Using the Indicators of Hydrologic Alteration and GIS to Assess the Effects of Urbanization on Flood Risk

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Outline

- Introduction
  - Objective
  - Project Overview
- Data and Methods
  - IHA - Indicators of Hydrologic Alteration
  - Image Classification: Impervious Surface Coverage (ISC)
  - Spatial analysis using GIS
- Results
- Conclusion
- Discussion

Introduction

- Objective
  - Exploratory research
  - How has urbanization and ISC affected local flood risk in Baltimore County?
  - Is the IHA an effective method of measurement?
- Location
  - Baltimore County, MD
- Time Period
  - 1986 - 2005

IHA - Indicators of Hydrologic Alteration

- Brian D. Richter
- Parametric and *Non-Parametric statistical analysis
- 33 hydrologic parameters
- Grouped into 5 categories
  - Magnitude, frequency, duration, timing, and rate of change
  - Includes annual, monthly, 1, 3, and 7 day statistics
    - Median values
- Assess ecological impact of a disturbance
  - Pre vs. Post
  - Proven effective for urbanization
    - Urbanization as a disturbance
- Available through the Nature Conservancy

IHA Score Card

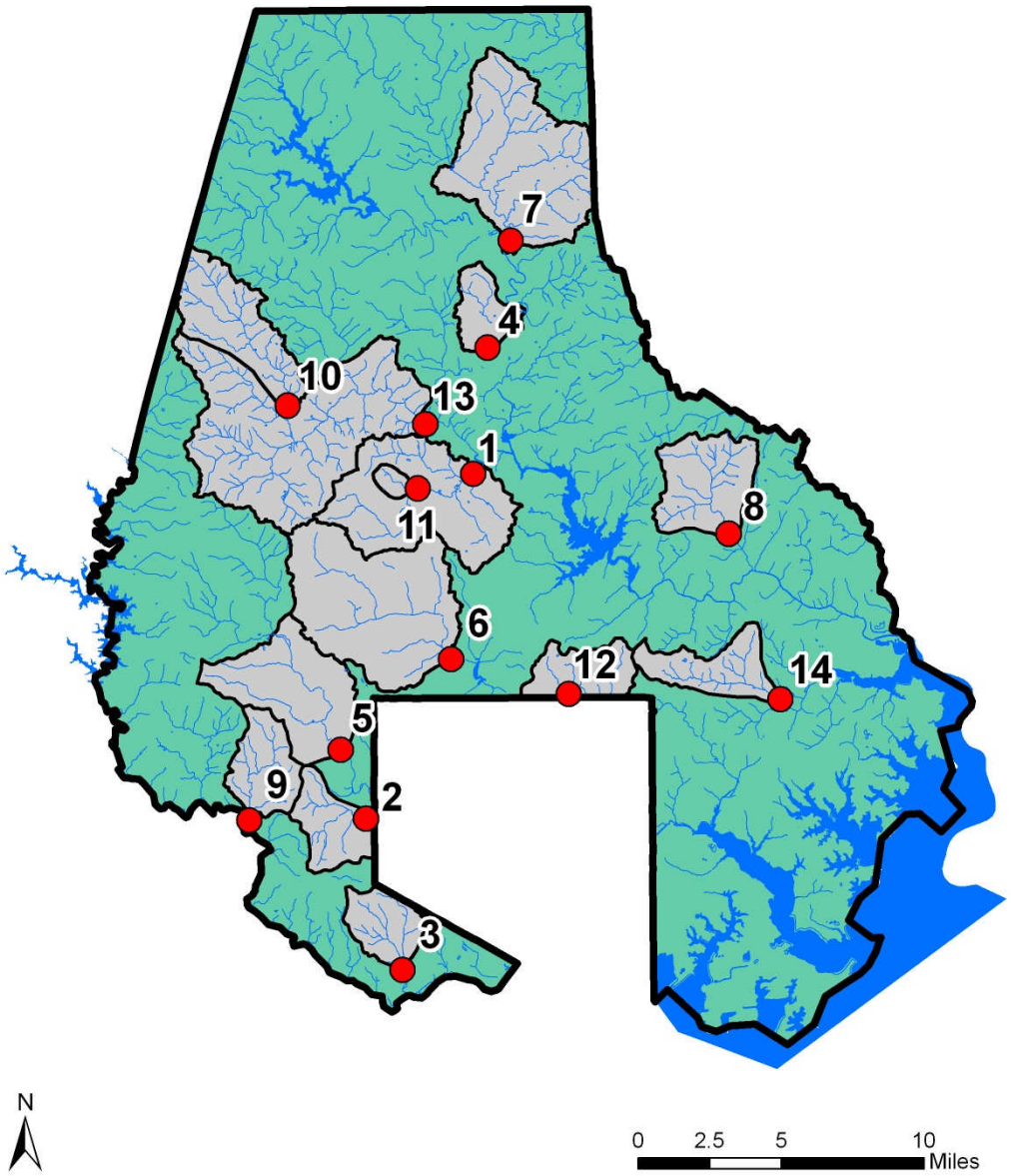
Non-Parametric IHA Scorecard								
BeaverDamRun								
	Pre-impact period:			Post-impact				
Watershed area	1			1				
Mean annual flow	24.92			31.34				
Mean flow/area	24.92			31.34				
Annual C. V.	1.21			1.58				
Flow predictability	0.68			0.74				
Constancy/predictability	0.71			0.65				
% of floods in 60d period	0.26			0.28				
Flood-free season	13			9				
	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October	13	18.5	0.4192	0.4324	0.4231	0.03149	0	0.968
November	17	22.75	0.1029	0.4176	0.3382	3.057	0	0.01602
December	19	22.5	0.2895	0.7111	0.1842	1.457	0	0.4635
January	20	25.5	0.275	0.2157	0.275	0.2157	0	0.7047
February	23	25	0.2935	0.515	0.08696	0.7548	0.5616	0.3493
March	23	25.5	0.3261	0.3431	0.1087	0.05229	0.5225	0.9309
April	23.5	28.75	0.3936	0.5261	0.2234	0.3365	0.2342	0.4725
May	22	22	1.432	0.3182	0	0.7778	0.962	0.2793
June	18	18.25	0.9097	0.3356	0.01389	0.6311	0.8719	0.3504
July	14	19	1.171	0.5355	0.3571	0.5428	0.3263	0.2523
August	9.3	12	1.21	0.3313	0.2903	0.7262	0.2763	0.3053
September	14.5	10.63	0.8121	0.6918	0.2672	0.1481	0.4535	0.7267

MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT		
Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.	
Parameter Group #2								
1-day minimum	7.3	6.95	0.6986	0.5108	0.04795	0.2689	0.9039	0.5445
3-day minimum	7.467	7.683	0.7411	0.4805	0.02902	0.3516	0.9029	0.4384
7-day minimum	7.571	8.721	0.7642	0.4795	0.1519	0.3725	0.5666	0.3473
30-day minimum	9.137	10.8	0.8699	0.5344	0.1824	0.3857	0.6366	0.3223
90-day minimum	14.83	20.47	0.7968	0.5643	0.3809	0.2918	0.2833	0.4705
1-day maximum	398	548.5	0.9183	0.8409	0.3781	0.0843	0.1772	0.8749
3-day maximum	178	300	0.8624	0.5831	0.6854	0.3239	0.03003	0.5916
7-day maximum	95.71	160.8	0.7037	0.526	0.6799	0.2526	0	0.6336
30-day maximum	45.87	66.33	0.6938	0.3494	0.4462	0.4965	0.1091	0.2302
90-day maximum	31.44	41.08	0.5668	0.5251	0.3065	0.07357	0.1351	0.9479
Number of zero days	0	0	0	0				
Base flow index	0.3663	0.2581	0.2299	0.3849	0.2953	0.6738	0	0.2102
Parameter Group #3								
Date of minimum	266	263	0.2077	0.06011	0.01639	0.7105	0.8398	0.3744
Date of maximum	43	301.5	0.4549	0.3463	0.5874	0.2387	0.4505	0.3343
Parameter Group #4								
Low pulse count	15	8	0.7	0.2813	0.4667	0.5982	0.2653	0.1321
Low pulse duration	2	3.25	1.75	1.423	0.625	0.1868	0.08509	0.7708
High pulse count	29	32	0.5345	0.2891	0.1034	0.4592	0.4124	0.3684
High pulse duration	2	2	0.5	0	0	1	0	0.3403
Low Pulse Threshold	14							
High Pulse Threshold	26							

Data

- Hydrologic data
  - 14 USGS Stream Gages
  - 5 year collection periods
    - Helps eliminate outliers
  - 1984-1988 - Early urbanization stage (1986)
  - 2003-2007 - Post urbanization stage (2005)
- Stream Catchments
  - DNR data
- Urbanization
  - Impervious surface coverage
    - Image Classification
      - Landsat TM and ETM+ (30m)
      - 1986 and 2005

Baltimore County
Stream Gages and Catchments



1	BEAVERDAM RUN AT COCKEYSVILLE, MD
2	DEAD RUN AT FRANKLINTOWN, MD
3	EAST BRANCH HERBERT RUN AT ARBUTUS, MD
4	GUNPOWDER FALLS AT GLENCOE, MD
5	GWYNNS FALLS AT VILLA NOVA, MD
6	JONES FALLS AT SORRENTO, MD
7	LITTLE FALLS AT BLUE MOUNT, MD
8	LONG GREEN CREEK AT GLEN ARM, MD
9	PATAPSCO RIVER AT HOLLOFIELD, MD
10	PINEY RUN AT DOVER, MD
11	POND BRANCH AT OREGON RIDGE, MD
12	WEST BRANCH HERRING RUN AT IDLEWYLDE, MD
13	WESTERN RUN AT WESTERN RUN, MD
14	WHITEMARSH RUN AT WHITE MARSH, MD

Methods

- Flood Vulnerability
  - Fluctuation and flashiness
  - IHA Data
  - Range between average min and max flow
    - 3 and 7 day averages
    - Ex. 10cfs (min) and 40cfs = range of 30cfs
  - Variable
    - Percent change in range from 1986 – 2005
      - ex. 20cfs (‘86 range) to 30cfs (’05 range) = 50% increase

Hydrologic Range Increase

Gage Site	1986 3 Day Min	1986 3 Day Max	2005 3 Day Min	2005 3 Day Max	1986 3 Day Range	2005 3 Day Range	3 Day %
BEAVERDAM RUN AT COCKEYSVILLE, MD	7.467	178	7.683	300	170.533	292.317	**71.41%**
DEAD RUN AT FRANKLINTOWN, MD	0.6267	53	0.47	93.6	52.3733	93.13	**77.82%**
EAST BRANCH HERBERT RUN AT ARBUTUS, MD	0.36	31.23	0.46	34.43	30.87	33.97	**10.04%**
GUNPOWDER FALLS AT GLENCOE, MD	53.83	307.6	99.67	493	253.77	393.33	**54.99%**
GWYNNS FALLS AT VILLA NOVA, MD	3.9	281.8	24	449.3	277.9	425.3	**53.04%**
JONES FALLS AT SORRENTO, MD	5.267	150	5.3	264.2	144.733	258.9	**78.88%**
LITTLE FALLS AT BLUE MOUNT, MD	16.33	280.8	22.17	380.3	264.47	358.13	**35.41%**
LONG GREEN CREEK AT GLEN ARM, MD	2.2	52.33	2.533	104.2	50.13	101.667	**102.81%**
PATAPSCO RIVER AT HOLLOFIELD, MD	14.67	701.3	21.67	1472	686.63	1450.33	**111.22%**
PINEY RUN AT DOVER, MD	3.933	98.83	6.1	129	94.897	122.9	**29.51%**
POND BRANCH AT OREGON RIDGE, MD	0.01	0.3533	0.05083	0.5783	0.3433	0.52747	**53.65%**
WEST BRANCH HERRING RUN AT IDLEWYLDE, MD	0.1767	19.38	0.1783	22.08	19.2033	21.9017	**14.05%**
WESTERN RUN AT WESTERN RUN, MD	13.83	364.2	21.33	492.8	350.37	471.47	**34.56%**
WHITEMARSH RUN AT WHITE MARSH, MD	0.5617	113.2	0.5117	180.7	112.6383	180.1883	**59.97%**

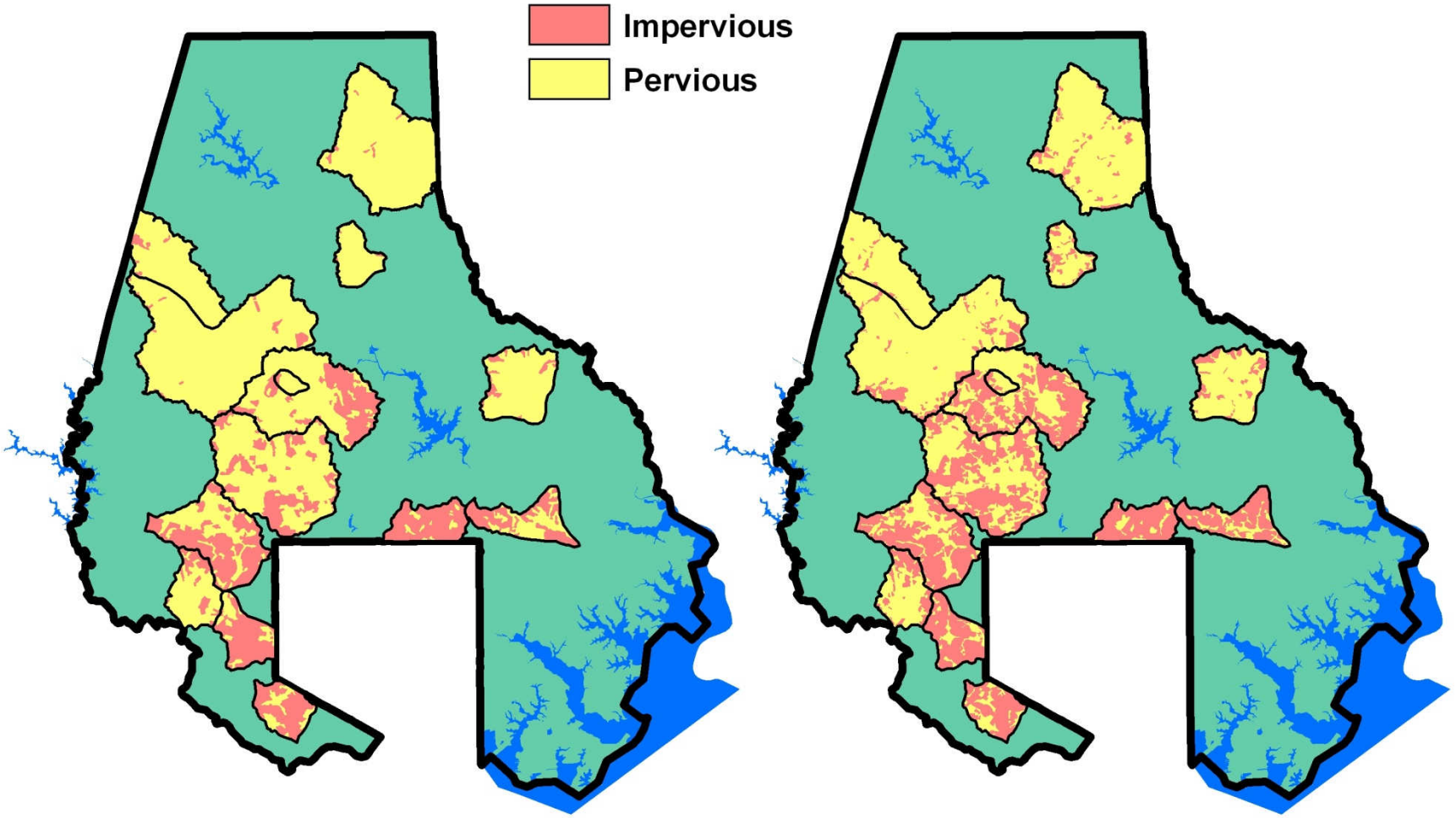
Methods Cont'd

- Urbanization
  - ISC area per stream catchment
    - Contributes directly to stream gage
  - Variable
    - Percent change in ISC
    - Based on total area
      - New ISC area / catchment area

Increased ISC (m^2)

Catchment/Gage	Total Area	1986 ISC	2005 ISC	ISC Difference	New ISC
BEAVERDAM RUN AT COCKEYSVILLE, MD	54625836.09	17538010.11	29408122.62	11870112.51	**68%**
DEAD RUN AT FRANKLINTOWN, MD	16834878.71	13134682.20	13917317.38	782635.18	**5%**
EAST BRANCH HERBERT RUN AT ARBUTUS, MD	14545255.66	10733837.69	10555637.11	-178200.57	**-1%**
GUNPOWDER FALLS AT GLENCOE, MD	12244537.63	359347.72	3521866.32	3162518.59	**26%**
GWYNNS FALLS AT VILLA NOVA, MD	38963516.98	23664872.94	27099583.35	3434710.41	**9%**
JONES FALLS AT SORRENTO, MD	65685325.58	18040763.11	33697899.47	15657136.36	**24%**
LITTLE FALLS AT BLUE MOUNT, MD	61614197.97	1111182.29	5666943.41	4555761.12	**7%**
LONG GREEN CREEK AT GLEN ARM, MD	26987917.27	2721148.18	5321731.18	2600583.00	**10%**
PATAPSCO RIVER AT HOLLOFIELD, MD	18205830.39	4180658.96	6470472.60	2289813.64	**13%**
PINEY RUN AT DOVER, MD	30030423.53	1245751.74	1283443.04	37691.31	**0%**
POND BRANCH AT OREGON RIDGE, MD	2964725.691	371876.07	917020.25	545144.18	**18%**
WEST BRANCH HERRING RUN AT IDLEWYLDE, MD	16065911.08	14731262.35	14082947.15	-648315.20	**-4%**
WESTERN RUN AT WESTERN RUN, MD	87370787.78	3069994.74	11027540.07	7957545.33	**9%**
WHITEMARSH RUN AT WHITE MARSH, MD	18672257.81	10779363.35	14602754.31	3823390.96	**20%**

Impervious Surface Coverage

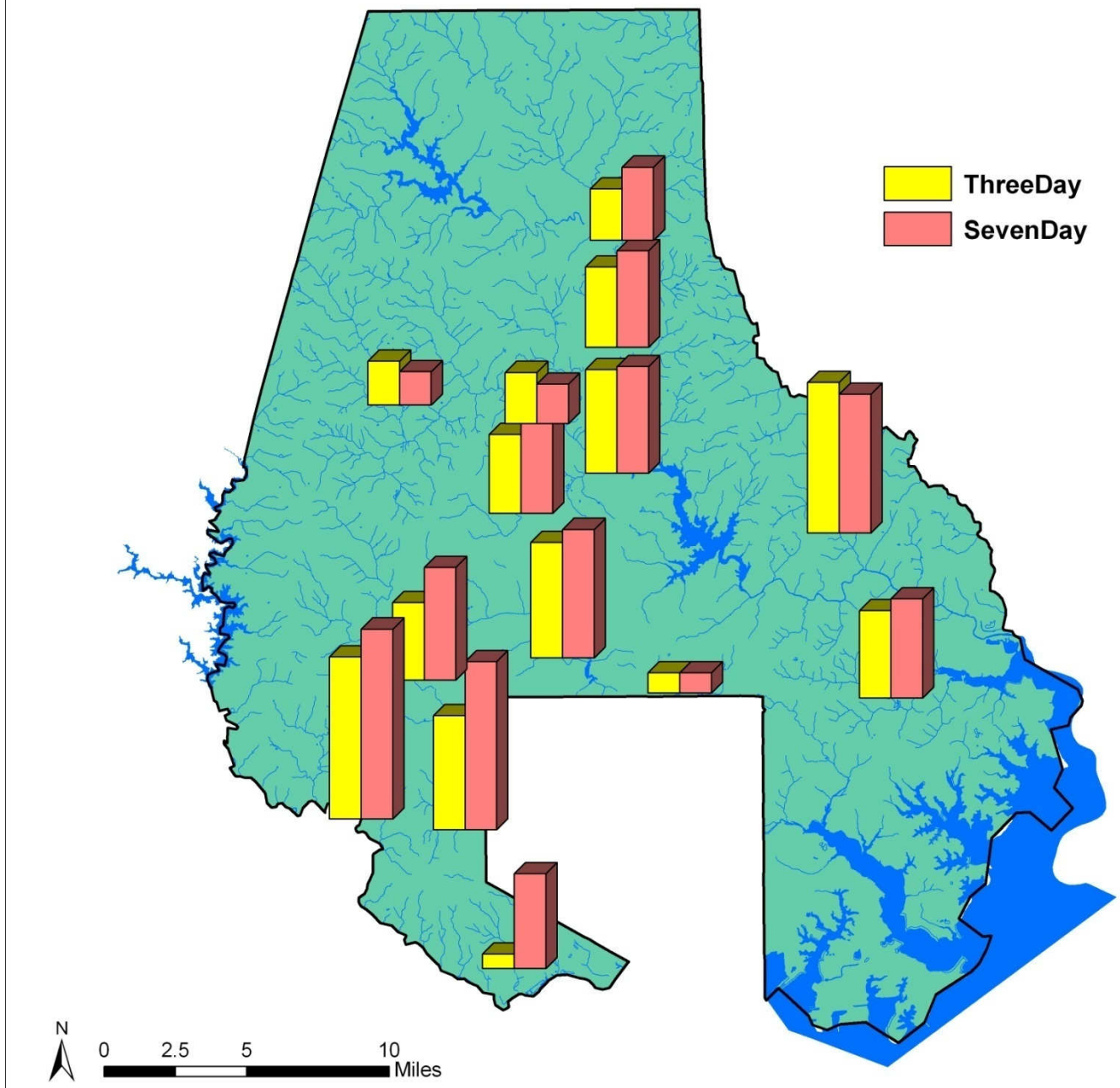


Results

- Flood Vulnerability
  - All streams had an increase in both 3 and 7 day ranges (min and max averages)
  - Highest 3 and 7 day increase
    - Patapsco River at Hollofied
    - 111% and 130%
  - Lowest 3 day increase
    - E. Branch Herbert Run at Arbutus
    - 10%
  - Lowest 7 day increase
    - W. Branch Herring Run at Idlewylde
    - 14%

Streamflow Range Increase		
Gage Site	3 Day %	7 Day %
BEAVERDAM RUN AT COCKEYSVILLE, MD	71.41%	72.54%
DEAD RUN AT FRANKLINTOWN, MD	77.82%	115.13%
EAST BRANCH HERBERT RUN AT ARBUTUS, MD	10.04%	64.66%
GUNPOWDER FALLS AT GLENCOE, MD	54.99%	66.39%
GWYNNS FALLS AT VILLA NOVA, MD	53.04%	76.76%
JONES FALLS AT SORRENTO, MD	78.88%	87.57%
LITTLE FALLS AT BLUE MOUNT, MD	35.41%	50.30%
LONG GREEN CREEK AT GLEN ARM, MD	102.81%	94.52%
PATAPSCO RIVER AT HOLLOFIELD, MD	111.22%	130.19%
PINEY RUN AT DOVER, MD	29.51%	23.21%
POND BRANCH AT OREGON RIDGE, MD	53.65%	64.79%
WEST BRANCH HERRING RUN AT IDLEWYLDE, MD	14.05%	13.98%
WESTERN RUN AT WESTERN RUN, MD	34.56%	27.01%
WHITEMARSH RUN AT WHITE MARSH, MD	59.97%	68.26%

3 and 7 Day Increase Percentage

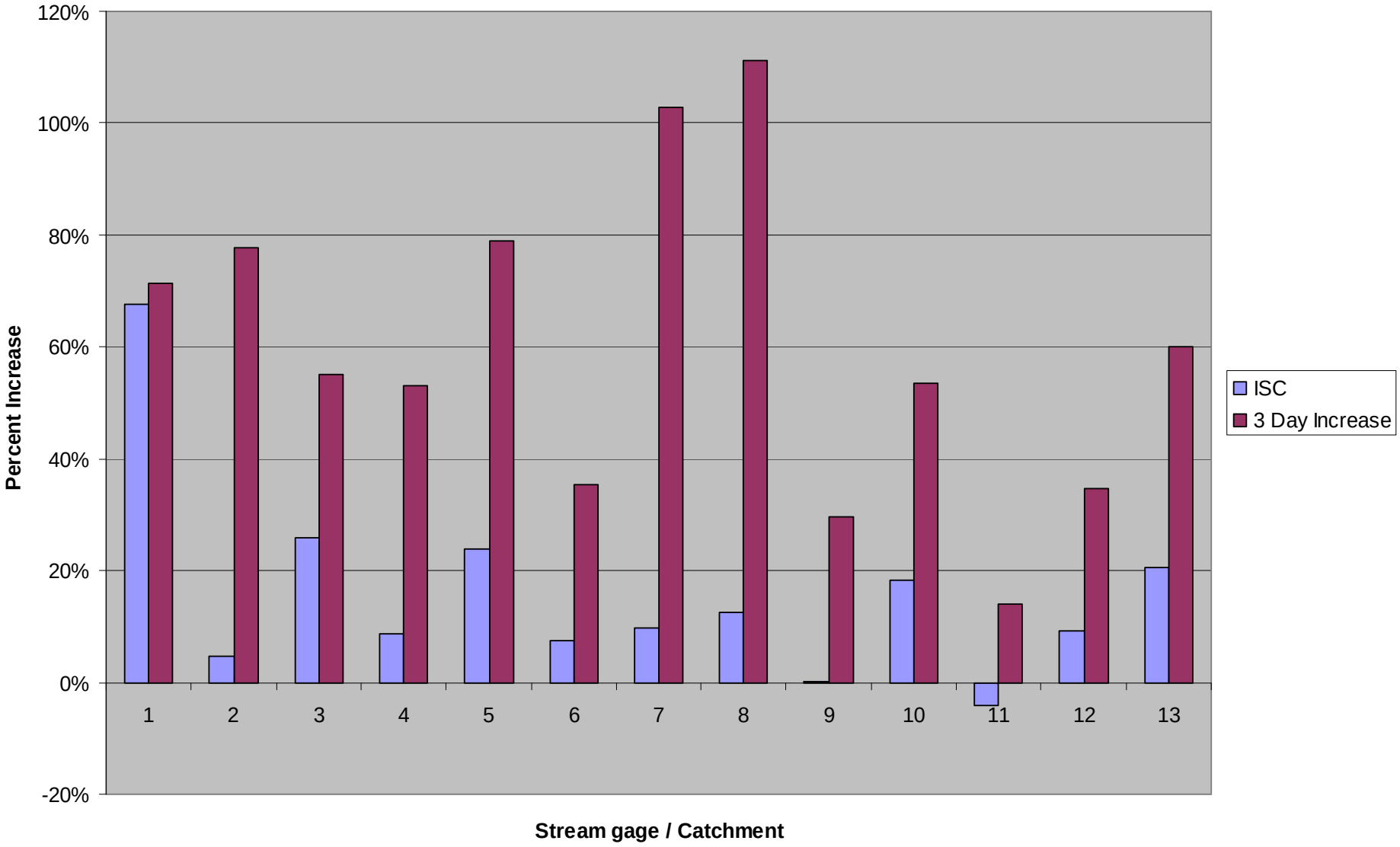


Results Cont'd

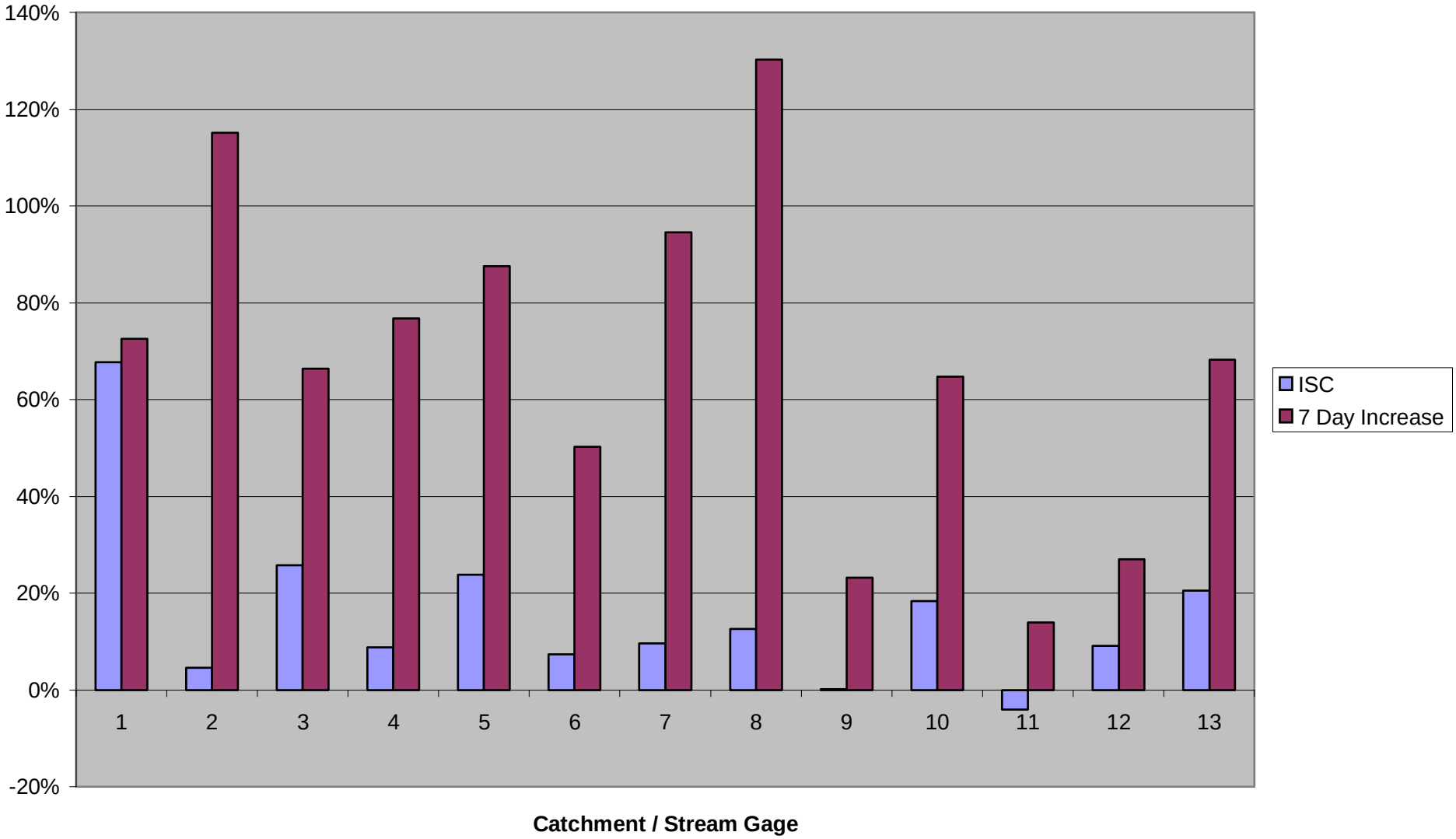
- Urbanization
  - Increased ISC
    - 12 out of 14 catchments
    - Highest Increase:
      - Beaver Dam Run, 68%
  - Decreased ISC
    - 2 of 14 catchments
      - E. Branch Herbert Run, -1%
      - W. Branch Herring Run, -4%

Catchment/Gage	New ISC	3 Day %	7 Day %
BEAVERDAM RUN AT COCKEYSVILLE, MD	68%	71.41%	72.54%
DEAD RUN AT FRANKLINTOWN, MD	5%	77.82%	115.13%
EAST BRANCH HERBERT RUN AT ARBUTUS, MD	-1%	10.04%	64.66%
GUNPOWDER FALLS AT GLENCOE, MD	26%	54.99%	66.39%
GWYNNS FALLS AT VILLA NOVA, MD	9%	53.04%	76.76%
JONES FALLS AT SORRENTO, MD	24%	78.88%	87.57%
LITTLE FALLS AT BLUE MOUNT, MD	7%	35.41%	50.30%
LONG GREEN CREEK AT GLEN ARM, MD	10%	102.81%	94.52%
PATAPSCO RIVER AT HOLLOFIELD, MD	13%	111.22%	130.19%
PINEY RUN AT DOVER, MD	0%	29.51%	23.21%
POND BRANCH AT OREGON RIDGE, MD	18%	53.65%	64.79%
WEST BRANCH HERRING RUN AT IDLEWYLDE, MD	-4%	14.05%	13.98%
WESTERN RUN AT WESTERN RUN, MD	9%	34.56%	27.01%
WHITEMARSH RUN AT WHITE MARSH, MD	20%	59.97%	68.26%

ISC and 3 Day Increase



ISC and 7 Day Increase



Correlation Results

- 3 Day Correlation

  .3767

- 7 Day Correlation

  .2189

Conclusions

- Increased flood risk from 1985 – 2005
  - Increased flashiness and fluctuation
- Increased urbanization
  - ISC
  - 12 of 14 catchments
- Correlation
  - Weak correlation between urbanization (ISC) and flood risk

Conclusions Cont'd

- IHA
  - Is effective for demonstrating hydrologic patterns
  - Results do show a significant change in Baltimore county stream flow
  - However, not necessarily due to urbanization
    - And the amount of urbanization

Discussion

- USGS Stream Data
  - Convenient and thorough
  - Limited data for time studies
- Urbanization
  - ISC accurate indicator
  - Image classification
    - Satisfactory for this size study
    - Higher resolution?
      - Better accuracy and specific studies
      - Data availability

Discussion Cont'd

- IHA
  - Useful for various research
    - Many variables and statistics
    - Ease and compatibility
  - Many variables for other research
  - Take results with discretion
    - Meteorological events ex. droughts
    - Controlled flows and Releases?
      - Dams?

Questions or Suggestions