Preliminary Evaluation Feasibility of Aeration for Reducing the Chesapeake Bay Dead Zone Update 2/20/2019

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Here's the Basic Idea

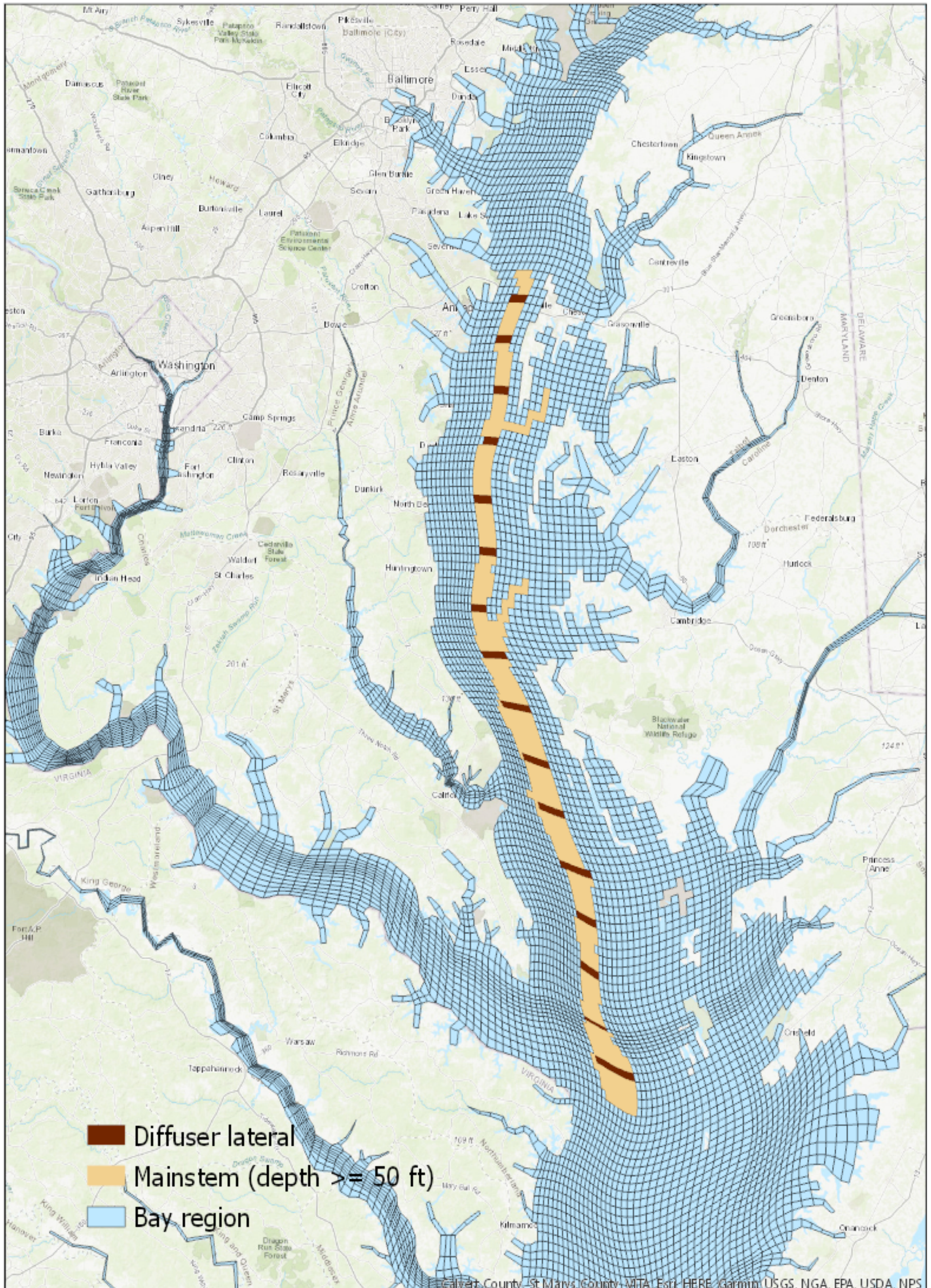
- Do what you oughta, add O2 to water
- Do this by pumping air into the dead zone
- The O2 will dissolve into the water as the bubbles rise
- Tide will disperse the O2 North/South
- East/West pipes will disperse O2 E/W
- Figure out if it's feasible to add enough O2 to offset the imbalance between respiration and natural aeration

Here's NOT the Basic Idea

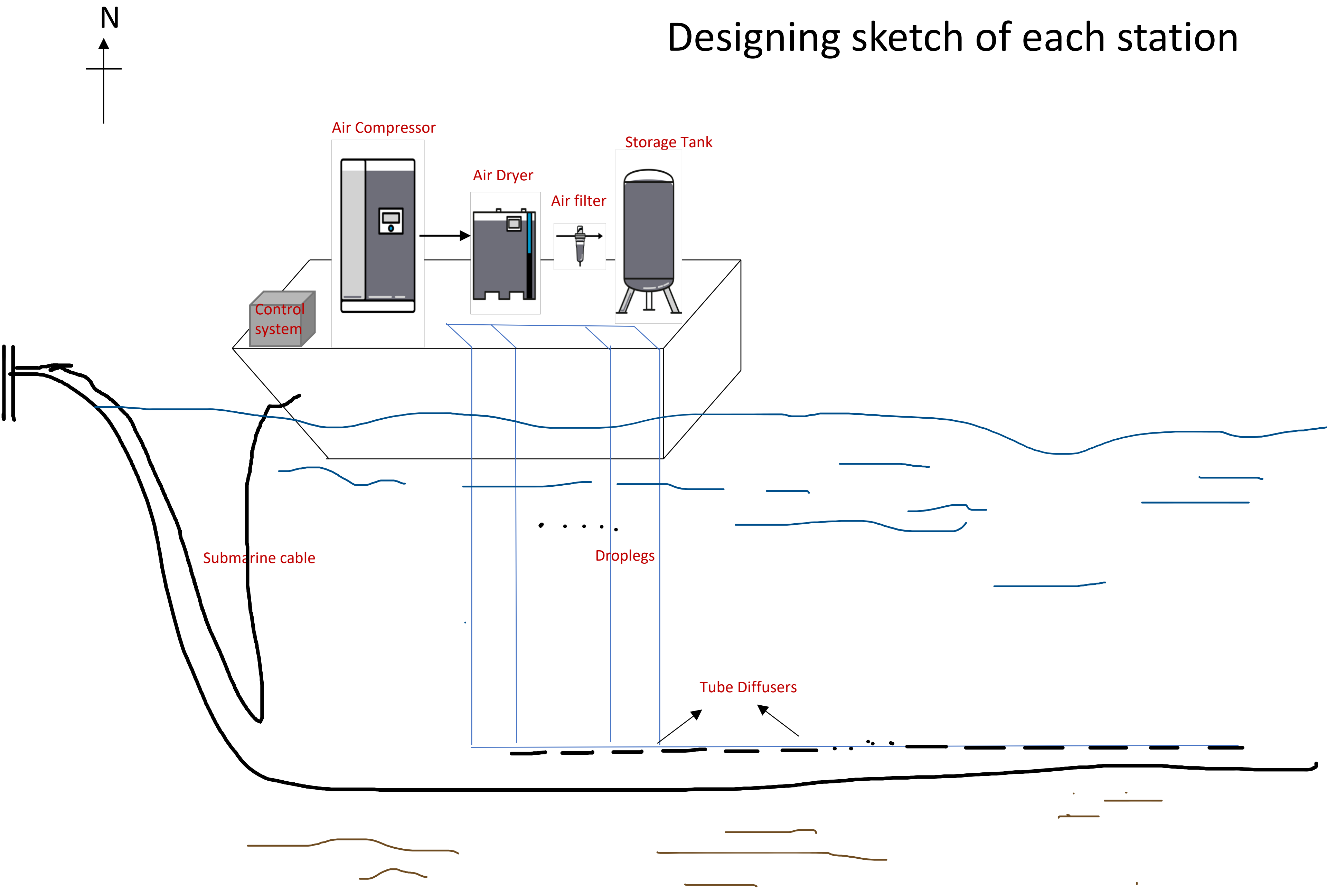
- Use bubbles to break up the pyncnocline
  - Thus increase natural aeration
- Choose a method for pumping air
- Choose an energy source
- ~~Use pure O2~~
- Design a system (yet)
- Promote an agenda (yet)

Diffuser lateral distribution Diagram

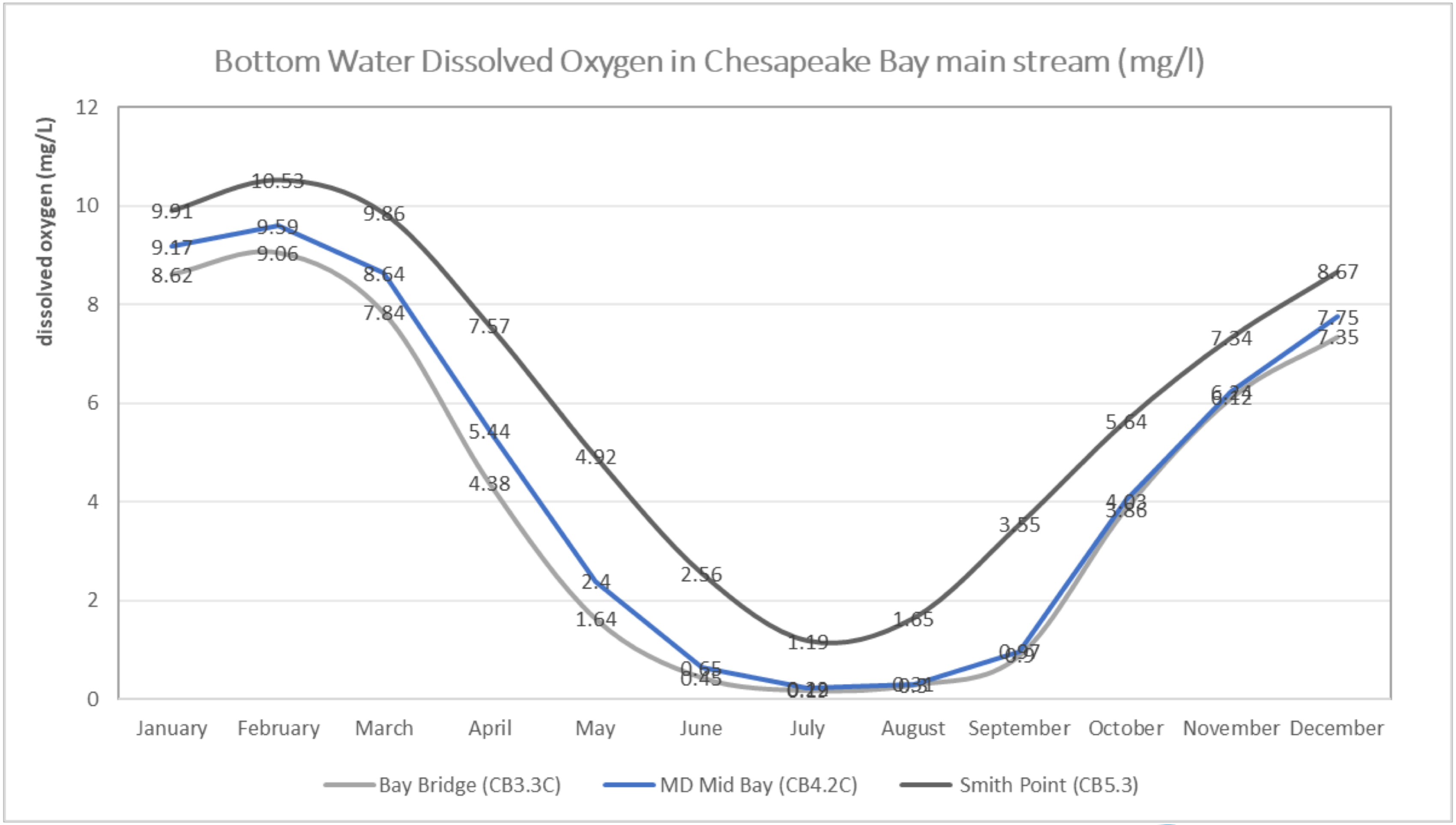
- Air distribution lateral laid east/west across the Bay's north/south axis with 5 miles interval (approximately same distance as tidal excursion);
- Total 16 laterals, barges parking at the margin of dead zone as off-shore platform;



Designing sketch of each station



How Much O_2 is Needed?



HYDROLOGICS

Columbia, MD • Raleigh, NC • Portland, OR • Boston, MA

Several Numbers:

1. $1,982.6 M: State and Federal partners invested in Watershed restoration in fiscal year 2017 [1];

2. $47 M: directed to help meet the goals of the Chesapeake Bay Total Maximum Daily Load by CBP Funds[1];

3. According to EPA officials, it may take a significant number of years for changes to occur in water quality after implementation of TMDLs[2];

4. $80 M: Welfare effect (equivalent to 80 Millions dollars) with 25% increase of DO levels across the region[3];

Reference:

1. www.chesapeakeprogress.com/funding;
2. https://www.epa.gov/tmdl/impaired-waters-restoration-process-recovery;
3. *Massey, D. M., S. C. Newbold, and B. Gentner. 2006. Valuing water quality changes using a bioeconomic model of a coastal recreational fishery. Journal of Environmental Economics and Management 52: 482–500.*

Engineering Cost Analysis:

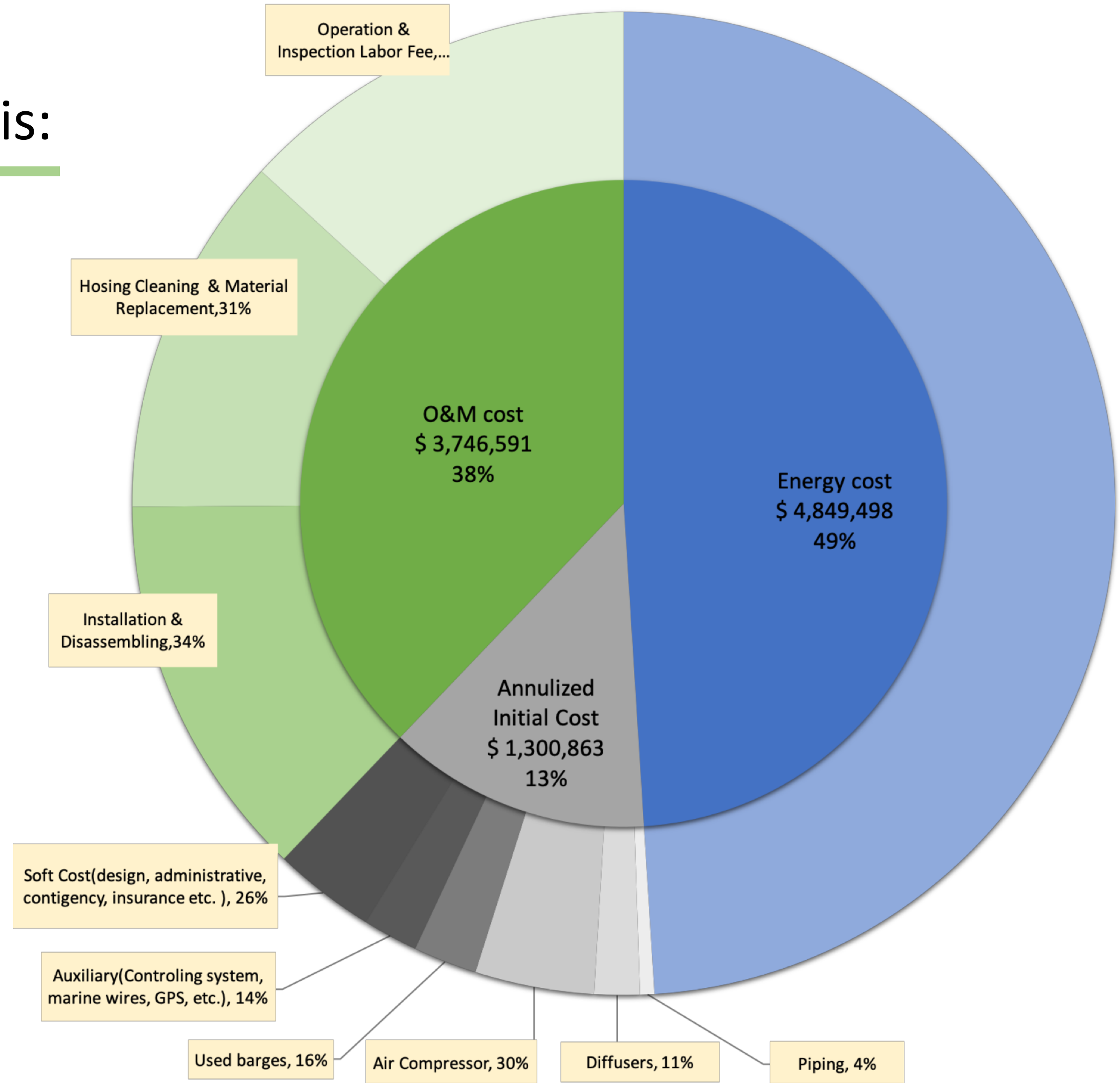
Total Annual Cost:

$9,896,952;

Assumption:

1. 5% interest rate for aeration project;
2. 10 years projected life

On the order of **0.5%** of current combined Federal and State Bay Program expenditures on an annual basis (4)



Reference:

1. Boyle, William C. (1990). *Fine pore aeration for wastewater treatment*. Park Ridge, N.J., U.S.A : Noyes Data Corp;

2. W. Harris, Roy & John , Jr, Cullinane,M & Sun, Paul. (1982). *Process Design and Cost Estimating Algorithms for the Computer Assisted Procedure for Design and Evaluation of Wastewater Treatment Systems (CAPDET).* 1706. ;

3. Web Price;

4. www.chesapeakeprogress.com/funding

How about using Concentrated O2?

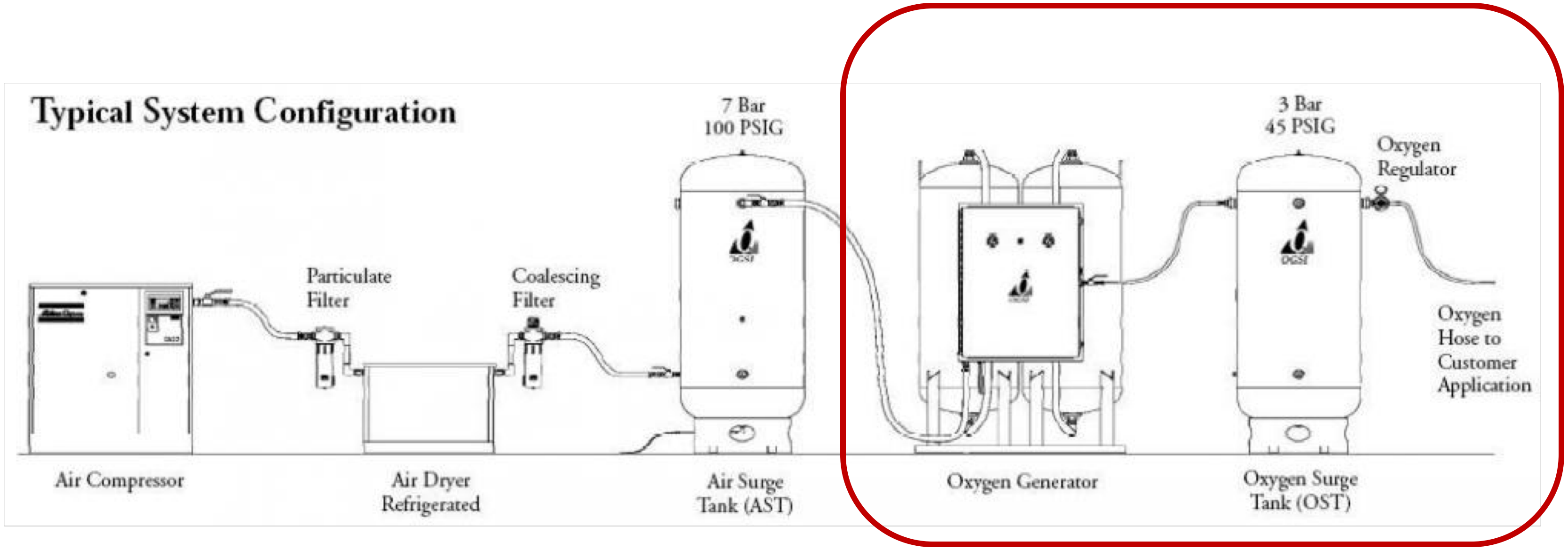


Table-1: Initial Cost Estimation

Piping System	$	358,400	3%
Diffusers System	$	1,139,409	10%
Air Compressor System	$	2,274,233	19%
90% Oxygen Generator System	$	2,226,272	19%
Used Barge	$	1,600,000	14%
Auxiliary	$	1,150,881	10%
Soft Cost	$	3,009,723	26%
Total Estimated Initial Cost	**$**	**11,758,918**	

Table-2 Cost Estimation of using Concentrated Oxygen

Annualized Initial Cost	$	1,522,834	12%
Energy cost	$	7,465,355	58%
Annual O&M cost	$	3,900,167	30%
Operation & Inspection	$	1,528,071	
Hosing cleaning & Material replacement	$	1,179,409	
Installation and Disassembling	$	1,192,687	
Equivalent annual cost	**$**	**12,888,356**	

Energy Cost Estimation:

❖ Table-3: Energy Demand Comparison

		1: Using Air	2: Using 90% Oxygen
Oxygen Needed	mg/day	3.10E+12	2.39E+12
Concerntrated Oxygen Requirment	l/day		1.98E+09
Air Requirement	l/day	1.20E+10	9.27E+09
work Required	J/day	1.46E+12	2.26E+12
Energy Requirement	KWh/day	5.08E+05	7.82E+05
Annual Energy Cost (50% efficiency)	$	4.85E+06	7.46E+06

❖ Table-4: Energy Options

	1. Commercial electricity	2. Solar generation	3. Source From Marine
Strategy	• Connected by marine wires	• Connected by marine wires; • 2256 KW solar panels with $1.95/W[1] can cover full demand considering renewable energy incentives.	• Wave with average height 1.5 ft and period 4s is likely to produce an integrated volumetric air flow of about 1E+09 liter per day with 5 barges.
Levelized cost	$0.11 /KWh $4.47 E-06/l Air	$0.092 /KWh $6.2 E-06/ml Air	(Unfinished, Need check!)
Co-benefits		- Green Energy; - Likely to be more cost-effective in 2-3 years.	- Green Energy; - Reduce wave impact on navigation and bank erosion.

1. Fu, Ran, Feldman, David J., Margolis, Robert M., Woodhouse, Michael A., & Ardani, Kristen B. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017*. United States. doi:10.2172/1390776.

But, Will It Work??

- Testing with CBWQSTM
- Adding O_2 to model
  - Vertical distribution of O_2 injection per calculations from dirty bubble formula
  - Assume ~~uniform~~ distribution of O_2 proportional to depth injection in all model columns > 50' deep between Smith Point and Bay Bridge in main channel
  - Total O_2 addition consistent with cost estimate
  - Correct 2' error in depths from first run

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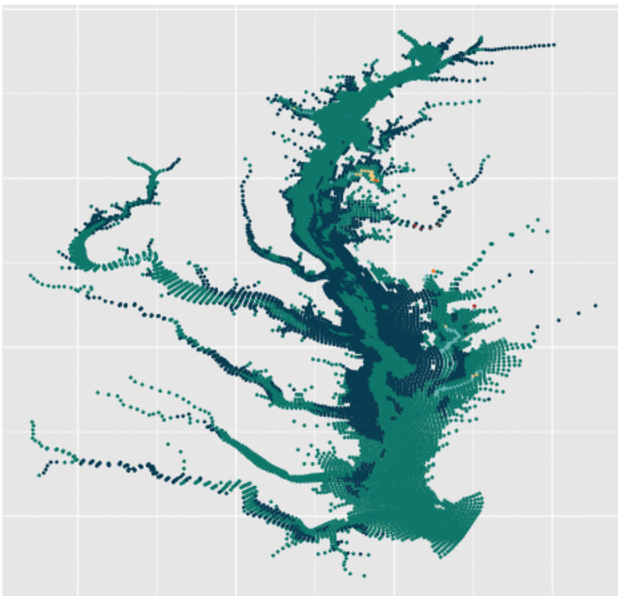
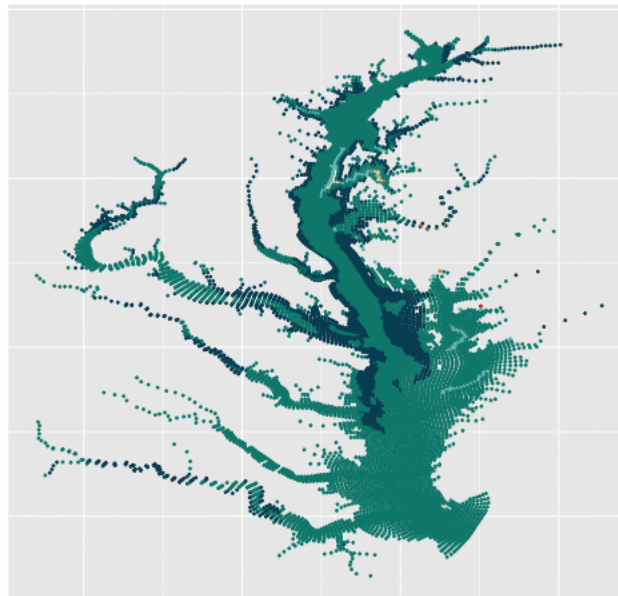
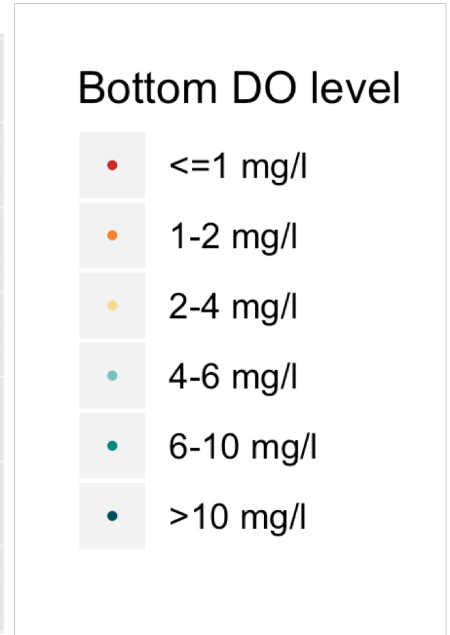
Comparison of Bottom DO level in May to Oct., 1993-1996

2013 DO 1993-05-01

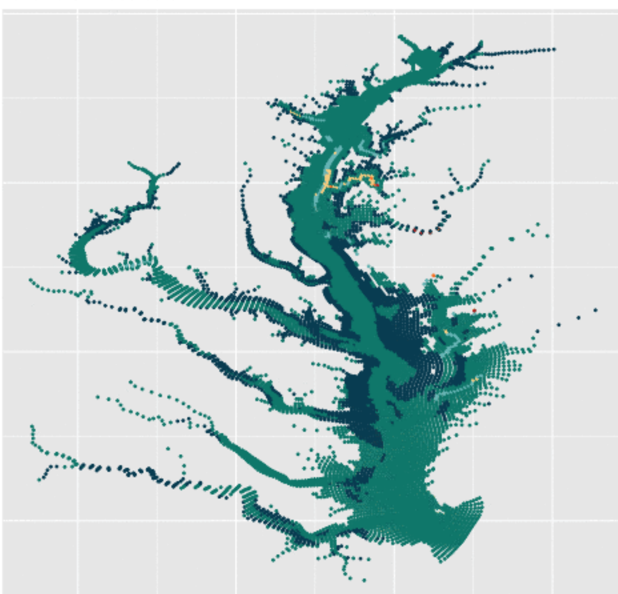


WIP2 1993-05-01





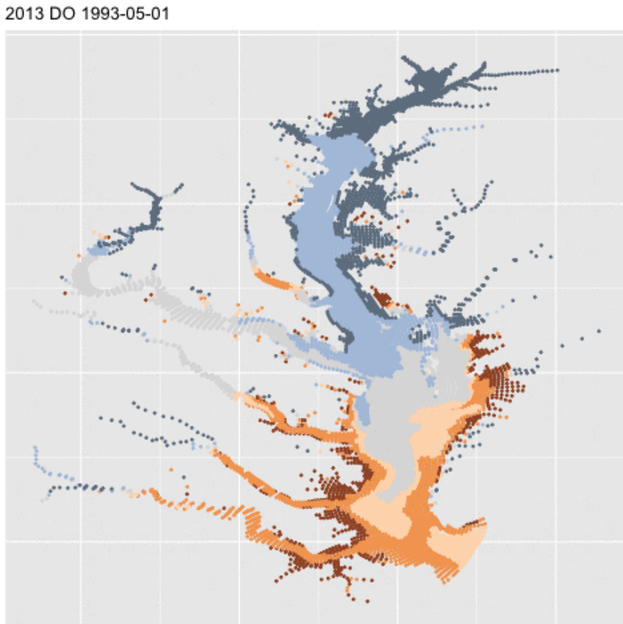
2013 BASE 1993-05-01

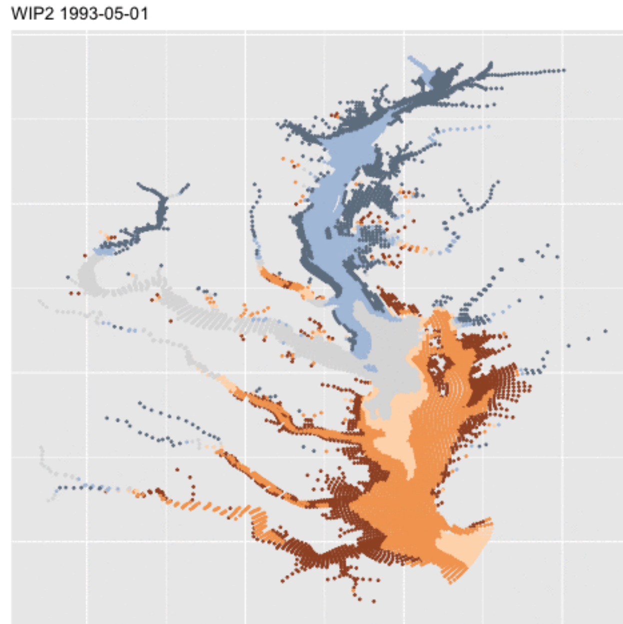


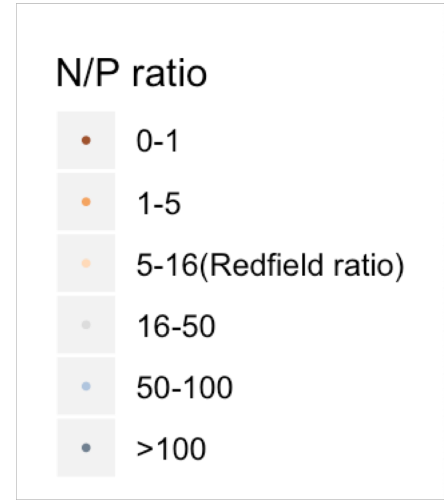
Click the links below to see full animations of simulated DO level:

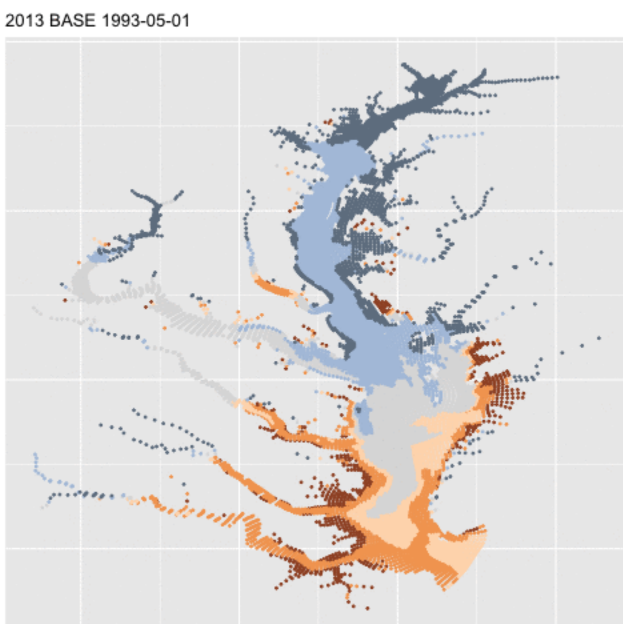
- Based on 2013 loadings;
- Based on 2013 loadings with aeration;
- Full implementation of WIP2 State loading allocations;

Comparison of N/P ratio in May to Oct., 1993-1996





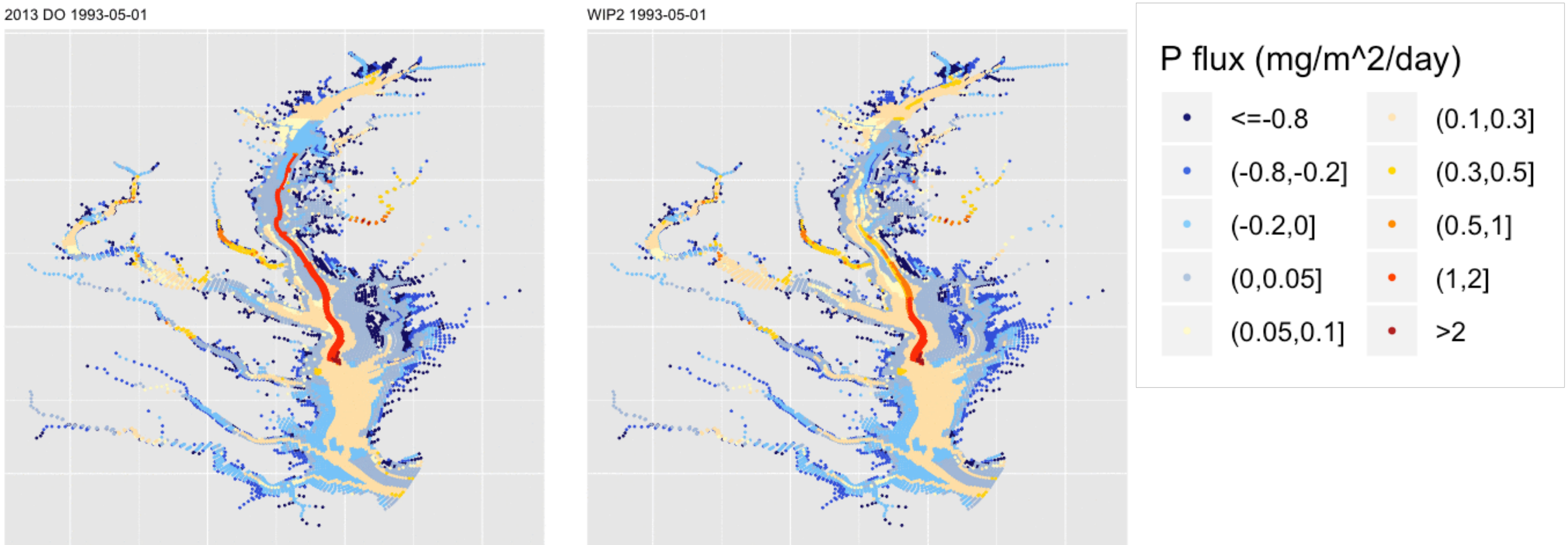


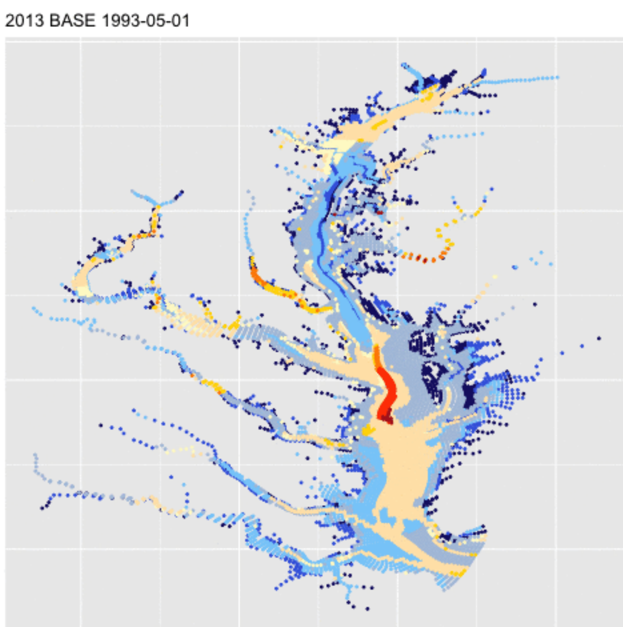


Click the links below to see full animations of simulated N/P ratio:

- Based on 2013 loadings;
- Based on 2013 loadings with aeration;
- Full implementation of WIP2 State loading allocations;

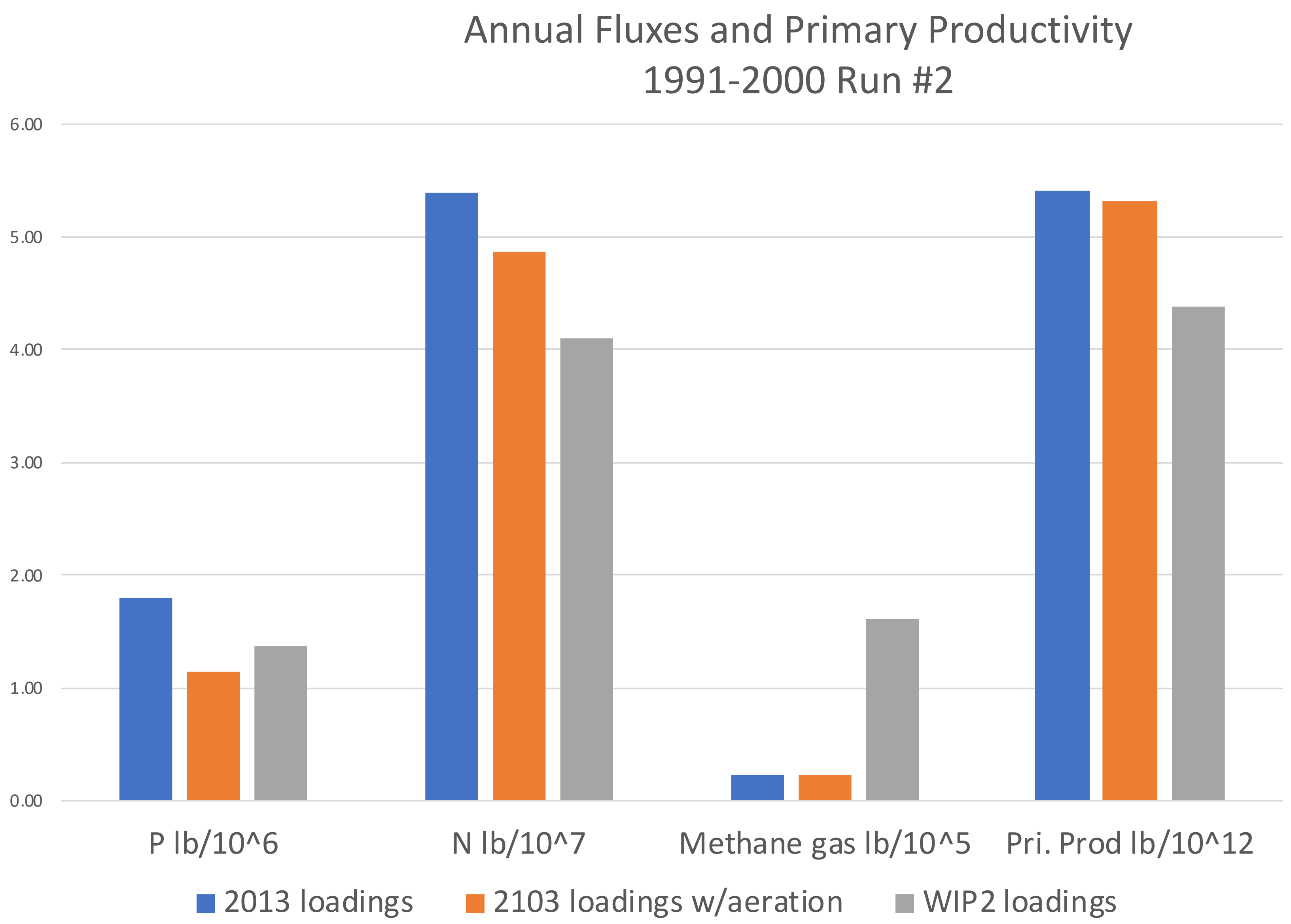
Comparison of P flux in May to Oct., 1993-1996





Click the links below to see full animations of simulated P flux:

- Based on 2013 loadings;
- Based on 2013 loadings with aeration;
- Full implementation of WIP2 State loading allocations;


Annual Fluxes and Primary Productivity
1991-2000 Run #2
6.00
5.00
4.00
3.00
2.00
1.00
0.00
P lb/10^6
N lb/10^7
Methane gas lb/10^5
Pri. Prod lb/10^12
2013 loadings
2103 loadings w/aeration
WIP2 loadings

A Model Simulation and Exploration of Engineered Aeration in the Chesapeake Bay

- Collaborating with Lora Harris and Jeremy Testa and Bill Ball on a paper with this title
- Would like additional collaborators to help describe potential ecological impacts, positive and negative
- Target submission late spring

Panel at NAEP Conference in Baltimore in May

- Short presentation on concept and potential for benefits and negative impacts
- Open discussion with responses by panelists

Research Opportunities and Proof of Concept

- Pilot Station with monitoring
- Comparison of Model results and data (similar to Rock Creek)
- Intensive monitoring for potential negative impacts
- Fish Behavior in vicinity of diffusers
- Preliminary design and costing
- Others?

Thank You

Discussion,
Comments and Suggestions?

Animation of Central Bay (CB4/CB5) Base Run (Top) – Infusion (Bottom)