An Integrative Watershed Modeling Framework (IWMF) for Ecosystem Sustainability Assessment at the Watershed Scale

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ABSTRACT:

The public's right to continued access and use of ecosystem services requires an evaluation of the environmental risks that are associated with activities such as urban development, agriculture, forestry, mining, water withdrawal, and dam construction. Human activities can cause hydrological alterations and other stressors that occur over time and interact with one another, resulting in combined and cumulative environmental effects on the ecosystem. Assessing the combined environmental effects of human activities, such as urban development and dam construction, on downstream water availability, quality, and demand and on channel morphology and biological integrity of aquatic ecosystems is a major challenge that affects the application of established assessment protocols, such as the Total Maximum Daily Load (TMDL) development process. One way to address the combined and cumulative environmental effects of urban development and water resources development jointly is to use comprehensive watershed models that can simulate the interactions between multiple stressors. Many watershed models and modeling approaches are not adequately comprehensive and do not address changes in water availability resulting from reduced base flow due to increased impervious cover or increased water withdrawal.

This study presents a modeling approach or framework that would allow resource managers and decision-makers to link upstream development activities, particularly urban development and water resources development, to downstream environmental effects. The proposed integrative watershed modeling framework (IWMF) is an iterative and adaptive watershed modeling approach that is suitable for evaluating combined environmental effects associated with different land and water development scenarios and selecting specific development alternatives leading to sustainable use of ecosystem services. The proposed framework is based on the Hydrological Simulation Program-FORTRAN (HSPF) and has three main components: water availability (hydrological alterations), water quality (water quality alterations), and water demand (water allocation) simulation models.

MODELING CHALLENGES:

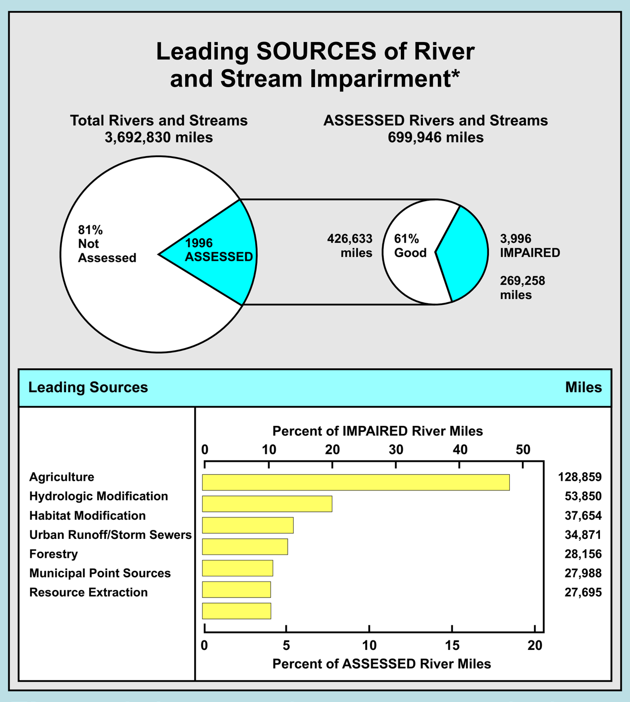

Figure 1: Increased stressor complexity

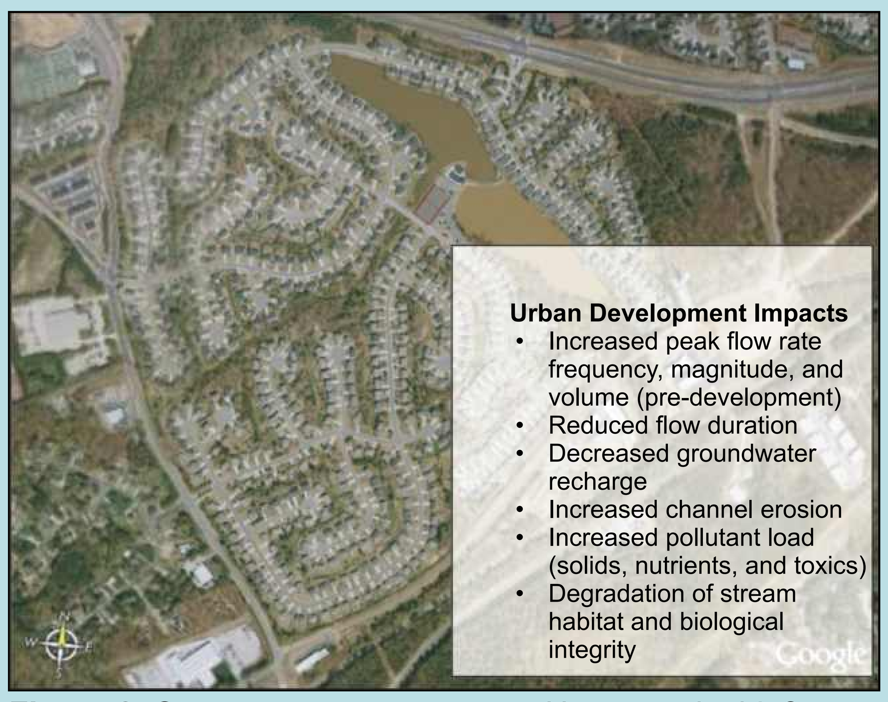

Figure 2: Stormwater management - How sustainable?

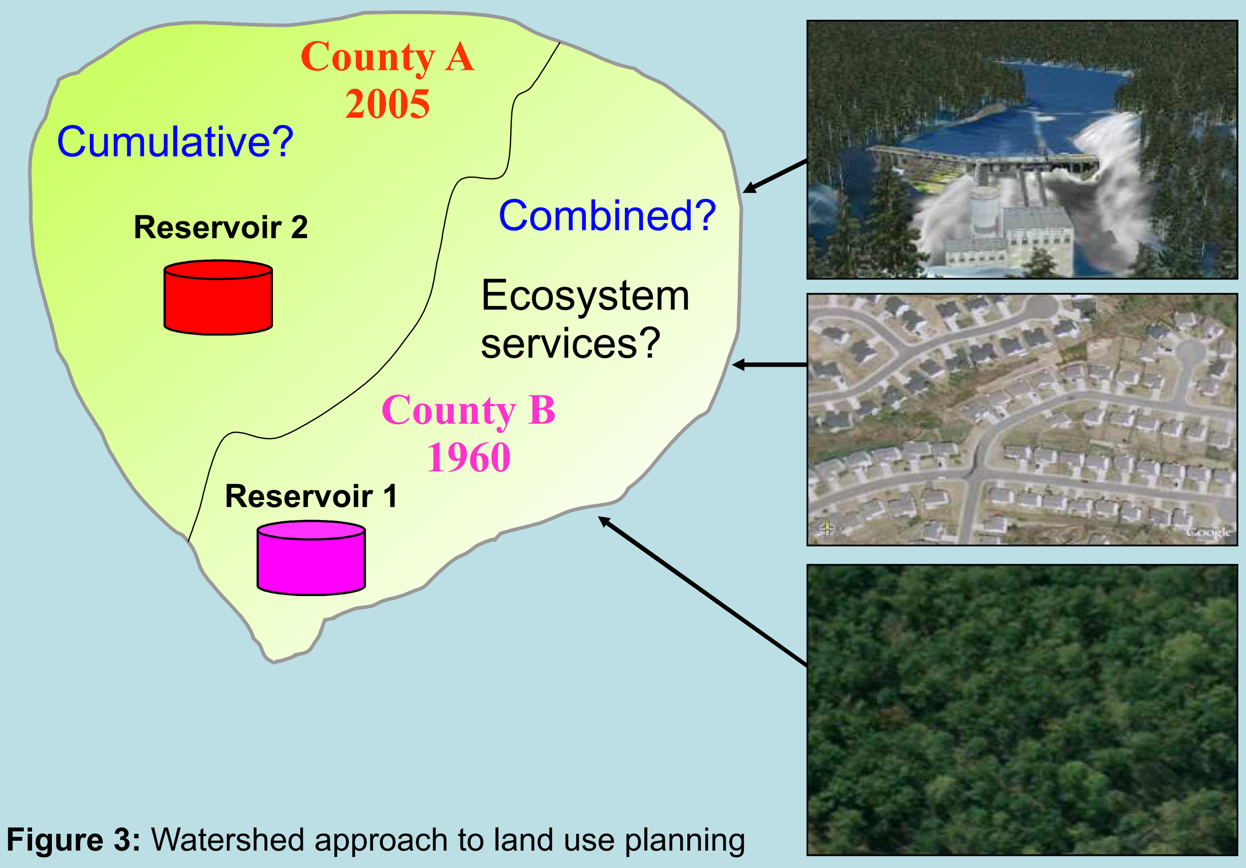

Figure 3: Watershed approach to land use planning

METHODOLOGY:

Part 1. Quantify land use change

- Hypothetical build-out scenario development
  - Convert forest and agriculture land to urban land with 15, 45, 85 percent of impervious cover
    - » 15% - Low density residential
    - » 45% - high density residential
    - » 85% - commercial
  - Maintain 13% of pervious urban land (green open space)

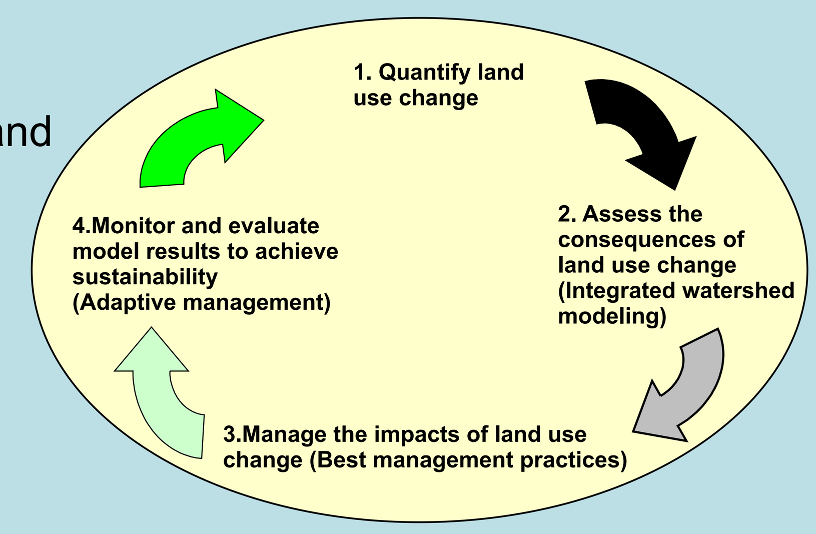

Figure 4: IWMF Framework

Part 2. Simulate hydrological and water quality alteration indicators

- Hydrologic indicator for increased flooding (Q5)
- Hydrologic indicator for channel morphological change (bankfull flow)
- Hydrologic indicator for baseflow reduction (Q95)
- Hydrologic indicator for ecological flow requirement (7Q10)

Part 3. Manage the impacts of land use change (Best management practices)

- Reservoir (watershed-wide land use planning)
- Other structural BMPs (site specific and source control measures)
  - Rain Barrels
  - Swales
  - Habitat Gardens
  - Retention Ponds
  - Stream Bank Restoration
  - Backyard Wetlands
  - Rain Gardens
  - Infiltration Basins
  - Porous Pavement Systems
  - Infiltration Trenches

Part 4. Monitor and evaluate model results to achieve sustainability (Adaptive management)

- Evaluate impacts of alternative development and management in an iterative fashion using an integrated watershed modeling approach

CASE STUDY:

Indian Creek, North Carolina

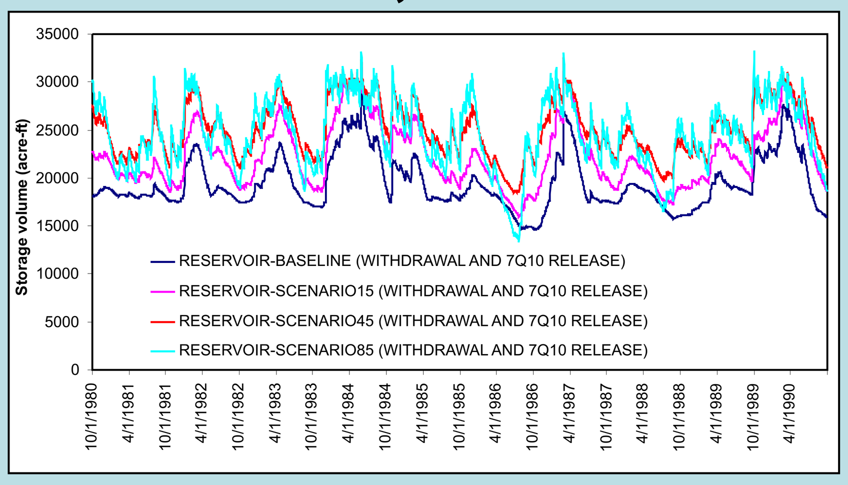

Figure 5: Long-term changes in water availability and demand (baseline and alternative scenarios).

Model results showing an IWMF simulation of reservoir storage (water availability) under baseline and alternative land use scenarios (15, 45, and 85% impervious cover) while maintaining a constant water supply withdrawal (26 MGD) and 7Q10 ecological flow release (6.5 ft^3/sec).

IWMF Re-enforces NYC Decision:

New York City opted to provide water purification service by purchasing development rights in watersheds of the Catskill Mountains for $1 billion; whereas building a filtration plant would have cost $6 to 8 billion plus $300 million in annual operating costs (Source: Science July 22, 2005).

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