Seeking Simple Models of Highly Nuanced Systems: Building a Model of Water Quality Management

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Governance networks emerge as the aggregate of the behaviors of the individual actors in the system as they pursue their own ends (Koliba *et al*, 2011). This is one of the defining dynamics of a complex adaptive system (Axelrod and Cohen, 2000), placing governance networks, and the systems in which they operate, in that framework. This means that the actions and interactions of each of the many actors and many types of actors in the system will have implications for the system's overall performance. What the framework does not indicate is what those implications will be and how they will manifest. Identifying the implications requires, first, identifying the actors and the rules by which they operate (Axelrod and Cohen, 2000; Ostrom, 2005). Second, it requires defining a plausible model that encodes these rules and the relevant actor characteristics to generate behaviors and test for alternate patterns (Ostrom, 2005; Epstein, 2006). Agent-based modeling offers a particularly attractive tool for this effort, as this type of modeling builds system by aggregating the behaviors of agent populations and embedding those agent populations within higher-level populations, just as occurs in empirical governance networks. This allows for addressing questions of how multiple agent populations relate to each other in the kind of complex relationships that exist between governance levels.

This study builds a model of the most basic levels of operation for the water quality governance system in the Lake Champlain Basin as an examination of how to apply agent-based modeling to governance systems. It examines the relationships between multiple tiers of governance, their relationships between each other and their relationships with governed populations. It uses data from organizational and institutional websites, combined with expert interviews to understand the formal and informal modes of operation in the system to define a model of governing actors interacting with governed agents to manage water quality. The design efforts show how complex system structure and rules of interaction as well as a large number of classes of deliberative actors prevent the formation of simple models.

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Outline v3

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I. Introduction and Problem
   A. Generative Modeling in a system of varyingly embedded actors
   B. Primary Research Question: How do these actors interact with each other and how can it be modeled?
   C. Intermediary Research Questions
      1. Who are the actors?
      2. What rules do they follow?
      3. What rules govern interaction?
      4. What model structures match to system structure?

II. Governance Systems/Networks and Complex Adaptive Systems
   A. Emerging use of networks and systems approaches in public admin
      1. First emergence in emergency management (Comfort, *Shared Risk*)
      2. Koliba *et al*, 2011 for application to non-EM policy domains
      3. Nested structure of governance (Koliba *et al*, 2011)
   B. Complex Adaptive Systems and their use in public admin
      1. Basics of what they are
      2. How LCB fits as a complex system
      3. How to analyze
         i. IAD and *Harnessing Complexity* frameworks
         ii. Network and simulation modeling
      4. Generative Social Science and the Non-Reductionist approach
   C. Policy Informatics and Knowledge in Complex Systems
      1. Data-driven policy and forecasting (Knowledge Commons)
      2. Role of modeling (SD/ABM) in policy informatics (Chris's work)
      3. Use of Models
         i. Initial Conditions
         ii. Model Runs
         iii. Model Outputs

III. Data Sources
   A. Actors
      1. State and Federal Agencies
         i. NRCS programs and their websites
         ii. ANR and AAFM programs and websites
      2. Basin Program and its publications

3. TMDL and OFA plans for fuller picture of actors, including NGOs

B. Rules
   1. Cover individual behavior
   2. Cover interactions between actors
   3. Interviews used to probe beyond official rules (including transcription coding)

C. Data Analysis
   1. Websites and public data give official structures
   2. Interviews give unofficial
   3. Examined for patterns between interviews and across sources
   4. Where found indicate reliable structures for the model

IV. Model Structure (Present govABM v.4.x diagrams)

A. Model Initial Conditions
   1. Policy and Program Conditions
   2. Applicant Conditions
   3. Initial Conditions for items 1 and 2
      i. Conceptual
         a. Network
            i. Existence
            ii. Structure
            iii. Multiplexity
         b. Substantive
      ii. Empirical
      iii. Technical

B. Agent-based model
   1. Federal Policy Domains
      i. Sub-agents
         a. Federal Programs (National Offices)
         b. Federal Programs (State Offices)
         c. Applications to federal programs
      ii. Process and controls
         a. Planning
         b. Outreach
         c. Application review
         d. Budgeting/fund distribution
   2. State Policy Domains
      i. Sub-agents
         a. Stake Programs
         b. Applications to state programs
         c. Towns

d. Landowners

ii. Processes and controls

a. Various planning processes

b. Application review

c. Budgeting, funds distribution, and coordination

d. Network effects

i. Plan acceptance

ii. Program use decisions

3.NGO Policy Domains

4.These three domains exist in Main Object

i. Accounts for federal separations

ii. Allows for defining overlapping and non-overlapping domains

C. Space for experimentation

1.Program/Policy tool funding levels

i. Absolute level

ii. Relative weightings

2.Level of applicant buy-in

3.Operational Cost structures

4.Network layout/Level of impact

5.Network positions and information flow

D. Model Outputs

1.Detailed data output

2.System behavior outputs

V. Conclusions and Future Research

A. Simple models can speak to pieces of a system

B. Models with interacting populations will be inherently complex; the simplest functional models will still be complicated

C. Complex systems require non-reductionist approaches to allow for a wide space of potential output that can account for nuanced agent choice/Complex nesting relationships will generate a complicated model

D. Simplicity is still the goal, but it can quickly and easily be overwhelmed when accuracy requires multiple populations of deliberative agents with *multiplex* relationships

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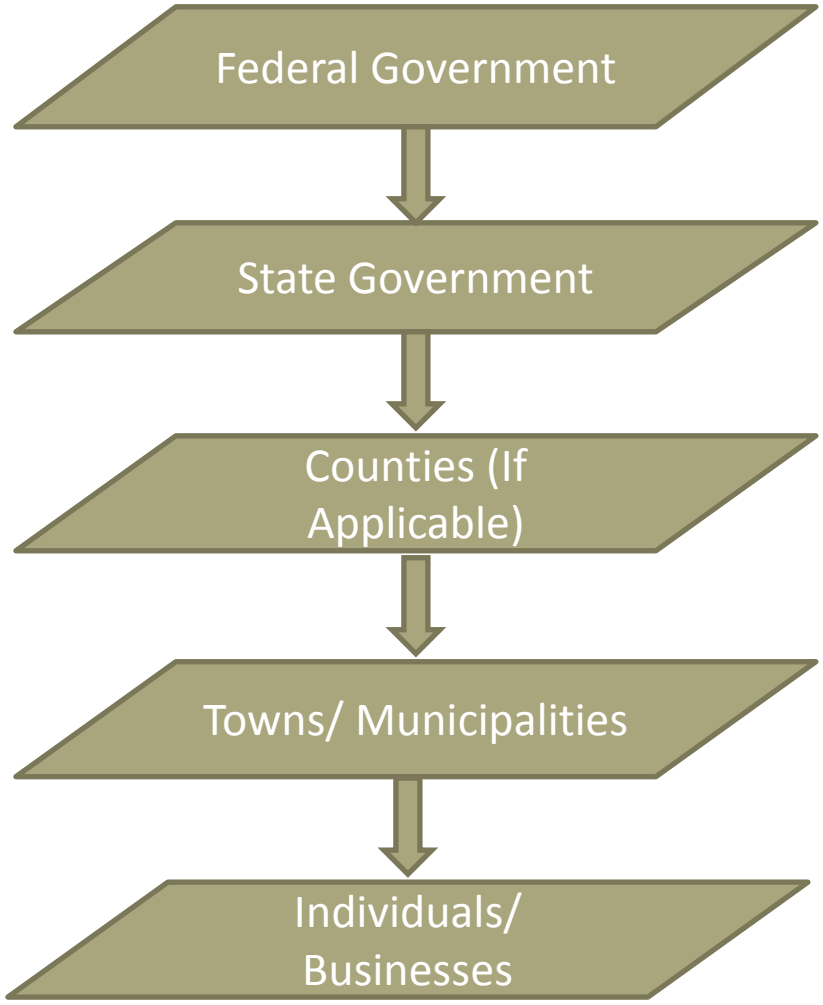
Analyzing Governance Networks

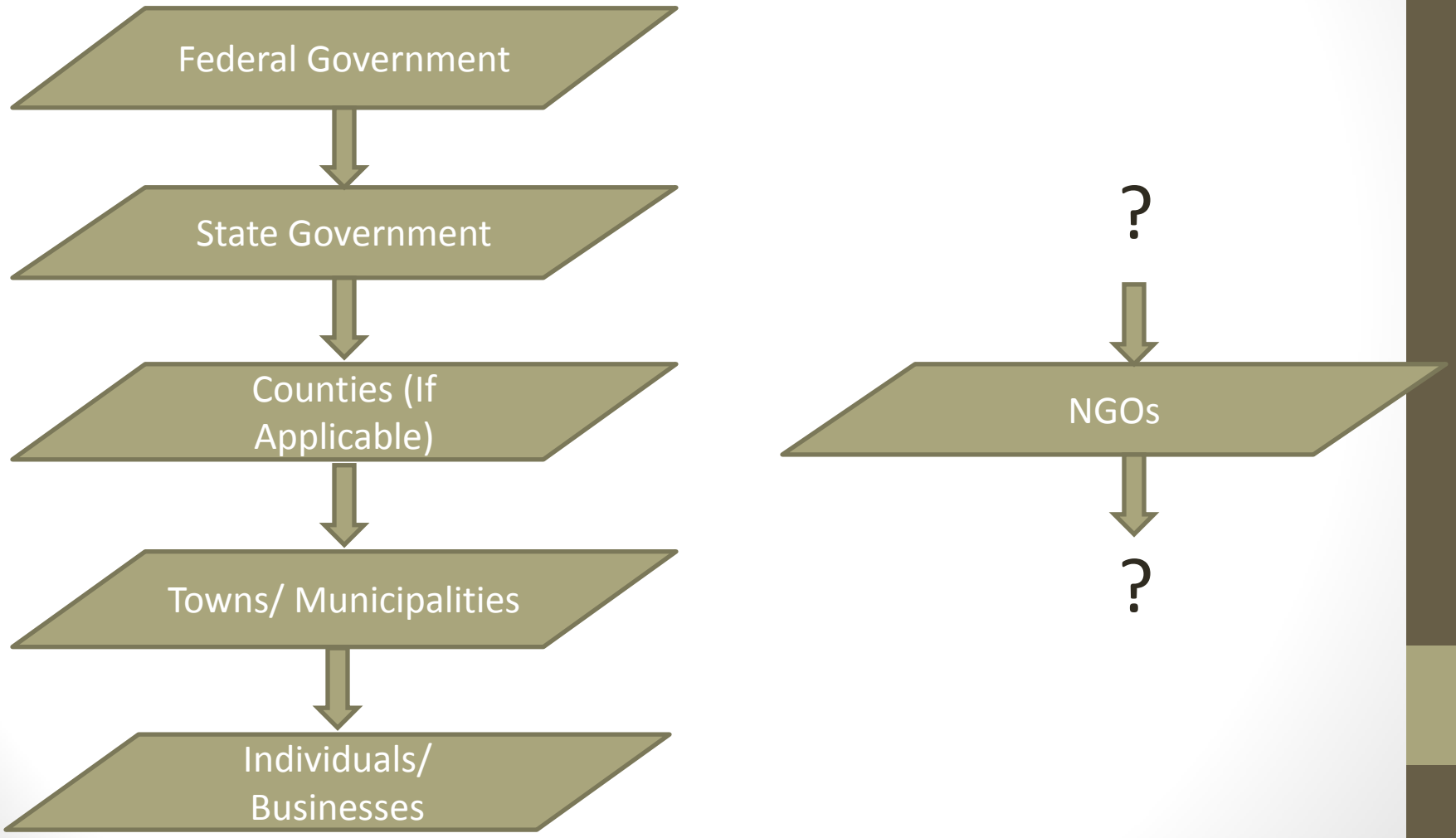
- Many actors of different types: Which do you analyze?
  - Federal programs?
  - State programs?
  - Local towns?
  - Individuals?
- Each could (and should) be a separate unit of analysis
- Each level is important
- Each level influences all the others

- How do each relate to each other and how does those relationships impact system performance?

Nested Sets


Federal Government
State Government
Counties (If Applicable)
Towns/ Municipalities
Individuals/ Businesses

Nested Sets


Federal Government
State Government
Counties (If Applicable)
Towns/ Municipalities
Individuals/ Businesses
?
NGOs
?

Governance Networks and Complex Adaptive Systems

- Emerging use of networks and systems approaches in public administration
  - Network of actors engaged in a policy domain
  - System emerges from the aggregated actions of the actors
  - Networks exist embedded in other networks

- Complex Systems
  - Actively and continuously adapting to changes in the system
  - Interdependent, non-linear relationships and path dependency
  - Studied through tailored frameworks
    - Ostrom's Institutional Analysis and Development (IAD) framewok
    - Axelrod and Cohen's Complex Adaptive Systems framework

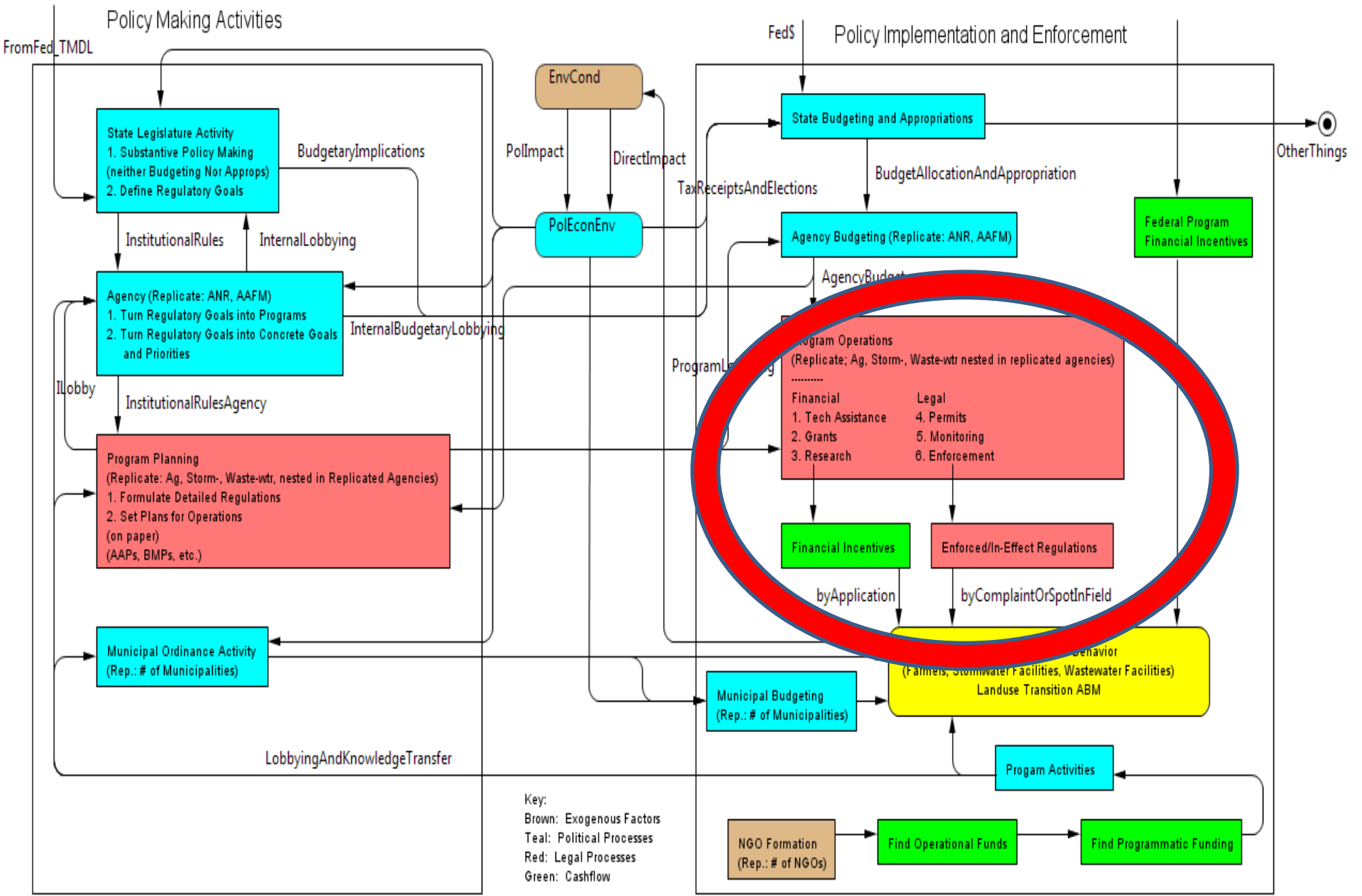
Agent-Based Governance Model (GovABM)

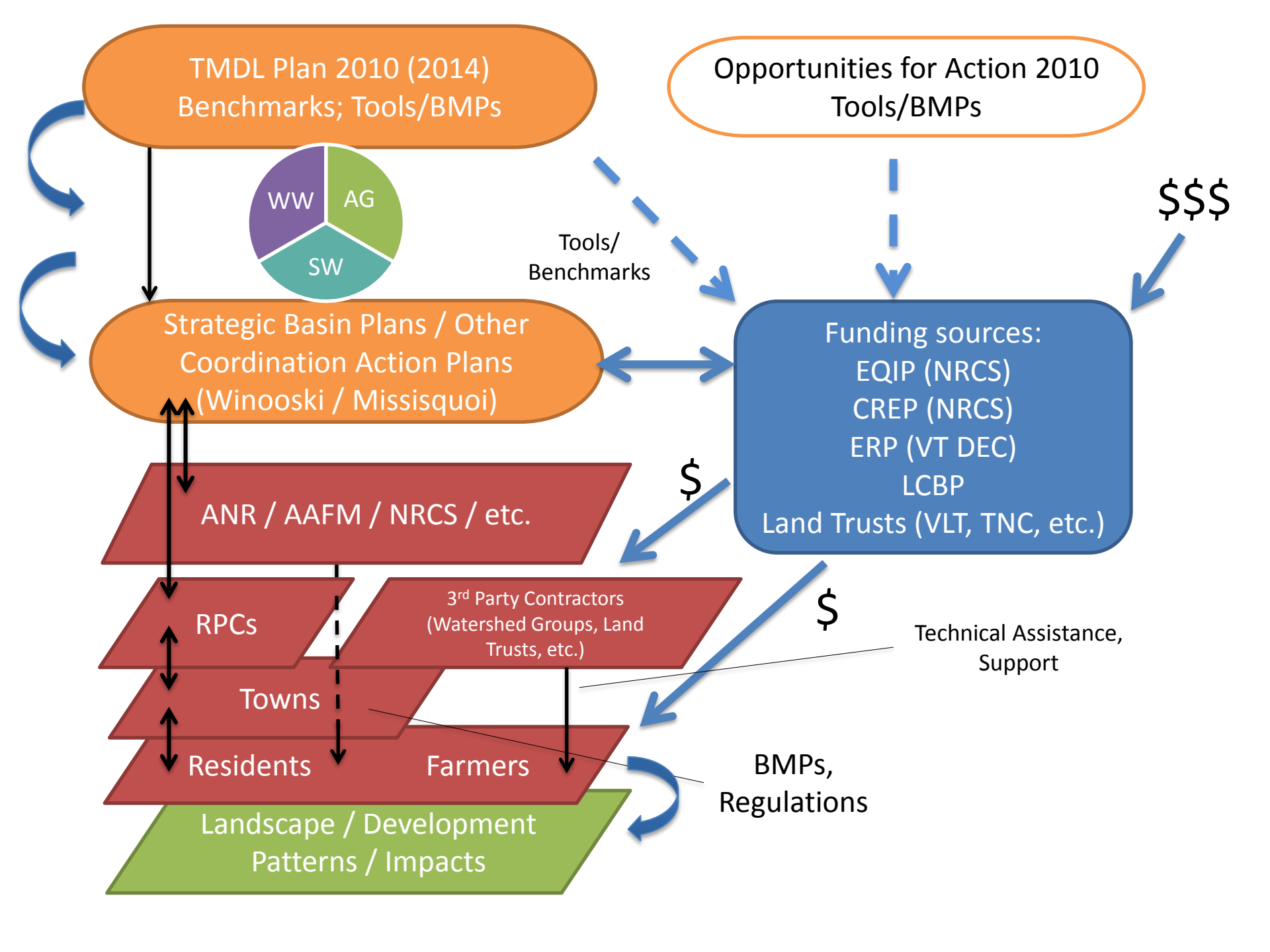
- Empirical governance systems are an aggregation of actors, their behaviors, and the nested networks of actors

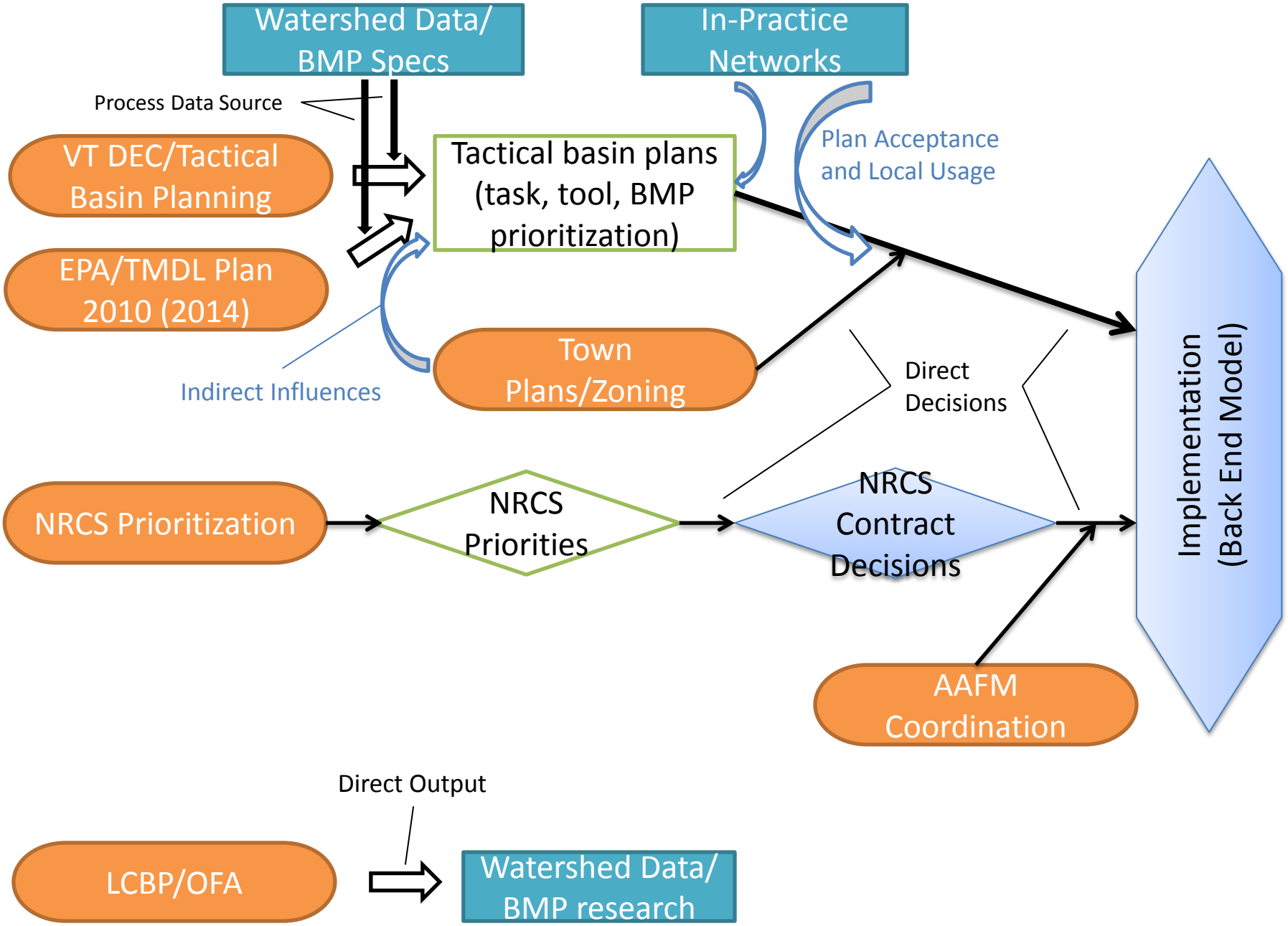
- Agent-based modeling matches this construction, allowing for the nesting of agent populations
  - Agents within agents within agents within…
  - Consistent line of agents (International → Federal → State → …)
  - Varying behaviors and parameters for each population and subpopulation

- Allows for emergent behavior patterns

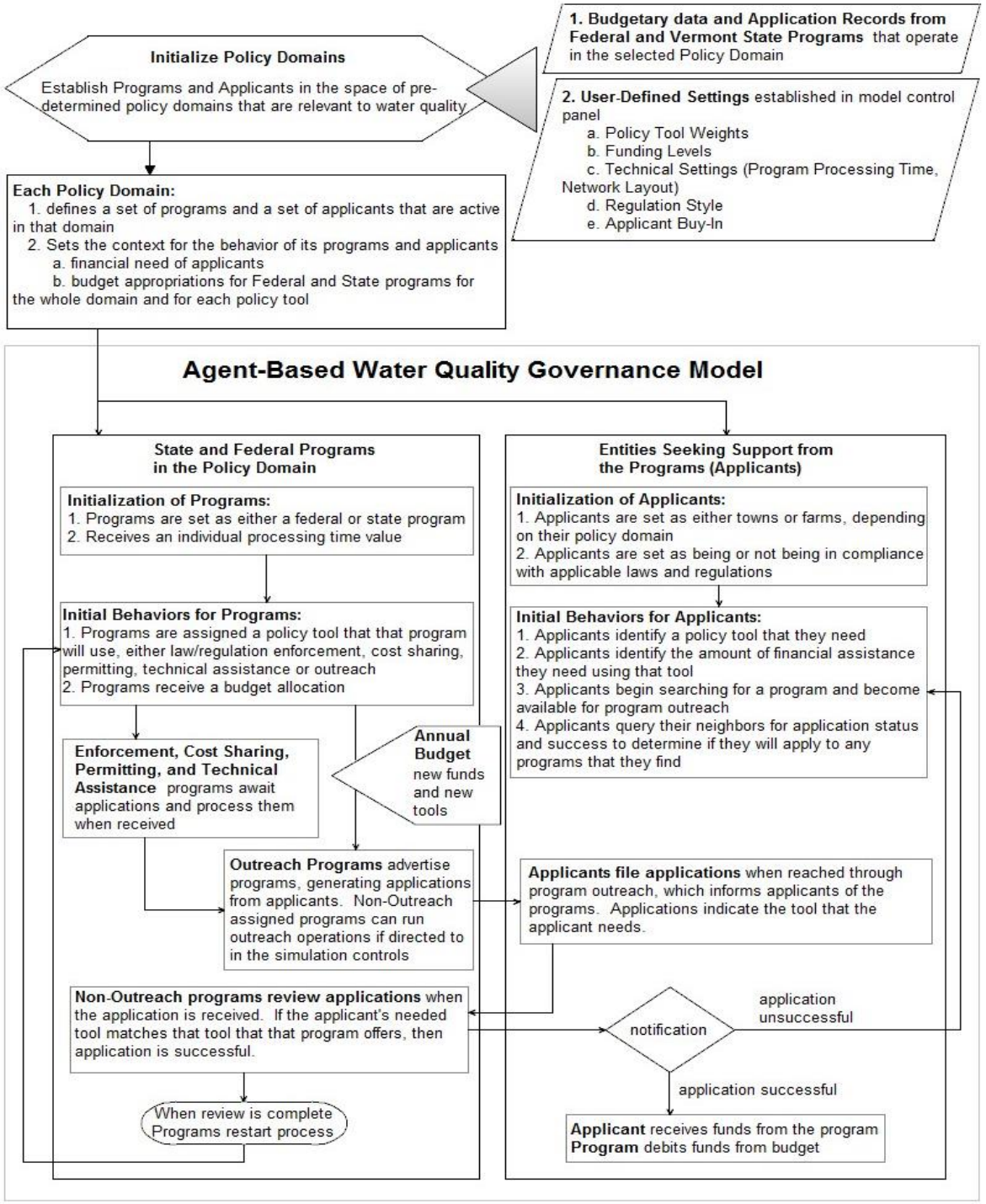
Full System with Decision Mechanisms (GovABM v.2.0)




TMDL Plan 2010 (2014)
Benchmarks; Tools/BMPs
Opportunities for Action 2010
Tools/BMPs
WW
AG
SW
Tools/
Benchmarks
$$$
Strategic Basin Plans / Other
Coordination Action Plans
(Winooski / Missisquoi)
Funding sources:
EQIP (NRCS)
CREP (NRCS)
ERP (VT DEC)
LCBP
Land Trusts (VLT, TNC, etc.)
$
ANR / AAFM / NRCS / etc.
RPCs
3rd Party Contractors
(Watershed Groups, Land
Trusts, etc.)
$
Technical Assistance,
Support
Towns
Residents
Farmers
BMPs,
Regulations
Landscape / Development
Patterns / Impacts


Watershed Data/ BMP Specs
In-Practice Networks
Process Data Source
VT DEC/Tactical Basin Planning
Tactical basin plans (task, tool, BMP prioritization)
Plan Acceptance and Local Usage
EPA/TMDL Plan 2010 (2014)
Indirect Influences
Town Plans/Zoning
Direct Decisions
Implementation (Back End Model)
NRCS Prioritization
NRCS Priorities
NRCS Contract Decisions
AAFM Coordination
Direct Output
LCBP/OFA
Watershed Data/ BMP research

Process Map: GovABM v.3.2



Model Nested Populations (GovABM v.4.0)

- Federal Domains
  - Federal Programs (National Office)
    - Federal Programs (State Office)
      - Applications to federal programs
- State Domains
  - State Programs
    - Applications to state programs
  - Towns
    - Landowners
- NGO Domains
  - NGOs

Model Dynamics

- Primary Processes
  - Writing plans
    - Prioritizing policy tools
    - Prioritizing water quality management tools
    - Determining general support for the plan
  - Implementing programs
    - Budgeting from plans
    - Generating, assessing, and funding contracts for voluntary actions
    - Enforcing regulations for mandatory actions
- Agent Networks
  - Between landowners
  - Between governance levels

Simulation Controls

- Selection of Active Domains in each Domain Population
- Selection of State, Local, and Federal conservation priorities
- Selection of Policy Scenarios
  - Controls will give a name and description of each scenario
  - Controls will allow differing combination of the scenarios to be selected
  - Selection will set Main-Level parameter values

Conclusions

- Nested Agent-Based Modeling
  - Use ABMs to match the agent structure of groups, cells, and individuals
  - Addresses the problem of relationships between varying units of analysis

- Generative Social Science
  - Fill gaps in data
  - If you can recreate it, then you can explain it

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