United States Environmental Protection Agency

Developing Oxidized Nitrogen Atmospheric Deposition Source Attribution from CMAQ for Air-Water Trading for Chesapeake Bay

Robin L. Dennis

Atmospheric Modeling and Analysis Division, NERL, EPA

Chesapeake Bay
Modeling Quarterly Review Meeting
Annapolis, Maryland
July 24, 2013

There is strong interest in air-water trading so states can get water quality credit

EPA United States Environmental Protection Agency

The Chesapeake Bay TMDL sets limits on the load that can be delivered from tributaries and the air to the Bay. The TMDL takes into account nitrogen deposition reductions from current national air rules (such as CAIR)

States may go beyond national CAA rules to meet local air quality standards

It is important to the costly, water-oriented TMDL process to take advantage of air emissions reductions that would occur in addition to national air rules

Because of the complex chemistry, transport and transformations, calculation of the incremental benefit needs an air quality model

We do not want to run the air quality model many times over (due to computational expense)

There is a special source attribution version of CMAQ (DDM-3D) that tracks the individual contribution of emissions by source or region, to the total deposition

Use CMAQ with DDM-3D Adapted for Deposition

EPA United States Environmental Protection Agency

- DDM-3D calculates in the forward sense: how a specific source or sources impacts the domain

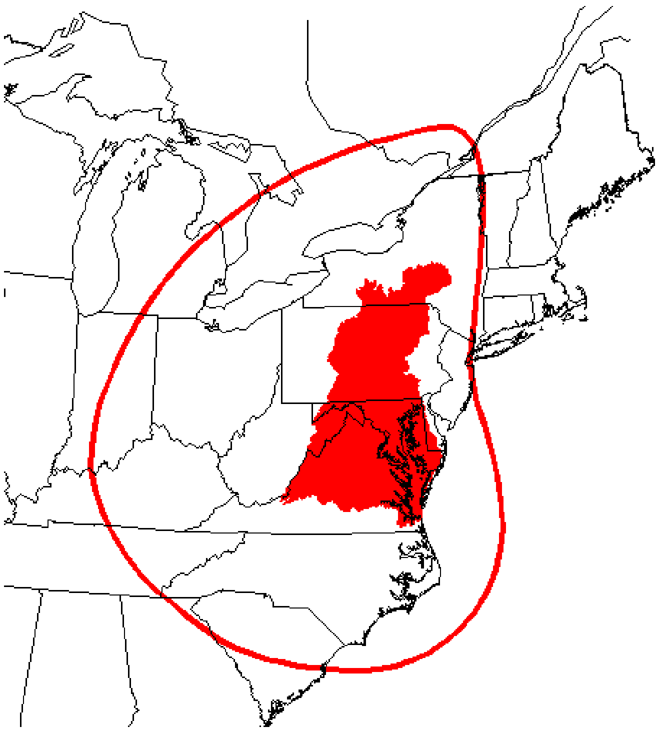
- DDM-3D for deposition estimates the fraction of the total deposition attributed to emissions from a particular source type or region

- We track NO_X emissions (oxidized nitrogen deposition) for a 2020 CAIR future

- We use the CMAQ DDM-3D version with 12km grids over the airshed domain

- We then create simplified state-level delta emissions–to-delta atmospheric deposition transfer coefficients by major source sectors within a state

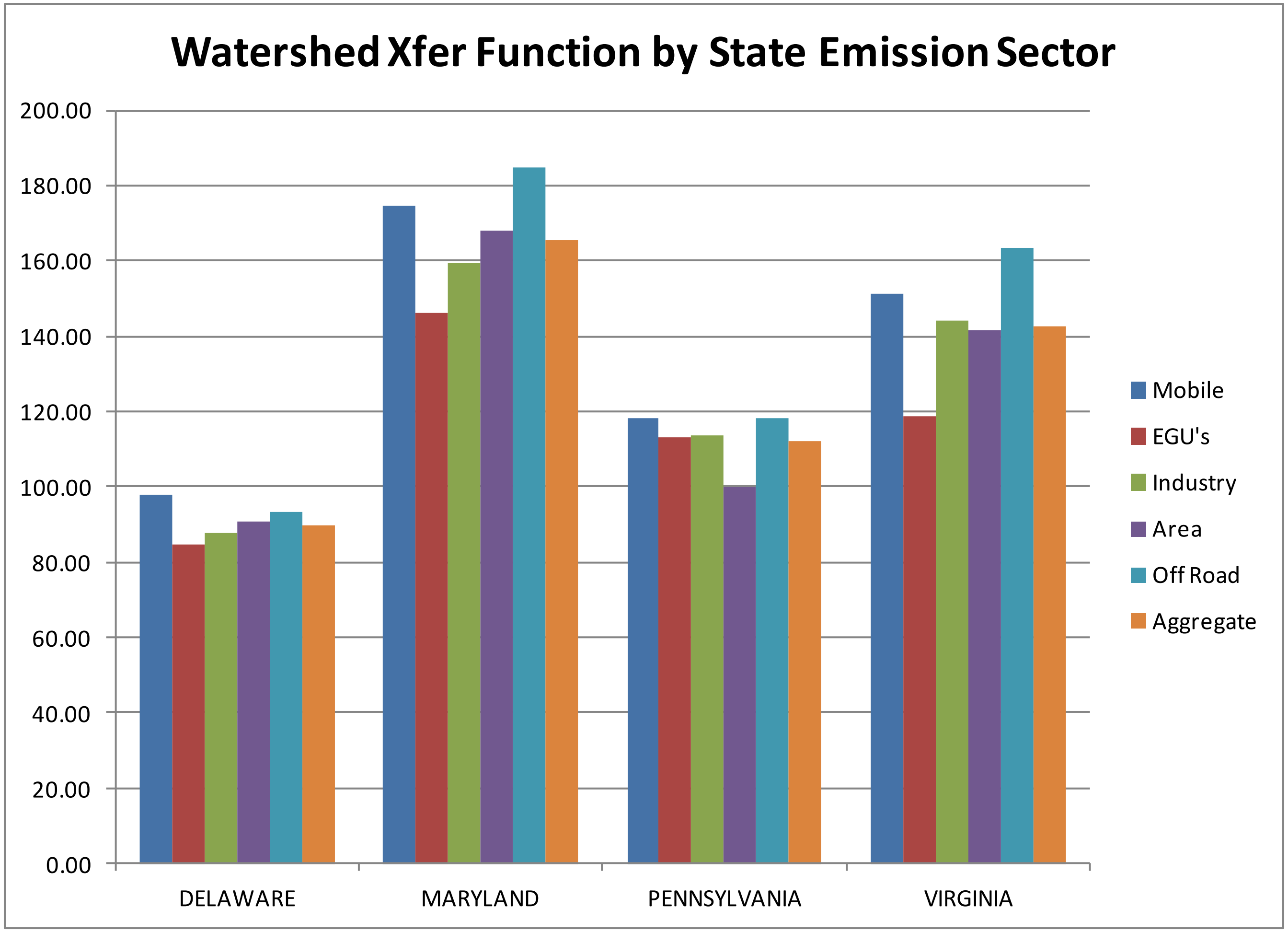
OXIDIZED NITROGEN AIRSHED FOR: CHESAPEAKE BAY



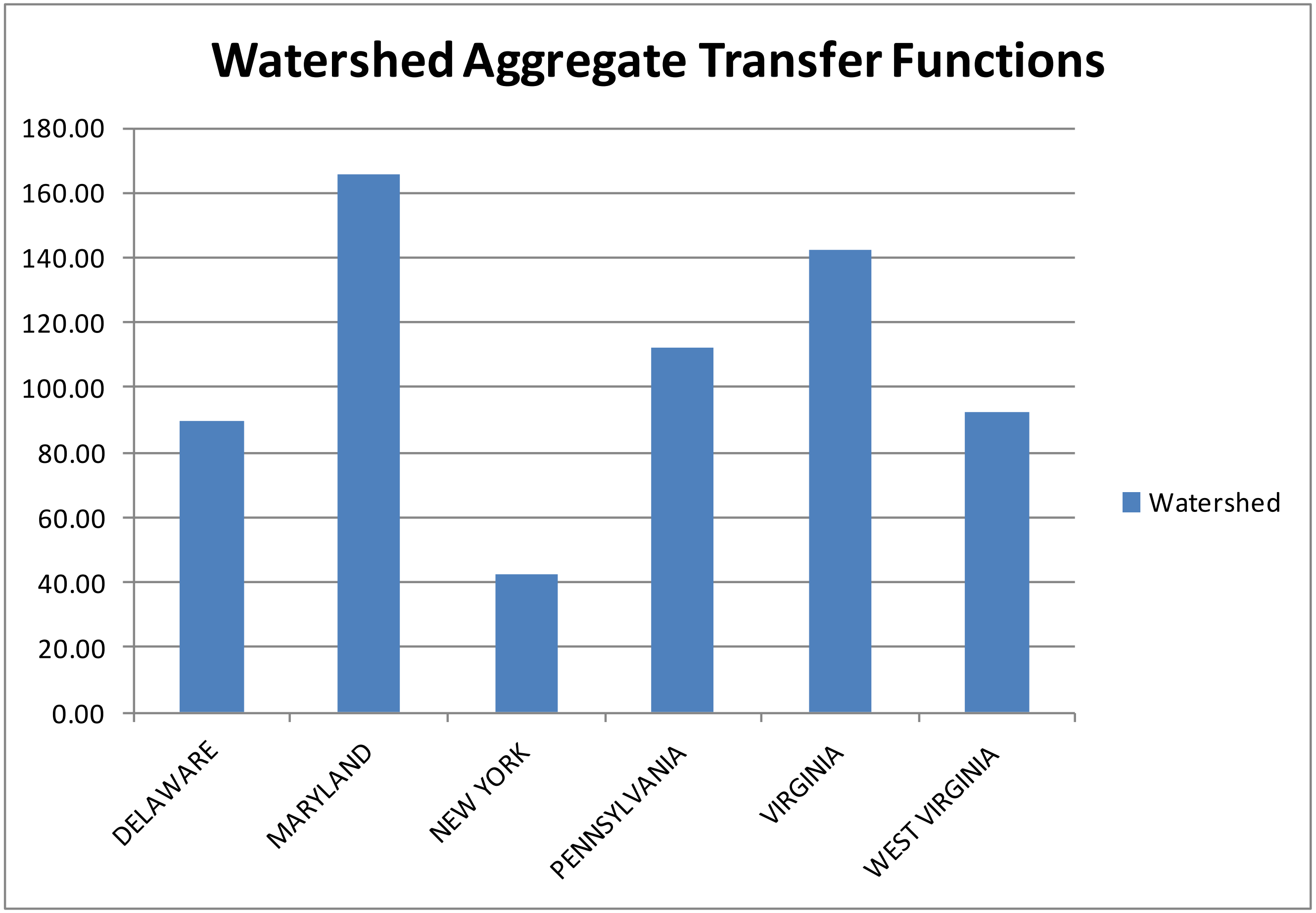
New Direction

- We clearly need to look at more than one sector at a time to achieve sufficient loading reductions
- We most likely need to look at more than one state
- It makes sense to work at the watershed level rather than the tributary level and also work at the tidal bay level
- We would like to see how much each state is contributing to the deposition to the watershed area in other states as well as to itself and to the tidal bay
- So it makes sense to orient the analysis towards emitting states and the watershed area of receiving states

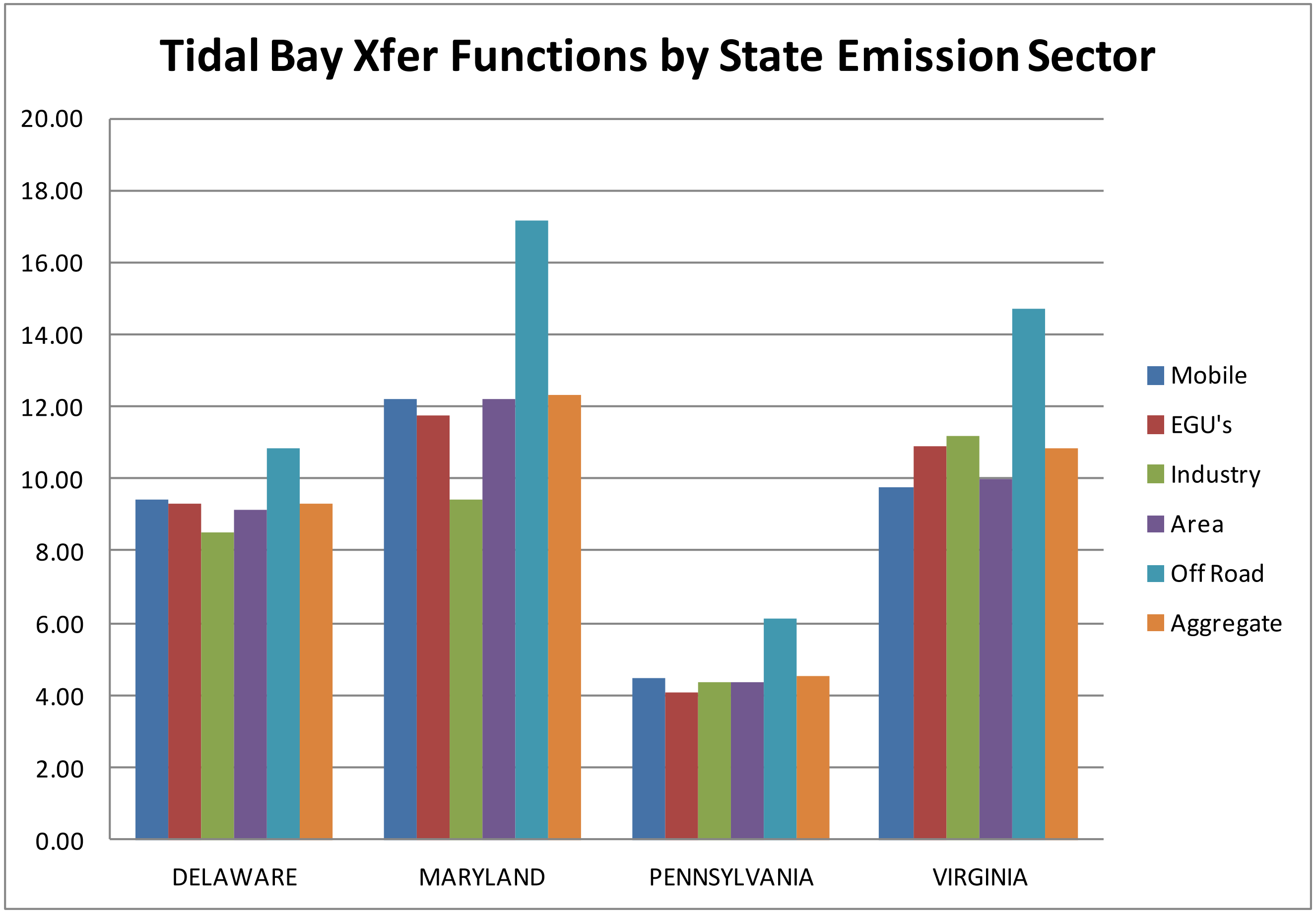
Transfer Functions at the Watershed Level by Sector are Similar



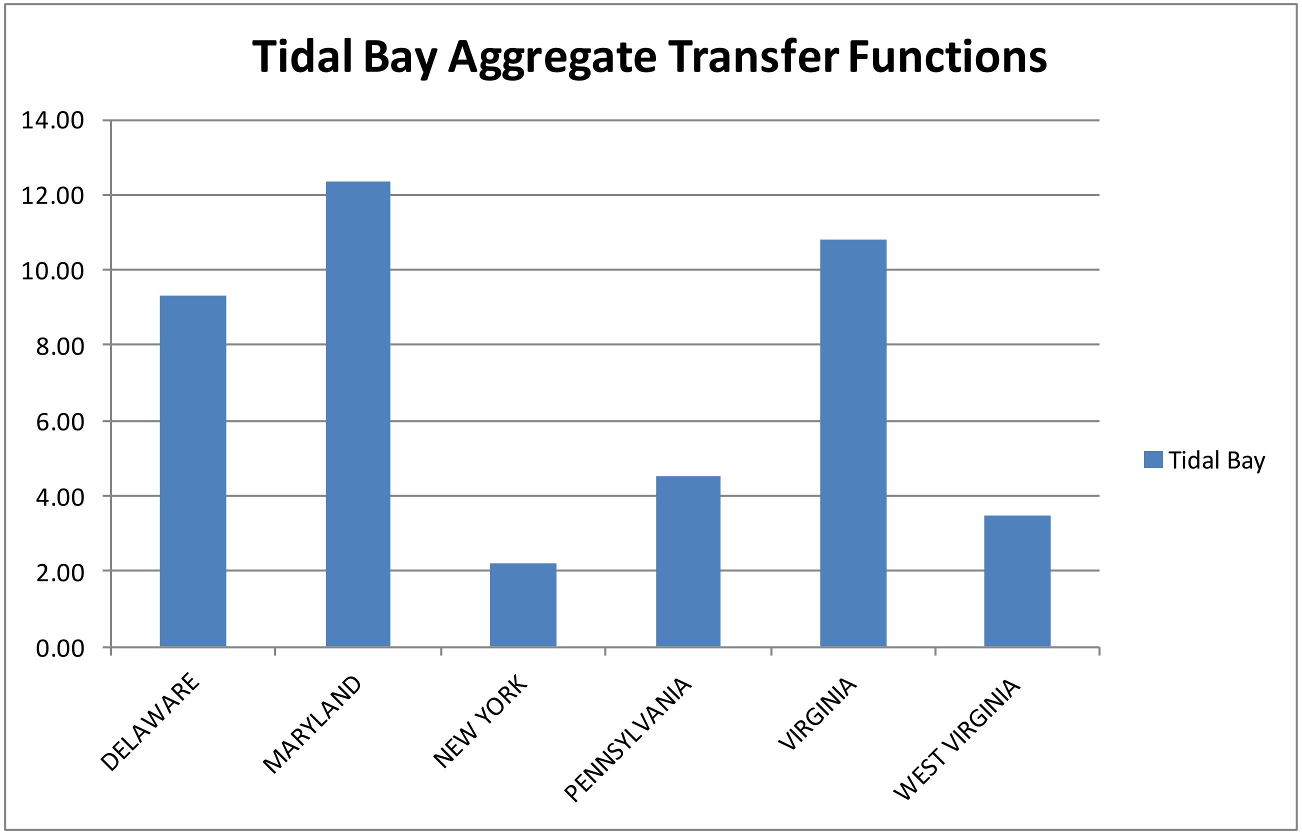
Transfer Functions at the Watershed Level by State Show Differences



Transfer Functions for the Tidal Bay by Sector are Similar



Transfer Functions for the Tidal Bay by State Show Differences



The Aggregate State Transfer Functions at the Watershed Level can be Parsed to the Watershed Area within each State

United States Environmental Protection Agency

State Level Transfer Coefficients to State Watershed Area						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N
Delaware	5.40	2.31	0.44	0.87	1.10	0.44
Maryland	19.46	57.16	5.30	14.33	20.95	10.60
New York	5.31	7.25	11.50	10.47	4.76	4.73
Pennsylvania	23.86	49.09	16.37	62.28	24.79	28.11
Virginia	19.55	43.34	7.84	20.59	85.05	27.70
W. Virginia	1.88	6.04	1.03	3.73	5.50	9.88
WaterSHED Aggregate	75.46	165.19	42.49	112.27	142.15	81.47

An Example of State NO_X Emission Changes Summed Across All Sectors For All of the Bay States

State Level NO_X Emission Changes						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Sector ↓	tons-NOx	tons-NOx	tons-NOx	tons-NOx	tons-NOx	tons-NOx
Area	-1,215	-10,939	-27,856	-3,126	-29,606	17,204
Off Road	-393	-1,796	-7,340	-5,860	6,307	-4,269
Mobile	1,727	2,877	14,302	30,005	-4,073	1,454
EGU's	-5,175	-7,228	-19,499	-13,471	-17,783	-10,979
Industry	-1,602	3,498	-5,045	-19,499	-13,541	-25,508
TOTAL	-6,659	-13,588	-45,438	-11,950	-58,696	-22,098

Example estimates from Mary Jane Rutkowski

Converting the NO_X Emission Changes to tons-N Reduced

State Level Tons-N Emissions Reduced						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Sector ↓	tons-N	tons-N	tons-N	tons-N	tons-N	tons-N
Area	370.0	3,330.5	8,481.1	951.7	9,013.8	-5,238.1
Off Road	119.8	546.9	2,234.7	1,784.2	-1,920.2	1,299.8
Mobile	-525.7	-875.8	-4,354.5	-9,135.3	1,239.9	-442.7
EGU's	1,575.6	2,200.5	5,936.7	4,101.2	5,414.3	3,342.7
Industry	487.8	-1,065.1	1,535.9	5,936.6	4,122.7	7,766.2
TOTAL	2,027.4	4,137.0	13,834.0	3,638.4	17,870.5	6,728.0

Example estimates from Mary Jane Rutkowski

Multiplying by the Transfer Function to Calculate the kg-N Deposition Change

EPA United States Environmental Protection Agency

Change in Deposition to Watershed Area due to Change in State Emissions						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep
Delaware	10,954.8	9,558.1	6,151.2	3,168.1	19,585.5	2,958.6
Maryland	39,448.9	236,461.2	73,355.2	52,154.9	374,431.1	71,301.5
New York	10,758.6	30,002.0	159,071.5	38,107.4	85,011.4	31,854.3
Pennsylvania	48,376.8	203,076.9	226,518.9	226,603.5	442,931.1	189,151.6
Virginia	39,634.0	179,294.9	108,407.1	74,910.2	1,519,893.5	186,370.6
W. Virginia	3,810.8	24,973.5	14,262.6	13,557.5	98,375.9	66,490.3
WaterSHED Deposition	152,984.0	683,366.6	587,766.5	408,501.5	2,540,228.5	548,126.9

State Basin Attenuation Factors to Calculate the kg-N Delivered Load Change

Fraction of Watershed Deposition that Reaches the Bay to Result in Load Delivered to the Bay						
Receptor Basin →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
	fraction	fraction	fraction	fraction	fraction	fraction
State-Basin Attenuation	0.0740	0.0819	0.0503	0.0966	0.0492	0.0361

New Watershed Average = 0.0712
Old Watershed Average = 0.1107

Multiplying by the Attenuation Factor (0.1107) to Calculate the kg-N Delivered Load Change

United States Environmental Protection Agency

Change in Load Delivered to Bay due to Change in Watershed Deposition						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N	kg-N	kg-N	kg-N	kg-N	kg-N
Delaware	810.1	706.8	454.9	234.3	1,448.4	218.8
Maryland	3,230.5	19,363.8	6,007.1	4,271.0	30,662.2	5,838.9
New York	541.2	1,509.2	8,001.9	1,916.9	4,276.4	1,602.4
Pennsylvania	4,672.4	19,613.7	21,877.8	21,886.0	42,779.5	18,268.8
Virginia	1,949.2	8,817.5	5,331.3	3,684.0	74,746.8	9,165.5
W. Virginia	137.5	901.0	514.6	489.1	3,549.3	2,398.9
Total Load Change (kg-N)	11,340.8	50,912.2	42,187.6	32,481.3	157,462.7	37,493.3

Converting the kg-N to lbs-N Delivered Load Change

Change in Load Delivered to Bay due to Change in Watershed Deposition						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	lb-N	lb-N	lb-N	lb-N	lb-N	lb-N
Delaware	1,782.2	1,555.0	1,000.7	515.4	3,186.4	481.3
Maryland	7,107.0	42,600.5	13,215.6	9,396.1	67,456.9	12,845.6
New York	1,190.6	3,320.3	17,604.2	4,217.3	9,408.1	3,525.3
Pennsylvania	10,279.2	43,150.2	48,131.2	48,149.2	94,114.9	40,191.3
Virginia	4,288.2	19,398.6	11,729.0	8,104.8	164,443.0	20,164.1
W. Virginia	302.5	1,982.3	1,132.1	1,076.1	7,808.5	5,277.6
Total Load Change (lb-N)	24,949.8	112,006.8	92,812.8	71,459.0	346,417.8	82,485.3

Total Load Reduction to Bay = 730,132 lbs

The Aggregate State Transfer Functions to the Tidal Bay for each State can be Defined

United States Environmental Protection Agency

State Level Transfer Coefficients to Tidal Bay Area						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N	kg-N/ton-N
Tidal Bay Aggregate	9.34	12.34	2.21	4.51	10.83	3.48

Converting the State NO_X Emission Changes to tons-N Reduced (same as before)

State Level Tons-N Emissions Reduction						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Sector ↓	tons-N	tons-N	tons-N	tons-N	tons-N	tons-N
Area	370.0	3,330.5	8,481.1	951.7	9,013.8	-5,238.1
Off Road	119.8	546.9	2,234.7	1,784.2	-1,920.2	1,299.8
Mobile	-525.7	-875.8	-4,354.5	-9,135.3	1,239.9	-442.7
EGU's	1,575.6	2,200.5	5,936.7	4,101.2	5,414.3	3,342.7
Industry	487.8	-1,065.1	1,535.9	5,936.6	4,122.7	7,766.2
TOTAL	2,027.4	4,137.0	13,834.0	3,638.4	17,870.5	6,728.0

Example estimates from Mary Jane Rutkowski

Multiplying by the Transfer Function to Calculate the kg-N Deposition Change (No Attenuation)

Change in Deposition to Tidal Bay Area due to Change in State Emissions						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep	kg-N Dep
Tidal Bay Deposition	18,926.9	51,052.3	30,543.7	16,415.1	193,540.4	23,428.4

The Two Sources of the Change In Loading to the Bay Are Fairly Comparable and Are Added Together

Change in Total Loading to the Tidal Bay due to the Change in State Emissions						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	kg-N	kg-N	kg-N	kg-N	kg-N	kg-N
Watershed Loading	11,340.8	50,912.2	42,187.6	32,481.3	157,462.7	37,493.3
Tidal Bay Deposition	18,926.9	51,052.3	30,543.7	16,415.1	193,540.4	23,428.4
Total Loading to the Bay	30,267.7	101,964.4	72,731.4	48,896.5	351,003.0	60,921.7

TOATLS: The Two Sources of the Change In Loading to the Bay Are Converted to Pounds and Added Together

Change in Total Loading to the Tidal Bay due to the Change in State Emissions						
Emitter →	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia
Receptor ↓	lb-N	lb-N	lb-N	lb-N	lb-N	lb-N
Watershed Loading	24,949.8	112,006.8	92,812.8	71,459.0	346,417.8	82,485.3
Tidal Bay Deposition	41,639.2	112,315.0	67,196.2	36,113.3	425,788.8	51,542.5
Total Loading to the Bay	66,588.9	224,321.8	160,009.0	107,572.2	772,206.6	134,027.8

Total Load Reduction to Bay = 1,464,726 lbs
Roughly 50:50

Summary

- Now seeing a potential for significant load reductions
  - Makes sense to work at the watershed level
  - Makes sense to use total state-level NO_X emission reductions
  - Makes sense to combine NO_X emission reductions across states
    - See if the states can combine or share efforts on this
- Working at the state level may be a viable approach when combined with state watershed area attenuation factors
- Including the reduction in direct load to the Bay is beneficial
- Presented this to Air Directors Meeting in March 2013 and got concurrence on using the aggregate approach to account for all states and all sectors

Summary (cont.)

- Through the Air Director's, the Modeling Workgroup, and the Water Quality Goal Implementation Team will develop an air-water exchange procedure to account for nitrogen emission reductions above and beyond what's already accounted for
- Only implemented emission reduction programs will be counted in the air-water exchanges; double-counting avoided
- Increases in air emission as well as decreases will be taken into account
- At the 2017 Midpoint Assessment, the new bi-directional CMAQ and updated scenarios that include the latest State SIPS and national program changes would replace previous air-water exchanges

United States Environmental Protection Agency

Thanks

Questions?