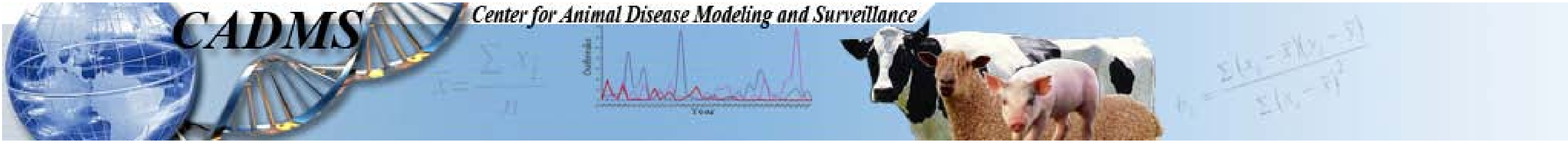


Modeling Wildlife/Livestock Disease Transmission

Tim Carpenter

Center for Animal Disease Modeling and Surveillance (CADMS),

School of Veterinary Medicine, University of California, Davis

CADMS Base and Projects

- **25 FTEs**
  - **Computational biology, Computer science, Ecology and Evolution, Environmental Engineering, Economics, Entomology, Epidemiology, GIS, Hydrology, Medicine, Microbiology, Modeling, Oceanography, Parasitology, Statistics, Veterinary Medicine, Virology, Wildlife Medicine**
  - **Undergraduates, Veterinary students, Graduate students (MPVM & GGE, etc.) Postdoctoral fellows, Visiting scientists**

US Collaborators

Universities
National Labs
USDA, DOI, USFS, IC , DHS
State Depts. of F&G and F&A,
Industry

International Collaborators

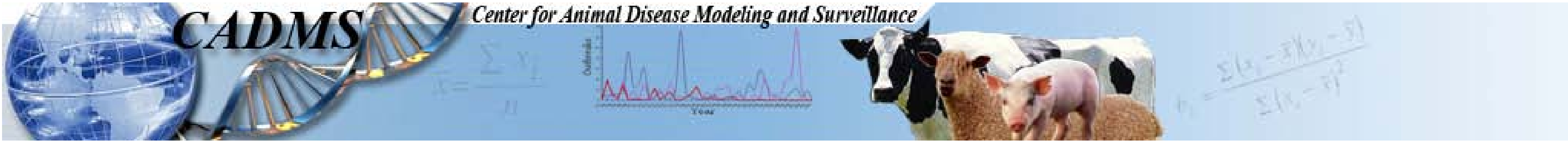
- **Argentina, Australia, Canada, Chile, China, Colombia, Costa Rica, Denmark, France, Germany, Great Britain, Israel, Italy, Iran, Israel, Kenya, Kuwait, Mexico, New Zealand, Northern Ireland, Pakistan, Palestine, Republic of Korea, Spain, Switzerland, Thailand**

The Challenge of Wildlife Disease Modeling

- DATA

Wildlife Data

- Typically unavailable
- When available, analysis needed to make it useful for modeling purposes

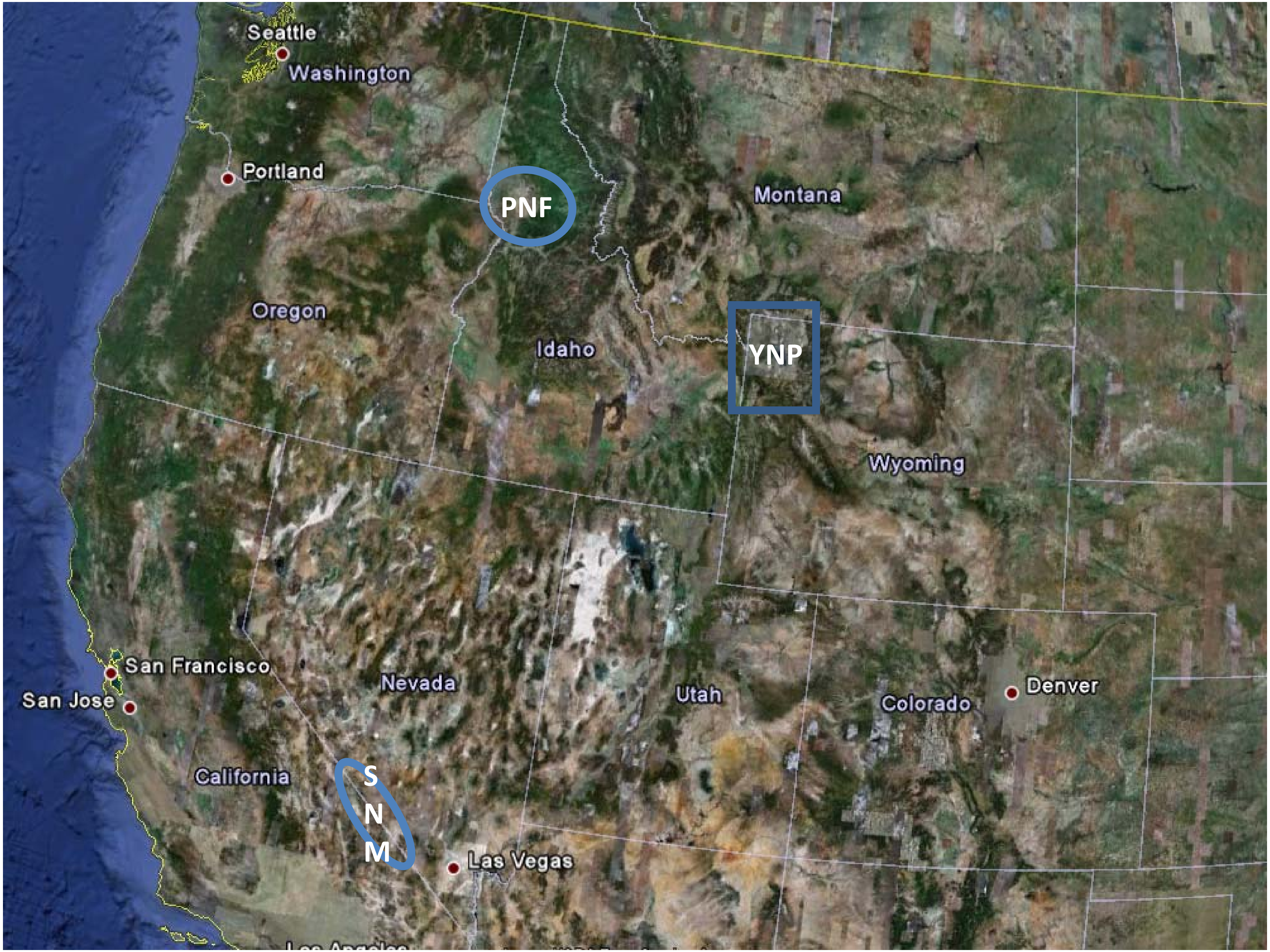


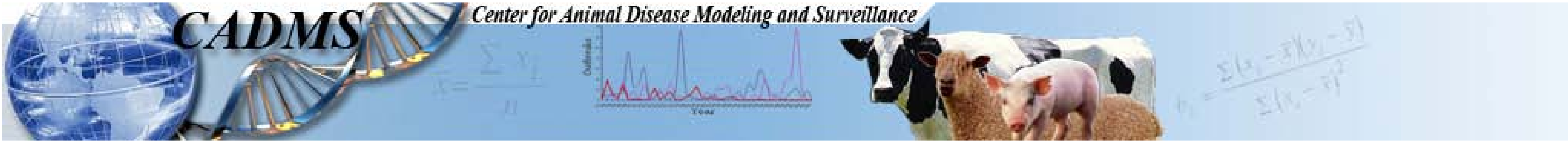
Outcome Metrics
Livestock vs. Wildlife

- **Livestock** – time to eradication, no. of IPs, no. animals slaughtered, number of herds under quarantine, time to eradication, economic impact
- **Wildlife** –probability of transmission to/from livestock, probability of establishment as a reservoir, probability of extirpation.

Wildlife Disease Modeling at CADMS

- Brucellosis in Bison and Elk in Yellowstone National Park
- Toxoplasmosis in wildlife in California
- Feral swine movements/contacts (LKH)
- **Pneumonia in Bighorn Sheep in the** Sierra Nevada Mountains and **Payette National Forest**


Seattle
Washington
Portland
PNF
Montana
Oregon
Idaho
YNP
Wyoming
San Francisco
San Jose
Nevada
Utah
Colorado
Denver
California
S
N
M
Las Vegas



Case Study: Bighorn Sheep in PNF

- Requested by USFS in 2009
- Pursuant to >14,000 comments on PNF EIS in 2005
- Need to address concerns of BHS viability
- Collaborators included USDA, USFS, tribes, State Departments of Agriculture and Fish and Game
- Our charge assess long-term viability of BHS and develop
    - Habitat model
    - Core herd home range analysis
    - Foray (sallie or sortie) analysis
    - Contact analysis
    - Disease model

source: Harrington and Tumay, 2000. Simulation Modeling Methods

Bighorns, beware: bill would let F&G shoot to kill

- The Associated Press
Published: 04/16/09

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ELSEWHERE
• http://www.idahostatesman.com/

BOISE, Idaho — House lawmakers approved a bill mandating the state Department of Fish and Game kill or move wild sheep that wander onto public grazing allotments above Hell's Canyon, North America's deepest river gorge.

The measure cleared the Senate before Thursday's 51-17 vote.

It now goes to Gov. C.L. "Butch" Otter.

Western Idaho rancher Ron Shirts has frequented the 2009 Legislature this year, to rail against a 1997 agreement ranchers signed with the U.S. Forest Service, states and sheep groups to protect their operations from problems, should transplanted bighorns mix with domestic sheep.

With the Forest Service considering forcing Shirts and others to shutter grazing to protect bighorns from deadly illnesses, this latest bill aims to send a message to federal managers to stop.

Environmentalists want foes to work on a solution.

Bighorn Sheep Viability UPDATE TO THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

Nez Perce & Clearwater N.F., BLM, Congressional Staff Briefing

Payette National Forest

January 2010

373 page document

Modeling Approaches

- **Bottom up**
  - All lowest-level activities are defined first
  - May result in too much detail too soon
  - Usually preferred by analysts
- **Top down**
  - Decomposition of a major process until a sufficient level of detail is obtained in describing the behavior of a process
  - Advantages are simplicity and easily communicated
  - Drawback is that it can leave out activities or details, assuming they will be modeled in another process

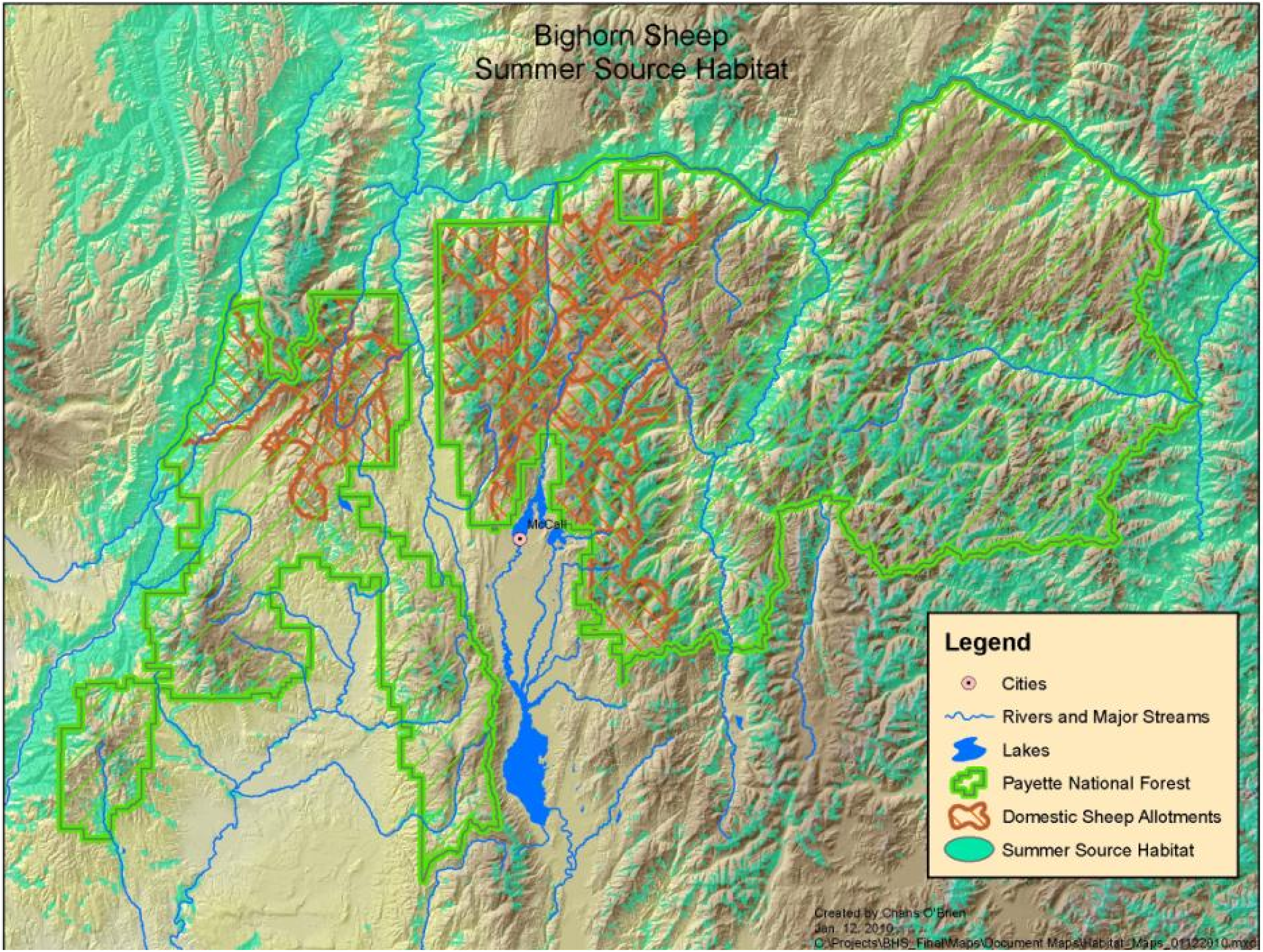
Top Down vs. Bottom Up Examples for BHS Problem

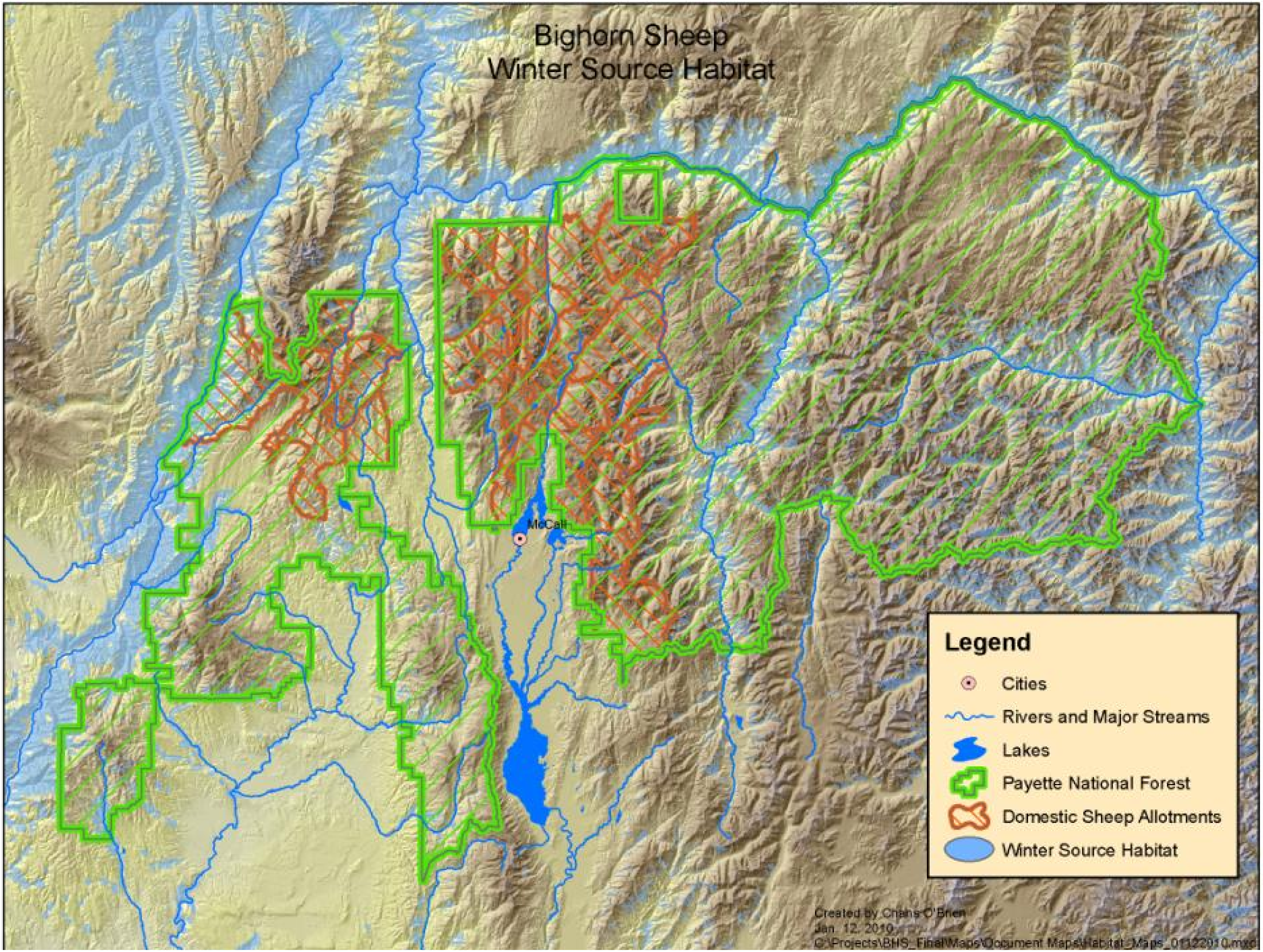
- **Bottom up**
  - Activities to be defined: herd demographics (lamb, ewe, ram (LER) composition); lambing rate; LER survival rate; LER disease prevalence and incidence rates; LER case-fatality rates; recruitment rates, sallies, home ranges, habitat suitability, seasonality, etc.
- **Top down**
  - Major process = BHS annual population numbers
  - Decomposition into the following processes: annual net growth (non-diseased, endemic and epidemic herds); pneumonia impact; BHS-DS contacts; BHS-BHS contacts

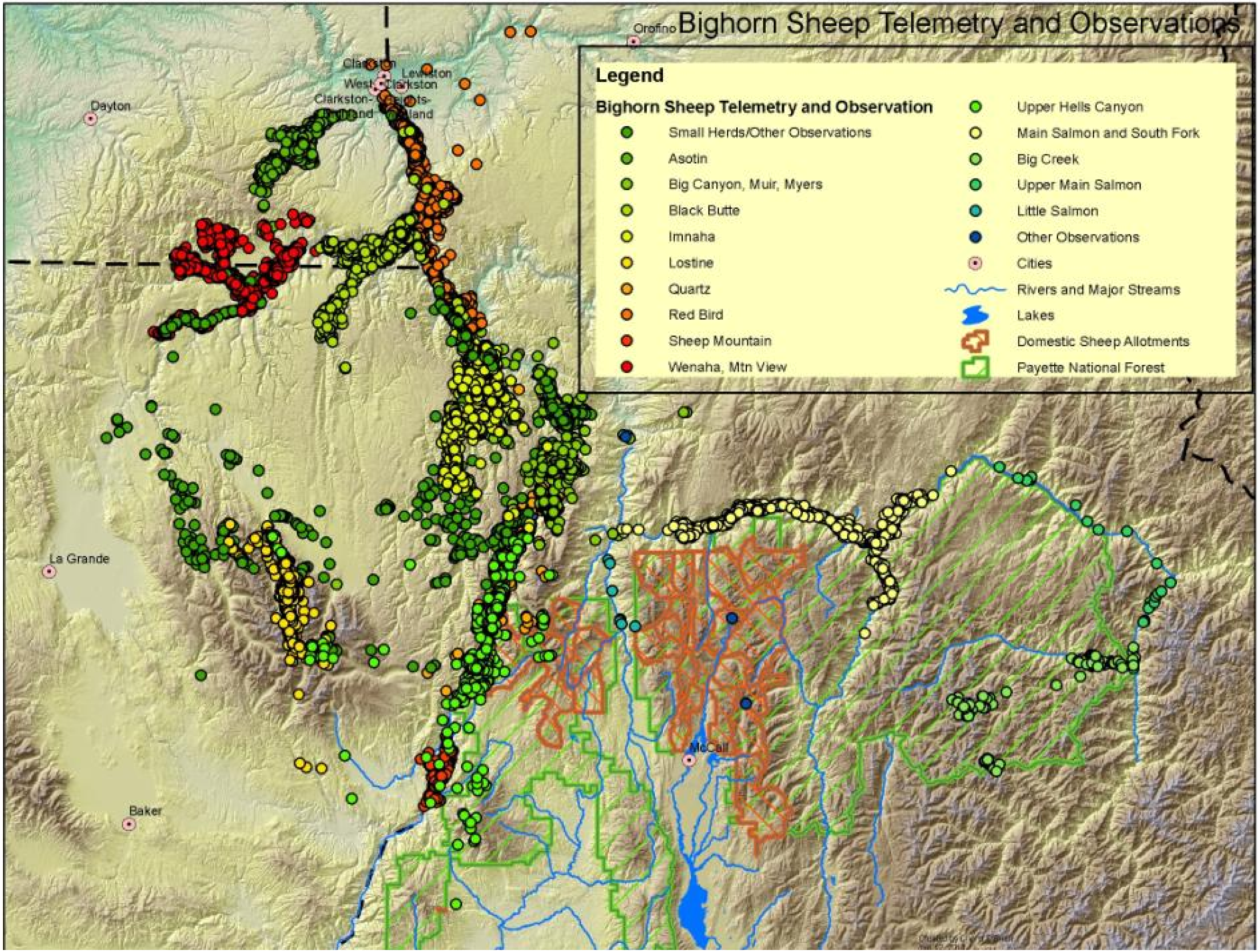
Top Down vs. Bottom Up

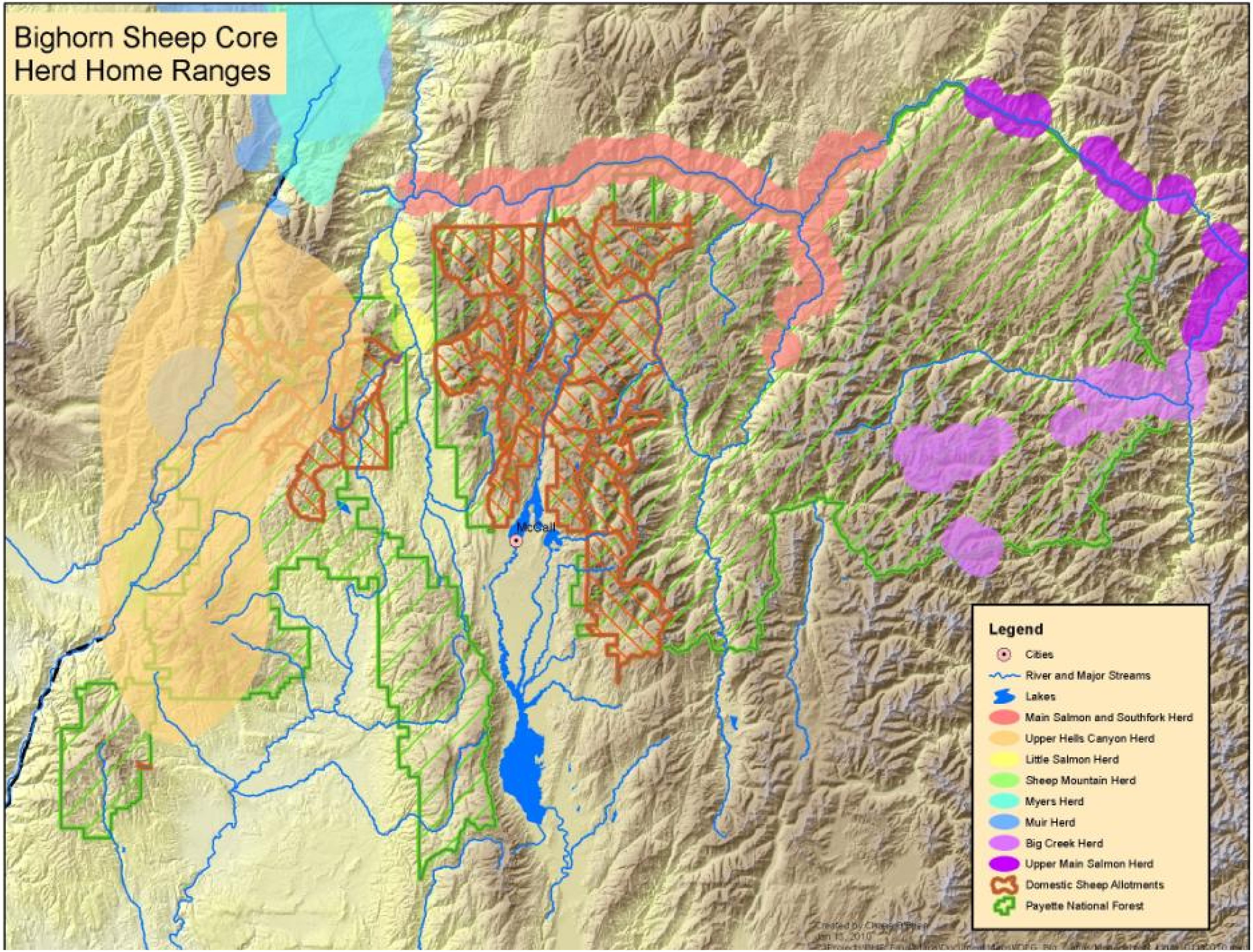
"Based on our experience, we recommend the top-down approach, because incorporating too much detail too soon is one of the pitfalls of process simulation… We recommend that a process not have any more than five to seven subprocesses…"

source: Harrington and Tumay, 2000. Simulation Modeling Methods

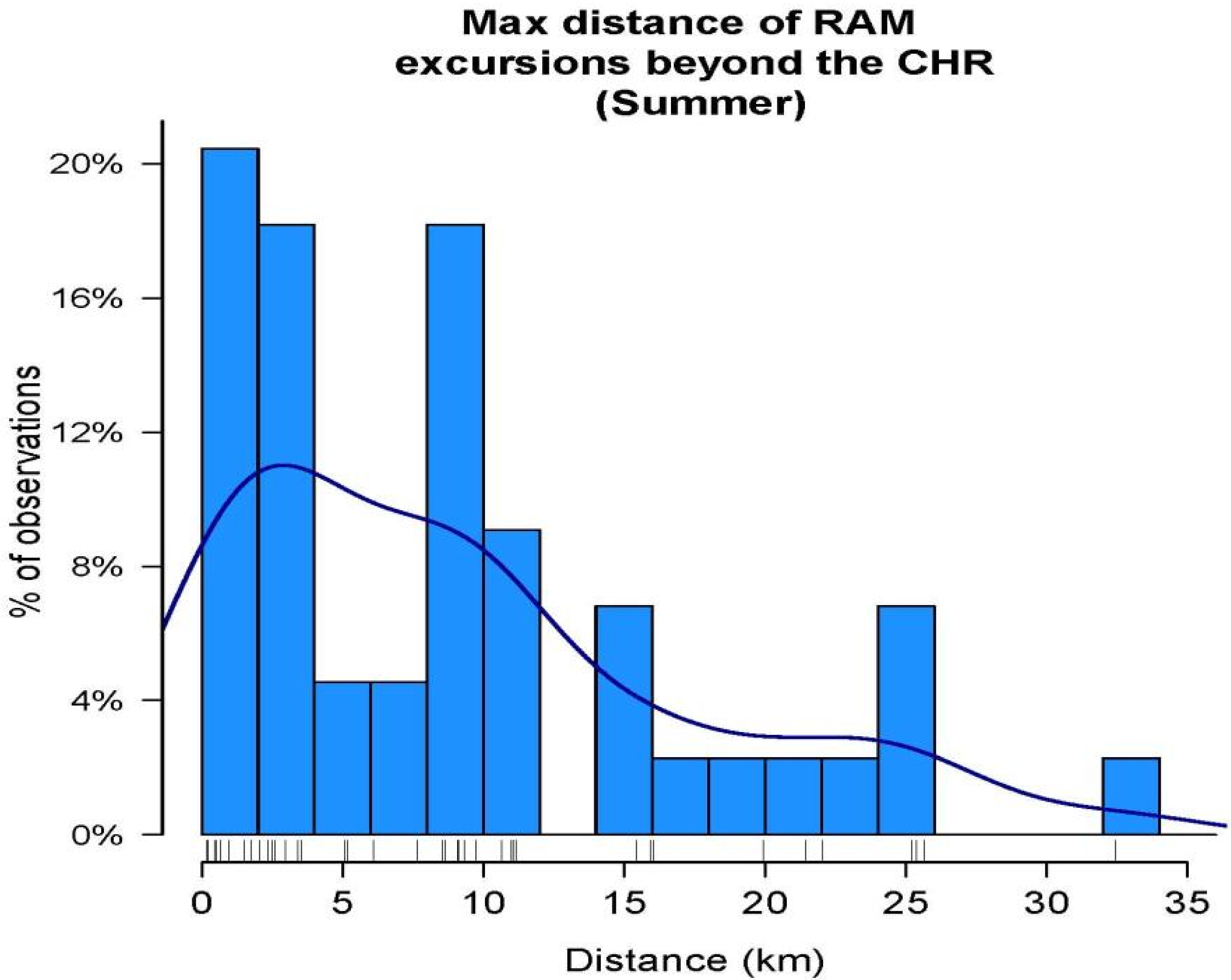

Bighorn Sheep
Summer Source Habitat
McCall
Legend
Cities
Rivers and Major Streams
Lakes
Payette National Forest
Domestic Sheep Allotments
Summer Source Habitat
Created by Chris O'Brien
Jan. 12, 2010
C:\Projects\BHS_FinalMaps\Document Maps\Habitat_Maps_01122010.mxd


Bighorn Sheep
Winter Source Habitat
McCall
Legend
Cities
Rivers and Major Streams
Lakes
Payette National Forest
Domestic Sheep Allotments
Winter Source Habitat
Created by Chans O'Brien
Jan. 12, 2010


Bighorn Sheep Telemetry and Observations
Legend
Bighorn Sheep Telemetry and Observation
Small Herds/Other Observations
Asotin
Big Canyon, Muir, Myers
Black Butte
Imnaha
Lostine
Quartz
Red Bird
Sheep Mountain
Wenaha, Mtn View
Upper Hells Canyon
Main Salmon and South Fork
Big Creek
Upper Main Salmon
Little Salmon
Other Observations
Cities
Rivers and Major Streams
Lakes
Domestic Sheep Allotments
Payette National Forest
Orofino
Dayton
La Grande
Baker
McCall


Bighorn Sheep Core
Herd Home Ranges
McCall
Legend
Cities
River and Major Streams
Lakes
Main Salmon and Southfork Herd
Upper Hells Canyon Herd
Little Salmon Herd
Sheep Mountain Herd
Myers Herd
Muir Herd
Big Creek Herd
Upper Main Salmon Herd
Domestic Sheep Allotments
Payette National Forest


Main Salmon & Southfork
Core Herd Home Range
Legend
Cities
Telemetry and Observations
River and Major Streams
Lakes
Main Salmon & South Fork Core Herd Home Range
Domestic Sheep Allotments
Payette National Forest


Max distance of RAM
excursions beyond the CHR
(Summer)
20%
16%
12%
8%
4%
0%
% of observations
0
5
10
15
20
25
30
35
Distance (km)

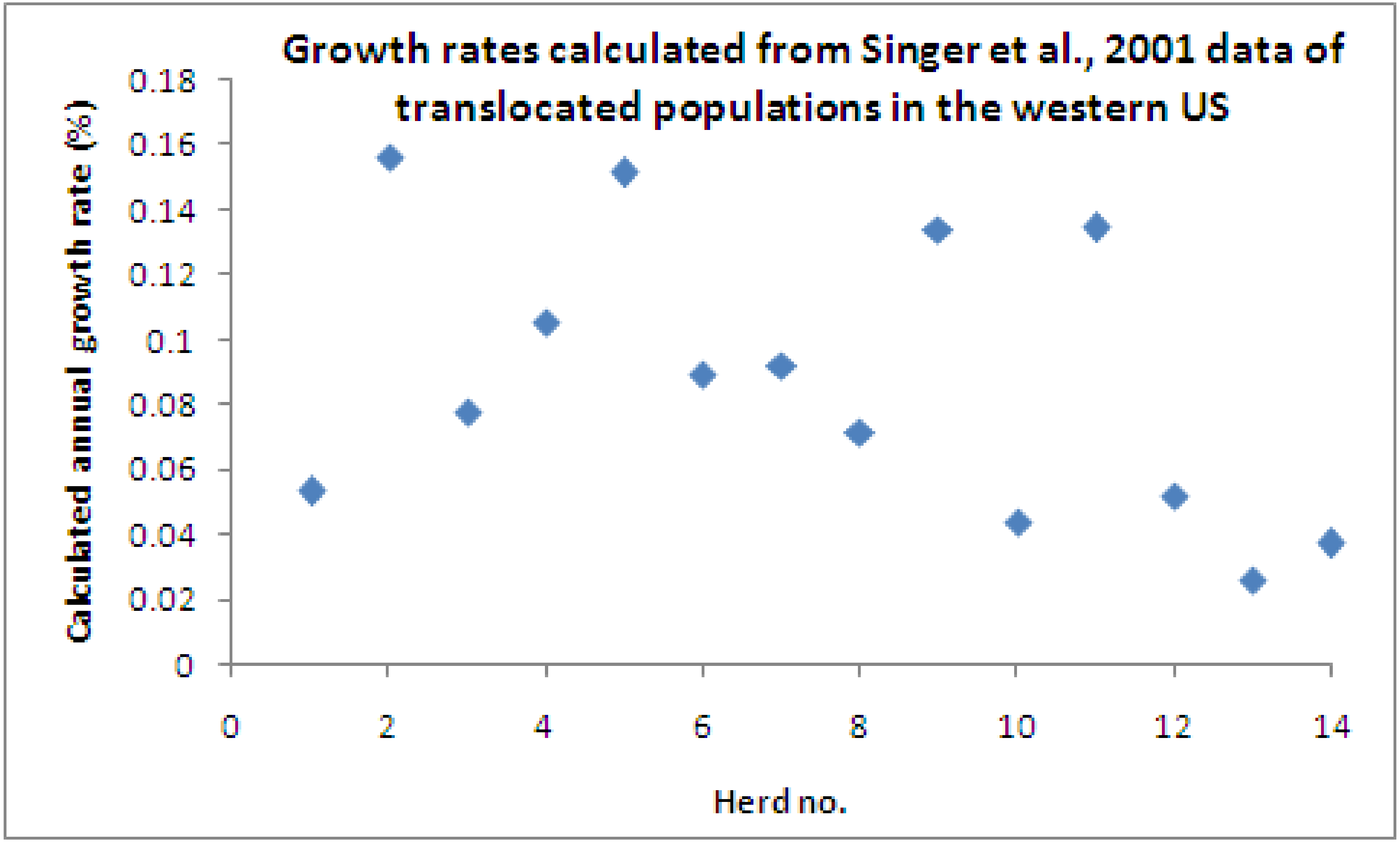
Parameters (subprocesses) obtained from data, literature and expert opinion

- Herd growth rate
- Herd carrying capacity
- Minimum viable population numbers
- Probability of an epidemic
- Probability of herd-to-herd contact
- Impact of an epidemic (1 or multiple years)
- Impact of an endemic condition

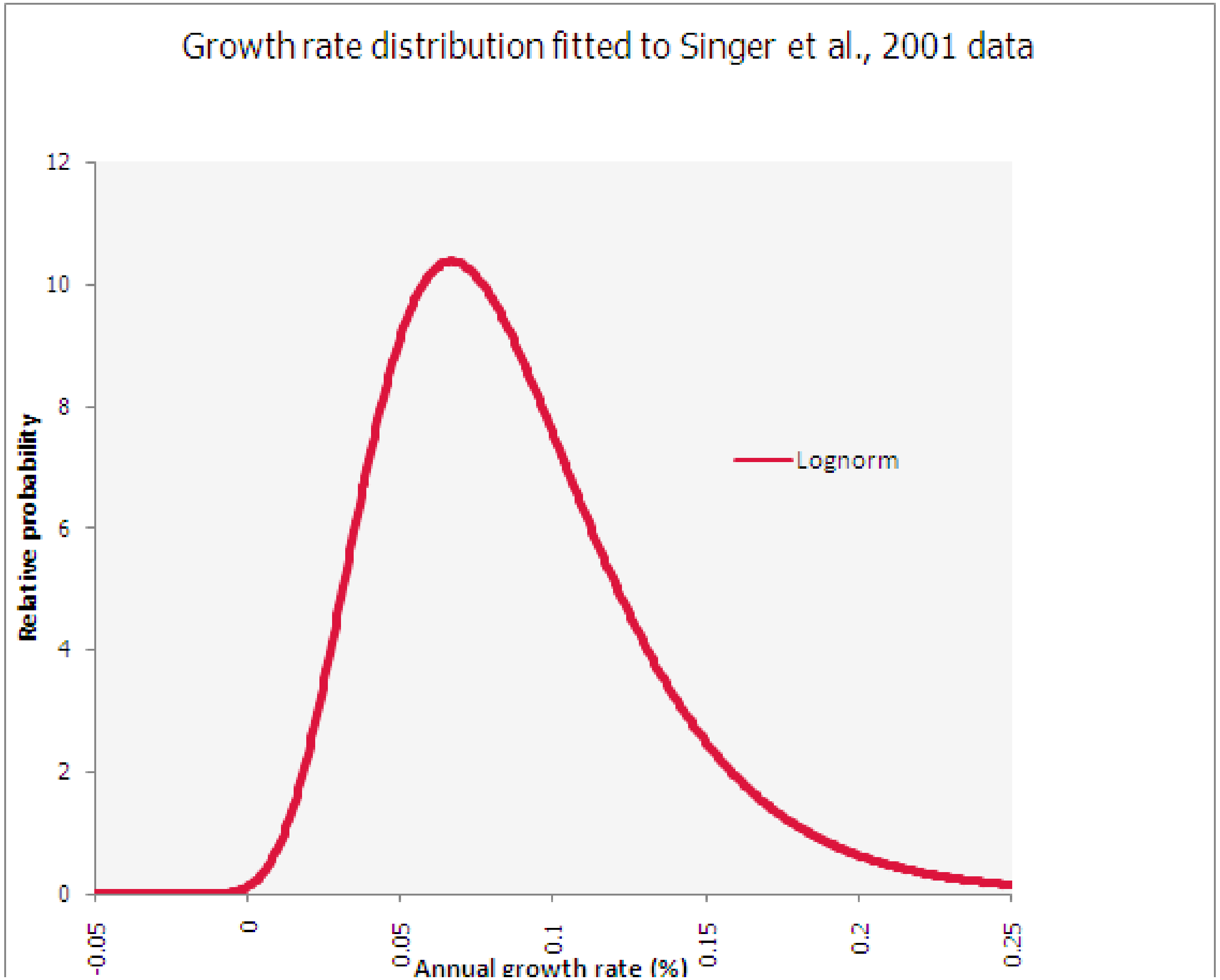
Bighorn Sheep Pneumonia Model

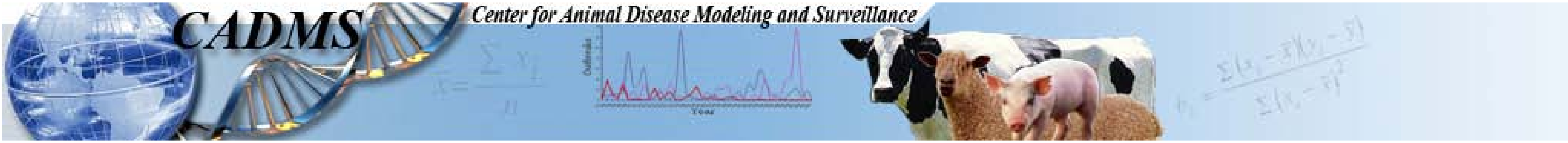
- Uses contact probabilities from core herd range (CHR) and foray behavior analyses
- Predicts herd growth in absence of disease
- Predicts the probability of disease spread within and among bighorn sheep populations
- Determines short-term impact and persistence in the infected herd over time
- Parameters are stochastic and based on historic data and historic records
- Results are used as a relative comparison between alternatives

Example of input parameterization (herd growth rate)



Example of Input Parameterization (herd growth rate)





Contact Probability Matrix

	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW
1		Probability of		**FROM**																	
2				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3		interherd	contact	Asotin	Big_Canyon	Big_Creek	Black_Bu	Imnaha	Lick_Cree	Little_Sa	Lostine	Main_Salmo	McGraw	Mountain_\	Muir	Myers	Quartz	Red_Bird	Sheep_Mou	Upper_I	Wenaha
4		1	Asotin	0.0000	0.0000	0.0000	0.0055	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0233	0.0000	0.0000	0.0000	0.0187	0.0000	0.0000	0.0070
5		2	Big Canyon	0.0000	0.0000	0.0000	0.0000	0.0199	0.0000	0.0005	0.0000	0.0018	0.0008	0.0000	0.9990	0.9999	0.9990	0.0060	0.0000	0.0000	0.0000
6	**TO**	3	Big Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9999	0.0000
7		4	Black Butte	0.0049	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0180	0.0039	0.0000	0.0001	0.9999	0.0000	0.0000	0.0092
8		5	Imnaha	0.0000	0.0198	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024	0.0000	0.9990	0.0238	0.0322	0.9999	0.0000	0.0000	0.0000
9		6	Lick Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10		7	Little Salmo	0.0000	0.0005	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0247	0.0152	0.0000	0.0093	0.0151	0.0224	0.0000	0.0000	0.0000	0.0000
11		8	Lostine	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0002	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000
12		9	Main Salmo	0.0000	0.0014	0.0010	0.0000	0.0000	0.0002	0.0103	0.0000	0.0000	0.0030	0.0000	0.0074	0.9999	0.0145	0.0000	0.0000	0.9999	0.0000
13		10	McGraw	0.0000	0.0006	0.0000	0.0000	0.0019	0.0000	0.0115	0.0015	0.0026	0.0000	0.0000	0.9990	0.0098	0.9999	0.0000	0.9999	0.0000	0.0000
14		11	Mountain V	0.0126	0.0000	0.0000	0.0266	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100	0.0000	0.0000	0.9999
15		12	Muir	0.0000	0.9999	0.0000	0.0035	0.9990	0.0000	0.0022	0.0002	0.0027	0.9999	0.0000	0.0000	0.9999	0.9999	0.9999	0.0018	0.0000	0.0000
16		13	Myers	0.0000	0.9999	0.0000	0.0000	0.0178	0.0000	0.0061	0.0000	0.9990	0.0099	0.0000	0.9990	0.0000	0.9999	0.0057	0.0000	0.0000	0.0000
17		14	Quartz	0.0000	0.9999	0.0000	0.0001	0.9999	0.0000	0.0057	0.0015	0.0041	0.9999	0.0000	0.9990	0.9999	0.0000	0.0066	0.0018	0.0000	0.0000
18		15	Red Bird	0.0069	0.0029	0.0000	0.9990	0.9999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.9990	0.0045	0.0074	0.0000	0.0000	0.0000	0.0004
19		16	Sheep Mou	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.9999	0.0000	0.0140	0.0000	0.0115	0.0000	0.0000	0.0000	0.0000
20		17	Upper Mair	0.0000	0.0000	0.9999	0.0000	0.0000	0.0000	0.0000	0.0000	0.9999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21		18	Wenaha	0.0035	0.0000	0.0000	0.0264	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9990	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000

Bighorn sheep herd-to-herd individual animal contact probability matrix

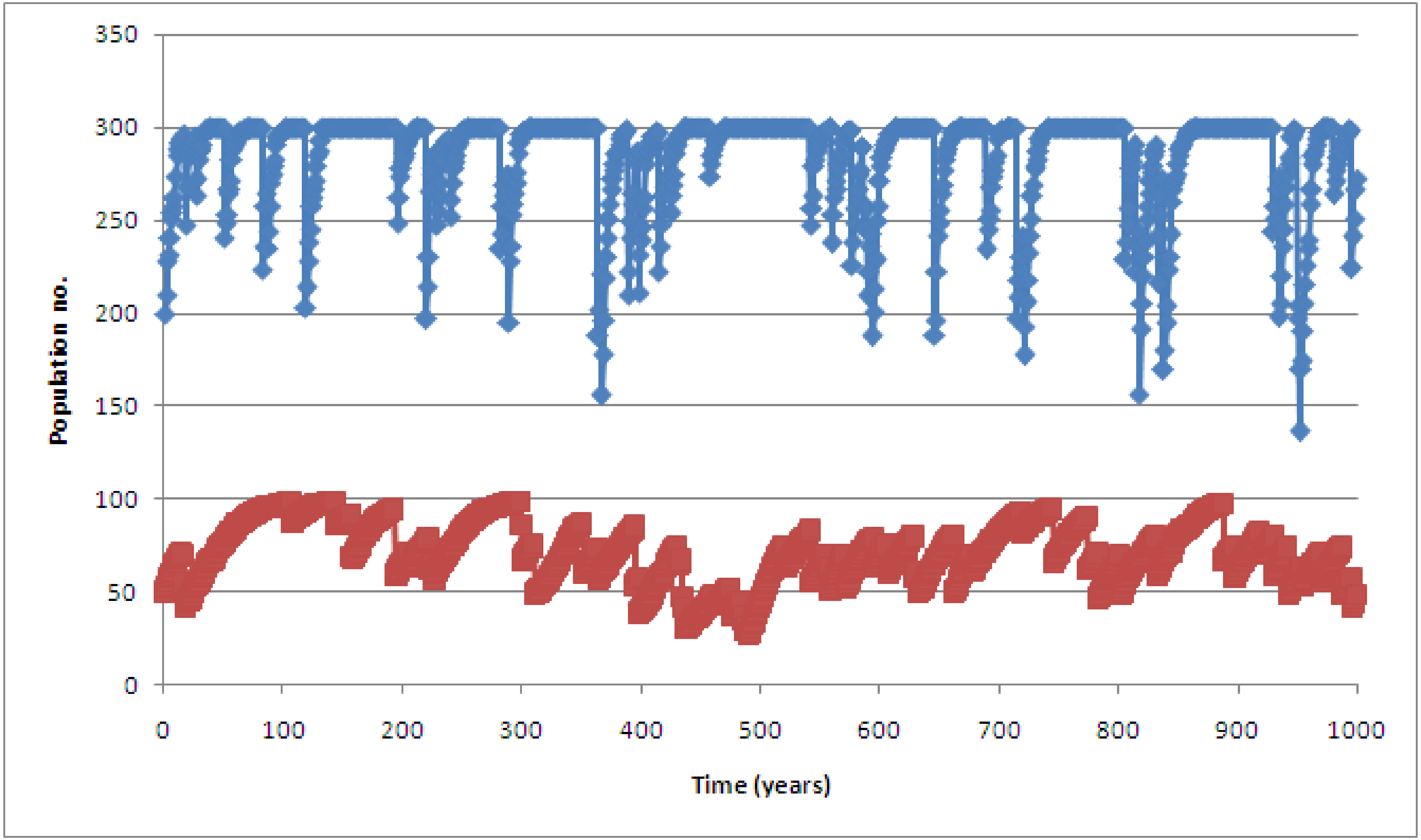
Disease Model Input Parameters

	BZ	CA	CB
29	BHS to BHS effective transmission probability	0.75	
30	scenario no.	1	
31	Domestic to BHS effective transmission probability	0.25	
32	Hell's Canyon total population IHL	10000	
33		min	max
34	Duration of adverse herd infection effect (years)	4	10
35	Extended effect impact	-0.13	0
36	Duration of infectious years	1	4
37	Outbreak impact (prop. dec.)	0.69	

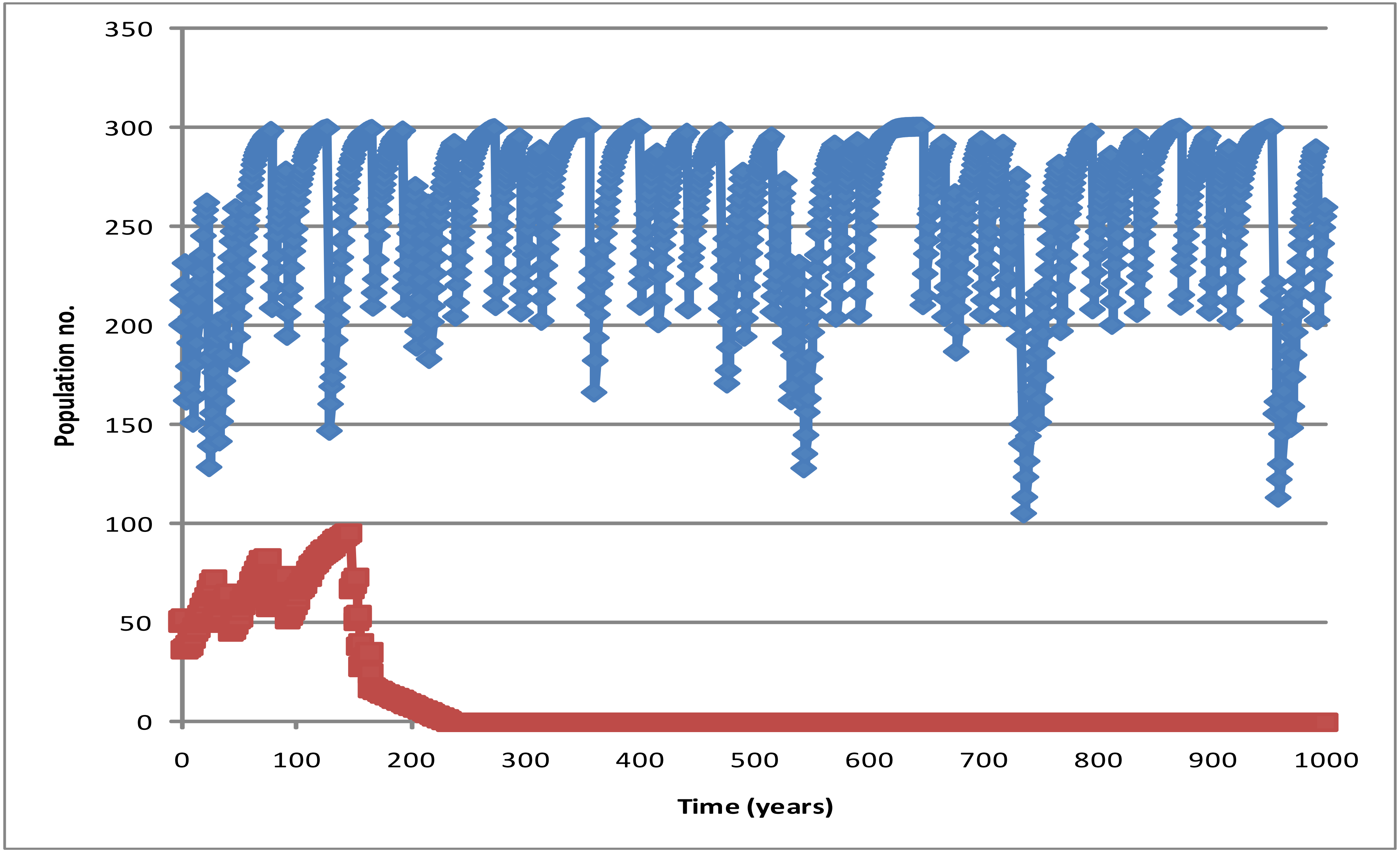
Figure 5-6. Model parameters and sample values for disease spread and control

Preliminary Results and Lessons Learned

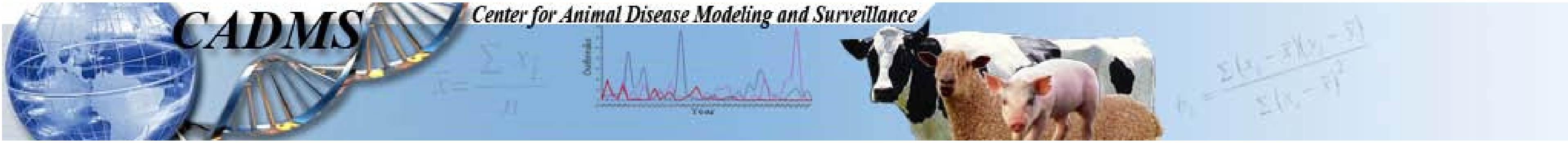
Simulation Results
(2 hypothetical herds)



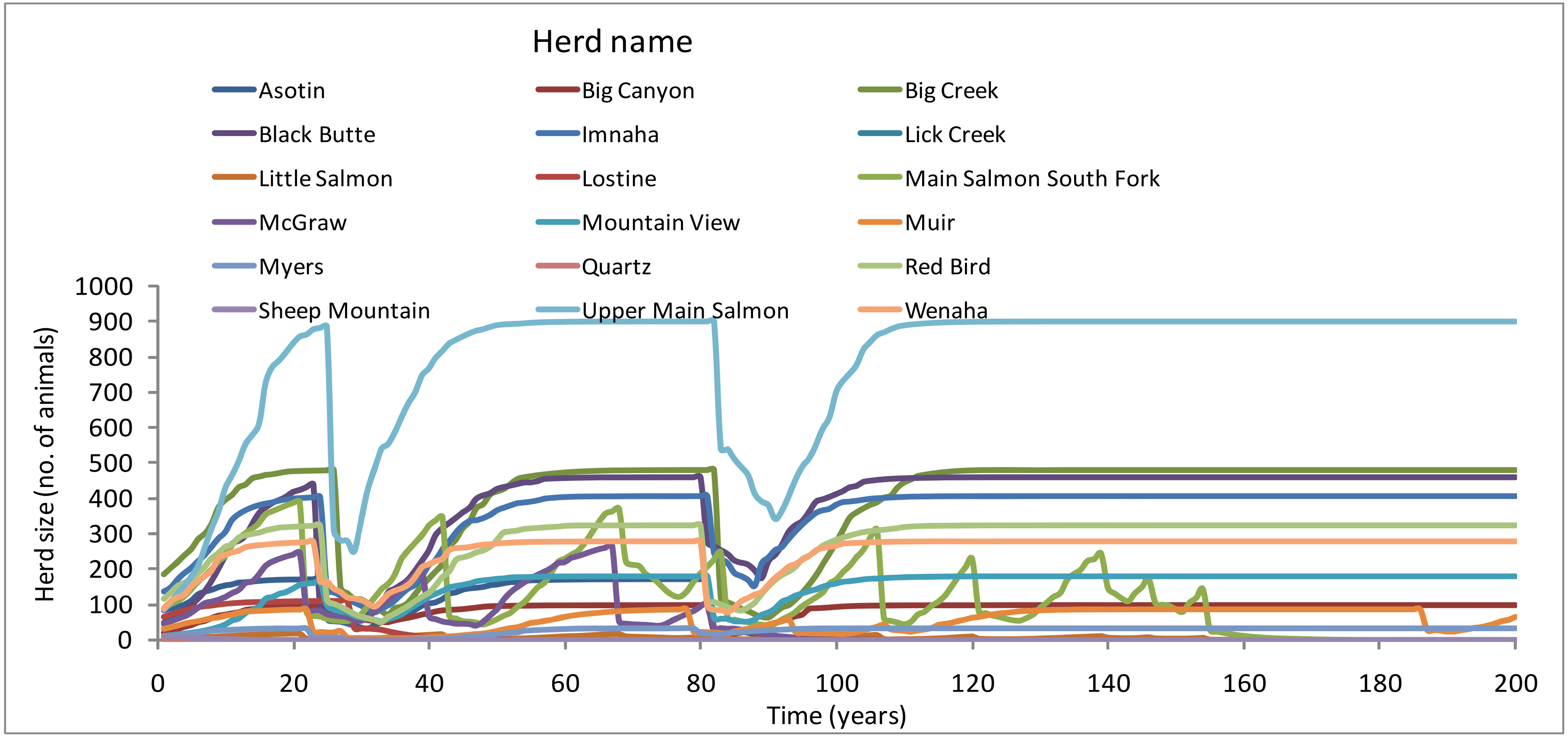
Simulation Results
(2 hypothetical herds)

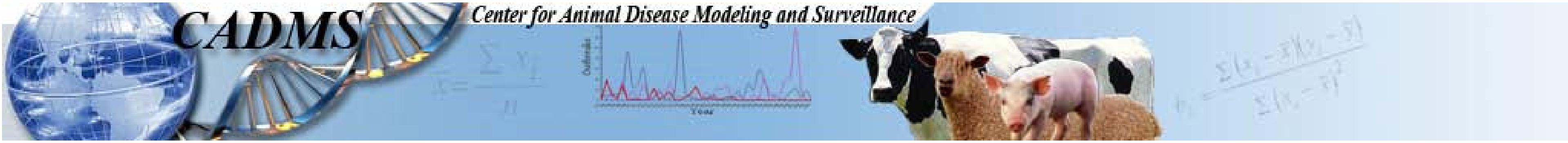


Final Results and Actions

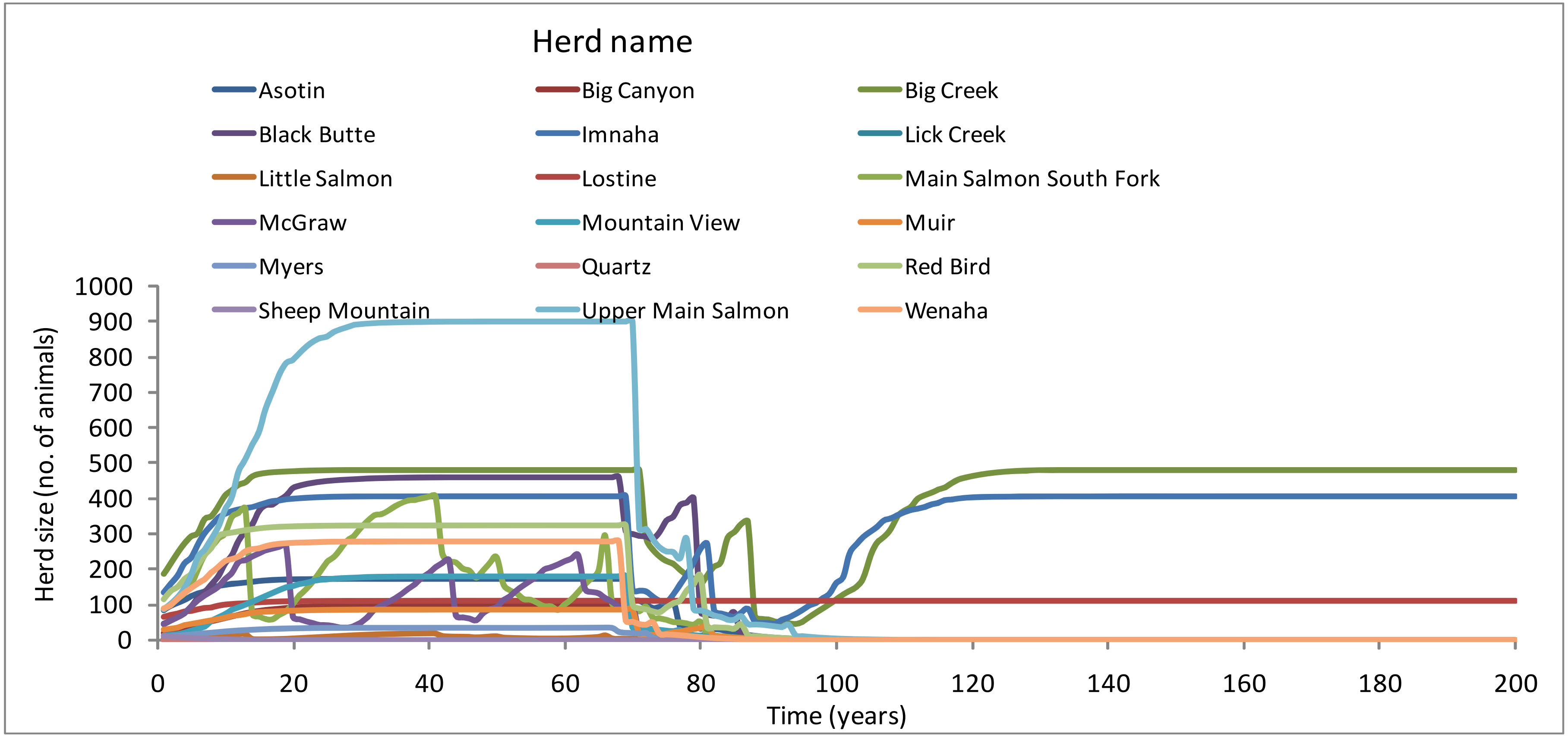


Sample Simulation Results from Final Model



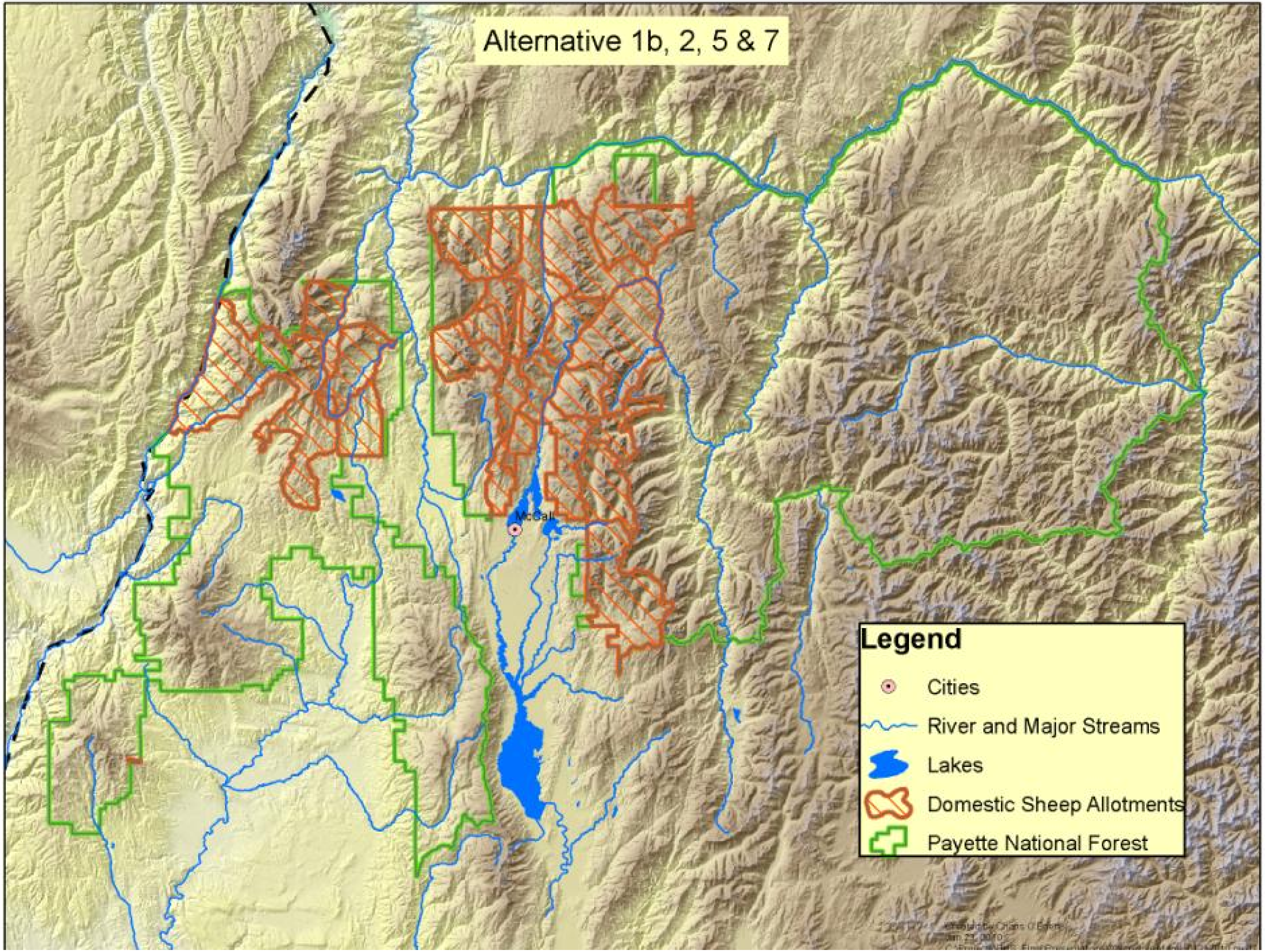


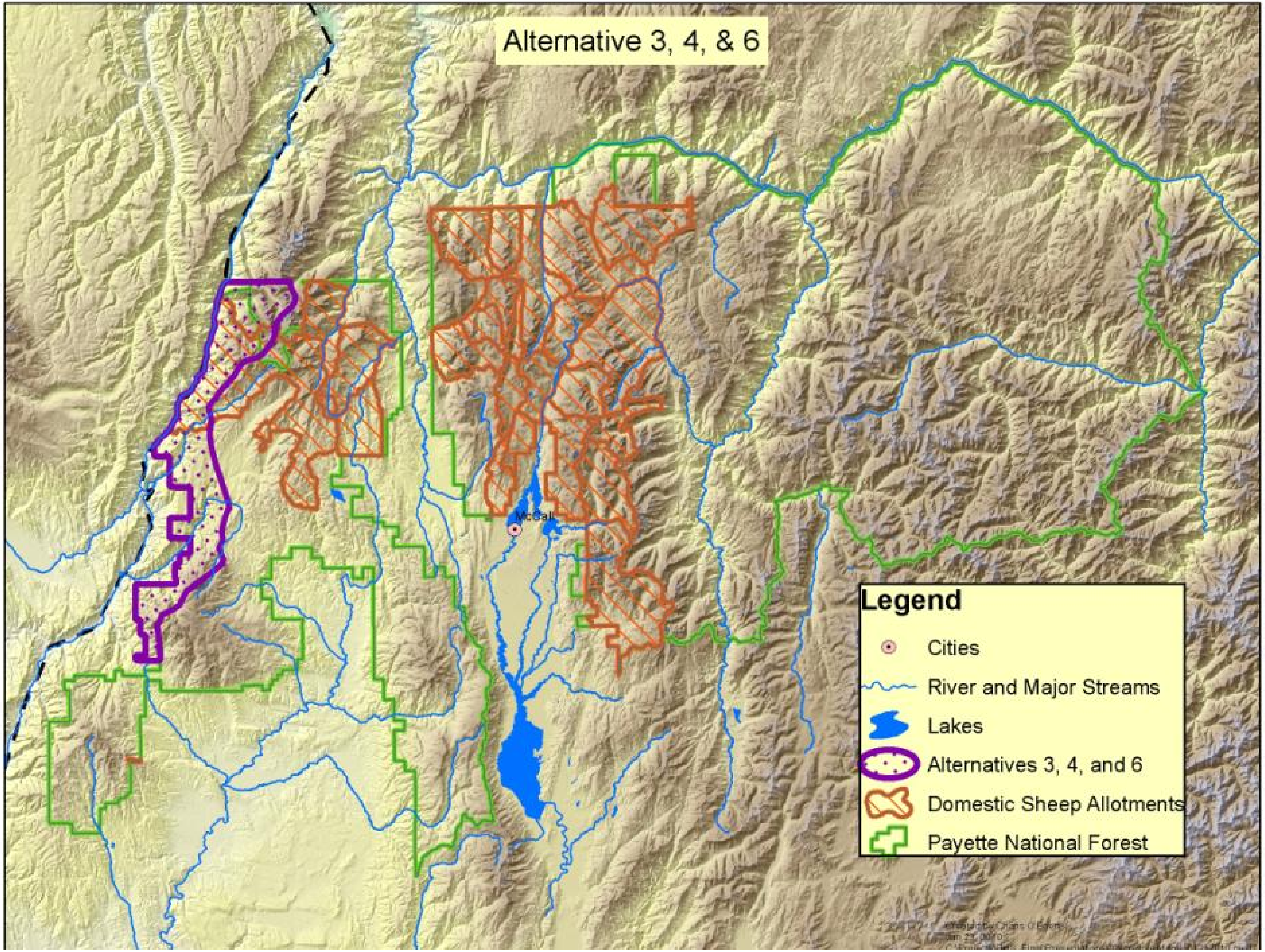
Sample Simulation Results from Final Model

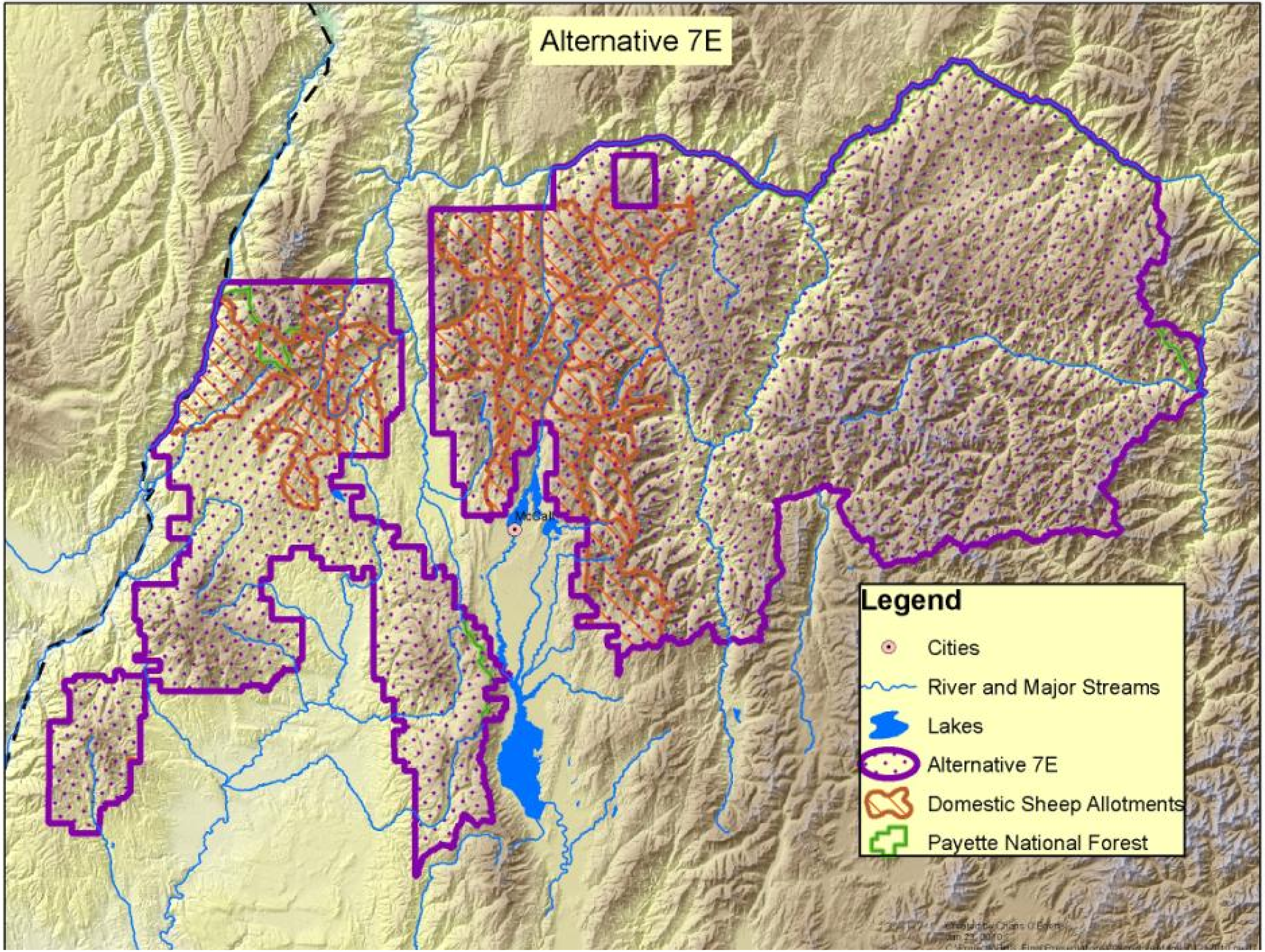


Simulation Results

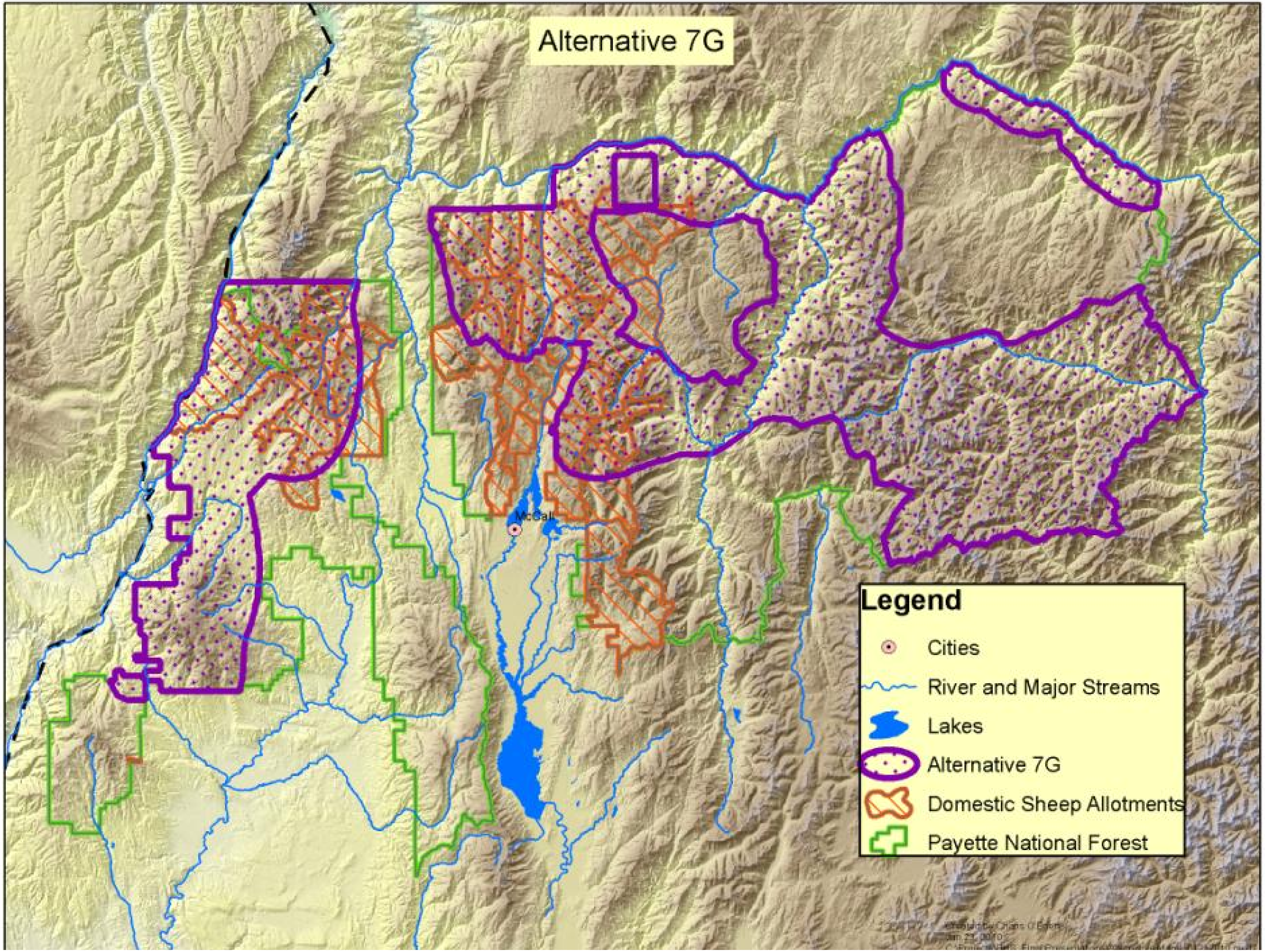
- Output will provide information regarding
  - probability of herd extirpation over 1000 years
  - expected time to extirpation
  - minimum population size


Alternative 1b, 2, 5 & 7
McCall
Legend
Cities
River and Major Streams
Lakes
Domestic Sheep Allotments
Payette National Forest

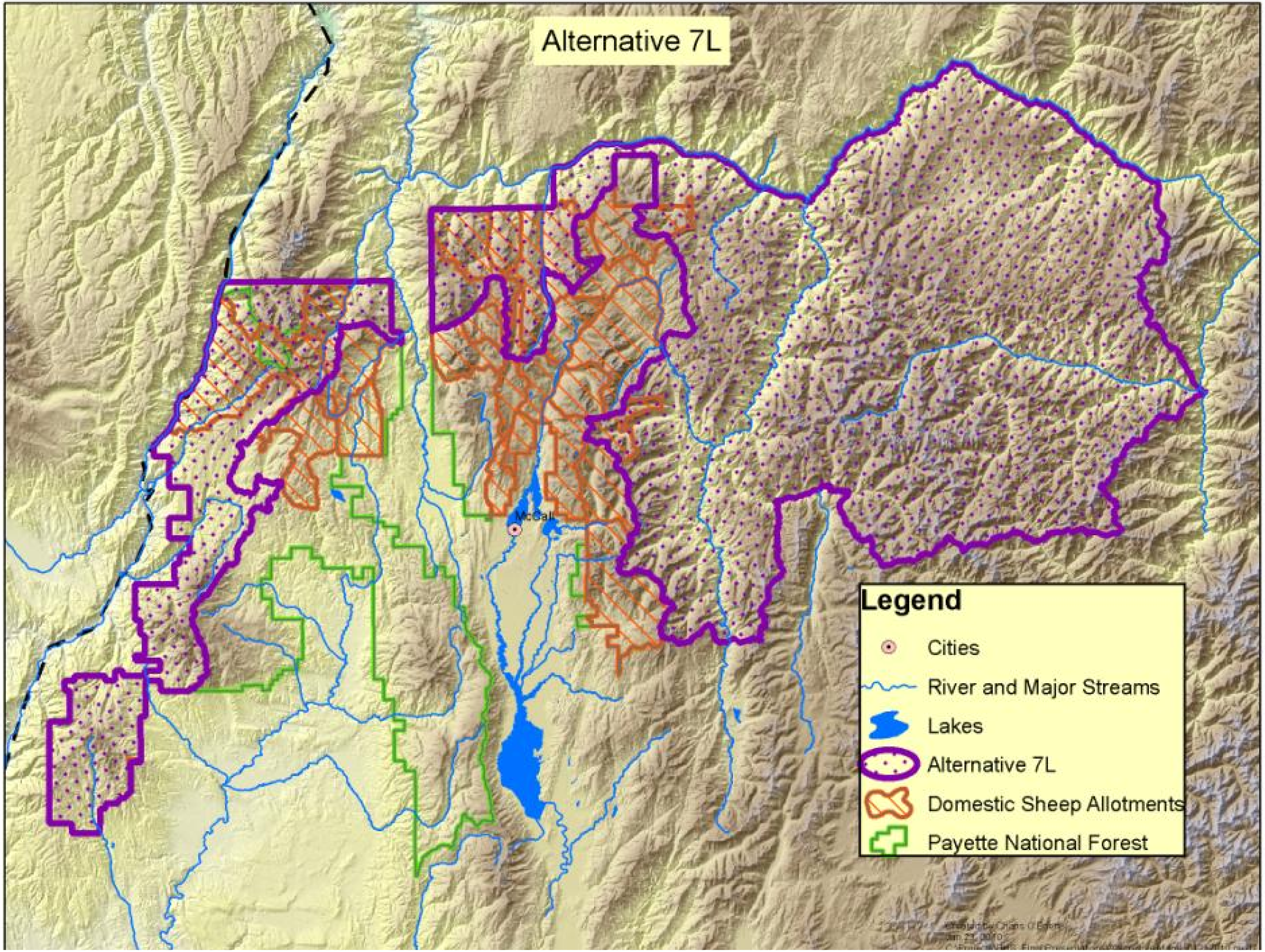

Alternative 3, 4, & 6
McCall
Legend
Cities
River and Major Streams
Lakes
Alternatives 3, 4, and 6
Domestic Sheep Allotments
Payette National Forest



Alternative 7E
McCall
Legend
Cities
River and Major Streams
Lakes
Alternative 7E
Domestic Sheep Allotments
Payette National Forest



Alternative 7G
McCall
Legend
Cities
River and Major Streams
Lakes
Alternative 7G
Domestic Sheep Allotments
Payette National Forest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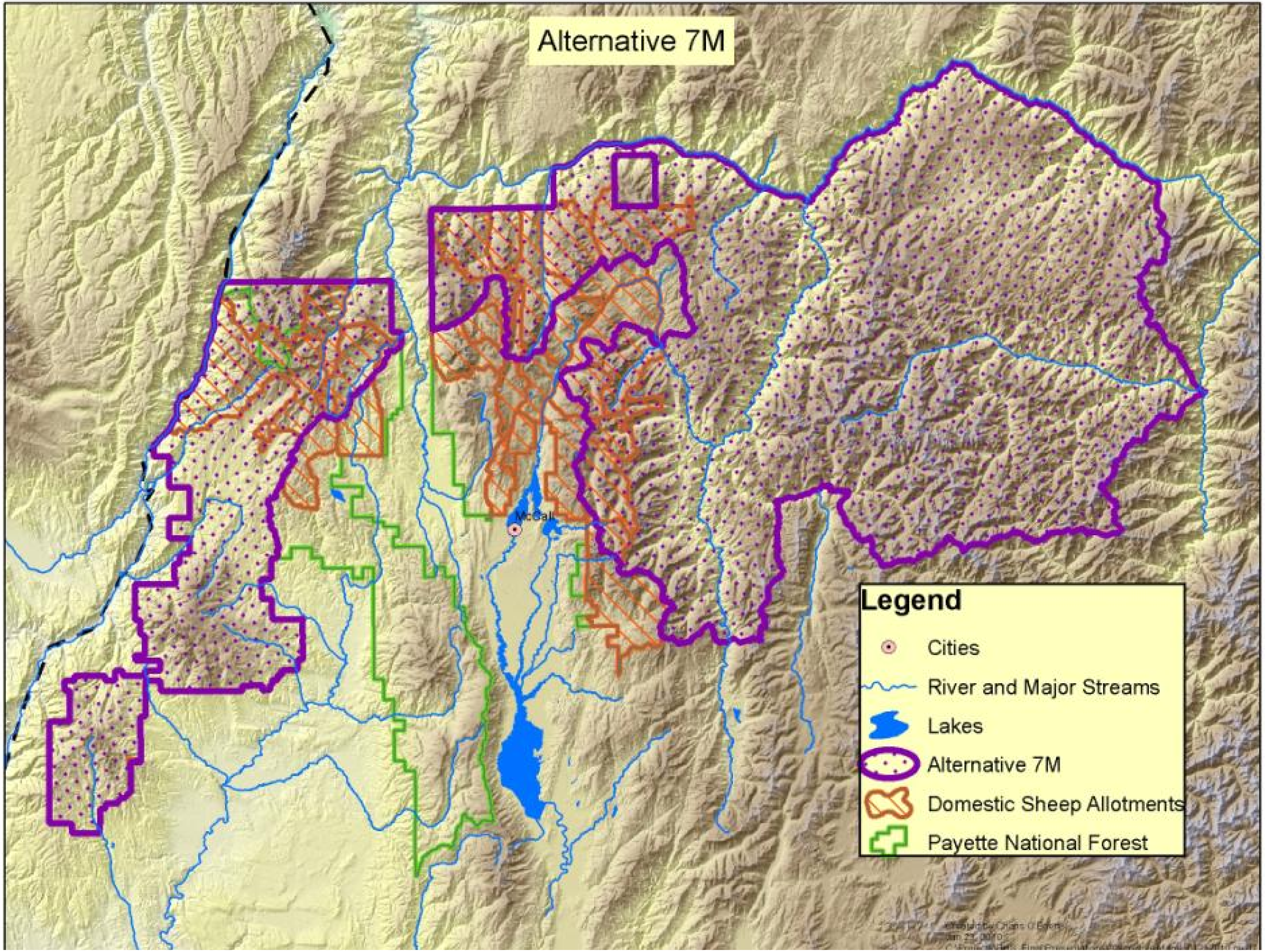
McCall
Legend
Cities
River and Major Streams
Lakes
Alternative 7L
Domestic Sheep Allotments
Payette National Forest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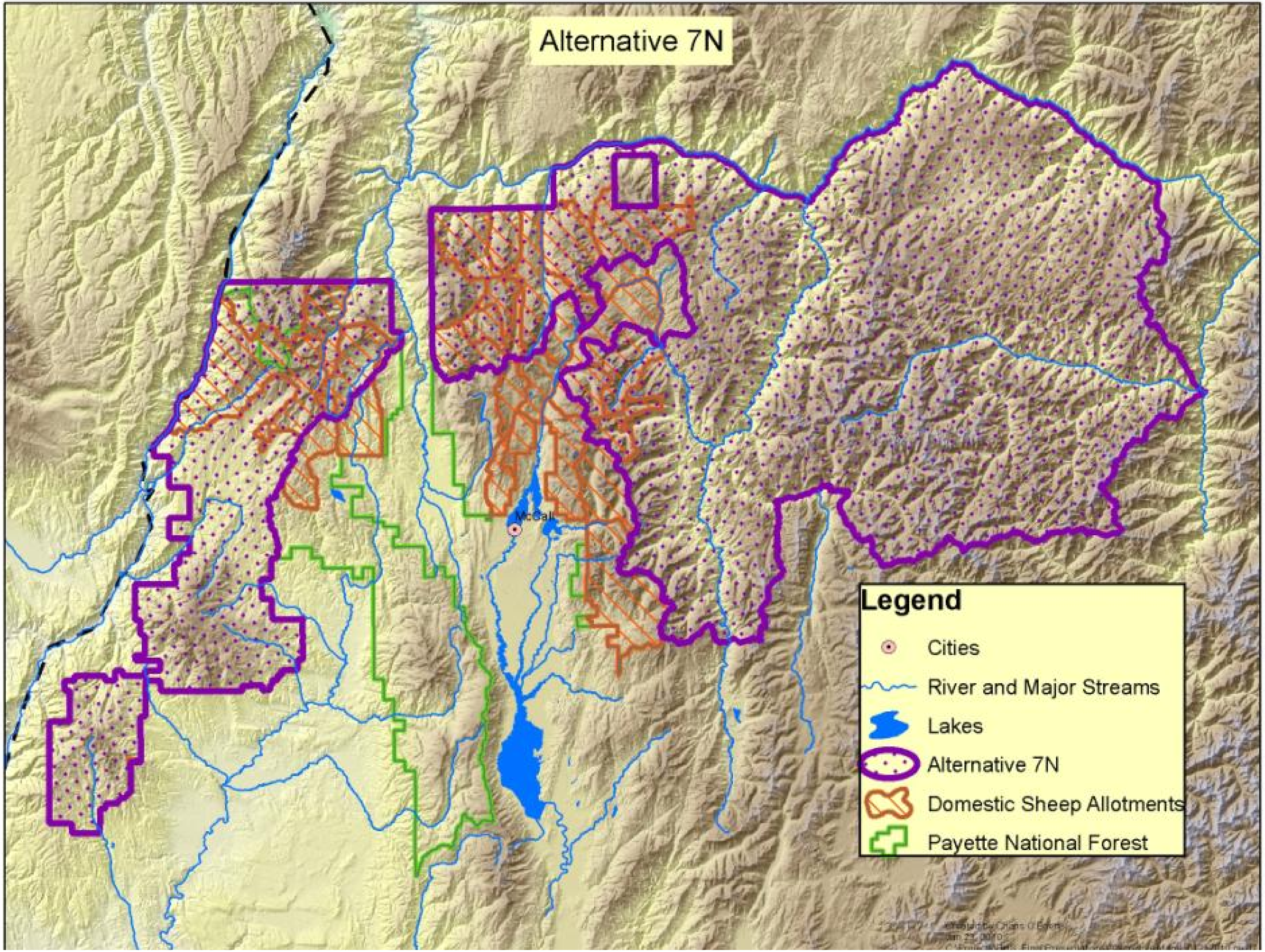
River and Major Streams
Lakes
Alternative 7M
Domestic Sheep Allotments
Payette National Forest


Alternative 7N
McCall
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River and Major Streams
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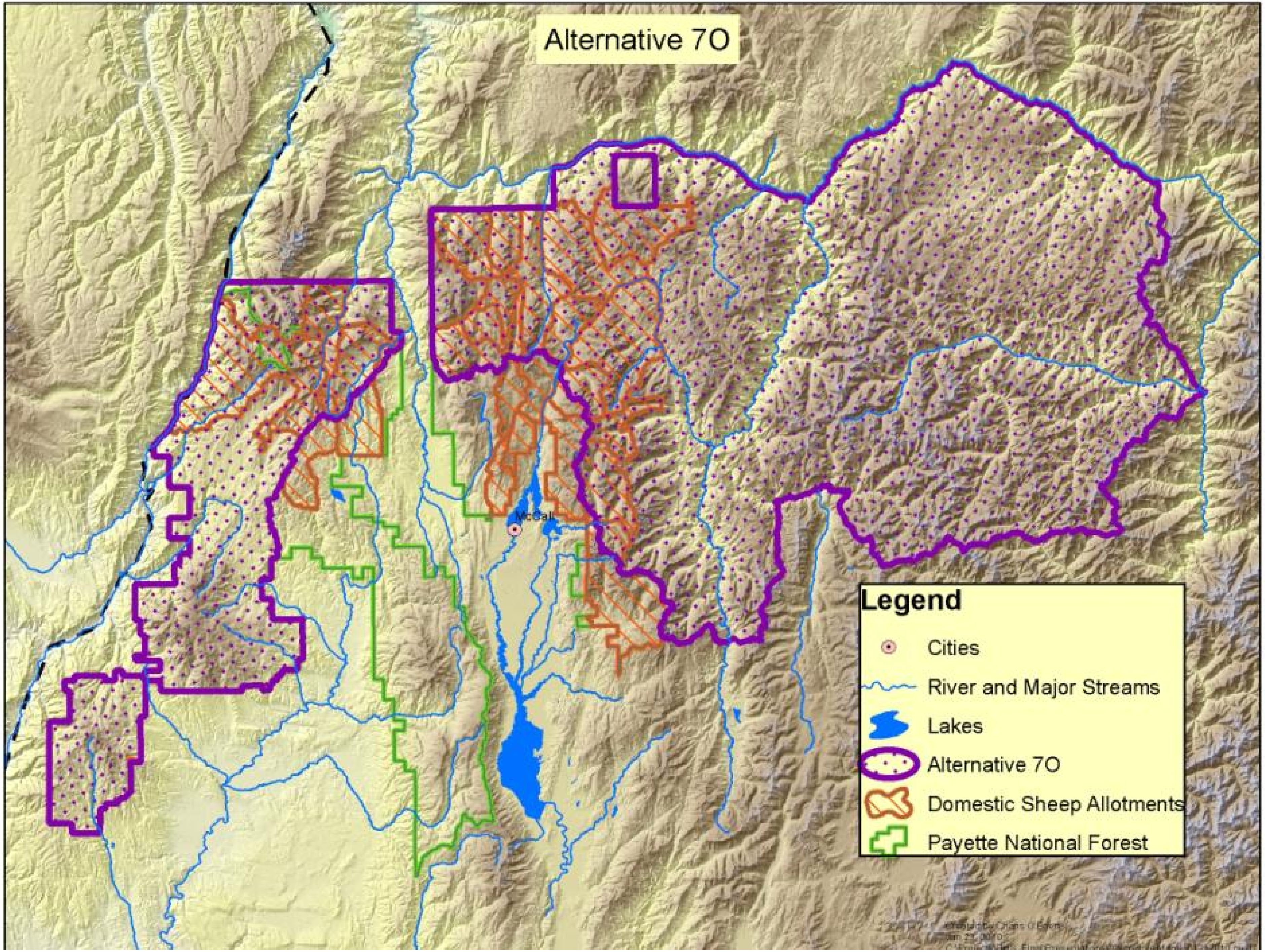
Alternative 7N
Domestic Sheep Allotments
Payette National Forest


Alternative 7O
McCall
Legend
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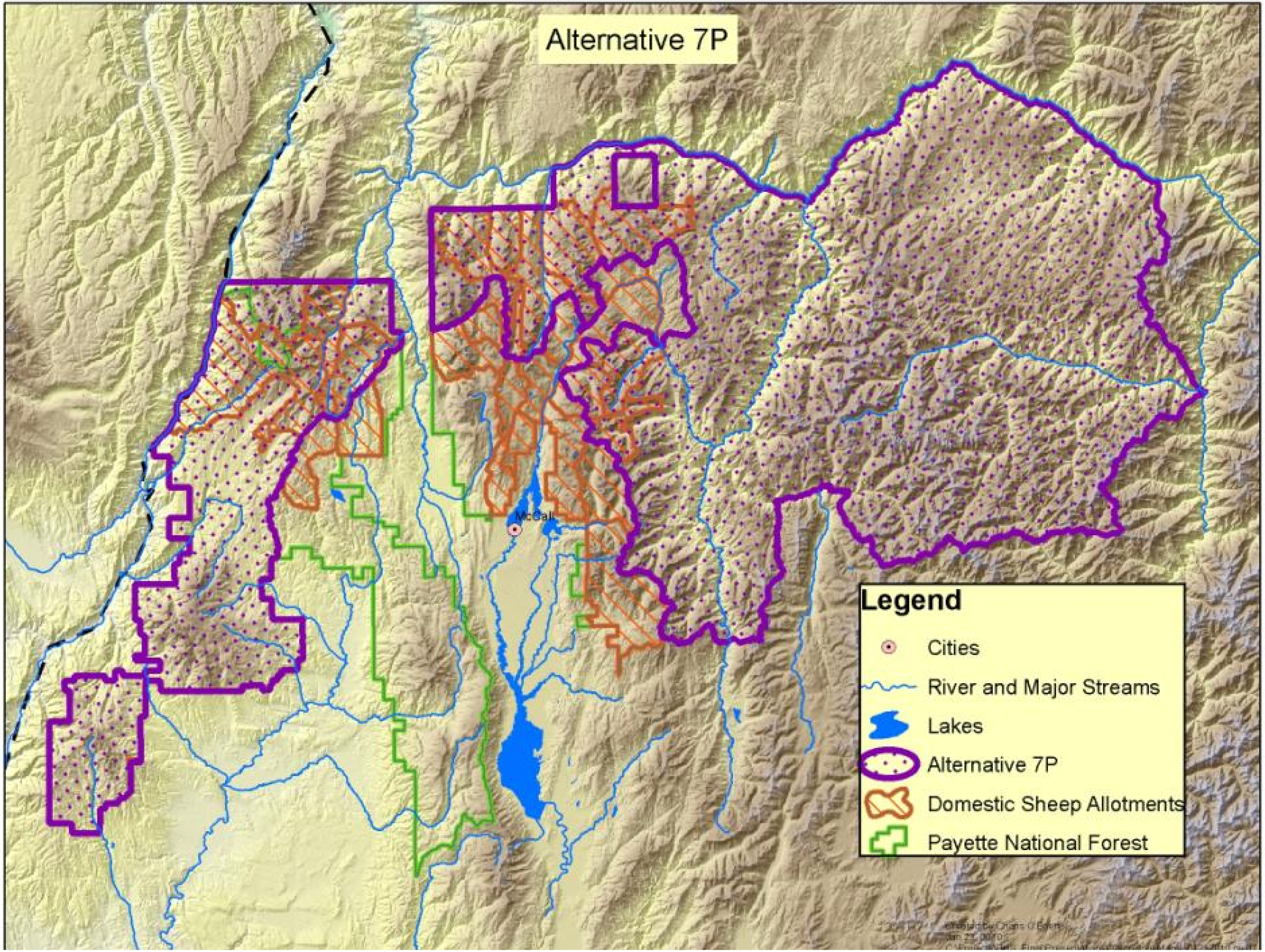
River and Major Streams
Lakes
Alternative 7O
Domestic Sheep Allotments
Payette National Forest


Alternative 7P
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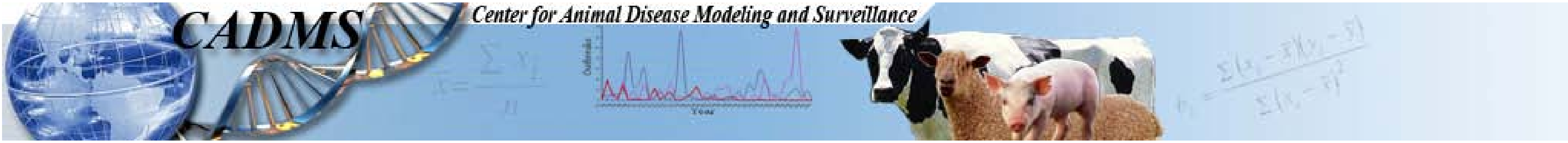
Legend
Cities
River and Major Streams
Lakes
Alternative 7P
Domestic Sheep Allotments
Payette National Forest

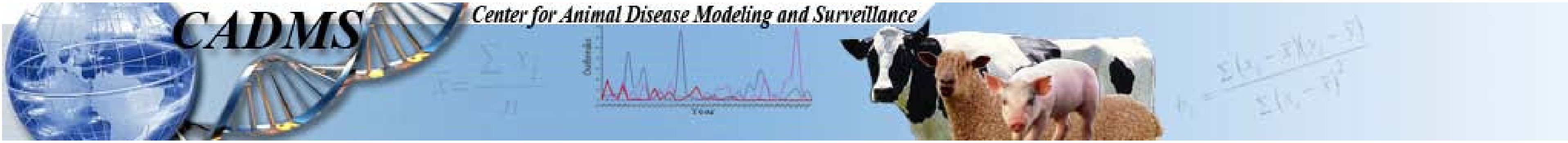


Protected Summer Source Habitats for Bighorn Sheep, and Remaining Suited Rangeland for Domestic Sheep

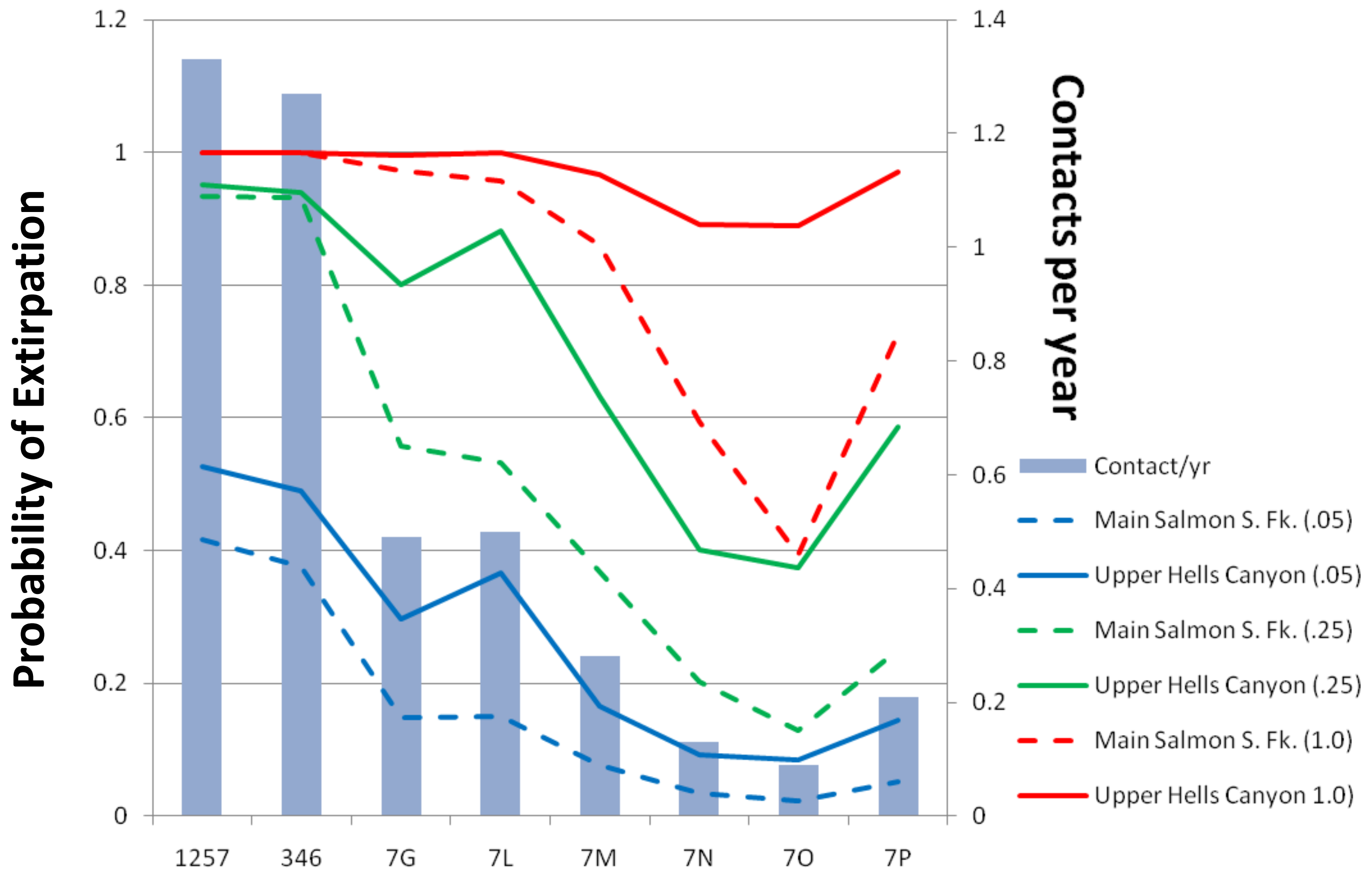
Alternative	Protected BHS Summer Habitat (Acres)	Protected BHS Summer Habitat (Percent)	Suitable Range Acres	Suitable Range Percent
1b, 2, 5, 7	0	0.00%	100310	100.00%
3, 4, 6	33918	9.20%	93082	92.79%
7E	368641	100.00%	0	0.00%
7G	263338	71.43%	38468	38.35%
7L	315715	85.64%	64311	64.11%
7M	338934	91.94%	43245	43.11%
7N	337532	91.56%	38392	38.27%
7O	346696	94.05%	31592	31.49%
7P	332372	90.16%	46106	45.96%

Probability of Extirpation for Main Salmon and Southfork

Main Salmon South Fork						
Effective Contact Rates	**0.05**	**0.1**	**0.25**	**0.5**	**0.75**	**1**
Alt_1257	0.417	0.694	0.933	0.995	0.999	1
Alt_346	0.376	0.645	0.931	0.995	0.999	1
Alt_7G	0.148	0.282	0.558	0.818	0.931	0.973
Alt_7L	0.151	0.257	0.532	0.793	0.918	0.958
Alt_7M	0.076	0.176	0.369	0.605	0.754	0.861
Alt_7N	0.034	0.074	0.203	0.334	0.501	0.594
Alt_7O	0.022	0.04	0.129	0.211	0.292	0.393
Alt_7P	0.051	0.12	0.251	0.481	0.616	0.728
No Allotments	0	0	0	0	0	0

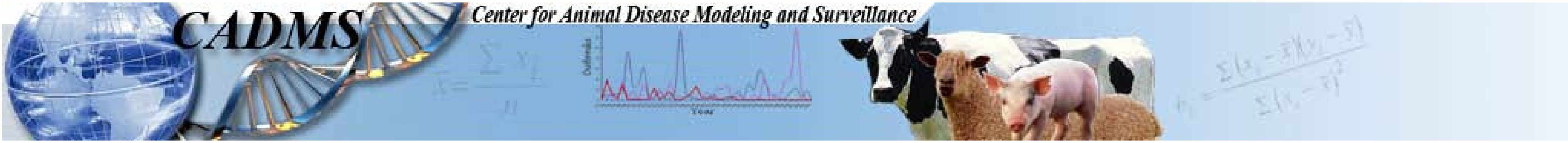


Rates of Extirpation by Varying Effective Contact Rates by Alternative



Recommendations

- Modified 7O
- 94% of bighorn sheep summer habitat is protected (347,000 acres added)
- 31% rangeland suited for domestic sheep and goat grazing (68,000 acres reduced)
- Mean disease outbreak intervals 230 to 46 years



Recommendations Timeline

- Record of decision signed July 20, 2010
- Posted in the Federal Register on July 30, 2010
- 45-day appeal period (ends September 13, 2010)
- Sept. 16 leave country (safehaven in CH and IT)
- Implement 30 days post decision

Outbreak kills hundreds of bighorn sheep

By MARTIN GRIFFITH, Associated Press Writer

STORY

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Story Published: Feb 26, 2010 at 6:48 PM PST | Story Updated: Feb 26, 2010 at 6:48 PM PST

RENO, Nev. (AP) — Pneumonia outbreaks that have killed hundreds of wild bighorn sheep this winter in several Western states have wildlife officials grappling with how to minimize the impact.

The disease shows up sporadically in wild herds, but it's unusual to have so many outbreaks in so many states, wildlife officials said Friday.

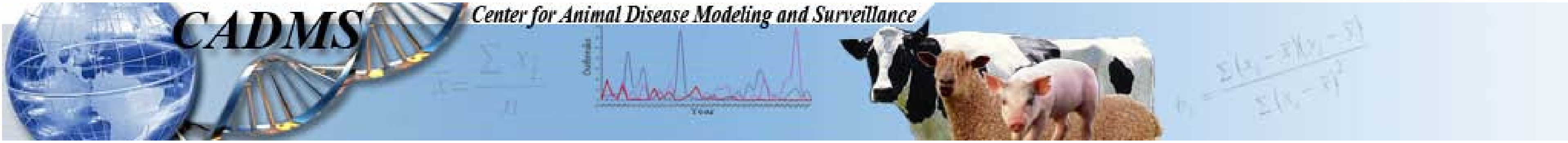
More than 400 bighorn sheep in Nevada, Montana, Utah and Washington have died or been killed by wildlife officials this winter, and the death toll is expected to rise in coming weeks. More than half were from four herds in western Montana alone.

Comments (21)

"I'd lean toward saying this is unprecedented," said Vivaca Crowser, a spokeswoman for Montana Fish, Wildlife & Parks.

Wildlife officials said there's no effective treatment or vaccination for pneumonia, so they're left with few good options: let the disease run its course or start killing sick sheep to save the healthy ones.

"It's not a pleasant task but we know if we don't get ahead of the disease, we could lose everything," said Charlie Greenwood, a wildlife manager with the Utah Division of Wildlife Resources.



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