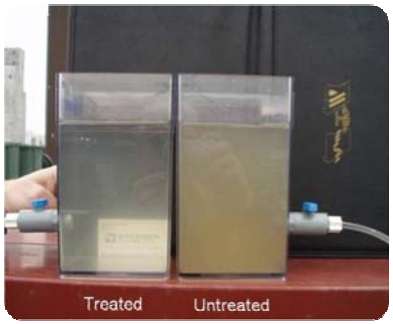
BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH



Wet-Weather Flows

Jim Fitzpatrick

91st Annual Water and Wastewater School

August 3 - 6 2010

KU THE UNIVERSITY OF KANSAS

Overview

- Wet-Weather Flow Treatment Challenges
- Auxiliary Treatment Strategy
- High-Rate Treatment Processes and Technologies
- Closing Thoughts

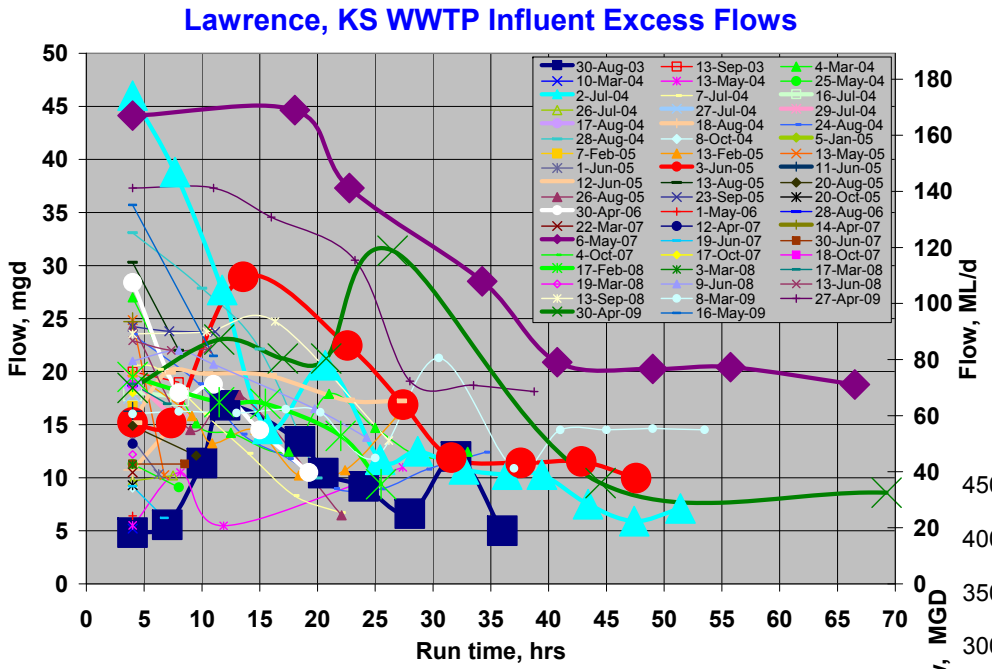
Wet-Weather Flow Treatment Challenges

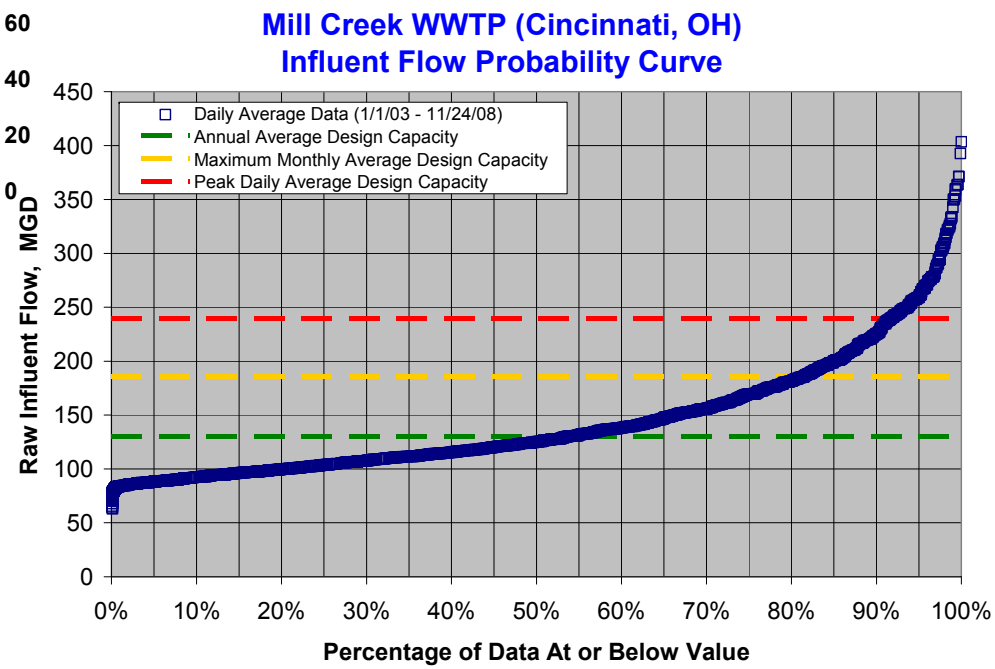
Totally different set of technical and ecological issues than dry-weather flow treatment

Aggressive SSO or CSO control usually results in higher peak flows to treat

- Realistic long-term I/I removal goals
  - Old sewers leak…new sewers will leak when they get old.
  - Significant effort and continuous expense. Year after year after year…after year...after year…
  - Private property issues
- Increased storage may not eliminate need for high-rate treatment
  - Storage dewatering rates, back-to-back storms, etc.
  - Too much storage may be more detrimental to environment
- Cost/benefit of I/I removal vs. conveyance & treatment determined through comprehensive analysis

Wet-weather flows are generally highly variable and infrequent…

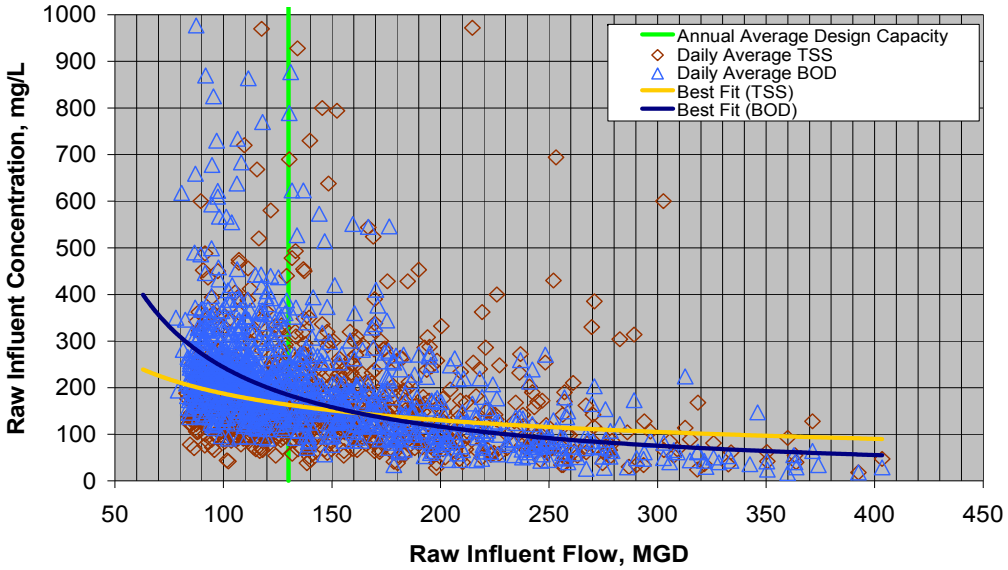




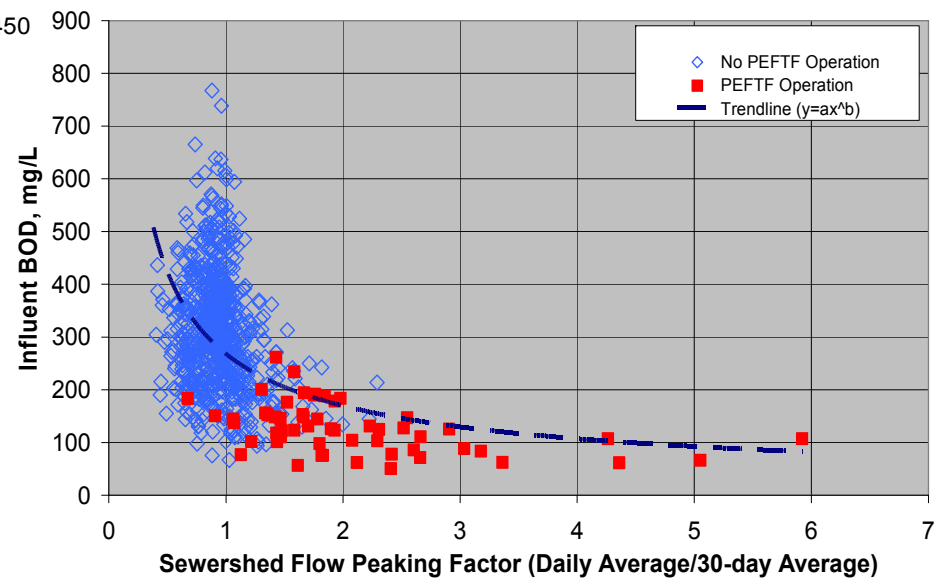
- $Q_{PKHR} \approx 5$ to $10 \times Q_{AA}$
- Similar for other CSS and SSS communities
- Site-specific climates

…with highly variable influent quality

Mill Creek WWTP (Cincinnati, OH)
Influent Characteristics (Jan '03 - Nov '08)



Nelson WWTP Complex (Johnson County, KS)
Influent Characteristics (Jan '03 - Nov '08)



- **C << C_{AA} after first flush**
- **Similar for other CSS and SSS communities**

Pollutants of concern are generally different than normal dry-weather conditions

- D.O. sags generally much less of a concern vs. dry weather.
  - High flows/volumes, turbulence, etc. in receiving stream
  - Larger assimilative capacity
- Main wet-weather POCs are generally:
  - **Floatables**. Trash, plastics, etc. Ingestion and entanglement by wildlife. Aesthetics
  - **Solids**. Prevent silt and sediments from burying eggs and larvae.
  - **Biological pathogens** (bacteria, viruses, etc.). Human health concern vs. aquatic toxicity concern.
- **Predominantly non-point sources**

Biological treatment processes can be optimized, but have inherent limitations

- Wet-weather capacity is inexact. Different storm-to-storm, antecedent conditions, etc.
- Cold influent (snowmelt) challenges.
- Building more biological treatment units will not necessarily increase wet weather capacity. **Biomass has finite capacity.**
- **Save Your Biomass**
  - Absolutely critical component of POTW
  - Recovery can take weeks or months
  - BNR biomass are particularly sensitive

- Capacity bottleneck is usually existing clarifiers and/or filters (physical/chemical process units)

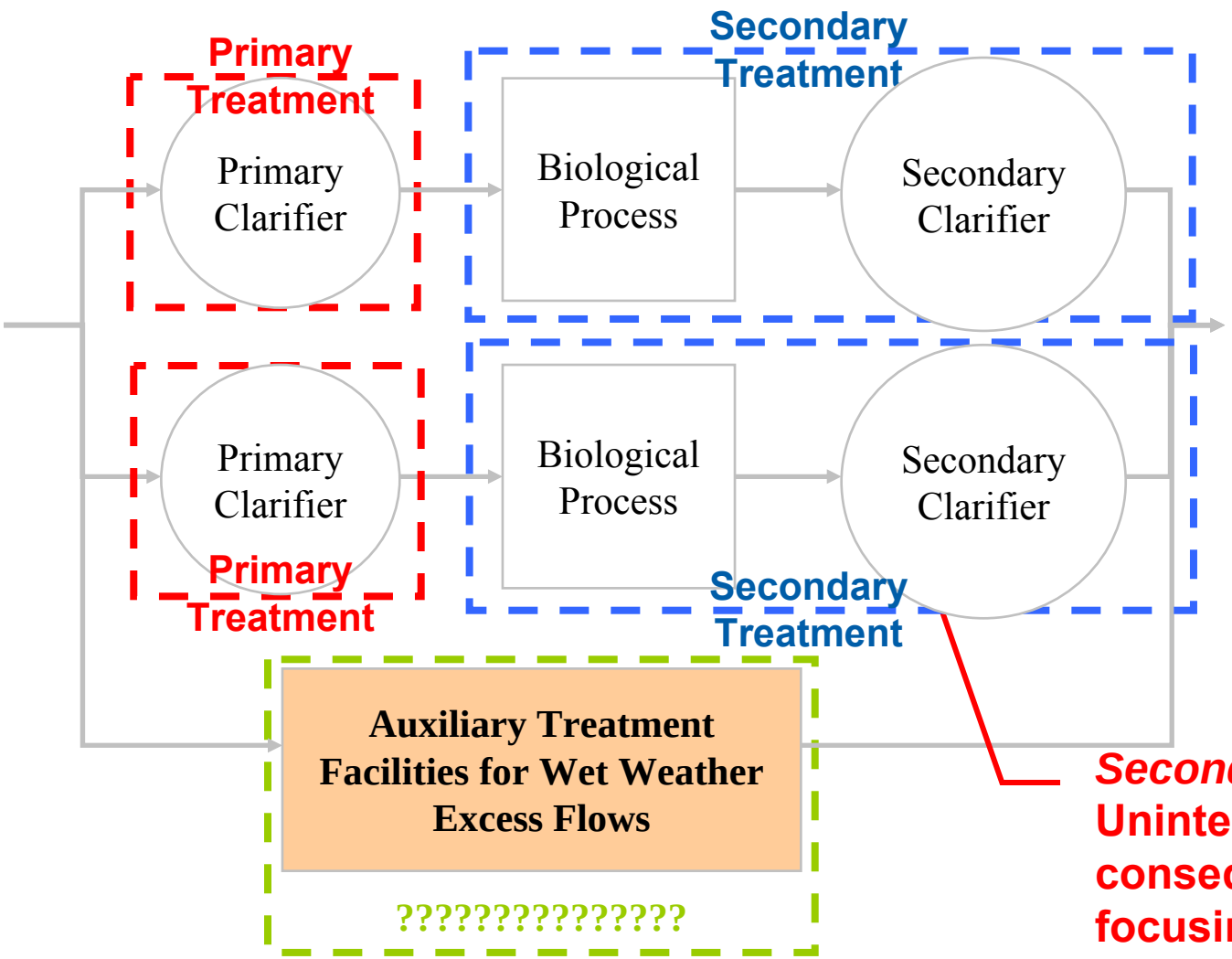
⚠ CAUTION

USEPA WET-WEATHER
EXCESS FLOW
TREATMENT POLICIES
UNDER CONSTRUCTION.

⚠ CAUTION

SOME OF THE VIEWS
EXPRESSED ON THE
NEXT FEW SLIDES MAY
NOT ENTIRELY REFLECT
CURRENT THINKING OF
EVERY REGULATOR.

Misinterpretation of "*Secondary Treatment*"



***Secondary ≠ Biological*. Unintended consequence from focusing only on dry weather.**

We don't currently have technology-based effluent limits for wet-weather conditions

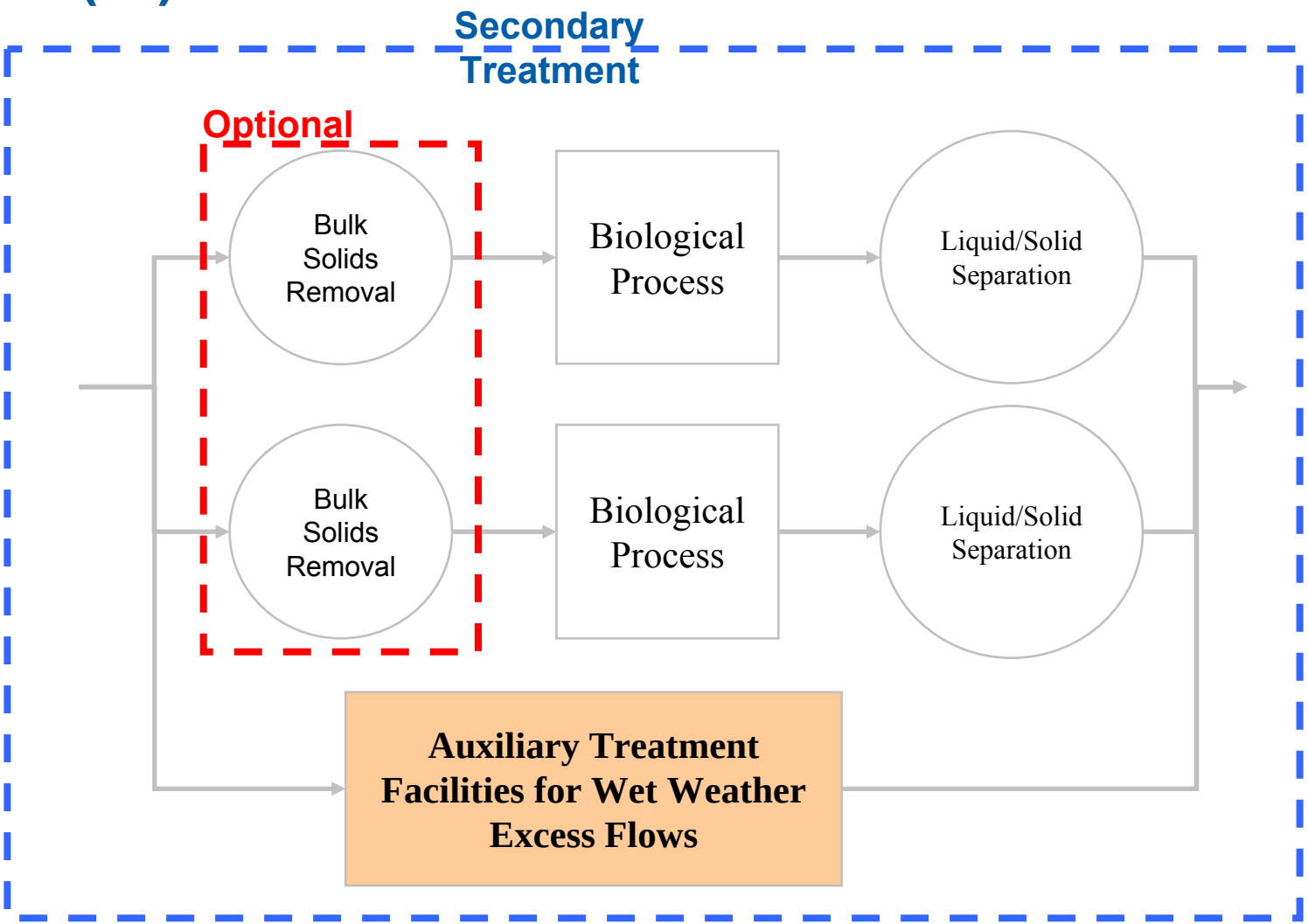
- 40 CFR 133 assumes long-term average influent…TSS/BOD = 200/200 mg/L.
- Long-term effluent from entire POTW…**not** short-term performance criteria for biological trains…**not** wet-weather influent conditions.
- Narrative allowances in 40 CFR 133 and 122(m) for wet weather.

Parameter	Units	40 CFR 133.102				40 CFR 133.105			
		Secondary Treatment				Equivalent to Secondary Treatment			
		Max	Min	Weekly Average	Monthly Average	Max	Min	Weekly Average	Monthly Average
pH	SU	9.0	6.0	-	-	9.0	6.0	-	-
TSS	mg/L	-	-	≤45	≤30	-	-	≤65	≤45
	% Removal	-	-	-	≥85% [A]	-	-	-	≥65% [A]
BOD_5	mg/L	-	-	≤45	≤30	-	-	≤65	≤45
	% Removal	-	-	-	≥85% [A]	-	-	-	≥65% [A]

Notes:

A. Based on monthly average influent and effluent concentrations only. Special considerations for lower requirements with combined sewers and less concentrated influent for separate sewers.

"*Secondary Treatment*" per 40 CFR 133 & 122.41(m)

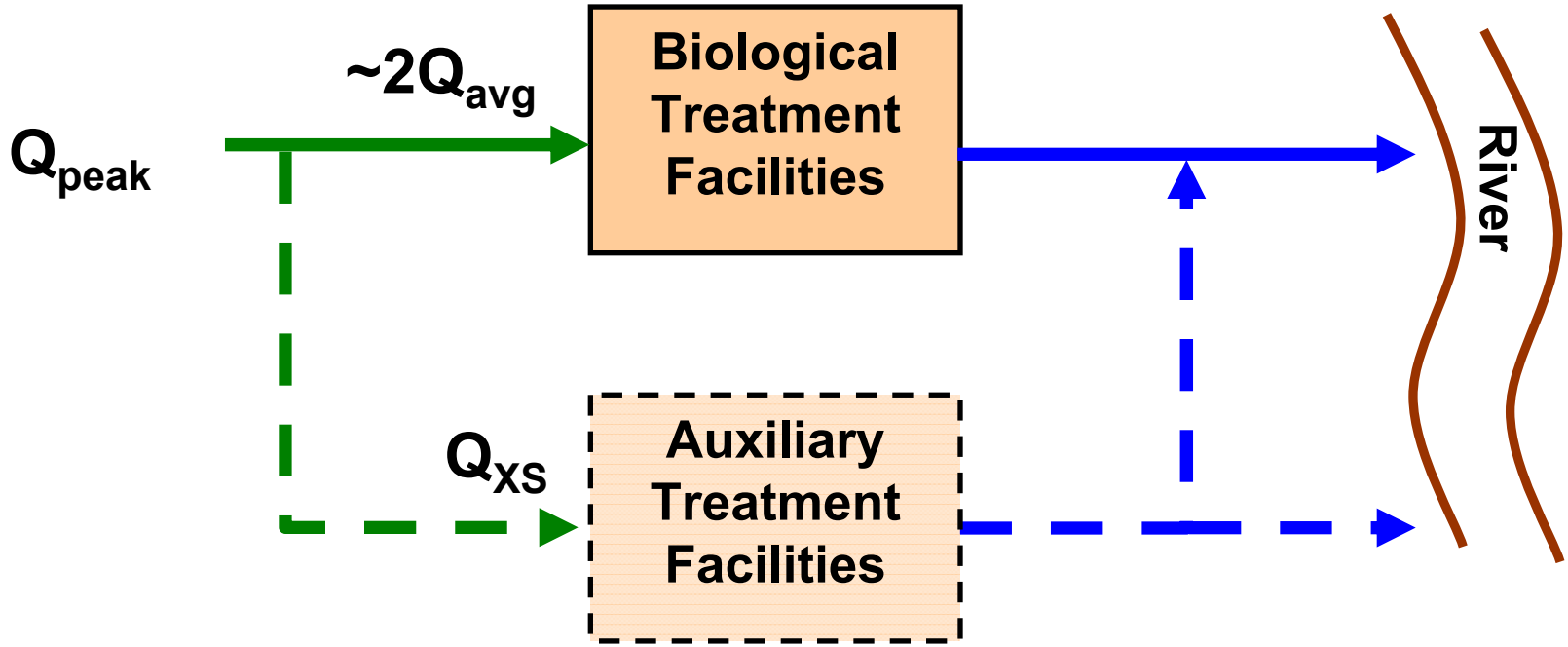


Auxiliary Treatment Strategy

A proven strategy for treating wet-weather flows…

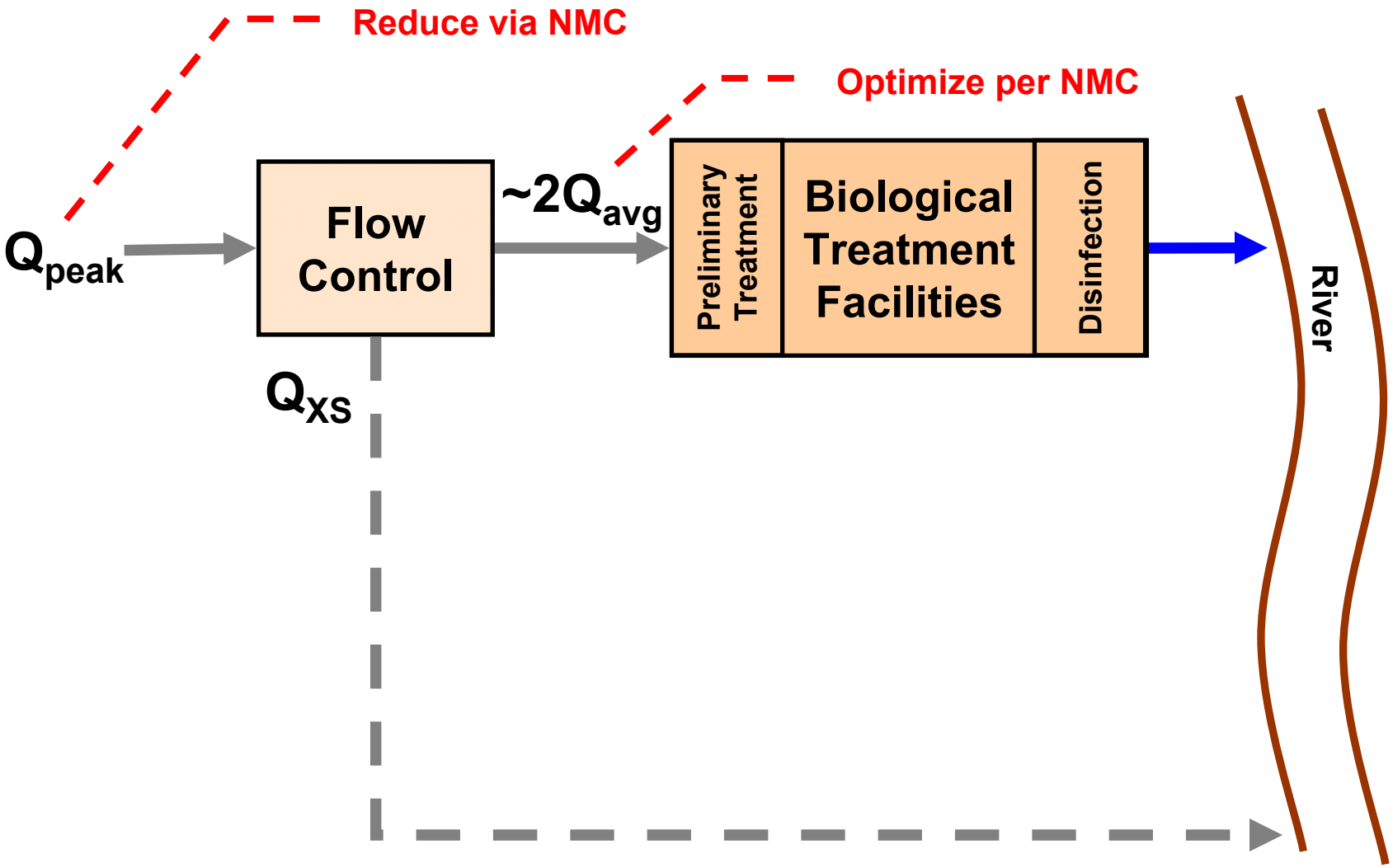
…while minimizing SSOs or CSOs

Parallel auxiliary treatment has a long track record as an effective wet-weather strategy



- Complement the inherent wet-weather limitations of biological processes
- Auxiliary treatment facilities optimized for wet weather influent
- Enable POTW to achieve secondary treatment effluent quality during both dry and wet weather

Some lessons learned from CSO control…



Additional treatment presumed by USEPA 1994 CSO Control Policy

Combined sewer flows remaining after implementation of the nine minimum controls and within the criteria specified at II.C.4.a.i or ii, should receive a minimum of:

- Primary clarification (Removal of floatables and settleable solids may be achieved by any combination of treatment technologies or methods that are shown to be equivalent to primary clarification.);
- Solids and floatables disposal; and
- Disinfection of effluent, if necessary, to meet WQS, protect designated uses and protect human health, including removal of harmful disinfection chemical residuals, where necessary.

Minimum Required, Except:

(i) ≤ 4 to 6 events per year
OR
(ii) ≤ 15% of system-wide annual average collected volume

6. Operational

After agreem
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The revised op
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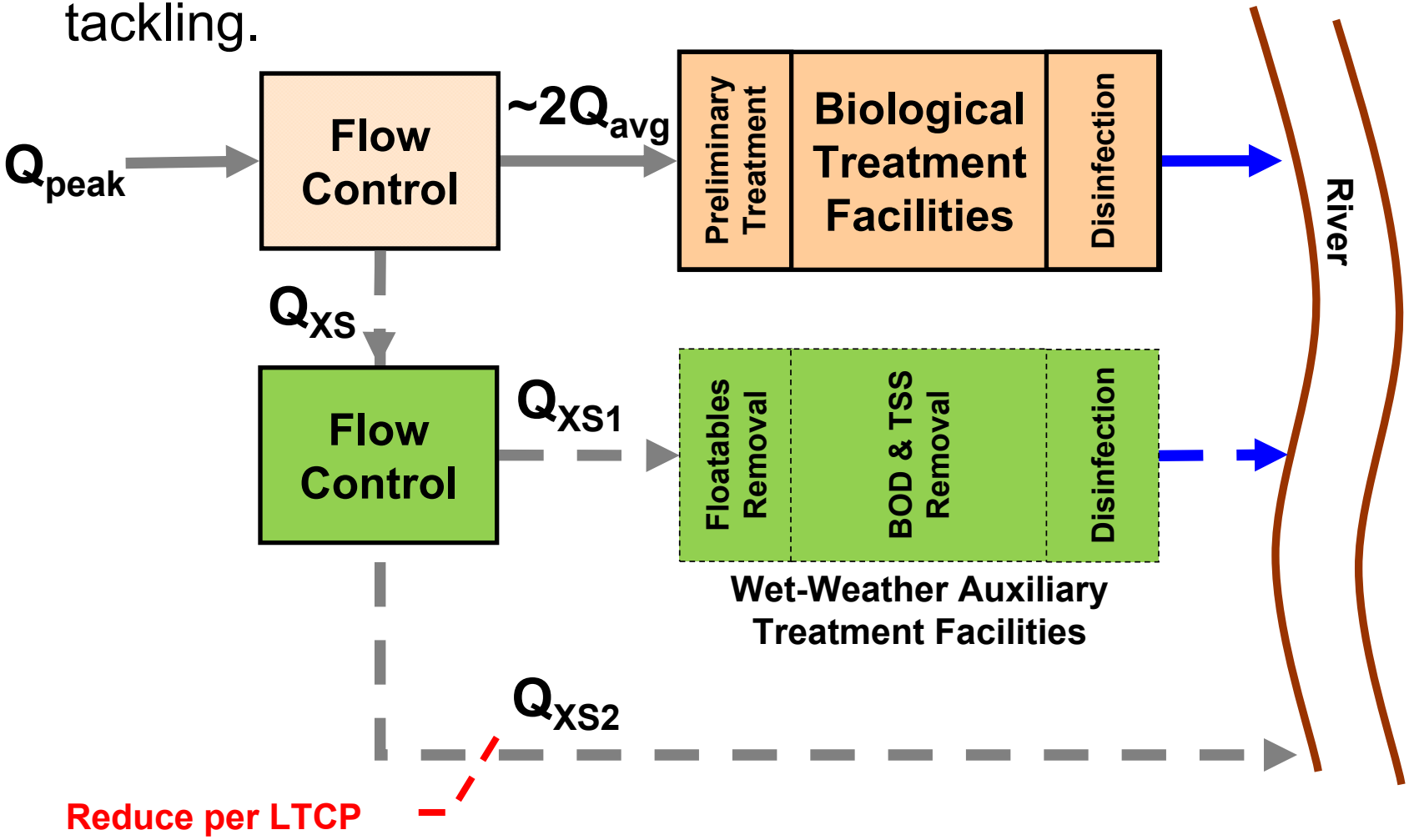
of pollutants du

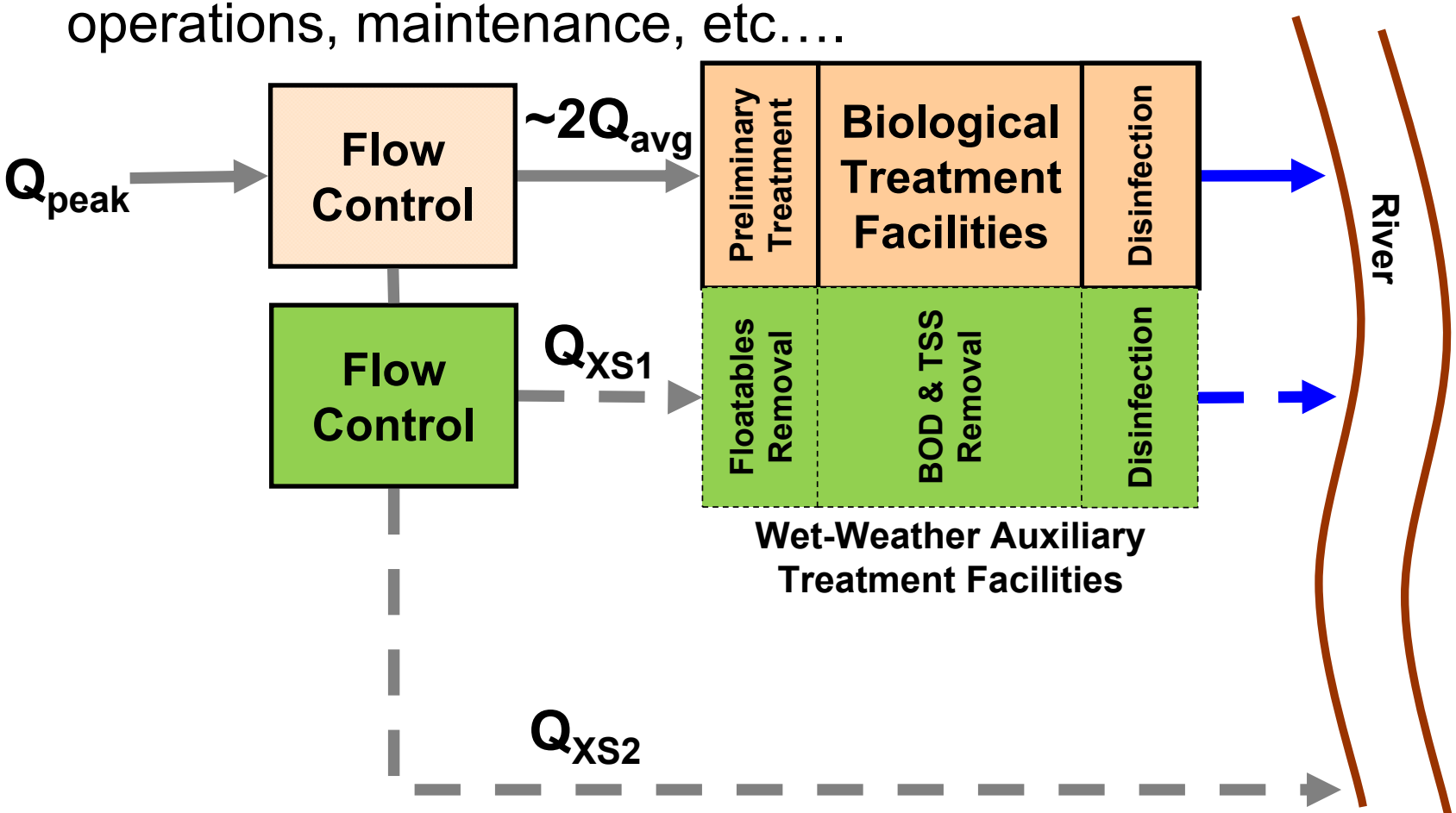
Additional treatment per CSO Control Policy...

- LTCP implementation scenario that many POTWs are now tackling.



Integrated CSO Pollution Control Facilities

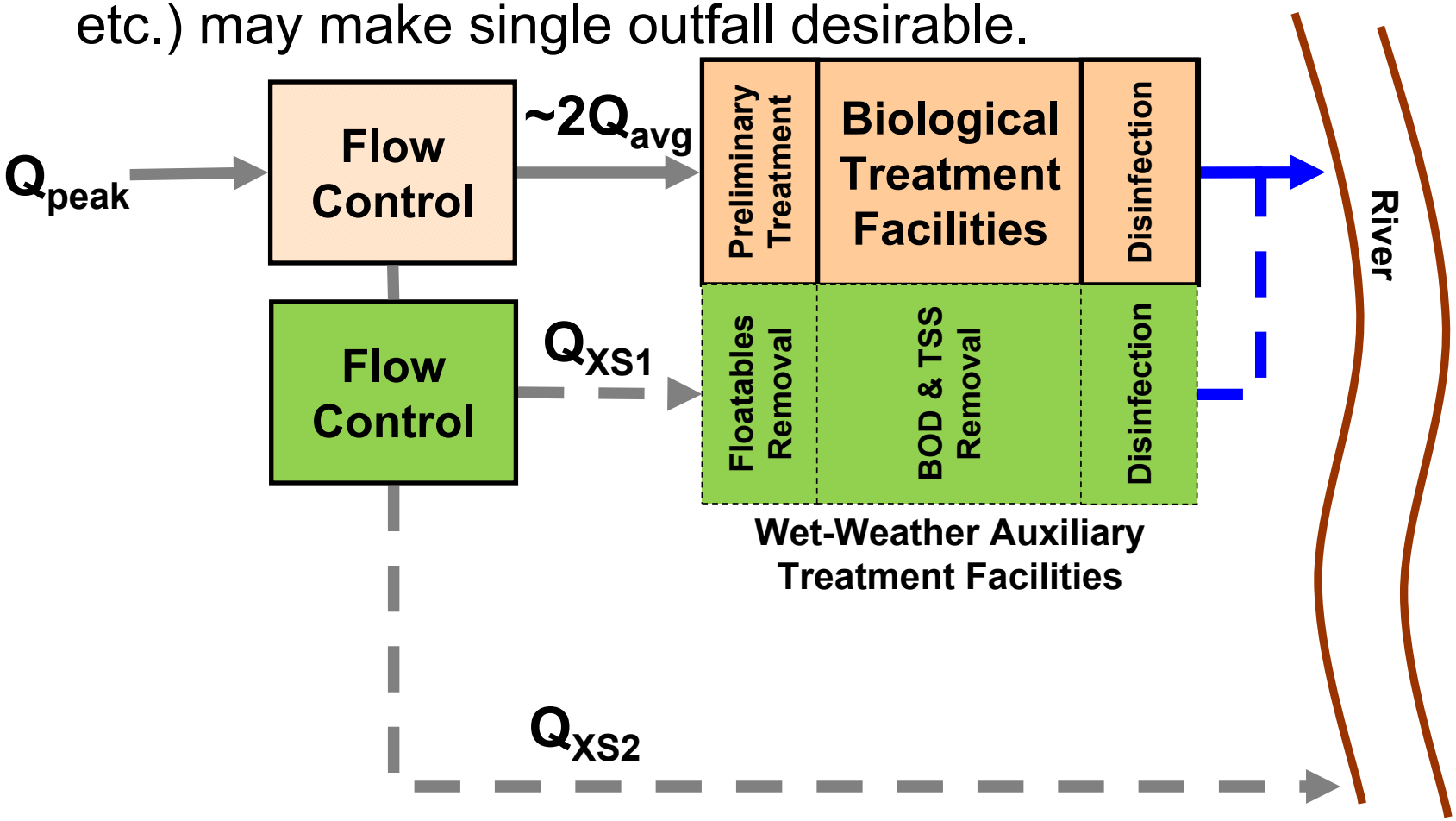
- Optimal design in many cases for event response, operations, maintenance, etc….



- …so, may be optimal design for water quality protection.

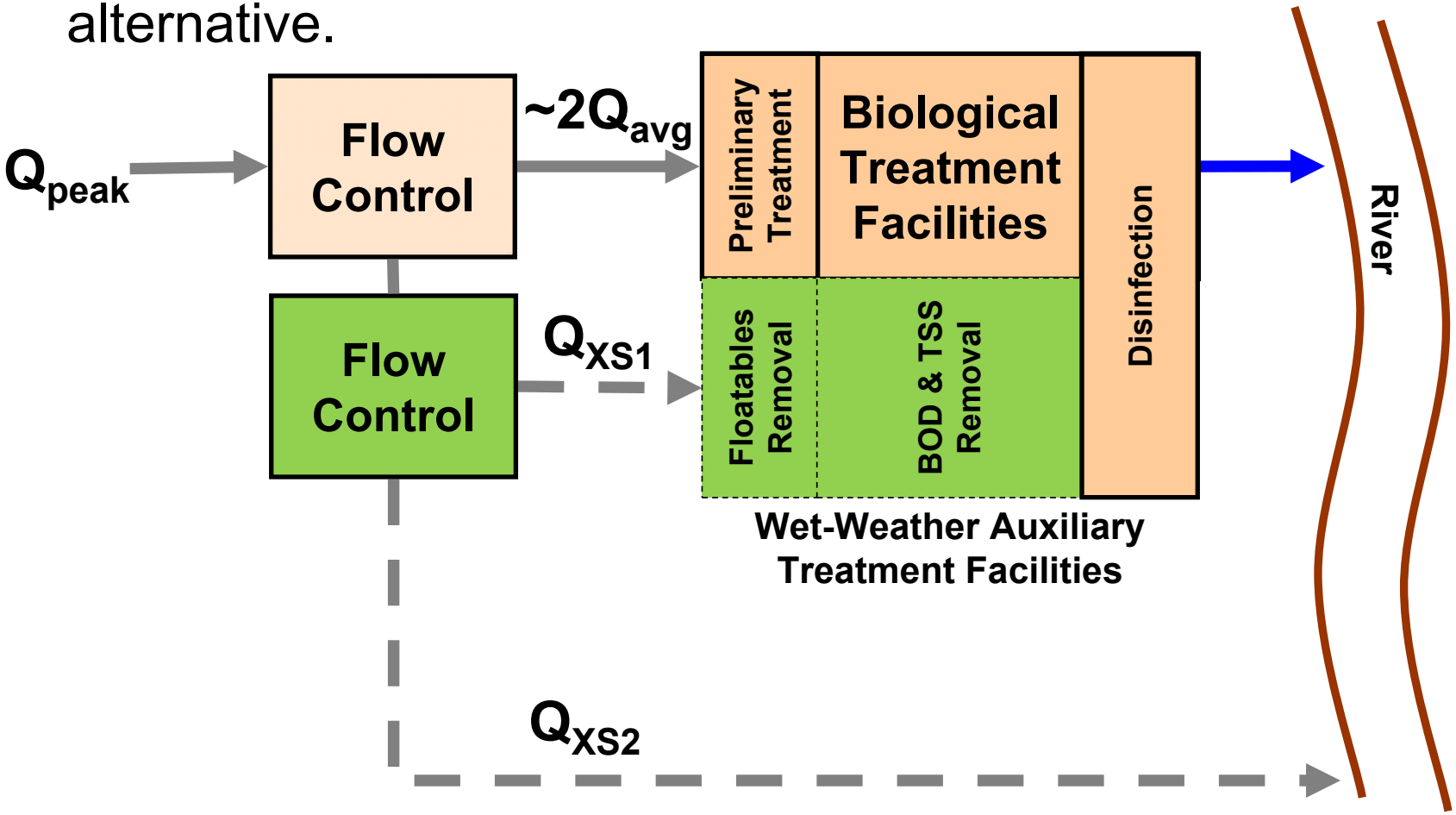
How far can we go with integrated facilities?

- Site-specific design constraints (levees, effluent pumping, etc.) may make single outfall desirable.



How far can we go with integrated facilities?

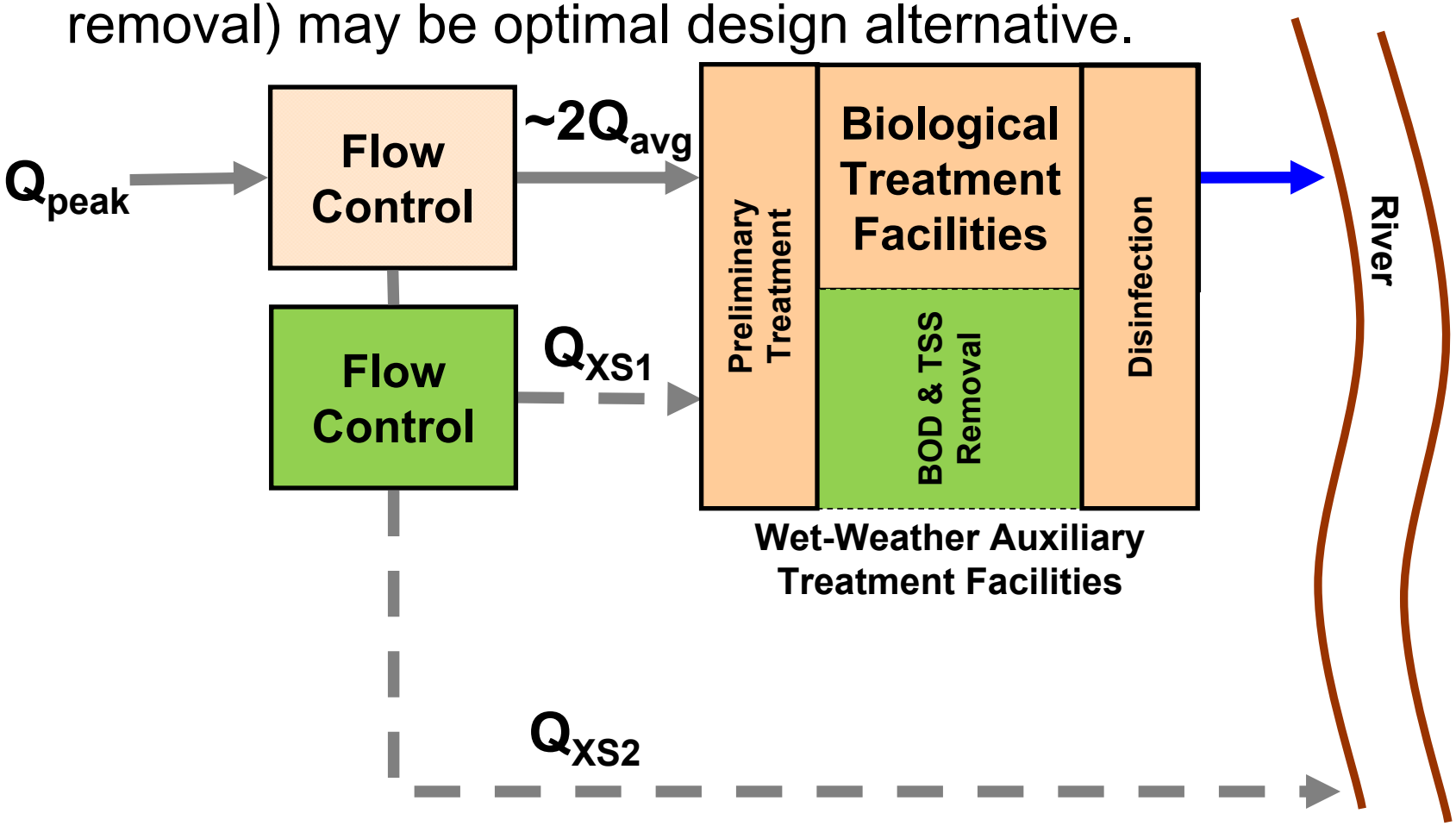
- Combined disinfection facilities may be optimal design alternative.



- Instead of separate monitoring <u>sites</u>, specify separate monitoring <u>conditions</u>

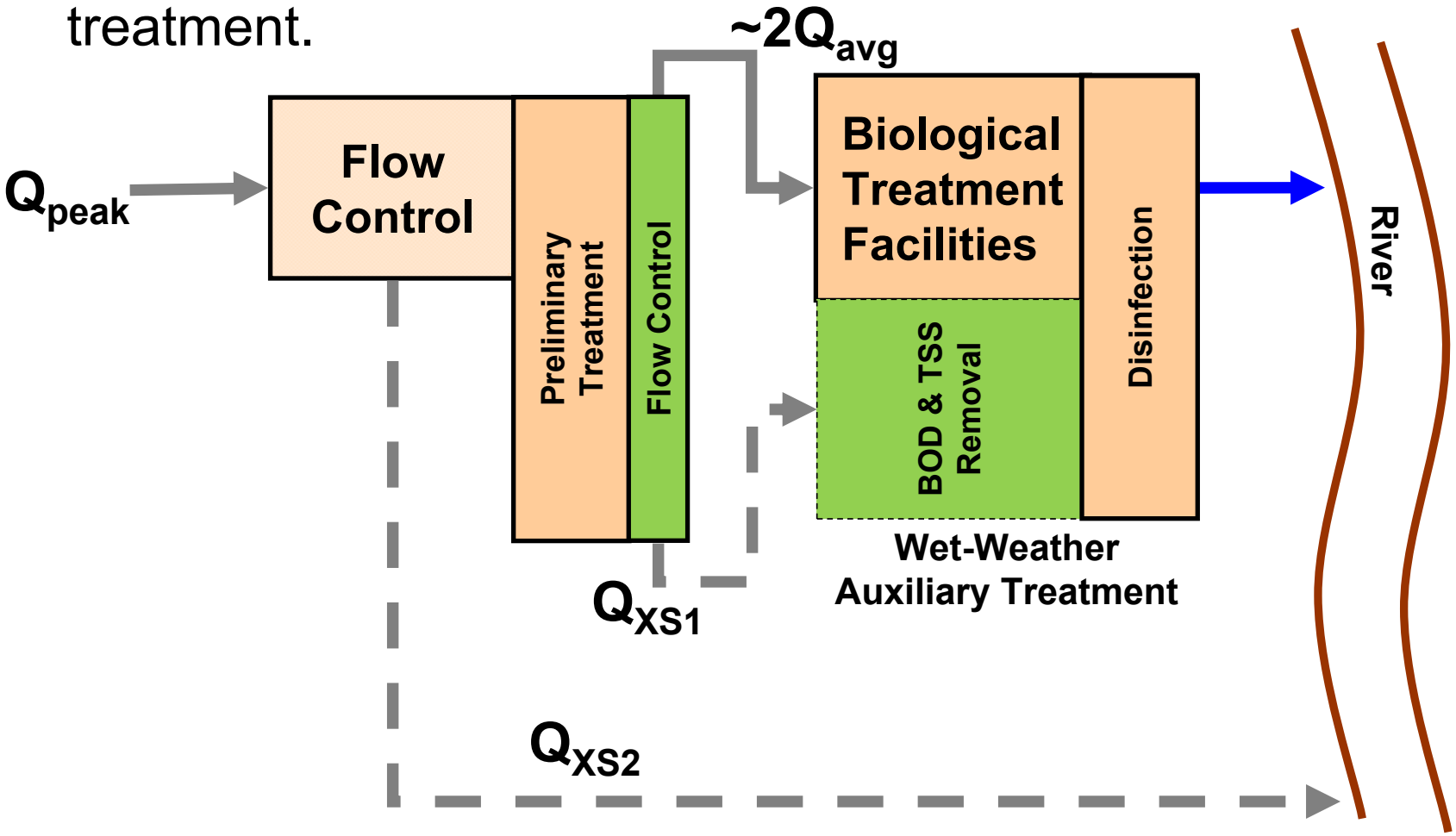
How far can we go with integrated facilities?

- Combined preliminary treatment facilities (screening & grit removal) may be optimal design alternative.

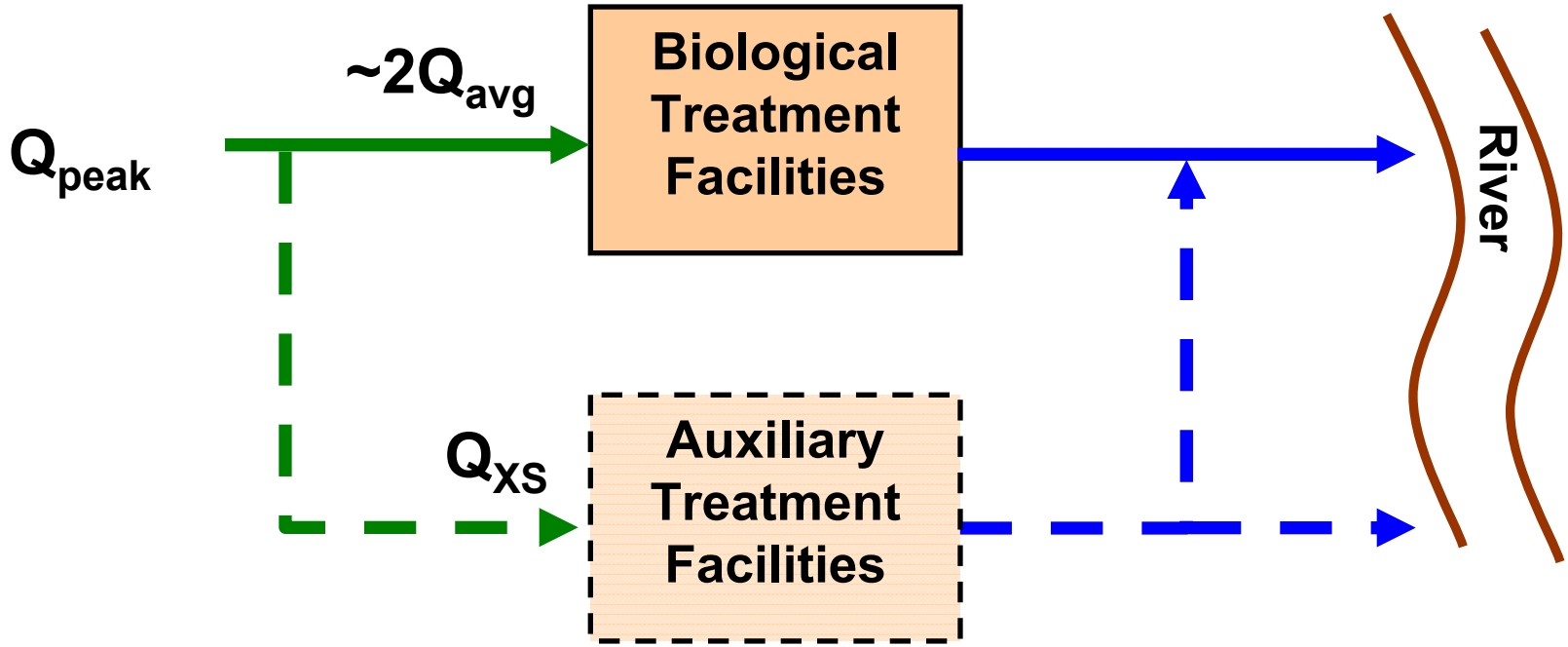


How far can we go with integrated facilities?

- Same as previous slide, except flow split is after preliminary treatment.



Wet-weather events lend themselves to a parallel auxiliary treatment strategy



- Complement the inherent wet-weather limitations of biological processes
- Auxiliary treatment facilities optimized for wet weather influent
- Enable POTW to achieve secondary treatment effluent quality during both dry and wet weather

What are "auxiliary treatment facilities"?

- Permitted use implied at 40 CFR 122.41(m)(4)(i)(B)
- Wet-weather influent characteristics are amenable to advanced physical or chemical treatment and <u>not optimal for biological treatment.</u>
  - USEPA (2008), *Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Flow Management*, EPA 832-R-06-006
  - USEPA (2007), *Wastewater Management Fact Sheet, In-Plant Wet Weather Peak Flow Management*, EPA 832-F-07-016
  - WEF (2006), *Guide to Managing Peak Wet Weather Flows in Municipal Wastewater Collection and Treatment Systems*
  - USEPA (2004), *Report to Congress, Impacts and Control of CSOs and SSOs*, EPA 833-R-04-001

Some perspective on auxiliary treatment technologies…

- Conventional Sedimentation + Disinfection
  - Long understood by POTWs to generally support CWA and codified secondary effluent quality (40 CFR 133)
  - General consensus among scientists and engineers in the treatment profession. Perhaps some site specific exceptions.
  - Supported by USEPA 1994 CSO Control Policy
- Today's Advanced HRT Alternatives
  - Built upon proven physical/chemical mechanisms
  - Produce very high quality wet-weather effluent
  - Small footprint…high capacity

High-Rate Treatment Technologies

Today's advanced physical or chemical technologies were not envisioned by the NPDES program when "blending" or "bypassing" was defined.

Auxiliary treatment facilities generally consist of multiple process units

- Influent or Effluent Pumping
- Screening
- Grit Removal
- BOD & TSS Removal
- Effluent Disinfection

Solids Handling Considerations

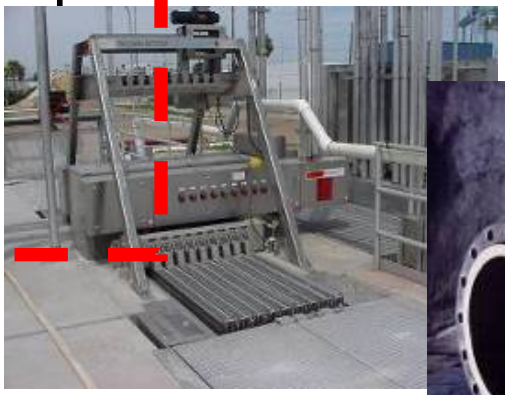
Various technology and design alternatives for each process unit

Effluent Disinfection

Effluent Disinfection Alternatives Include…

- Chlorination
  - Gas vs. Hypochlorite
  - Onsite generation?

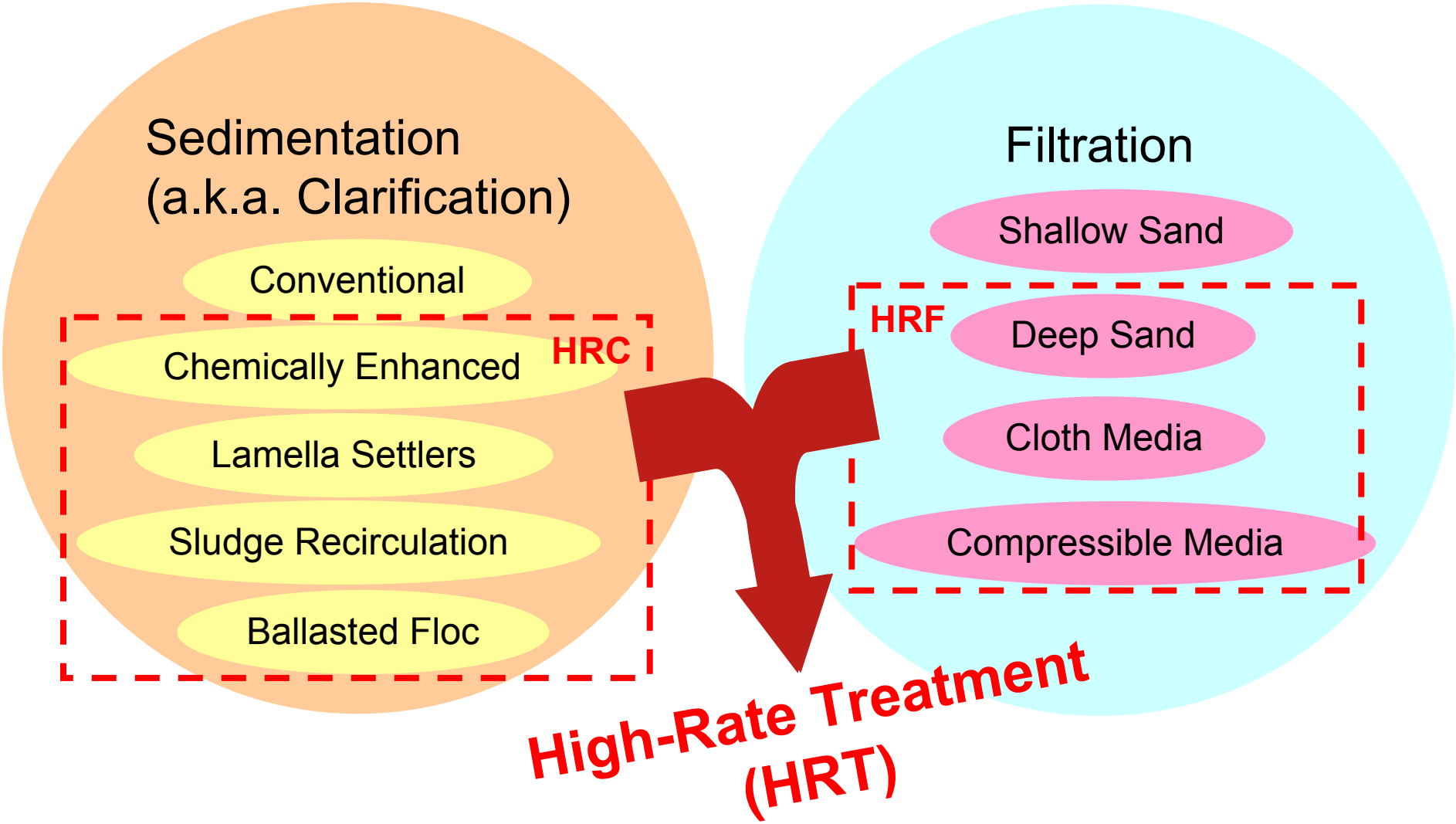
- UV
  - Low Pressure High Output
  - Medium Pressure
    - Open Channel
    - Closed Vessel



- Other? O_3, ClO_2, PAA, BCDMH

BOD & TSS Removal

Many of today's HRT technologies weren't available when NPDES regulations were formed



Conventional Sedimentation

- Also known as:
  - Primary Clarification
  - Settling
  - Gravity Settling
  - *Primary Treatment*

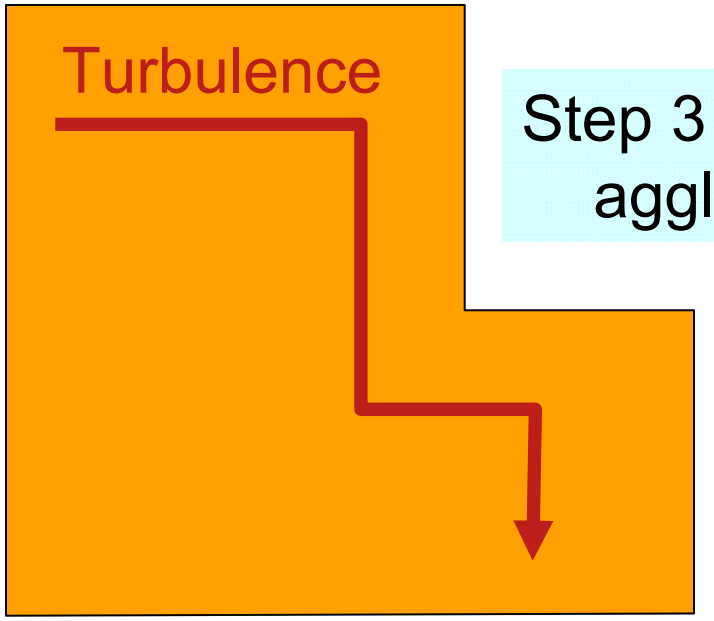
Chemically enhanced sedimentation continues to prove its effectiveness

- 1500 BC - Alum coagulation by Egyptians
- 1740 AD - Chemical sewage treatment in Paris
- Today – a.k.a. **CEPT** (Chemically Enhanced Primary Treatment) or **CEC** (Chemically Enhanced Clarification) or **CES** (Chemically Enhanced Settling or Sedimentation)

The 4 Basic Steps of CEPT

Step 1 – Coagulant Addition: Rapid mixing of metal salt and/or cationic polymer.

Step 2 – Flocculant Addition: Rapid mixing of anionic polymer. If ballast or other measures also taken, CEPT ➔ HRC.

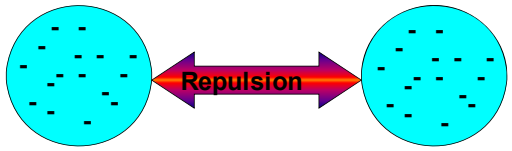


Step 3 – Flocculation: Low turbulence to agglomerate particles into floc.

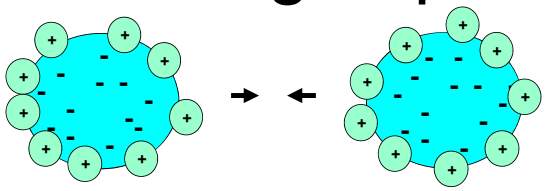
Step 4 – Settling: Quiescent zone to separate floc from clarified effluent.

What are we trying to do with coagulants and flocculants?

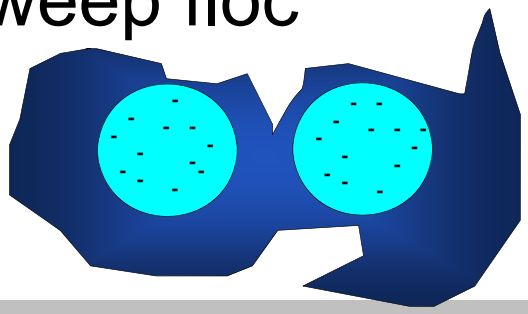
- Most particles in water tend to have a negative surface charge.



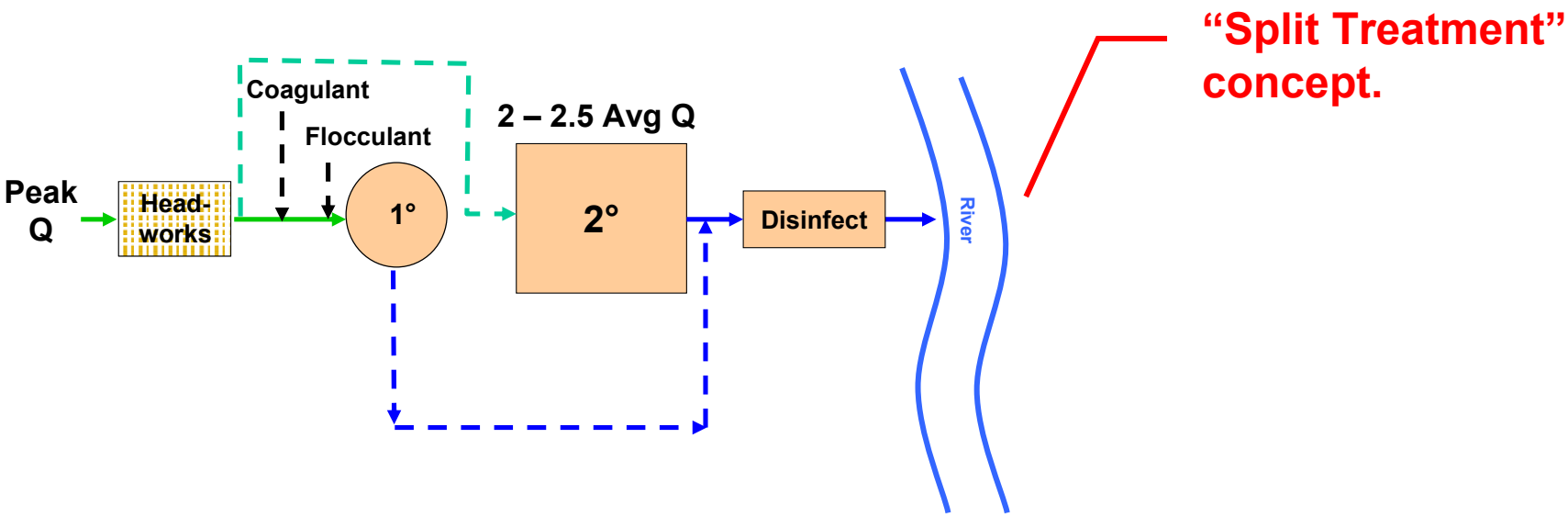
- Coagulants result in cations adsorbing to particle, canceling repulsive forces.



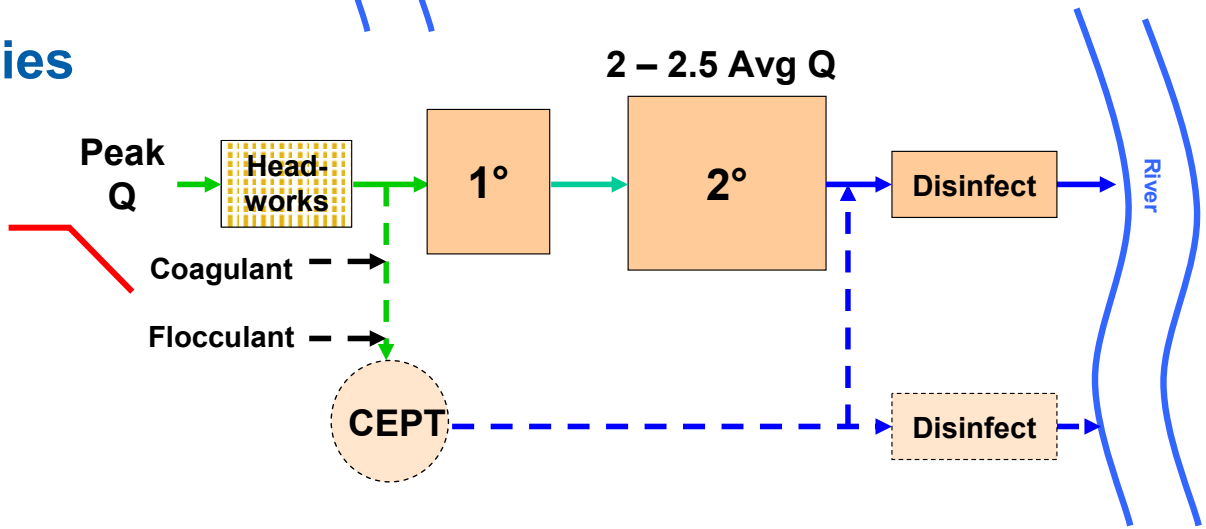
- Flocculants help to compensate for coagulant overdosing and imperfect flocculation conditions. Glue particles together into a floc. “Sweep floc coagulation”



CEPT can be implemented different ways



CEPT with Existing Facilities



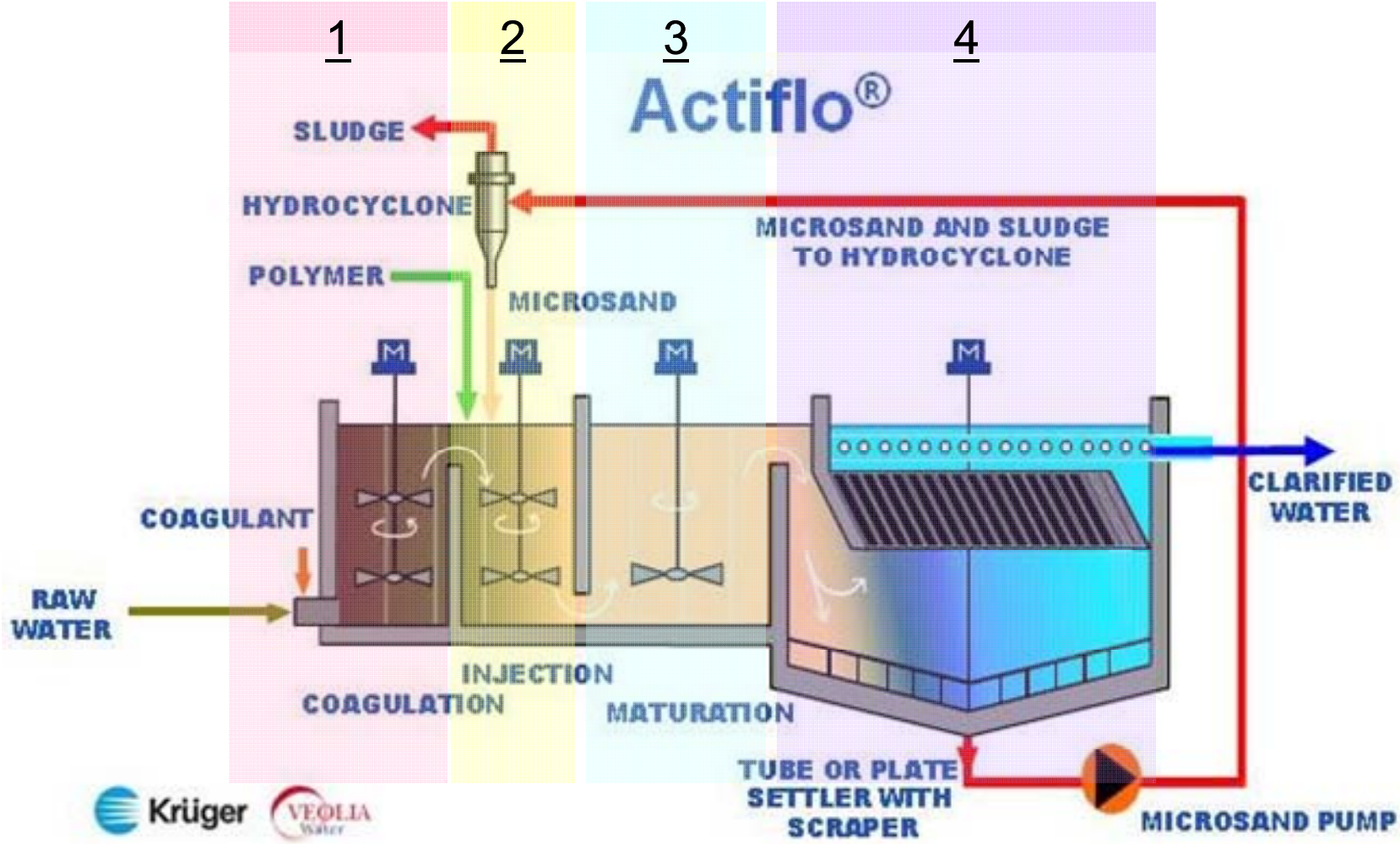
Potential enhancement for existing peak flow clarifiers.

Additional CEPT Facilities

Sludge Recirculation and Ballasted Flocculation

- Same chemical enhancements as CEPT, but:
  - Use lamella settlers to decrease settling tank footprint
  - Recirculate solids to further enhance flocculation
  - Add ballast or other mechanism to create denser floc
  - Generally higher chemical dose than CEPT, but not always
- Also known as Chemically Enhanced High Rate Settling, Ballasted Flocculation (and others).

HRC - Ballasted Flocculation (Sand)

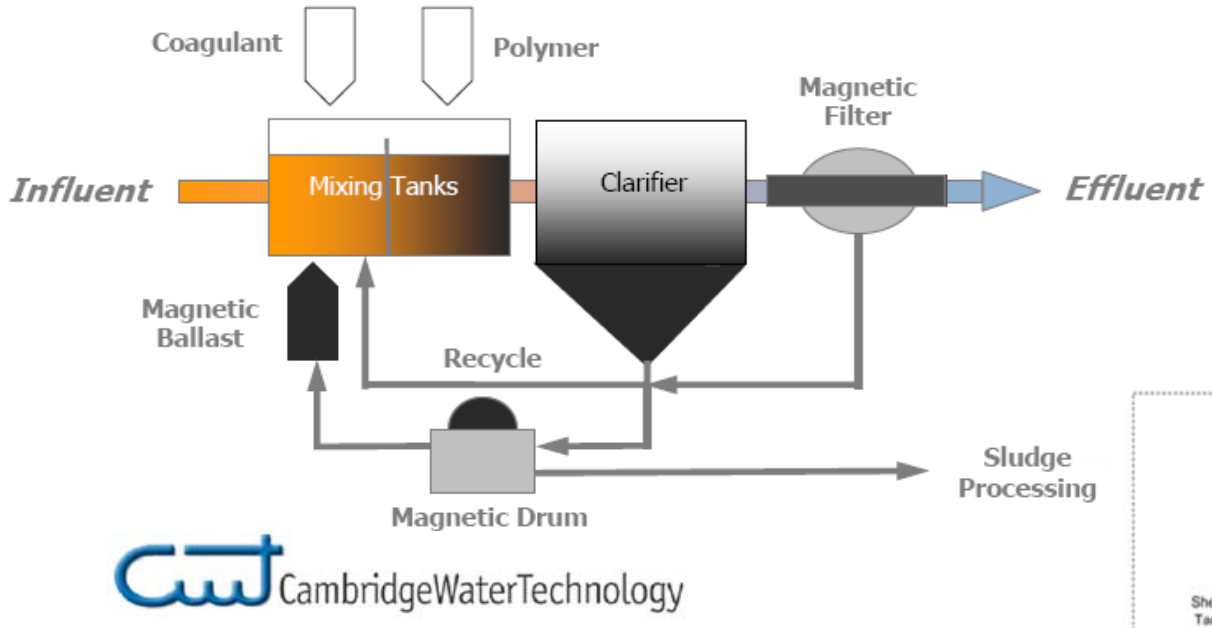


CSO/SSO

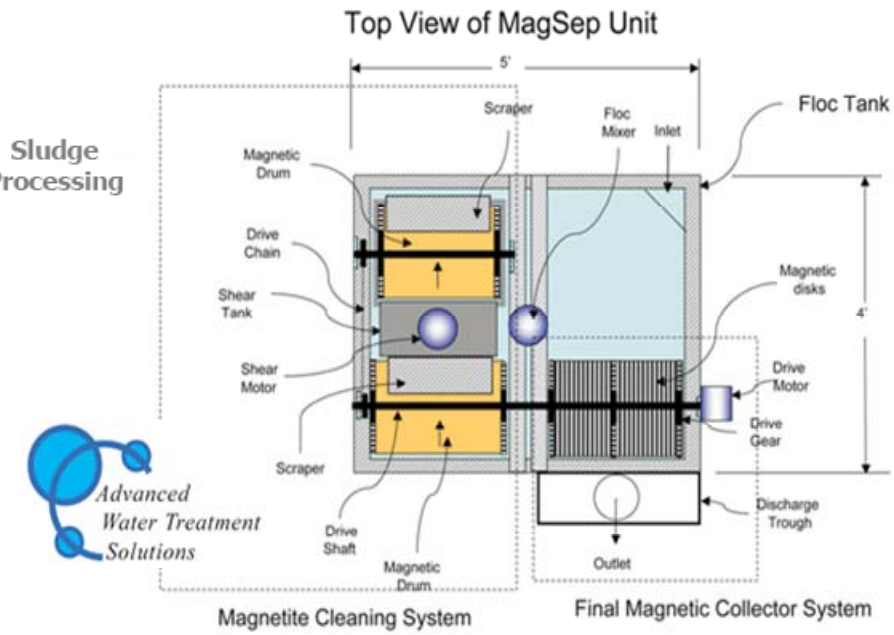
43 worldwide, 15 U.S. (July, 2008)

HRC - Ballasted Flocculation (Magnetite)

CoMag™

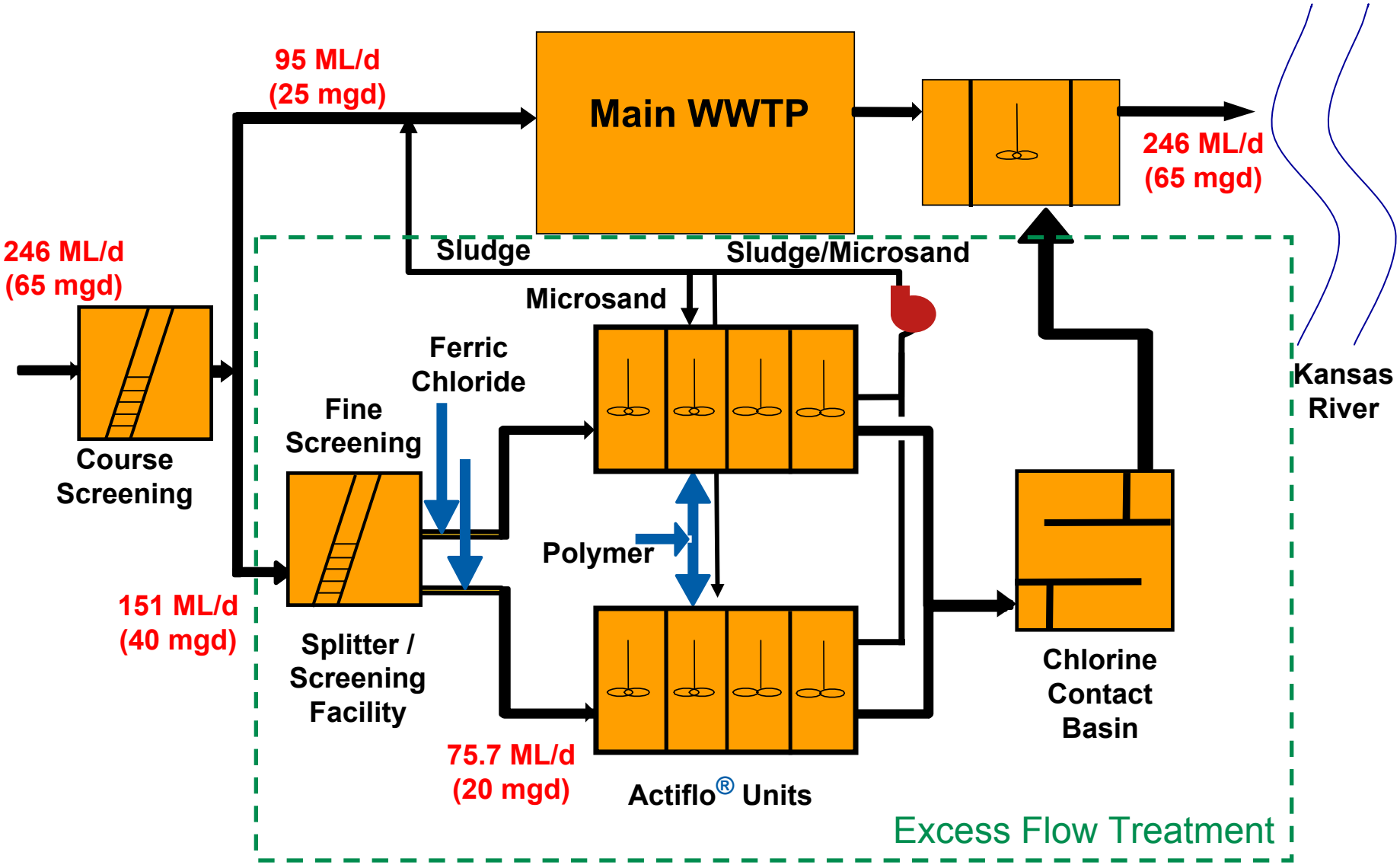


MagSep

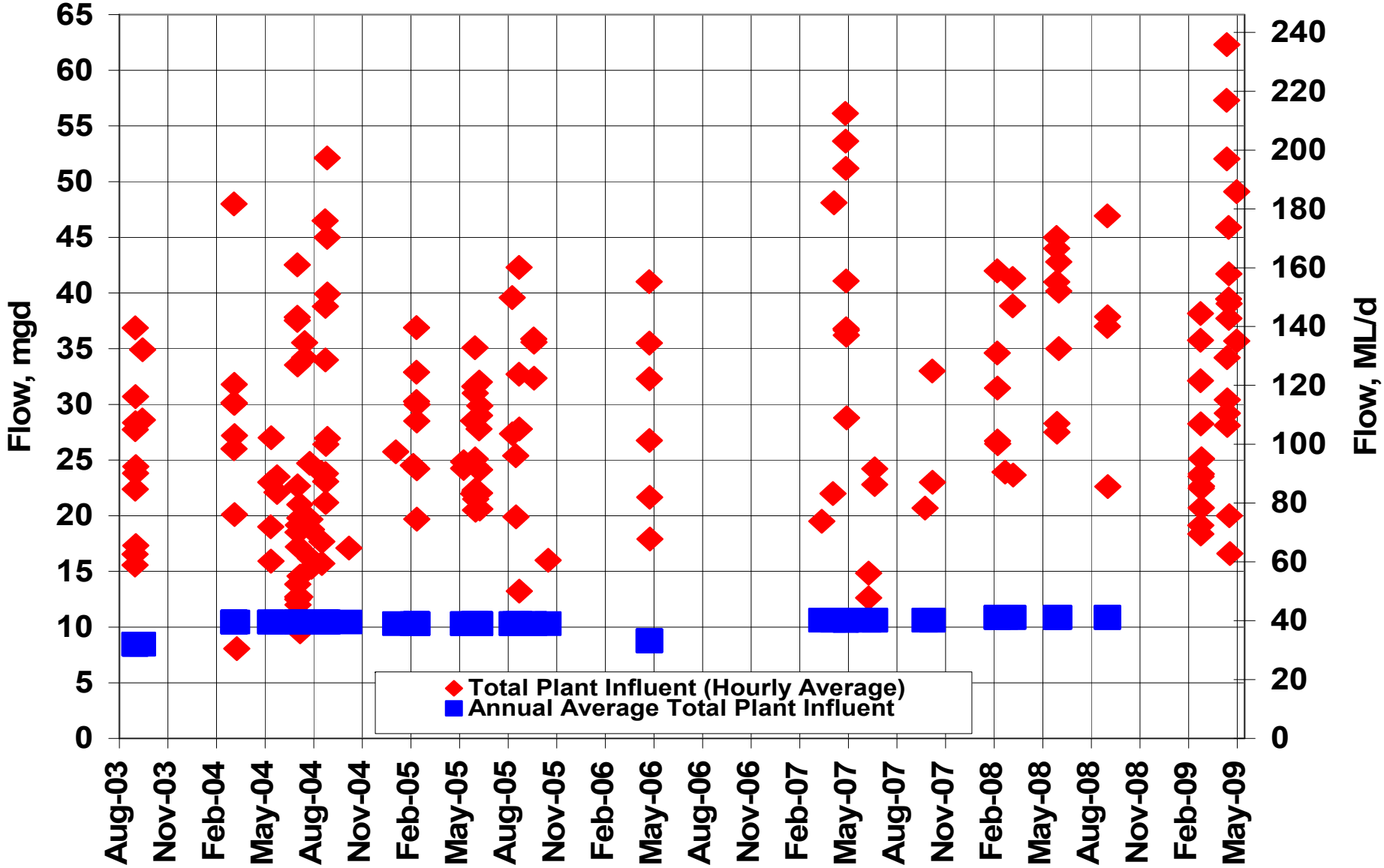


Lawrence, Kansas Excess Flow Treatment Upgrades

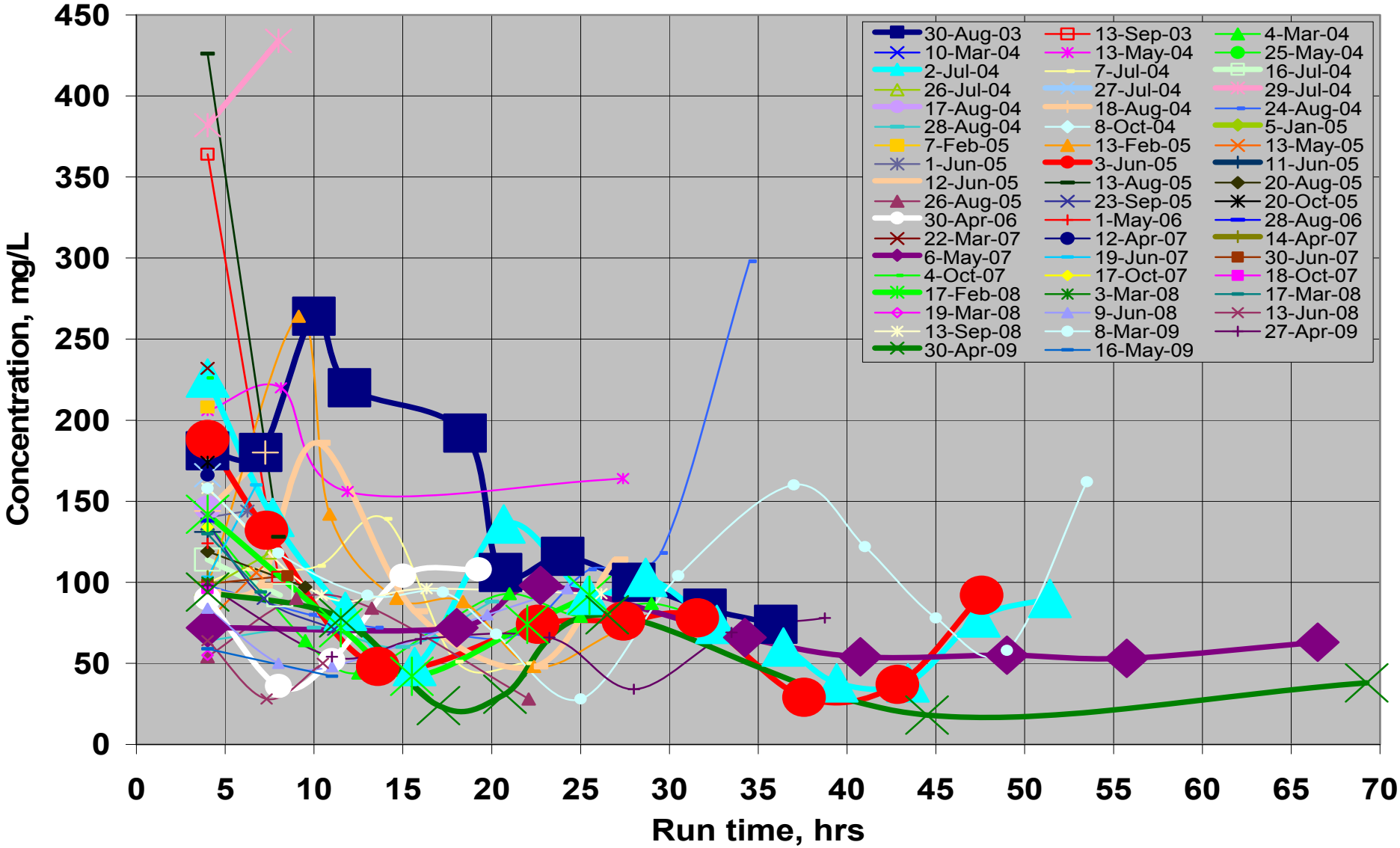
Lawrence Wet Weather Flow Schematic



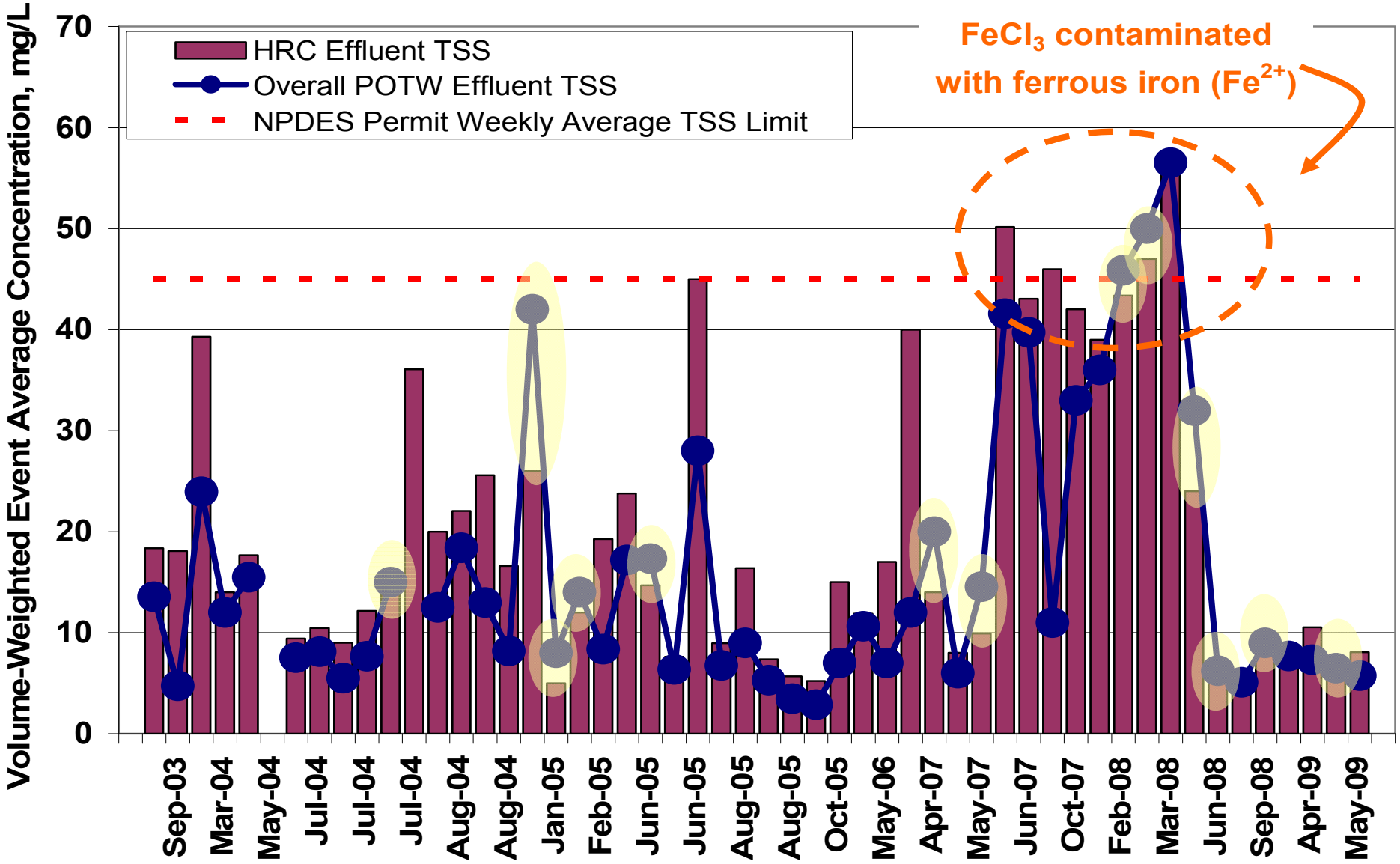
Lawrence Wet Weather Flows



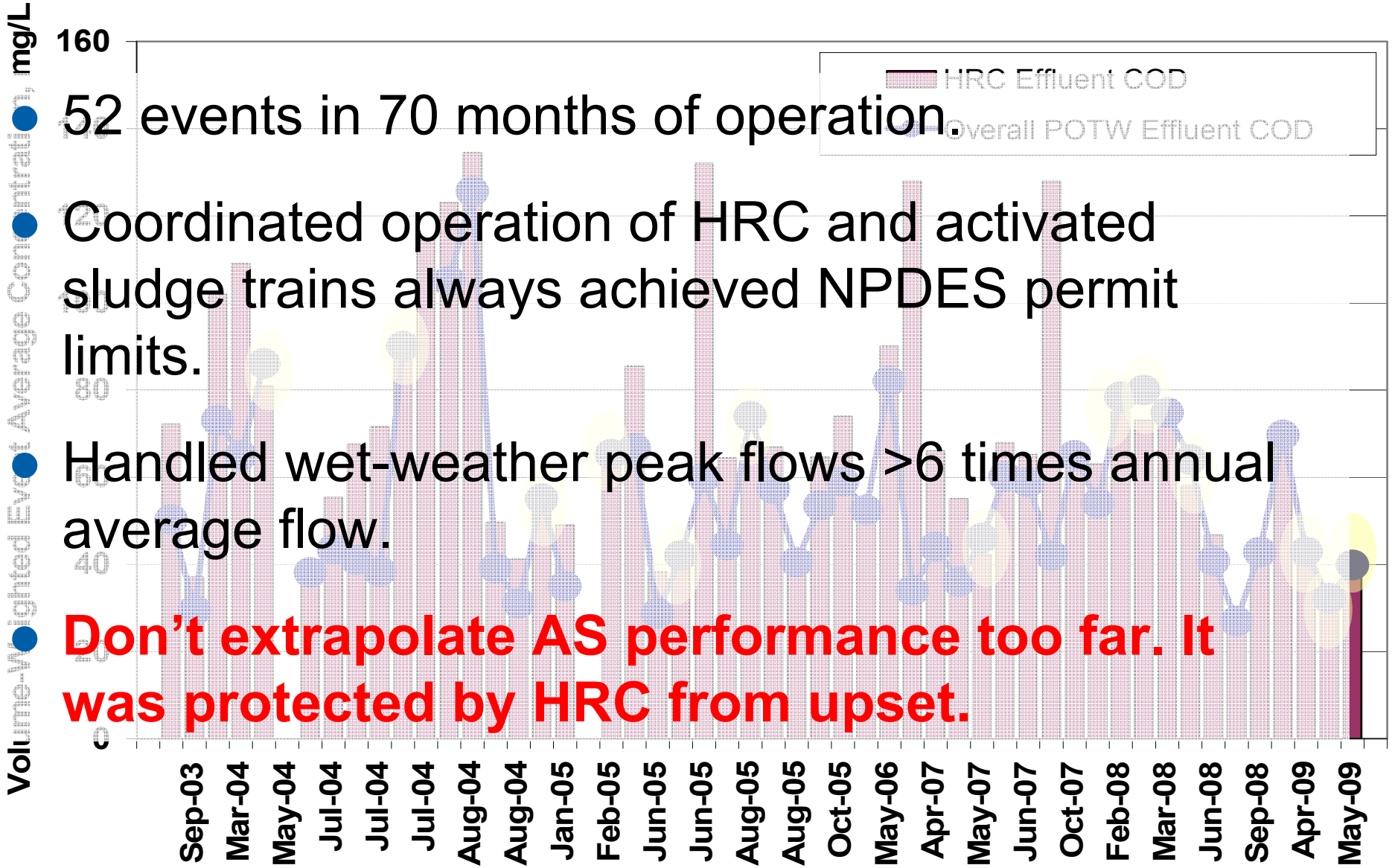
Lawrence Wet Weather Influent TSS



Lawrence Wet Weather Effluent TSS

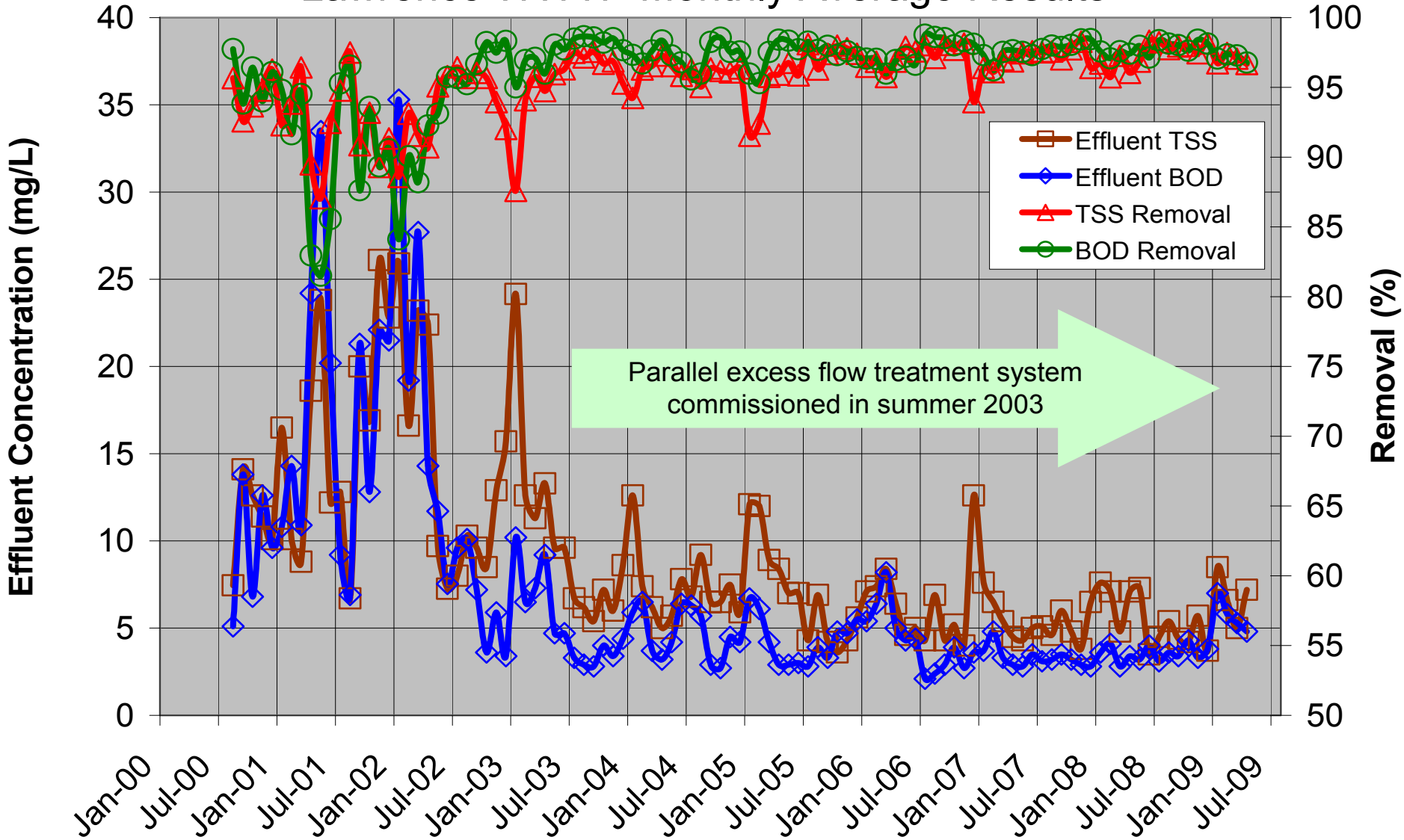


Lawrence Wet Weather Effluent COD

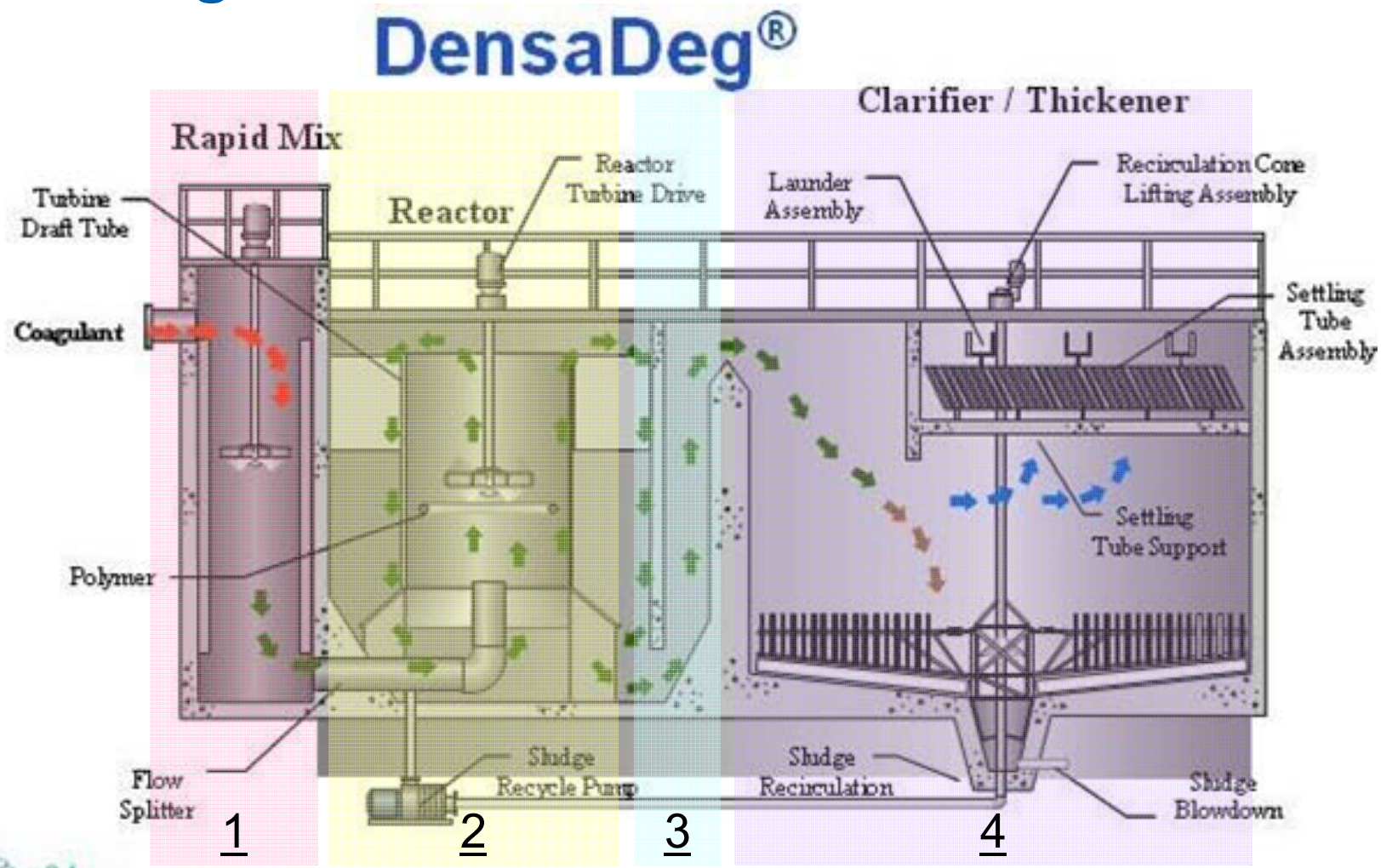


- 52 events in 70 months of operation.
- Coordinated operation of HRC and activated sludge trains always achieved NPDES permit limits.
- Handled wet-weather peak flows >6 times annual average flow.
- **Don't extrapolate AS performance too far. It was protected by HRC from upset.**

Lawrence WWTP Monthly Average Results



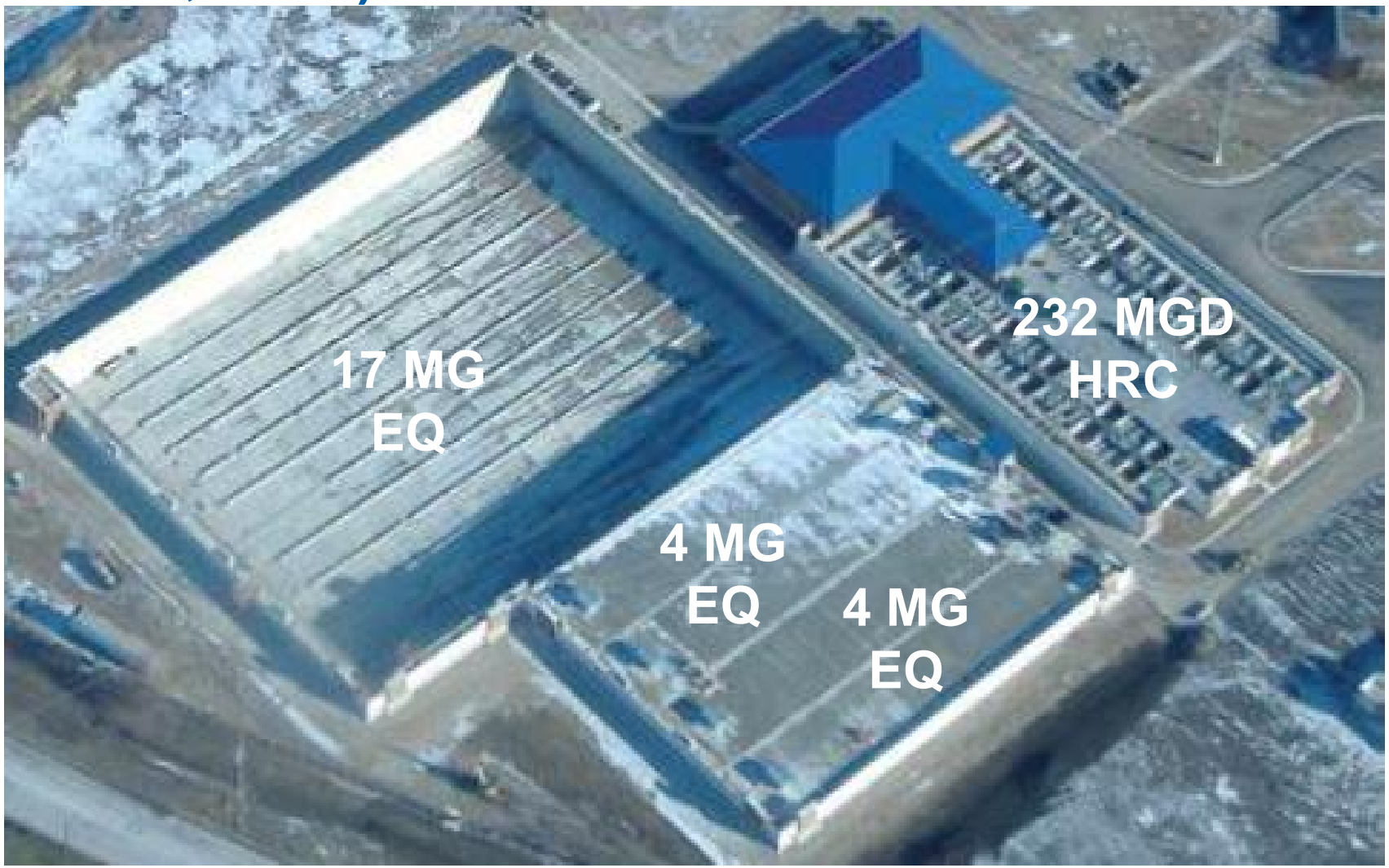
HRC - Sludge Recirculation



CSO/SSO

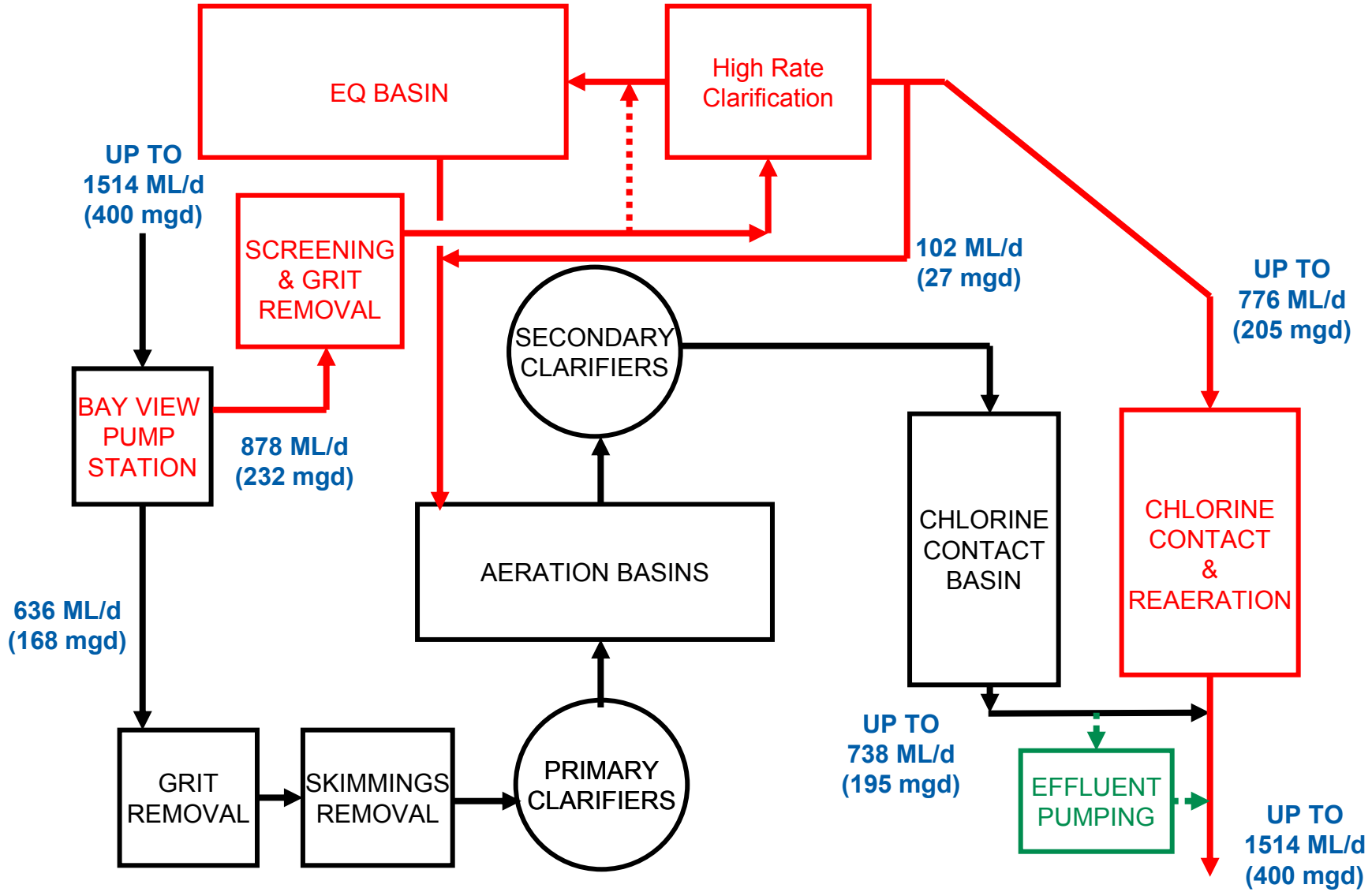
11 worldwide, 2 U.S. (July, 2008)

Excess Flow Treatment at Bay View WWTP (Toledo, Ohio)

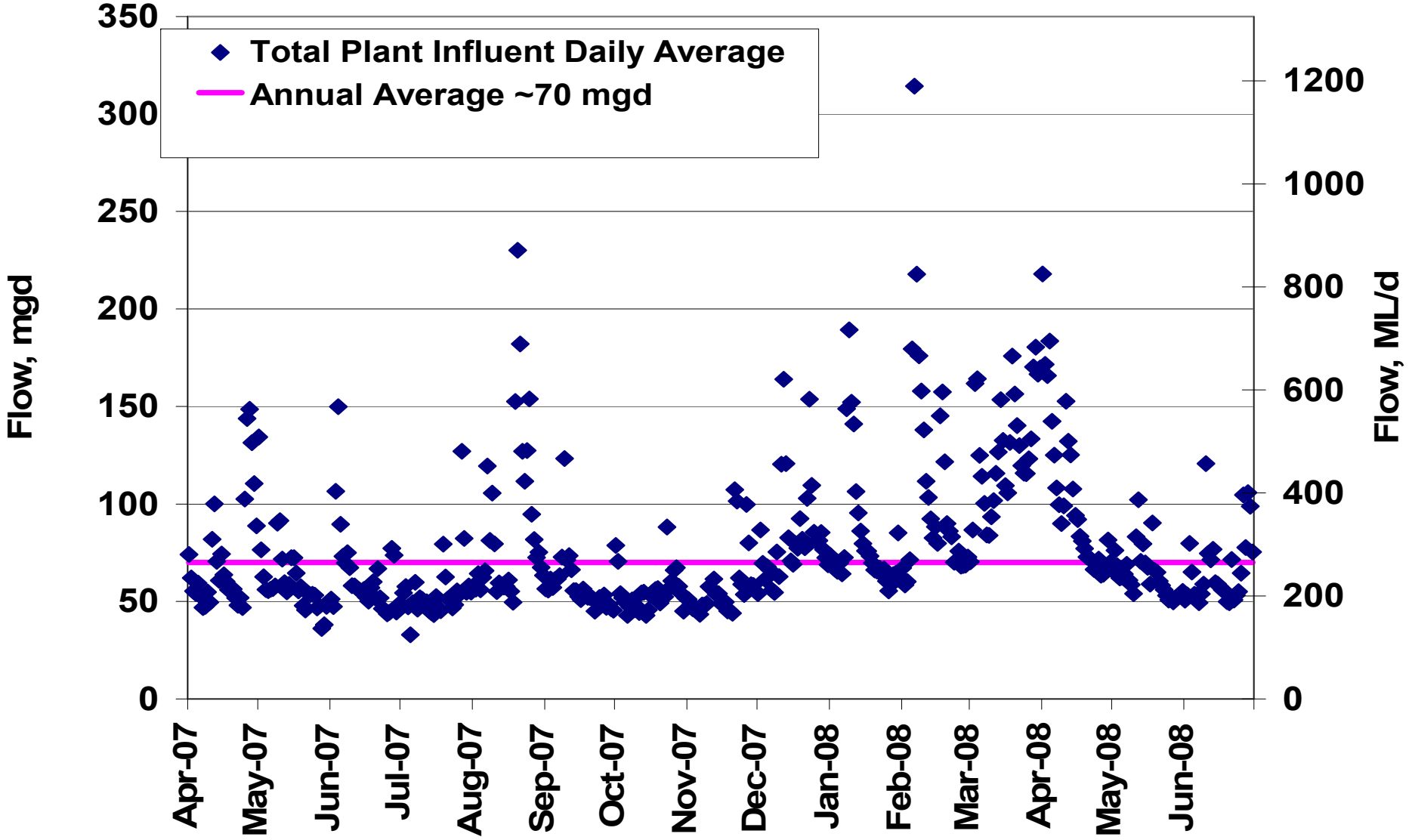


Toledo DensaDeg HRC System

Bay View WWTP Wet Weather Flow Schematic

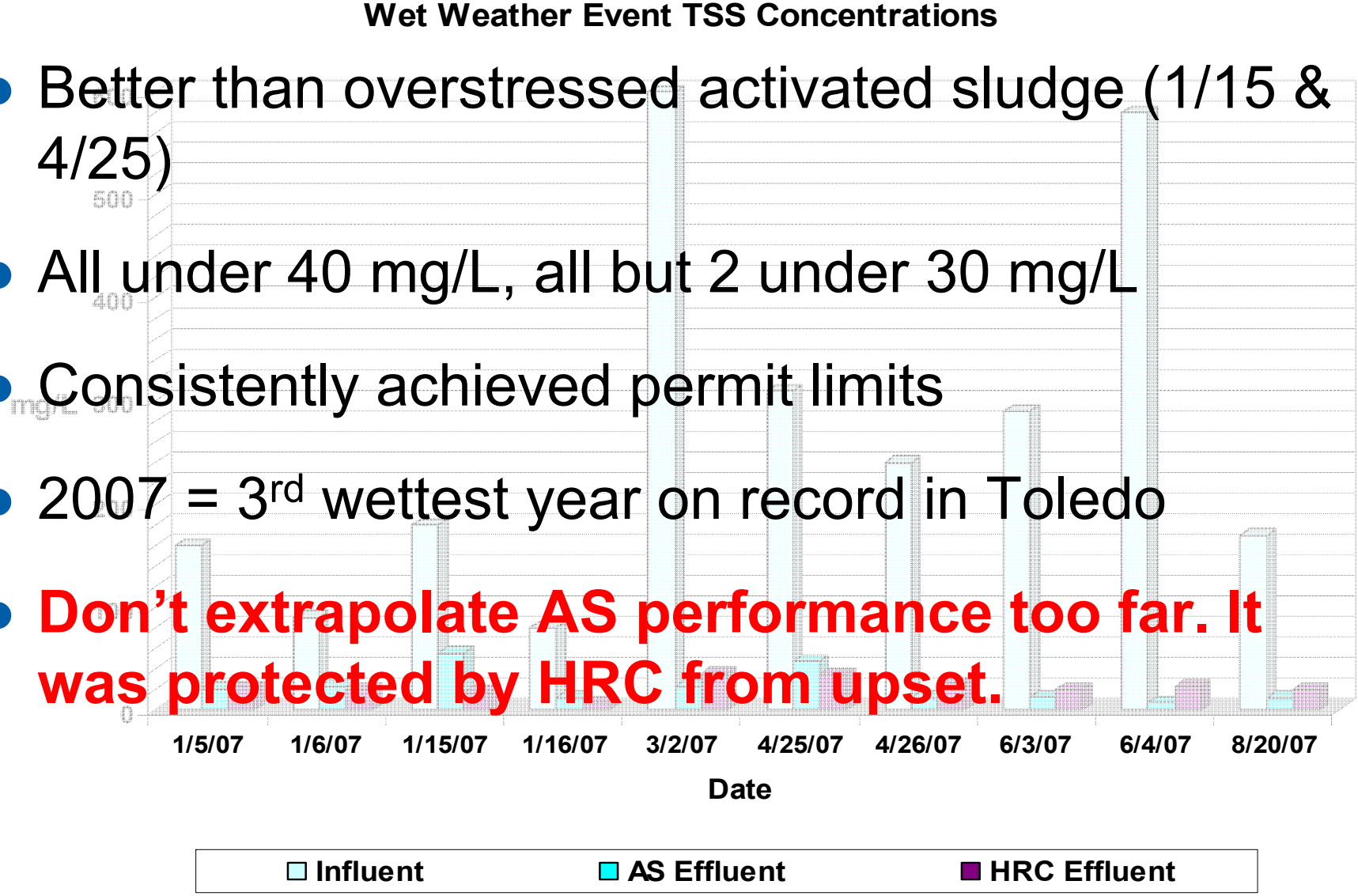


Bay View WWTP Wet Weather Flows



Toledo Parallel Excess Flow Treatment

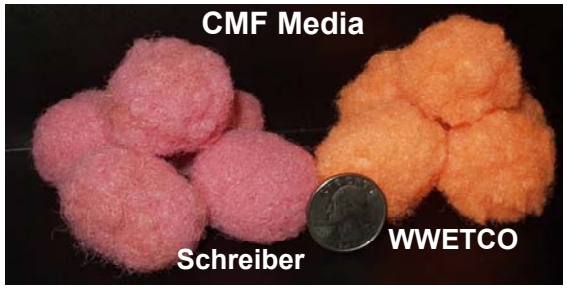
- Better than overstressed activated sludge (1/15 & 4/25)
- All under 40 mg/L, all but 2 under 30 mg/L
- Consistently achieved permit limits
- 2007 = 3rd wettest year on record in Toledo
- **Don't extrapolate AS performance too far. It was protected by HRC from upset.**

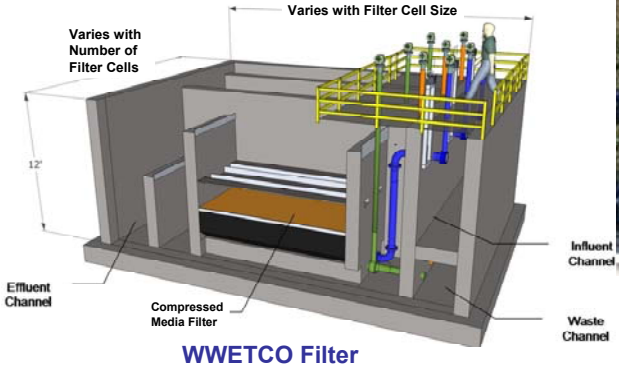


HRF alternatives offer similar TSS & BOD as HRC, but no chemicals required

- 2000 BC - Granular filtration in ancient Sanskrit writings

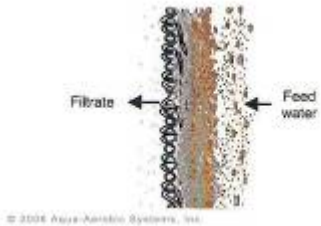
- Today
  - Deep-bed granular media
  - Compressible media
  - Cloth media

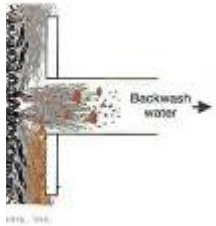




WWETCO Filter

Schreiber Fuzzy Filter





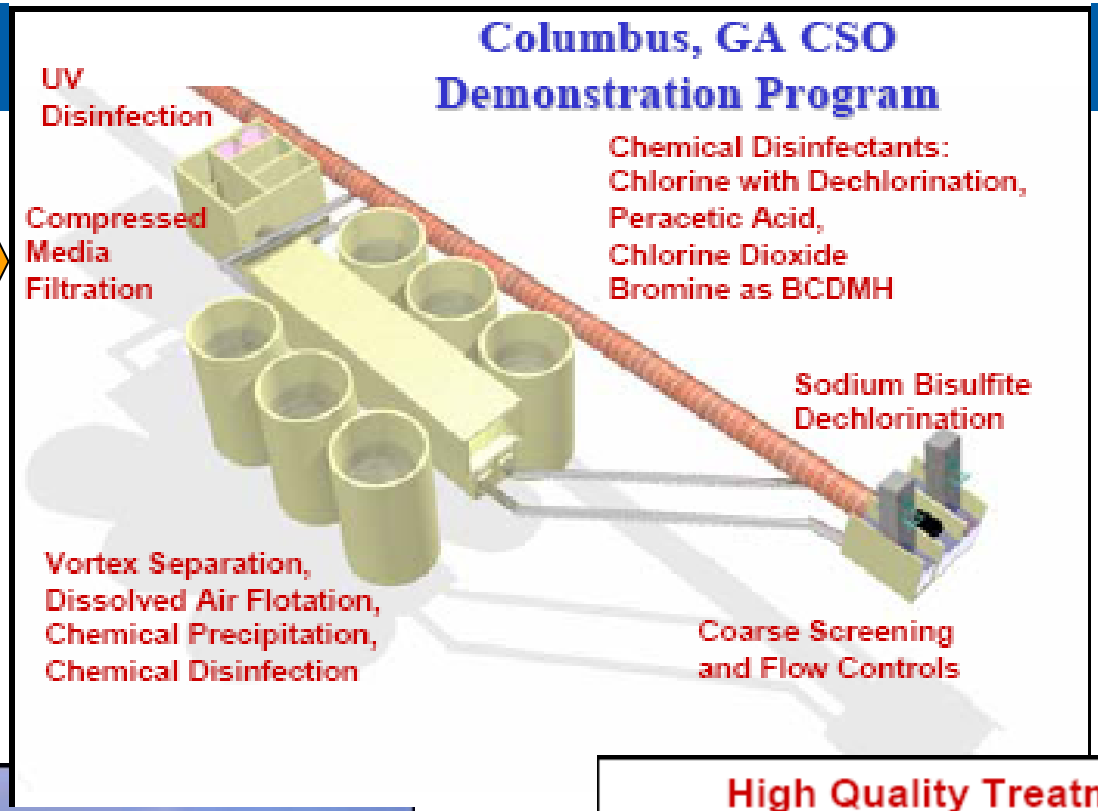
Full-scale CMF wet-weather treatment facilities

Atlanta, GA
www.cleanwateratlanta.org

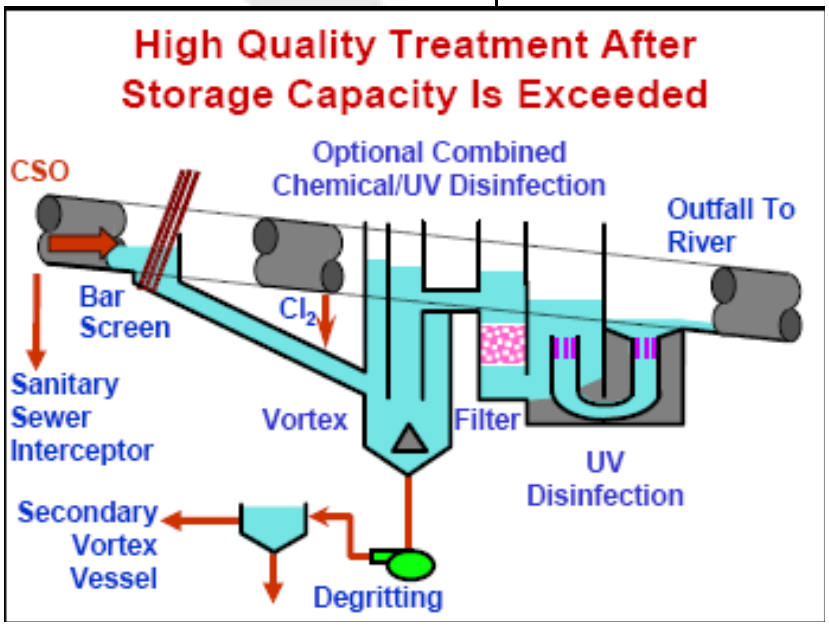
Columbus, GA
www.cwwga.org
Walter F. George Reservoir

Chattahoochee River Watershed

CMF


Columbus, GA CSO
Demonstration Program
UV
Disinfection
Compressed
Media
Filtration
Chemical Disinfectants:
Chlorine with Dechlorination,
Peracetic Acid,
Chlorine Dioxide
Bromine as BCDMH
Sodium Bisulfite
Dechlorination
Vortex Separation,
Dissolved Air Flotation,
Chemical Precipitation,
Chemical Disinfection
Coarse Screening
and Flow Controls

Uptown Park
Water Resources Facility


High Quality Treatment After
Storage Capacity Is Exceeded
CSO
Optional Combined
Chemical/UV Disinfection
Outfall To
River
Bar
Screen
Cl_2
Sanitary
Sewer
Interceptor
Vortex
Filter
UV
Disinfection
Secondary
Vortex
Vessel
Degritting

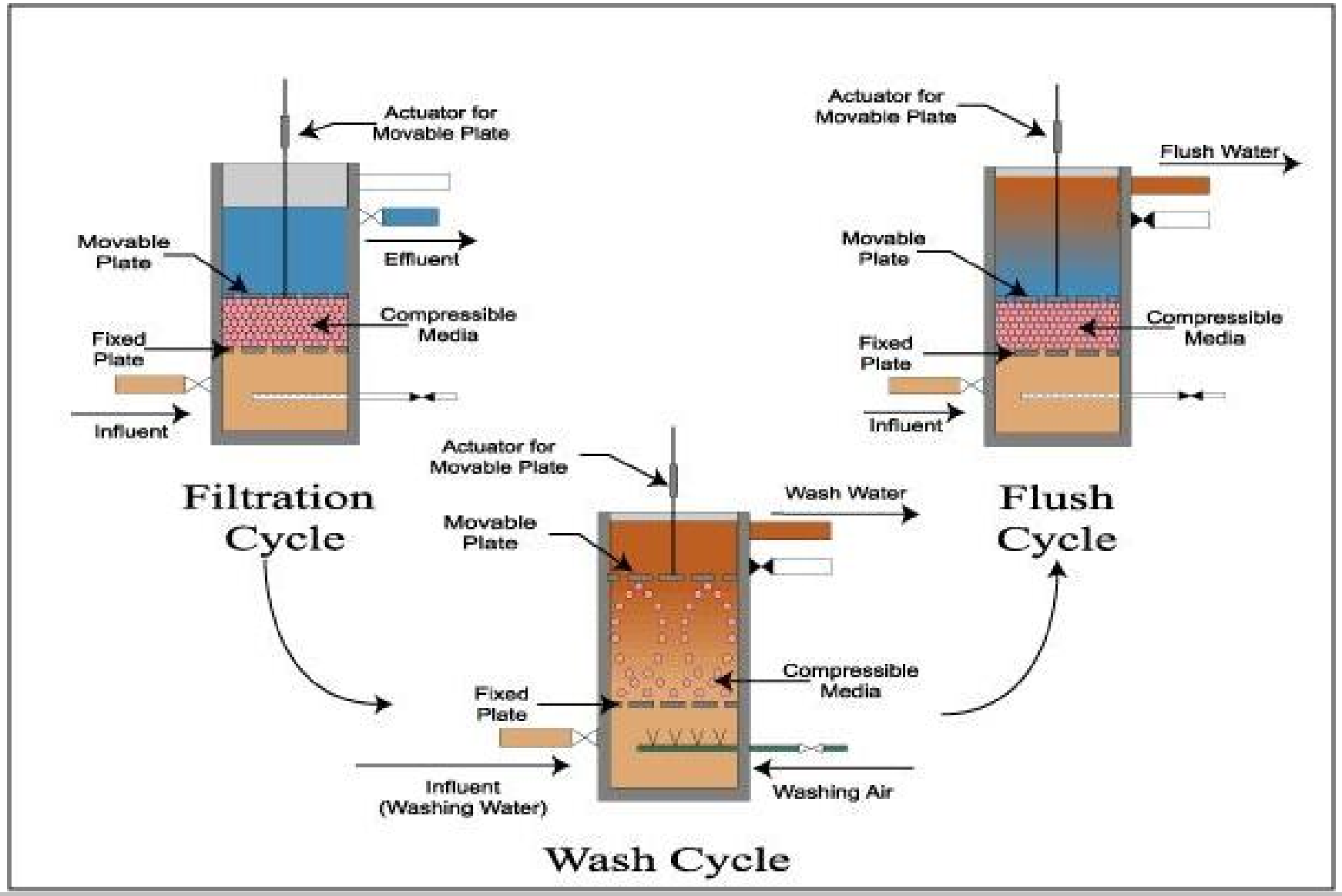
Columbus LTCP Implementation and Keys to Compliance Success

- 1990 to 1995: CSO Control Program Development
- 1996 to 2001: Regional Watershed Studies
- 2001 to Present Day: Watershed Controls Implementation and Demonstrations
  - Satellite auxiliary treatment facilities
  - Monthly monitoring and reporting of events, bacteria, TSS and phosphorous
  - Demonstration approach. Comprehensive multi-year post-construction watershed monitoring and modeling study and water quality compliance analysis.
  - Development of science-based frequency criteria for WQS
    - Impaired water definitions from USEPA *Guidance for 2006 Assessment, Listing and Reporting Requirements, p. 67* http://www.epa.gov/owow/tmdl/2006IRG/report/2006irg-report.pdf
  - TMDL evaluation and implementation plan with Georgia reasonable potential analysis. Columbus LTCP has no reasonable potential to violate WQS. CSO control facilities have no numerical effluent limits.
  - Columbus will be able to show the Chattahoochee River at Columbus is not impaired and request a Record of Decision to be removed from the impaired water classification (next impairment cycle is 2010)

CMF Media

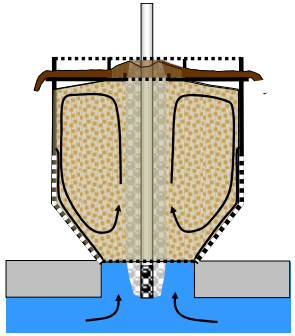
Schreiber

CMF – Fuzzy Filter

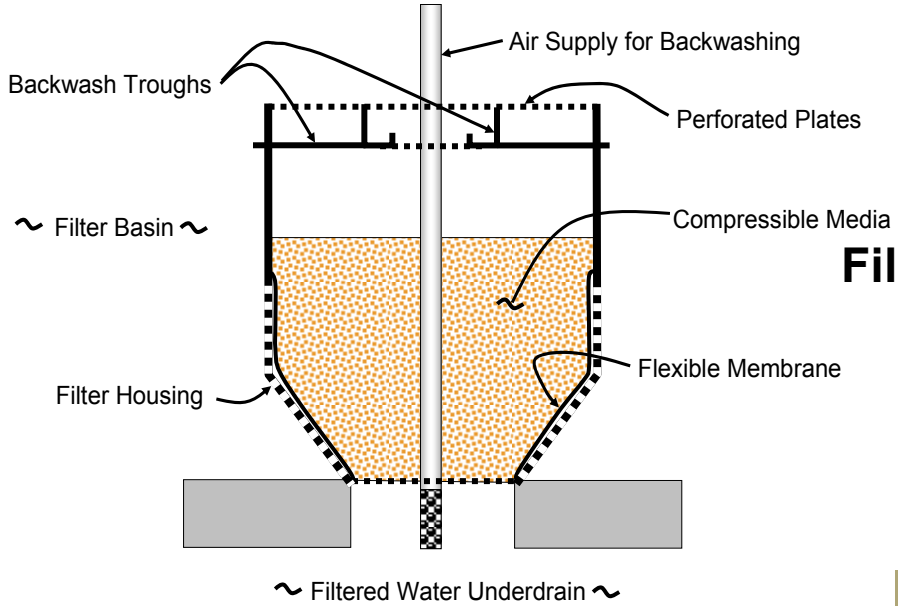


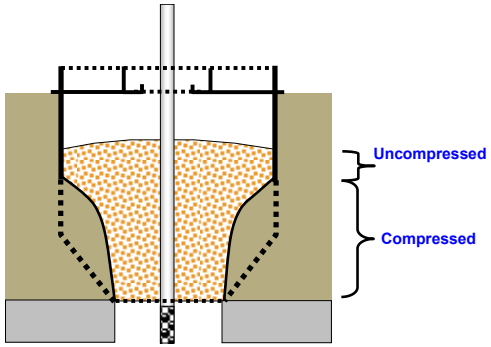
85 mgd Fuzzy Filter at West Area CSO Treatment Facility (Atlanta, Georgia)

CMF – WWETCO

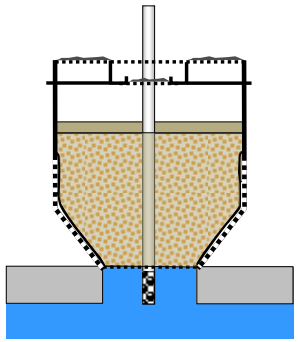


Air Scour Backwash

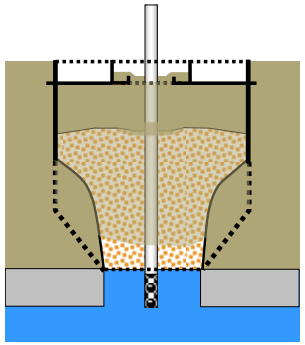




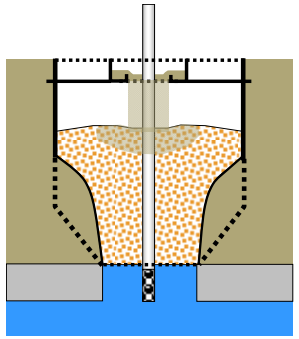
Fill & Compress



Drain & Uncompress

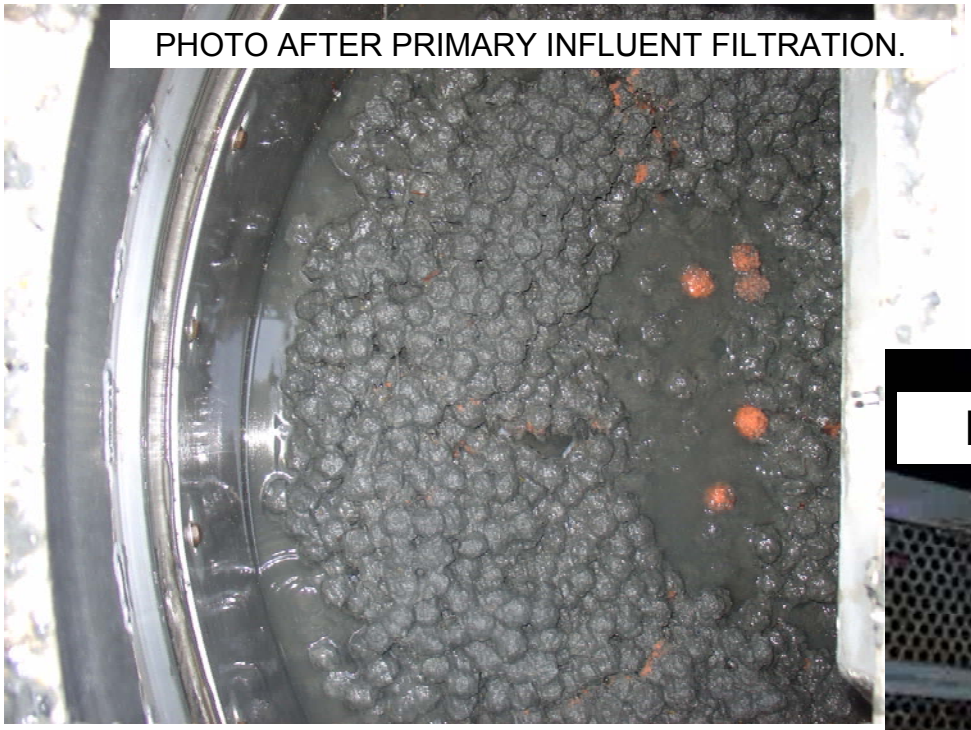


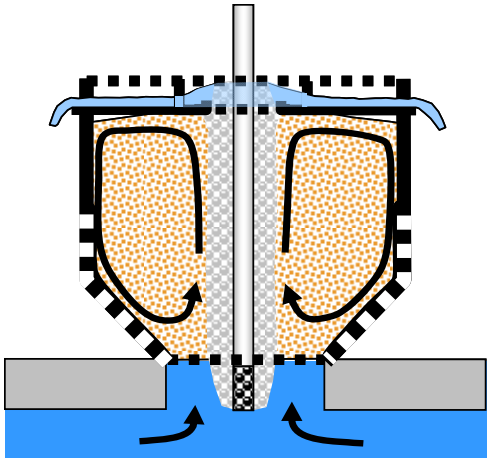
Filter End



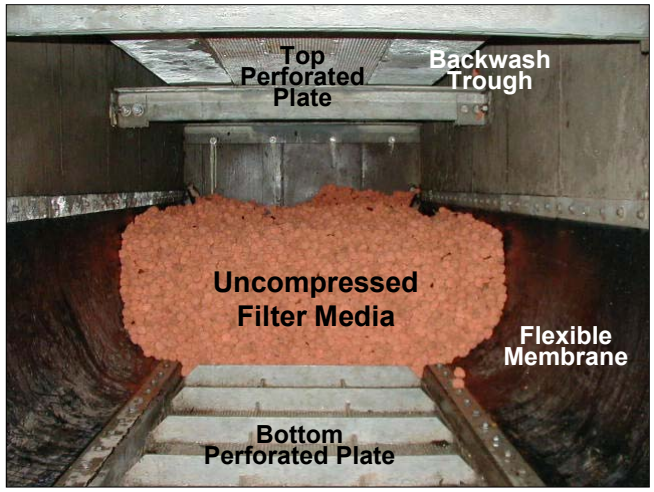
Filter Start

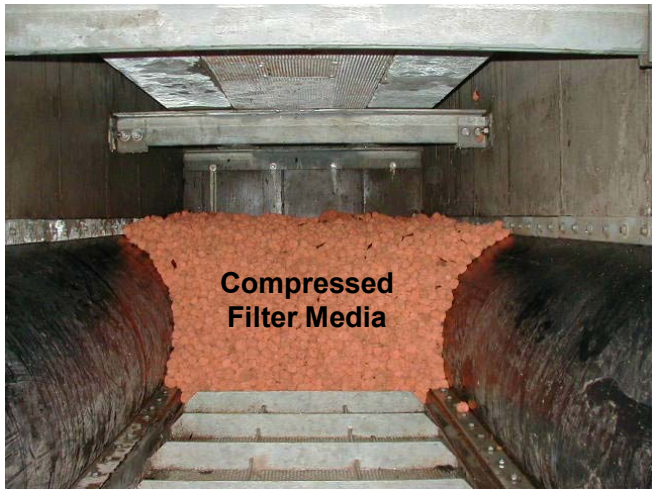
CMF Backwash





10 mgd WWETCO Filter at Weracoba Creek Stormwater BMP (Columbus,



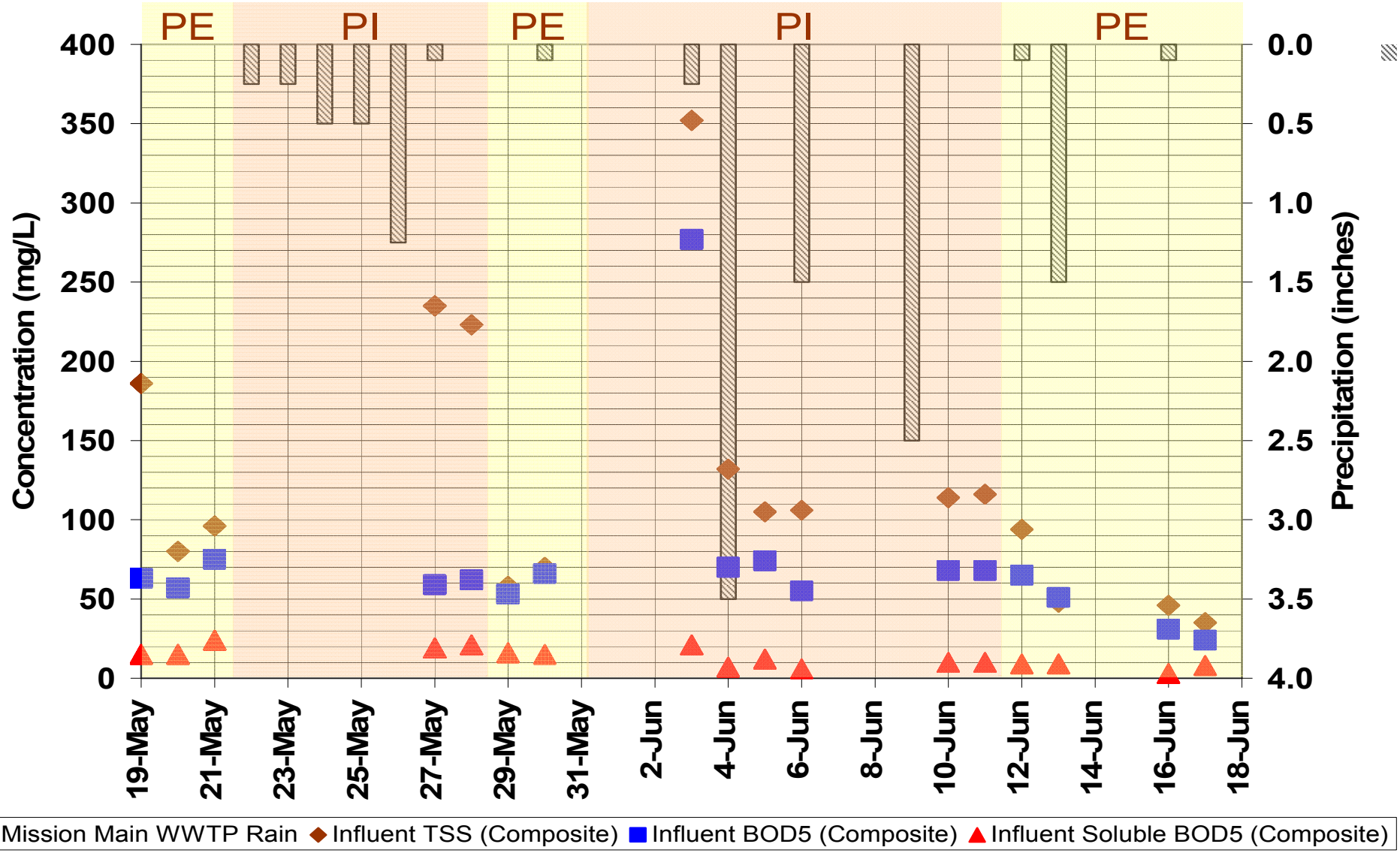


Triple bottom line evaluations of satellite PEFTFs in Johnson County, Kansas…

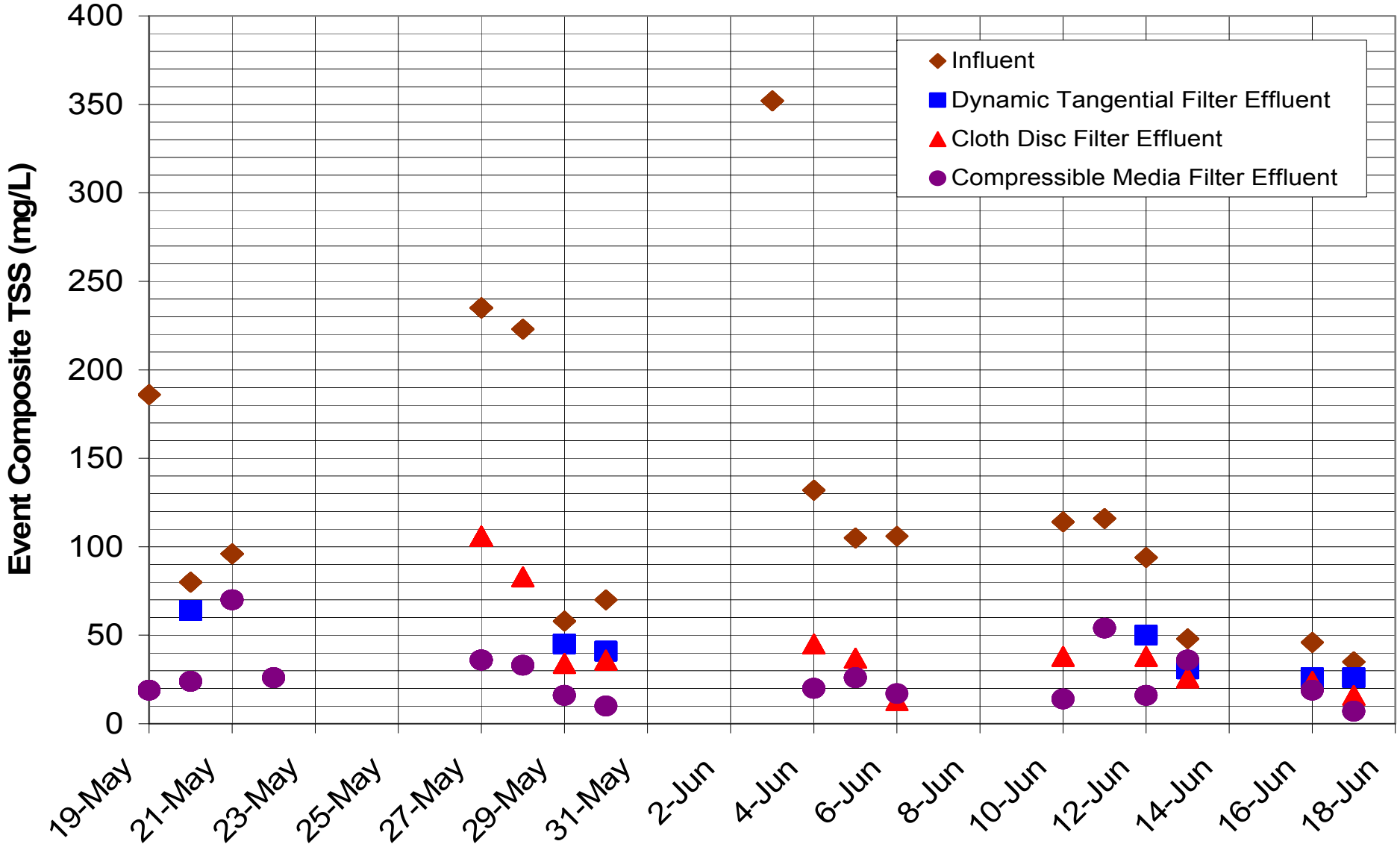
- Bench-scale (Jar Testing)
  - HRC: CEPT, ballasted flocculation, sludge recirculation
- Full-scale trials
  - CEPT

…led to side-by-side HRF testing in 2008

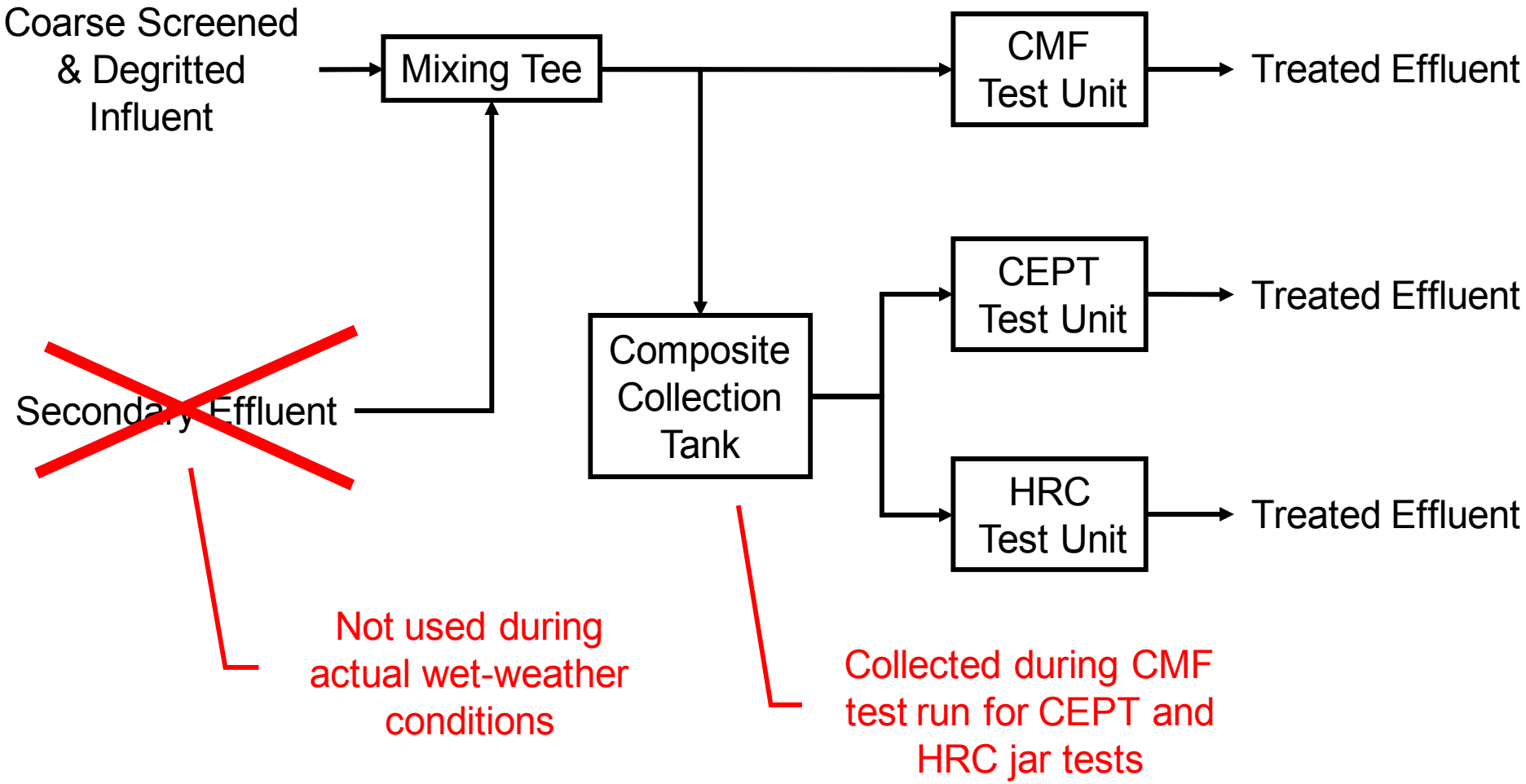
Influent Characteristics - JCW 2008 Filter Pilot



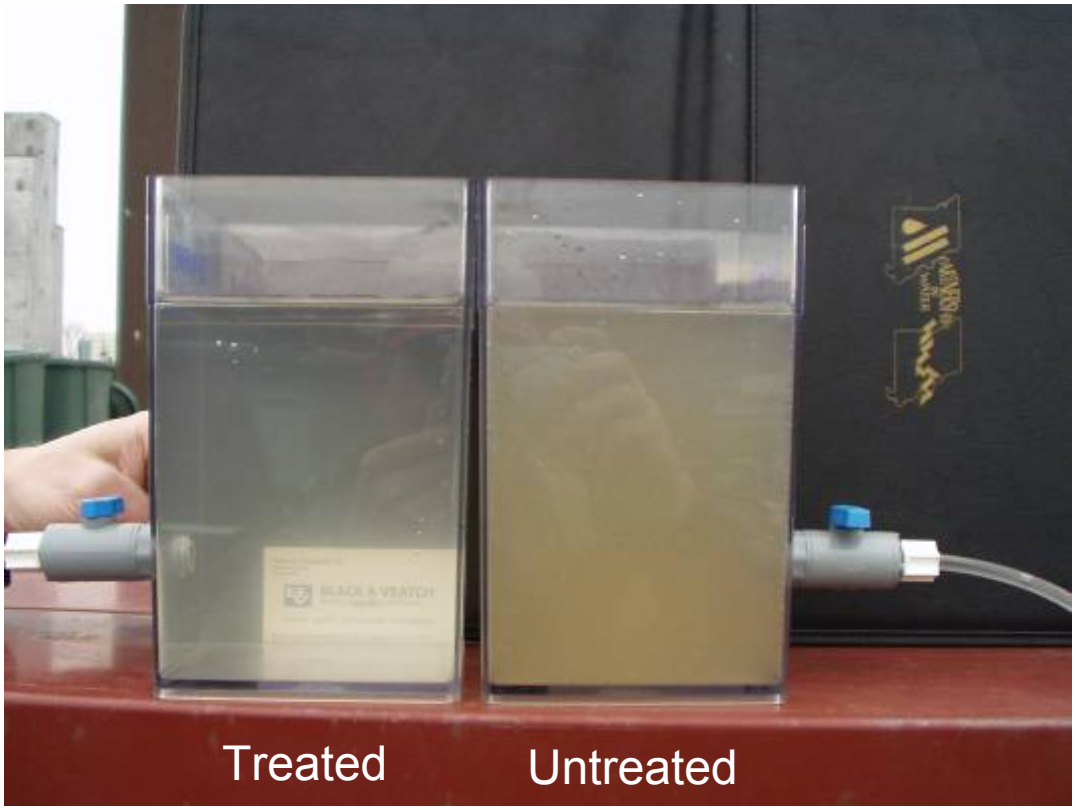
Effluent TSS - JCW 2008 Filter Pilot



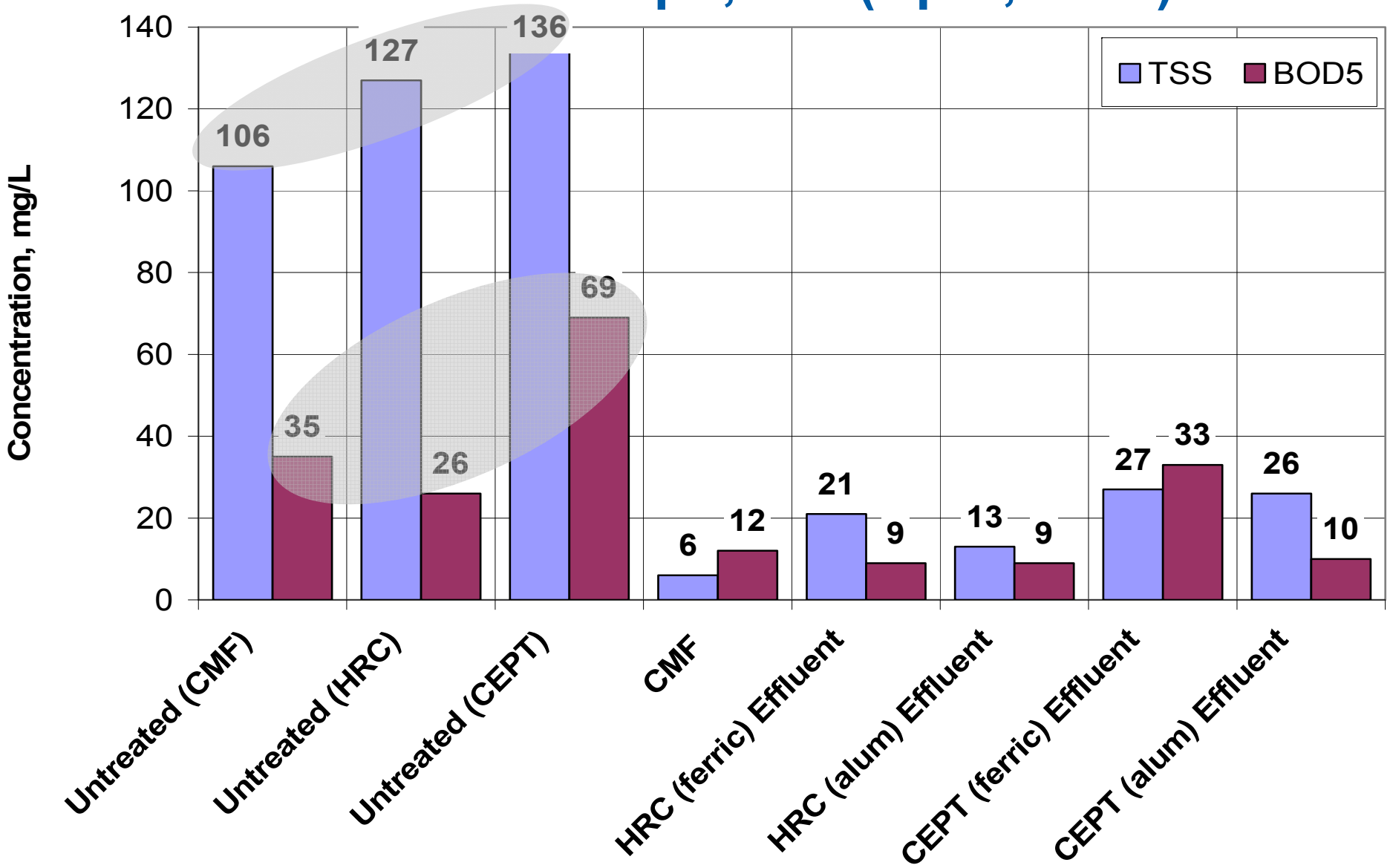
Wet Weather Treatability Tests (St. Joseph, Missouri Water Protection Facility



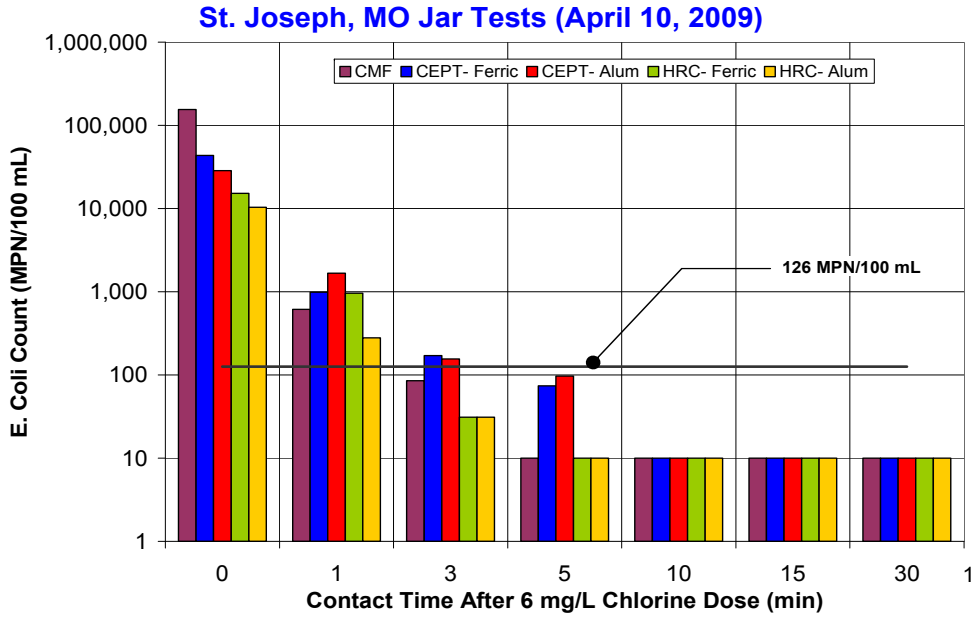
April 2009 Wet-weather Treatability Testing (St. Joseph, MO)

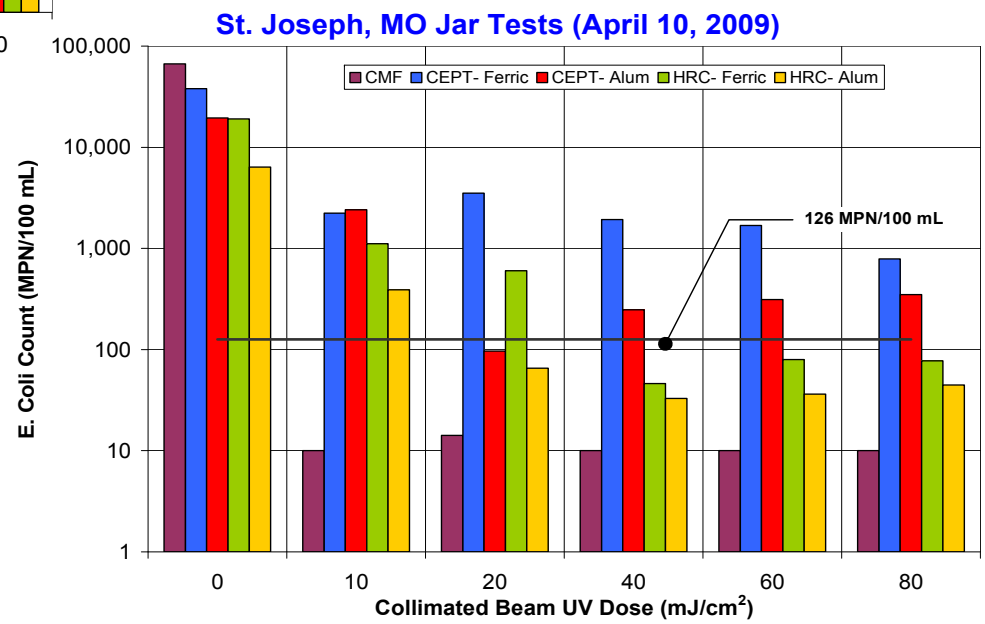


TSS and BOD – St. Joseph, MO (April, 2009)



Effluents were tested for both hypochlorite and UV dose response…



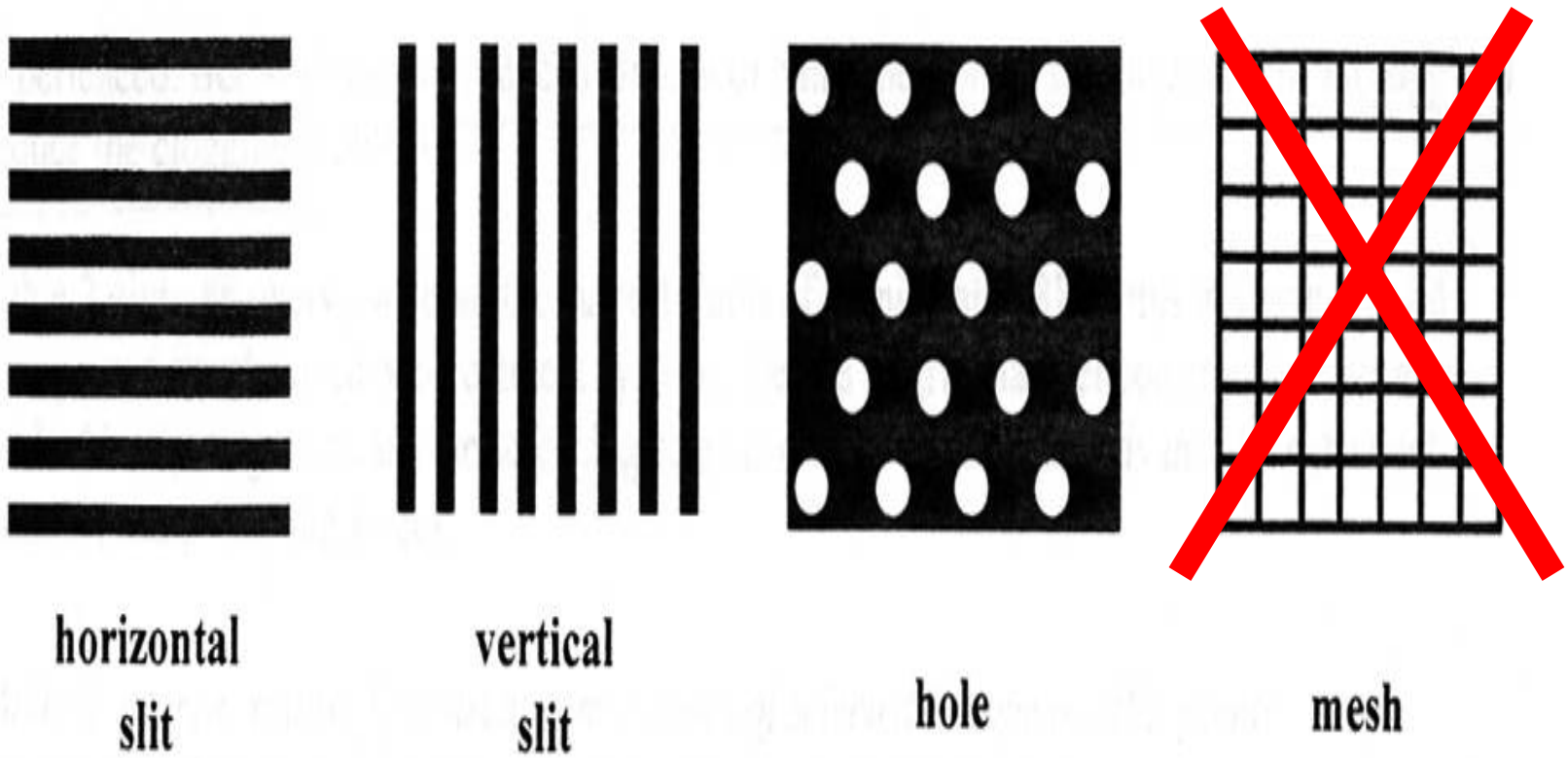


Screening and Grit Removal

Screening and Grit Removal

- Best alternatives are highly site-specific.
- Depends upon downstream treatment technologies.
- Something like a “rock box” + coarse screens may be fine for conventional processes…but some TSS removal designs need enhanced grit and screenings removal.
- Many equipment alternatives to choose from.

Screen Geometry



Reference: Schier etal WEFTEC 2005

Many grit removal alternatives

- Level needed is highly site-specific.
- Besides downstream liquids train, remember solids train (digesters, sludge pumps, etc.).
- Some screens are sensitive to grit and some grit units are sensitive to screenings.
- Headworks
  - Settling channel, stilling well, “rock box”
  - Detritus tank
  - Aerated basin
  - Vortex separator – hydraulic or mechanically induced

Closing Thoughts

Latest Regulatory Activities

- 2005 **draft** Peak Wet Weather Discharge Policy
  - Has not been finalized.
  - 2009 - Numerous comments on Draft UA Guidance
  - 2010 – EPA public comment period on SSO and Peak Flows Policy

Draft Guidance on Preparing a Utility Analysis

July 2009

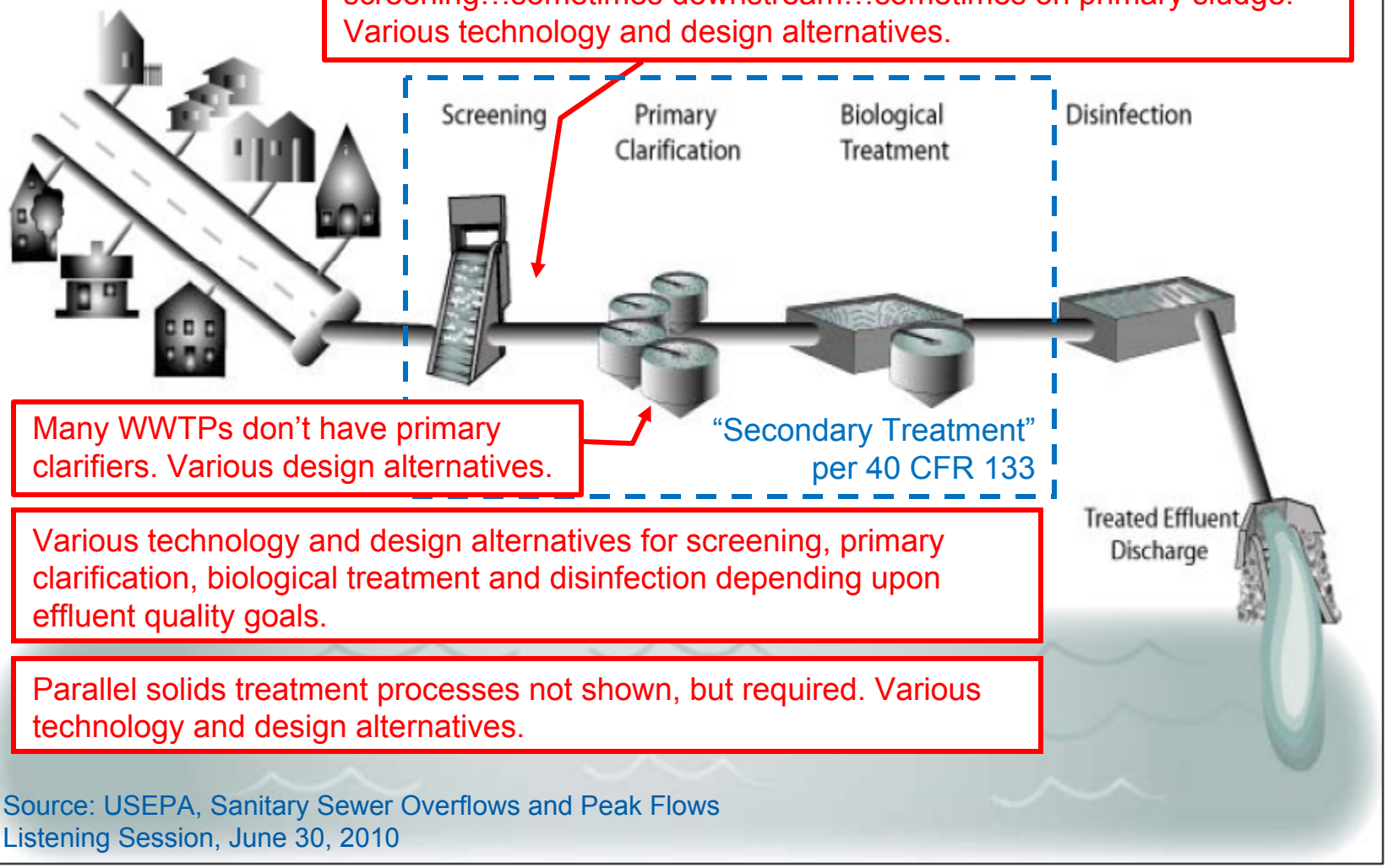
EPA
United States
Environmental Protection
Agency

Sanitary Sewer Overflows
and Peak Flows
Listening Sessions

US Environmental Protection Agency
Office of Water

All Flow Through Biological Treatment

Many WWTPs also have a grit removal step…sometimes upstream of screening…sometimes downstream…sometimes on primary sludge. Various technology and design alternatives.



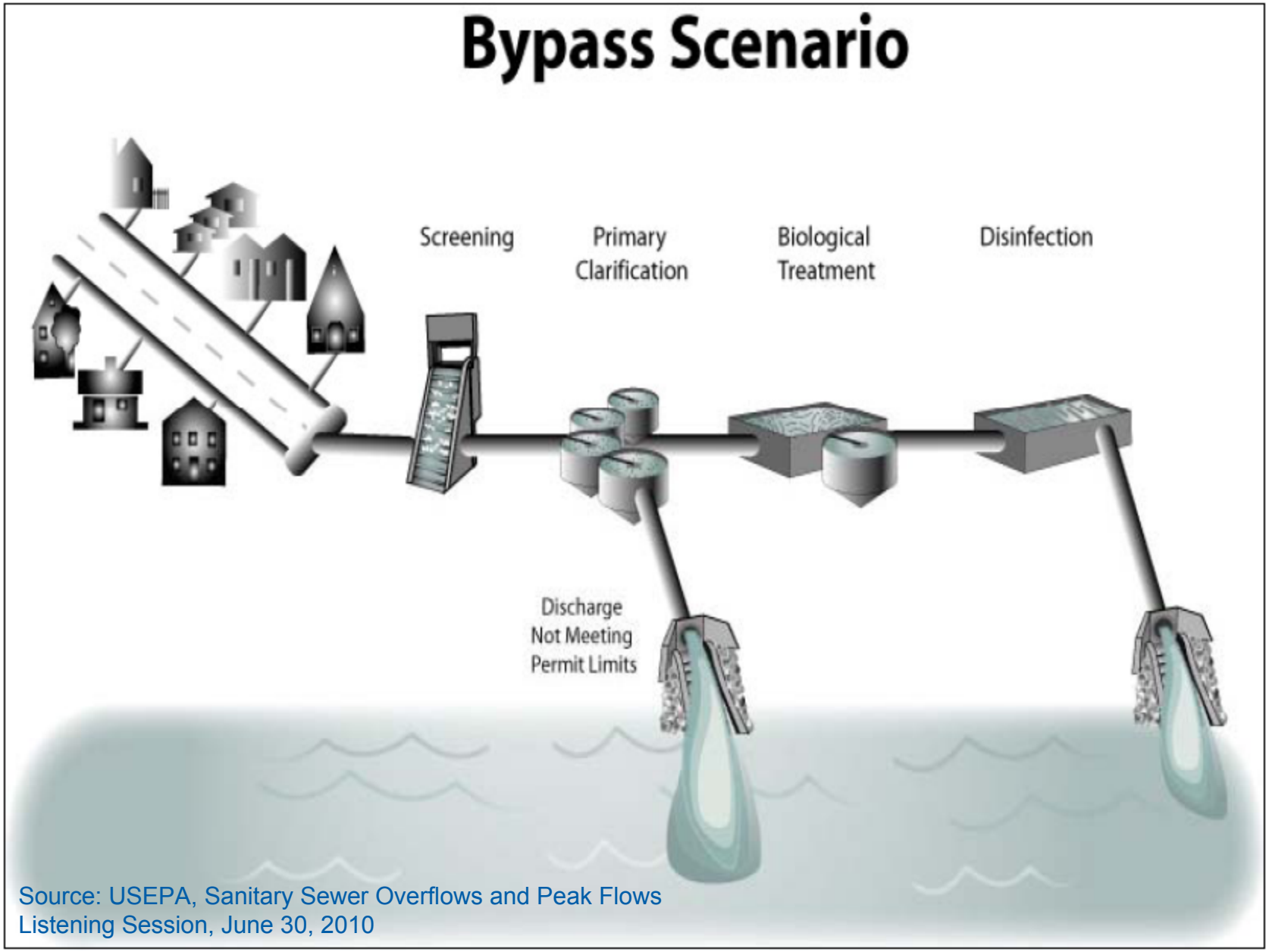
Many WWTPs don't have primary clarifiers. Various design alternatives.

Various technology and design alternatives for screening, primary clarification, biological treatment and disinfection depending upon effluent quality goals.

Parallel solids treatment processes not shown, but required. Various technology and design alternatives.

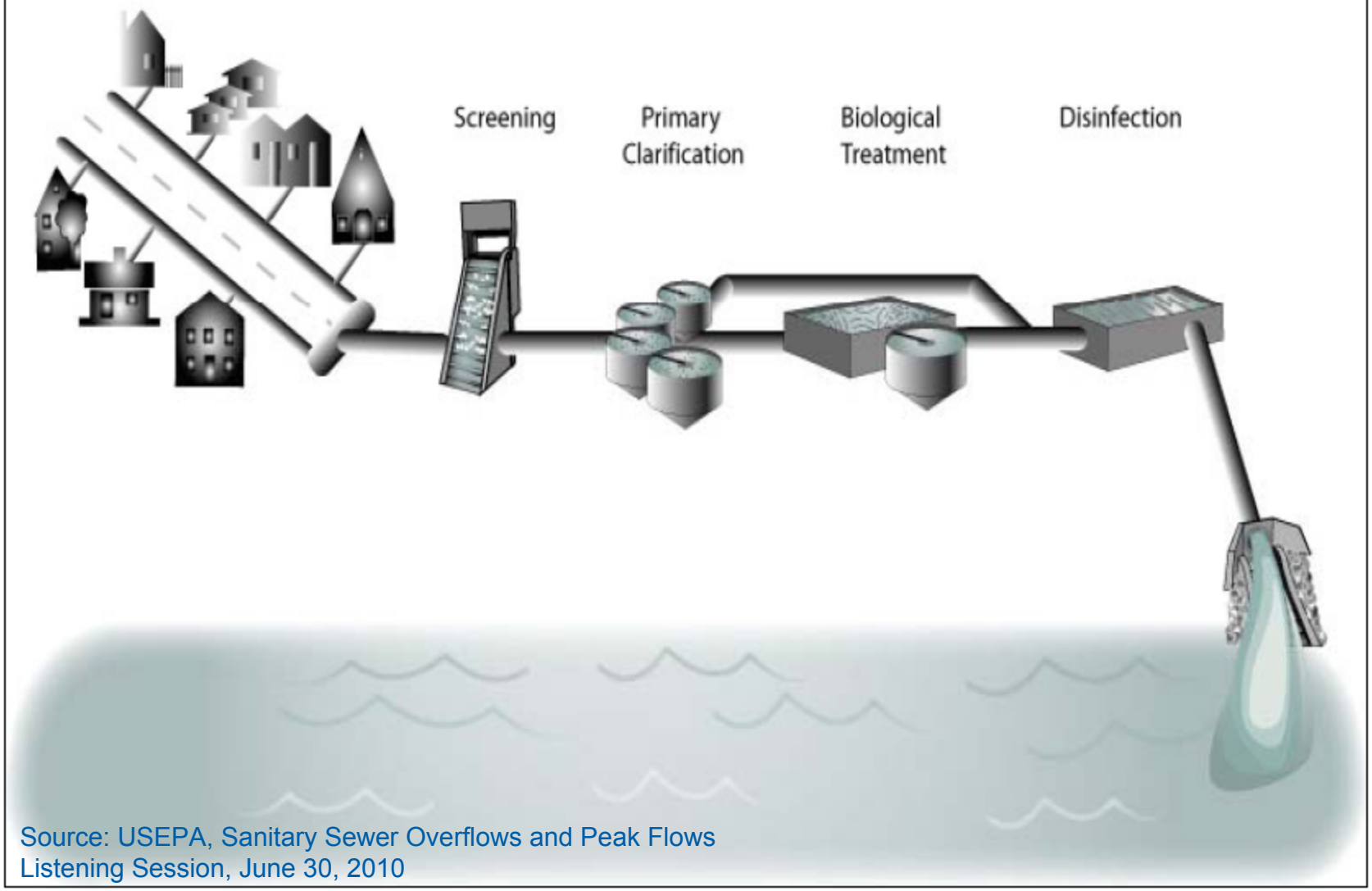
Source: USEPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

Bypass Scenario



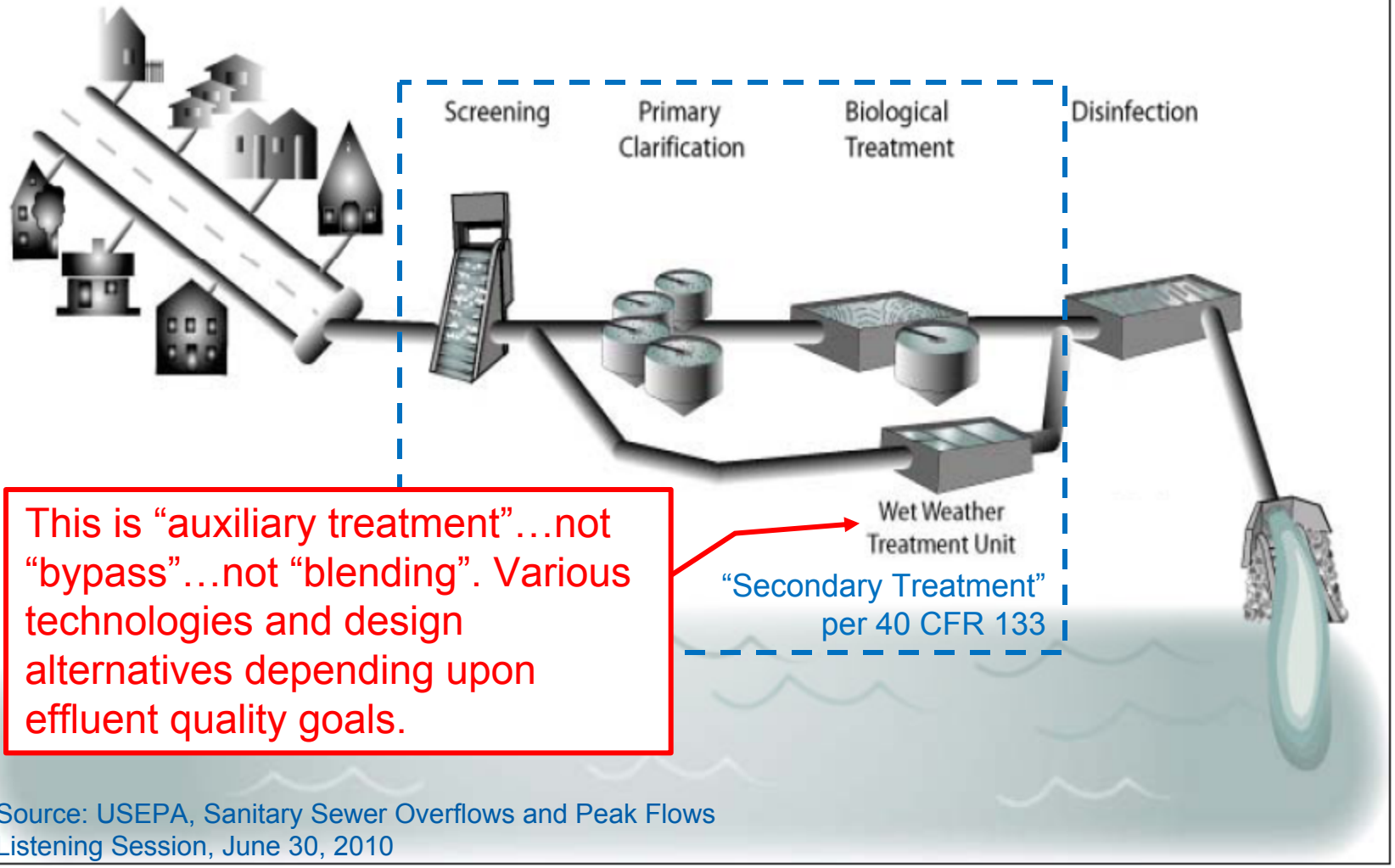
Source: USEPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

Blending Scenario



Source: USEPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

~~Blending~~ Scenario With Alternative Wet Weather Treatment



This is "auxiliary treatment"…not "bypass"…not "blending". Various technologies and design alternatives depending upon effluent quality goals.

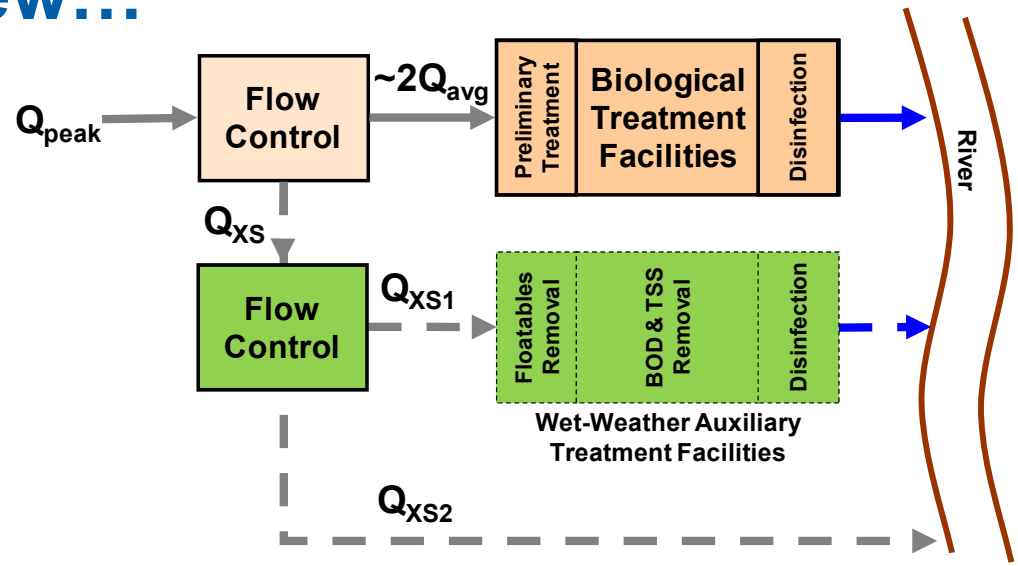
Source: USEPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

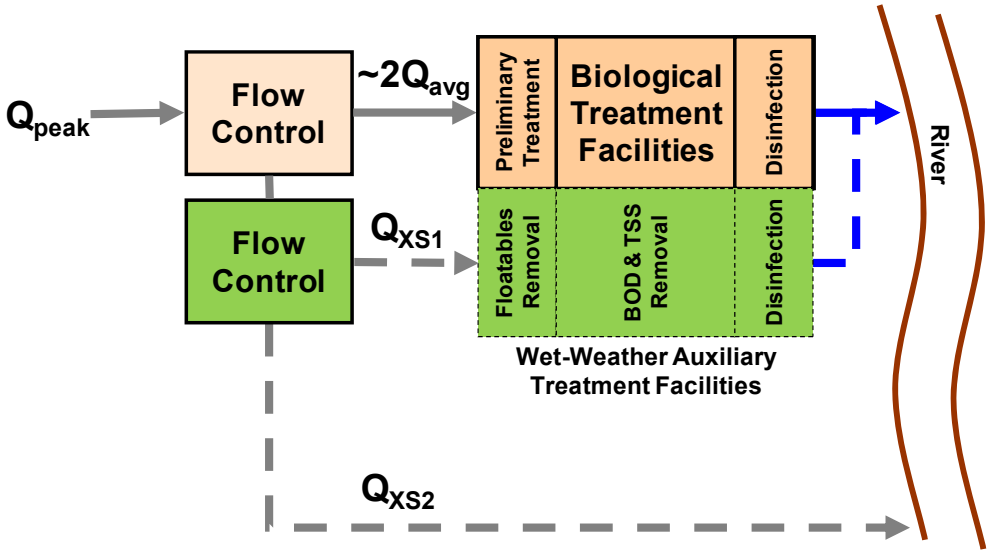
Holistic view is needed to stay focused on sustainable water quality protection

- 40 CFR 133.102
  - *Secondary* Treatment ≠ 100% *Biological* Treatment. It just so happens that biological treatment has proven to be the optimal technology for dry-weather influent characteristics.
- 40 CFR 122.41(m)
  - Intended to prevent taking units out of service unnecessarily during dry weather (i.e. lower level of treatment).
  - Never intended to prevent from bringing additional units into service to provide higher level of treatment during wet weather.
  - Auxiliary treatment facilities are simply another treatment train within the overall secondary treatment boundary. Uses technologies optimized for wet-weather influent characteristics.
- 1994 CSO Control Policy does not even require "secondary treatment" of excess flows

Potential regulatory disconnects without holistic view…

Parallel auxiliary wet-weather treatment approach is allowed and encouraged by the 1994 CSO Control Policy…





…but integrating the same or higher levels of water quality protection into a WWTP is discouraged by recent interpretations of the 2005 draft Peak Flow Discharge Policy.

Summary and Conclusions

- Sewer systems will always have significant wet weather peaking factors.
- The 2005 proposed Peak Wet Weather Discharge Policy has not been enacted…EPA considering new SSO and Peak Flows Policy rulemaking.
- Clean Water Act regulations focus on dry-weather and have not established science-based wet weather water quality criteria, treatment standards or effluent limitations
- Floatables, solids and biological pathogens are the primary pollutants of concern
- Auxiliary treatment of excess flows with physical or chemical technologies is a proven and sound approach

For Additional Information…

BLACK & VEATCH
Building a world of difference.®

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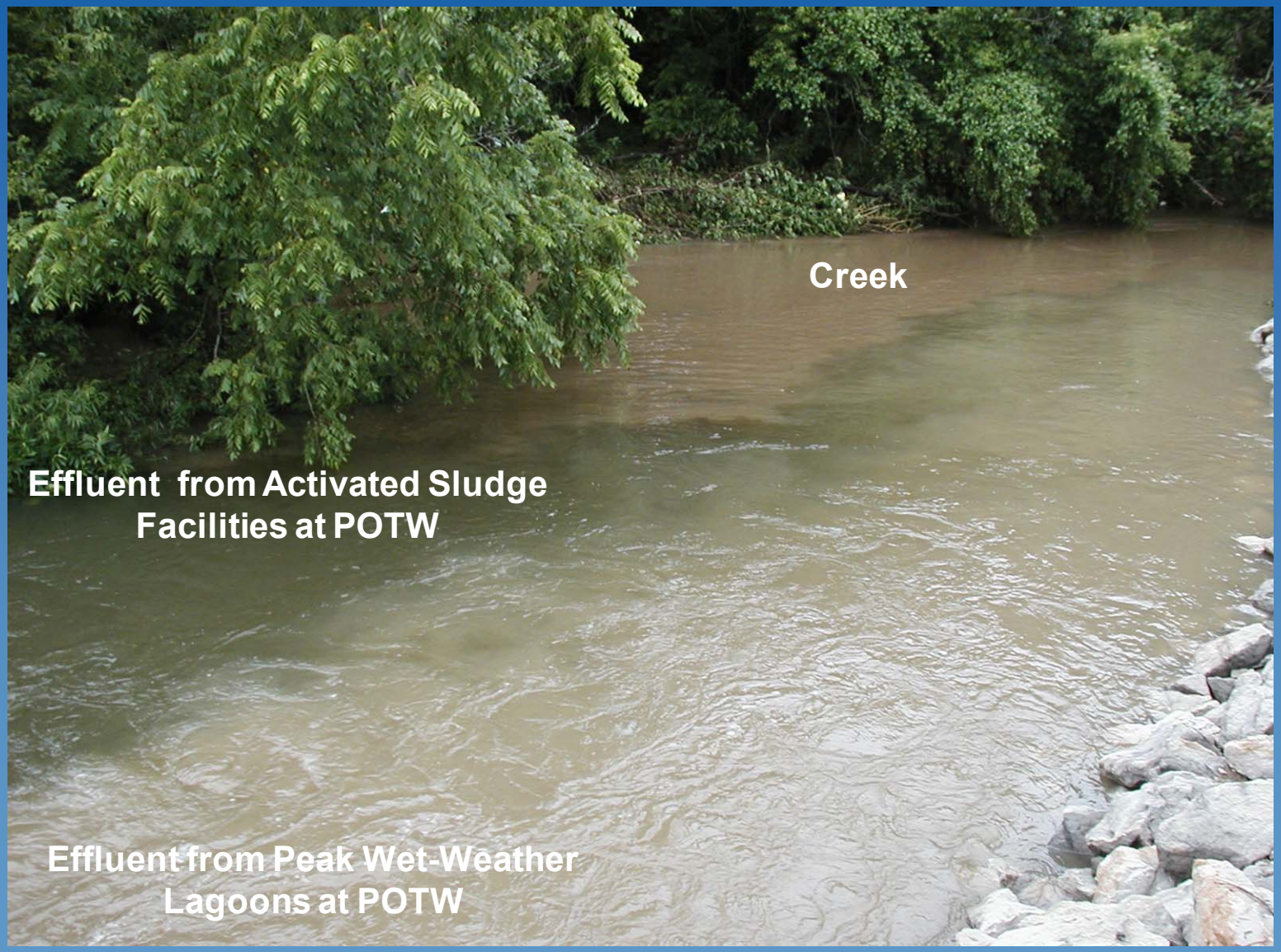
Discussion


Creek
Effluent from Activated Sludge Facilities at POTW
Effluent from Peak Wet-Weather Lagoons at POTW

Extras

Parallel excess flow treatment ≠ bypass (cont'd)

- **40 CFR 122.41(m)(1)(i)**

promptly submit such facts or information.

(m) *Bypass*—(1) *Definitions.* (i) *Bypass* means the intentional diversion of waste streams from any portion of a treatment facility.

(ii) *Severe property damage* means substantial physical damage to property, damage to the treatment facilities

(ii) The Director may approve an anticipated bypass, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above in paragraph (m)(4)(i) of this section.

(n) *Upset*—(1) *Definition.* *Upset* means an exceptional incident in which there is unintentional and temporary non-

Diversion **involves decreasing flows. Parallel treatment concept does not decrease flows to any portion of the treatment facility. We are increasing flows to all portions of the treatment facility.**

Parallel excess flow treatment ≠ bypass (cont'd)

- **40 CFR 122.41(m)(4)(i)(B)**

(C) Violation of a maximum daily discharge limitation for any of the pollutants listed by the Director in the permit to be reported within 24 hours. (See § 122.44(g).)

(iii) The Director may waive the written report on a case-by-case basis for reports under paragraph (l)(6)(ii) of this section if the oral report has been received within 24 hours.

(7) *Other noncompliance.* The permittee shall report all instances of noncompliance not reported under

(4) *Prohibition of bypass.* (i) Bypass is prohibited, and the Director may take enforcement action against a permittee for bypass, unless:

(A) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

(B) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not

The use of auxiliary treatment facilities is a feasible alternative to a bypass; therefore, using them can't be a bypass

Parallel excess flow treatment ≠ bypass (cont'd)

- **40 CFR 122.41(m)(2)**

damage does not mean economic loss caused by delays in production.

(2) *Bypass not exceeding limitations.* The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of paragraphs (m)(3) and (m)(4) of this section.

(3) *Notice*—(i) *Anticipated bypass.* If

erly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

(2) *Effect of an upset.* An upset constitutes an affirmative defense to an action brought for noncompliance with such technology based permit effluent limitations if the requirements of paragraph (n)(3) of this section are met. No determination made during adminis-

Parallel excess flow treatment is not bypass, but does provide essential maintenance of biomass to assure efficient operation.

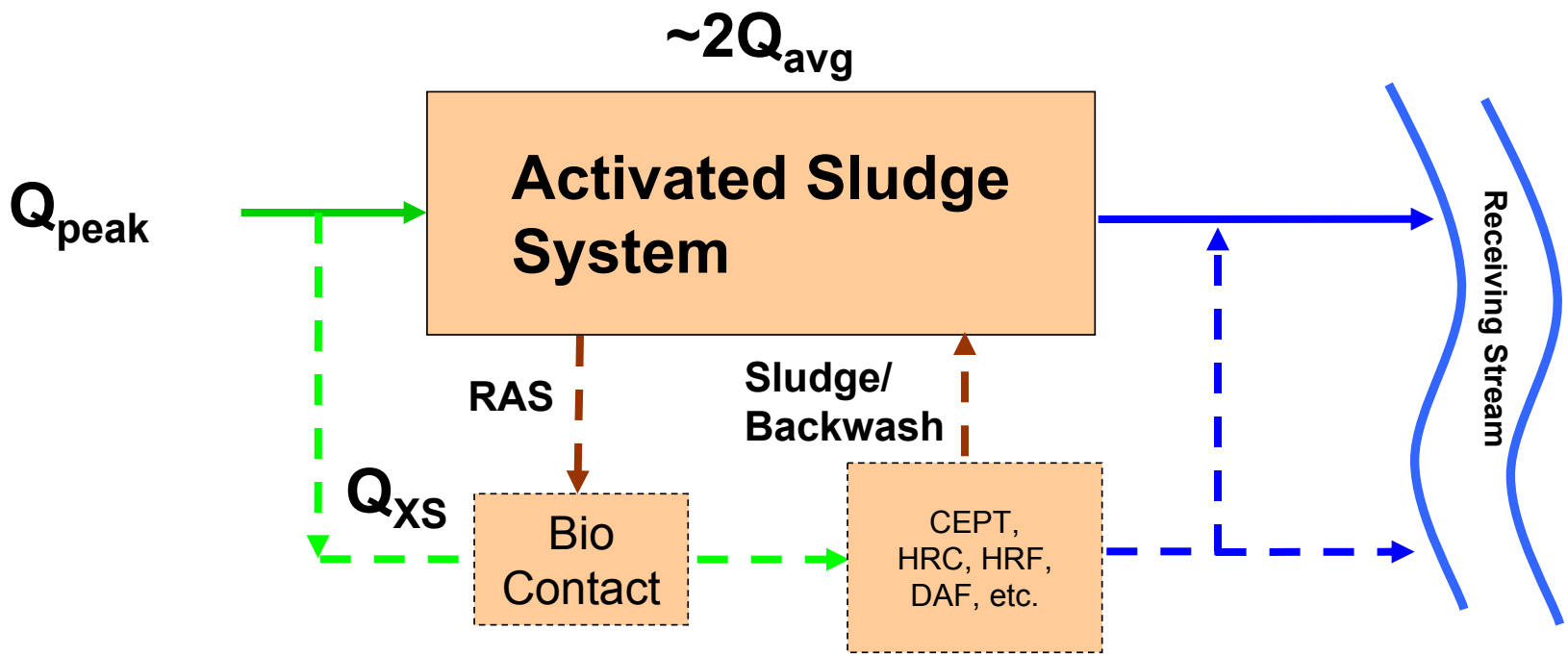
Biological treatment probably has many more unknowns than other technology alternatives

- Filtration
  - 2000 BC - Granular filtration in Greece and India
  - Today - Particle size distribution data or pilot trials to confirm solids loading rates, hydraulic loading rates, backwash frequencies, etc.
- Sedimentation
  - 1500 BC - Alum coagulation by Egyptians
  - 1740 AD - Chemical sewage treatment in Paris
  - Today - Jar tests to optimize chemicals. Pilot and full-scale stress tests to confirm design SOR for CEPT.
- Biological
  - Early 1900's - First activated sludge WWTPs
  - Today - Wet-weather capacity is inherently inexact. Many, many variables affect biomass behavior.

Site-Specific R&D

Process R&D

High-Rate Contact Stabilization Concept



- Ye olde contact stabilization configuration of activated sludge…with high-rate solid/liquid separation technologies.
- Another parallel auxiliary treatment strategy.

Potential R&D needs for high-rate contact stabilization concept

- Actual wet-weather influent (vs. surrogate influent).
- Repeatable results from site to site?
  - Concerns about extrapolating and generalizing results based on statistically small dataset.
- Is claimed biological uptake significant?
  - Conventional “soluble” BOD includes colloidal fraction largely removed by advanced phys/chem.
  - What about adsorption onto hydrous metal complexes similar to the latest thinking on chemical phosphorus removal?

Potential R&D needs for high-rate contact stabilization concept (cont'd)

- Capacity of available biomass must be considered.
  - Any added risk to biomass health?
  - What about BNR bugs or unintended inhibition to BNR processes?
  - May not be able to truly assess biomass impacts without auxiliary treatment facilities at same scale as dry-weather activated sludge facilities.
- Piloting to date limited to activated sludge operated in contact-stabilization mode.
  - What about fixed-film (TF, MBBR, IFAS, BAF, SAF)?
  - What about other AS operating modes or configurations?
- Any significant water quality benefits to warrant the significant additional complexity and expense above and beyond today's advanced physical/chemical alternatives?