Development of an Integrated Strategy for Meeting Dissolved Oxygen Standards Proposed for the Chicago Area Waterway System (CAWS)

David Zenz

MWRDGC Monitoring and Research Seminar Series

October 30, 2009

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Presentation Overview

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- **Study Objectives & Waterway System Overview**
- IEPA Proposed DO Standards
- General Study Approach
- Long List Evaluation of Technologies
- Short List Evaluation of Technologies
- Cost Estimate

Objective of Study

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Determine the Technologies and Costs

to Meet New Proposed IEPA Dissolved Oxygen (DO) Water Quality Standards

for the Chicago Area Waterway System (CAWS)

Chicago Area Water System (CAWS)

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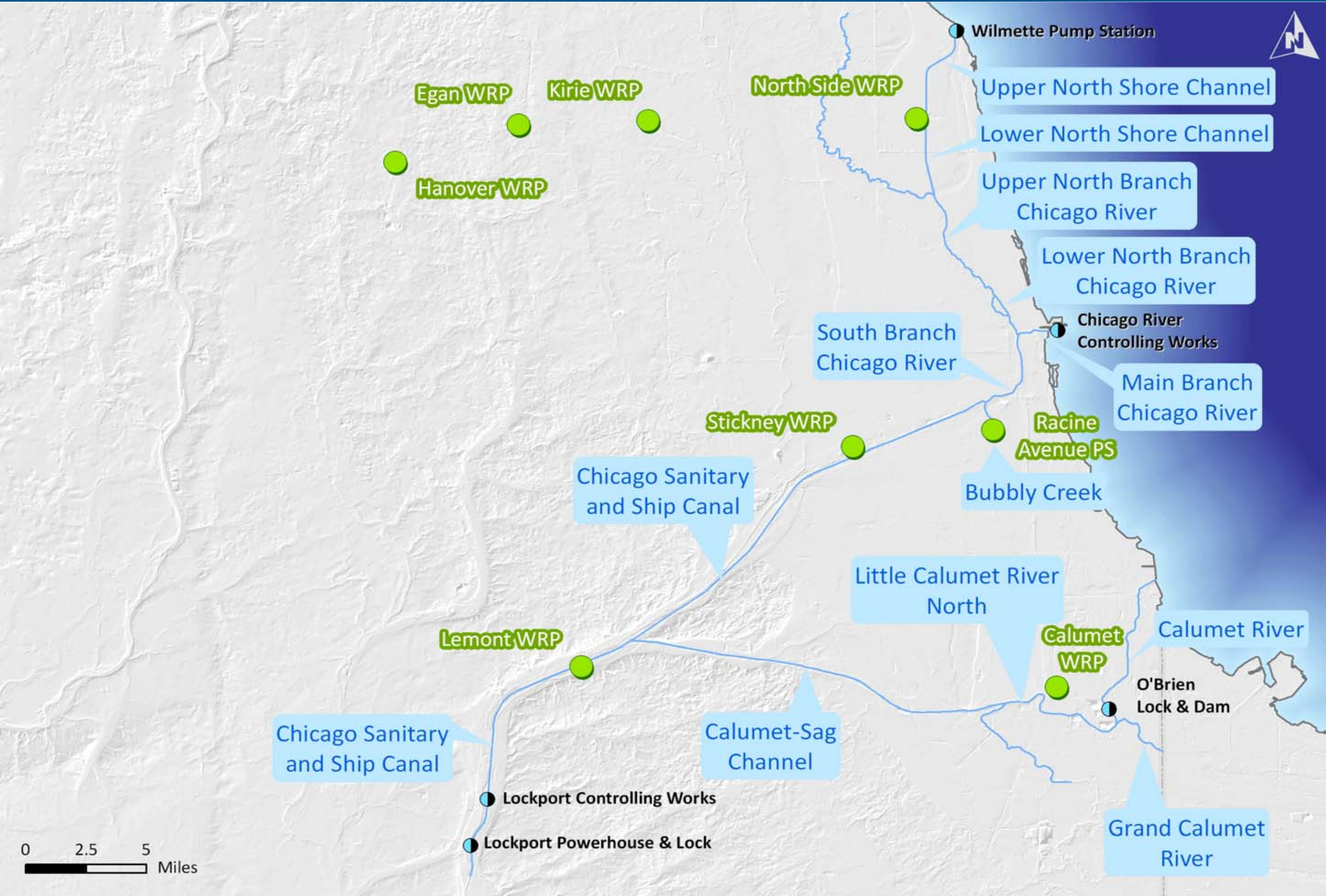

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IEPA Proposed DO Standards

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Aquatic Life Use “A” Waters

March through July

5.0 mg/l minimum at all times

August through February

4.0 mg/l daily minimum averaged over 7 days

3.5 mg/l minimum at all times

NSC
UNBCR
Cal-Sag
LCRN
Lower Calumet
Grand Calumet

Aquatic Life Use “B” Waters

Year Round

4.0 mg/l daily minimum averaged over 7 days

3.5 mg/l minimum at all times

LNBCR
Chicago River
SBCR
Bubbly Creek
CSSC
Upper Calumet

IEPA Existing vs. Proposed DO Standards

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Waterway	Existing	Proposed	
	Daily Minimum (mg/L)	Daily Minimum (mg/L)	Avg Weekly Minimum (mg/L)
UNSC	5	3.5/5.0	4
LNSC	4	3.5/5.0	4
UNBCR	4	3.5/5.0	4
LNBCR	4	3.5	4
Chicago River	5	3.5	4
SBCR	4	3.5	4
Bubbly Creek	4	3.5	4
CSSC	4	3.5	4
Cal-Sag	3	3.5/5.0	4
LCRN	4	3.5/5.0	4
Upper Calumet River	5	3.5	4
Lower Calumet River	4	3.5/5.0	4
Grand-Cal	4	3.5/5.0	4

March through July / August through February

Presentation Overview

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- Study Objectives & Waterway System Overview
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- **General Study Approach**
- Long List Evaluation of Technologies
- Short List Evaluation of Technologies
- Cost Estimate

General Study Approach

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- Develop Long List of potential options
- Develop Short List of potential options
- Consensus decision on final mix of options to meet proposed IEPA standards for
  - 90% Compliance with Standards
  - 100% Compliance with Standards
- Prepare detailed cost estimate

Presentation Overview

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- Study Objectives & Waterway System Overview
- IEPA Proposed DO Standards
- General Study Approach
- **Long List Evaluation of Technologies**
- Short List Evaluation of Technologies
- Cost Estimate

Long List Technologies

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- Directly or indirectly increase CAWS DO to achieve IEPA proposed standards
- Have reliable cost data available
- Have a history of successful application, preferably in CAWS setting

Expectations Workshop Decisions

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Previously agreed upon Long List supplemental aeration technologies

- U-Tube
- Porous Ceramic Diffusers (Blower on Shore)
- Jet Aeration (Venturi Aeration System)
- Sidestream Elevated Pool Aeration (SEPA)

Previously recommended flow augmentation alternatives

- Aerated flow augmentation for UNSC
- Flow augmentation with supplemental aeration for Bubbly Creek

U-Tube (HPO)

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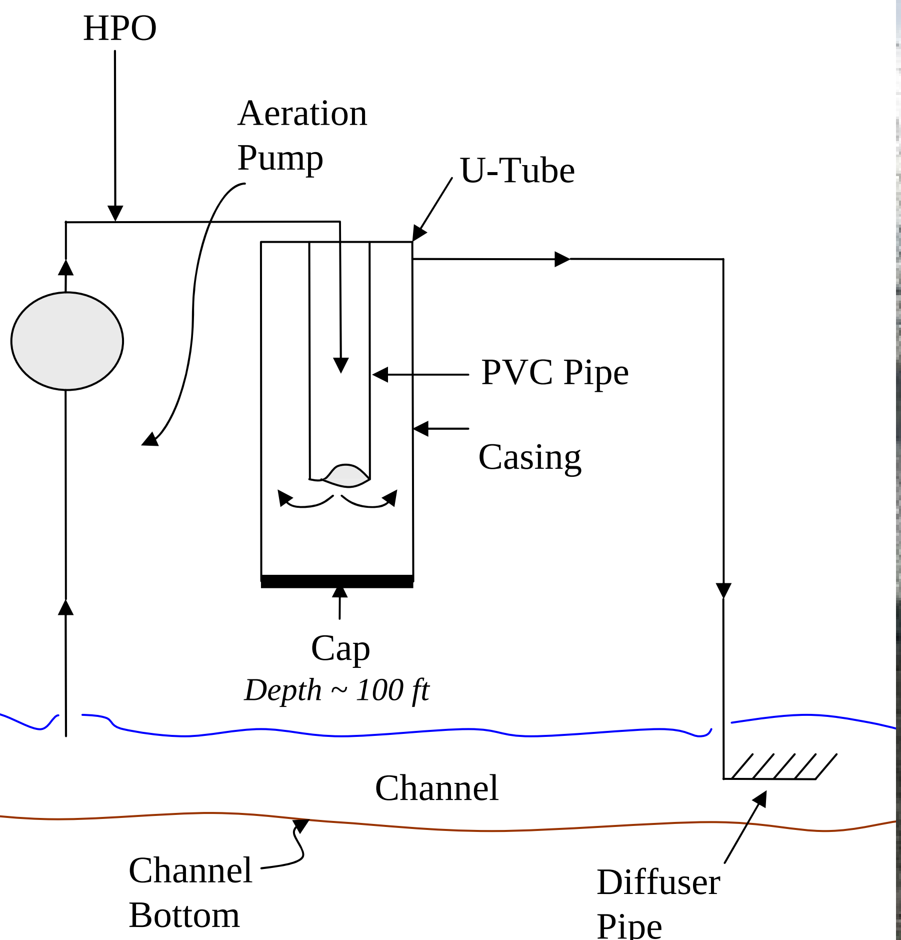

Stockton, CA
HPO Tank

Porous Ceramic Diffusers

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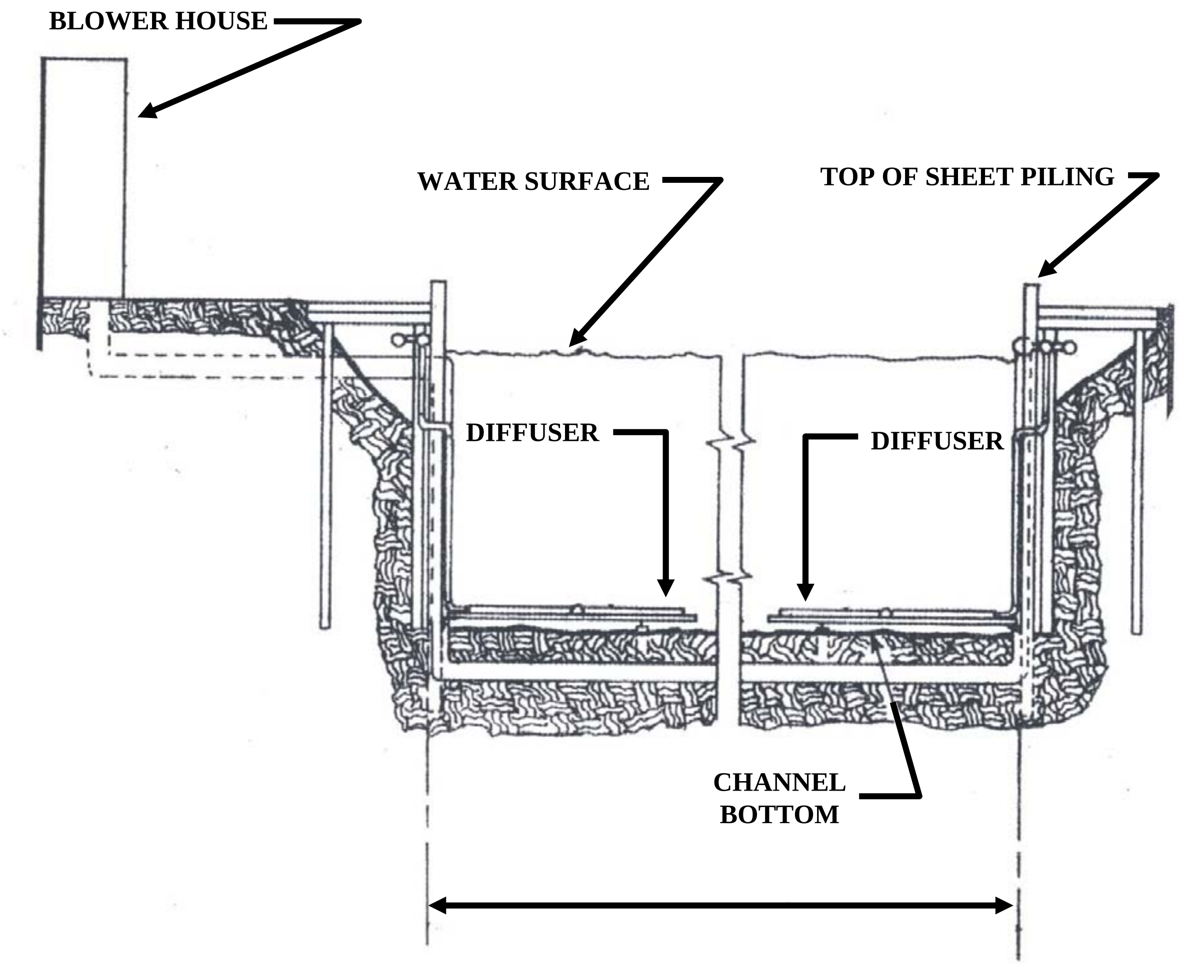
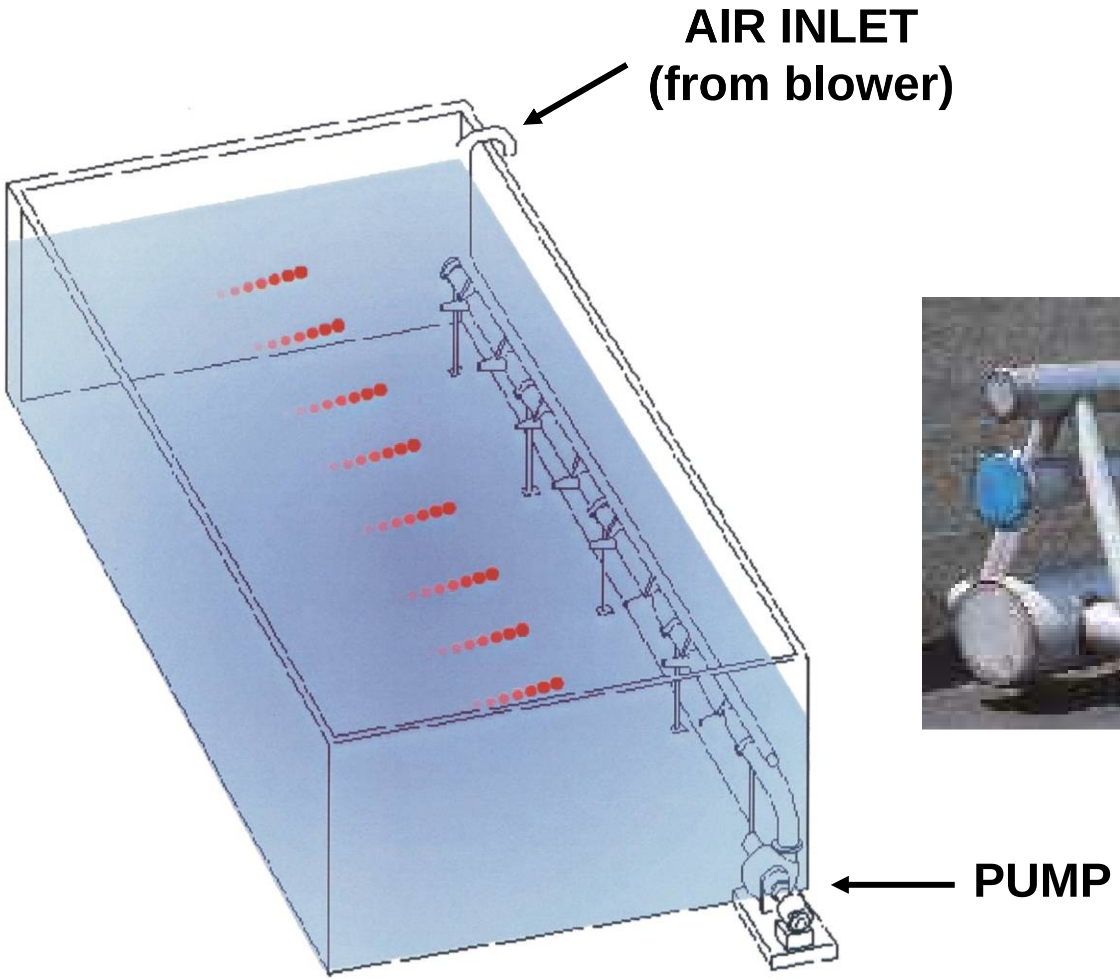


Porous Ceramic Diffusers

Webster Avenue
Aeration Station

Jet Aerator



SEPA

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SEPA Station #5

Additional Long List Technologies Considered

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Supplemental Aeration

Presented to District by Others

- Coherent Water Resonator
- Venturi Oxygenator
- Stainless Steel Fine Bubble Disk Aeration

Technologies Suggested by AECOM

- Constructed Urban Waterfalls
- Barge Mounted Aeration

Sediment Treatment

- Capping
- Chemical Treatment
- Stabilization

Bubbly Creek CSO Diversion

- RAPS and Bubbly Creek CSOs to CSSC

Waterway Relocation

- Relocate Wilmette Pump Station

Additional Supplemental Aeration Technologies

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Presented to the District by Others

- Coherent Water Resonator

  Rejected due to:

  - Safety of electromagnetic waves unknown
  - Lack of full-scale application

- Venturi Oxygenator

  Rejected due to:

  - Cooling water discharges to CAWS are relatively small
  - Private sector approval required

- Stainless Steel Fine Bubble Disk Aeration

  Conditionally Rejected:

  - AECOM may consider as cost-effective alternative to ceramic diffuser aeration

Additional Aeration Technologies

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Technologies Suggested by AECOM

- Constructed Urban Waterfalls
- Barge Mounted Aeration

Constructed Urban Waterfalls

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- Architecturally significant constructed urban waterfalls could be used for oxygenation
- Have been applied in visible, high traffic areas
- Examples in New York and Canada were constructed for aesthetics, not for oxygenation

Constructed Urban Waterfalls

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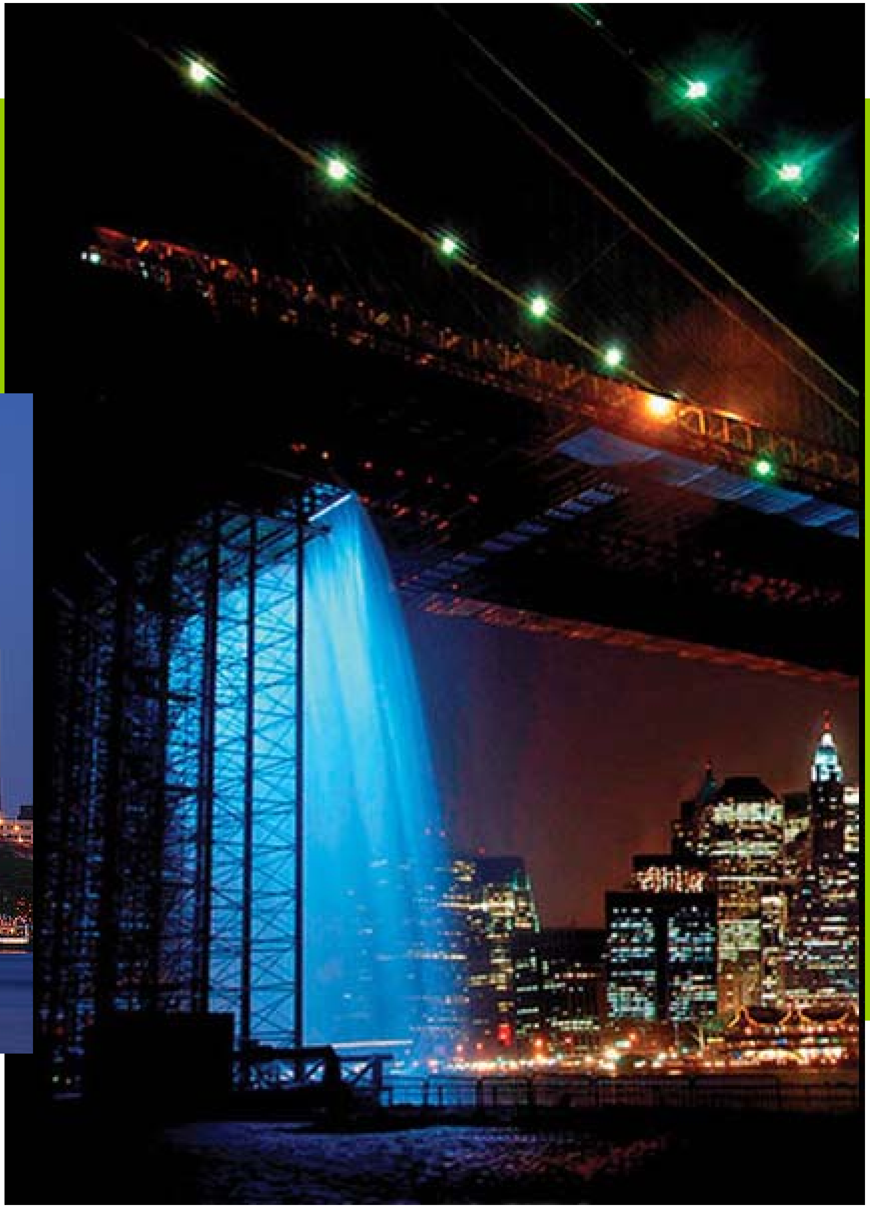
- New York City, New York
- 4 constructed
- $15 million construction cost

Image Source: flickr member bly2k



Constructed Urban Waterfalls

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Advantages

- **Directly increases D.O.**
- **Low construction cost**
- Emphasizes waterways within the architectural and artistic vision of urban areas
- Potential tourism revenue generated
  - NYC estimates $55M in Summer 2008

Disadvantages

- **Aeration efficiency is not known**
- **Application as supplemental aeration has not been demonstrated**
- Excessive height and spray may be required to reach desired level of performance
- Spray may impact river and shoreline users, such as:
  - Odor
  - Navigation
  - Spray contact
- Winter operation difficulties

REJECTED

Barge Mounted Aeration

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- River barge could inject O_2 into river via hydraulically operated diffuser lowered into water
- Water could be withdrawn from the river, oxygenated on-board the barge, and returned to the river
- Barge could also be fitted with surface aerators
- Barge would be moved to high oxygen demand areas
- Typically operated in wide, navigable waterways

Barge Mounted Aeration

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- Shanghai, China
- O_2 generator on board
- 10,000 lbs O_2 per day

Image Source: Environmental Science & Engineering Magazine

Barge Mounted Aeration

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Advantages

- **Directly increases D.O.**
- **Demonstrated technology in CAWS type settings**
- **Cost data available**
- Can be brought to low DO waterways reaches as needed
- Mobile with no permanent equipment required on land
- Could be contractor operated
- Research value for sampling and monitoring

Disadvantages

- **May negatively impact waterway traffic**
- May require multiple barges
- High O&M costs
  - Labor
  - Fuel
  - Maintenance
- Complex operations

Accepted Conditionally for Applicable Waterways

Non-Aeration Technologies Considered

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- **Sediment Treatment**
  - **Capping**
  - **Chemical Treatment**
  - **Stabilization**
  - **On-Site Sediment Management**
- Bubbly Creek CSO Diversion
  - RAPS and Bubbly Creek CSOs to SBCR
- Waterway Relocation
  - Wilmette Pumping Station Relocation
- Other Technologies
  - Aquatic vegetation
  - Micropore membrane aeration
  - Phytoremediation
  - Biological Additives

Sediment Treatment Technologies

- Capping
- Chemical Treatment
- Stabilization
- On-site Sediment Management

Sediment Capping

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- Material is placed over contaminated sediment
- “Passive” materials, such as sand, are used solely to reduce contact with the water column
- “Active” materials can be used to bind or degrade heavy metals, PAHs, VOCs, PCBs, and other contaminants

Capping Materials

- **Clean sediments**
- **Sand**
- **Gravel**
- **AquaBlock®**
- **Geotextile mats**
- **Coke Breeze**
- **Apatite**
- **Granular Activated Carbon (GAC)**
- **Clay**
- **Nitrate, etc.**

Sediment Capping

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Advantages

- **Indirectly increases D.O.**
- **Record and history of application, including USEPA and USACE**
- Both S.O.D. and pollutant leaching are significantly reduced
- "Active" capping may reduce contaminants in existing sediment
- Can provide clean surface substrate for recolonization of aquatic organisms
- Minimal impact on surrounding areas

Disadvantages

- **Benefits negated by future sediment deposition from CSO events**
- **Does not directly increase D.O.**
- **Testing needed for reliable cost estimate**
- Leaves contaminated sediments in place
- Reduces water depth
- Long-term monitoring and maintenance
- Factors increase costs / reduce feasibility:
  - Fine sediments
  - High velocities
  - Ice jams
  - Freeze/thaw
  - Debris laden sediment
  - High gas production
  - Irregular channel bottom

Sediment Treatment Technologies

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- Capping

  Conditionally accepted pending study by Dr. Melching using DuFlow model

- Chemical Treatment
- Stabilization
- On-site Sediment Management

Rejected Due to:

- Lack of cost data
- Lack of application in CAWS type systems
- Benefits negated by future CSO sediment deposition
- On-site sediment management requires sediment removal

Non-Aeration Technologies Considered

AECOM

- Sediment Treatment
  - Capping
  - Chemical
  - Stabilization
  - On-Site Sediment Management
- **Bubbly Creek CSO Diversion**
  - **RAPS and Bubbly Creek CSOs to SBCR**
- **Waterway Relocation**
  - **Wilmette Pumping Station Relocation**
- **Other Technologies**
  - **Aquatic vegetation**
  - **Micropore membrane aeration**
  - **Phytoremediation**
  - **Biological Additives**

Bubbly Creek CSO Diversion

- Discharge from RAPS and Bubbly Creek CSOs could be diverted to CSSC
- Provides an opportunity for a mixed-use flow augmentation tunnel
- Rejected
  - Expensive
  - Moves problem downstream

Waterway Diversion

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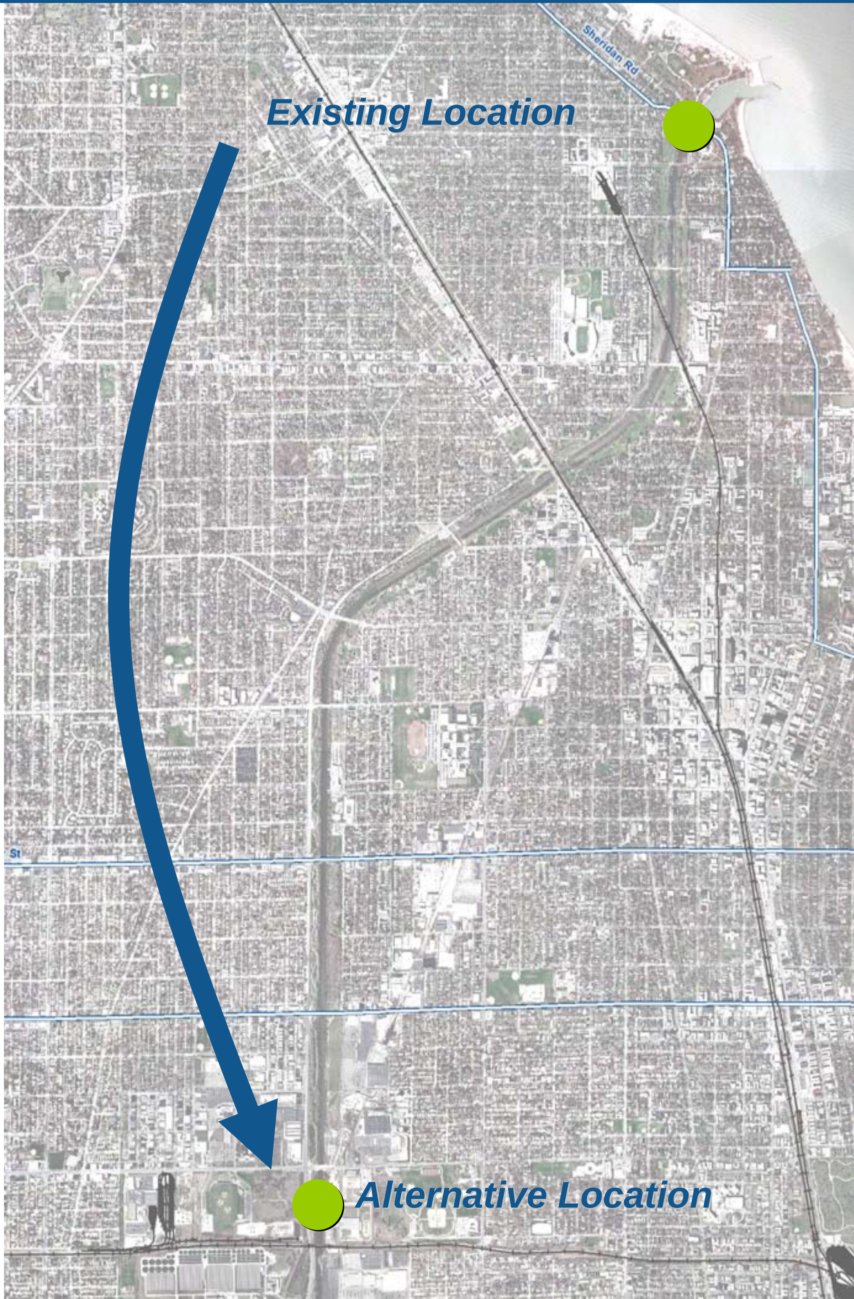
- Relocate CAWS-Lake boundary to just upstream of NSWRP outfall
- ~4 miles of UNSC becomes part of Lake Michigan
- UNSC CSOs must be diverted to LNSC
- Rejected
  - Expensive
  - Negatively impacts Lake Michigan



Other Technologies

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- Aquatic vegetation
- Micropore membrane aeration
- Phytoremediation
- Biological Additives

Rejected due to:

- Limited performance and cost information is available
- Untested in CAWS type system
- Feasibility and applicability is questionable without further research

Alternatives Selected During Long List Workshop

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- Flow Augmentation
  - Bubbly Creek (for SBCR)
- Aerated Flow Augmentation
  - Upper NSC
- Supplemental Aeration
  - U-Tubes
  - Porous Ceramic Diffusers
  - Jet Aeration
  - SEPA
  - Barge Mounted
- Sediment Oxygen Demand Control
  - Sediment Capping

  Evaluated by Dr. Melching using DUFLOW model

Sediment Capping

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Findings from DUFLOW Model

- Reducing SOD can improve DO compliance during dry weather periods
- Reducing SOD has little effect on the very low DO resulting from storms and CSOs
- SOD reduction would not substantially reduce the size of aeration stations needed to achieve 100% compliance.

REJECTED

Additional Issues Raised After Long List Workshop

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- 100% compliance with IEPA proposed standards may require:
  - Supplemental aeration of UNSC
  - Aerated Flow Augmentation of Little Calumet River upstream of Calumet WRP
  - Aeration of Chicago River during stagnant conditions
- For Aerated Flow Augmentation consider:
  - Venturi Aerator
  - Speece Cones

The following force-main aeration technologies were accepted for inclusion on the Long List:

- U-Tube (HPO)
- Venturi (HPO)
- Speece Cone (HPO)

Short List Evaluation Technology Matrix

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	UNSC	LNSC	NBCR	Chicago River	SBCR	Bubbly Creek	CSSC	Calumet Sag	Little Calumet	Calumet River
Flow Augmentation										
Aerated Flow Augmentation										
U-Tube (HPO)										
Venturi (HPO)										
Speece Cone (HPO)										
Supplemental Aeration										
Porous Ceramic Diffusers										
U-Tube (HPO)										
Jet Aeration										
SEPA										
Barge Mounted										

Short List Evaluation Matrix Criteria

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Criteria	Weight (%)
Life Cycle Costs	50
Maintainability	5
Operability	10
Reliability	10
Energy Efficiency	5
Impacts on Neighbors	5
Impacts on River Users	5
Safety	10

Short List Evaluation Matrix Summary

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✓ Alternative Considered

	UNSC	LNSC	NBCR	Chicago River	SBCR	Bubbly Creek	CSSC	Calumet Sag	Little Calumet	Calumet River
Flow Augmentation						✓				
Aerated Flow Augmentation	✓			✓		✓			✓	
U-Tube (HPO)	**205**			**205**		**205**			**205**	
Venturi (HPO)	**200**			**200**		**200**			**200**	
Speece Cone (HPO)	198			198		198			198	
Supplemental Aeration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Porous Ceramic Diffusers	**273**	**273**	**273**	**178**	**278**	**250**	**280**	**275**	**273**	**280**
U-Tube (HPO)	**223**	**223**	**223**	153	**228**	**200**	**230**	**225**	**223**	**230**
Jet Aeration	198	198	198	113	203	175	205	200	198	205
SEPA	200	200	200	125	200	175	203	200	200	203
Barge Mounted	135	135	130	**155**	135	138	135	135	135	135

90% Compliance Final Short List Matrix

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✓ Alternative Considered for Waterway

	UNSC	LNSC	NBCR	Chicago River	SBCR	Bubbly Creek	CSSC	Calumet Sag	Little Calumet	Calumet River
Flow Augmentation						✓				
Aerated Flow Augmentation										
U-Tube (HPO)	✓					✓				
Venturi (HPO)	✓					✓				
Speece Cone (HPO)	✓					✓				
Supplemental Aeration										
Porous Ceramic Diffusers			✓		✓	✓	✓	✓		
U-Tube (HPO)			✓		✓	✓	✓	✓		
Jet Aeration										
SEPA										
Barge Mounted										

(1) Decisions made at Short List Workshop on 8/21/2008

100% Compliance Final Short List Matrix

AECOM

✓ Alternative Considered for Waterway

	UNSC	LNSC	NBCR	Chicago River	SBCR	Bubbly Creek	CSSC	Calumet Sag	Little Calumet	Calumet River	
Flow Augmentation						✓					
Aerated Flow Augmentation											
U-Tube (HPO)	✓			✓		✓			✓		
Venturi (HPO)	✓			✓		✓			✓		
Speece Cone (HPO)	✓			✓		✓			✓		
Supplemental Aeration											
Porous Ceramic Diffusers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
U-Tube (HPO)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Jet Aeration											
SEPA				✓		✓					
Barge Mounted				✓							

(1) Decisions made at Short List Workshop on 8/21/2008

Project Status

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- Short List of DO enhancement alternatives by waterway segment are completed
  - 90% compliance
  - 100% compliance
- DUFLOW modeling to determine location and sizing of DO enhancement alternatives not finalized
- Therefore detailed cost estimate has not been done
- “Rough cut” cost estimate to meet IEPA proposed DO standards has been presented at IPCB hearings

100% Compliance "Rough Cut" Cost Estimate Assumptions

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- Supplemental Aeration and / or Flow Augmentation Only
- Order of magnitude estimate
- Ceramic diffusers with blowers on shore
- U-Tube aeration of augmented flow
- Sizing of aeration and augmented flow amounts based upon preliminary modeling
- Existing aeration stations at full firm capacity
- Inflation corrected costs derived from previous AECOM study for UAA
- Operating costs based upon:
  - 1 month full capacity
  - 7 months half capacity
  - 4 months out-of-service

Aeration Station Locations

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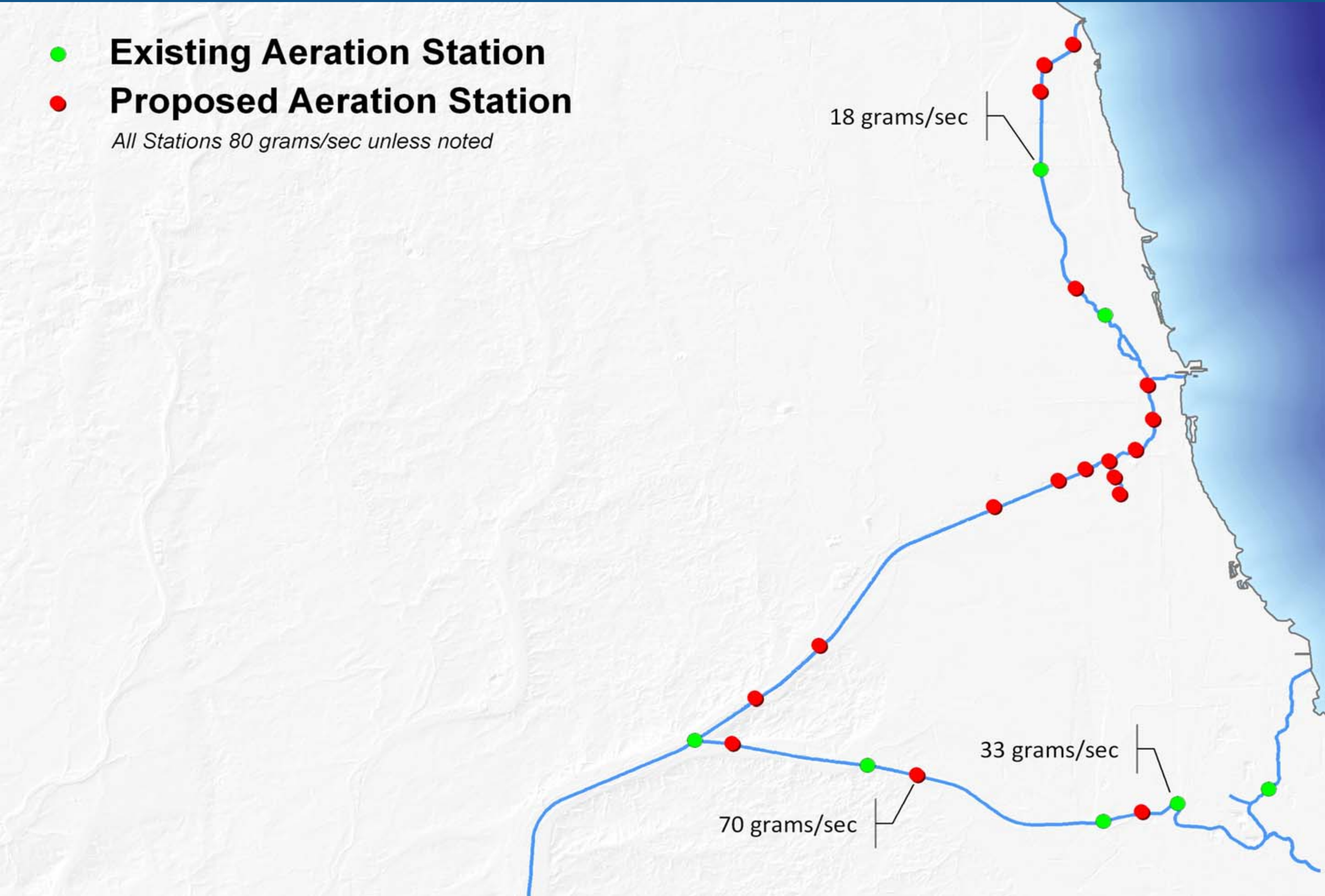

Summary of “Rough Cut” Cost Estimate

Total Capital Cost: $524,800,000

Total Annual Cost: $6,870,000

Total Present Worth: $656,600,000

Current Activities

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- District has developed its recommended CAWS DO standards
- DUFLOW modeling of supplemental aeration / flow augmentation necessary to meet District recommended standards is underway
- After modeling completion, AECOM to develop order of magnitude costs to meet District recommended DO standards

Future Activities

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- Modeling of supplemental aeration / flow augmentation necessary to meet IEPA standards using updated Marquette model
- Based upon modeling, detailed cost estimate for meeting IEPA standards will be developed

Questions?

Development of an Integrated Strategy for Meeting Dissolved Oxygen Standards Proposed for the Chicago Area Waterway System (CAWS)

David Zenz

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