100 Years of Atmospheric Deposition in the Chesapeake Bay Watershed

Water Quality Goal Implementation Team

March 22, 2021

Lew Linker[1], Doug Burns[2], Jesse Bash[3], Sarah Benish[4], Gary Shenk[2] and Gopal Bhatt[5]

1 EPA-CBPO, 2 USGS, 3 EPA NERL, 4 EPA ORISE, 5 Penn State

Chesapeake Bay Program

Science, Restoration, Partnership

Overview:

- 100 Years of Atmospheric Deposition in the Chesapeake Bay Watershed

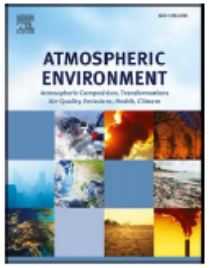
- Options in the Selection of Modeled Emission Sources in an Updated "Emission Source to Deposition" Tracer Analysis

- Undated Estimates of Atmospheric Deposition Delivered to the Bay

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: http://www.elsevier.com/locate/atmosenv



Atmospheric Environment 251 (2021) 118277
Available online 23 February 2021

Atmospheric nitrogen deposition in the Chesapeake Bay watershed: A history of change

Douglas A. Burns[a], Gopal Bhatt[b], Lewis C. Linker[c], Jesse O. Bash[d], Paul D. Capel[e], Gary W. Shenk[f]

a *U.S. Geological Survey, Troy, NY, USA*
b *Pennsylvania State University, Annapolis, MD, USA*
c *U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis, MD, USA*
d *National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA*
e *Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, Minneapolis, MN, USA*
f *U.S. Geological Survey, Annapolis, MD, USA*

A Short History of the Assessment of Atmospheric Deposition of Nitrogen in the Chesapeake Bay Program

1985 – “There is no atmospheric deposition of nitrogen.”

1995 – “Ok, there is some atmospheric deposition of nitrogen……but its uncontrollable.”

2005 – “Wow! The CAA national program is sure removing a lot of nitrogen from the Chesapeake watershed.” (and other coastal watersheds too).

2015 – The atmospheric deposition of nitrogen to tidal water is an important component of the TMDL allocations. “We couldn’t have done the restoration without the air reductions.”

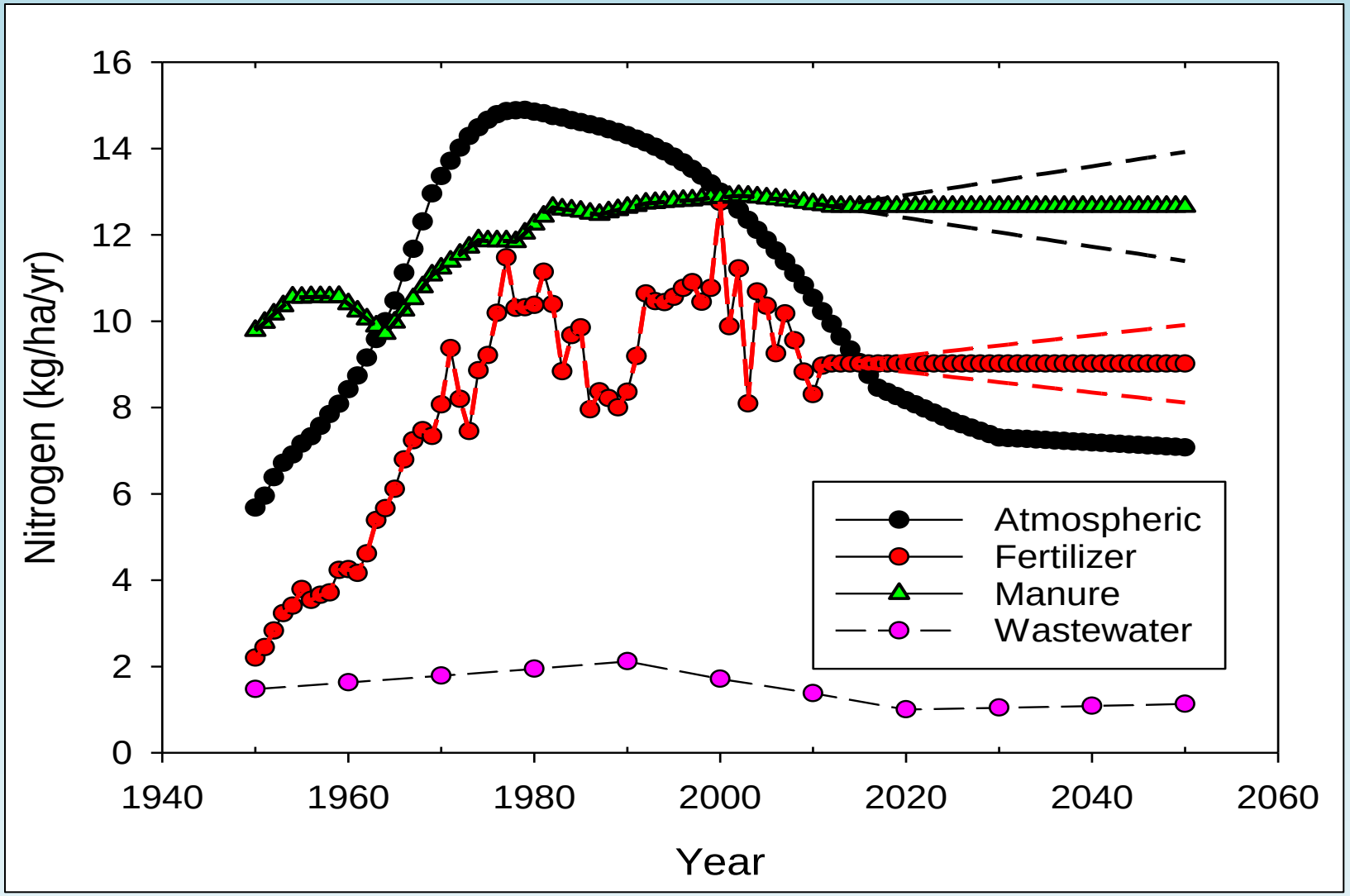
Century-Long 1950 to 2050 Data Set

- Motivation for USGS-led effort was to provide a long duration data set that could be used for model calibration, historical reconstructions, and making future projections
- Based on data and approaches implemented by the Chesapeake Bay Program – data are used in modeling and to serve stakeholder needs, meeting goals of the TMDL, 1984 to 2015
- Group of experts extended the data set back to 1950 and forward to 2050 using statistical relations, land use projections, projections based on clean air rules
- Data set is in review as two Science Base data releases – spatially-gridded N loads for (1) atmospheric deposition, (2) fertilizer, manure, and wastewater

Source: Burns et al. presentation to NADP Annual Meeting October 2020

USGS science for a changing world

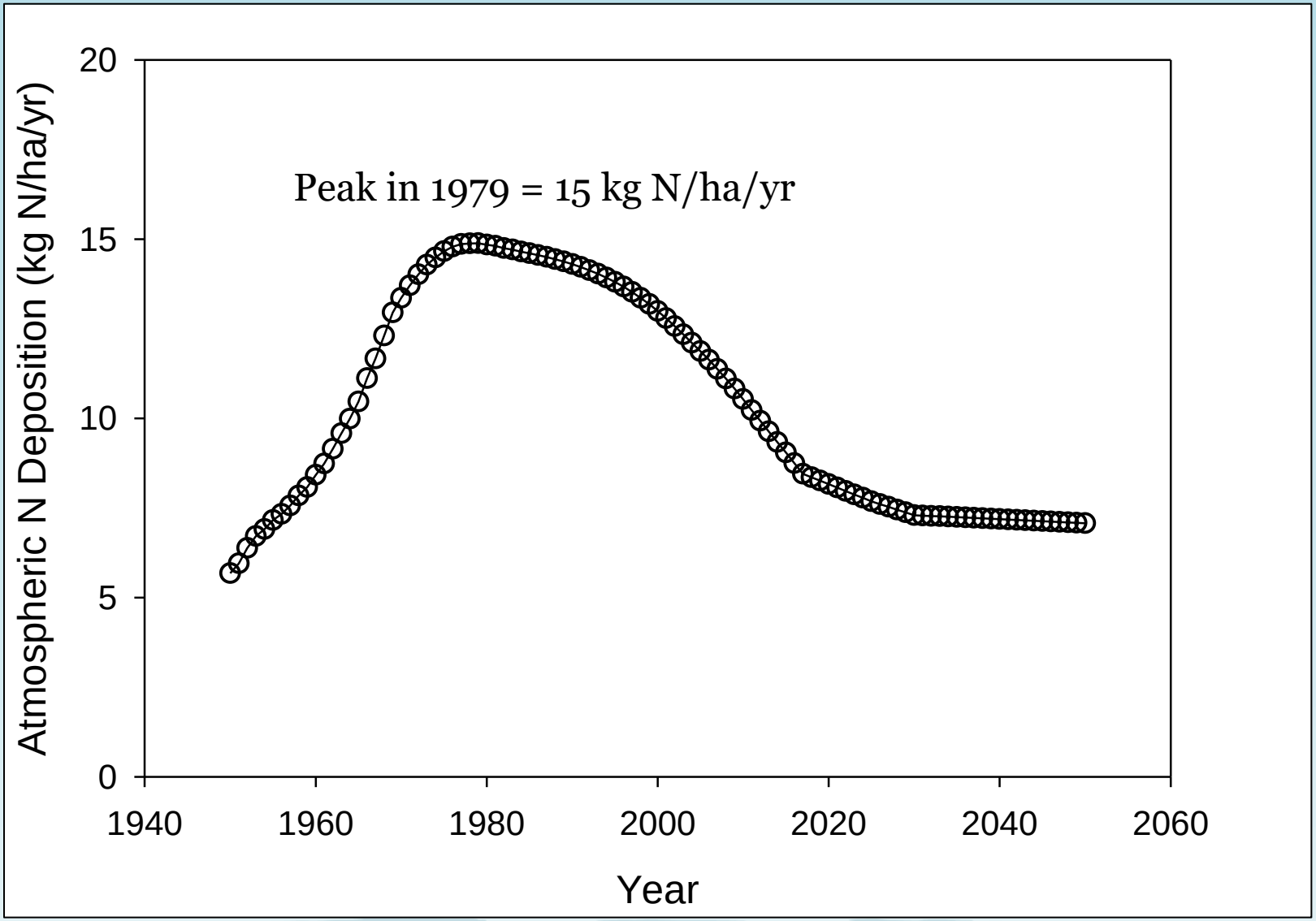
Multiple Nitrogen Sources – 1950 to 2050



Source: Burns et al. presentation to NADP Annual Meeting October 2020

USGS science for a changing world

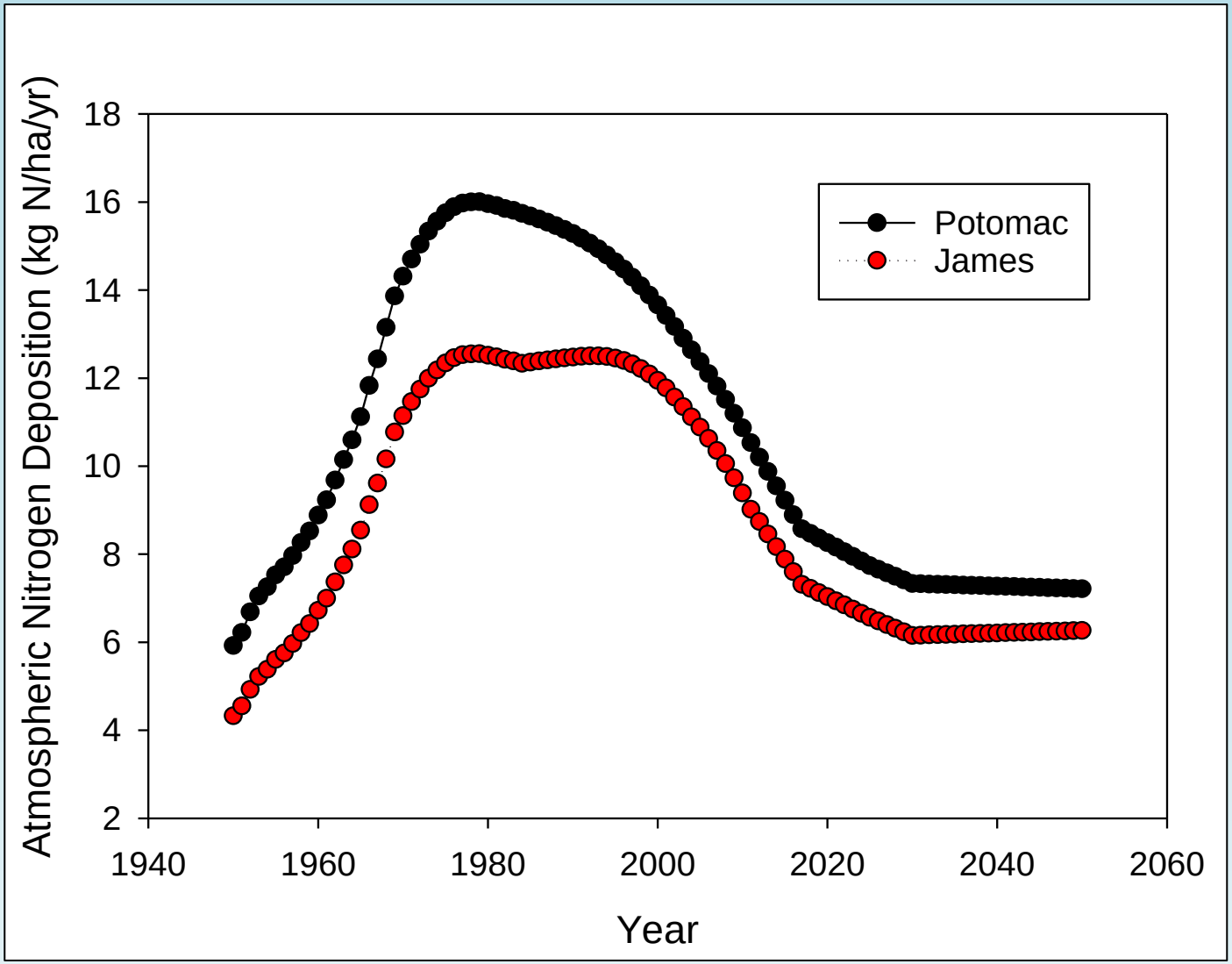
Atmospheric N Deposition 1950 to 2050



Source: Burns et al. presentation to NADP Annual Meeting October 2020

USGS science for a changing world

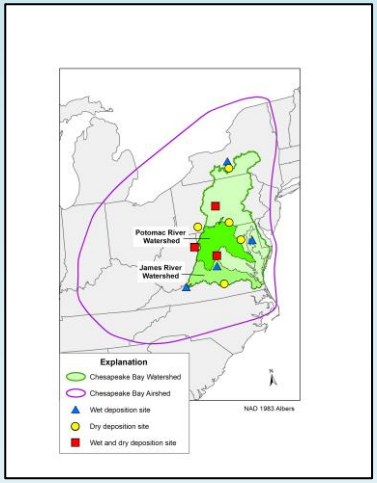
Spatial Variation in Atmospheric N Deposition



NADP and CASTNET sites largely in rural areas, capture regional patterns

Model reflects diverse sources and more N species

Potomac 2X more ag and urban land cover than James

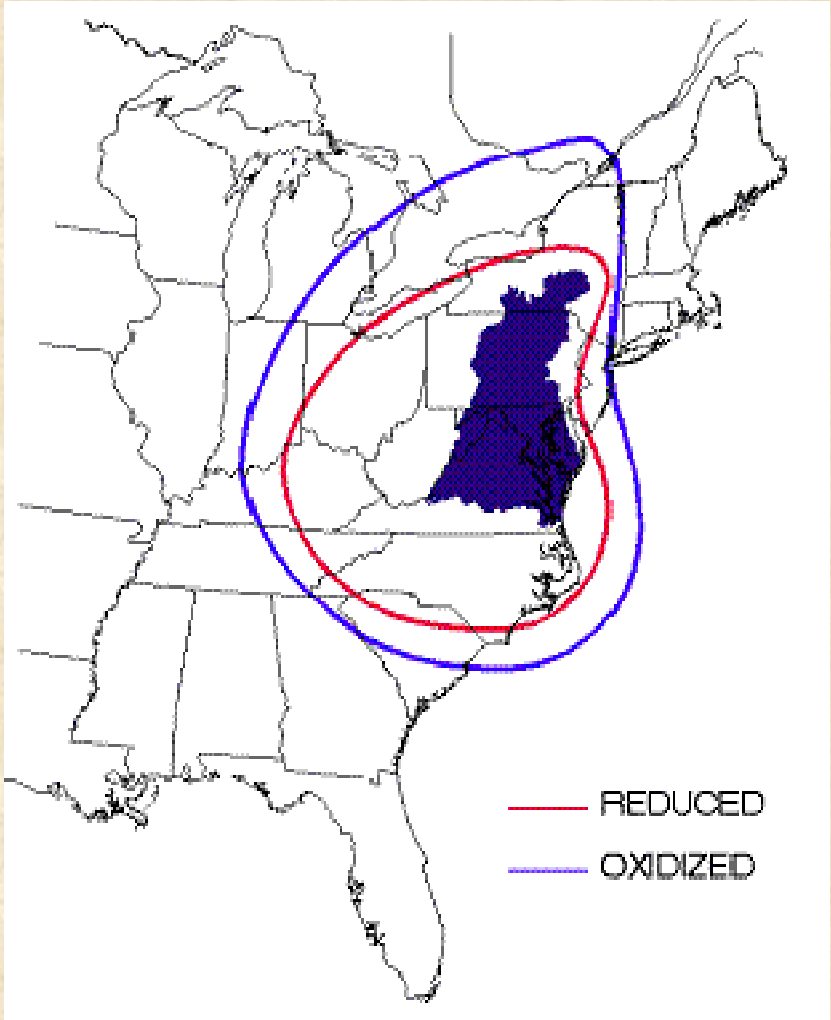


Source: Burns et al. presentation to NADP Annual Meeting October 2020

USGS science for a changing world

Chesapeake Bay Airshed

The Bay's NOx airshed—the area where emission sources that contribute the most airborne nitrates to the Bay originate—is about 570,000 square miles, or nine times the size of the Bay's watershed. About 50 percent of the nitrate deposition to the Bay is from air emission sources in Bay watershed jurisdictions. Another 25 percent of the atmospheric deposition load to the Chesapeake watershed is from the remaining area in the airshed. The remaining 25 percent of deposition is from the area outside the Bay airshed. The ammonia airshed is similar to the NOx airshed, but slightly smaller.



Geographic Source Regions: Source-Receptor Tracer

Source Apportionment of Nitrogen in the Chesapeake Bay Using the CMAQ-ISAM Model

Recent advances in the CMAQ Airshed Model have allowed updated and improved estimates of the transport and fate of atmospheric emissions of oxidized nitrogen (NOx) and ammonium (NH_4^+). The analysis centers on the question, "For a nitrogen emission source from different regions in the Chesapeake watershed, what is the fraction that is deposited to regions, States, or to a point?"

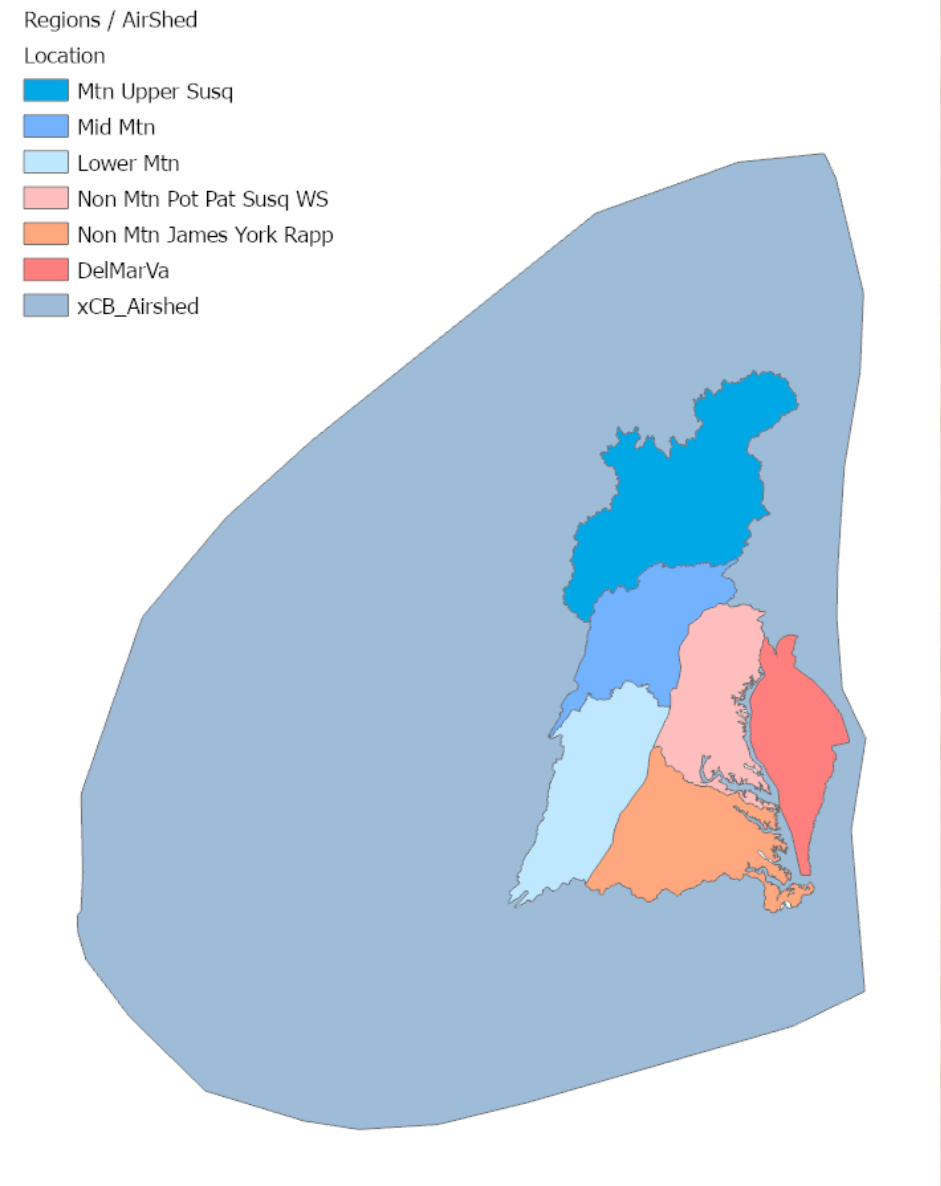
Table 1, Example of an area and source sector matrix for emissions using CMAQ's Integrated Source Apportionment Model option. Note, that each area x sector sources would be tracked for each emission species, e.g. NO_x, NH_3, etc.

	Manure Poultry (MP)	*Manure Other (MO)*	*Fertilizer (F)*	*Mobile on road (MR)*	*Mobile off road (OR)*	*EGU*	*Other Points Sources (OP)*
DE	DE_MP	DE_MO	DE_F	DE_MR	DE_OR	DE_EGU	DE_OP
MD	MD_MP	MD_MO	MD_F	MD_MR	MD_OR	MD_EGU	MD_OP
NY	NY_MP	NY_MO	NY_F	NY_MR	NY_OR	NY_EGU	NY_OP
PA	PA_MP	PA_MO	PA_F	PA_MR	PA_OR	PA_EGU	PA_OP
VA	VA_MP	VA_MO	VA_F	VA_MR	VA_OR	VA_EGU	VA_OP
WV	WV_MP	WV_MO	WV_F	WV_MR	WV_OR	WV_EGU	WV_OP

Geographic Source Regions: Source-Receptor Tracer

Oxidized (NOx) and reduced (NH4) nitrogen from eight emission sources will be traced. They are: 1) electric generating units (EGUs), 2) mobile sources, 3) off-road sources, 4) poultry manures, 5) other animal manures, 6) ammonia from fertilizer, 7) marine sources and 8) all other sources.

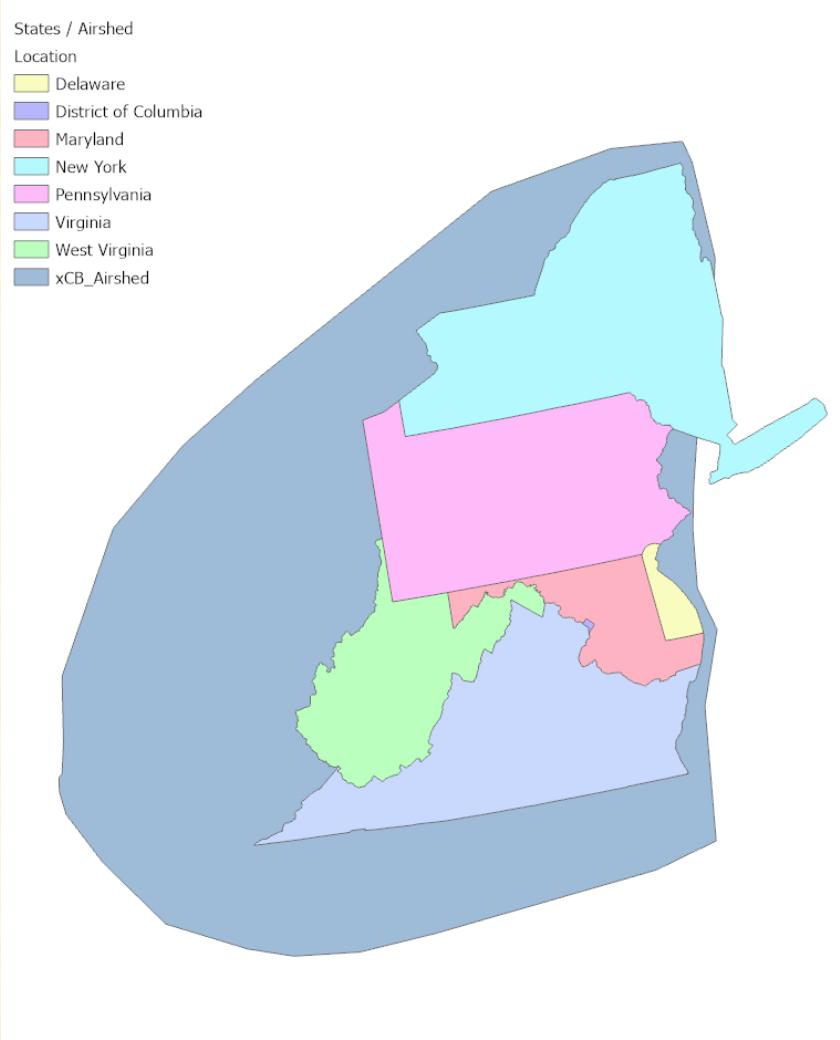
The regions generating the sources are shown here. Each region will include from emissions each of the eight tagged sectors, e.g., state or region contribution of NOx and ammonia from EGUs, etc. Using geographic source regions allows a better assessment of deposition changes from each source area receiving management actions and is the recommended approach.



State Source Regions: Source-Receptor Tracer

An alternative approach that can be applied is the source regions of the six CBP States. This approach allows for an assessment of the deposition from each state and sector to each receiving area of a region, State, or point. For example, if a CBP State were to put controls on an emission source throughout the State, such as EGUs then this could be the preferred emission source approach. Either a regional or a State source approach can be applied but not both because of resource limitations.

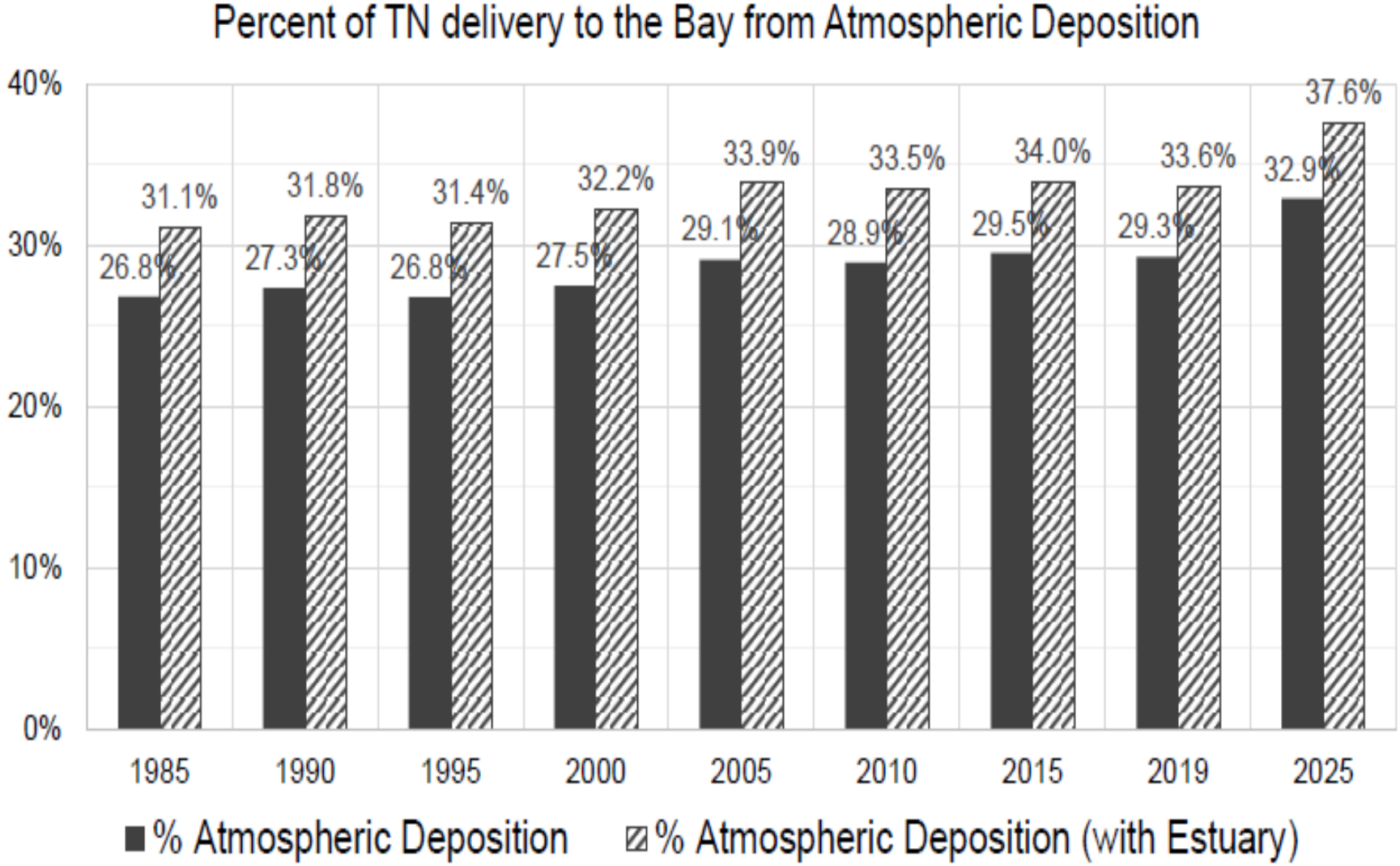
Deposition will be a time series of model output of deposition on a CMAQ grid scale of 12 km by 12 km. Post-processing will allow the output to be provided by 1) CBP States and DC, and/or 2) major CBP basins, and/or 3) seasons of deposition. The estimated deposition to the whole CBP State, to the portion of the CBP State in the Chesapeake Bay (CB) watershed, and deposition to the Chesapeake airshed outside the CB watershed will be provided.



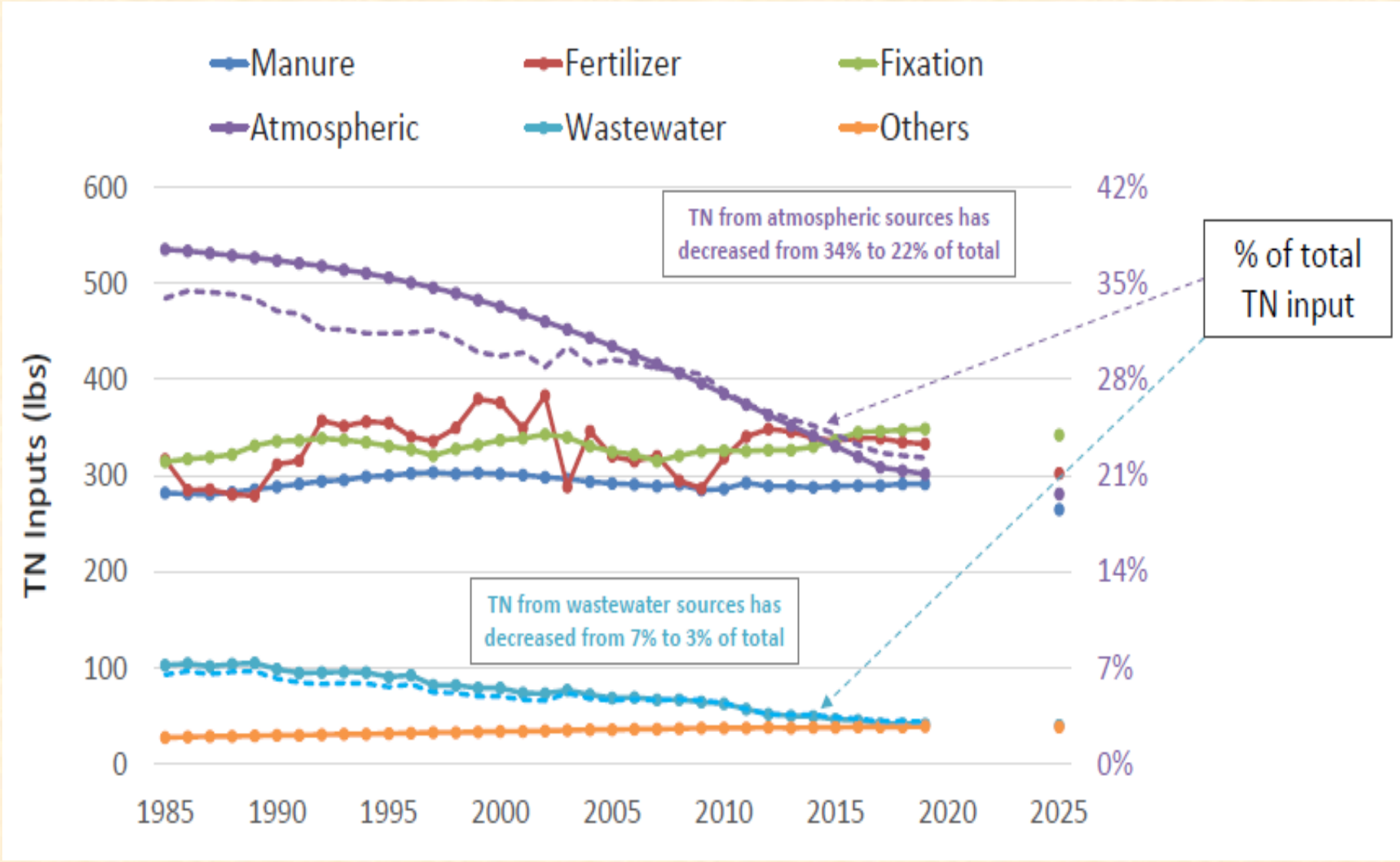
Estimated Fraction of TN Delivery to Tidal Bay From Atmospheric Deposition - Burns et al., 2021

Citation	Year	Estimate (% total N load)	Uncertainty Range (% total N load)	Dry Dep Included?	Org N Included?	Comment
Fisher & Oppenheimer, 1991	1984	34	29 – 39[a]	Yes	No	Equal source retention
Fisher & Oppenheimer, 1991	1984	39	34 – 44[a]	Yes	No	Differential source retention
Hinga et al., 1991	1986	31	12 – 59[b]	Yes	No	
Jaworski et al., 1997	1990-93	61[c]	NA	Yes	Yes	Regression based on 17 sites
Alexander et al., 2001	early 1980s–93	28	22-34	No	No	Steady-state model, dep to Bay excluded
Castro et al., 2001	1979-96[d]	23	NA	Yes	No	Nitrate dep only
Castro & Driscoll, 2002	1997	27	NA	Yes	Yes	
Boyer et al., 2002	1991	25[c]	NA	Yes	Yes	Net atmos dep
Castro et al., 2003	1979-96[d]	30	NA	Yes	Yes	
Ator et al., 2011	2002	17	NA	No	No	Steady-state model, dep to Bay excluded
Birch et al., 2011	2008	24	NA	Yes	No	
Linker et al., 2013	1985–2005	1985=32 2005=27	NA	Yes	Yes[e]	Modeled dep, dep to Bay excluded
Ator et al., 2019	1992, 2012	<10	NA	No	No	Steady-state models, dep to Bay excluded

Estimated Fraction of TN Delivery to Tidal Bay From Atmospheric Deposition



Phase 6 Estimates of TN Input to the Chesapeake Bay Watershed



Conclusions:

- Cleaner air means cleaner water everywhere. The Clean Air Act has helped Americans breathe easier and live healthier, reducing illnesses and premature deaths and contributing to a stronger economy and better quality of life. At the same time, the Act has helped protect our waters by reducing NOx emissions. Atmospheric Deposition contributes about one third of the total nitrogen loads delivered to the tidal waters of the Bay.
- Load reductions tracked in the Chesapeake Bay watershed take into account the national nitrogen emission reductions and subsequent Chesapeake watershed deposition reductions that are due to national programs.
- Trends in NOx and ammonia - Loads of oxidized nitrogen (NOx) are decreasing and will continue to decrease until 2020 and beyond. Loads of reduced nitrogen or ammonia are steady or increasing slightly.