A Hedonic Analysis of Water Quality and the Chesapeake Bay TMDL

Patrick Walsh
Charles Griffiths
Dennis Guignet
Heather Klemick
US EPA
National Center for Environmental Economics
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Disclaimer: The views presented here do not necessarily represent the views of the EPA.

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Chesapeake Bay

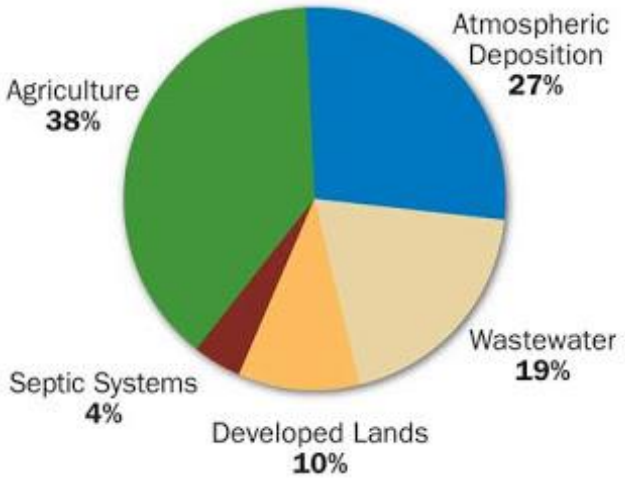
- Largest estuary in the US
- Drainage basin covers 6 states: NY, PA, DE, MD, VA, WV, as well as DC
- Watershed home to more than 17 million people
  - Lots of homes.

Chesapeake Bay Pollution

- History of pollution problems
- Large nutrient inputs and other pollution → algal blooms, toxic algae, poor water quality, other environmental disamenities.
  - Degraded ecosystems
  - Dead zones, decreased fish, oyster, crab, etc. harvest.
  - Estimated 200,000 acres of oyster reefs in Colonial times – Today only 36,000.

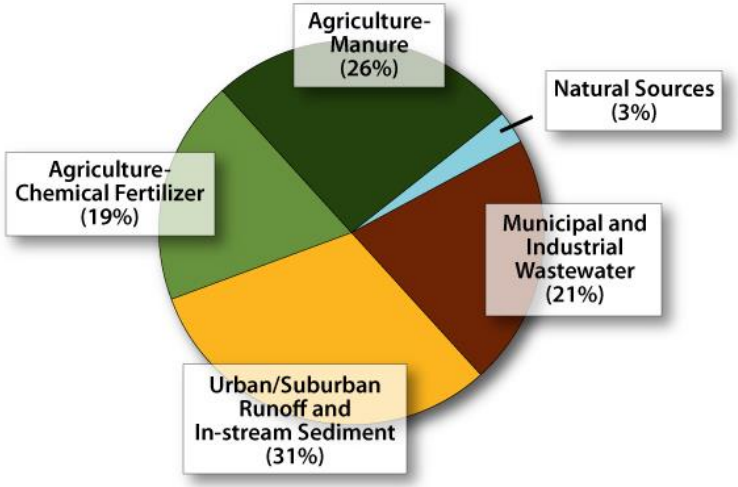
- Approximately 100,000 new residents in the watershed each year.

Sources of Nitrogen Pollution



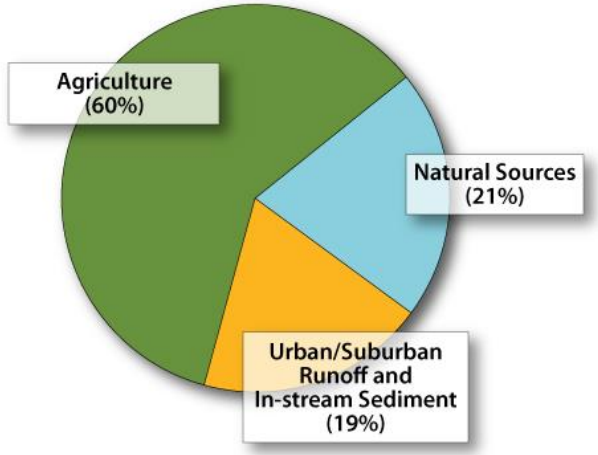
Source: Chesapeake Bay Program Phase 4.3 Watershed Model, 05/11.
Values do not add up to 100% due to rounding.

Sources of Phosphorus to the Bay



Note: Does not include loads from the ocean, tidal shoreline erosion, or direct atmospheric deposition to tidal waters. Wastewater loads based on measured discharges; other loads are based on an average-hydrology year using the Chesapeake Bay Program Watershed Model Phase 4.3 (Chesapeake Bay Program Office, 2009).

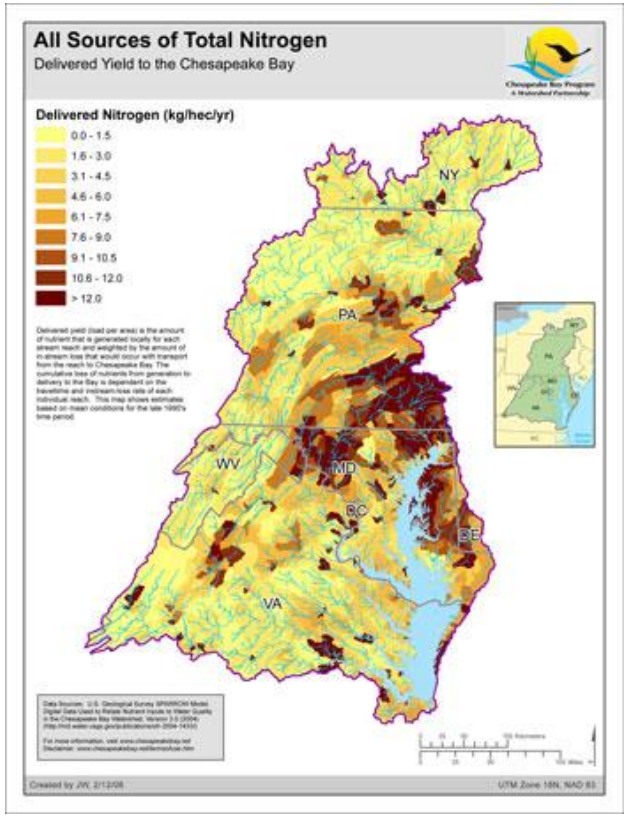
Sources of Sediment to the Bay



Note: Does not include loads from the ocean or tidal shoreline erosion. Loads are based on an average-hydrology year using the Chesapeake Bay Program Watershed Model Phase 4.3 (Chesapeake Bay Program Office, 2009).

Chesapeake Bay TMDL

- Extensive restoration efforts over last 25 years
  - Executive Orders, range of state and local efforts
    - Insufficient progress
    - Continued poor water quality
  - Externality
    - PA, NY Farming inputs.
- Dec 29, 2010: Chesapeake Bay Total Maximum Daily Load (TMDL) – historic and comprehensive "pollution diet".
  - Nitrogen (25%), phosphorus (24%) sediment (20%) reductions.
- "Novelty": comprehensive involvement of all state actors in the watershed
  - Externality
  - Using extensive modeling tools and planning coordinated by EPA



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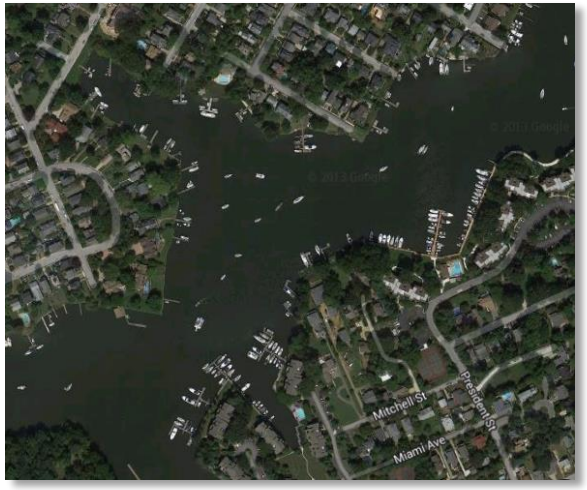
Chesapeake Bay TMDL Valuation

- In 2011, EPA committed to assess the benefits and costs of the TMDL.
- NCEE, and Chesapeake Bay Program Office (CBPO).
  - SP Survey (3 years!!!)
  - Commercial and recreational fishing
  - Air Quality Impacts
  - Property price benefits
  - Dredging and several other categories
  - Costs

Property Prices



- Hedonic analysis of water quality in 14 MD counties
- Recreational and aesthetic improvements from the TMDL may be reflected in nearby property prices.

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Hedonic Water Quality Literature

- Majority from the **northeastern US**, in **Lakes**
  - Three recent studies in Florida, one on a Bay/Lagoon (Bin and Czajkowski).
- **Chesapeake Bay** – Leggett and Bockstael (2000), Poor et al. (2007)
- Multiple **water quality indicators** have been used
  - Oil content, turbidity (Feenberg and Mills, 1980) Fecal Coliform (Leggett and Bockstael, 2000), survey responses (Michael et al., 2000), Inorganic Nitrogen (Poor et al., 2007), TN, TP, CH (Walsh et al., 2011) "Location grade" (Bin and Czajkowski, 2013), several others.
- **Water clarity** is the **most prevalent in the literature**
  - Michael et al (1996), Boyle et al (1999), Boyle and Taylor (1999), Gibbs et al (2002), Krysel et al (2003), Walsh et al. (2011), Zhang V Tech Dissertation
  - Easily perceived, usually good representation of "quality."
- Majority of studies find a **significant relationship between water quality and home prices.**

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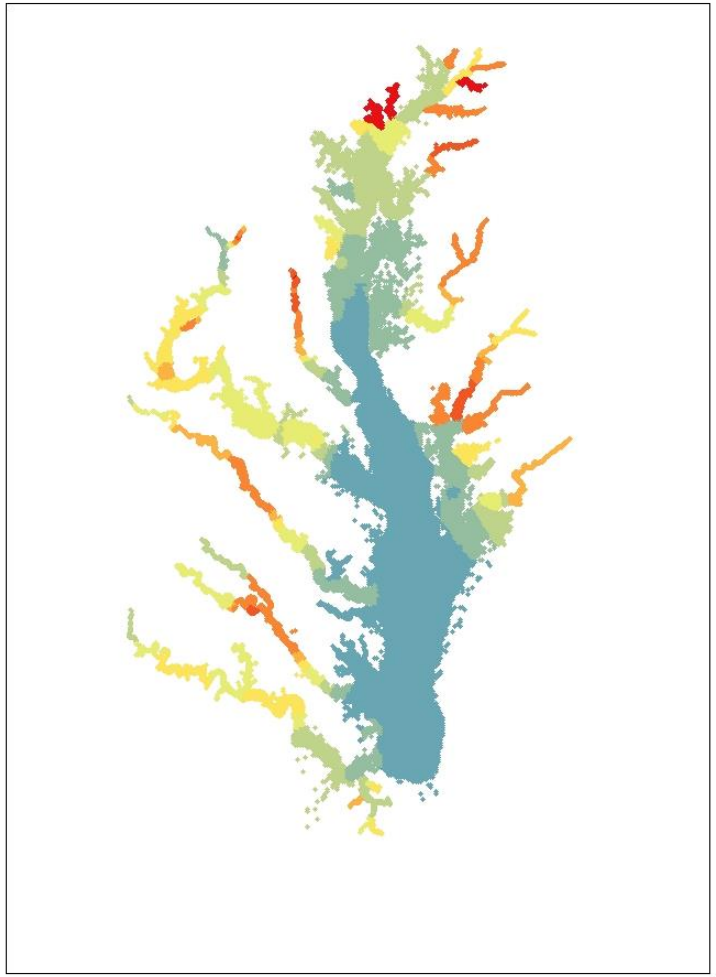
Water Quality Indicator

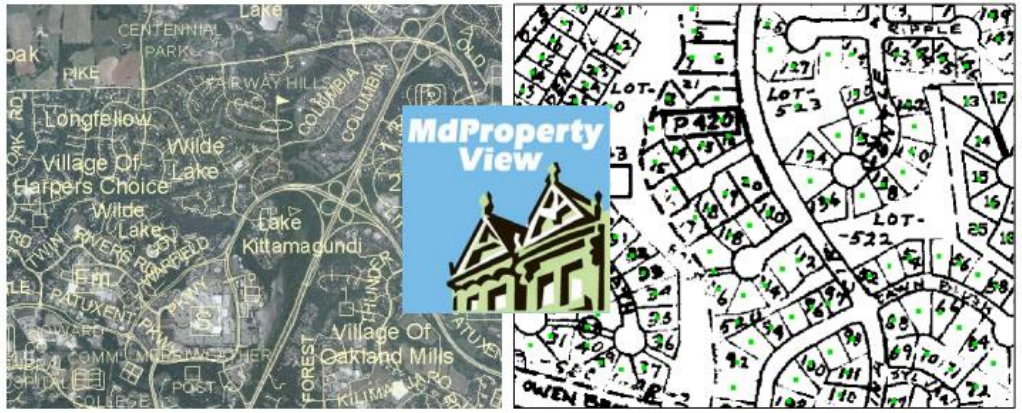
- Select K_D, the light attenuation coefficient
  - Clarity: K_D=1.45/SDM
  - Good historical data
  - CBPO's water quality model: project scenarios
    - TMDL vs baseline

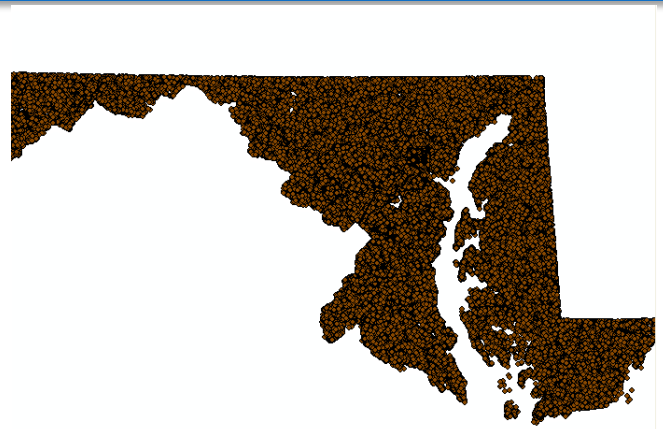
- Chesapeake Bay has water quality criteria for clarity.
  - SP survey

1991-2000



Property Data

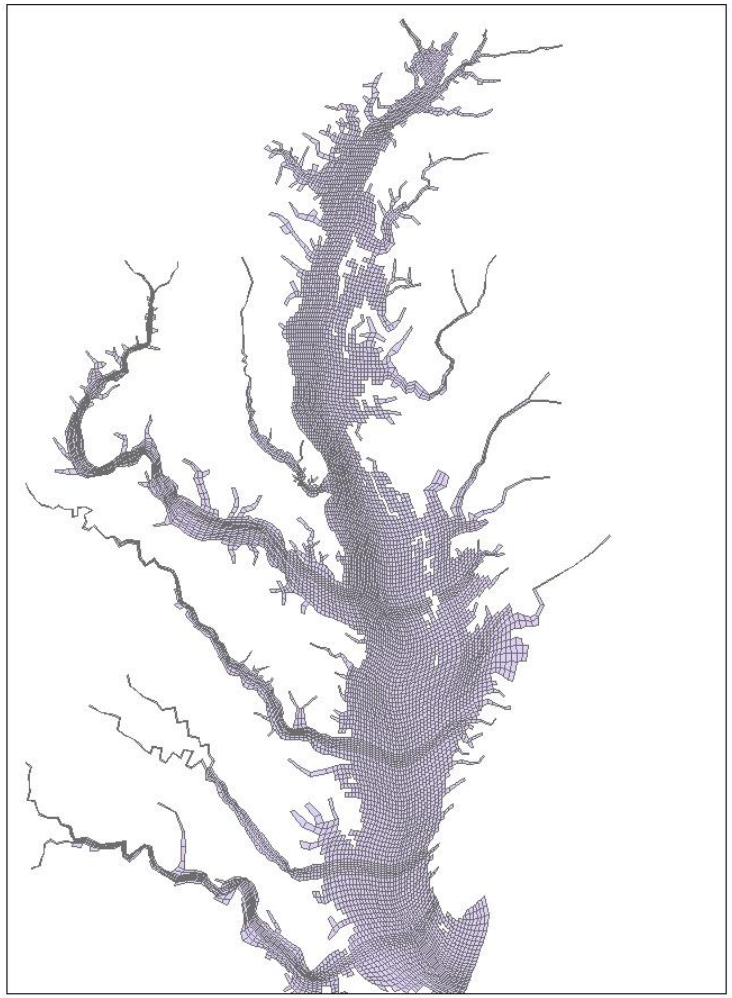




- Full set of parcels/sales from 1996-2008 from MD PropertyView
- GIS Maps
  - Census, waterbodies, zoning, open space

Data

- Water Quality
  - Interpolate historical data from monitoring stations
    - CBPO – WQ -> Interpolator cells
      - Approximately 1 km X 1 km
- GIS, Census data
  - High or medium density area, forest, etc
  - Open space, ag., wetlands
  - Dist to primary road, dist to nearest beach
  - Dist to DC or Baltimore
  - Block Group socioeconomic characteristics
  - In Nuclear Evacuation Zone.
  - Within 2 miles of power plant.
  - Dist to Wastewater Treatment Plant (Leggett and Bockstael, 2000)



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Mean Values Across Counties

County	Obs	Sale Price[1]	Median HH Income	% Waterfront Properties	0 to 500m Buffer	500 to 1000m Buffer
Anne Arundel	76,842	373,198.5	71,050.3	0.104	0.436	0.232
Baltimore	34,781	167,765.5	46,110.7	0.094	0.403	0.231
Calvert	15,563	307,437.9	67,070.4	0.087	0.285	0.217
Cecil	10,816	250,575.5	52,912.1	0.088	0.282	0.213
Charles	5,397	292,141.8	60,277.3	0.077	0.242	0.229
Dorchester	4,358	217,661.8	39,613.3	0.168	0.383	0.266
Harford	17,483	230,198.7	60,394.6	0.035	0.189	0.208
Kent	3,388	307,314.0	42,557.2	0.141	0.431	0.207
Prince George's	24,969	264,662.2	64,917.9	0.006	0.107	0.194
Queen Anne's	8,674	392,945.1	64,719.4	0.166	0.461	0.264
Somerset	1,681	158,193.8	35,516.4	0.187	0.340	0.334
St. Mary's	5,966	278,966.8	62,988.9	0.108	0.241	0.158
Talbot	8,227	507,353.0	54,573.9	0.196	0.344	0.132
Wicomico	11,368	194,521.0	48,127.2	0.024	0.349	0.294

– Sale prices corrected for the seasonally adjusted HPI (Federal Housing Finance Agency).

Water Clarity Across Counties

County	K_D mean (m^{-1})	K_D std dev (m^{-1})	K_D min (m^{-1})	K_D max (m^{-1})	Secchi depth (m)	Number of segments[1]	Number of unique grid cells[2]
Anne Arundel	1.91	0.45	0.65	10.04	0.80	9	587
Baltimore County	3.15	1.42	1.36	8.05	0.55	6	190
Calvert	1.65	1.04	0.64	8.46	1.06	5	198
Cecil	2.98	1.03	1.30	7.41	0.56	7	222
Charles	2.77	0.79	1.50	5.77	0.56	4	179
Dorchester	2.06	0.72	0.66	9.67	0.78	10	211
Harford	3.77	1.32	1.28	7.65	0.46	3	34
Kent	3.67	1.47	1.13	8.86	0.48	6	140
Prince George's	3.15	1.24	1.22	10.86	0.52	5	164
Queen Anne's	1.89	1.21	0.72	8.86	0.95	7	240
Somerset	2.16	1.04	0.86	8.71	0.80	8	175
St. Mary's	1.75	0.73	0.77	5.19	0.94	3	179
Talbot	1.53	0.61	0.62	7.49	1.04	6	198
Wicomico	3.64	0.77	2.22	8.54	0.42	5	194

Notes: Summary statistics calculated for nearest two grid cells to each property in the county sales dataset located within 2000 meters of the Bay. Secchi depth measurement calculated by the formula SDM = $1.45/K_D$ (EPA, 2003).

[1] CBP divides the Bay mainstem and tidal tributaries into 78 distinct segments, each similar in terms of salinity and other natural characteristics, for monitoring and reporting purposes (EPA, 2004).

[2] Grid cells refer to the spatial grid of cells CBP uses to interpolate water quality data to. The cells are a maximum of 1km by 1km in size

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Methods

- Distance buffers

$$\ln(P) = \beta_0 + \beta_{WF} * WF + \beta_{WF_2} \ln(WQ) * WF + \sum \beta_{Di} \ln(WQ_i) * Dist_i +$$
$$\boldsymbol{\beta_{D_2}} * \mathbf{Dist} + \boldsymbol{\beta_H} * \mathbf{H} + \boldsymbol{\beta_L} * \mathbf{L} + \boldsymbol{\beta_T} * \mathbf{T} + \varepsilon$$

  - WF, 0-500, 500-1000,1000-1500, 1500-2000
- Regressions estimated for each county
  - Separate markets

… Other Alternatives

- Several others, some later explored in Meta-analysis.
  - Water quality not logged
  - 3 year water quality average, logged and not logged
  - Depth variable
  - Chlorophyll

Spatial Models

- Spatial dependence
  - Spatially correlated unobserved influences
  - Can cause bias or inconsistency in the estimated coefficients.
- Spatial Weights Matrix
  - Exogenously specify the neighborhood.
    - Nearest neighbor, Inverse Distance
      - Comparable sales
- General Spatial Model:

$$y = \rho W_1 y + X\beta + \varepsilon,\ \varepsilon = \lambda W_2 \varepsilon + u$$

Individual Condominium Unit Appraisal Report File # 11182

There are 6 comparable properties currently offered for sale in the subject neighborhood ranging in price from $ 215,000 to $ 375,000

There are 18 comparable sales in the subject neighborhood within the past twelve months ranging in sale price from $ 195,000 to $ 344,000

SALES COMPARISON APPROACH

FEATURE	SUBJECT	COMPARABLE SALE # 1		COMPARABLE SALE # 2		COMPARABLE SALE # 3	
Address and Unit #	2118 Bucknell Terrace 34	2202 Bucknell Terrace 34		10737 Bucknell Drive 18		10821 Bucknell Drive 29	
Project Name and Phase	Wheaton Towne 2 1	Wheaton Towne 1		Wheaton Square East 1		Wheaton Square East 1	
Proximity to Subject		0.07 miles W		0.19 miles SE		0.15 miles S	
Sale Price	$ 340,000		$ 344,000		$ 315,500		$ 290,000
Sale Price/Gross Liv. Area	$ 219.07 sq. ft.	$ 221.65 sq. ft.		$ 224.08 sq. ft.		$ 205.97 sq. ft.	
Data Source(s)		MLS/Agent LP: $348,900		MLS/Visual LP: $329,900		MLS/Visual LP: $299,500	
Verification Source(s)		Public Records DOM: 14		Public Records DOM: 19		Public Records DOM: 223	
VALUE ADJUSTMENTS	DESCRIPTION	DESCRIPTION	+(-) $ Adjustment	DESCRIPTION	+(-) $ Adjustment	DESCRIPTION	+(-) $ Adjustment
Sales or Financing Concessions		Conv @ Mkt none noted		Conv @ Mkt $5,500 C.C.	0	Conv @ Mkt 8,600 C.C.	0
Date of Sale/Time		C1/11S3/11		C3/10S5/10	0	C6/10S8/10	0
Location	Wheaton Towne	Wheaton Towne	0	Wheaton SQ	0	Wheaton SQ	0
Leasehold/Fee Simple	Fee Simple	Fee Simple		Fee Simple		Fee Simple	
HOA Mo. Assessment	$100	$130		$223		$202	
Common Elements and Rec. Facilities	Common area	Common area		Common area		Common area	
Floor Location	INT TH	INT TH		End TH	-10,000	INT TH	
View	Other TH	Other TH		Other TH		Other TH	
Design (Style)	Townhouse	Townhouse		Townhouse		Townhouse	
Quality of Construction	Brick	Brick		Brick		Brick	
Actual Age	1967 YB	1967 YB		1968 YB		1968 YB	
Condition	Good	Good/new reno	-10,000	Good		Good	
Above Grade Room Count	Total 6 Bdrms. 3 Baths 2.5	Total 6 Bdrms. 3 Baths 2.5		Total 6 Bdrms. 3 Baths 2.5		Total 6 Bdrms. 3 Baths 2.5	
Gross Living Area	1,552 sq. ft.	1,552 sq. ft.	0	1,408 sq. ft.	+10,800	1,408 sq. ft.	+10,800
Basement & Finished	760sf	760sf		704sf	0	704sf	0
Rooms Below Grade	RR,HB	RR,HB		RR	+5,000	RR	+5,000
Functional Utility	Average	Average		Average		Average	
Heating/Cooling	FWA/CAC	FWA/CAC		FWA/CAC		FWA/CAC	
Energy Efficient Items	Standard	Standard		Standard		Standard	
Garage/Carport	Off street park	Off street park		Off street park		Off street park	
Porch/Patio/Deck	Patio	Patio		Patio		Patio	
Fireplaces	2 fireplaces	2 fireplaces		no fireplaces	+5,000	no fireplaces	+5,000
Kitchen	Updated Kit	New Mod Kit	-10,000	Updated Kit		Full Mod Kit	+10,000
Net Adjustment (Total)		☐ + ☒ -	$ -20,000	☒ + ☐ -	$ 10,800	☒ + ☐ -	$ 30,800
Adjusted Sale Price of Comparables		Net Adj. 5.8 % Gross Adj. 5.8 %	$ 324,000	Net Adj. 3.4 % Gross Adj. 9.8 %	$ 326,300	Net Adj. 10.6 % Gross Adj. 10.6 %	$ 320,800

Summary of Sales Comparison Approach: Due to the paucity of recent sales of condominium townhouses in the subject's Wheaton market area, the comparables utilized are considered the best available. Comparable #1 was purchased as a foreclosure 10/2010, renovated and place back on the market. The townhouse was listed 1/15/2011 and contract in 14 days. According to the listing agent, the investor/contractor spent approximately $55,000 renovating the comparable. Comparable #1 offered new more expensive kitchen and bathrooms than the subject. Comparable #1 is located in competing Wheaton Towne Section 1 project. Comparable #2 was an updated end of group unit listed 3/12/2010. Comparable #3 was originally listed 3/17/2010 for $324,900. Comparables #1, #2 and #3 are the three highest price sales in the past 12 months of condominium townhouses in 20902 zip code that are over 10 years old.

Table of Results

	Bayfront	0-500 meters	500-1000 meters
Anne Arundel	-0.126***	-0.023***	-0.009
Baltimore County	-0.090***	0.009	-0.015*
Calvert	-0.033*	0.001	0.021*
Cecil	0.010	-0.001	0.003
Charles	-0.058	-0.056**	-0.107***
Dorchester	-0.078*	-0.008	-0.013295
Harford	-0.096***	0.001	0.012
Kent	-0.142***	0.008	0.002
Prince Georges	-0.062	-0.001	0.022**
Queen Annes	0.017	-0.060***	-0.068***
Somerset	-0.091	-0.055	-0.141***
St Marys	0.014	-0.015	0.017
Talbot	-0.156***	-0.014	-0.031
Wicomico	0.046	-0.015	-0.010

K_D and clarity inversely related

*** p<0.01, ** p<0.05, * p<0.1

Overall results

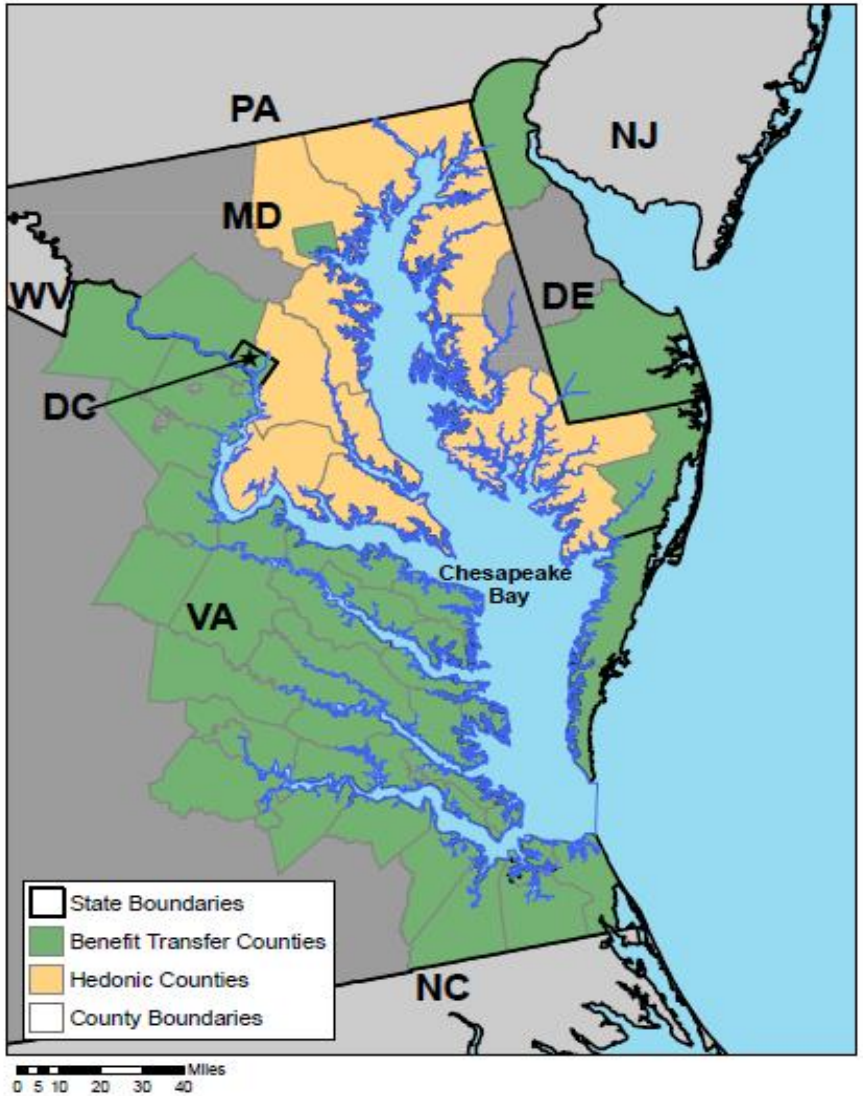
- Across the 14 counties:
  - 10 of 14 have negative waterfront coefficient
    - 7 of which are significant
  - None of the positive waterfront coefficients are significant
  - Mixed results beyond the waterfront
    - Evidence of impacts extending out past 500m in some counties.

Temporal Consistency?

- Length of data – questions about temporal consistency of estimates
- Identified several time demarcations to split the data
  - Run regressions on:
    - 1996-2001
    - 1996-2005
    - 2002-2008
    - 2002-2005
    - 2006-2008
- Results were mostly consistent across specifications, with minor differences in magnitude
  - Main difference: 2006-2008 data.
    - Larger variation in magnitude of the implicit prices.
    - However, when full model compared to 1996-2005, adding 2006-2008 did not appreciably change results.

Other Project Components

- Meta-analysis of 14 Counties, specifications



Conclusion

- Significant impact of water clarity in many waterfront counties
- The TMDL has potential to cause significant amount of property price benefits
- For full results (and benefit estimates), report is out spring 2015.

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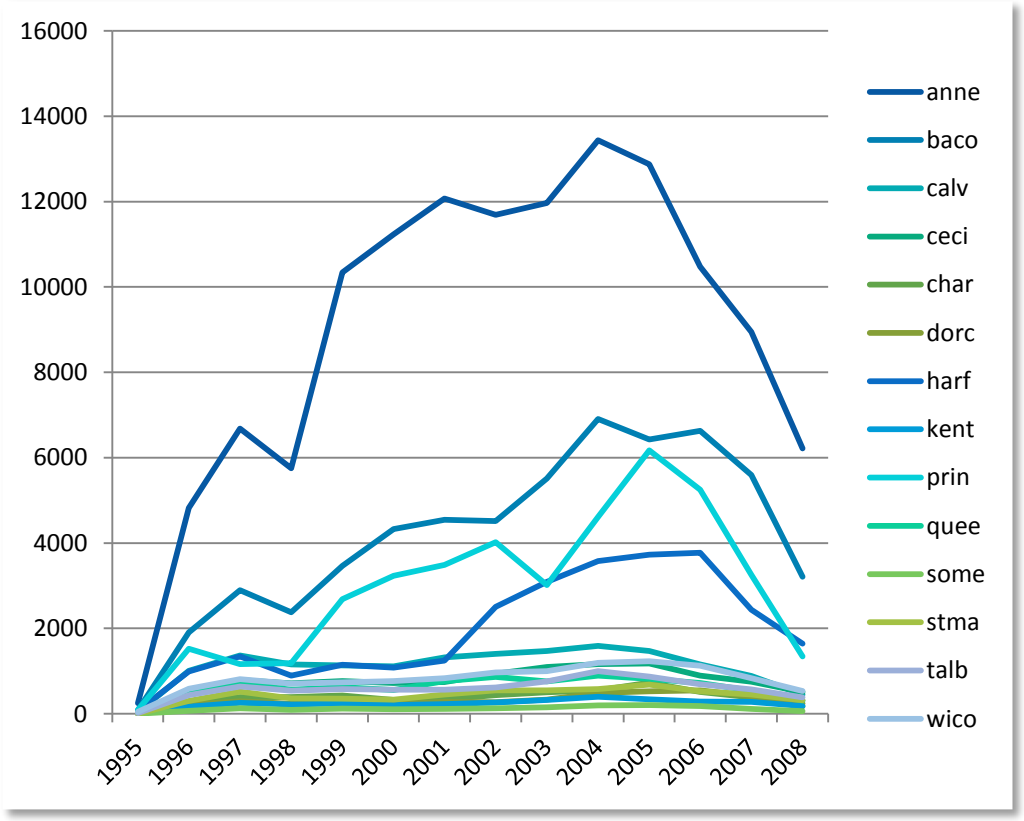
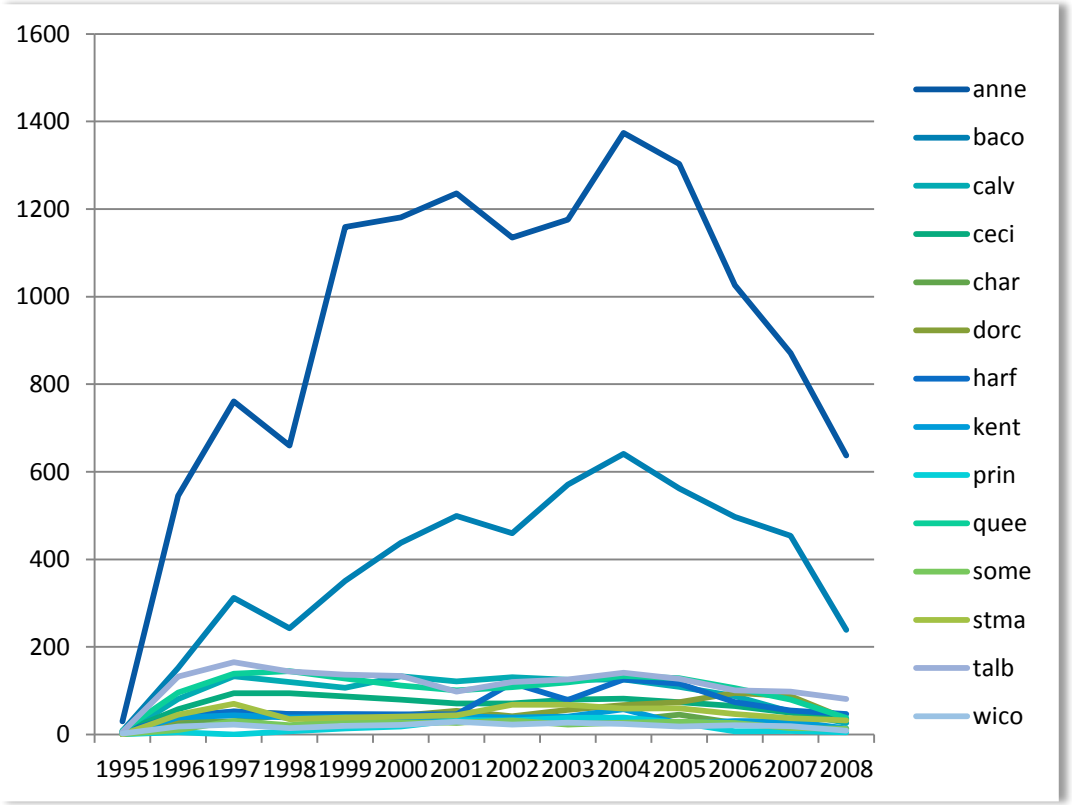
Appendix 1: Sales over time

- Total # of Sales



Total # of WF sales



Appendix 2

- Percent of Vacant Sales across Counties