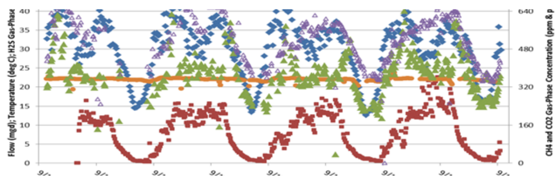
US Department of Energy Industrial Efficiency and Decarbonization Office | Measuring Life Cycle GHGs from WRRFs

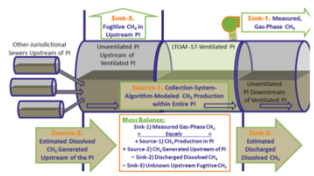
January 24, 2024

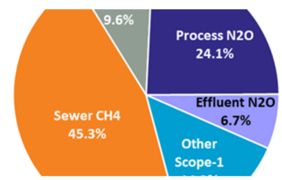
Sewer CH_4: as an Example *Very Tough GHG Nut to Crack*

Washington, DC

U.S. DEPARTMENT OF ENERGY







Brown AND Caldwell

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Presentation Overview

- Sewer CH_4 Fundamentals and Potential Significance
- Past Gravity-Sewer Results Create Questions
- Headworks Testing may beg even more Questions
- Project Summary of WRF's *Sewer-CH_4 Methods for Everyone*

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Sewer CH_4 Fundamentals and Significance

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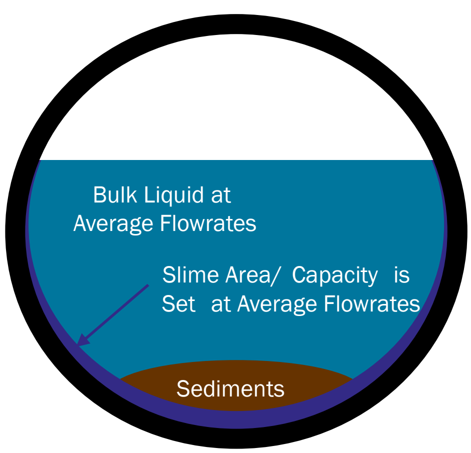
Sewer CH_4 Production Fundamentals



- Slime (biofilm) layers provide long residence time to support methanogens in deeper layers
- Sulfide reducers and hydrolyzers are more prominent in outer layers
- Some flow/velocity is needed to infuse carbon and sulfate into biofilm
- Sediments are not assumed as source for most networks

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Initial Assessment of 55% was Reduced to 45% of Scope-1 GHG

Plant Classification		% of US Flow in Category [1]	Estimated US National Flow, m^3/s	GHG Emissions Factor, MT CO_2e/mo per m^3/s treated [1]: Sewer CH_4	CH_3OH CO_2	Other Scope-1	US National GHG Emissions, 1,000 MT CO_2e/yr: Sewer CH_4	CH_3OH CO_2	Process N_2O	Effluent N_2O	Other Scope-1	Total Scope-1	Percentage Totals by GHG Emissions Source: Process N_2O as % of Scope-1	CH_3OH as % of Scope-1	Sewer CH_4 as % of Scope-1
ENR	w/o Digestion	4.3%	48	79.4	38.6	25.0	46	22	16	2	14	100	15.9%	22.2%	45.7%
	w/ Digestion	7.7%	85	79.4	94.7	25.0	81	97	35	3	26	241	14.3%	40.1%	33.6%
	ENR Totals:	12.0%	133				127	119	50	5	40	341	14.8%	34.9%	37.2%
BNR	w/o Digestion	17.7%	196	79.4	0.0	25.0	187	0	101	22	59	368	27.5%	0.0%	50.7%
	w/ Digestion	31.3%	347	79.4	25.2	25.0	331	105	231	38	104	809	28.5%	13.0%	40.9%
	BNR Totals:	49.0%	543				517	105	332	60	163	1,177	28.2%	8.9%	43.9%
Secondary	w/o Digestion	14.1%	156	79.4	0.0	25.0	148	0	57	29	47	281	20.4%	0.0%	52.7%
	w/ Digestion	24.9%	276	79.4	0.0	25.0	263	0	122	61	83	529	23.1%	0.0%	49.7%
	Secondary Totals:	39.0%	432				411	0	180	90	130	811	22.2%	0.0%	50.7%
	US National Totals:	100.0%	1,108				1,055	224	562	155	332	2,329	24.1%	9.6%	45.3%

Table from Willis, Chandran, Le (2021)

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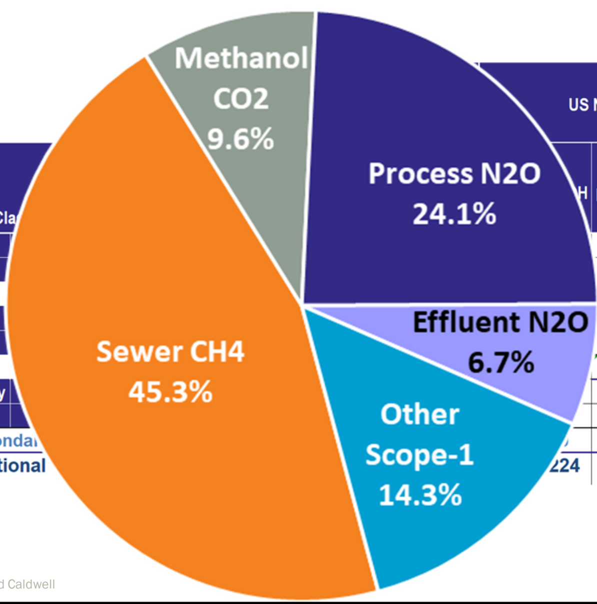
Initial Assessment of 55% was Reduced to 45% of Scope-1 GHG



Process N_2O	Effluent N_2O	Other Scope-1	Total Scope-1	Process N_2O as % of Scope-1	CH_3OH as % of Scope-1	Sewer CH_4 as % of Scope-1
16	2	14	100	15.9%	22.2%	45.7%
35	3	26	241	14.3%	40.1%	33.6%
50	5	40	341	14.8%	34.9%	37.2%
101	22	59	368	27.5%	0.0%	50.7%
231	38	104	809	28.5%	13.0%	40.9%
332	60	163	1,177	28.2%	8.9%	43.9%
57	29	47	281	20.4%	0.0%	52.7%
122	61	83	529	23.1%	0.0%	49.7%
180	90	130	811	22.2%	0.0%	50.7%
562	155	332	2,329	24.1%	9.6%	45.3%

Table from Willis, Chandran, Le (2021)

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Past Gravity-Sewer Results Create Questions

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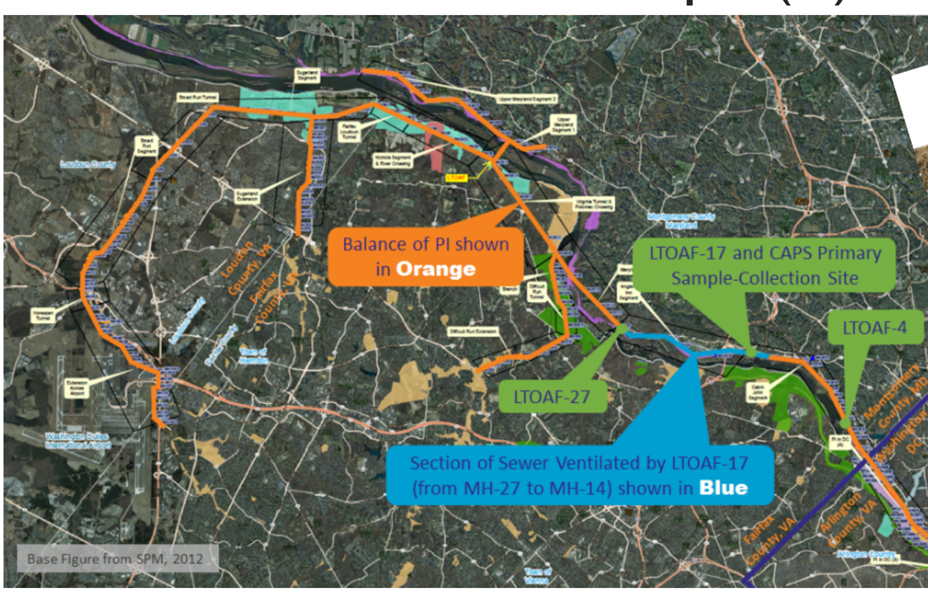
Overview of the Potomac Interceptor (PI) “CAPS” Test



Willis, et al. (2020)
WRF U5R12a/4885a&b

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Two Sampling Campaigns

- Summer
  - September 16, 17 and 18, 2014
  - Measured Daily-Average Potomac-Interceptor Sewage Temperatures of 21.5 to 22.1^{O}C
- Winter
  - April 7, 8, and 9, 2015
  - Measured Daily-Average Potomac-Interceptor Sewage Temperatures of 12.1 to 12.7^{O}C

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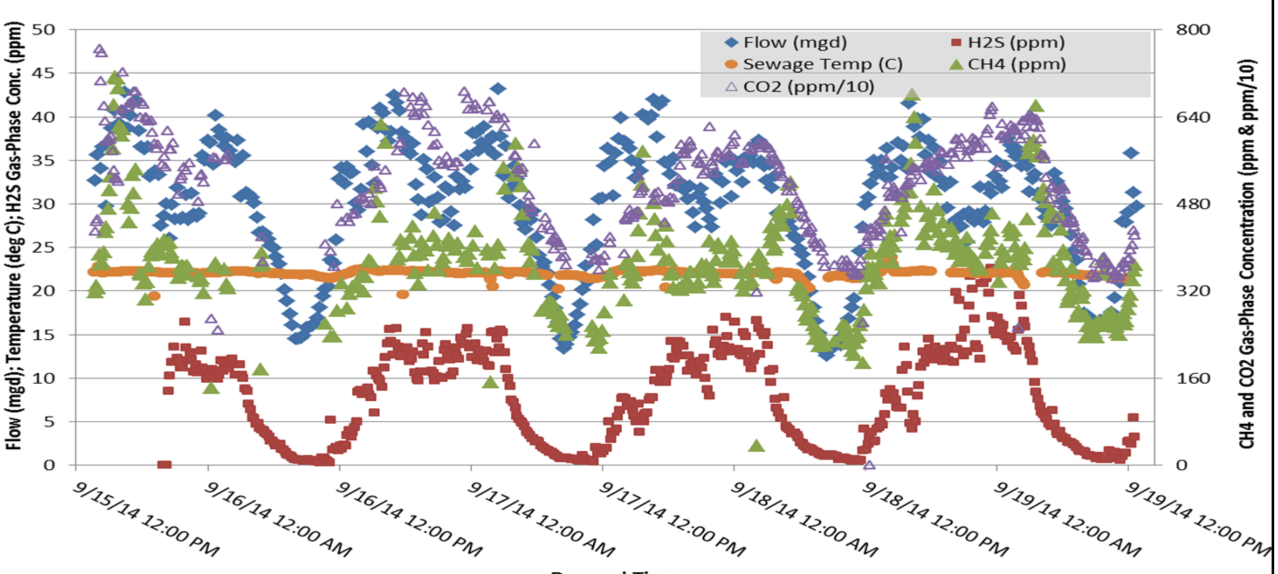
Results – Summer Sampling



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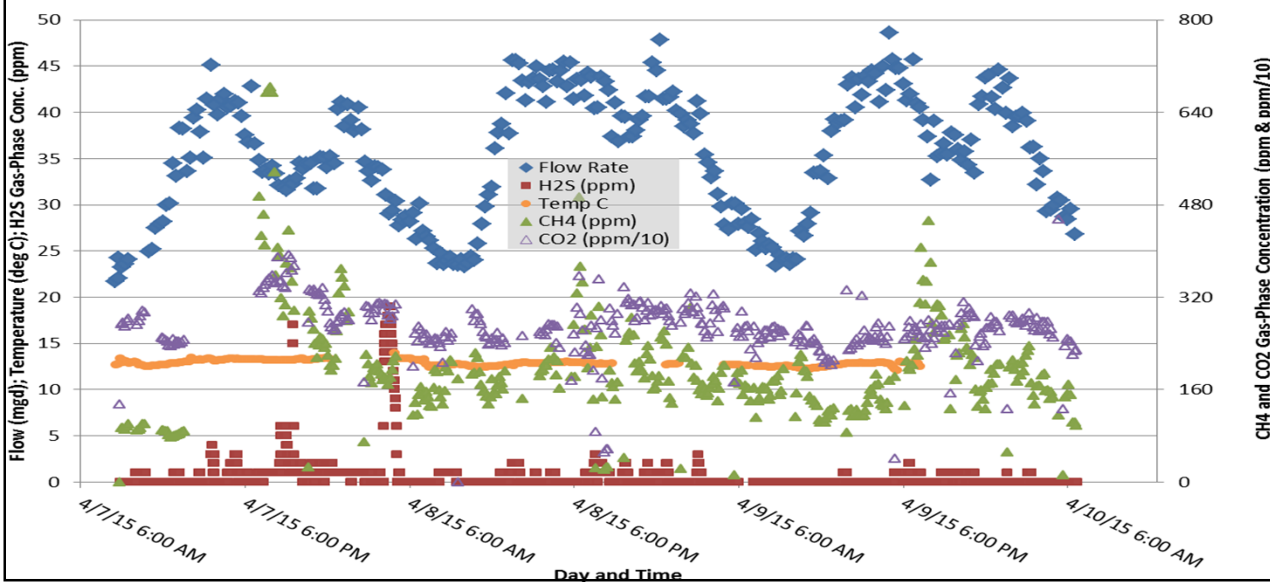
Results – Winter Sampling



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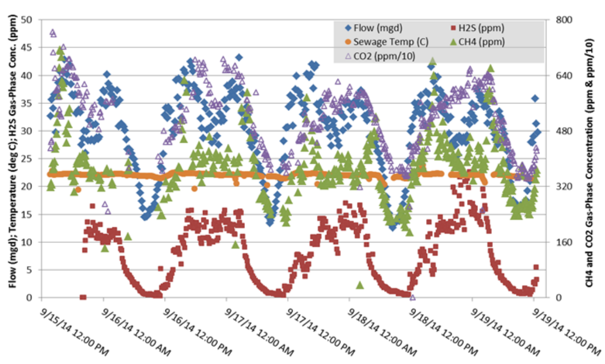
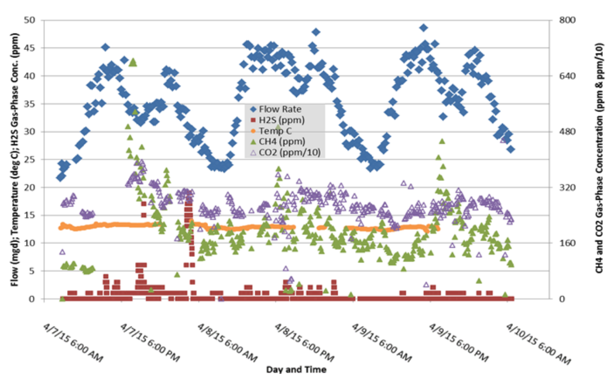
Results: Summer vs. Winter Comparison





- Winter CH_4 and CO_2 are ~half those in summer
- CO_2 is ~12X CH_4
- H_2S is much lower in the winter

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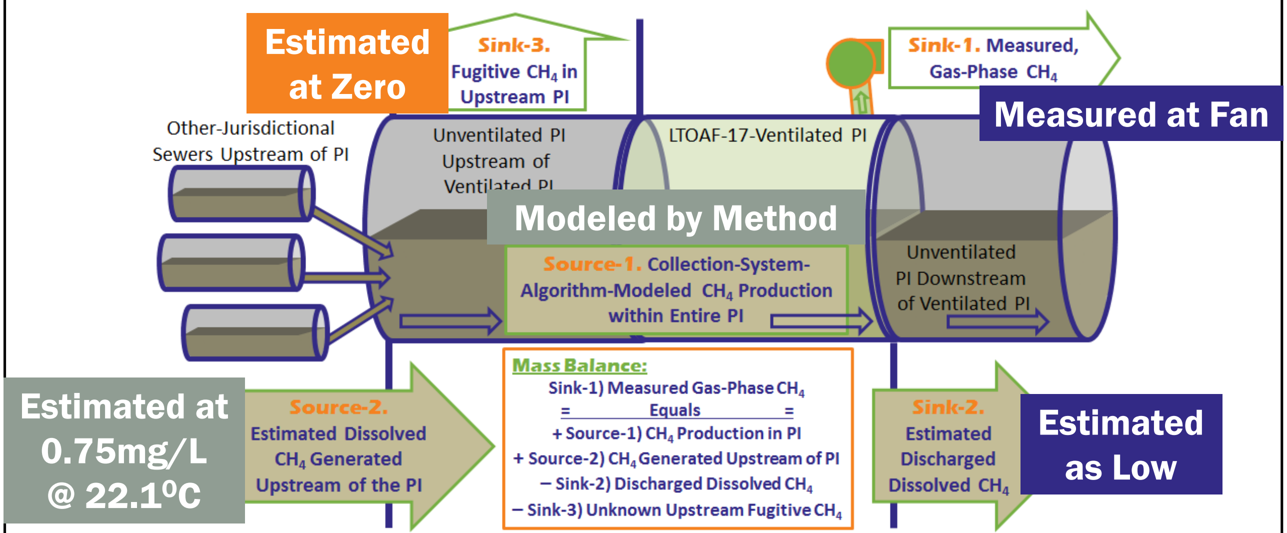
Methane Sources and Sinks for the Potomac Interceptor



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Results showed Apparently-Good Correlation with Temperature

Monitoring Day Designation:	Summer Day 1	Summer Day 2	Summer Day 3	Winter Day 1	Winter Day 2	Winter Day 3
Source-1) Simple-Algorithm-Predicted CH_4 Production within the Modelled PI						
Modelled Gravity Sewer CH_4, kg CH_4/D	63	62	60	38	37	38
Modelled Surcharged Sewer CH_4, kg CH_4/D	2.0	1.9	1.9	1.1	1.1	1.1
Modelled CH_4 Production in PI, kg CH_4/D	64.9	64.3	62.2	38.7	38.4	39.4
Modelled as % of Measured	49.7%	49.0%	47.0%	46.4%	55.6%	58.9%
Source-2) Estimated Transport of CH_4 into the PI from Other-Jurisdictional Sewers						
Average Dissolved CH_4 Feed Sewers to the PI, mg/L[a]	0.75	0.74	0.75	0.40	0.36	0.38
Estimated CH_4,Transport into the PI from Feed Sewers, kg CH_4/D	84.7	85.8	81.1	50.6	50.2	51.5
Transported CH_4 as % of Measured	64.9%	65.4%	61.3%	60.6%	72.7%	77.0%
Sink-2) Estimated Dissolved CH_4 Discharged from the LTOAF-17-Ventilated Reach						
Dissolved CH_4 Concentration Leaving LTOAF-17-Ventilated Section, mg/L	0.111	0.110	0.109	0.085	0.083	0.084
Dissolved CH_4 Discharged from LTOAF-17-Ventilated Section, kg CH_4/D	12.6	12.8	11.8	10.7	11.6	11.6
Transported CH_4 as % of Measured	9.6%	9.8%	8.9%	12.8%	16.8%	17.3%
Sink-1) Measured Data for each Day of Sampling						
Average PI Sewage Temperature, °C	22.1	21.8	21.5	12.7	12.1	12.6
Average Measured Flow at LTOAB-17, mgd	29.9	30.8	28.7	33.3	36.9	36.2
Measured CH_4 Emissions, kg CH_4/D	131	131	132	83	69	67
Total Accounted for CH_4 to be Emitted at LTOAF-17						
Total Modelled + Estimated - Discharged (Predicted) CH_4, kg CH_4/D	137	137	131	79	77	79
Total Predicted CH_4 as % of Measured	105.0%	104.6%	99.3%	94.2%	111.5%	118.6%
Average Seasonal Predicted CH_4 as % of Measured		103.0%			107.1%	

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"CAPS Gravity-Sewer Algorithm" estimated **methane production** in upstream PI

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"Backed into" **0.75mg/L** dissolved methane in imported sewage **at 22.1^{O}C**

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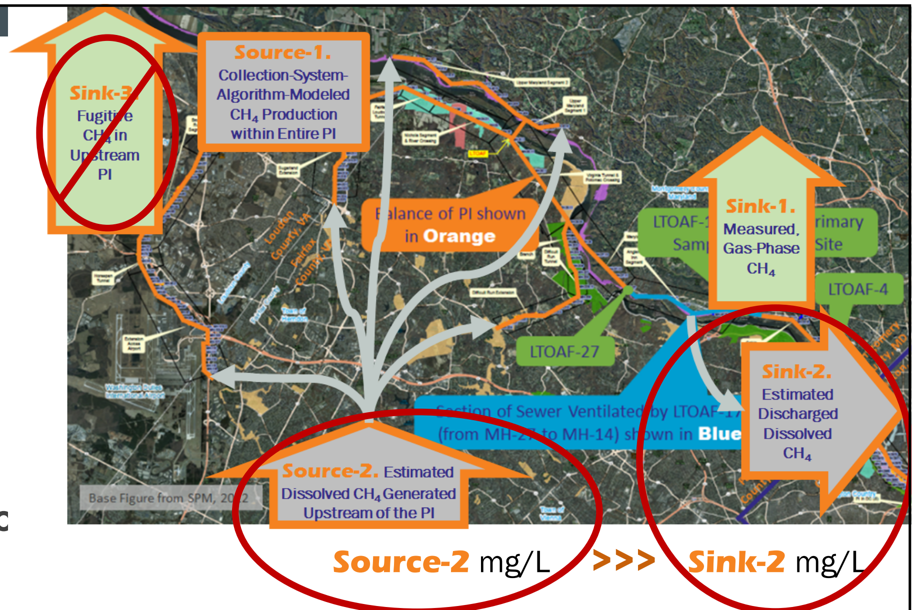
But Required Likely **False** Assumptions



A. Assumption of Zero Gas-Phase Emissions Upstream of Ventilated Sectic

B. 4 to 7X Higher Imported **Dissolved-CH_4** Concentrations than Discharged CH_4

But these mean our Method Under Reports CH_4

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Headworks Testing may beg even more Questions

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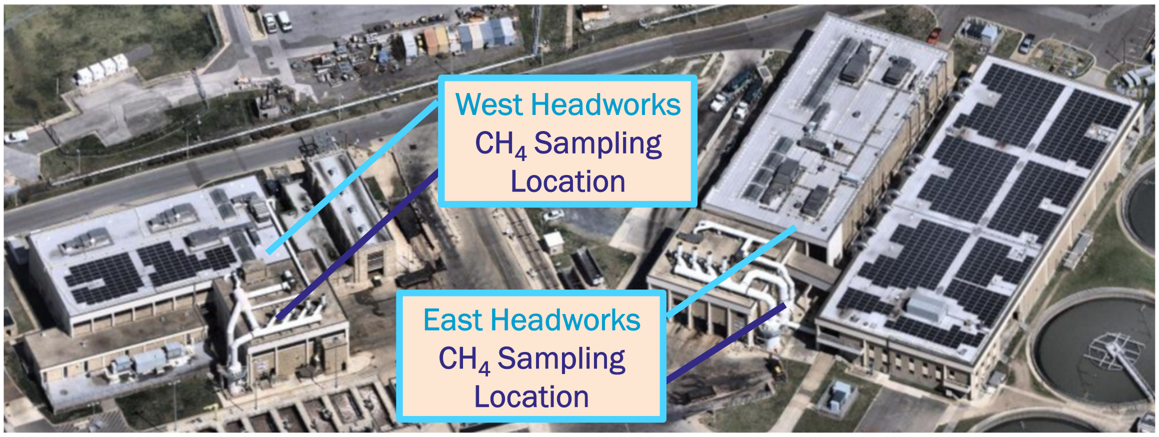
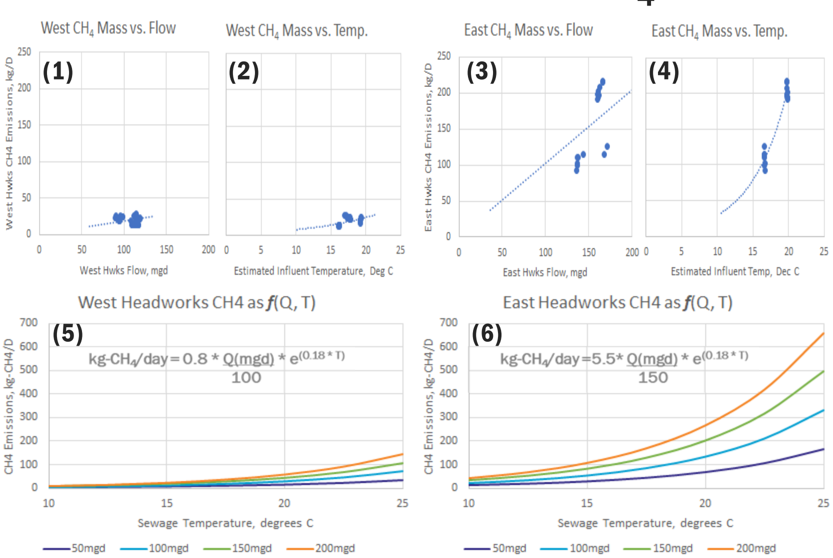
Blue Plains' West and East Headworks



Two Blue Plains Headworks CH_4 Measurements



- East Headworks emits ~4.6 X more CH_4 than West at same flows and temperatures
- Based exclusively on foul-air fluxes (Ignores liquid-phase)

➢ "Headworks CH_4" is subtracted from "Sewer CH_4" in GHG Inventory

Project Summary of WRF's *Sewer-CH_4 Methods for Everyone*

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A New WRF Project (#5220) will Investigate Sewer CH_4

- Develop larger gravity-sewer data set:
  - Two controlled-sewer experiments (UQ and Metro. U. of Toronto)
  - Full-scale campaigns at VCS Denmark, NEORSD, King County, Metro Vancouver, HRSD, and Melbourne Water
- Revise/refine/select gravity-sewer algorithm
- Apply that preferred methodology to 40 to 50 Partner sewersheds
- Develop a new, lower-tier methodology (for adoption by ICLEI and IPCC) to estimate collection-system CH_4 emissions using:

Sewer CH_4 (in kg-CH_4/day) = ***f (*** temperature, %-flooded, ytbd-size-criterion ***)***

Help Everyone Else add Sewer-CH_4 to their inventories by using the new lower-tier methodology (and allow USEPA to include it in future National GHG Emissions Sources and Sinks)

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Who is on the Team?

Owner: **Water Research Foundation**

Prime: **Brown and Caldwell**

Subcontracted Universities/Researchers: **The U. of Queensland**, **Aalborg U. / The WATTS guys**, **ICRA**

University Reviewers: **Columbia U.** **Princeton U.** **U.C. Irvine**

Participating Utilities: **Louisville MSD (KY, Primary Sponsor)**

FACSA (Spain) **King County (WA)** **Beaufort-Jasper WSA (SC)**

HRSD (VA) **Melbourne Water (Australia)** **Metro Vancouver (Canada)**

NEORSD (OH) **VCS (Denmark)** **WSSC (MD)**

PAC: **GHD** **NYC DEP (NY)** **US Water Alliance**

Controlled-Sewer Tests: **Metro. U. of Toronto (NSERC)** **The U. of Queensland (ARC)**

Others Tracking: **DOE** **GHD** **Jacobs** **Western U.** **US-EPA**

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QUESTIONS?

it's about connecting

Brown AND Caldwell essential ingredients®

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