Exploring impacts of land-use change and residential land-management behavior on water quality in the Potomac Gorge, USA via participatory modeling

Dawn C. Parker, Robin A. Brake, Ryan Albert, Susan A. Crate, R. Christian Jones and Charles Nguyen; Departments of Computational Social Science, Environmental Science and Policy & Sociology, George Mason University, Fairfax, VA USA

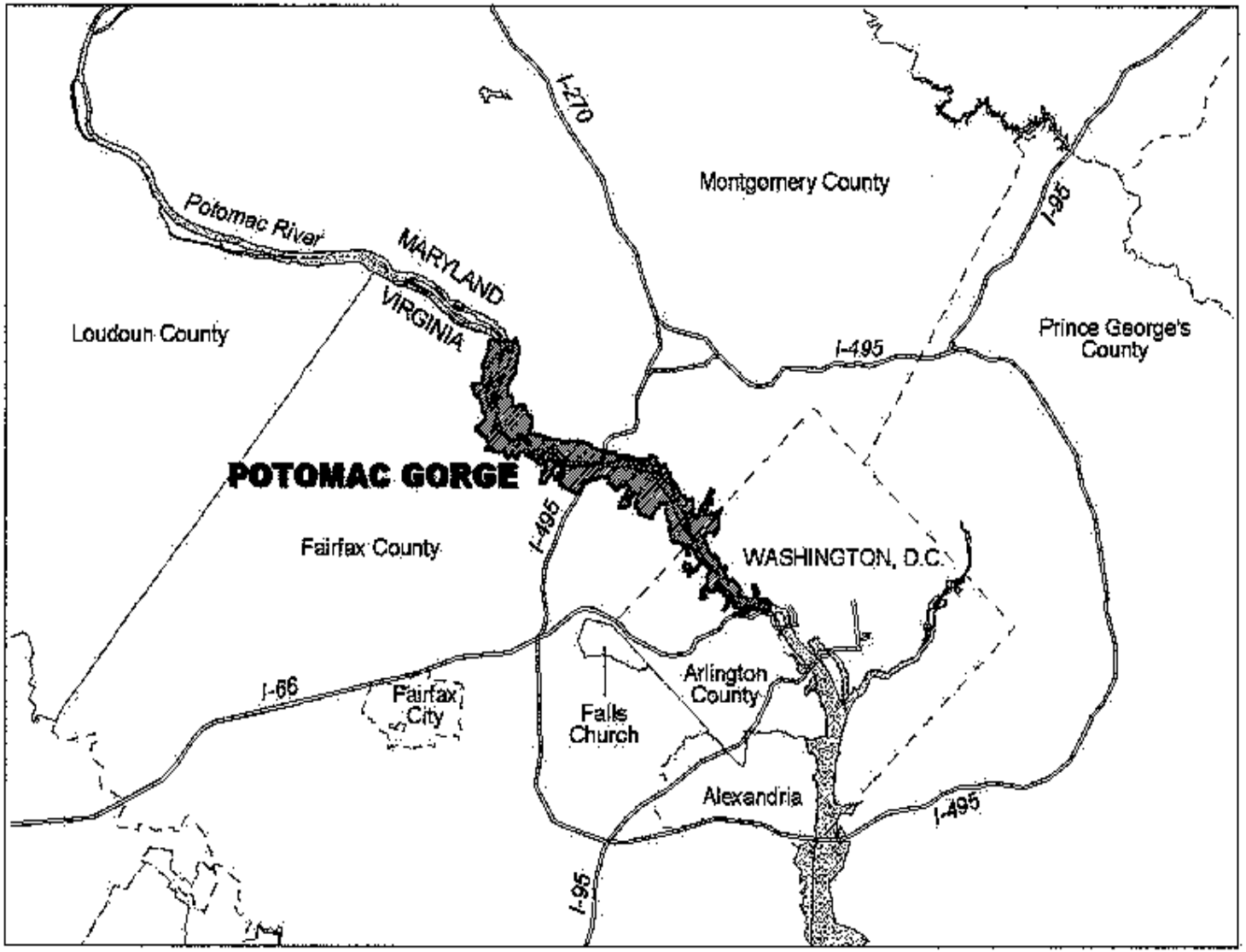
Giselle Mora-Bourgeois, Urban Ecology Research Learning Alliance, National Park Service, Washington DC, USA

Presented at the Transatlantic Land Use Conference, Washington, DC Sept. 24, 2007

Outline

- Study area and project goals
- Planned model components
- In-progress components--land-use change and water quality modeling (results from proximate watershed)
- In-progress component--household survey and statistical model
- Planned components--map-based front end for participatory model
- Reflections on challenges and successes to date

Study area: geographic and institutional context



(Source: Nature Conservancy, NPS)

The Potomac Gorge is a Biodiversity Hotspot that is…

-partially protected (two NPs, two NGO areas, private CEs)

-situated in an intensely changing landscape

-threatened from without

External Drivers & Offsite Impacts

Impact of Urban Stormwater

- Urban Stormwater is a major cause of impairment to aquatic ecosystems
- Known to cause increase in loadings of nutrients and toxics to water bodies and changes in hydrology
- Cumulative impact is significant

Project Partners/Funding

- Funded by the Chesapeake Watershed Ecosystem Studies Unit and the Urban Ecology Research Learning Alliance
- Project involves park managers from two Potomac Gorge national parks: the C&O Canal National Historical Park and the George Washington Memorial Parkway
- End users may include civic organizations and local governments as well as the National Park Service

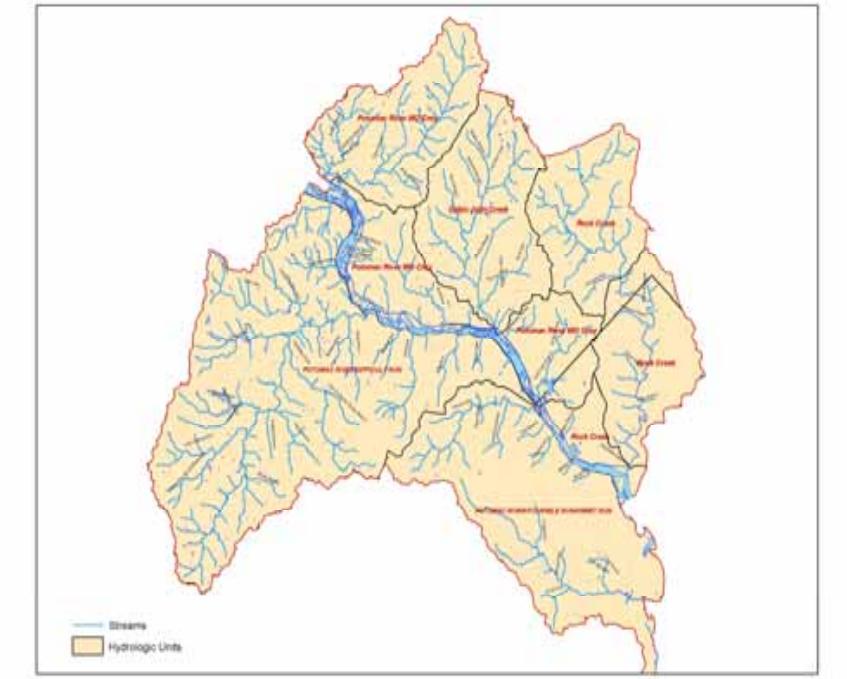
Project Goals

- Create “Pilot project” participatory modeling tool using both existing and newly developed components to explore:
  - Linkages between land use and water quality
  - Linkages between land owner behavior and water quality
  - Projections of land-use change and water quality
- Primary goal is to provide them with useful information to manage off-site threats to rare aquatic resources

Hybrid model components

- Nitrate/Nitrite water quality model(s)
- Land-use change estimates from existing models
- Survey regarding land-use practices
- Statistical resident behavior model based on survey
- Components to be packaged into spatially explicit interactive simulation model
- Desired extension: Flow projections using a model such as HSPF

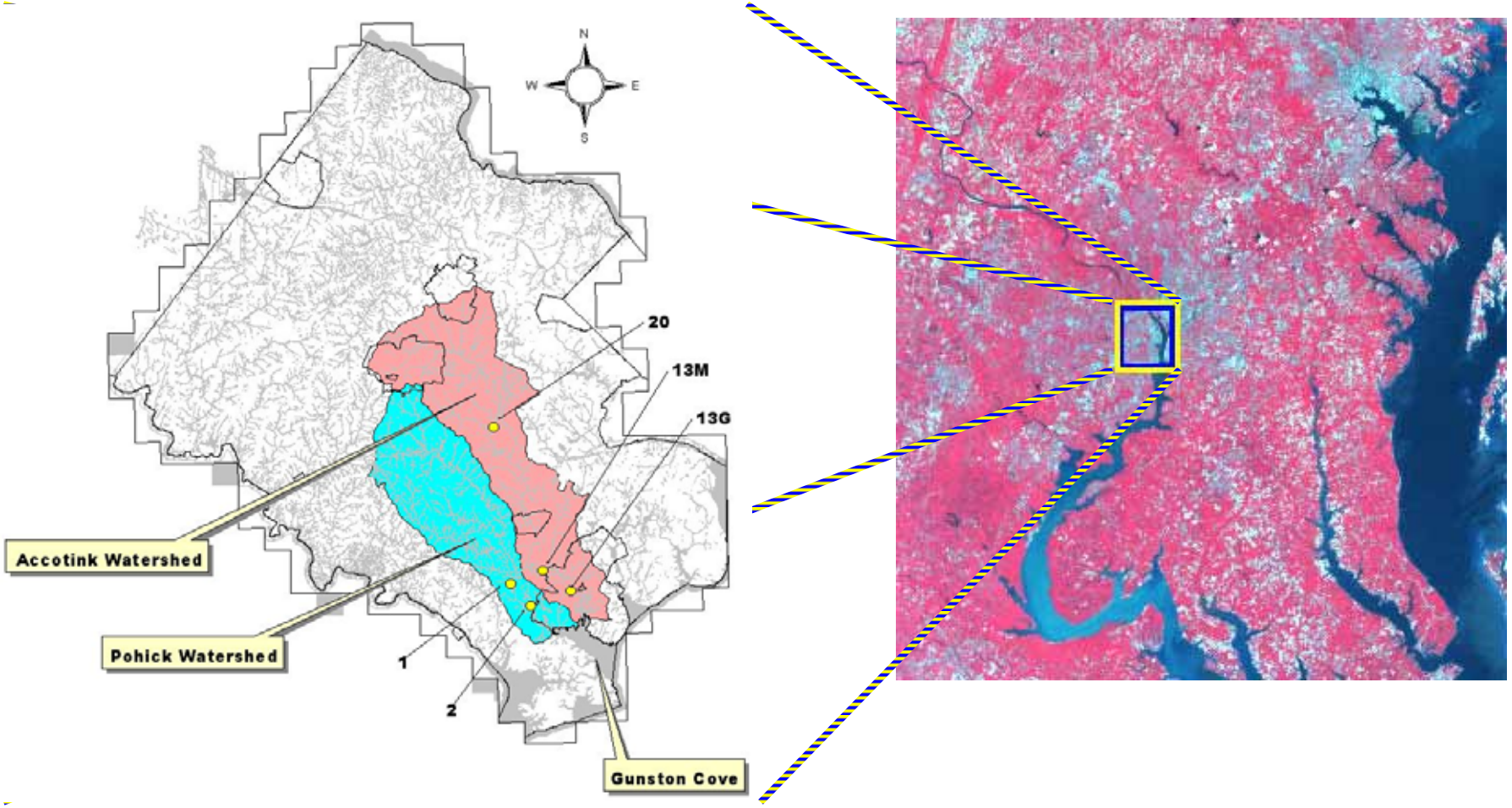
Water Quality Modeling



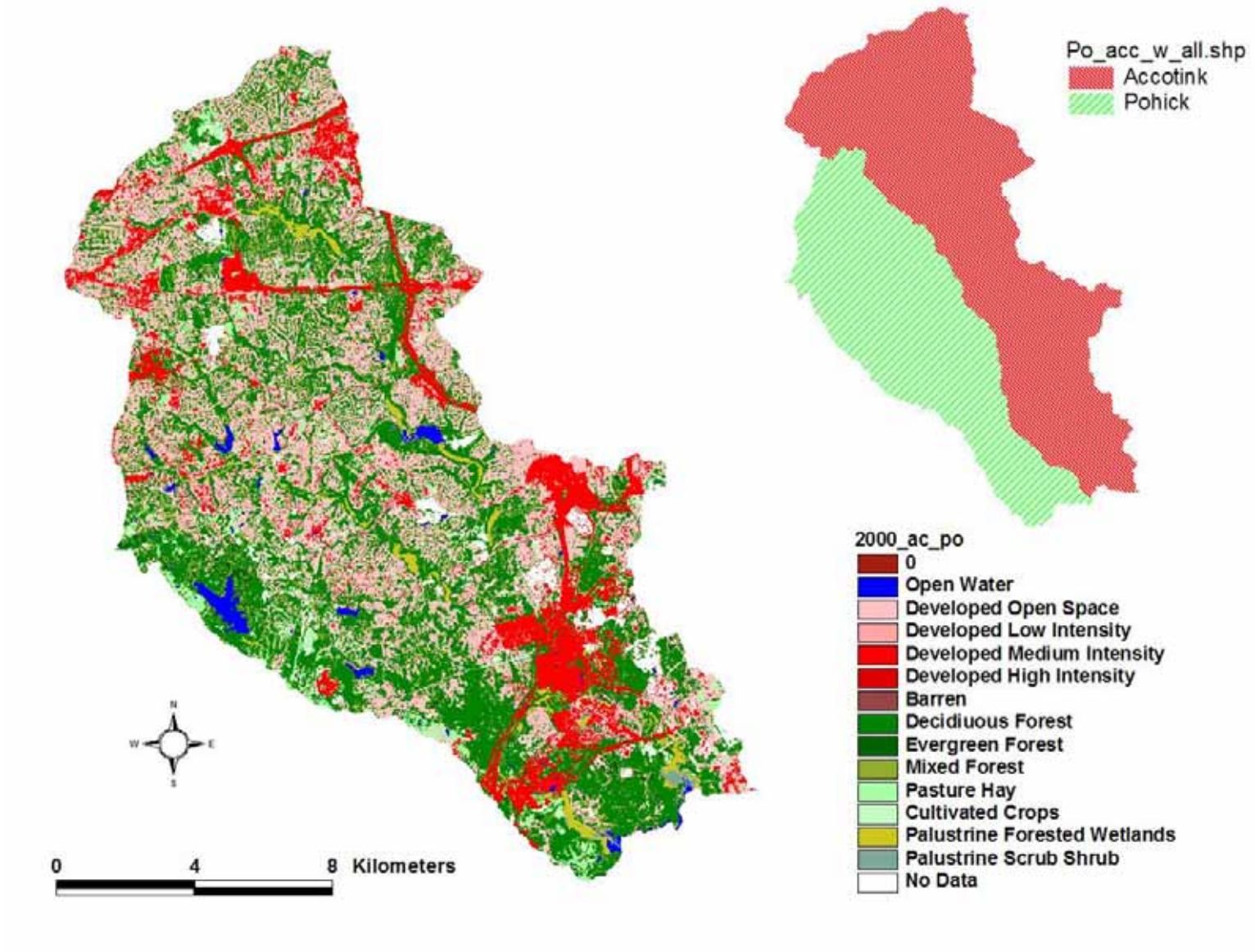
- Nitrate-nitrite loadings using export coefficient methods
- Developed for proximate watersheds; to be applied to Potomac Gorge watershed
- Ryan Albert dissertation

Map credit: Nature conservancy

Proximate Watersheds: Accotink and Pohick



Land use--combination of various intensities of development and open space

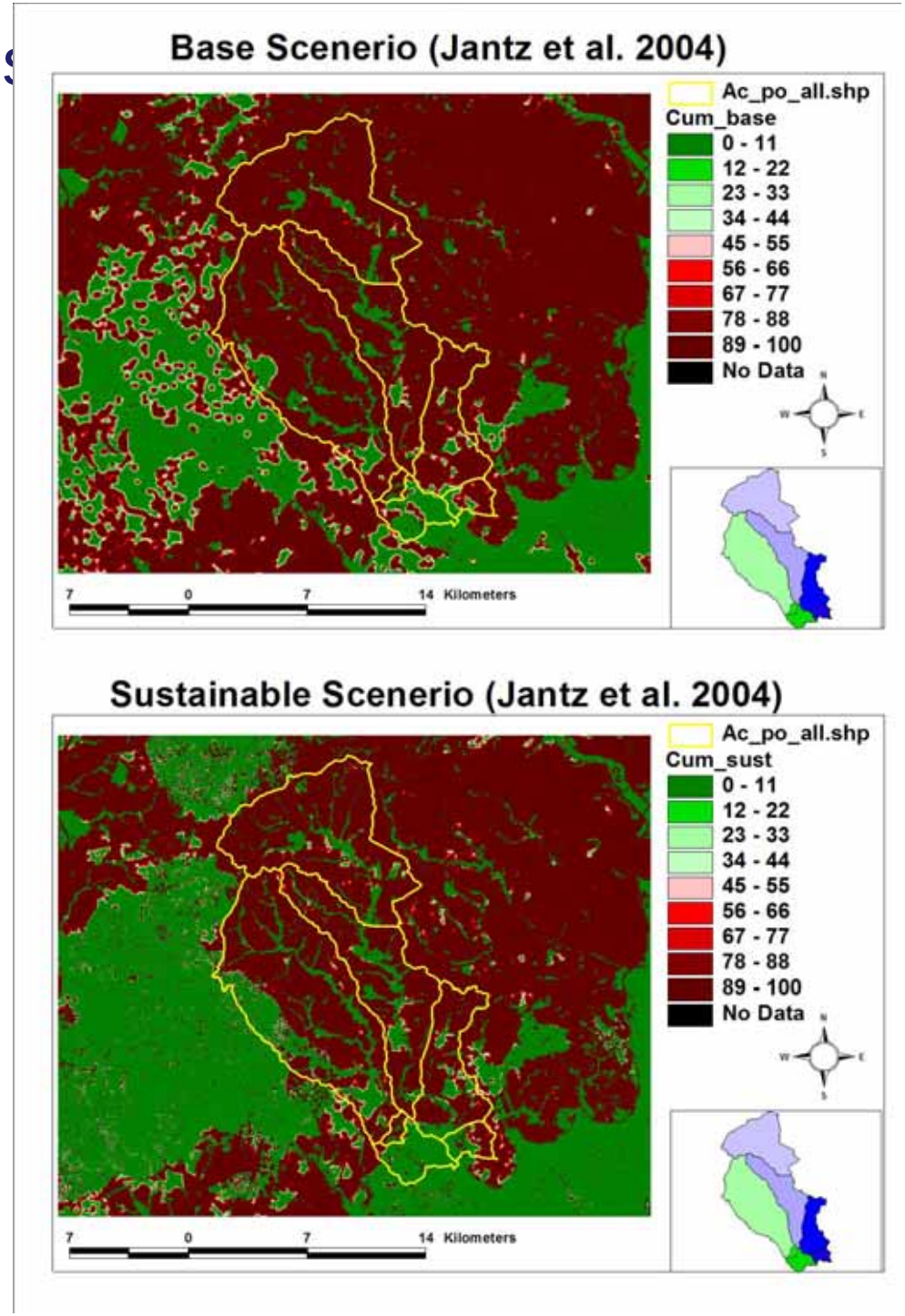


Future land use projections method 1: "Household" method

- Projections developed by Ryan Albert combine:
  - County-level data/projections on numbers of households
  - Remote sensing data
- Assume build-out based on current zoning
- Used to create density estimates and change projections at a watershed/sewershed scale
- Projections performed better than trends based on only RS data

Future Land Use Projections
Method 2:
Jantz Model Output

- Jantz Model output based on SLEUTH Cellular Automata mode
- Three different policy scenarios: current conditions (base), smart growth, and sustainable development
- 45 meter resolution: 100 Monte Carlo iterations run
- Data shared in probability of urbanizing map format.
- Model output for full Baltimore/DC area; Adapted to Accotink and Pohick



Urban Land Use Projections (2025/2030)

Site	JCC	ADJ-CC	ADJ-SG	ADJ Sustainable	HLU
Site 1	83.0%	76.1%	71.1%	65.6%	61.4%
Site 2	82.9%	76.0%	71.0%	65.6%	61.8%
Pohick All	**77.2%**	**70.2%**	**64.9%**	**59.4%**	**56.7%**
Site 20	90.6%	83.9%	80.9%	77.6%	74.9%
Site 13 Modified	87.9%	81.1%	78.3%	75.3%	71.3%
Site 13 Original	88.0%	81.3%	78.1%	74.2%	71.4%
Accotink All	**87.3%**	**80.6%**	**77.2%**	**73.2%**	**70.0%**

- Projections for Accotink vary from 70.0% urban to 87.3% urban (compared to 61.9% for 2004).
- Projections for Pohick vary from 56.7% urban to 77.2% urban (compared to 49.5% for 2004).

Projected Nitrate and Total Nitrogen Loading
(metric tonnes)

Nitrate Loading	High	Expected	CBP	Low
JCC	825.90	340.54	336.81	305.97
ADJ-CC	813.95	335.32	332.37	302.28
ADJ-SG	461.03	332.12	329.67	177.17
ADJ-Sust.	337.26	208.78	206.49	176.85
HLU	457.51	329.24	328.35	174.29

Total Nitrogen Loading	High	Expected	CBP	Low
JCC	1193.04	474.39	419.63	405.92
ADJ-CC	1176.21	463.94	413.41	398.89
ADJ-SG	591.49	457.54	409.64	241.14
ADJ-Sust.	590.23	303.11	255.69	240.53
HLU	586.54	451.77	408.24	236.32

Summary of land change/water quality projections for neighboring sub-watersheds: Nitrogen

- Both nitrate and nitrogen loads expected to increase
- Projected increases vary across land-use projection and loading coefficient scenarios
- Best management practices and mitigation measures could potentially compensate, assuming 40% reductions in new development and 15% reductions in existing development

Land Manager Behavior (In progress)

- Quantified via existing, and a new survey.
- New survey focuses on quantifying relationships between:
  - Behaviors affecting water quality on own land;
  - Demographics;
  - Socioeconomic status;
  - Information, attitudes, and beliefs of residents.
- Plan to incorporate data from 2 other surveys based on stratification by zip codes

Potential Behavior/WQ Linkages

- Best management practices to control water runoff (rain gardens, rain barrels, pervious paving, etc.)
- Percent turf grass
- Fertilizer and pesticide use practices
- Streamside buffer zones

What questions might the model answer?

- What effects might provision of new information have on residents' behaviors?
- To what extent can changes in behaviors alone improve water quality?
- How might future changes in demographics affect water quality metrics?

Participatory modeling questions and challenges

- Identifying goals of end-users
- Communicating what we might be able to build--before it is built
- Negotiating constraints on budget and expertise
- Understanding the organizational environment

What seems to contribute to meeting challenges to date?

- Frequent communication---meetings, formal and informal presentations
- First-level partners are also research scientists
- Two GRAs who also work in policy jobs
- Some congruence between our expertise/resources and the questions of interest to our natural resource management partners
- Issues are also of interest to a broader range of stakeholders--critical mass of interest and resources

Open Questions and Challenges

- How to communicate information and limitations of the model to end users?
- Choices for front-end: ArcGIS vs. custom product (familiarity vs. utility)
- Real underlying dynamic model or query from outcome database?

Long Term Goals

- Replace simple and borrowed land-use change projections with projections from an agent-based model of land-use change (theoretical prototype developed)
- Model would jointly determine land use change and land manager behavior
- Could be used to explore relative effectiveness of policy interventions that target land use vs. land manager behavior

Acknowledgements:

- Chesapeake Watershed Cooperative Ecosystem Studies Unit and Urban Ecology Research Learning Alliance
- Full citations to all works are on land-use modeling and spatial ABM bibliographies, my web site