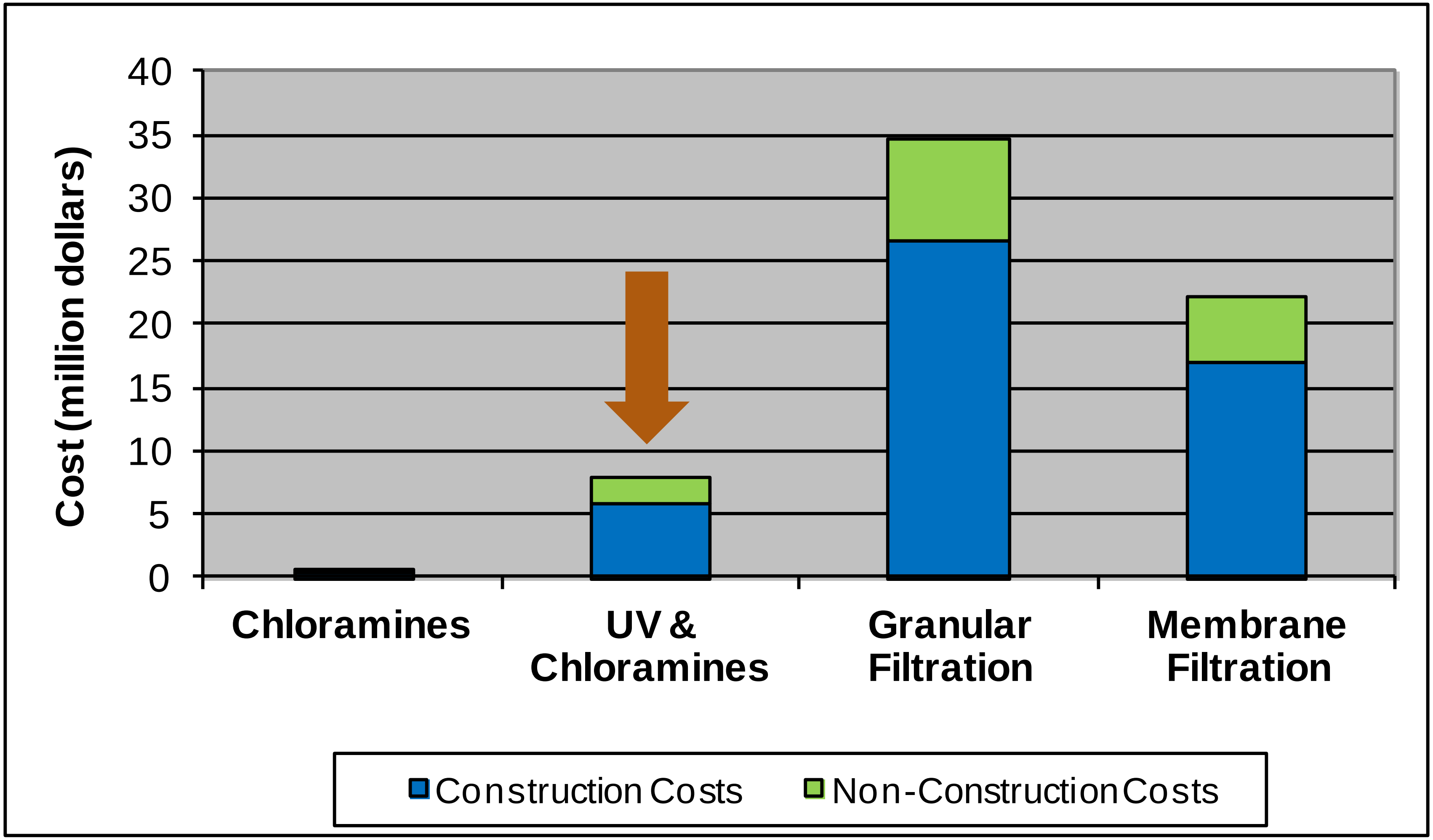
TTHM Locational Running Annual Average



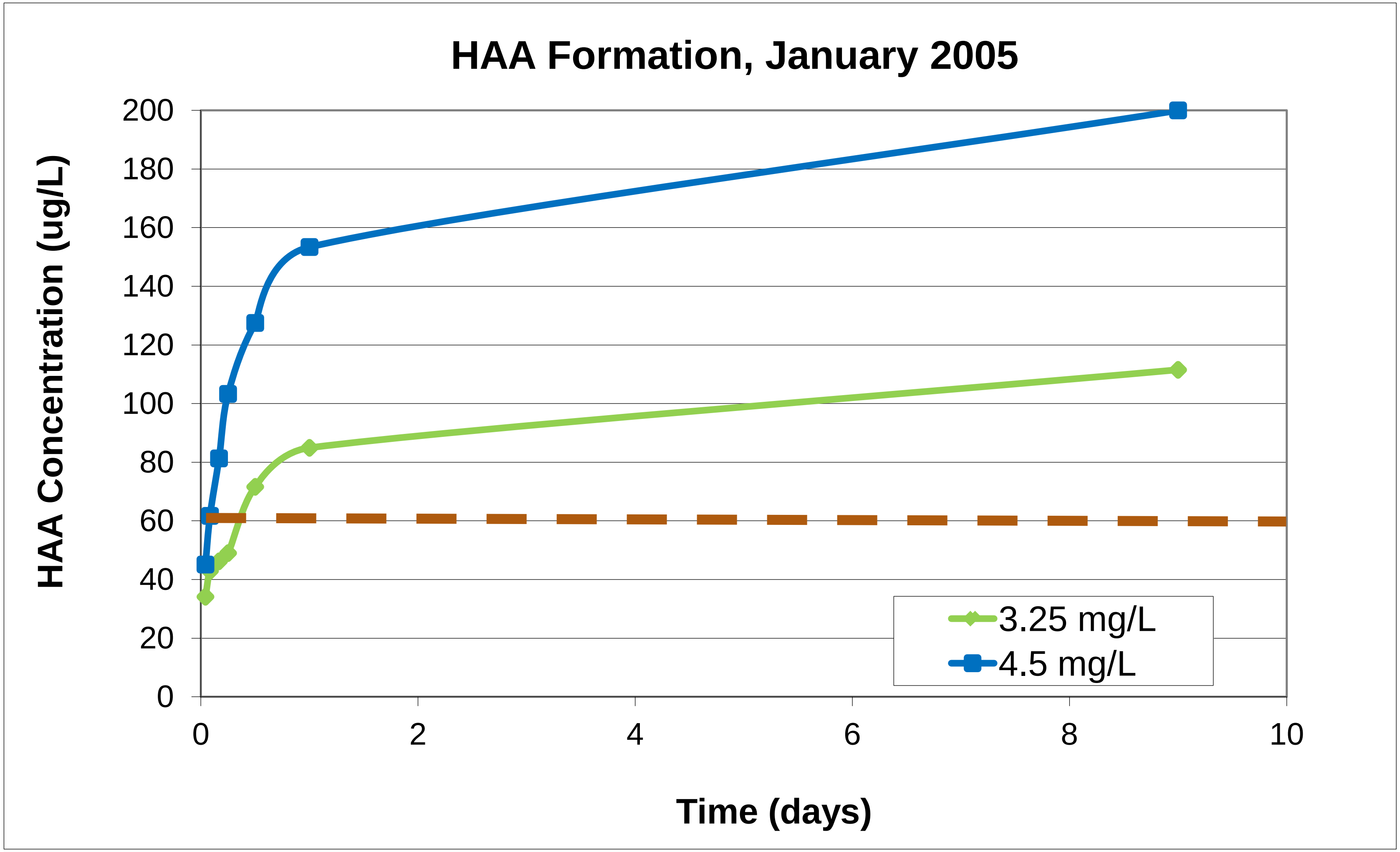
HAA5 Locational Running Annual Average



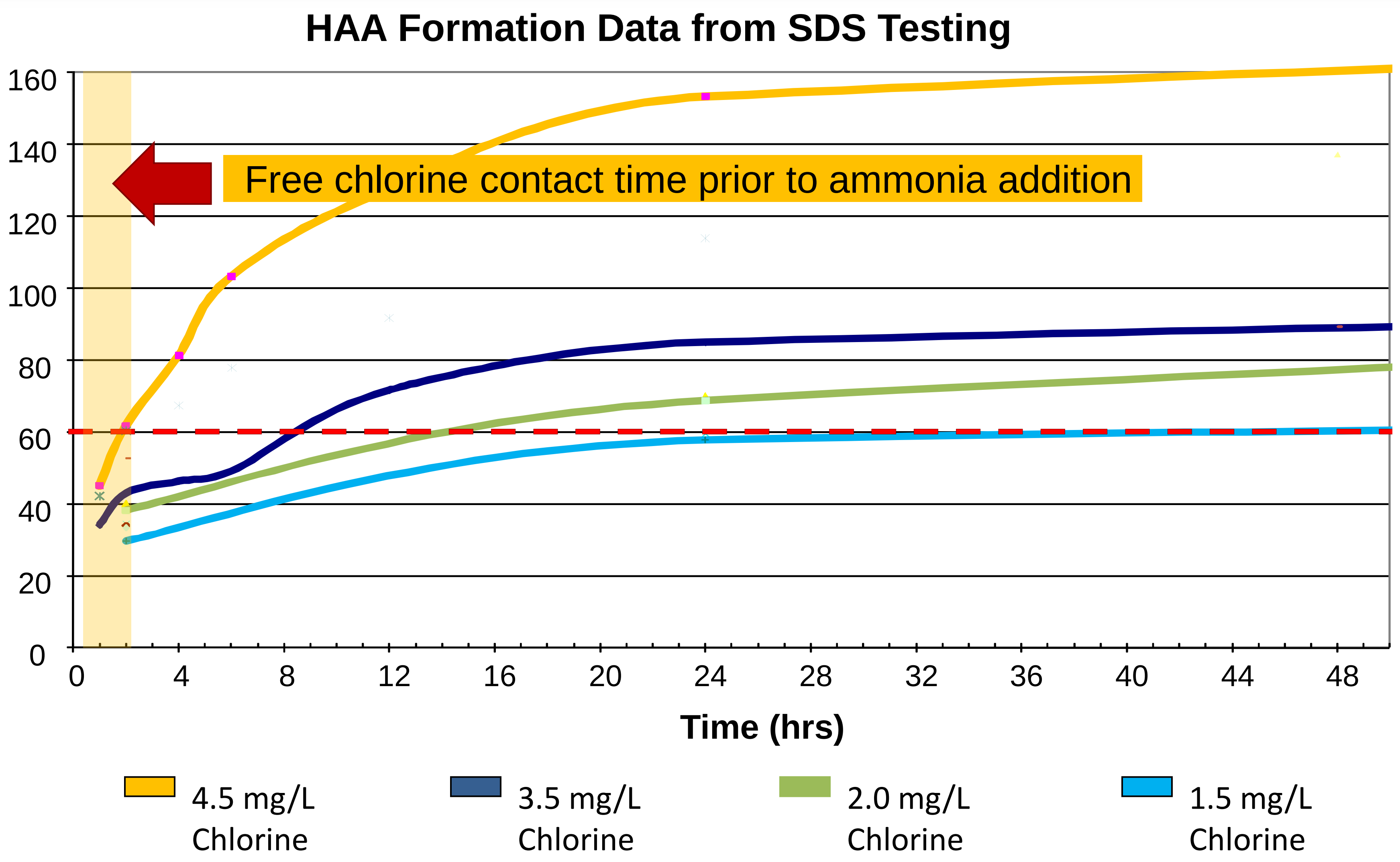
Treatment Alternatives Evaluation Capital Cost Estimates (Dec. 2004)



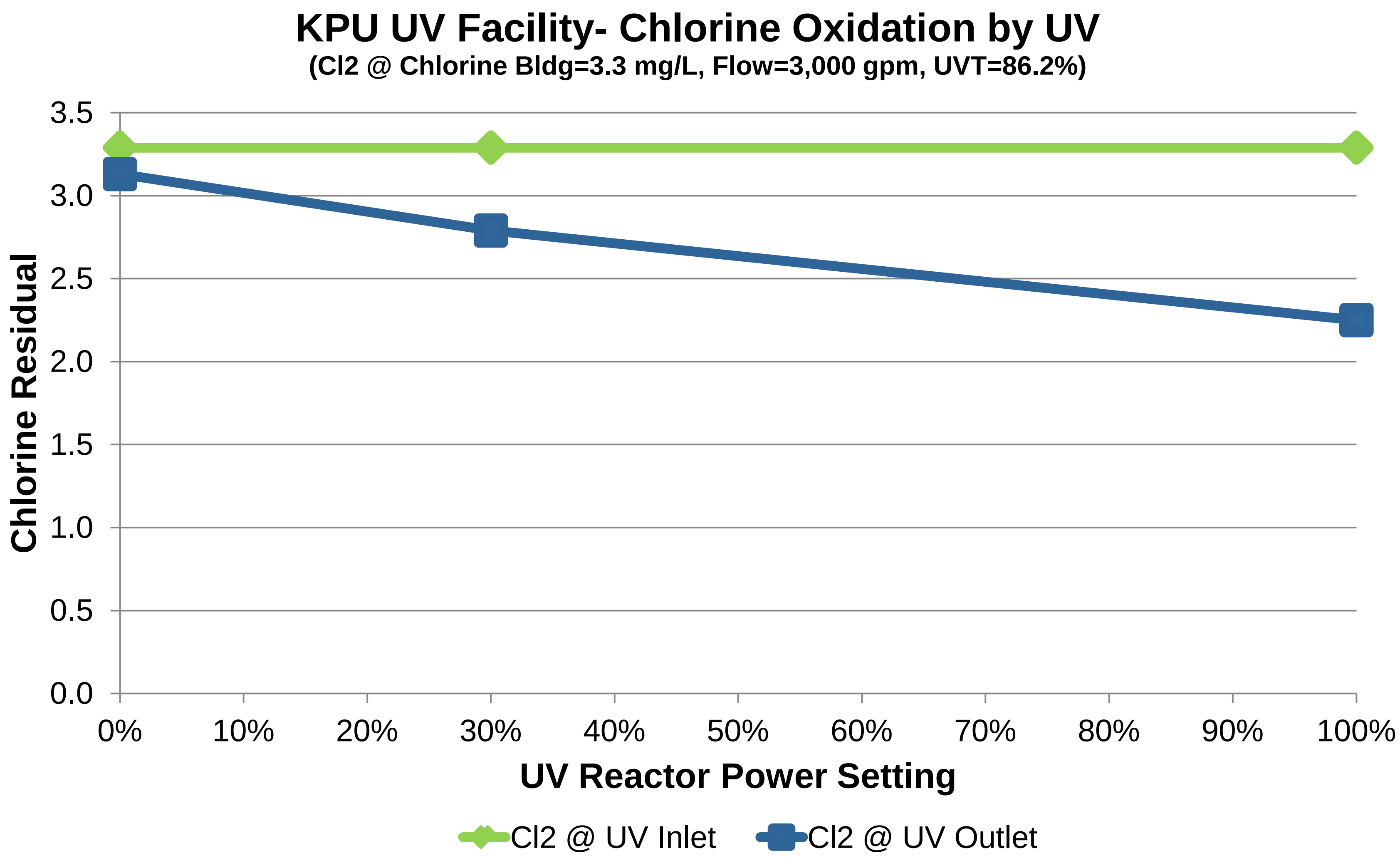
Determining the Rate of HAA Formation



Determining the Rate of HAA Formation

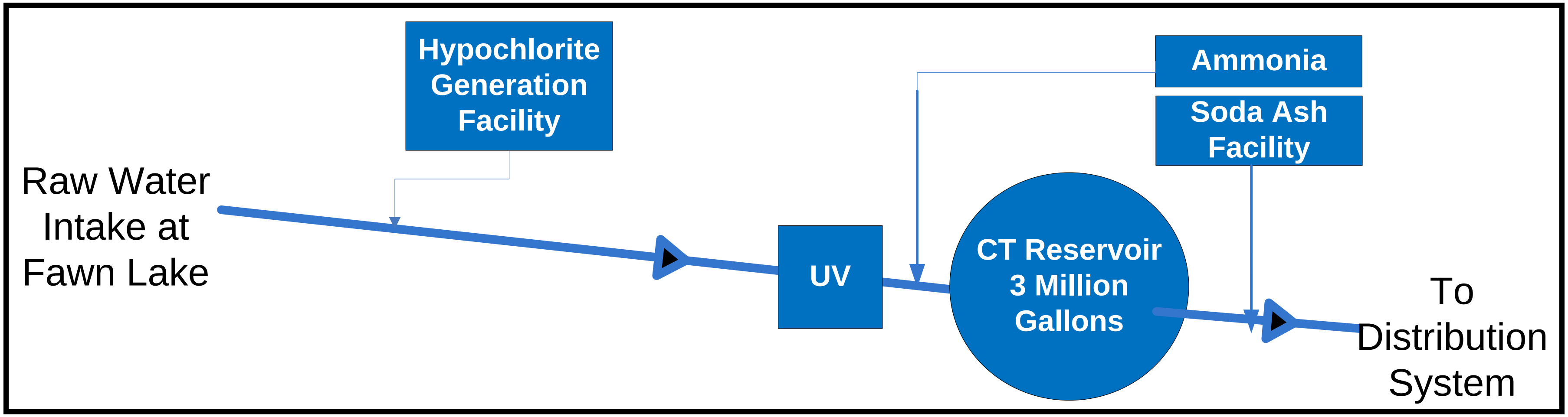


Chlorine Decay Through UV Reactors



Ketchikan's New Water Treatment System

- Unfiltered System
- UV for Crypto and Giardia inactivation
- Chlorine for virus inactivation
- Chloramines for distribution system disinfectant residual



Questions

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CalgonCarbon
Making Water and Air Safer and Cleaner

Disinfection By-Products
Meeting the Challenge of Compliance with USEPA DBPR Stage 2- City of Celina Experience

PNWS AWWA Yakima – May 2-4, 2012

William C. Zavora, PE

Senior Applications Engineer

Presentation Outline

- Background
- Investigation of Alternatives
- Pilot Testing Program
- Full Scale Implementation
- Operating Data
- Treatment Costs
- Current Status

Granular Activated Carbon

Background

- The City of Celina, OH, supplies drinking water to 11,647 residents

- Source water is *Grand Lake*, a 21 sq. mile water body

- *Grand Lake* contains high levels of total organic carbons (TOC) and supports a high concentration of Planktothrix algae

Background

Celina, Ohio

Grand Lake

Grand Lake / St Marys Watershed

Background

- Grand Lake watershed is primarily agricultural land
  - Lake itself is only 7' deep

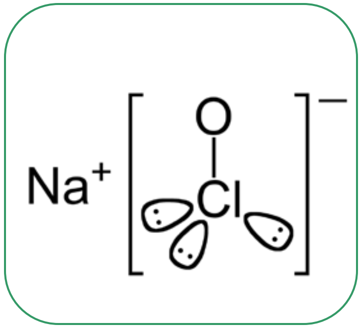
- TOC concentrations average 12.5 mg/l and peak at over 20 mg/l

- Turbidity ranges from 10 to 300 NTU

Image of water samples showing 5, 50, and 500 NTU turbidity

Background

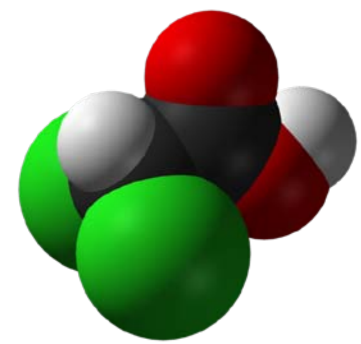
- Celina water treatment consisted of:
  - Lime slaking
  - Upflow clarification
  - Recarbonation
  - Sand Filtration
  - Ozonation
  - Chlorination for residual disinfection



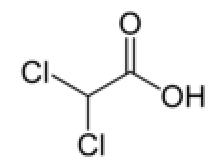
- In 1995, levels of disinfection by-products (DBPs) became an issue

Currently Regulated Disinfection By-Products

REGULATED CONTAMINANTS	Stage I MCL (mg/l)	Stage II MCL (mg/l)
TOTAL TRIHALOMETHANES (TTHM)	**0.080 RAA**	**0.080 LRAA**
Chloroform ($CHCl_3$)		
Bromodichloromethane ($CHBrCl_2$)		
Dibromochloromethane ($CHBr_2Cl$)		
Bromoform ($CHBr_3$)		
FIVE HALOACETIC ACIDS (HAA5)	**0.060 RAA**	**0.060 LLRA**
Monochloroacetic acid ($C_2H_3ClO_2$)		
Dichloroacetic acid ($CHCl_2COOH$)		
Trichloroacetic acid (CCl_3COOH)		
Bromoacetic acid ($C_2H_3BrO_2$)		
Dibromoacetic acid ($C_2H_2Br_2O_2$)		



Dichloroacetic Acid



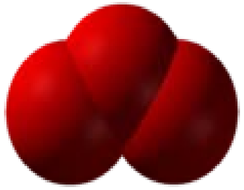
Plus 1.0 mg/L for chlorite and 10 ug/L for bromate

Background

- Total trihalomethane (TTHM) four-quarter running average was found to be 221.5 *u*g/l
  - US and Ohio EPA limits are 80 *u*g/l
- May 31, 2003: Ohio EPA placed the city water facility under a Findings and Orders consent degree with a scheduled compliance date for TTHM of November 2007

Investigation of Alternatives

- It was determined that none of the City's existing treatment processes were effective in reducing TTHMs
  - In fact, the ozonation was suspected of breaking down the TOC into compounds which would more easily react with chlorine to form TTHMs



Ozone

- The City began a program to investigate alternative solutions

Investigation of Alternatives

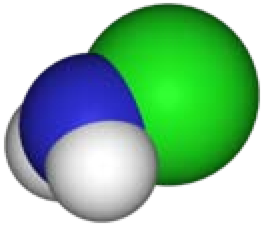
- Initial alternatives explored in 2003-2004
  - Switch to groundwater
    - Unrealistic – Great Lakes Water Compact prohibits withdrawal of water from GL watershed for expulsion into another basin – City discharges into Gulf of Mexico watershed
  - Sulfur modified iron (SMI)
    - No appreciable effect
  - Conventional water clarification system
    - Reduced TOC 69%, but TTHM remained at 170 *u*g/l
  - Magnetic ion exchange
    - 38%-48% DOC removal, but TTHM remained above 100 *u*g/l except when combined with chloramine as final disinfectant

Investigation of Alternatives

- In September 2004, City Council authorized an RFQ for facility improvements
- Floyd Browne and Metcalf & Eddy/AECOM were selected to lead the project
- Short list of treatment technologies was developed:
  - Switching to monochloramine disinfection
  - Installation of a reverse osmosis (RO) system
  - Installation of a granular activated carbon (GAC) system

Investigation of Alternatives

- Monochloramine addition was viewed as a potential short term solution
  - Technology was rejected due to:
    - Concerns regarding formation of emerging DBPs (e.g. N-Nitrosodimethylamine, cyanogen chloride)
    - Known effects of toxicity to marine life and potential nitrification in the distribution lines



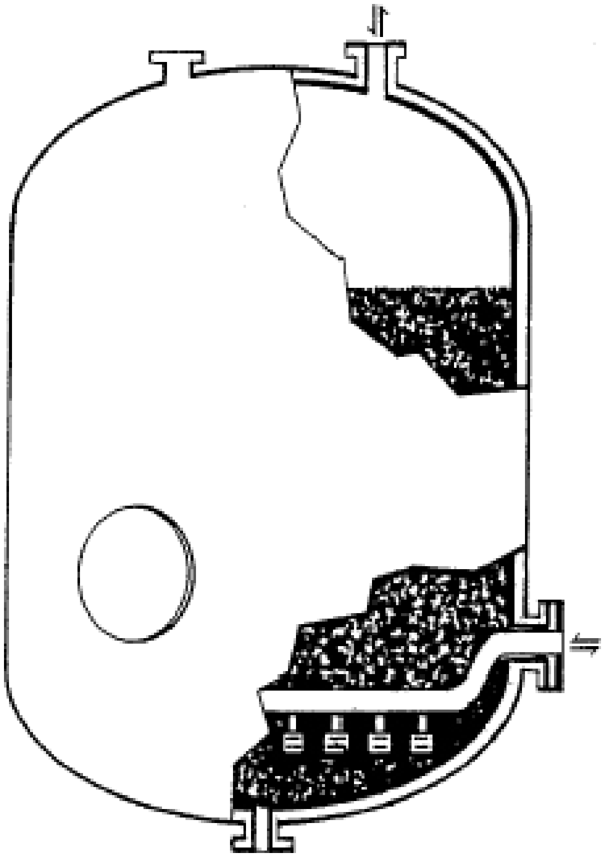
Chloramine

Investigation of Alternatives

- Reverse Osmosis (RO) to remove organic DBP precursors was considered
  - Problems arose in the piloting effort
  - Issues centered on pretreatment of water to protect the RO membranes from fouling
  - The pretreatment problem proved complicated and time consuming
  - Given the high degree of urgency to meet the consent decree and the complexity of the pretreatment issues, RO was eliminated as a viable solution

Investigation of Alternatives

- Ultimately, granular activated carbon (GAC) technology was selected
  - Well known technology
  - Widely effective for a broad variety of drinking water sources
  - Piloting was simple and easily implemented



Pilot Testing Program

- A 3-phase pilot study was begun on December 13, 2005
  - Phase I: evaluated different GAC products
  - Phase II: simulated a two-vessel series system containing the selected GAC
  - Phase III: studied the operation of two vessels in a lead/lag staged bed operation
- Water plant operation was expanded to 3 shifts
- Calgon Carbon Corporation provided pilot columns and various grades of GAC for testing

Pilot Testing Program

- Individual pilot columns were filled to 4' depth with selected products

- These were run in various combinations to simulate beds with 8' media depths

Pilot Testing Program

Pilot Testing Results

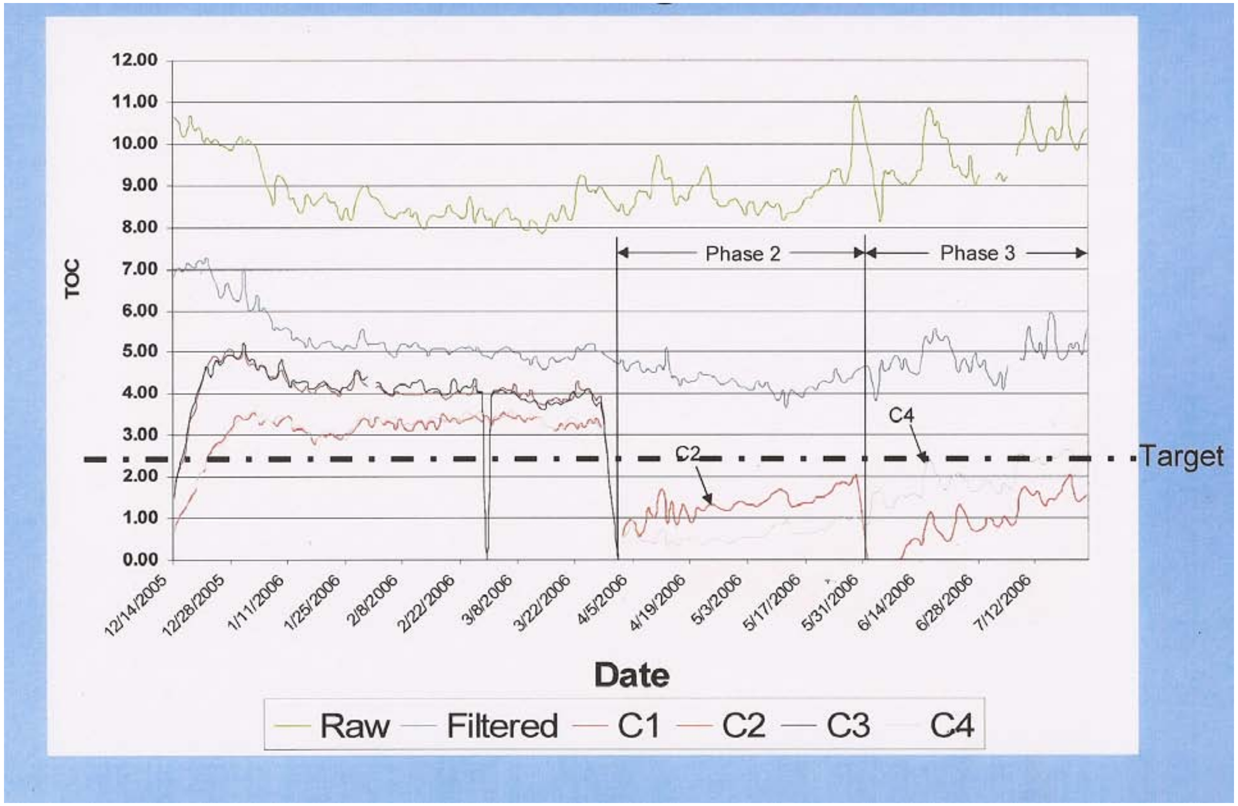
- Series operation with staged replacement (aka lead-lag) provided significant reduction in carbon usage over single bed operation
  - Staged Operation: spent GAC in lead vessel is exchanged with fresh GAC and valved to operated second in the series

- GAC adsorption could easily and consistently achieve targeted TOC level of 2.5 mg/l

- Projected annual operating cost (using virgin GAC only) was $1.21/1,000 gal treated
  - Assumes influent TOC of 10 mg/l
  - This cost is higher than average municipal GAC systems, which typically range from $0.15/1,000 gal to $0.70/1,000 gal treated
    - Increase due to extraordinarily high influent TOC level present at Celina

Pilot Testing Results

- Bituminous coal based, agglomerated GAC was found to provide the best performance
  - Specific type selected: Calgon Carbon FILTRASORB 300



Full Scale Implementation

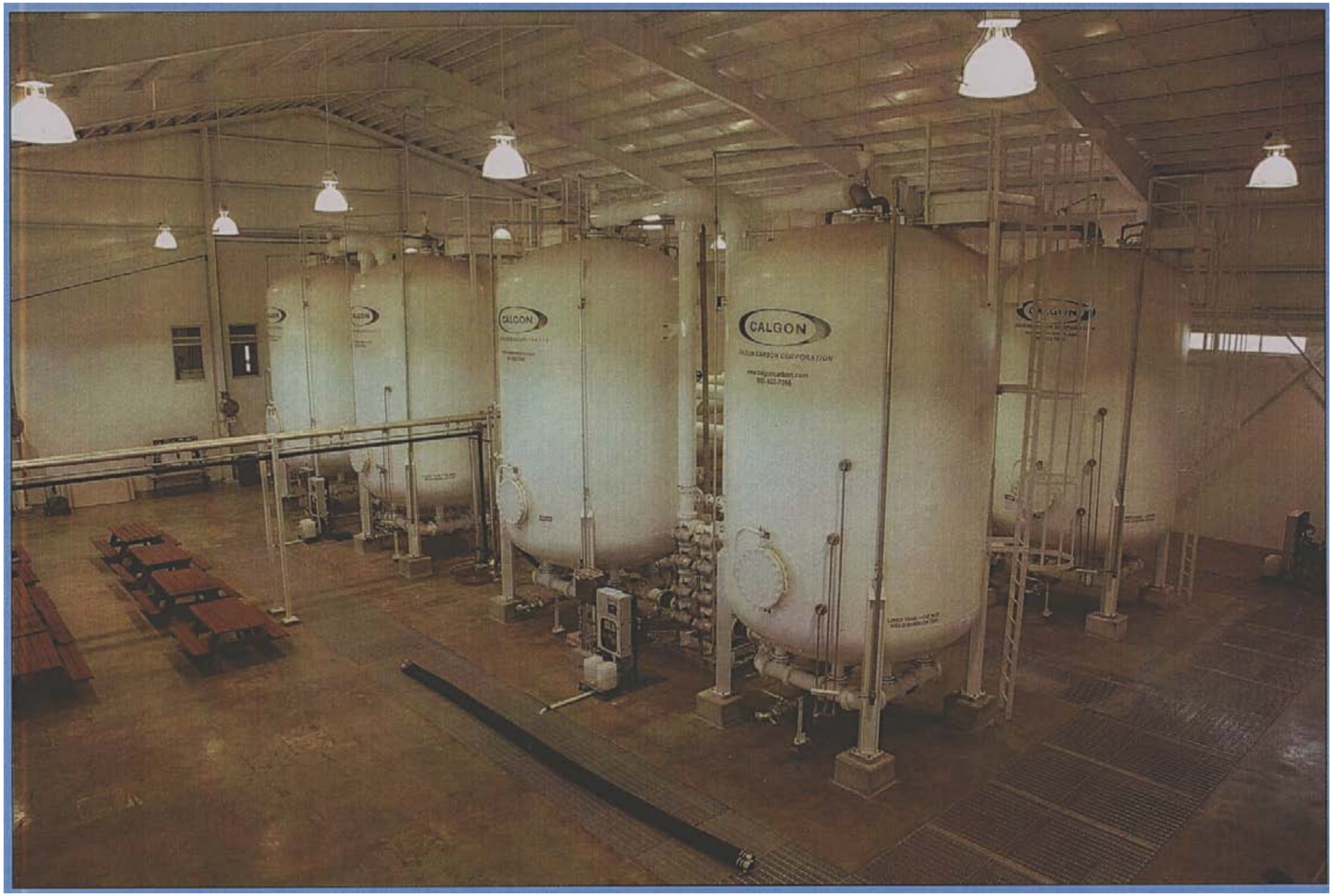
- Full scale system:
  - (8) x 40,000 lb. GAC pressure vessels
  - Operate in (4) parallel trains
  - Operate in staged sequence
  - Design flow rate: 520 gpm per vessel
    - 1.5 MGD (1040 gpm) per system
    - Current actual flow rate per train: 240 gpm (0.35 MGD)
    - At current flow, empty bed contact time (EBCT) = 78 minutes/vessel




Full Scale Implementation

- Full scale system:
  - At current flow, empty bed contact time (EBCT) = 78 minutes/vessel
  - **8 vessels, each holding 40,000 lbs. of GAC.**
  - **Assumed BWD density of 32 pcf.**
  - **GAC volume is therefore 40000/32 = 1,250 cf**
  - **Vessels are arranged in (4) parallel trains.**
  - **Current flow rate is 240 gpm per train, per note previous slide.**
  - **(2) vessels in each train operate in parallel, so that the flow rate per vessel is 120 gpm**
  - **Therefore total system flow at this time equals 120 gpm x 8 = 960 gpm, which equals 1.38 MGD**
  - **EBCT = (V*C)/Q, where V = GAC volume in cubic feet, Q = flow rate in gpm, and C = conversion factor of 7.48 gallons/cf**
  - **EBCT = (1250*7.48)/120 = 77.92 minutes**
  - EBCT (at design flow) = (1250*7.48)/260 = 36 minutes

Full Scale Implementation

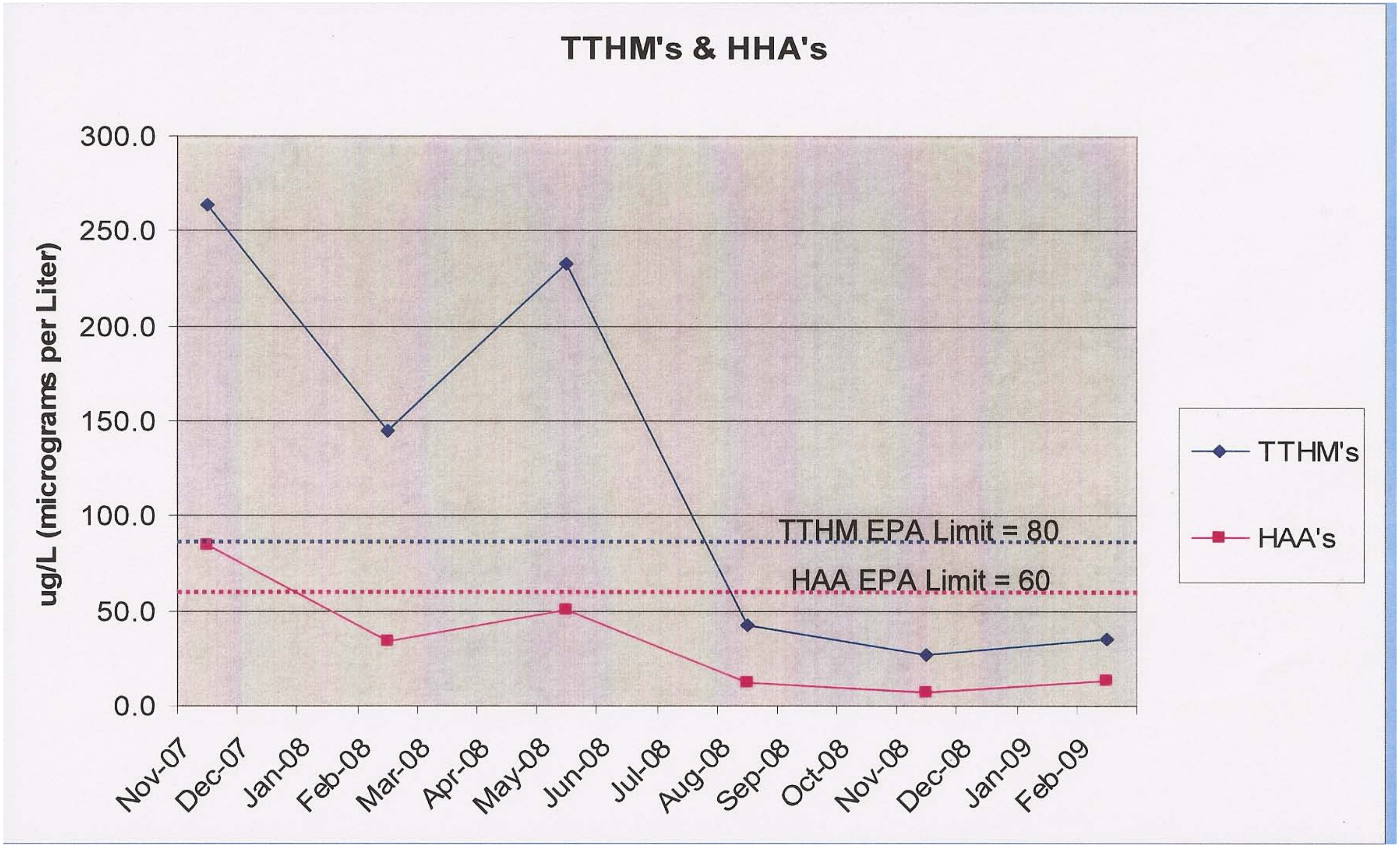


Full scale Celina systems – (8) x 12' diameter,
40,000 lb capacity vessels

Operating Data

- GAC system brought on-line July 2008
- System reduced finished water TOC to below 2.0 mg/l
- System reduced TTHM and HAA5 levels below the required levels of 80 *u*g/l and 60 *u*g/l, respectively

Operating Data



Treatment Costs

- Total capital cost for project: $7 million
  - Included: building, pumps, wet well, controls, lab, replacement intake structure, replacement sand filter valves, piloting, engineering, and the GAC system

- GAC system, including initial GAC fill, amounted to $1.73 million

$€£¥₣

Treatment Costs

- Plant has switched to custom reactivated GAC (from virgin GAC)
  - Significant reduction in operating cost
  - No measurable reduction in performance

- Operating cost: $384,000/year
  - $0.35/1,000 gal treated based on installed capacity
  - Includes: reactivation of GAC, addition of make-up GAC, transportation, warehousing and services

- Estimated ten (10) year lifecycle cost
  - $0.51/1,000 gal treated
  - Accounts for initial capital expenditure plus ongoing operating costs

$€£¥₣ → $€£¥₣ $€£¥₣ $€£¥₣ $€£¥ $€£¥₣ $€£¥₣

Current Status

- Since start-up of the GAC systems, the expanded and improved WTP has produced an average of 1.5 MGD of drinking water, consistently measuring below the treatment goals for TTHMs and HAA5s

- As of Sept 30, 2009, the Findings and Orders decree has been lifted

Current Status

- If necessary, space exists for an additional four (4) GAC adsorbers

- At this point, GAC addition appears to have completely solved the issues associated with DBP compliance, *while also* significantly improving the taste, odor, and appearance of the Grand Lake water

Thank You!

Questions?

Acknowledgements:
T. Mike Sudman – City of Celina
Todd W. Hone – City of Celina
Leo Zappa – Calgon Carbon
Cheryl L. Green – AECOM
Floyd Browne Group

Making Sure Your Polymer Dose is Safe: Limiting Acrylamide and Epichlorohydrin in Drinking Water Treatment

2012 PNWS-AWWA Annual Conference

Damon K. Roth, P.E. — EE&T, Inc.
David A. Cornwell, Ph.D., P.E., BCEE — EE&T, Inc.
Richard A. Brown, P.E. — EE&T, Inc.

Overview

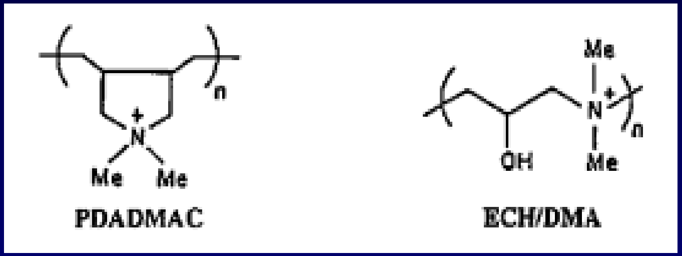
- Characteristics of polymers used in water treatment
- Regulation of residual monomer concentrations
- NSF dataset analysis
- Consideration of multiple application points

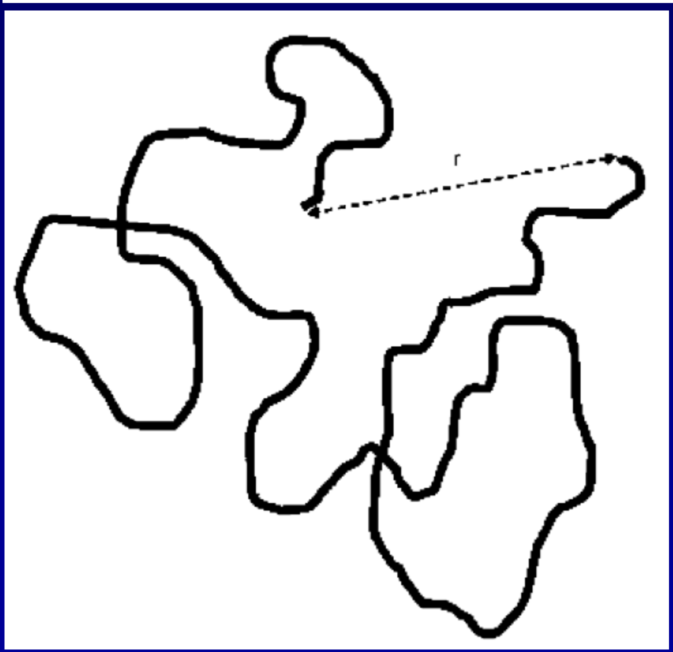
Overview

- **Characteristics of polymers used in water treatment**
- Regulation of residual monomer concentrations
- NSF dataset analysis
- Consideration of multiple application points

What are Polymers?

- Polymers are chains of individual monomer units
  - May be linked in linear or branch formation
  - Functional units interspersed along chain determine the polymer's ***charge density***
  - Overall length of the chain determines the polymer's ***molecular weight***





From Bolto and Gregory (2007)

Polymer Availability

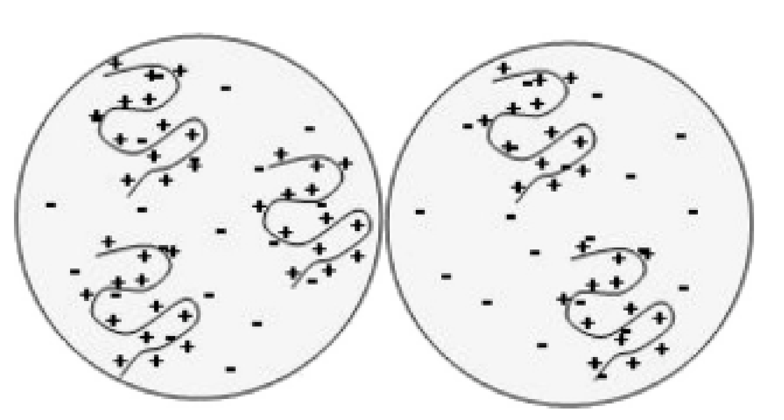
- Polymers my be supplied as dry product, or in an emulsion
- Amount of *active polymer* depends on specific product
  - Generally emulsions are 30% to 50% active polymer (may be 10% to 60%
  - Generally dry product is >90% active polymer

Polymers in Water Treatment

- Three classes of polymers used in drinking water treatment:
  - Epi-DMA polyamines (eplichlorohydrin/dimehtyamine polymers)
  - PolyDADMACs (poly(diallydimethyl ammoninium chlorides
  - PAMs (polyaryclamides)
- Unreacted monomers may be present
  - Epichlorohydrin → Epi-DMA polyamines
  - Acrylamide → PAMs

Polymer Characteristics

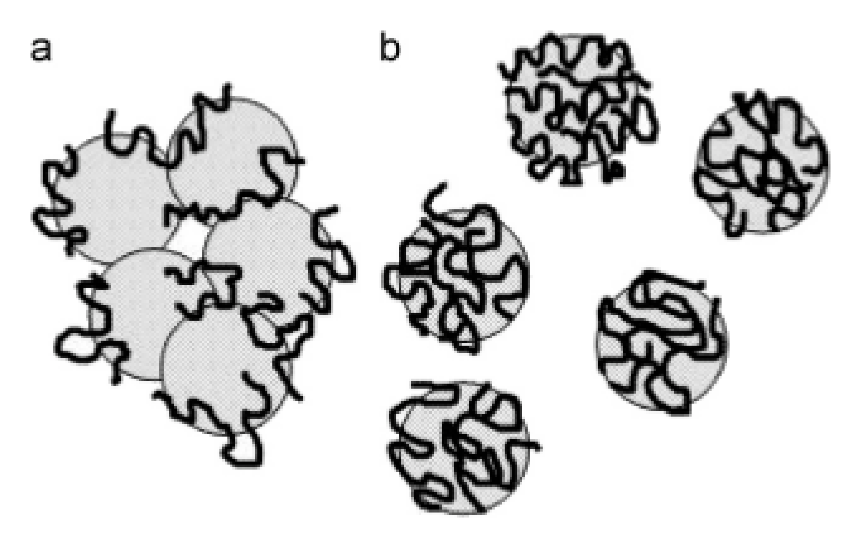
- Epi-DMA polyamines and PolyDADMACs are cationic polyelectrolytes
  - Generally low to medium molecular weight (MW) and high charge density (CD)
  - Particle removal through charge neutralization or electrostatic charge patch destabilization
  - Typically used for coagulation or flocculation



From Bolto and Gregory (2007)

Polymer Characteristics

- PAMs may be cationic, anionic, or non-ionic
  - MW is generally orders of magnitude higher than Epi-DMA polyamines or PolyDADMACs
  - Particle removal through inter-particle bridging
  - Used to aid coagulation, flocculation, or filtration
  - Also used to thicken and dewater treatment plant residuals



From Bolto and Gregory (2007)

Overview

- Characteristics of polymers used in water treatment
- **Regulation of residual monomer concentrations**
- NSF dataset analysis
- Consideration of multiple application points

Regulation of Residual Monomer Concentrations

- Acrylamide and epichlorohydrin are difficult to detect in drinking water
  - Absence of standardized analytical methods precludes establishment of MCLs
  - Both compounds have MCLG of zero
- Acrylamide and epichlorohydrin levels are regulated by treatment techniques (40 CFR 141.111)
  - Each PWS must certify that the combination of dose an monomer level does not exceed:
    - Acrylamide = 0.05% dosed at 1 ppm (or equivalent)
    - Epichlorohydrin = 0.01% dosed at 20 ppm (or equivalent)

Future Regulatory Considerations

- During the most recent Six-Year Review, USEPA identified the National Primary Drinking Water Regulations (NPDWRs) for acrylamide and epichlorohydrin as candidates for regulatory revision
- Consideration is based on improvements in manufacturing capabilities that have reduced residual monomer content in polymers formed from these compounds

Regulations/Guidelines in Other Countries

Country/Region	Regulation or Guideline	Acrylamide	Epichlorohydrin
United Kingdom	Residual Monomer	0.02%	0.002%
	Max. Dosage	0.25 mg/L avg.; 0.5 mg/L max.	2.5 mg/L avg.; 5.0 mg/L max.
	Expected Concentration in Water	0.05 μg/L avg.; 0.1 μg/L max.	0.05 μg/L avg.; 0.1 μg/L max.
European Union	Concentration in Water	0.1 μg/L	0.1 μg/L
World Health Org.	Concentration in Water	0.5 μg/L	0.4 μg/L
Australia	Concentration in Water	0.2 μg/L	0.5 μg/L

Table Adapted from EPA 815-B-09-007

Overview

- Characteristics of polymers used in water treatment
- Regulation of residual monomer concentrations
- **NSF dataset analysis**
- Consideration of multiple application points

Certification

- The treatment technique for acrylamide and epichlorohydrin requires utilities to certify compliance in writing to the State using third-party or manufacturer's certification
- Most common certification is NSF/ANSI 60

Certification Process

- Certification process includes toxicology review, manufacturing facility inspection, and product testing
- Manufacturer states the maximum use level (MUL) they are targeting
  - If normalized concentrations of contaminants met single product allowable concentrations (SPAC) of NSF/ANSI Standard 60, product is certified with target MUL
  - If product exceeds SPAC, either the product must be reformulated or the MUL must be lowered

Ambiguity in Certification

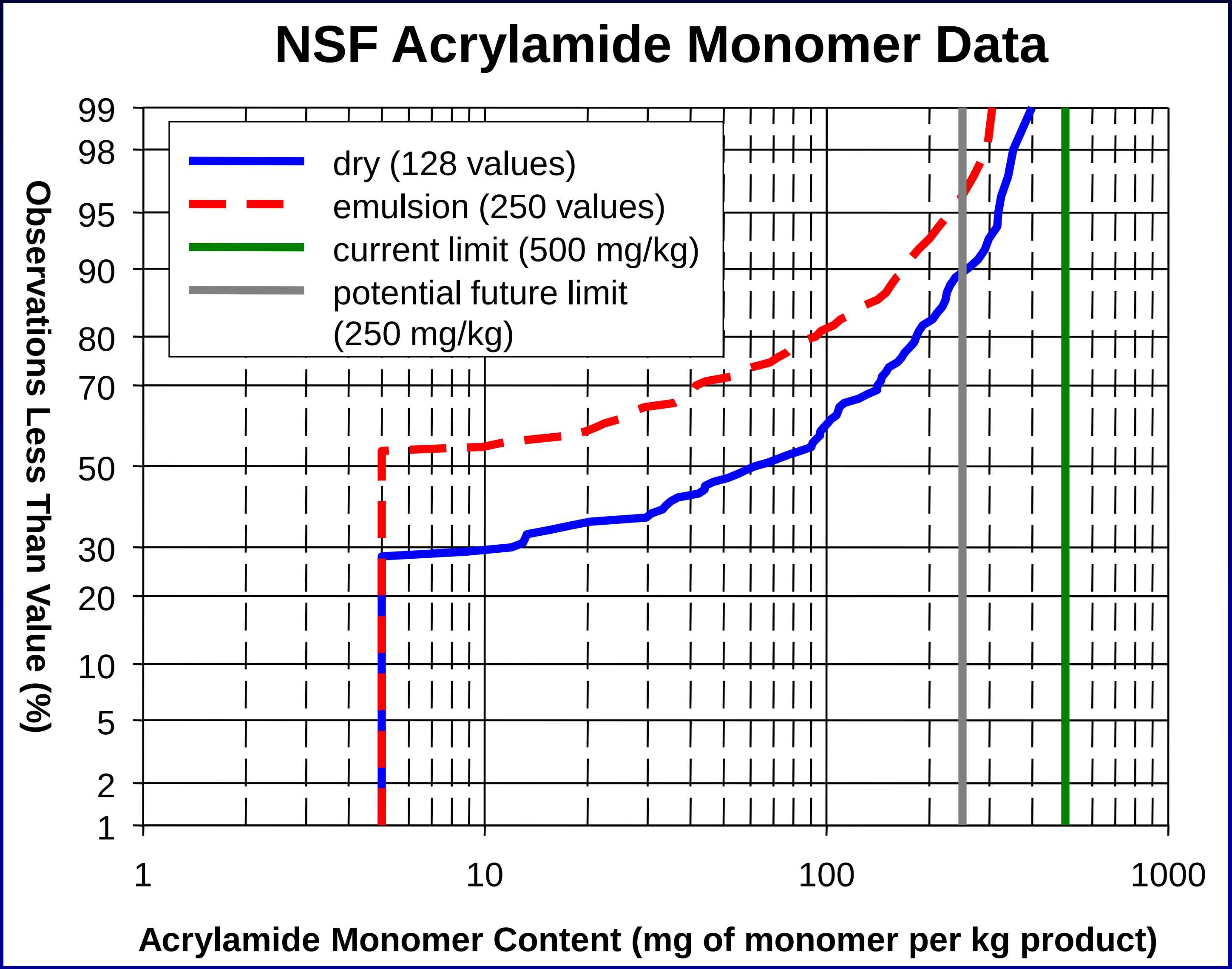
- Certified MUL is based on polymer dose "as product"
- Active polymer content of product is not known by NSF
- This opens the possibility of similar products with the same active polymer concentrations being certified for different MULs
- MUL is for single application, but PAMs may be used at several locations in the treatment train

NSF Data Analysis

- NSF provided blind data on residual acrylamide levels detected in PAMs

		Residual Monomer Content (mg/kg)			
	Number Analyzed	**Mean**	**Median**	**Max.**	**Std. Dev.**
Emulsion-form	250	51	Non-detect	393	78
Power-form	128	99	62	419	106

NSF Data Analysis



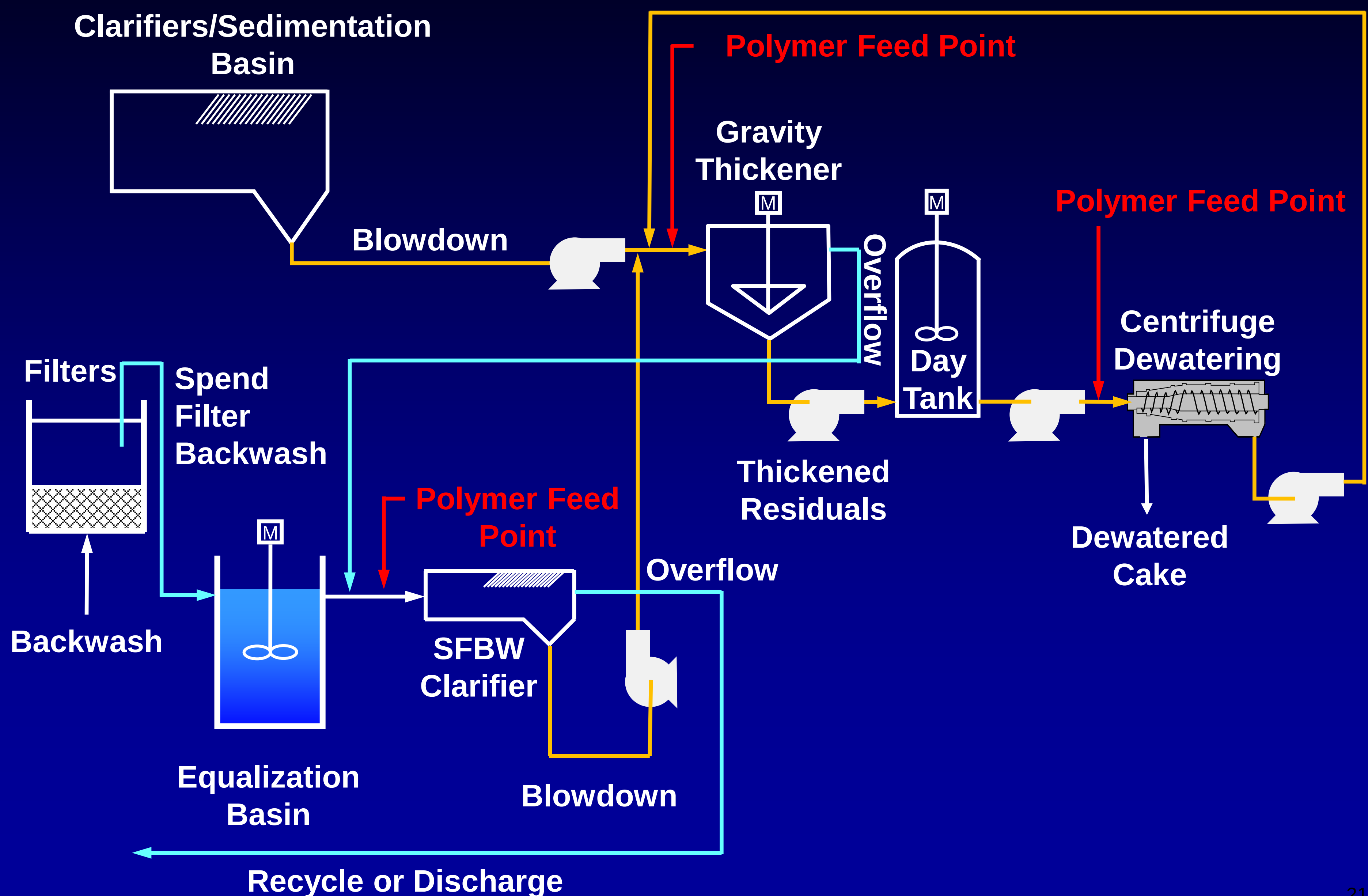
Overview

- Characteristics of polymers used in water treatment
- Regulation of residual monomer concentrations
- NSF dataset analysis
- **Consideration of multiple application points**

AWWA Standard

- AWWA has established standards for Epi-DMA polyamines and PAMs
  - AWWA B452 EPI-DMA Polyamines
  - AWWA B453 Polyacrylamides
- Latest draft of B453 addresses issue of multiple application points for PAMs
  - Draft language calculates average annual aggregate PAM dosage (annual mass of PAM usage divided by annual volume of water treated)

PAM Usage in Residuals Treatment



Typical Doses for Residuals Treatment

- Gravity thickening:
  - 1 to 3 lb active polymer/dry-ton residuals
- Belt filter press dewatering:
  - 2 to 8 lb active polymer/dry-ton residuals
- Centrifuge dewatering:
  - 2 to 15 lb active polymer/dry-ton residuals
- SFBW Clarification
  - 0.5 to 1.0 mg active polymer/L

Determining Proper Polymer Dose

- Multiple procedures may be used to determine optimum polymer dose
- For coagulant/flocculation aid, jar testing can provide dosing guidance
- For thickening/dewatering, time-to-filter (TTF) test can provide dosing guidance

Calculating Polymer Doses

- Depending on product, there is a significant difference between dose as neat product and dose as active polymer
- Monomer levels related to active polymer levels, not neat polymer dose
- For residuals treatment, polymer dose should be calculated based on mass:mass, not mass:volume

Potential Recycle Considerations

- Centrate (or pressate) only is recycled when dewatering is active
  – Some facilities operate 24 hours/day, some operate only 8 hours/day
- Thickener supernatant may only be discharged periodically
  – Batch thickeners are decanted periodically for relatively long durations
  – Continuous thickeners only discharge when receiving blowdown from sedimentation basins

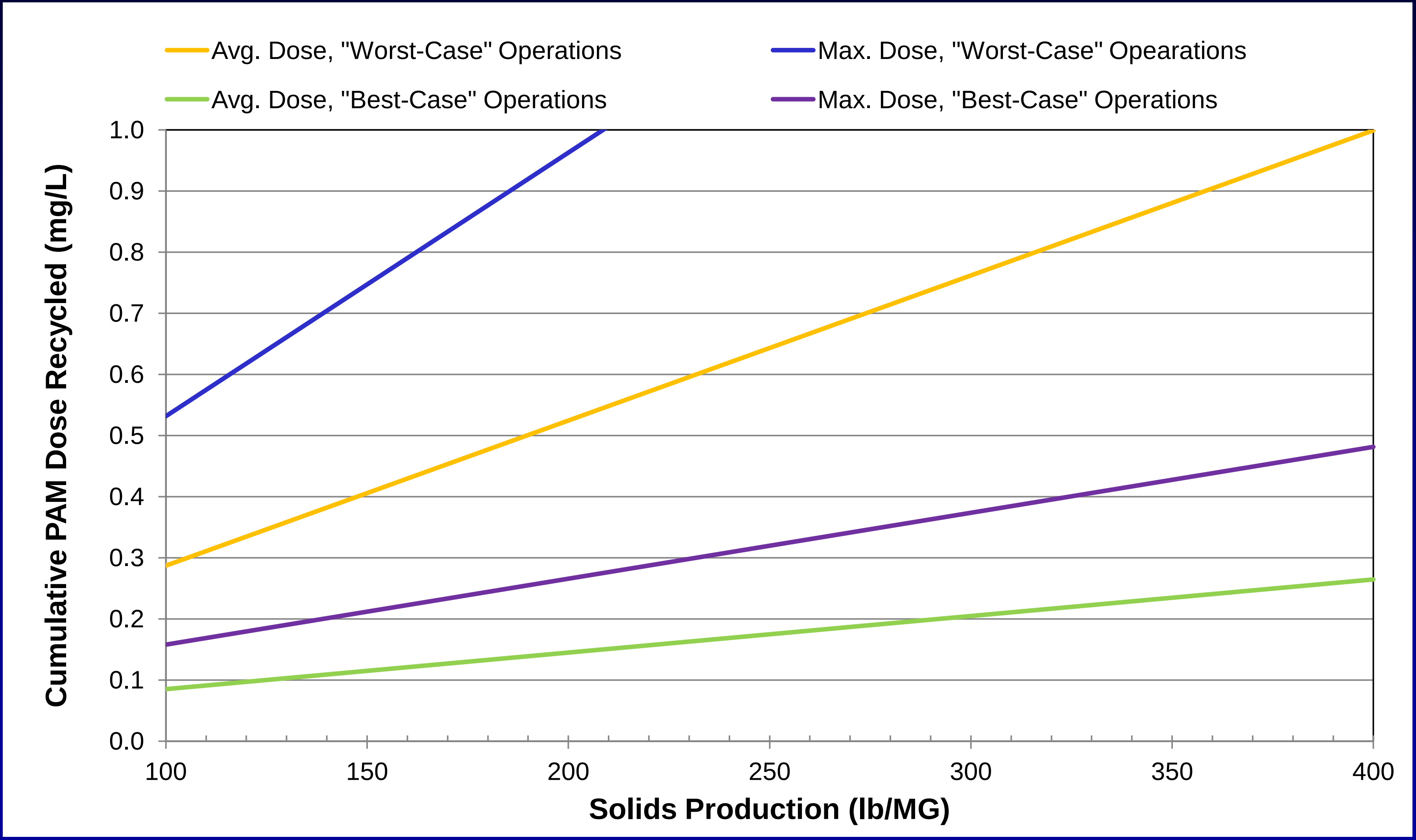
Potential Operations Scenarios

- "Best-Case" Operations:
  - Dewatering – 24 hrs/day, 7 days/week
  - Thickening – 24 hrs/day, 7 days/week
  - SFBW Recycle – 5% of plant flow
- "Worst-Case" Operations:
  - Dewatering – 8 hrs/day, 5 days/week
  - Thickening – 8 hrs/day, 7 days/week
  - SFBW Recycle – 10% of plant flow

Potential Dosage Scenarios

- Average Doses:
  - Dewatering – 8 lb/dry-ton
  - Thickening – 2 lb/dry-ton
  - SFBW Recycle – 0.5 mg/L
- Maximum Doses:
  - Dewatering – 15 lb/dry-ton
  - Thickening – 2 lb/dry-ton
  - SFBW Recycle – 1 mg/L

PAMs in Residuals Treatment



Next Steps

- As of November 2011, workgroup startup for revision to NPDWRs for acrylamide and epichlorohydrin had not yet begun

Questions?

Making Sure Your Polymer Dose is Safe: Limiting Acrylamide and Epichlorohydrin in Drinking Water Treatment

2012 PNWS-AWWA Annual Conference

Damon K. Roth, P.E. **(droth@eetinc.com)** EE&T, Inc.
David A. Cornwell, Ph.D., P.E., BCEE EE&T, Inc.
Richard A. Brown, P.E. EE&T, Inc.

So you have a SCADA, what's next?

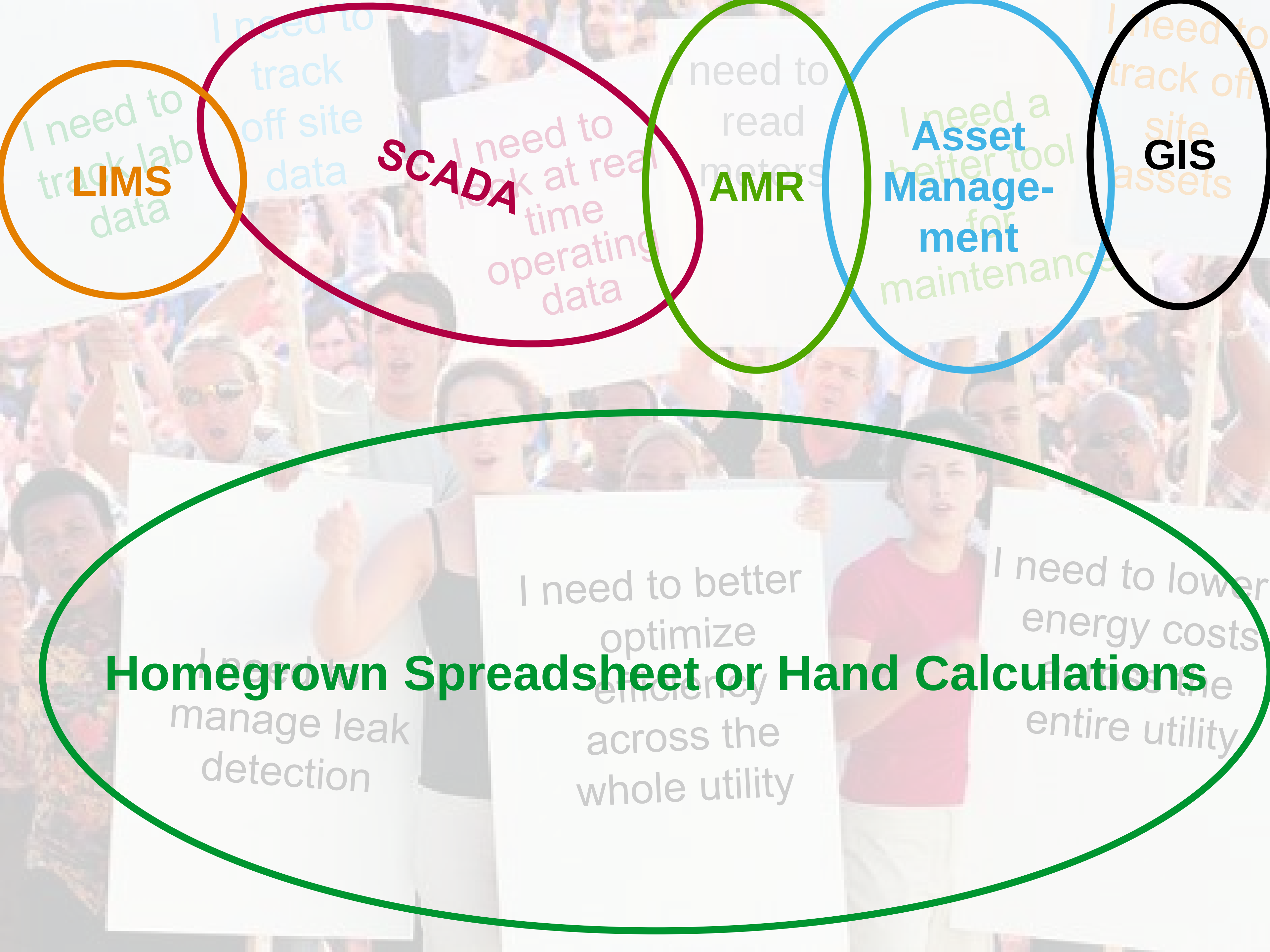
Using your facilities tools to drive efficiency and effectiveness

Schneider Electric


I Need To Track Lab Data
I Need To Track Off Site Data
I Need To Look At Real Time Operating Data
I Need To Read Meters
I Need A Better Tool For Maintenance
I Need To Track Off Site Assets
I Need To Manage Leak Detection
I Need To Better Optimize Efficiency Across The Whole Utility
I Need To Lower Energy Costs Across The Entire Utility

What is SCADA

- What SCADA is designed to do
  - View real time data
  - Allow for set point change
  - Short term trending
  - Alarming
- What it is not designed to do
  - In depth analysis
  - Complex trending
  - In depth Efficiency Calculations
  - In depth Effectiveness Calculations
  - Maintenance

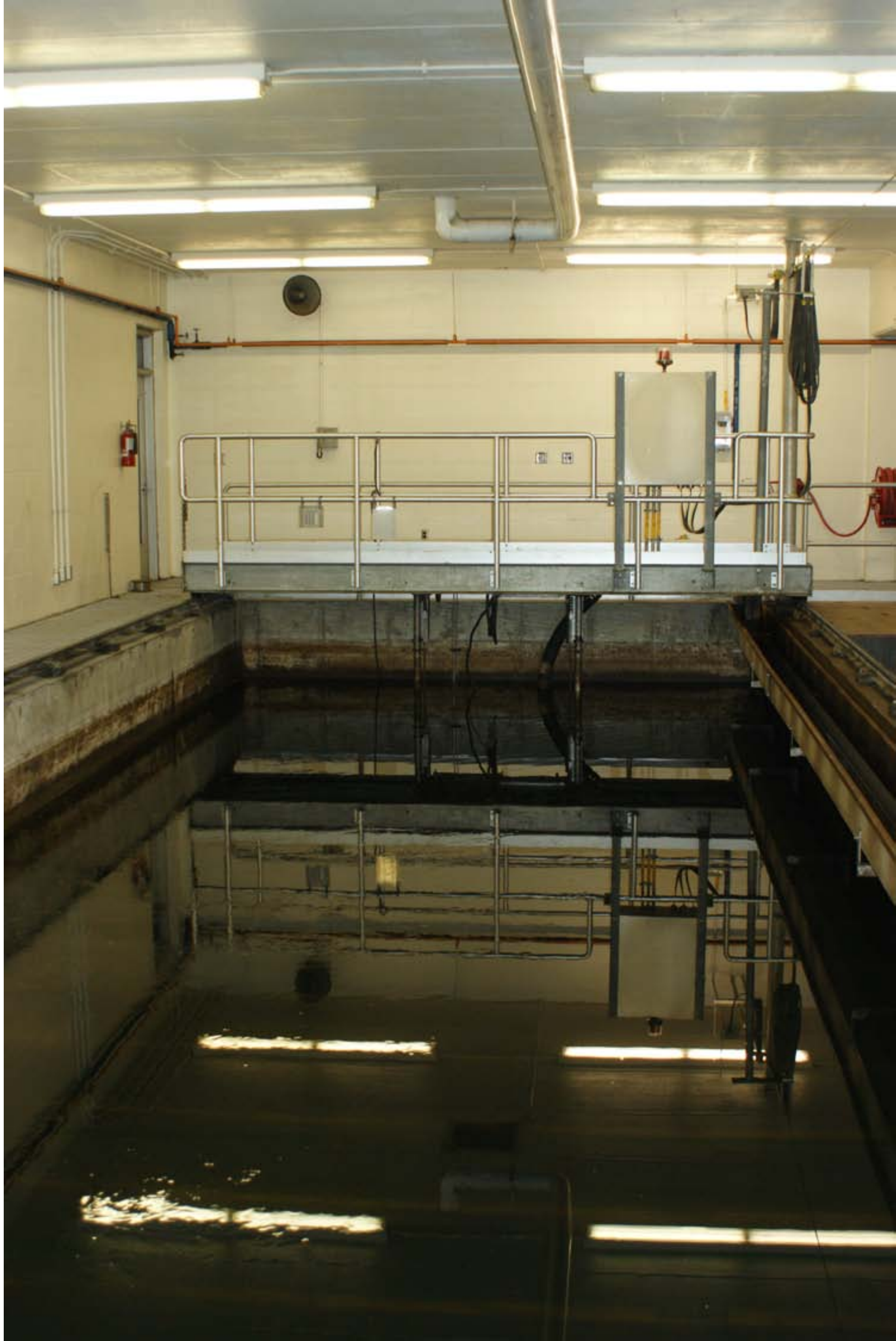

LIMS
SCADA
AMR
Asset Manage-ment
GIS
Homegrown Spreadsheet or Hand Calculations
I need to track lab data
I need to track off site data
I need to look at real time operating data
I need to read meters
I need a better tool for maintenance
I need to track off site assets
I need to better optimize efficiency across the whole utility
manage leak detection
I need to lower energy costs across the entire utility

The Situation

- Lots of Data
- Each software has unique features
- No coordination between them
- Correlation requires looking at each software individually
- Manpower Intensive

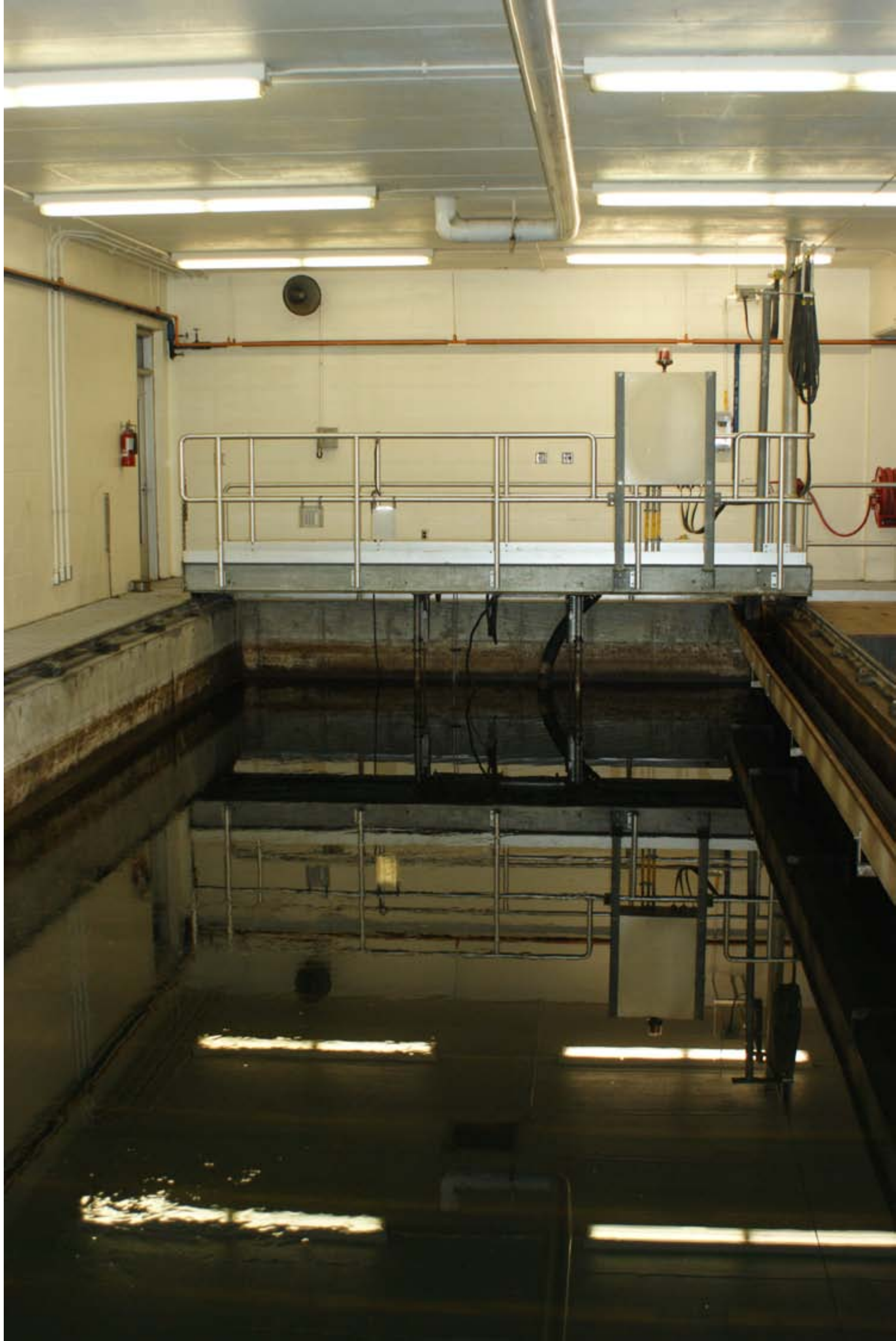
REAL LIFE EXPERIENCE:

A southern California water utility would take 3 to 4 weeks to determine the mass balance for a given point in time.



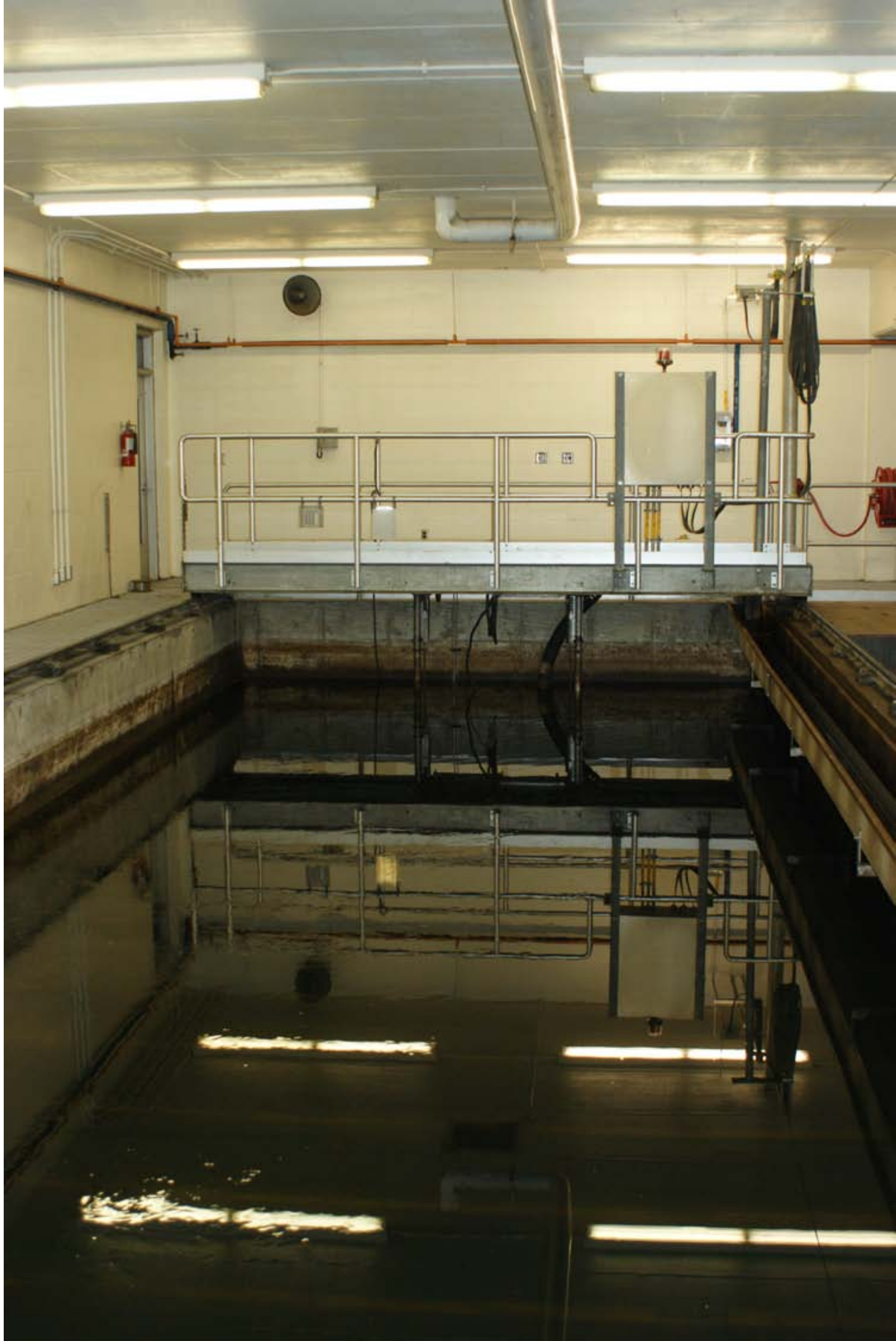
The Challenge

- Utilities need to Optimize
  - Rising Energy Prices
  - Reduced Tax Revenue
  - Restricted Funding



The Concept

- New Tools to…
  - Determine Efficiency
  - Determine Effectiveness
  - Correlate the data from a variety of sources



What is……Efficiency

- Actually produced vs. can be produced
- Given a fixed set of resources

Efficiency

- Usually looks at energy used to produce a unit
  - KWH/MGD (Pumping)
  - KWH/BOD (Biological Treatment)
  - KWH/SCFM (Blowers)
- Efficiency is more than energy

What is TCGW

- Total Cost for Good Water
  - Cost to produce and deliver 1 gallon of good water.
    - Energy cost
    - Maintenance cost
    - Staff Cost
    - Chemical Cost
    - Vehicle Cost
    - Fines

GOOD WATER

Meets Permit

Reaches Consumer (Water)

Discharged from Facility (Wastewater)

What is……Effectiveness

- Degree to which targeted problems are solved.
- Without regards to resource usage

What is OEE

- Overall Equipment Effectiveness
  - Parameter to determine best operating point
    - Machine or process
  - Designed by traditional manufacturing
    - Can be used in WWW

www.oee.com

How Does it Work

- OEE = A*P*Q
  - A = Availability (%)
  - P = Performance (%)
  - Q = Quality (%)

Determine Planned Production Time (PPT)

- Look at the total time in operation

- Deduct known downtime
  - Such as lunches, evening shutdown

- Result is Planned Production Time
  - Water and Wastewater Facilities cannot shut down
  - Basin and Pumps can

Determine Factors

- Availability
  - Operating Time/ PPT
- Performance
  - (Total Pieces/Operating Time) / Ideal Run Rate
- Quality
  - Good Pieces / Total Pieces

PIECES IN WATER WASTEWATER?

Water and Wastewater plants produce gallons of water. A gallon of water can be thought of as a produced piece

UV Example

- Given
  - 100 MGD plant
  - 2% off spec water
  - Lights on 24/7
  - Plant problem means a 50% run rate
  - Time frame of 1 day

WORLD CLASS OEE

Availability >= 90%

Performance >= 95%

Quality >= 99.9%

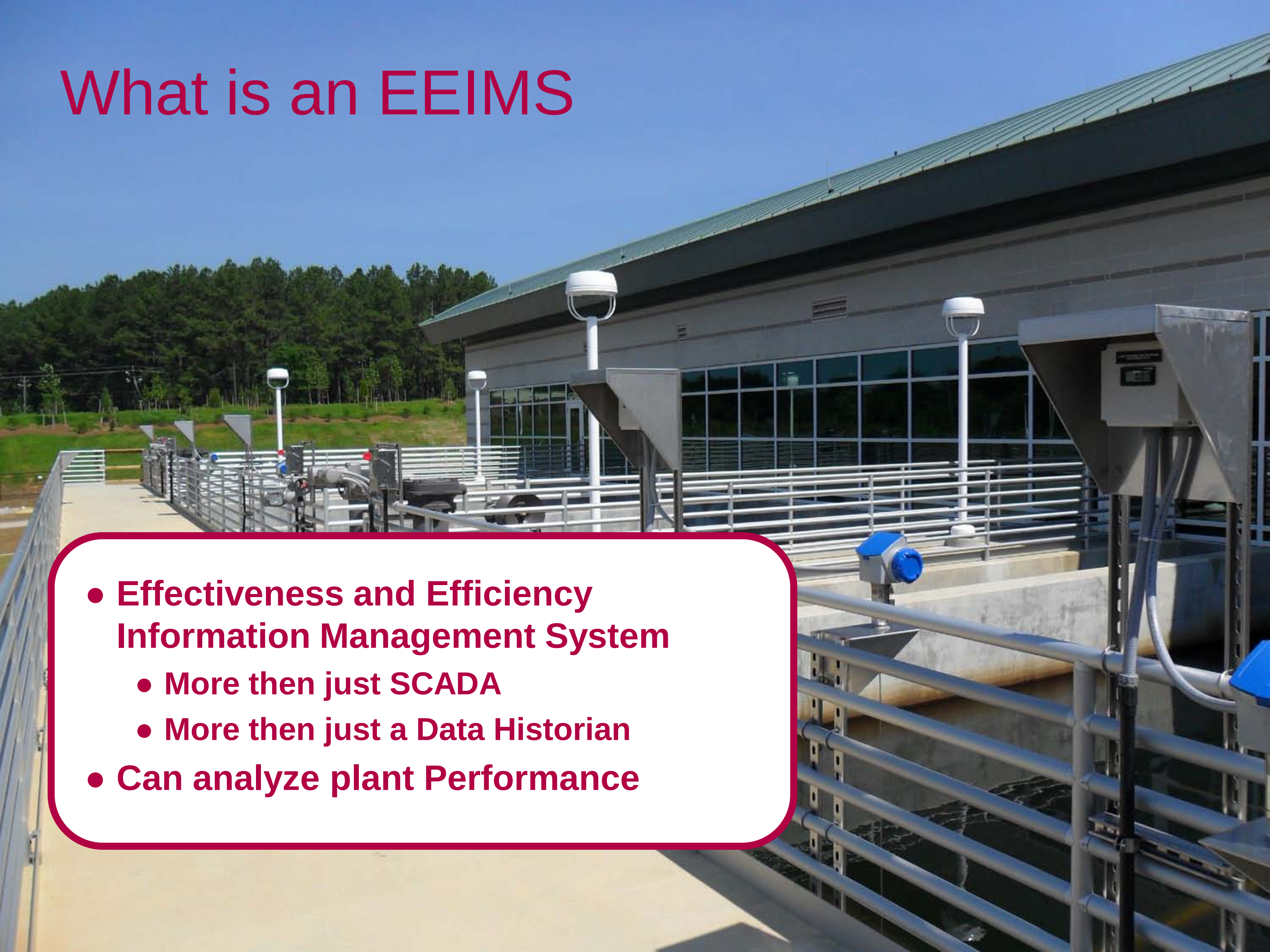
Overall OEE >= 85%

- OEE
  - PPT = 24 Hours
  - A = Operating Time / PPT = 1/1 = 100%
  - P = (Total Pieces/Operating Time) / Ideal Run Rate = (50MGD/1)/100MGD = 1/1 = 50%
  - Q = Good Pieces / Total Pieces = 49 MGD/50 MGD
  - OEE = A*P*Q = 100% * 50% *98% = 49%

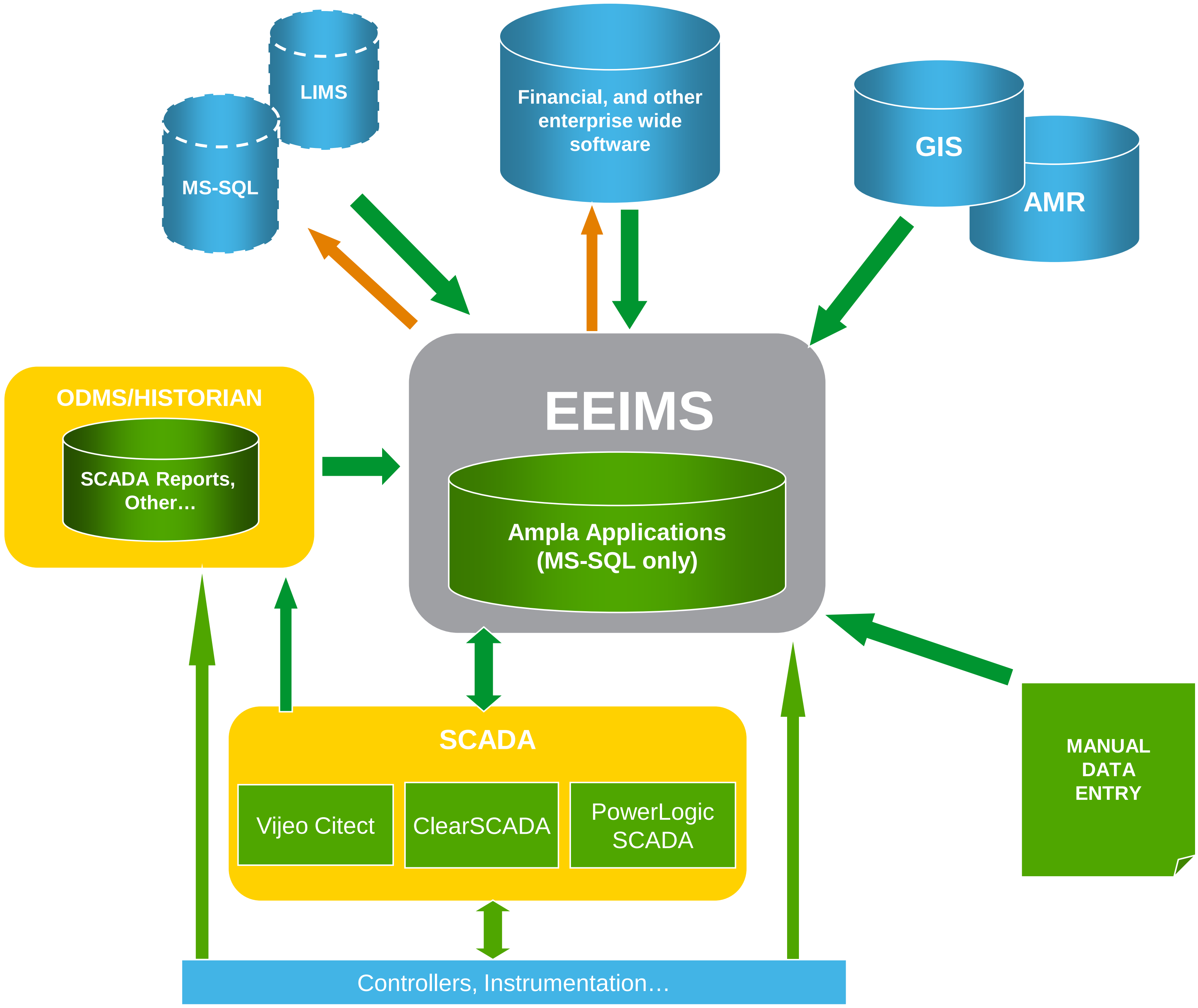
OEE and TCGW

- Combined together will give best operating point for plant
- Easy parameters to judge whole utility operation

What is an EEIMS



- **Effectiveness and Efficiency Information Management System**
  - **More then just SCADA**
  - **More then just a Data Historian**
- **Can analyze plant Performance**

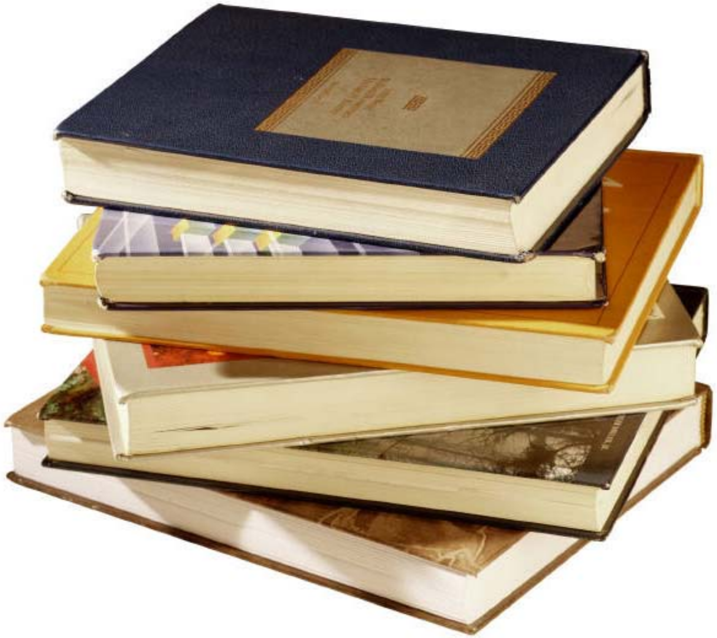

LIMS
MS-SQL
Financial, and other enterprise wide software
GIS
AMR
ODMS/HISTORIAN
SCADA Reports, Other…
EEIMS
Ampla Applications (MS-SQL only)
SCADA
Vijeo Citect
ClearSCADA
PowerLogic SCADA
MANUAL DATA ENTRY
Controllers, Instrumentation…

How does it work

- EEIMS looks into all data bases
- Consolidates and “Contextualizes” data
- Creates easy to understand reports
  - Leakage data
  - TCGW
  - OEE
  - Maintenance troubleshooting tool

What is Contextualized Data?

- Given:
  - Need to know Minimum and Maximum Turbidity
- Scenario #3
  - Over the past five Years
  - Filter out Unreliable data
    - Bad instrument
    - Unreal spikes (High during backwash)
  - Show results by Year, Month, and Week



CONTEXTUALIZE

Ability to automatically determine and remove anomalous data that can skew a desired measurement.

Real Life Case Study

- Original situation
  - Utility took weeks to do Mass Balance
  - Took weeks to find leaks
- With EEIMS
  - Can do Mass Balance
    - 1 Hour before present
    - After just a few clicks
    - Leaks found after a few hours
  - Filter behavior and DAF used together to optimize chemical usage
- Interesting Facts
  - EEIMS proved that 30 year operational “rules of thumb” were not necessarily correct.
  - Software retrained the staff on how the system behaved.