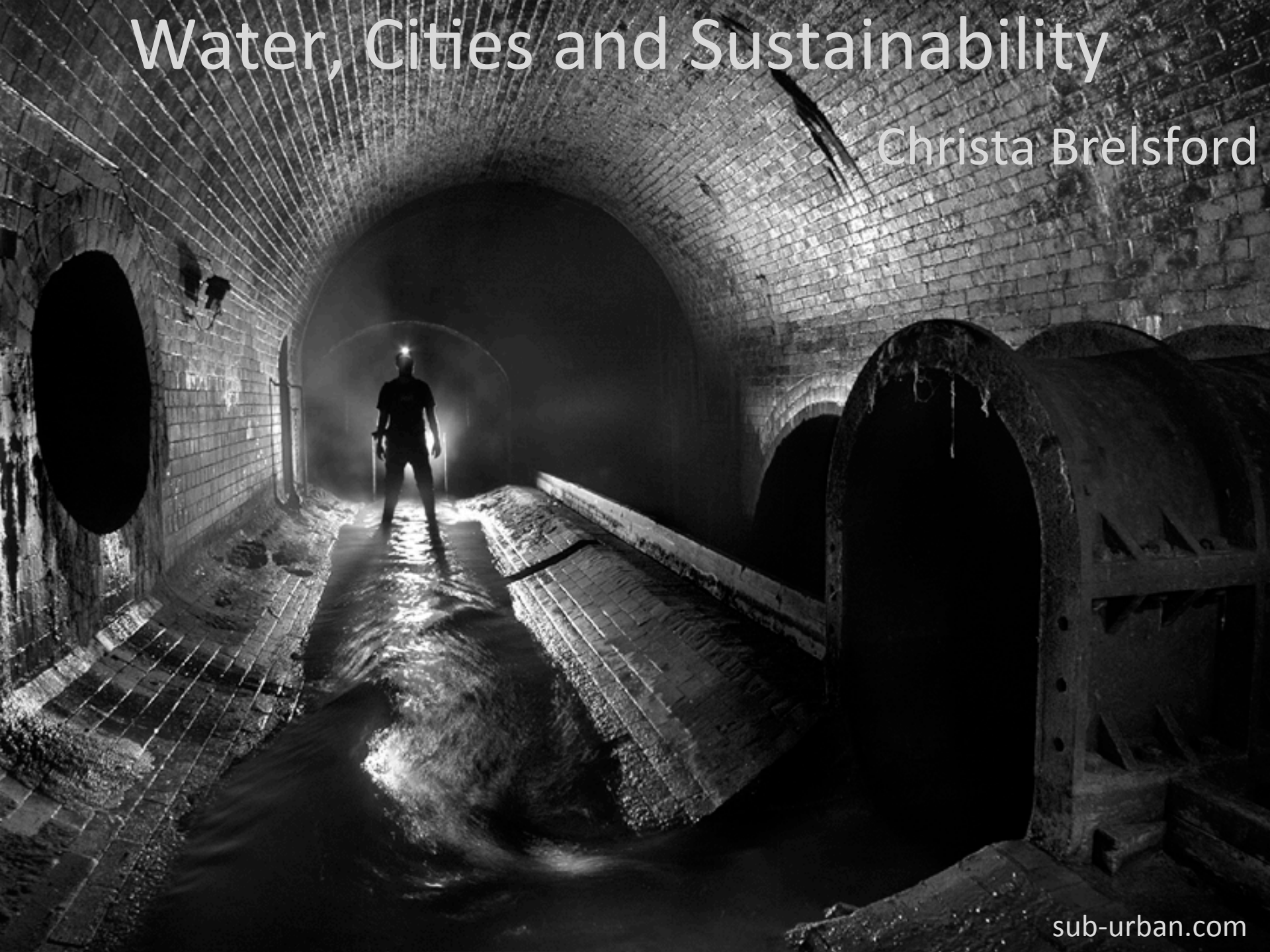
Water, Cities and Sustainability

Christa Brelsford



sub-urban.com


Topo
Imagery Topo
Imagery
Hydro-NHD
Hill Shade
HUC 2 - 09
HUC 2 - 17
HUC 2 - 04
HUC 2 - 01
HUC 2 - 10
HUC 2 - 07
HUC 2 - 16
HUC 2 - 14
HUC 2 - 11
HUC 2 - 05
HUC 2 - 06
HUC 2 - 18
HUC 2 - 15
HUC 2 - 03
HUC 2 - 13
HUC 2
Seattle
WASHINGTON
Portland
OREGON
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
Denver
OKLAHOMA
Oklahoma City
CALIFORNIA
San Francisco
San Jose
Los Angeles
San Diego
ARIZONA
Phoenix
NEW MEXICO
El Paso
TEXAS
Austin
San Antonio
Houston
Fort Worth
Mexico
Milwaukee
Chicago
Detroit
MI
WI
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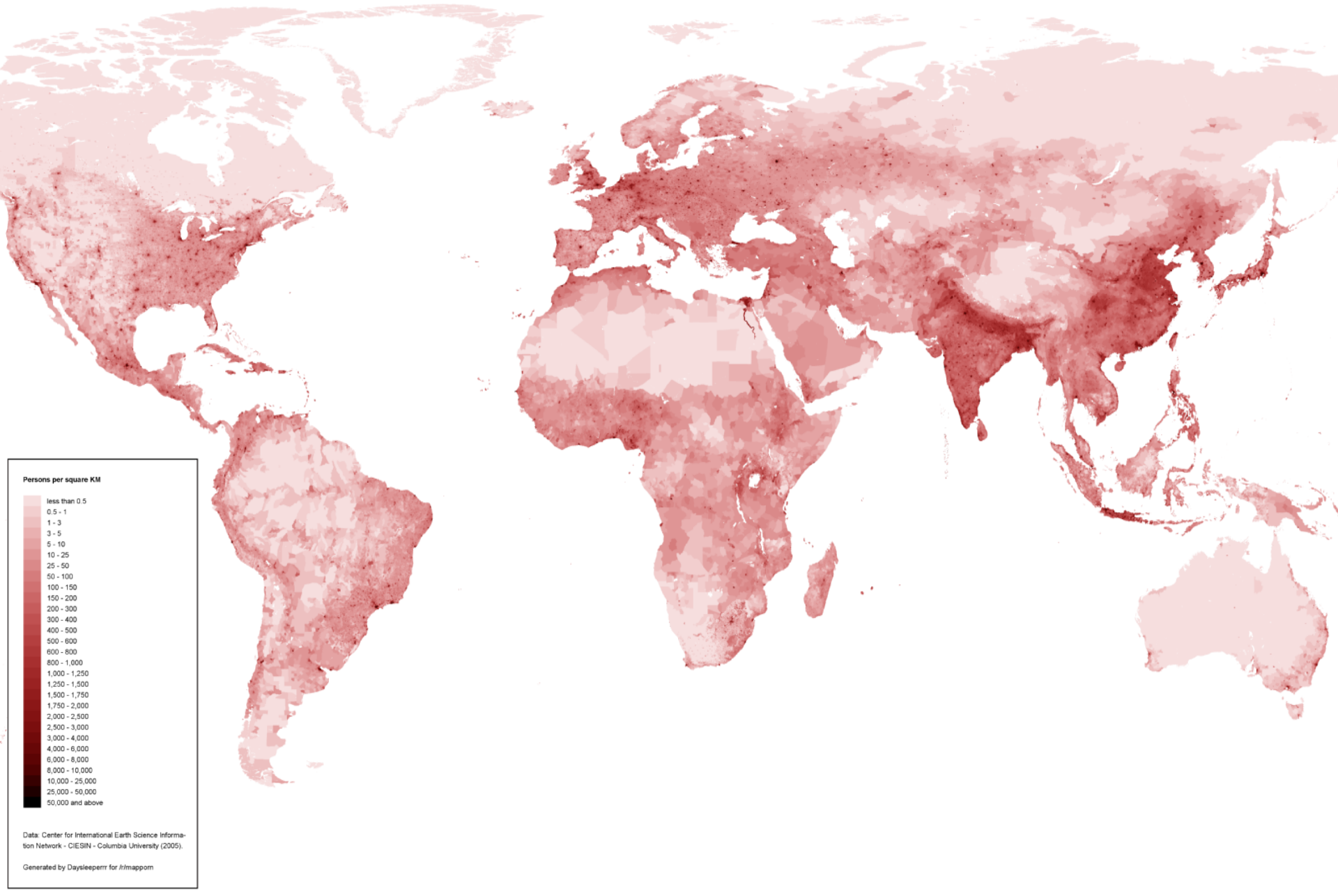
IL
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
New York
Philadelphia
Baltimore
Washington
MD
DE
NJ
CT
MA
Boston
NH
VT
ME
Memphis
Charlotte
Jacksonville
Columbus
Snake River
Columbia River
Platte River
Missouri River
Arkansas River
Canadian River
Colorado River
San Joaquin River
Ohio River
Tennessee River
Susquehanna River
Connecticut River
Red River
Mississippi R.
Brazos River
Chattahoochee River
Grande Rio
100
200mi

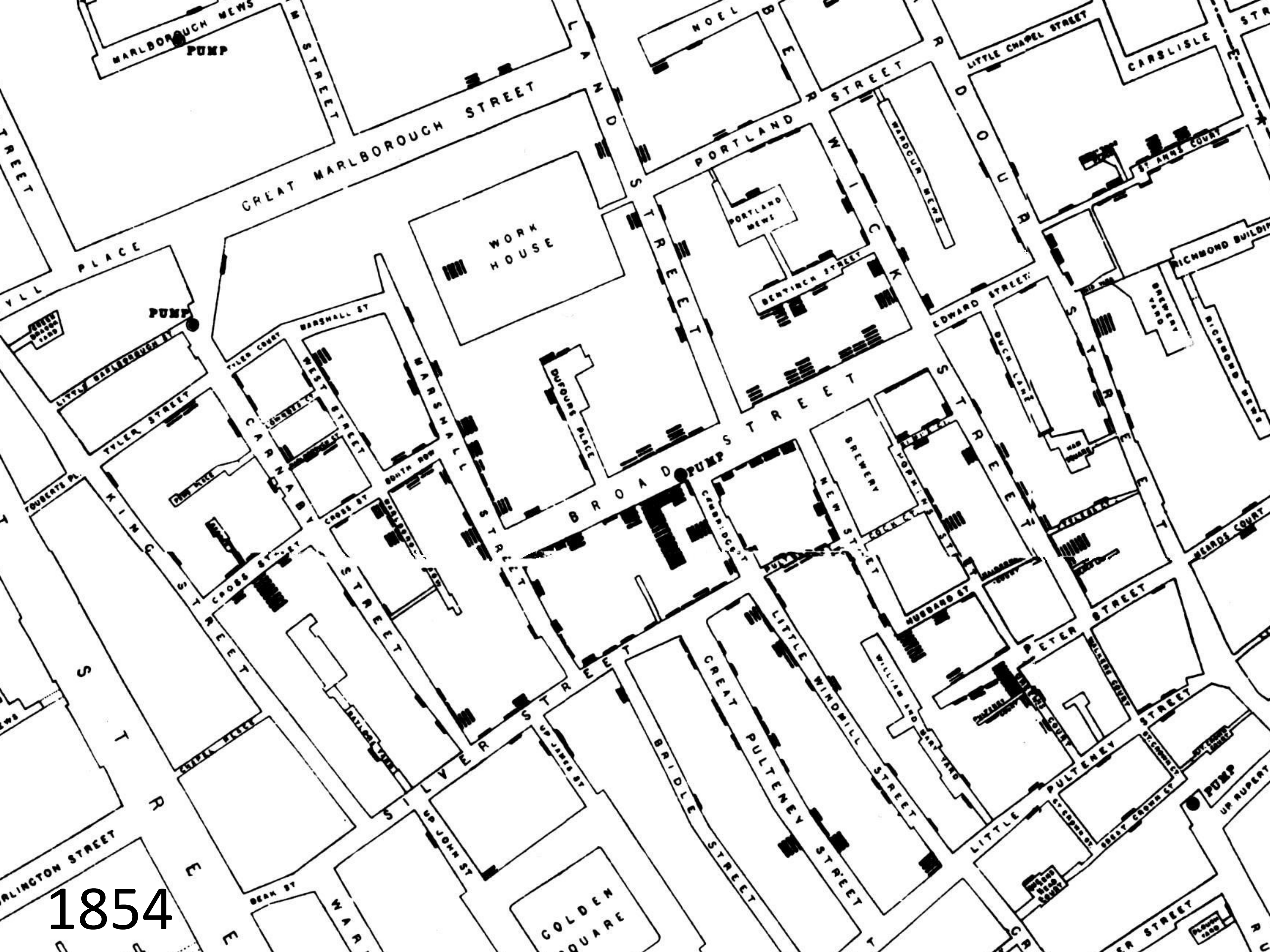

Persons per square KM
less than 0.5
0.5 - 1
1 - 3
3 - 5
5 - 10
10 - 25
25 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 800
800 - 1,000
1,000 - 1,250
1,250 - 1,500
1,500 - 1,750
1,750 - 2,000
2,000 - 2,500
2,500 - 3,000
3,000 - 4,000
4,000 - 6,000
6,000 - 8,000
8,000 - 10,000
10,000 - 25,000
25,000 - 50,000
50,000 and above
Data: Center for International Earth Science Information Network - CIESIN - Columbia University (2005).
Generated by Daysleeperrr for /r/mapporn

New York City

quality, robustness, and getting rid of .... stuff

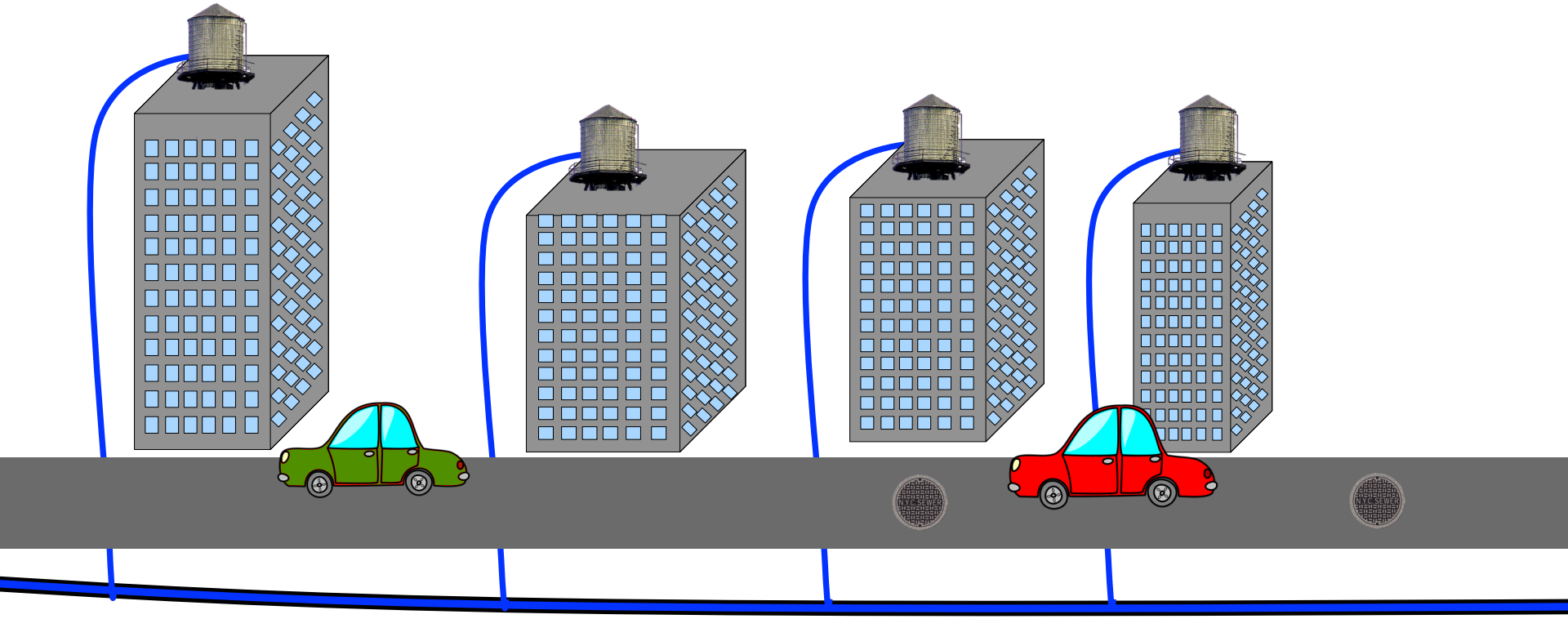
STONE BRIDGE, BROADWAY AT CANAL STREET

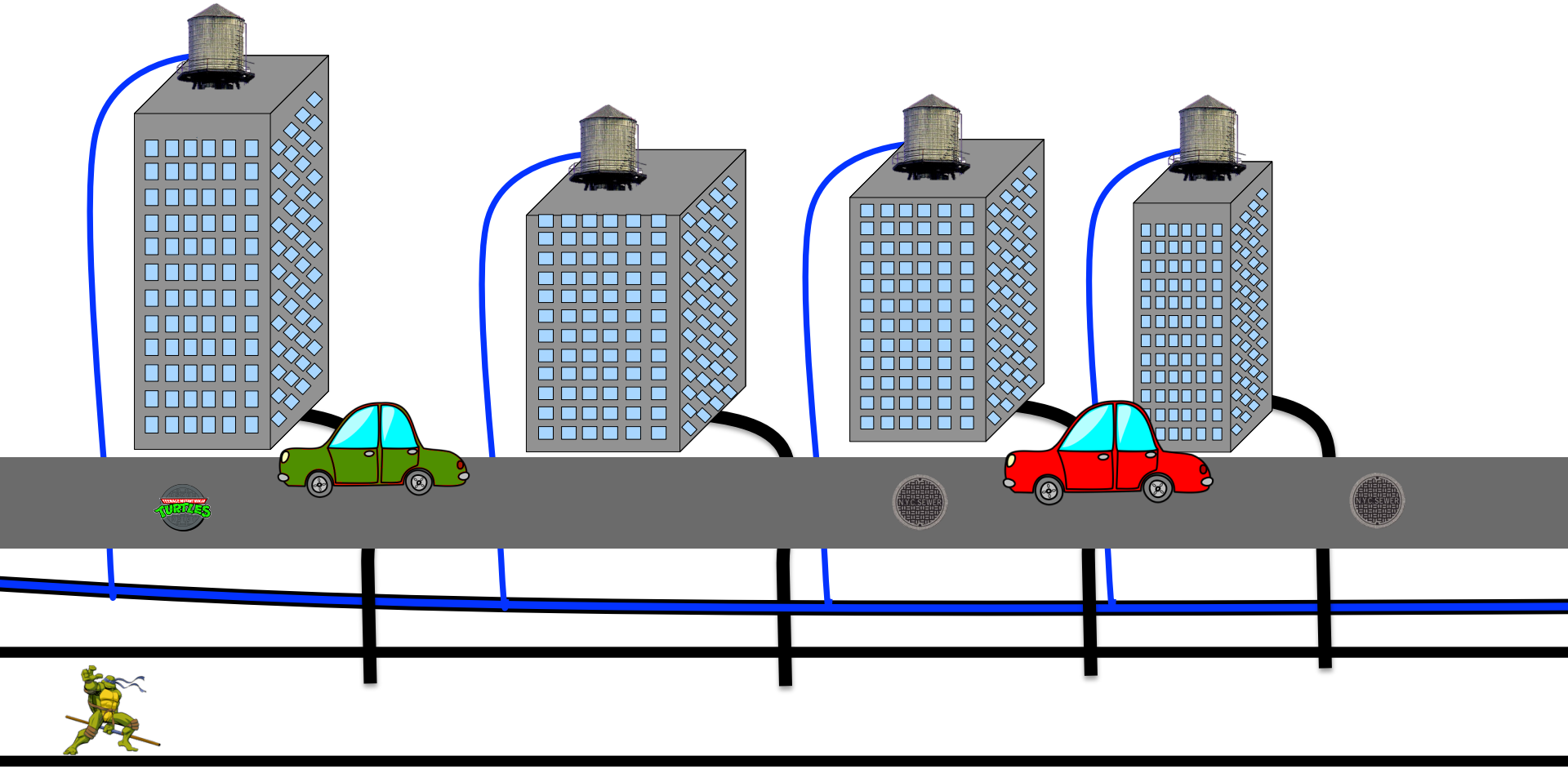

SLEEPY'S
SLEEPY'S
SLEEPY'S
SLEEPY'S
SLEEPY'S
Canal St
Google

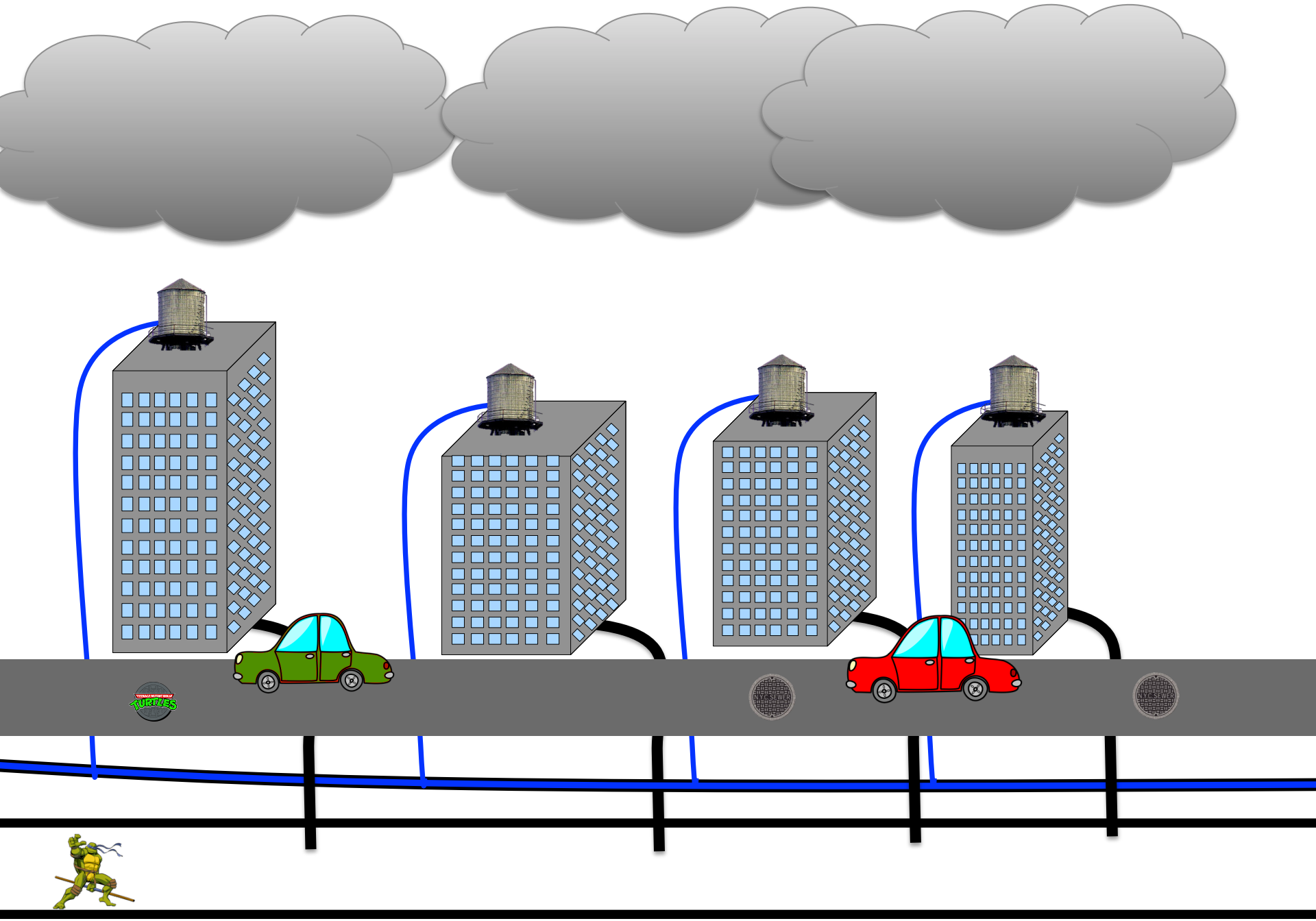

MARLBOROUGH MEWS
PUMP
GREAT MARLBOROUGH STREET
NOEL
PORTLAND STREET
LITTLE CHAPEL STREET
CARLISLE
ST ANNS COURT
WORK HOUSE
PORTLAND MEWS
BENTINCK STREET
WARDOUR MEWS
RICHMOND BUILDINGS
EDWARD STREET
BREWERY YARD
RICHMOND MEWS
DUCK LANE
DUFOURS PLACE
MARSHALL ST
TYLER COURT
LITTLE MARLBOROUGH ST
TYLER STREET
CARNABY
WEST STREET
MARSHALL STREET
BROAD STREET
PUMP
NEW STREET
BREWERY
HOPKINS ST
CROSS ST
KING STREET
CROSS STREET
HEARDS COURT
PETER STREET
HUSBAND ST
LITTLE WINDMILL STREET
WILLIAM AND MARY YARD
GREAT PULTENEY STREET
BRIDLE STREET
SILVER STREET
UP JOHN ST
UP JAMES ST
LITTLE PULTENEY STREET
GREAT CROWN CT
UP RUPERT
GOLDEN SQUARE
BEAK ST
ARLINGTON STREET
REGENT STREET
1854

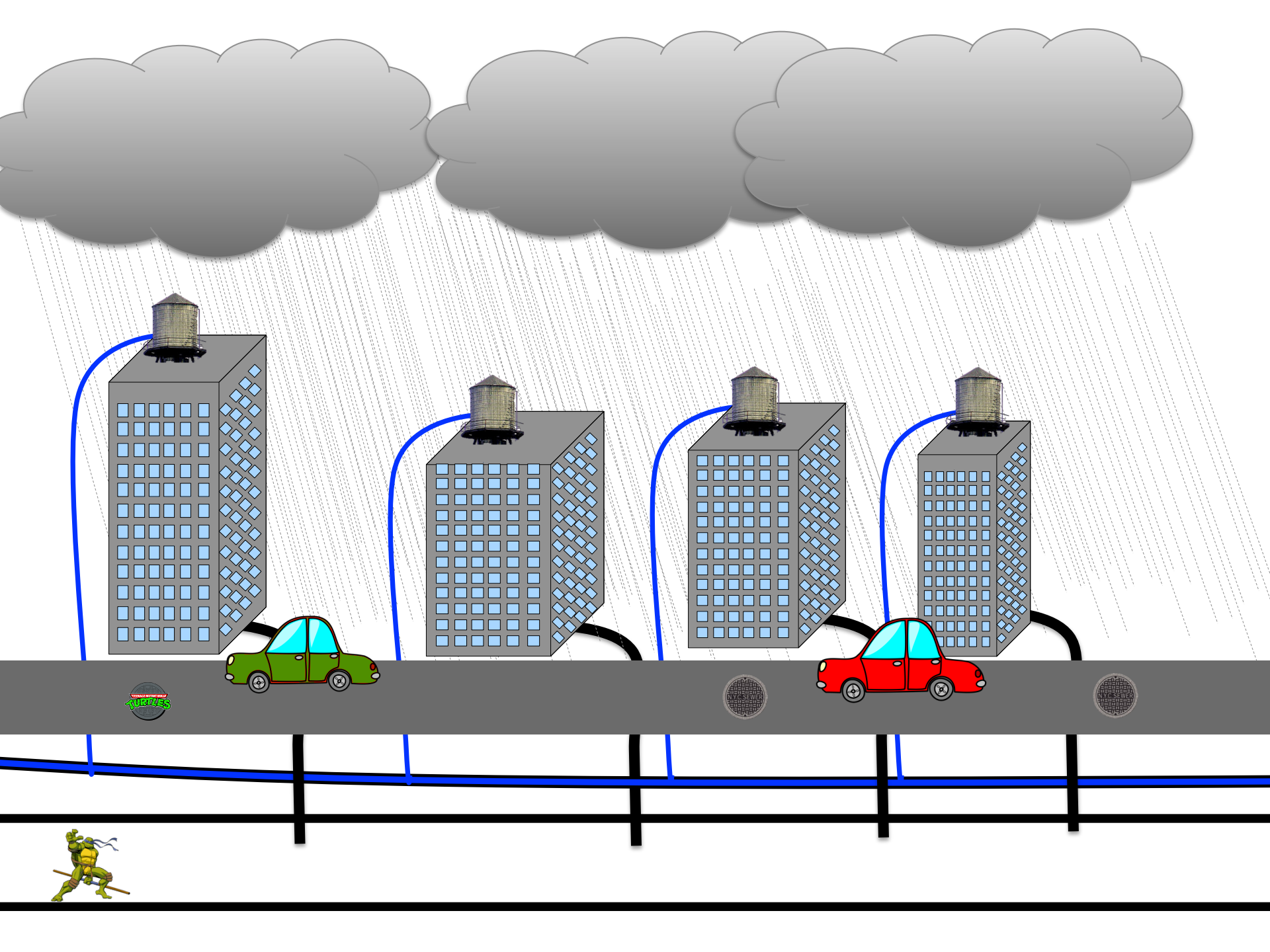

Catskill/Delaware Watersheds
Schoharie Reservoir
Pepacton Reservoir
Cannonsville Reservoir
Ashokan Reservoir
Neversink Reservoir
Rondout Reservoir
West Branch Delaware
East Branch Delaware
Esopus Creek
Schoharie Creek
Stamford Tunnel
West Delaware Tunnel
East Delaware Tunnel
Neversink Tunnel
Delaware Aqueduct
Catskill Aqueduct
Hudson River
Croton Watershed
West Branch Reservoir
New Croton Reservoir
Kensico Reservoir
Long Island Sound
Bronx
Manhattan
Queens
Brooklyn
Staten Island
Groundwater Service Area
New York Bay
Atlantic Ocean
PENNSYLVANIA
CONNECTICUT
NEW YORK
NEW JERSEY
NYC Environmental Protection
New York City's Water Supply System
Catskill / Delaware Watershed Area
Croton Watershed Area
Rivers and Reservoirs
Catskill Aqueduct and Tunnels
Croton Aqueduct
Delaware Aqueduct and Tunnels
County Borders
State Borders
www.nyc.gov/dep

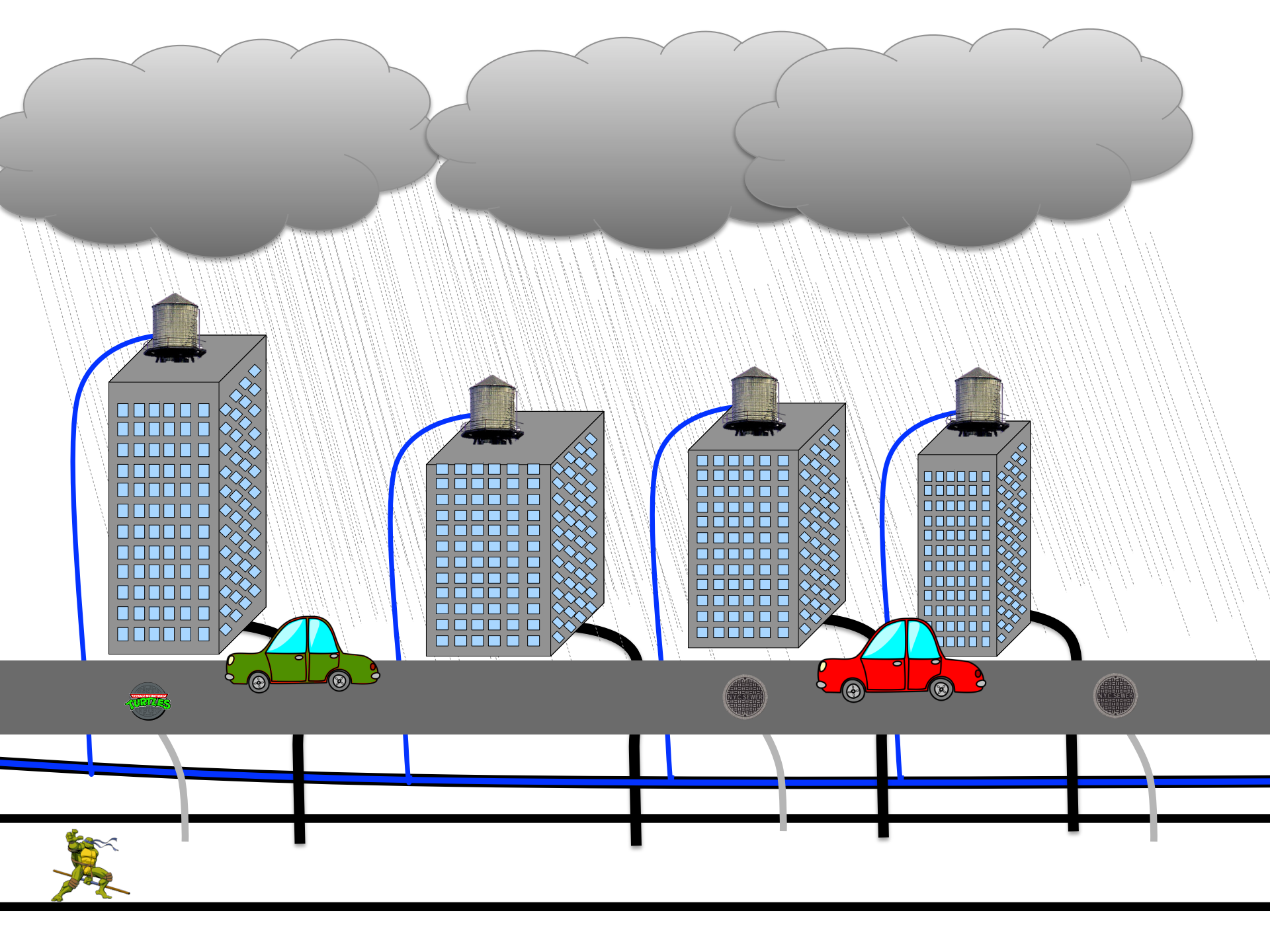

NYC
Environmental Protection
NEW YORK CITY
WATER INFRASTRUCTURE
NEW YORK
NEW JERSEY
Hudson River
Kensico Reservoir
Croton Aqueduct
Catskill Aqueduct
Delaware Aqueduct
WESTCHESTER COUNTY
Hillview Reservoir
Jerome Park Reservoir
City Tunnel No. 3
Stage 1
(Activated in 1998)
NY City Line
BRONX
Long Island Sound
City Tunnel 1
MANHATTAN
East River
NASSAU COUNTY
City Tunnel No. 3 (Stage 2)
Manhattan Section
(Newly Activated)
City Tunnel 2
QUEENS
City Tunnel No. 3 (Stage 2)
Queens/Brooklyn Section
(Under Construction)
Richmond Tunnel
BROOKLYN
STATEN ISLAND
Lower New York Bay
Atlantic Ocean

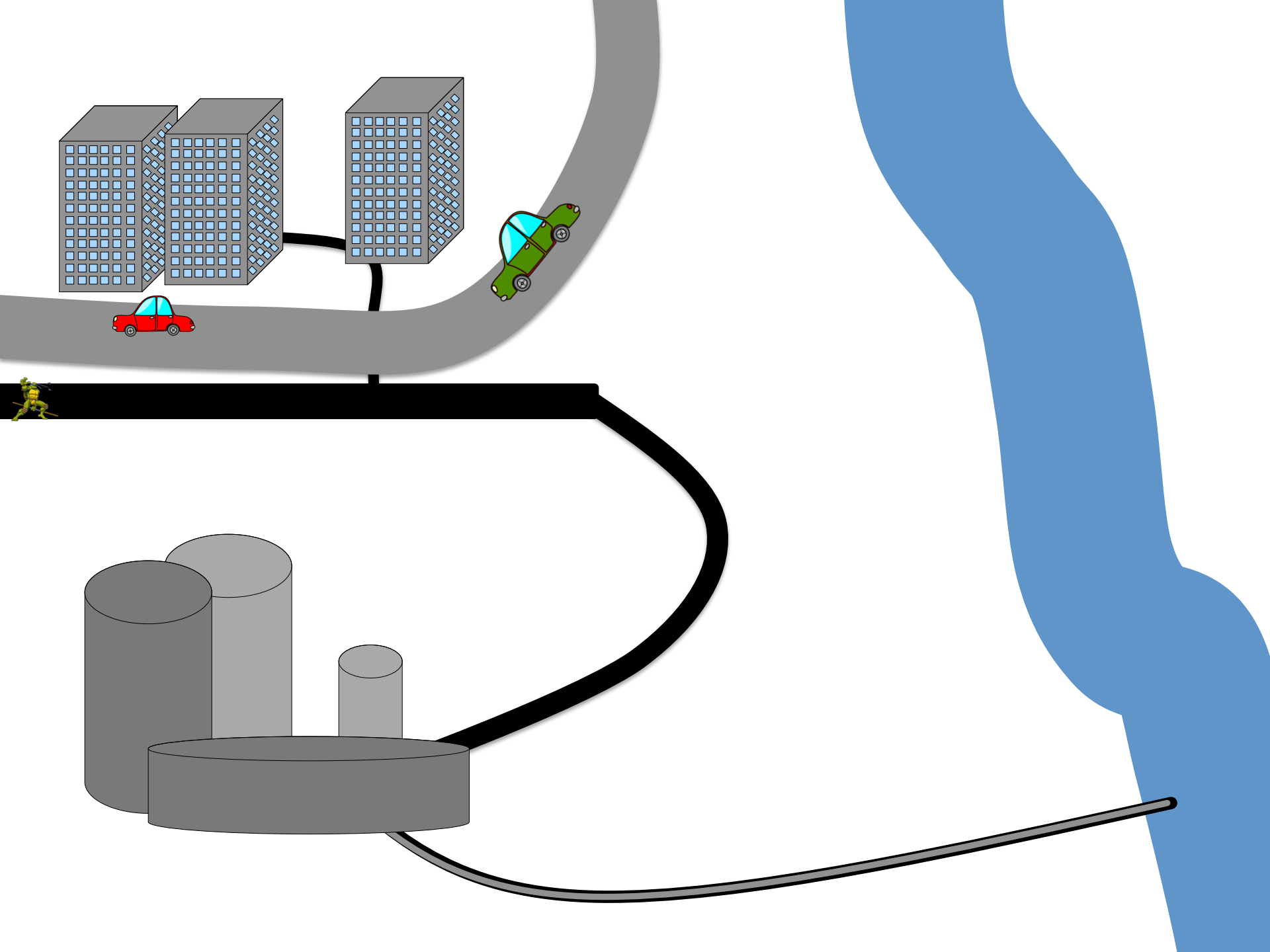

NYCSEWER
NYCSEWER

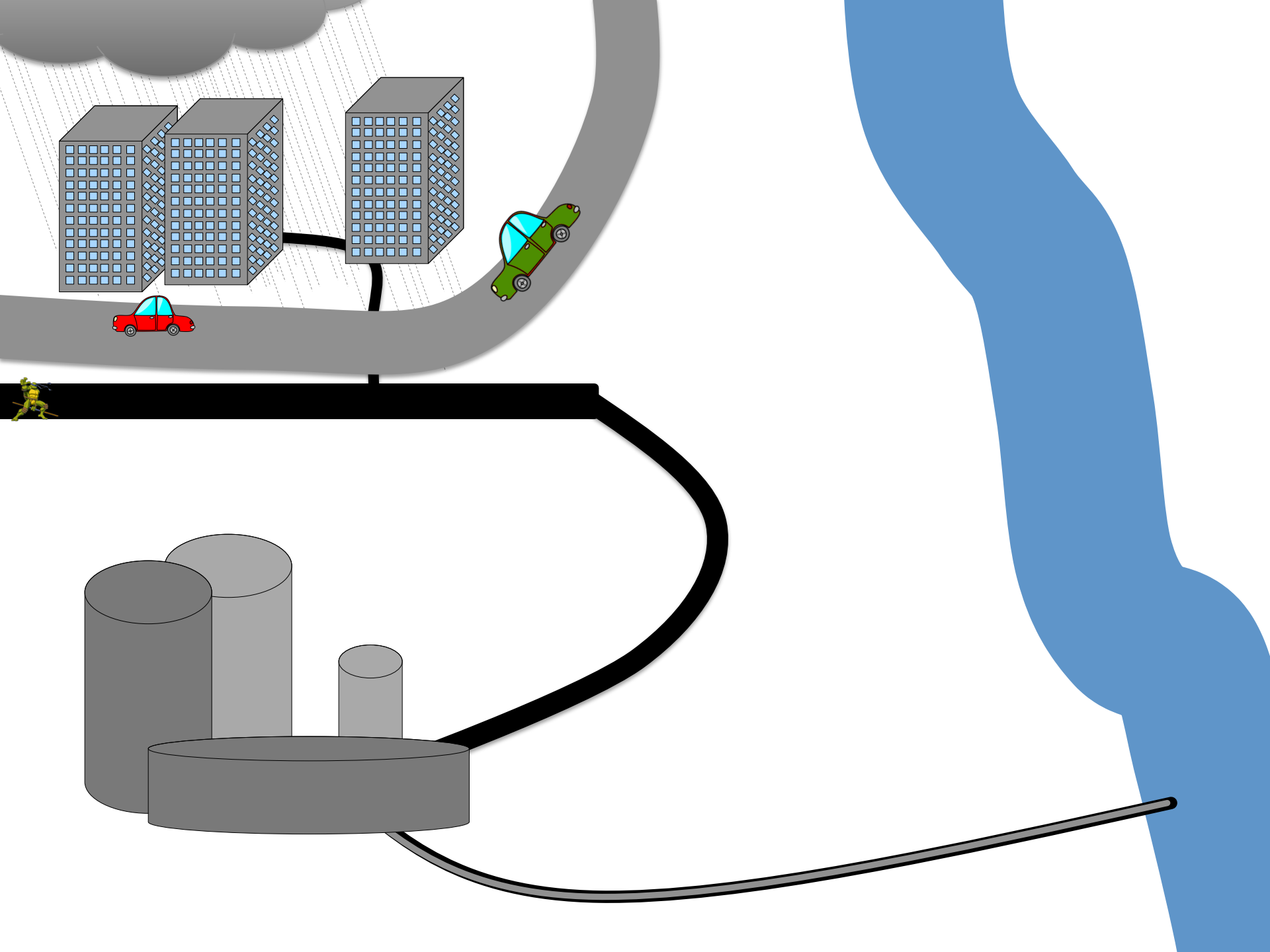

TEENAGE MUTANT NINJA
TURTLES
NYC SEWER
NYC SEWER

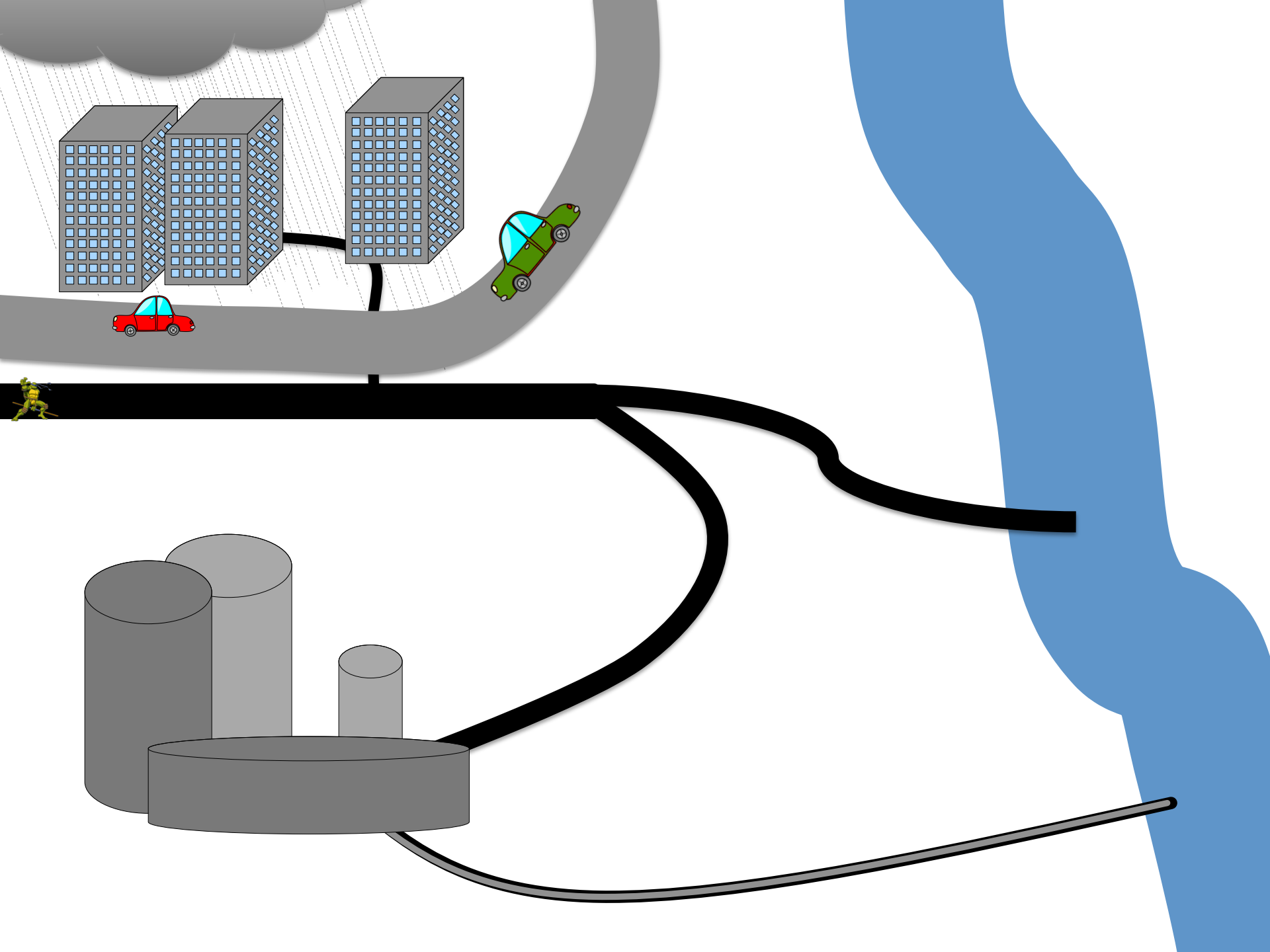

TURTLES
NYC SEWER
NYC SEWER


TEENAGE MUTANT NINJA
TURTLES
NYC SEWER
NYC SEWER

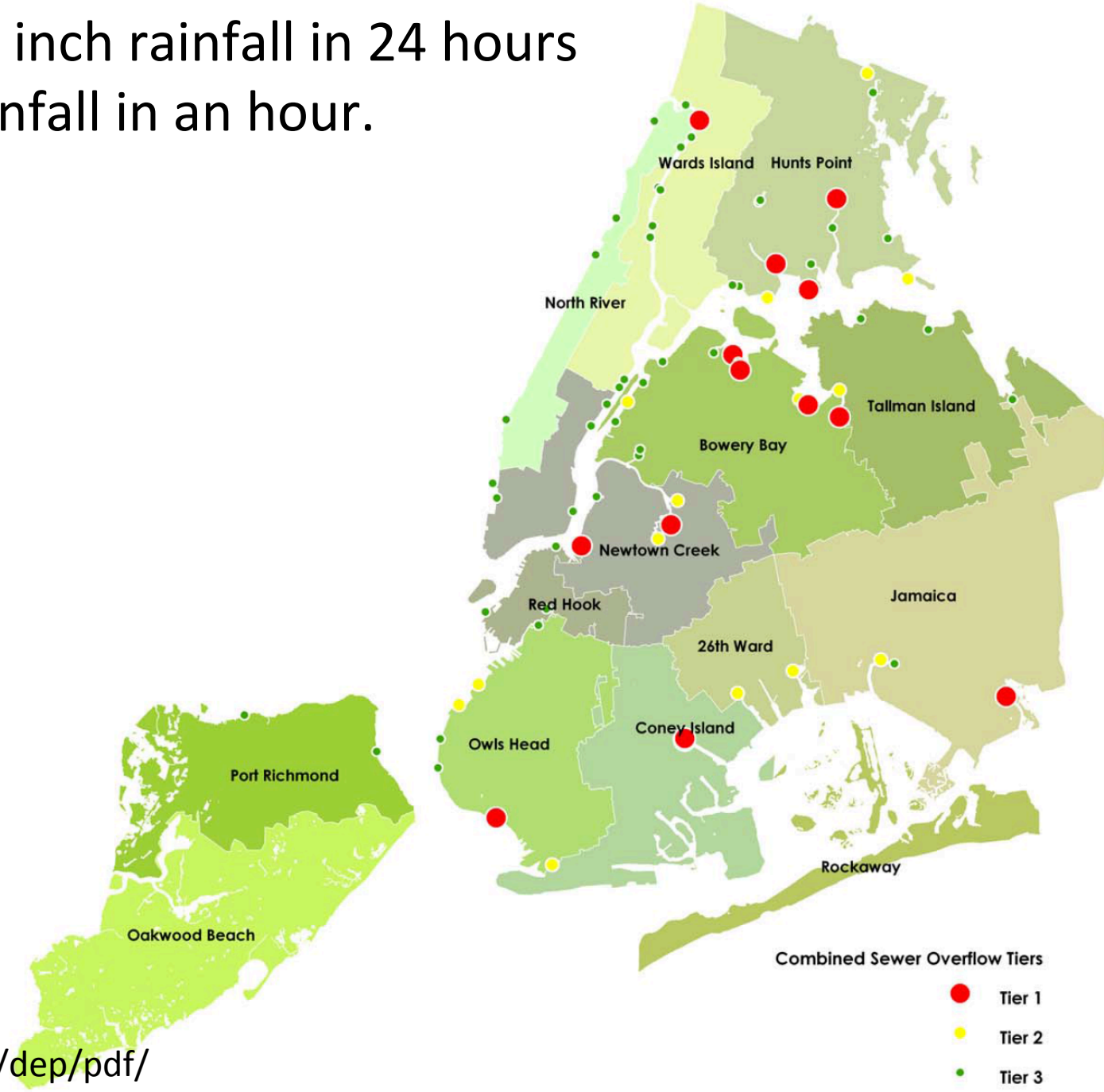

TURTLES
NYC SEWER
NYC SEWER





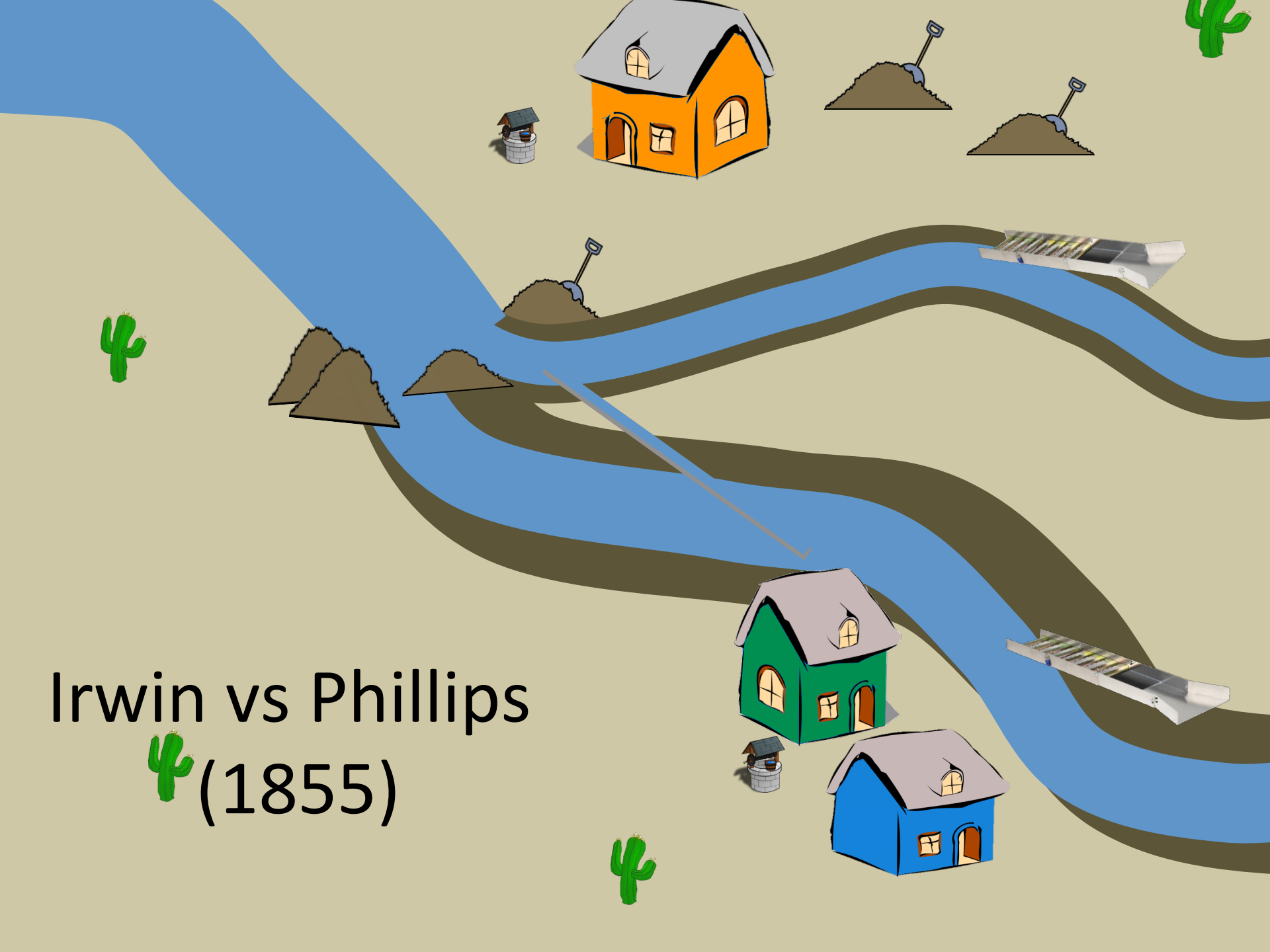


CSO's at about ½ inch rainfall in 24 hours or 1/10th inch rainfall in an hour.



http://www.nyc.gov/html/dep/pdf/green_infrastructure/cso_outfalls_map.pdf

Riparian Water Law


Irwin vs Phillips
(1855)


intent
diversion
beneficial use
priority

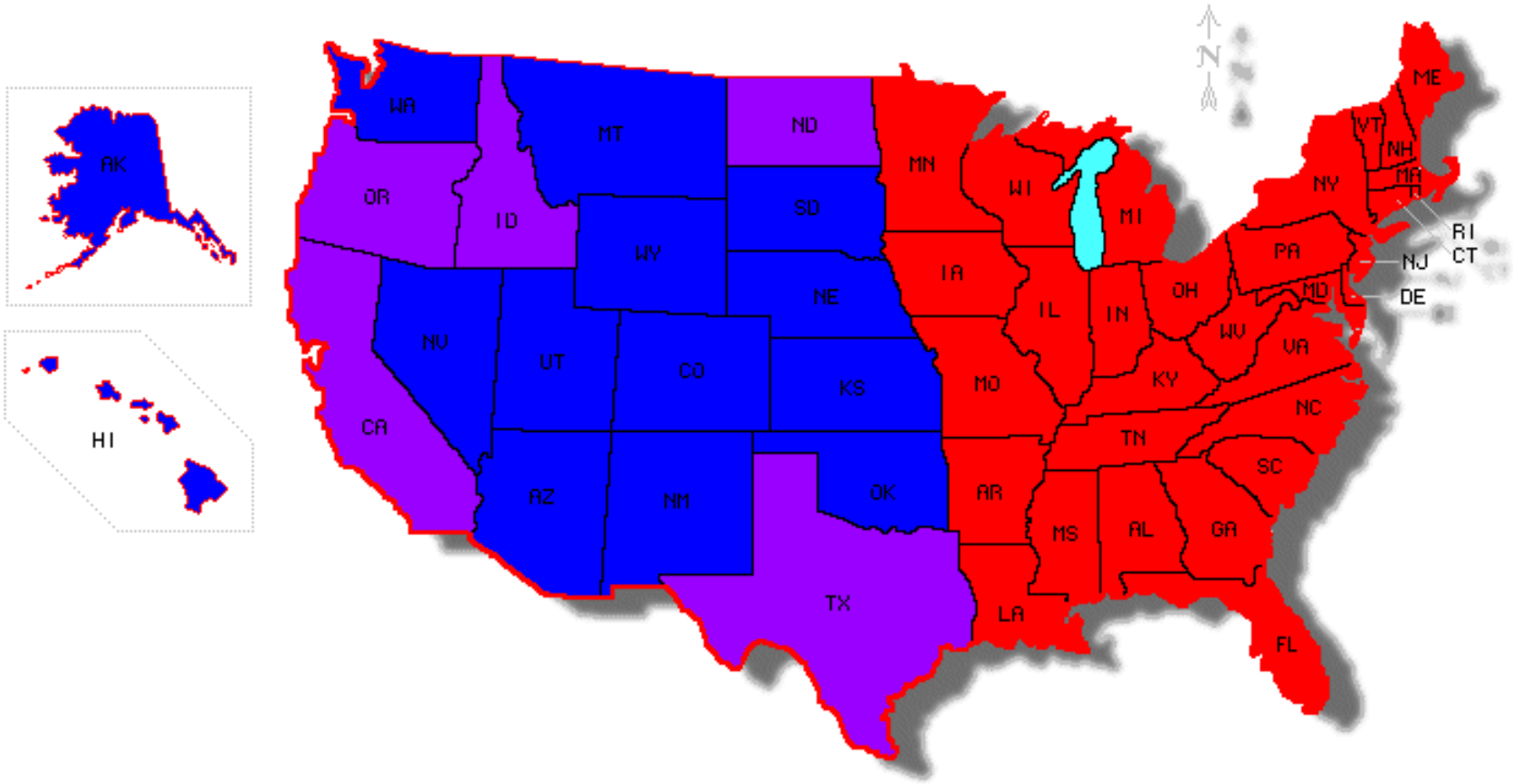
Doctrine of Prior Appropriation

Raquel Baranow


Cobalt123

allocation systems

- Prior Appropriation
- Riparian
- Combined



Source: diymaps.net (c)


Topo
Imagery Topo
Imagery
Hydro-NHD
Hill Shade
HUC 2 - 09
HUC 2 - 17
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HUC 2 - 01
HUC 2 - 10
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HUC 2 - 15
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Seattle
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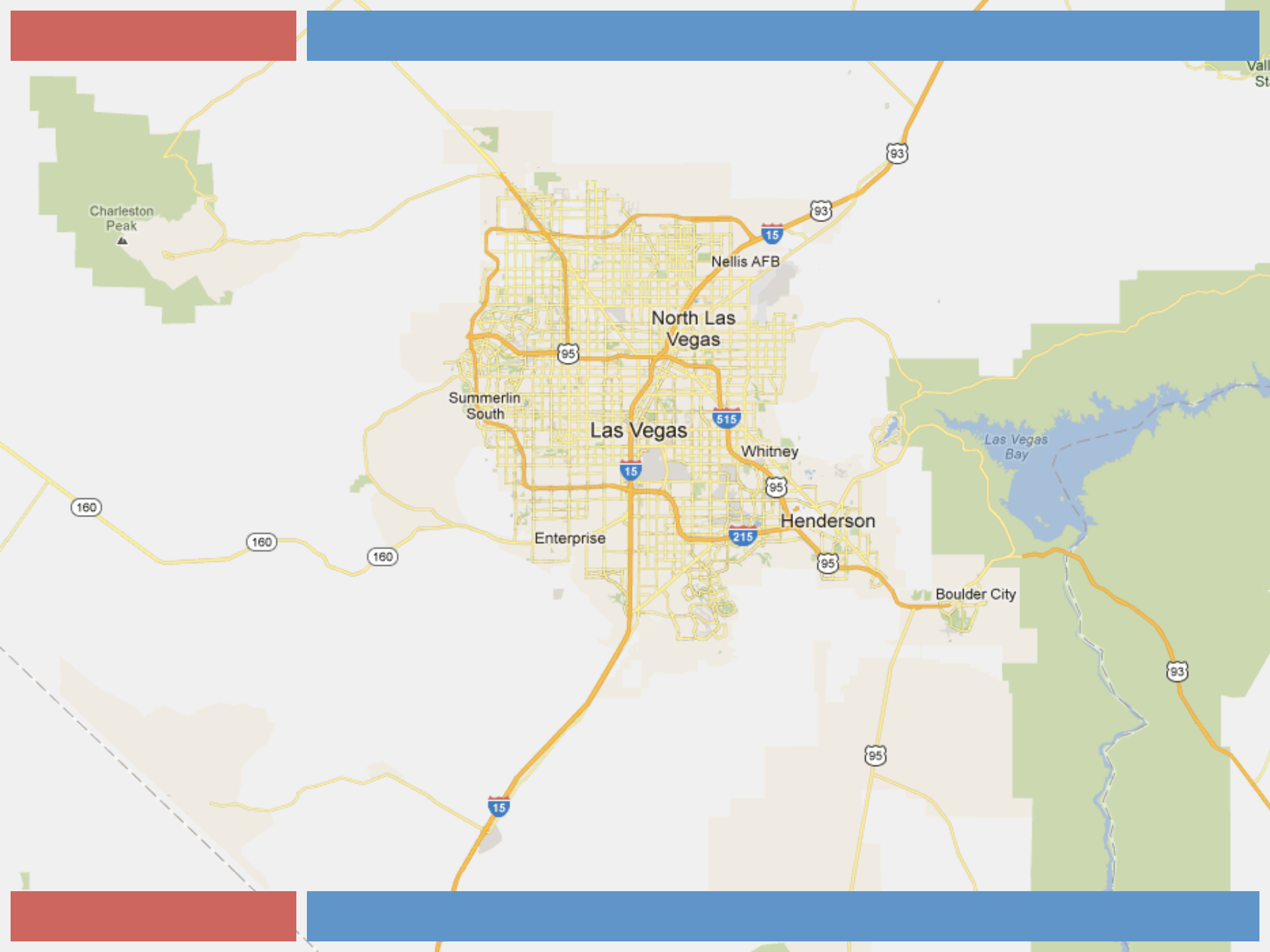
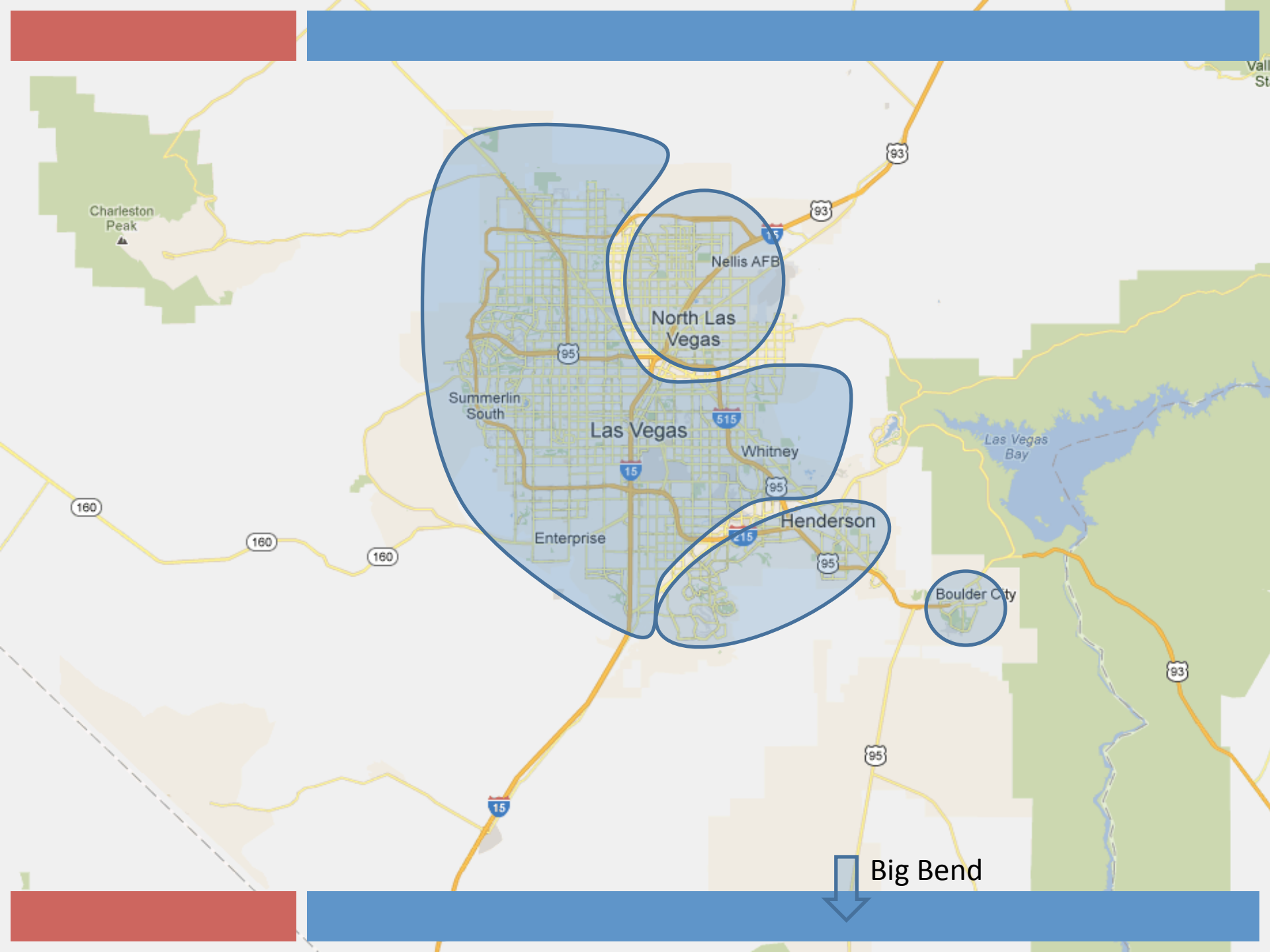
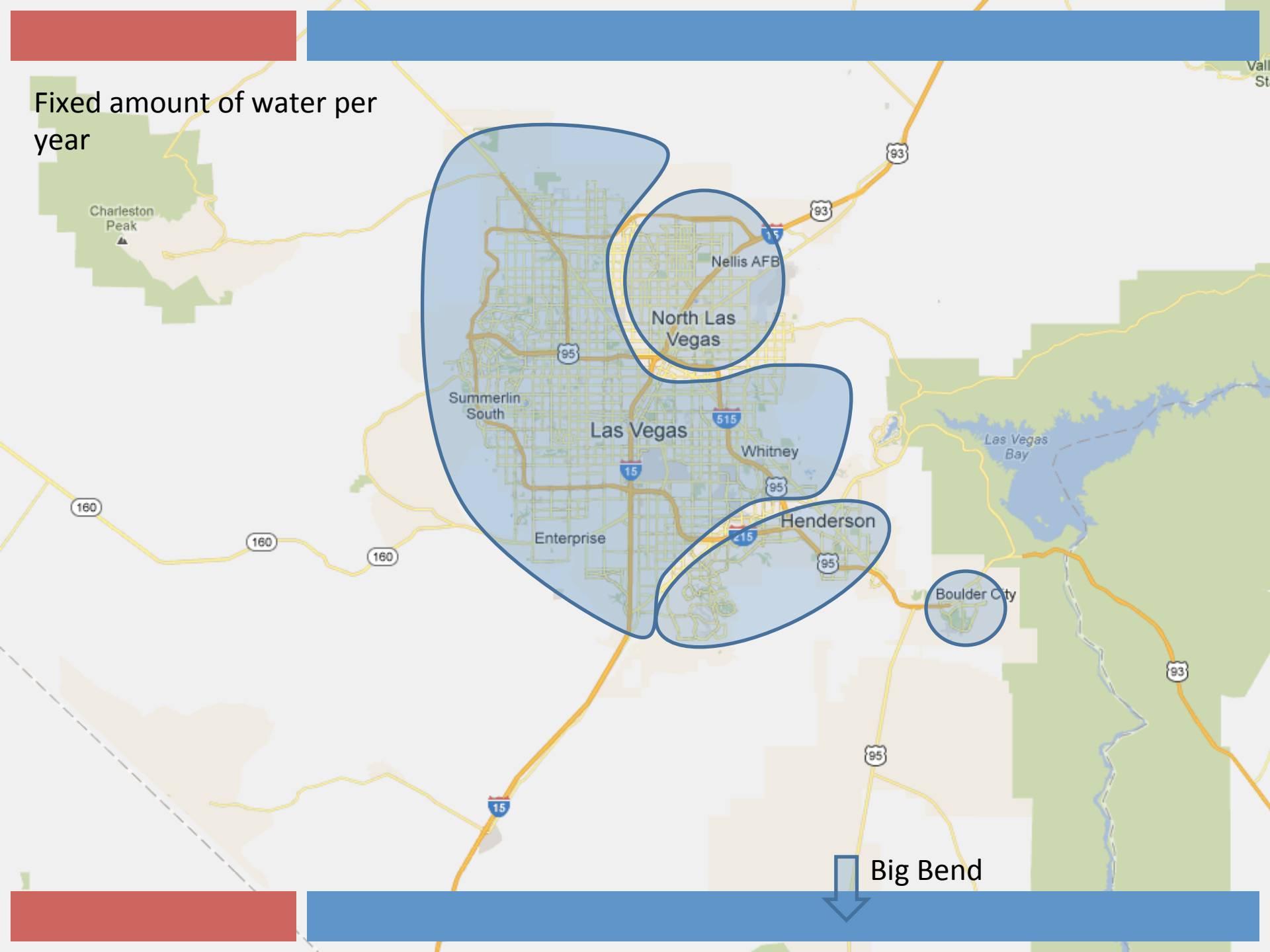
MINNESOTA
SOUTH DAKOTA
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
Denver
OKLAHOMA
Oklahoma City
CALIFORNIA
San Francisco
San Jose
Los Angeles
San Diego
ARIZONA
Phoenix
NEW MEXICO
El Paso
TEXAS
Austin
San Antonio
Houston
Fort Worth
Mexico
Milwaukee
Chicago
Detroit
MI
WI
IA
IL
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
New York
Philadelphia
Baltimore
Washington
MD
DE
NJ
CT
MA
Boston
NH
VT
ME
Memphis
Charlotte
Jacksonville
Columbus
Snake River
Columbia River
Platte River
Missouri River
Arkansas River
Canadian River
Colorado River
San Joaquin River
Ohio River
Tennessee River
Susquehanna River
Connecticut River
Red River
Mississippi R.
Brazos River
Chattahoochee River
Grande, Rio
100
200mi


Whiskey is for Drinking;
Water is for Fighting Over
matching fixed supply with growing demand


Charleston Peak
Nellis AFB
North Las Vegas
Summerlin South
Las Vegas
Whitney
Las Vegas Bay
Henderson
Enterprise
Boulder City
93
15
95
515
160
215


Charleston Peak
Nellis AFB
North Las Vegas
Summerlin South
Las Vegas
Whitney
Enterprise
Henderson
Las Vegas Bay
Boulder City
Big Bend
93
95
15
515
160

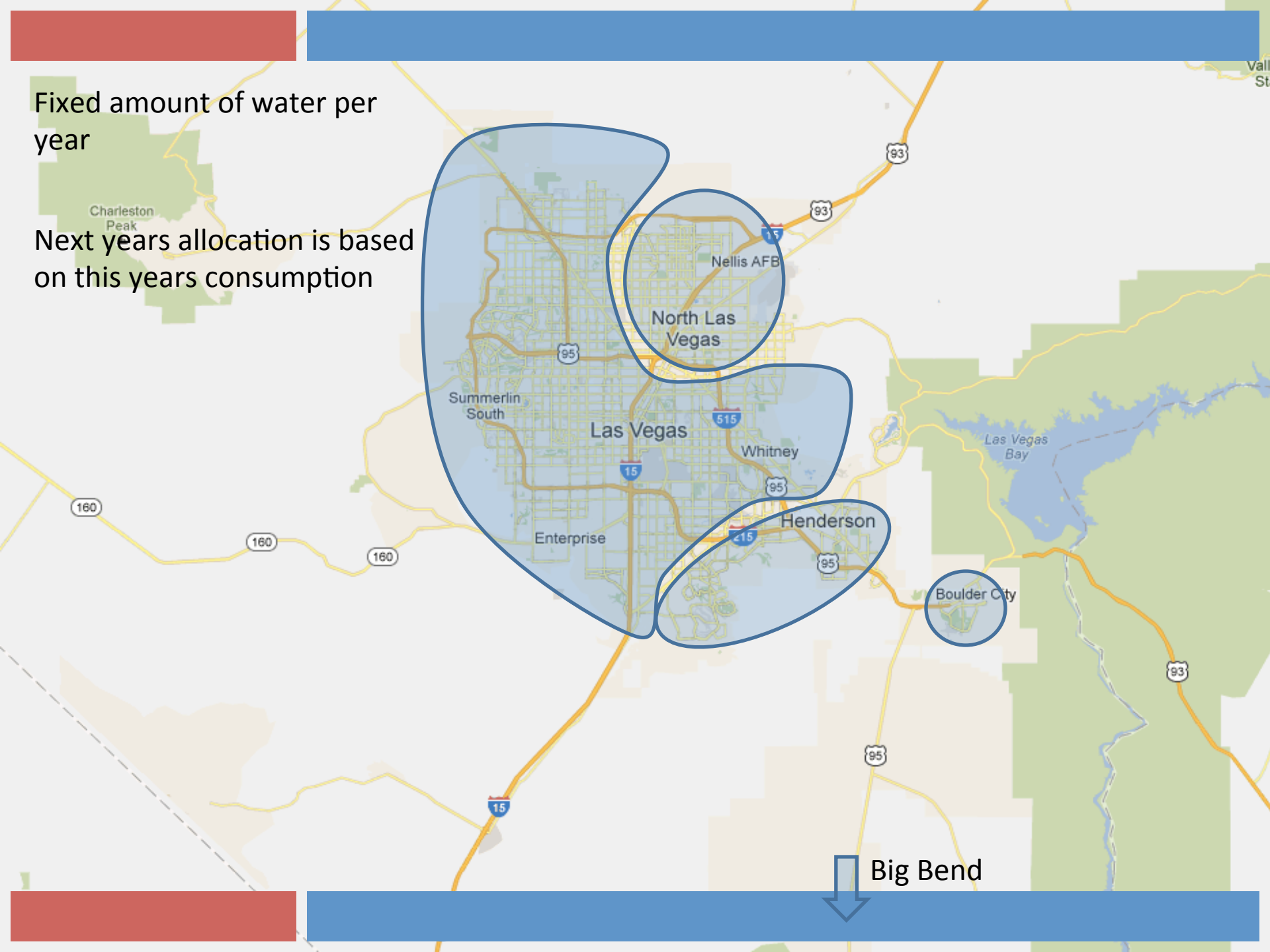
Fixed amount of water per year



Big Bend

Fixed amount of water per year

Next years allocation is based on this years consumption

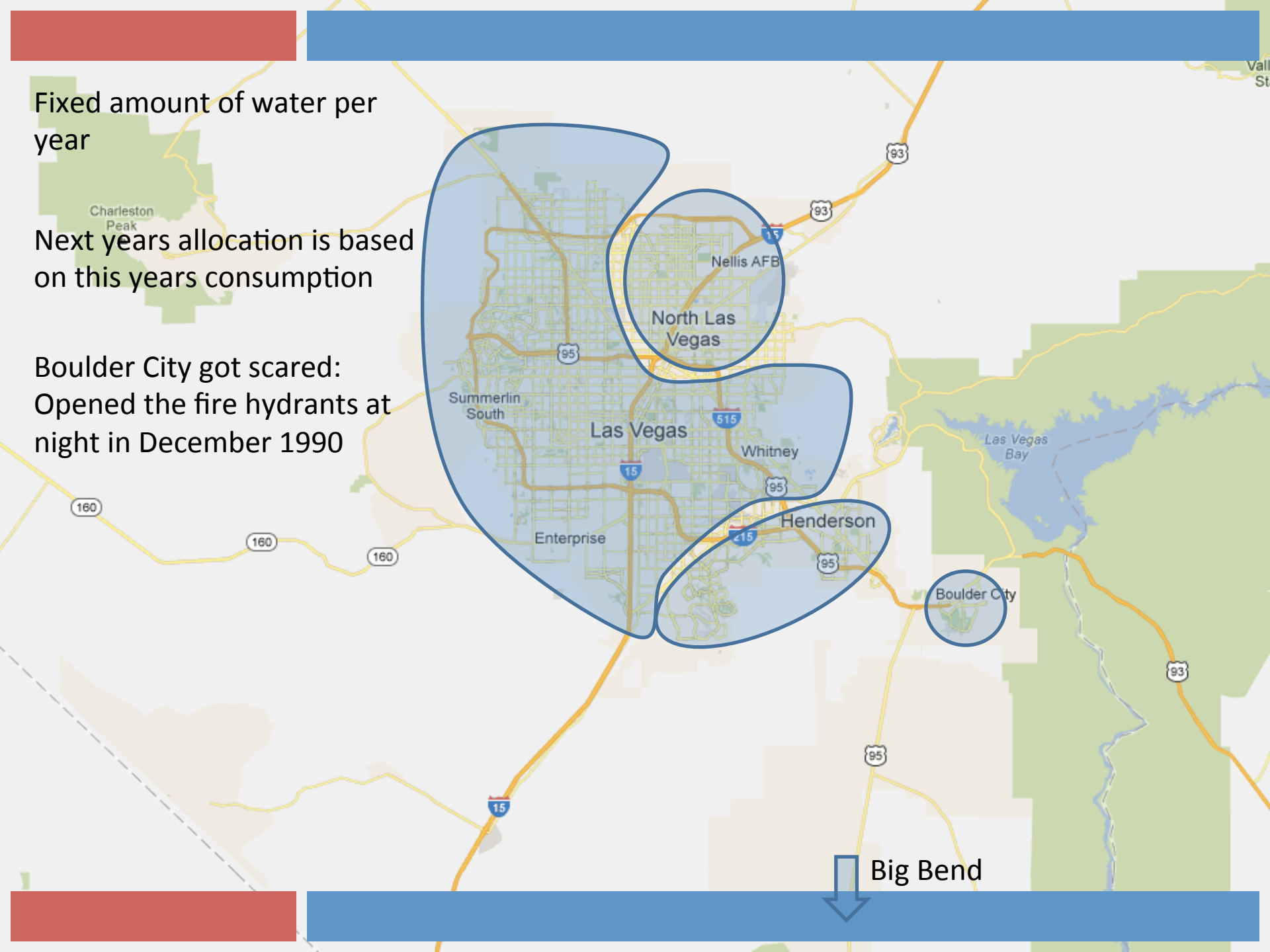


Big Bend

Fixed amount of water per year

Next years allocation is based on this years consumption

Boulder City got scared: Opened the fire hydrants at night in December 1990



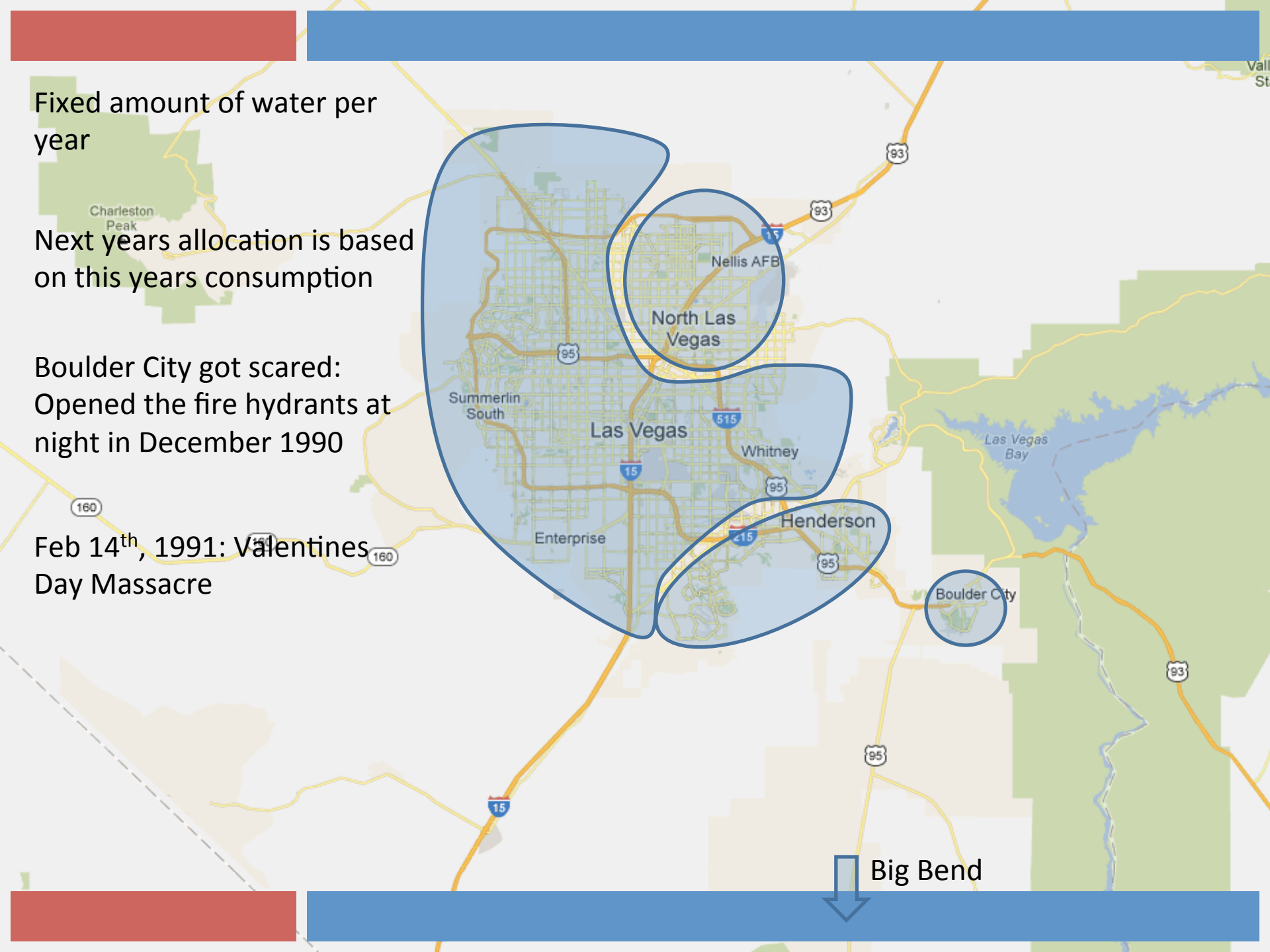
Big Bend

Fixed amount of water per year

Next years allocation is based on this years consumption

Boulder City got scared: Opened the fire hydrants at night in December 1990

Feb 14th, 1991: Valentines Day Massacre



Big Bend

Fixed amount of water per year

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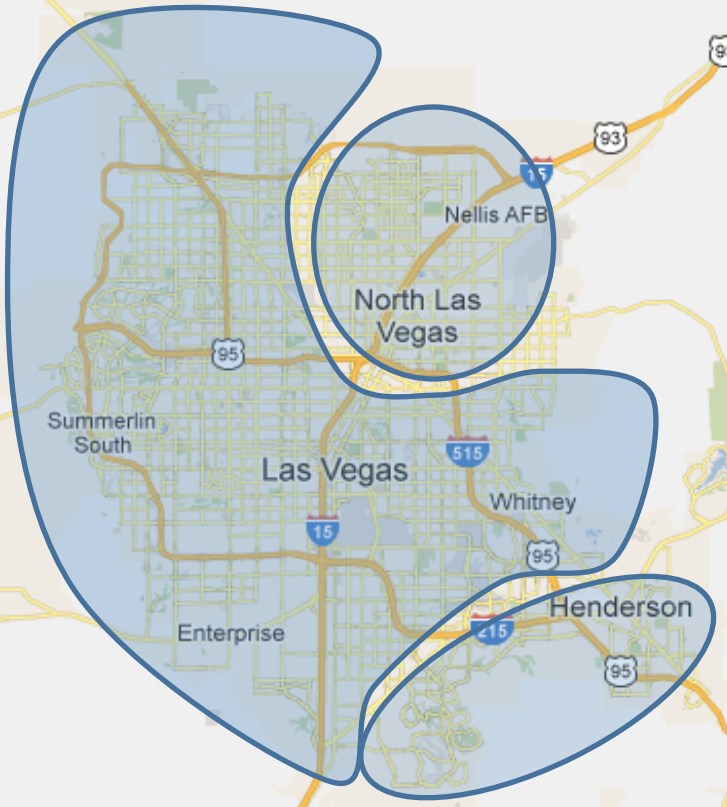
Boulder City got scared: Opened the fire hydrants at night in December 1990

Feb 14th, 1991: Valentines Day Massacre

June 27th, 1991: Southern Nevada Water Authority was created.



Big Bend

Fixed amount of water per year

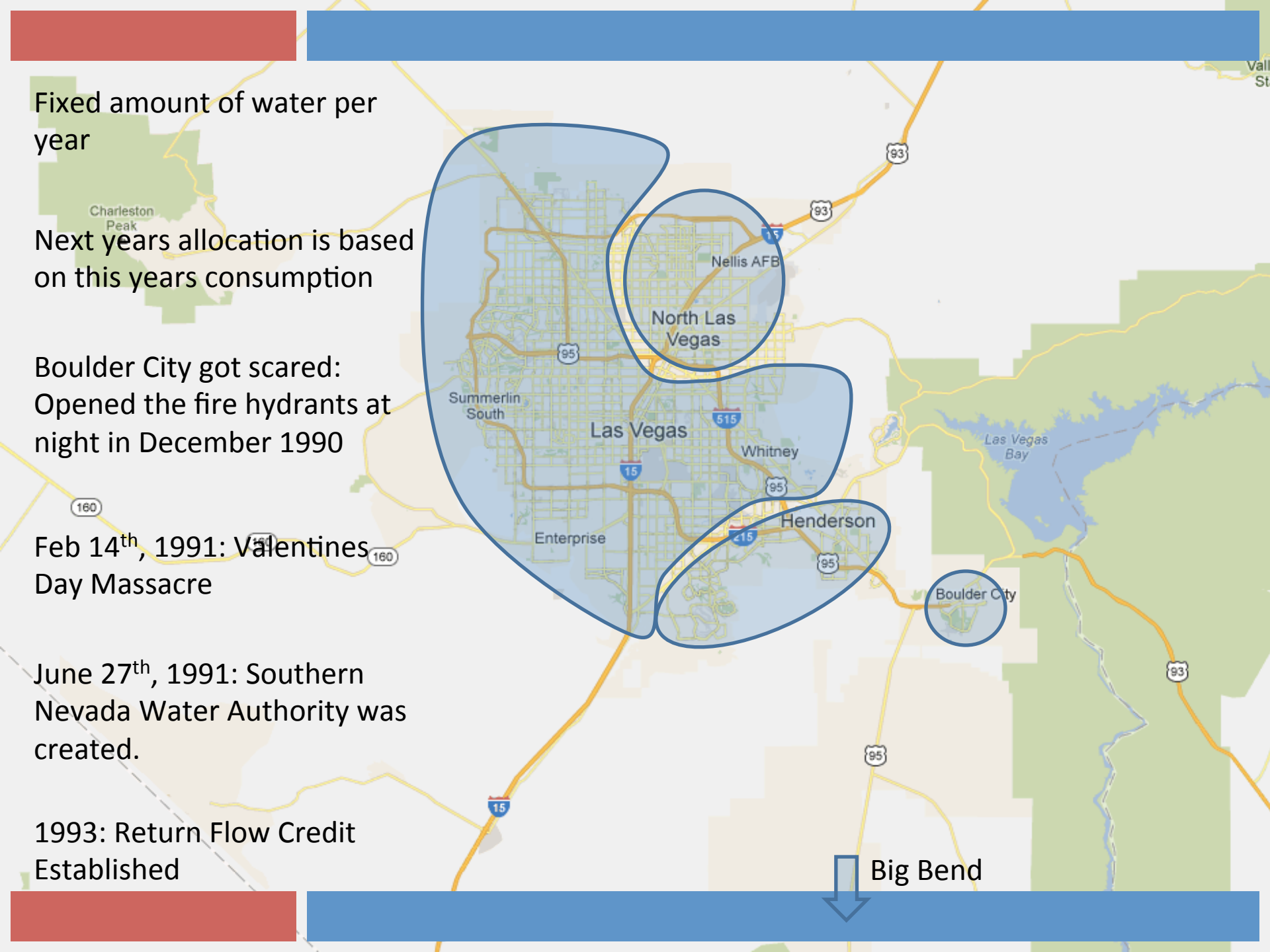
Next years allocation is based on this years consumption

Boulder City got scared: Opened the fire hydrants at night in December 1990

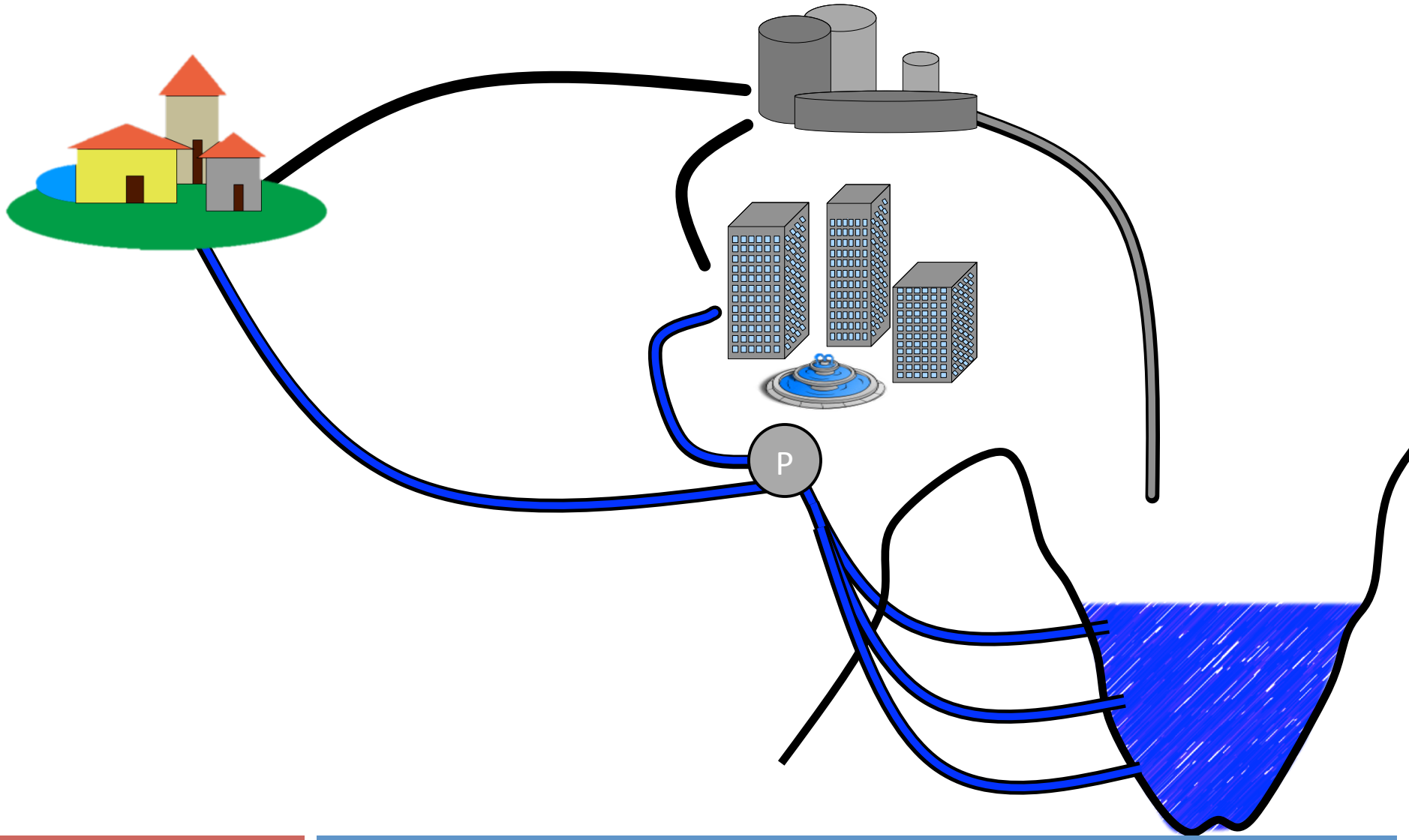
Feb 14th, 1991: Valentines Day Massacre

June 27th, 1991: Southern Nevada Water Authority was created.

1993: Return Flow Credit Established



Big Bend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LAS VEGAS WASH COORDINATION COMMITTEE

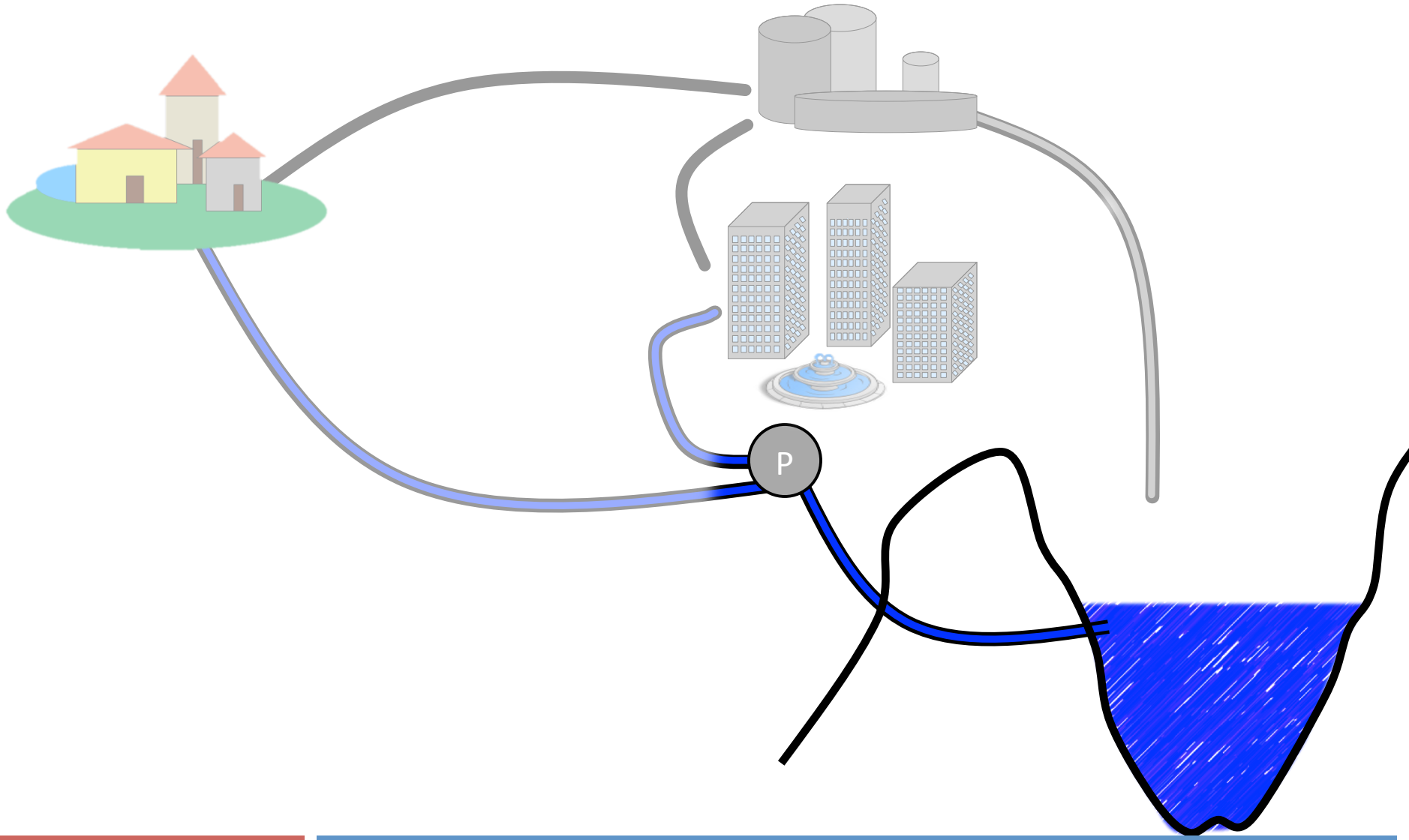
SEARCH: Go

WORKING TO STABILIZE AND ENHANCE THE VALUABLE ENVIRONMENTAL RESOURCES OF THE LAS VEGAS WASH

Annual bird surveys begin

Fast Track

- Meetings & Events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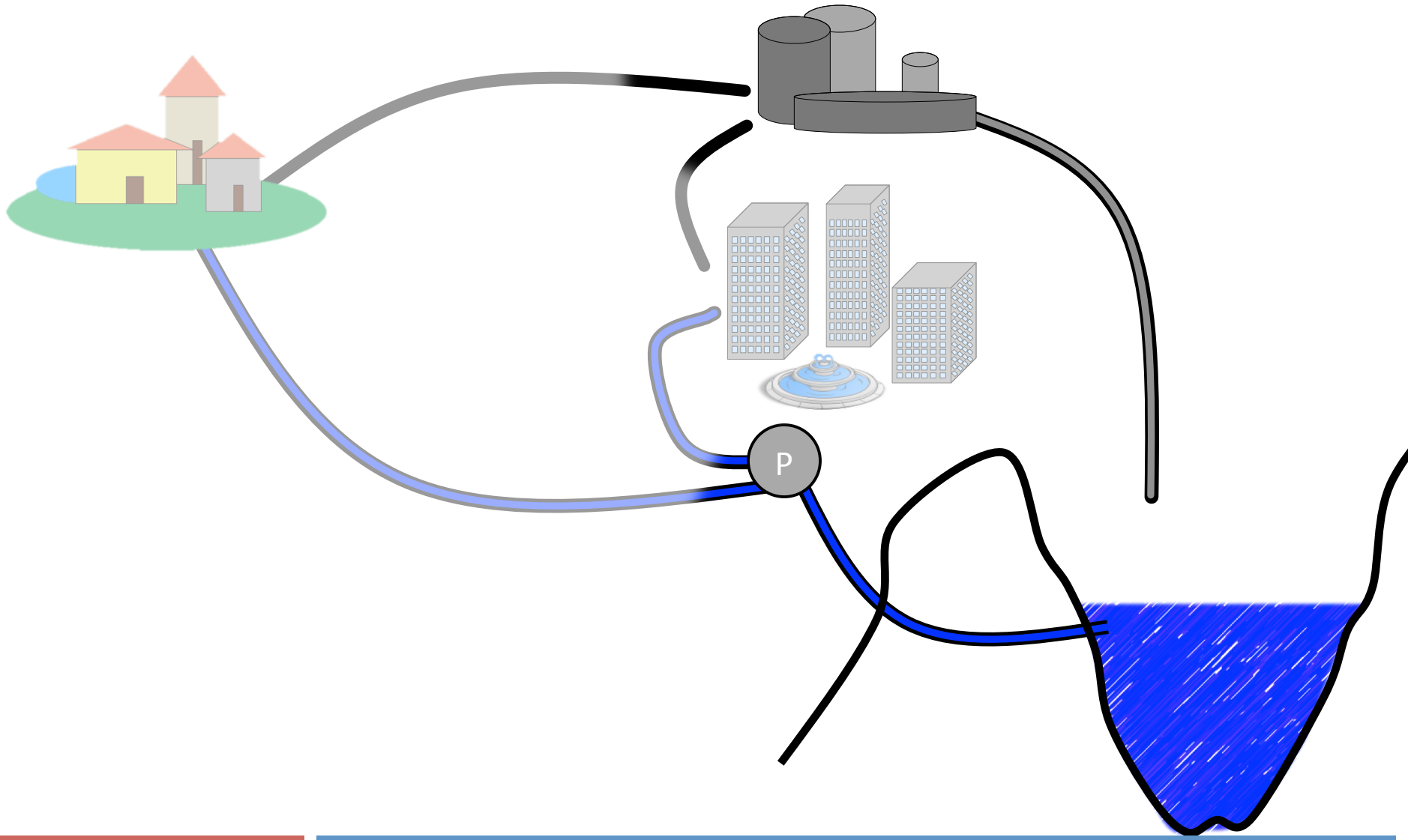
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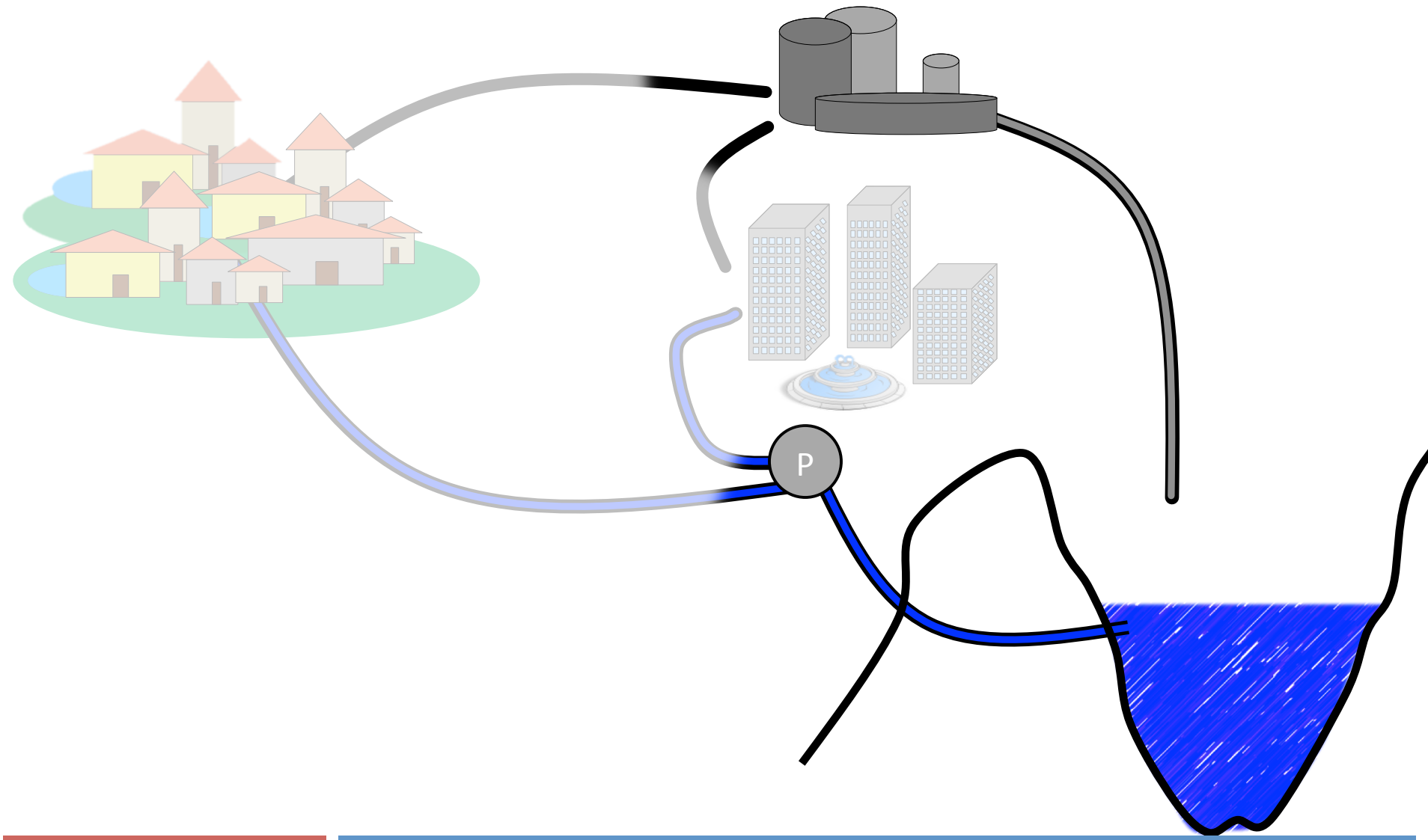
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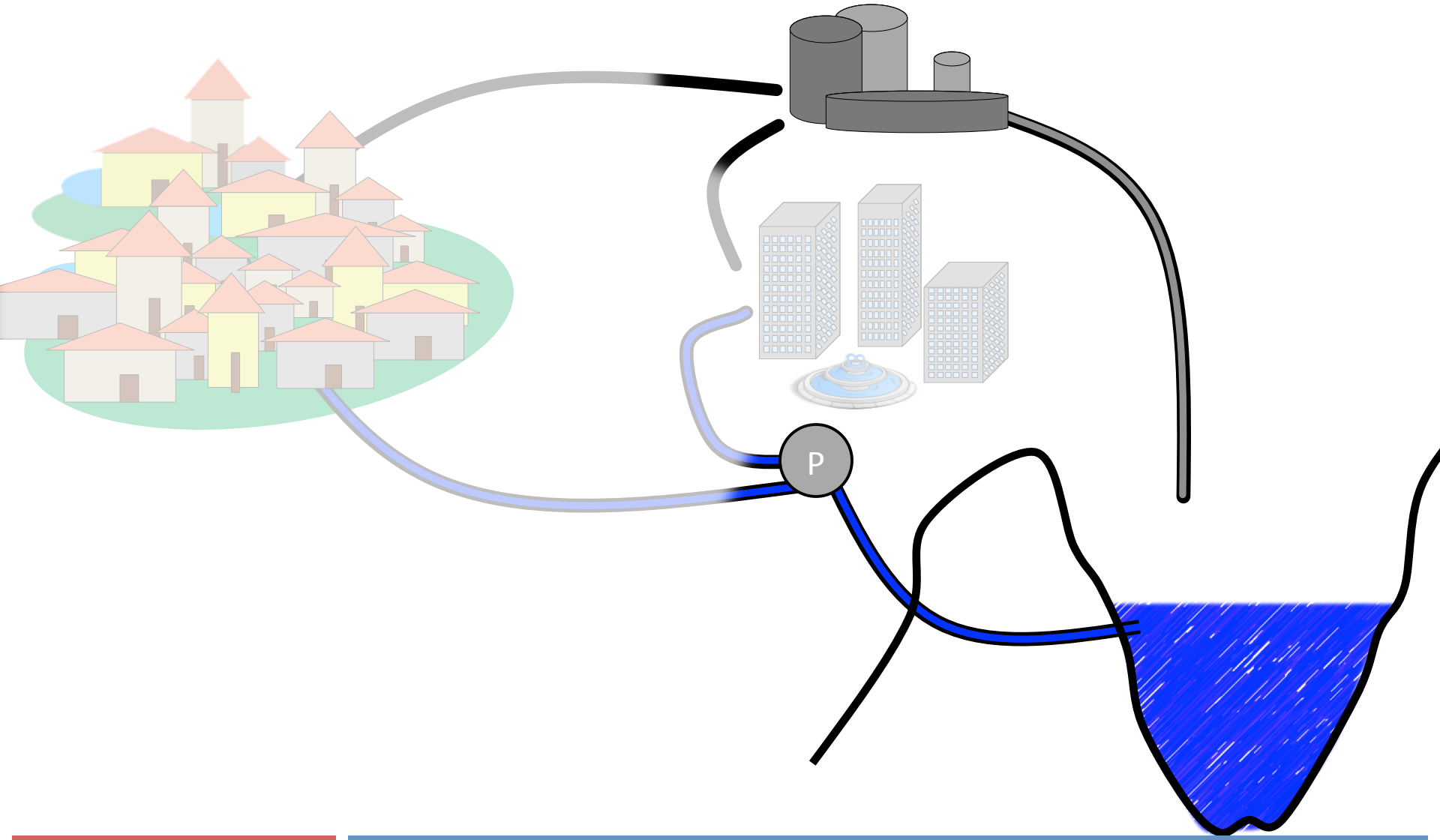
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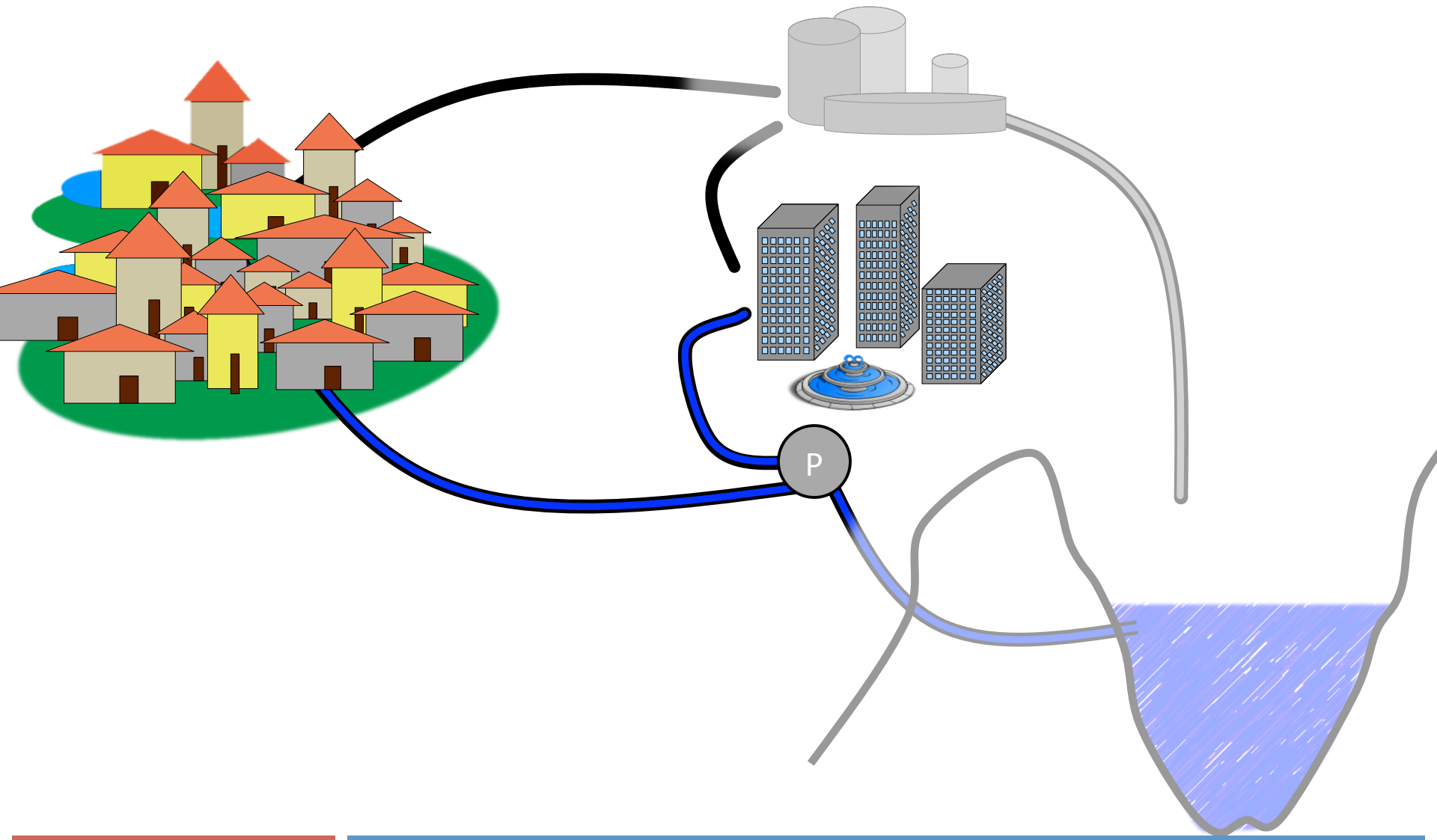
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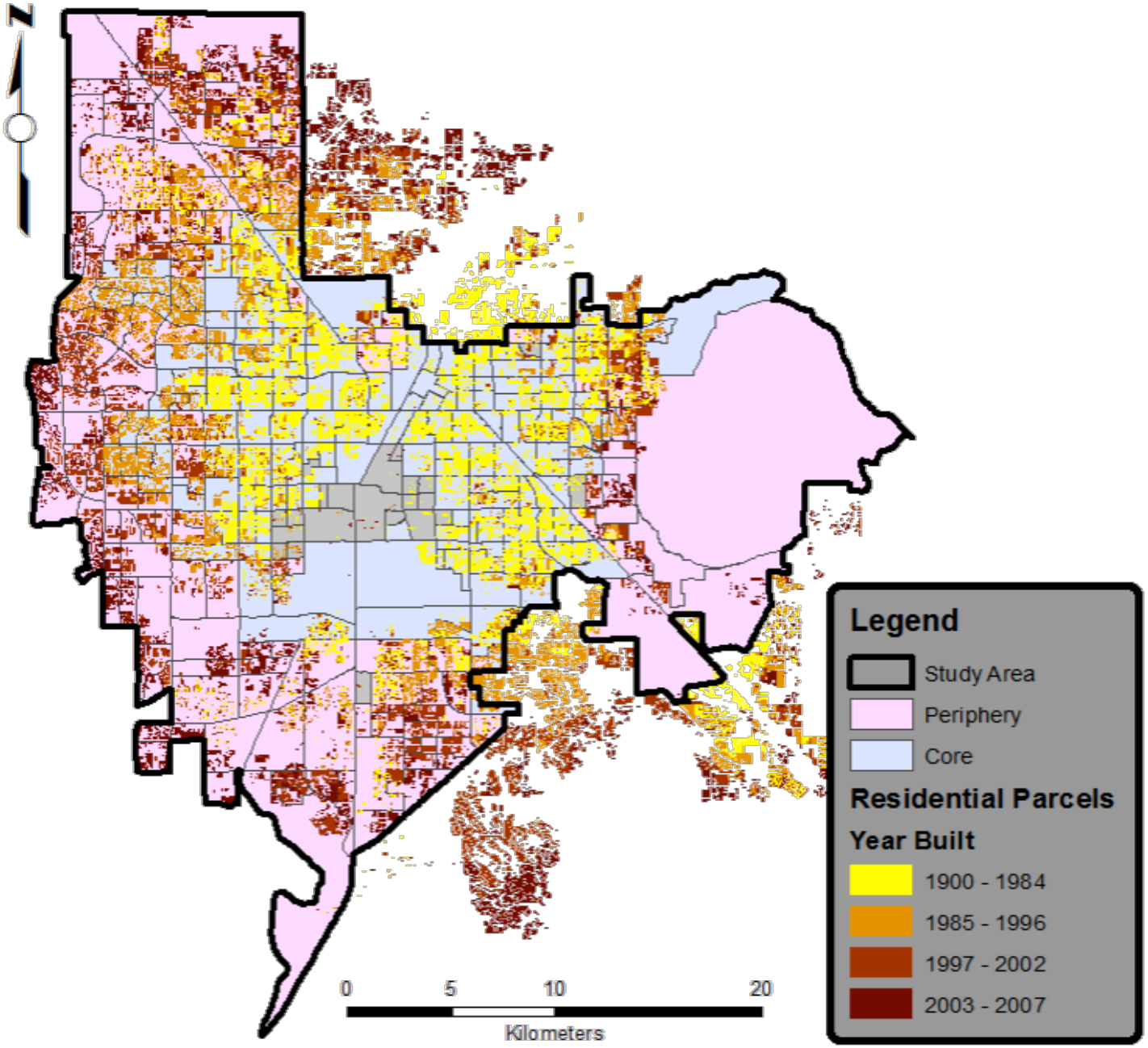
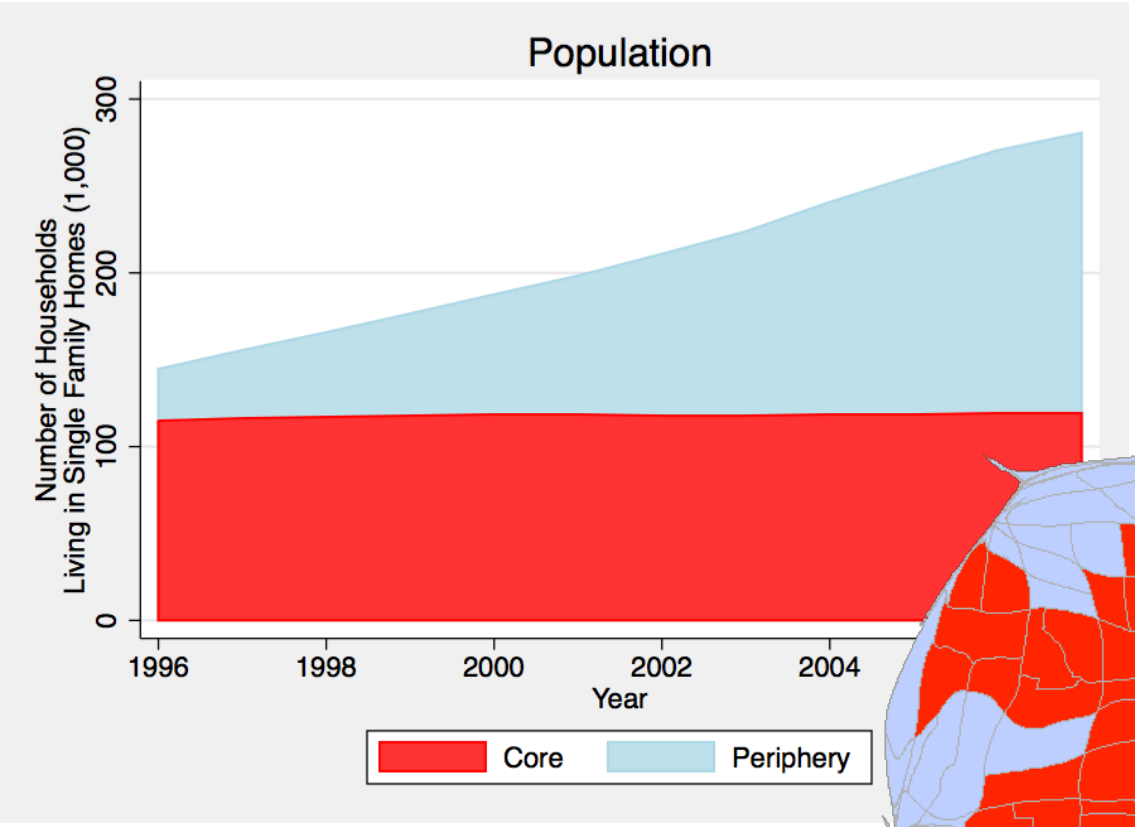
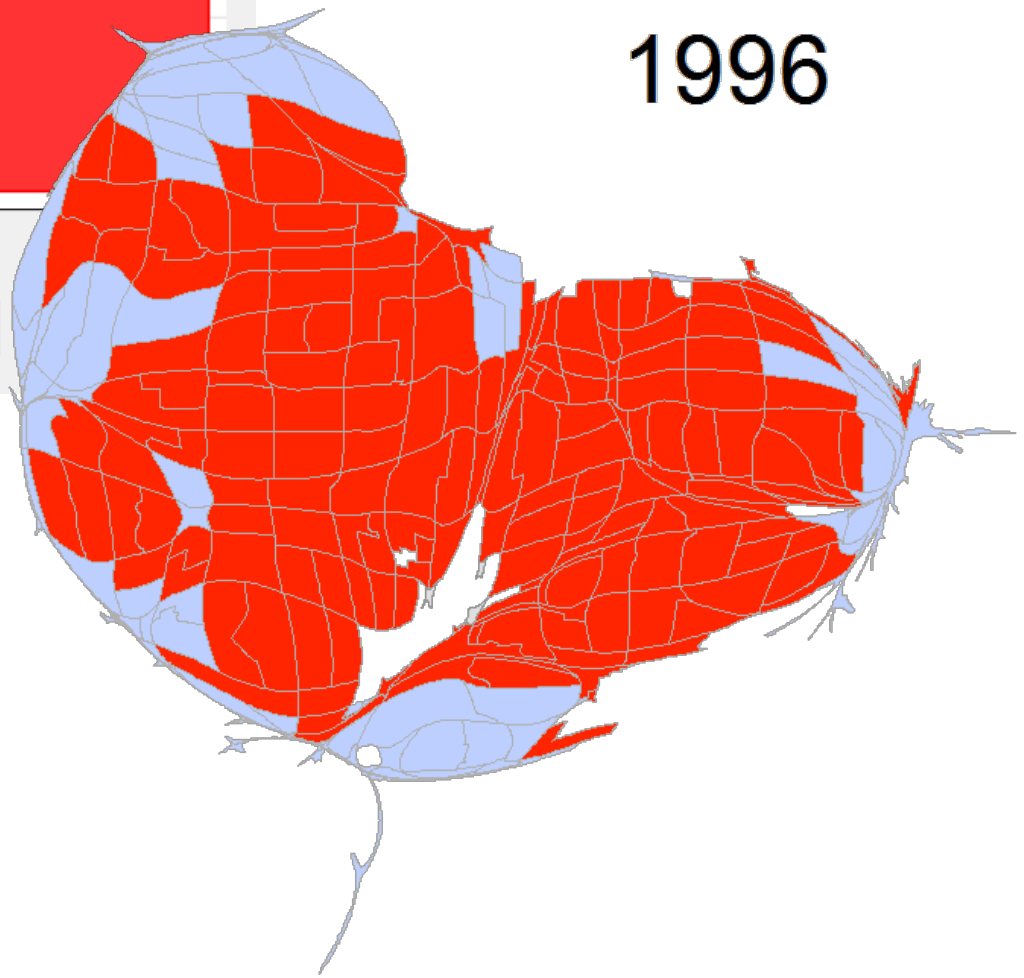
What combination of infrastructure change, population growth and policy choices drove Las Vegas' decline in residential water consumption?

Outline

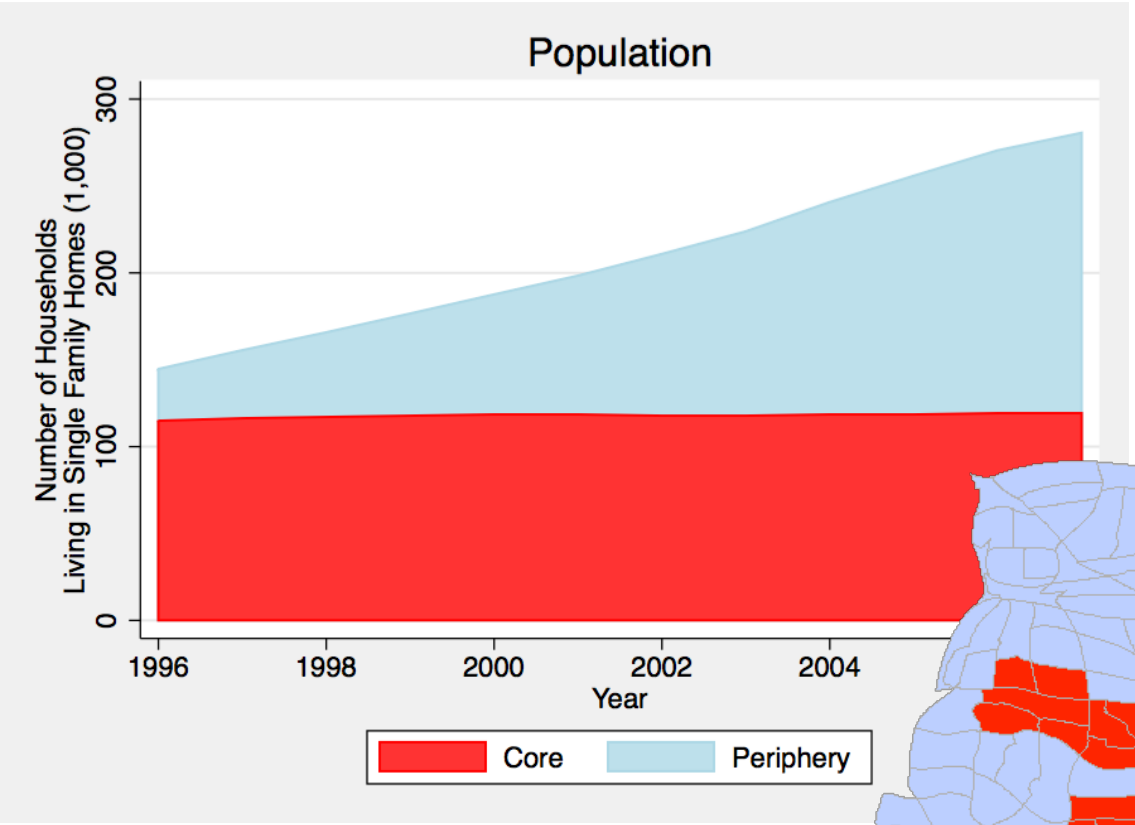
- Data
- Regression Model
- Regression Results
- Decomposition Analysis

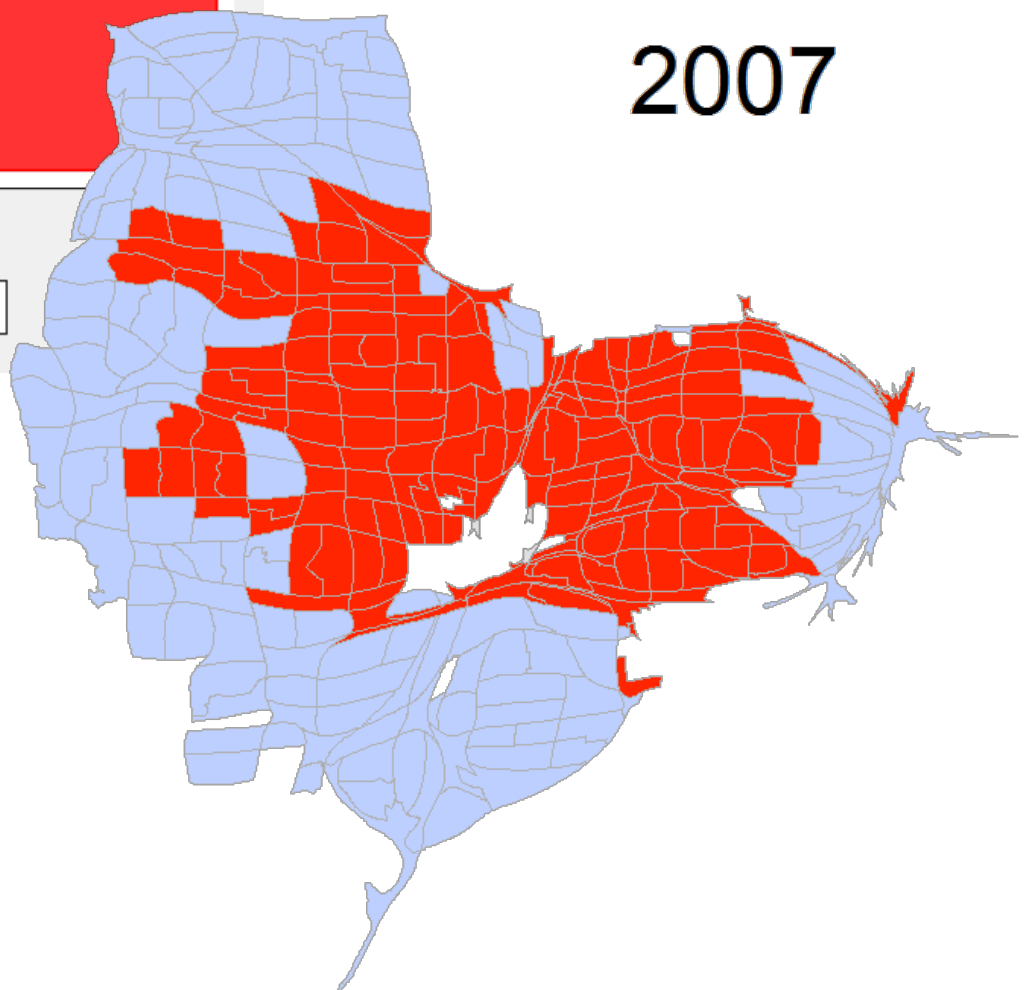

N
0
5
10
20
Kilometers
Legend
Study Area
Periphery
Core
Residential Parcels
Year Built
1900 - 1984
1985 - 1996
1997 - 2002
2003 - 2007



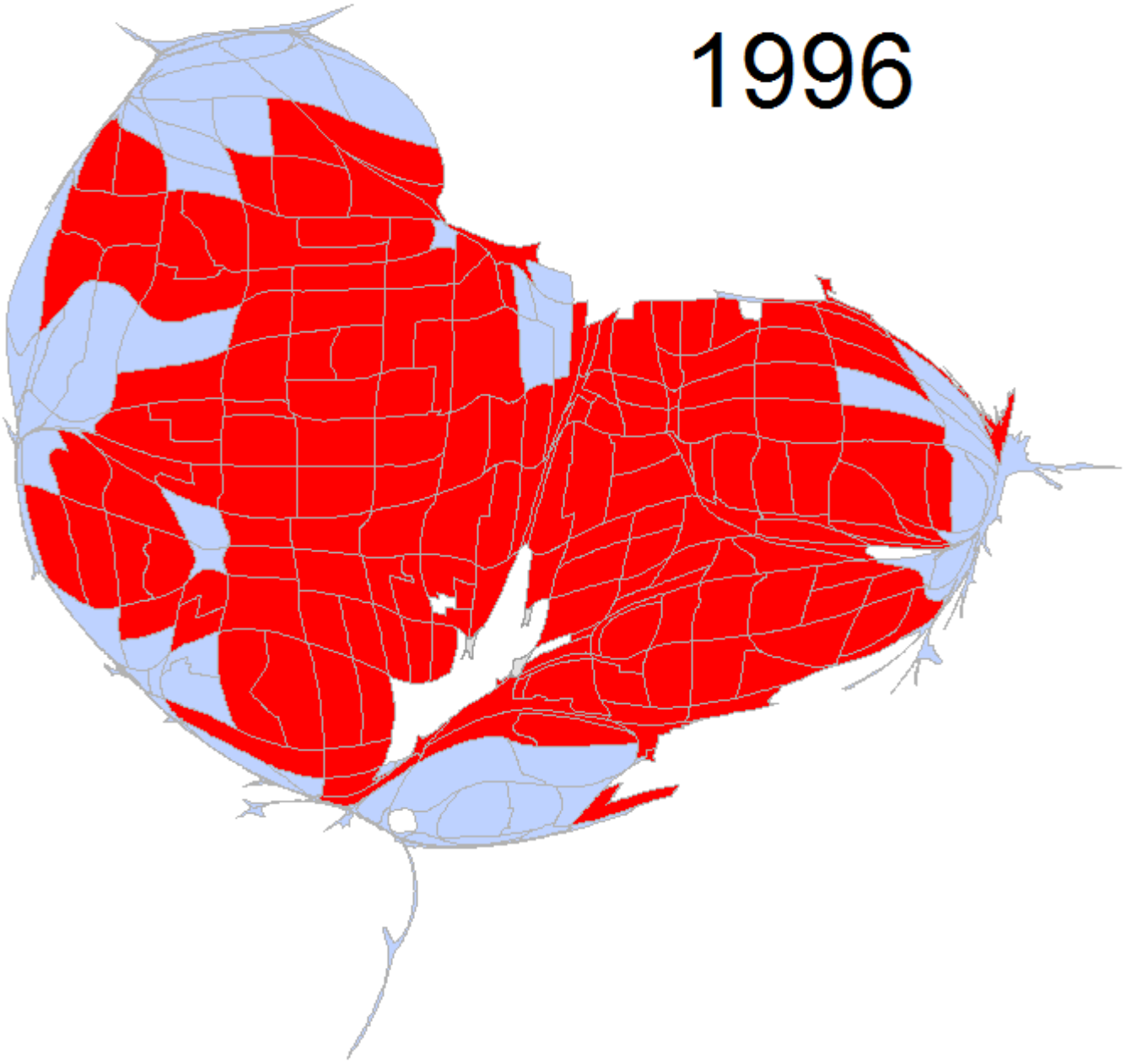


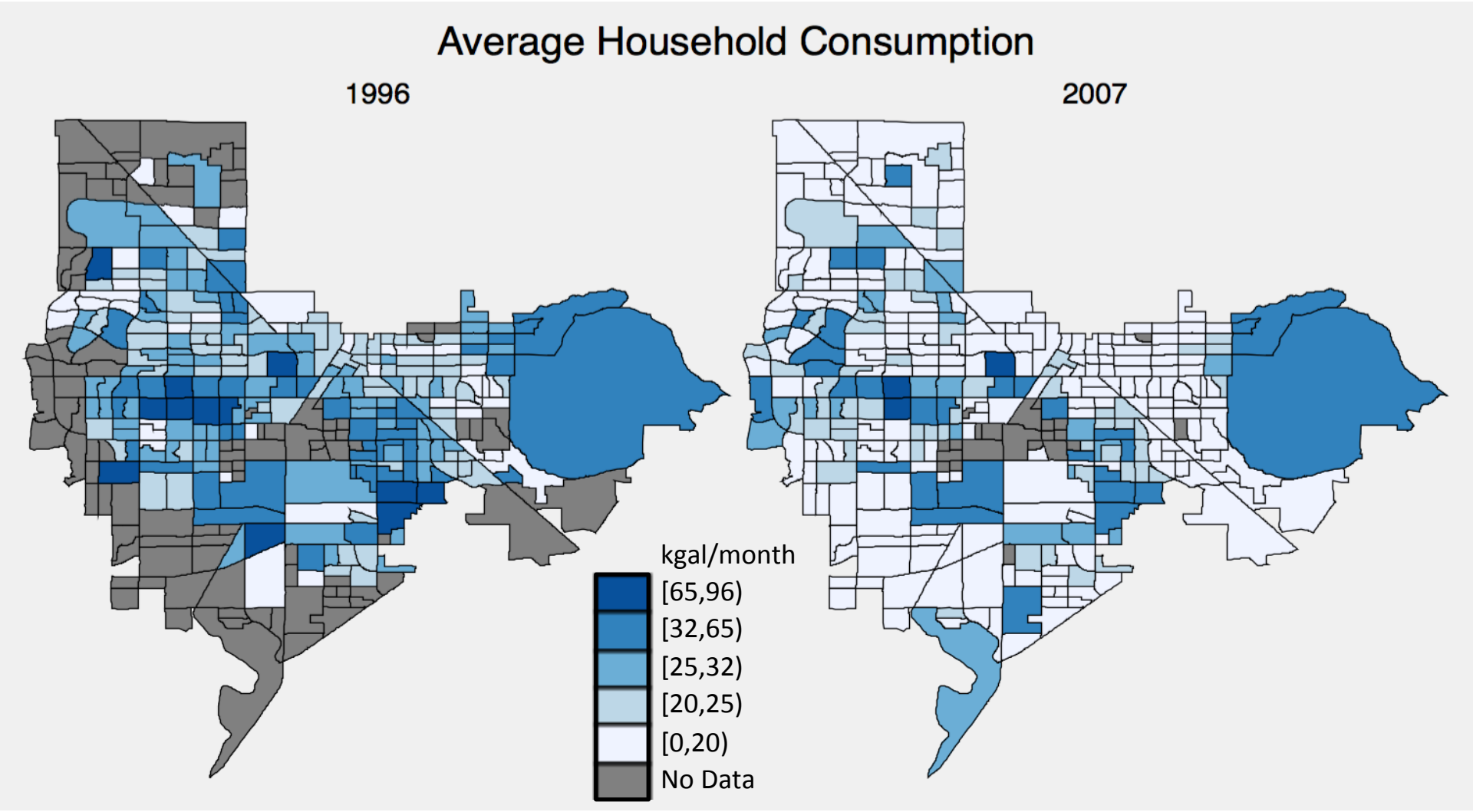
population area cartogram
based on 1996 population

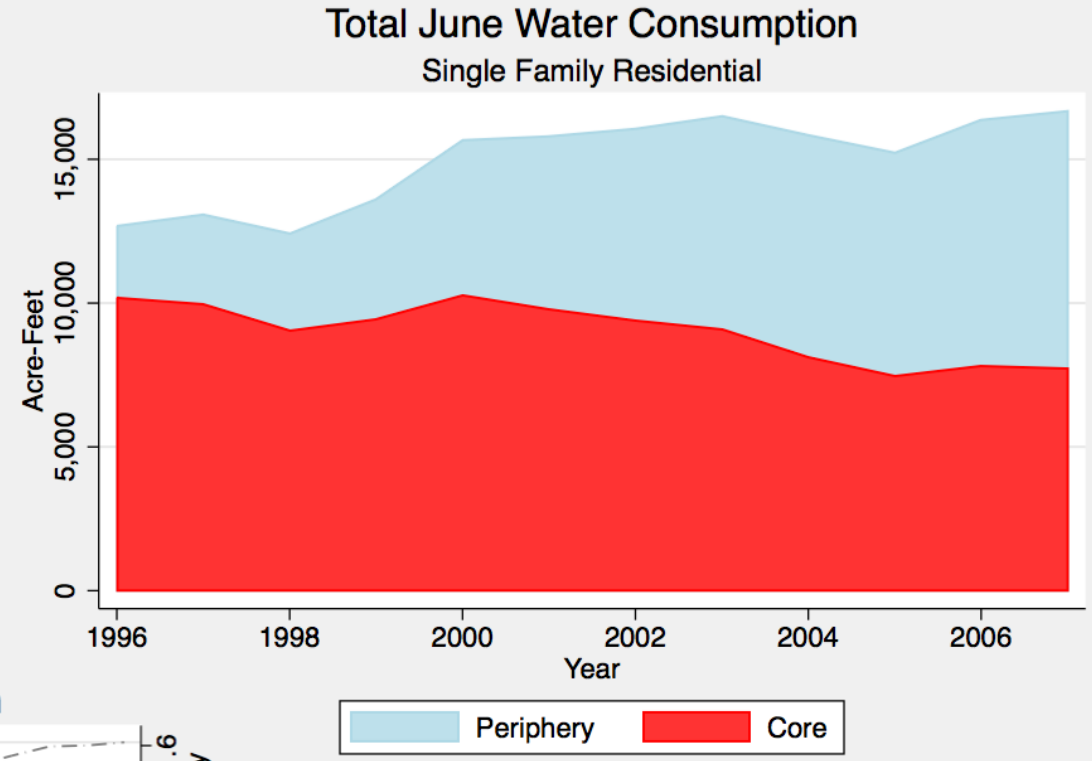


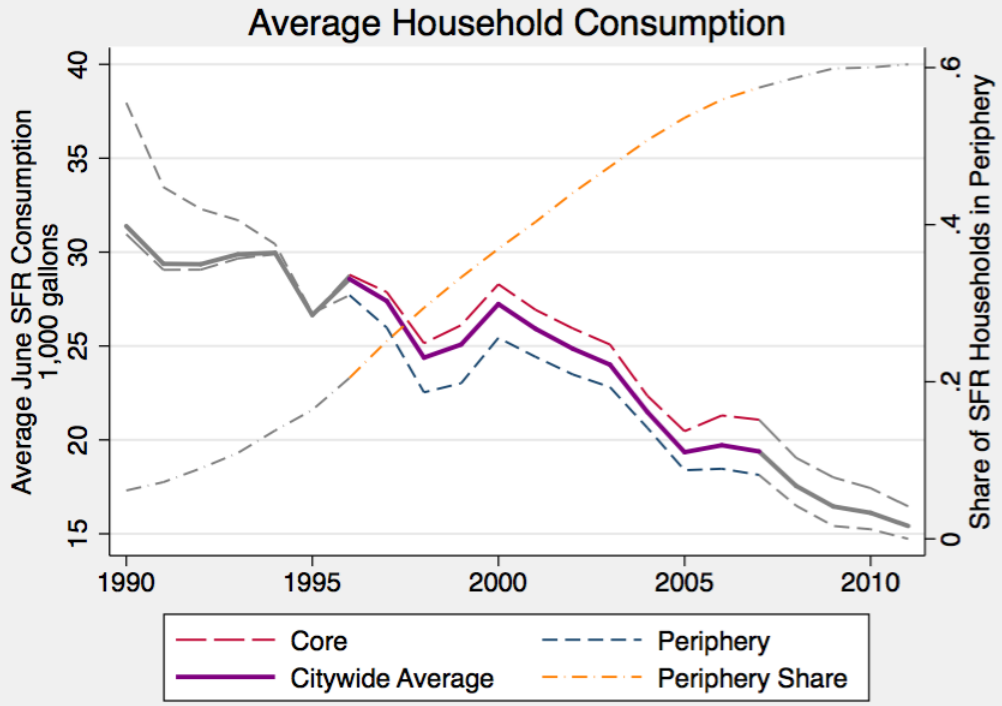


population area cartogram
based on 2007 population

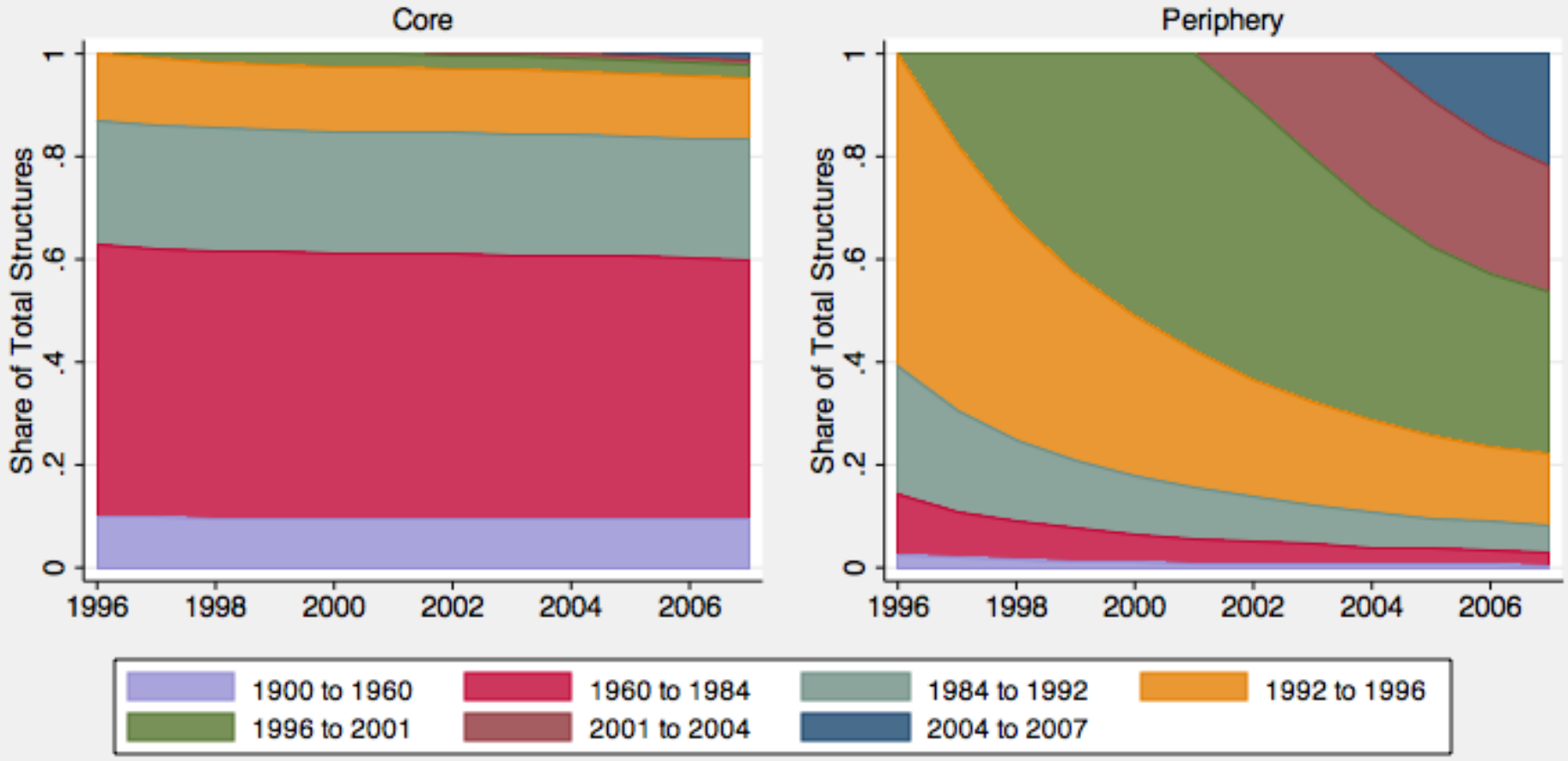

1996


Average Household Consumption
1996
2007
kgal/month
[65,96)
[32,65)
[25,32)
[20,25)
[0,20)
No Data


Total June Water Consumption
Single Family Residential
Acre-Feet
0
5,000
10,000
15,000
1996
1998
2000
2002
2004
2006
Year
Periphery
Core

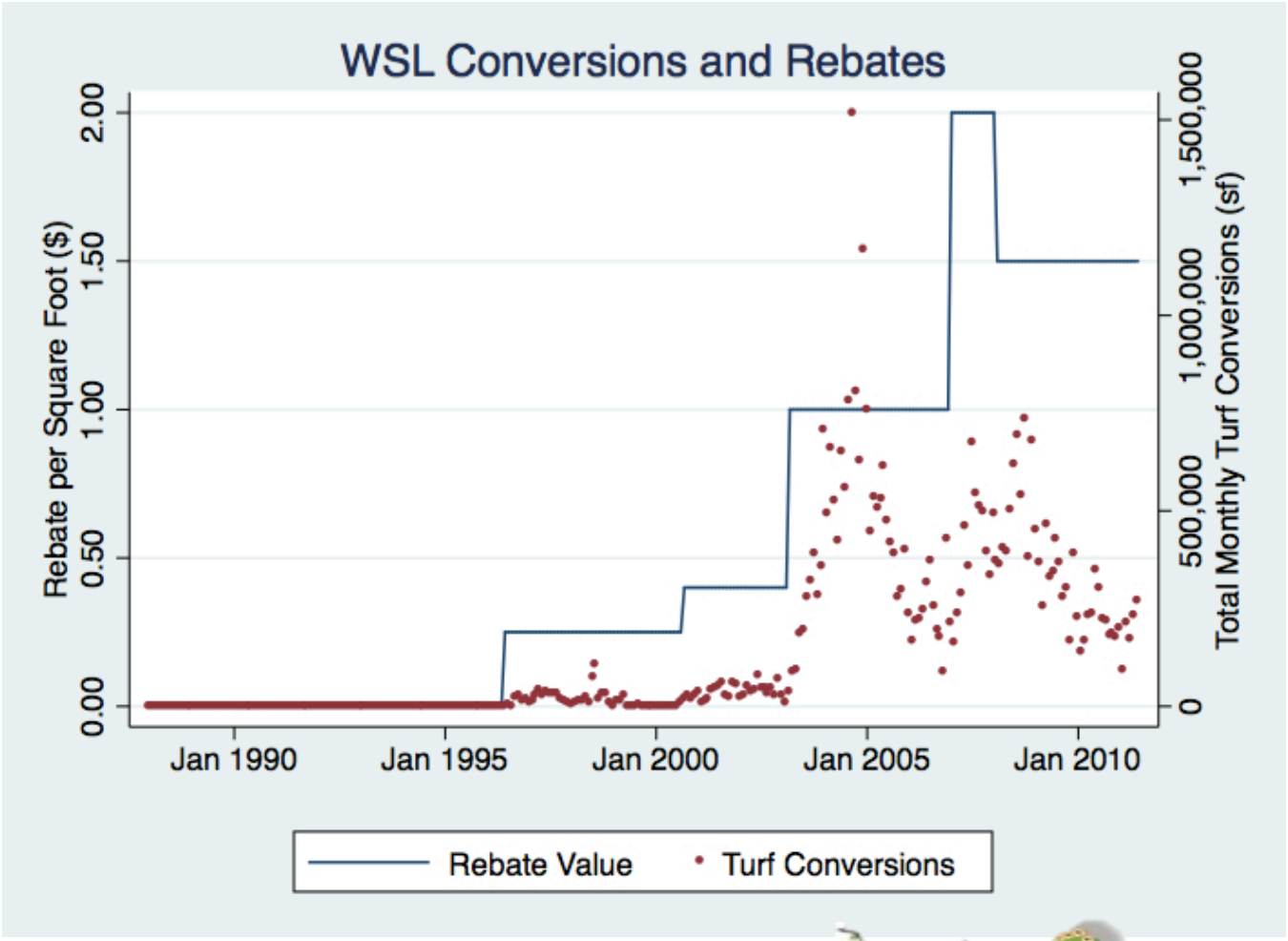

Average Household Consumption
Average June SFR Consumption
1,000 gallons
15
20
25
30
35
40
Share of SFR Households in Periphery
0
.2
.4
.6
1990
1995
2000
2005
2010
Core
Periphery
Citywide Average
Periphery Share

Home Vintages



Conservation Policies

- 96 • WSL program begins
- 99 • Irrigation Clock Rebate program begins
- 00 • Restrictions on turf in new construction
- 02 • Water Waste citations by LVVWD legally possible
- 04 •
  - WSL program scales up
  - Water Smart Homes program begins
  - Car Wash Coupon program begins
  - Strict restrictions on water features
  - Water Waste citations possible in practice
  - More restrictions on turf in new construction
  - Water price increase
- 05 •
  - Pool Cover program begins
  - Water Waste fines increased
- 07 • Conservation TV ads


WSL Conversions and Rebates
Rebate per Square Foot ($)
0.00
0.50
1.00
1.50
2.00
Total Monthly Turf Conversions (sf)
0
500,000
1,000,000
1,500,000
Jan 1990
Jan 1995
Jan 2000
Jan 2005
Jan 2010
Rebate Value
Turf Conversions

$$\boldsymbol{\beta}' = [\beta_0, \beta_1 \ldots \beta_n]$$

$$\boldsymbol{X_{it}} = [regressors]$$

$$\ln(W_{it}) = a + y_t + z_i + \boldsymbol{X_{it}\beta} + e_{it}$$

$$t \in [1996, 2007]$$

semi-log regression with temporal dummy variables

Model specifications

- Model 1: Temporal Dummy Variables Only
- Model 2: Model 1 + Infrastructure, Weather & Census

Regressors

- living area
- bedrooms
- plumbing fixtures
- vintage
- pool ownership rate
  - vegetation area
  - dirt area

- Clark County Assessor
  - Brelsford & Shepherd 2014

Regressors

- living area
- bedrooms
- plumbing fixtures
- vintage
- pool ownership rate
  - vegetation area
  - dirt area

- precipitation
- temperature
  - vegetation * temp
  - vegetation * precip
  - dirt * temp
  - dirt * precip
- pools * temp

- Clark County Assessor
  - Brelsford & Shepherd 2014

- PRISM

Regressors

- living area
- bedrooms
- plumbing fixtures
- vintage
- pool ownership rate
- vegetation area
- dirt area

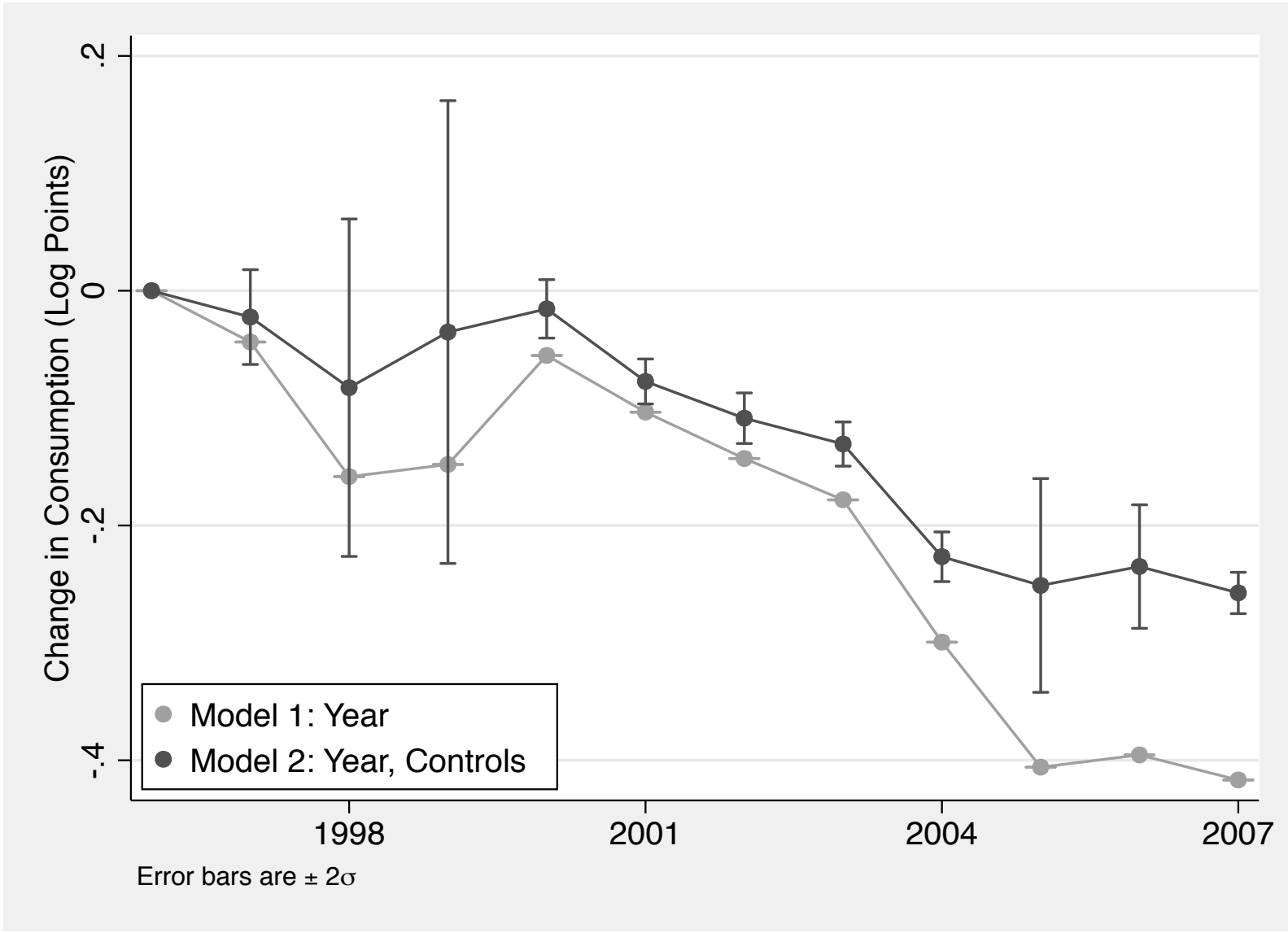
- precipitation
- temperature
- vegetation * temp
- vegetation * precip
- dirt * temp
- dirt * precip
- pools * temp

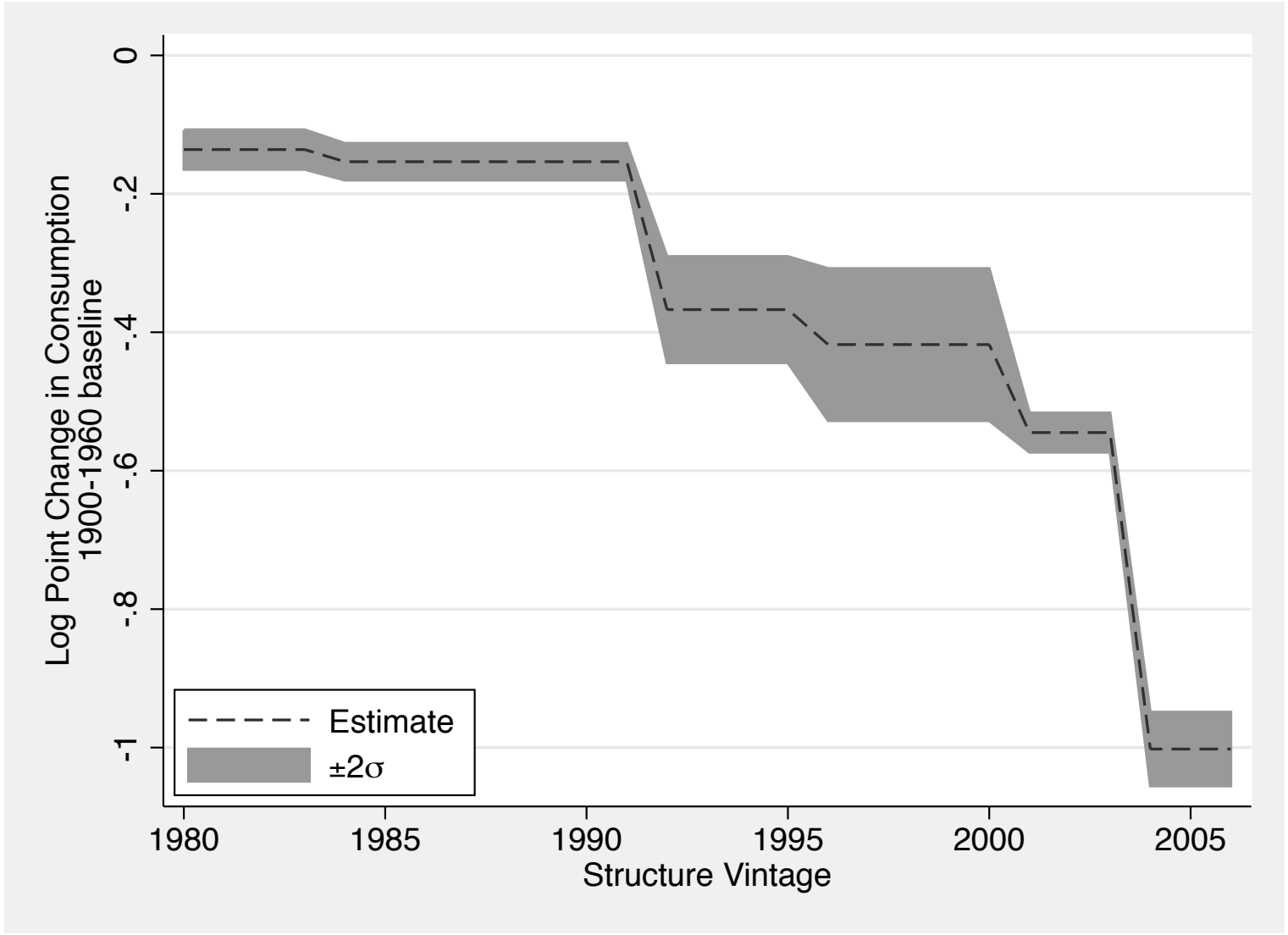
- Owner occupied
- Race & Ethnicity
- Household size
- Income

- Clark County Assessor
- Brelsford & Shepherd 2014

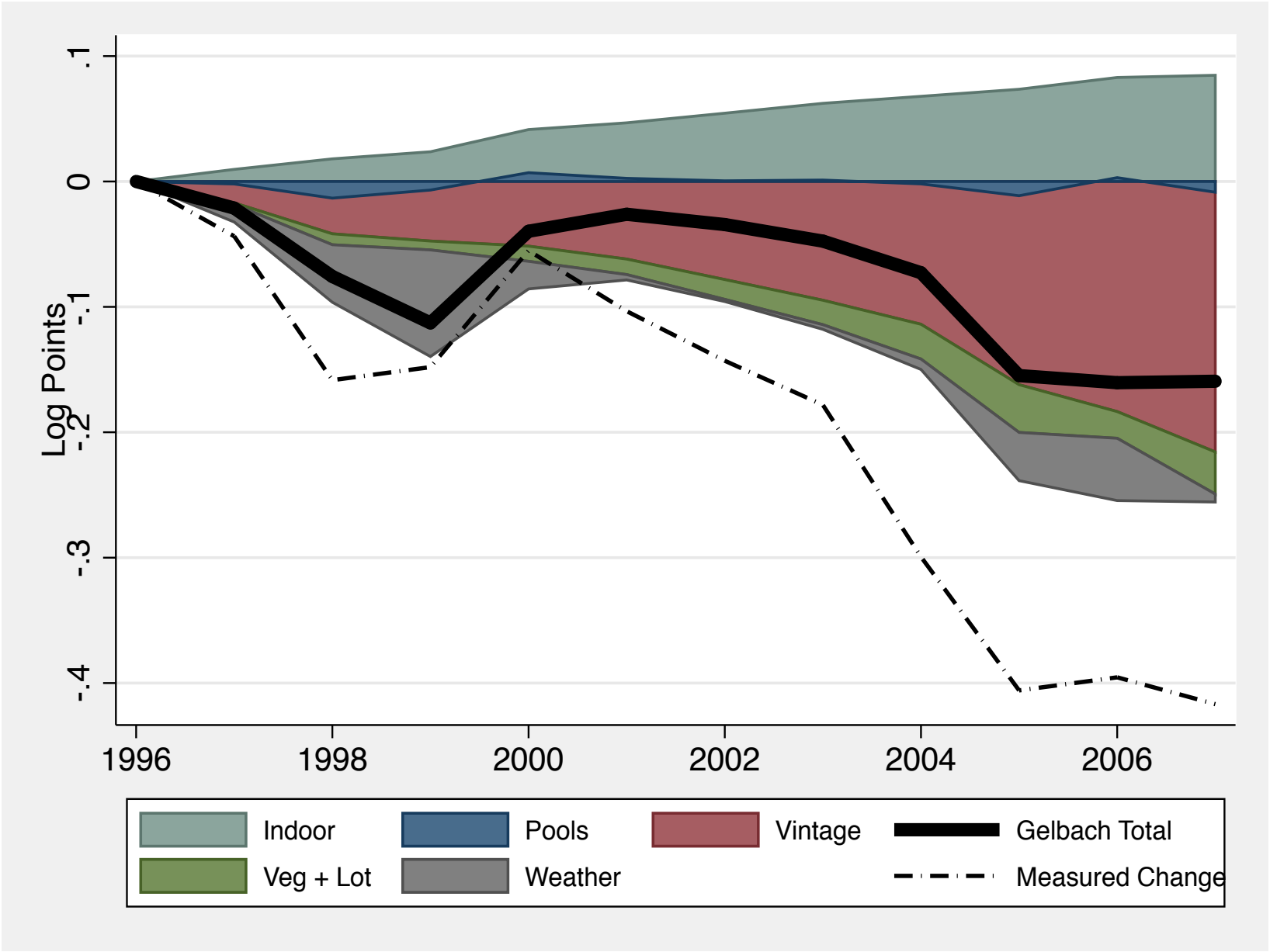
- PRISM
- US Census 2000

REGRESSION RESULTS


Change in Consumption (Log Points)
.2
0
-.2
-.4
1998
2001
2004
2007
Model 1: Year
Model 2: Year, Controls
Error bars are ± 2σ


Log Point Change in Consumption
1900-1960 baseline
0
-.2
-.4
-.6
-.8
-1
Estimate
±2σ
1980
1985
1990
1995
2000
2005
Structure Vintage

DECOMPOSITION ANALYSIS


Log Points
.1
0
-.1
-.2
-.3
-.4
1996
1998
2000
2002
2004
2006
Indoor
Pools
Vintage
Gelbach Total
Veg + Lot
Weather
Measured Change

COUNTERFACTUAL SCENARIO ESTIMATION

Scenario Estimation Method

- In each scenario, the variable in question is held constant at the 1996 levels.

$$\tilde{x}_{it} = x_{i1996}$$

- Using our regression results, we compare expected consumption under the scenario to true consumption.
- The actual changes that occurred in x caused the difference between measured and scenario consumption.

1. How did changing household infrastructure characteristics like house size, number of bedrooms or plumbing fixtures, and pool prevalence influence household water consumption?

2. How did changing vegetation area per household influence household consumption?

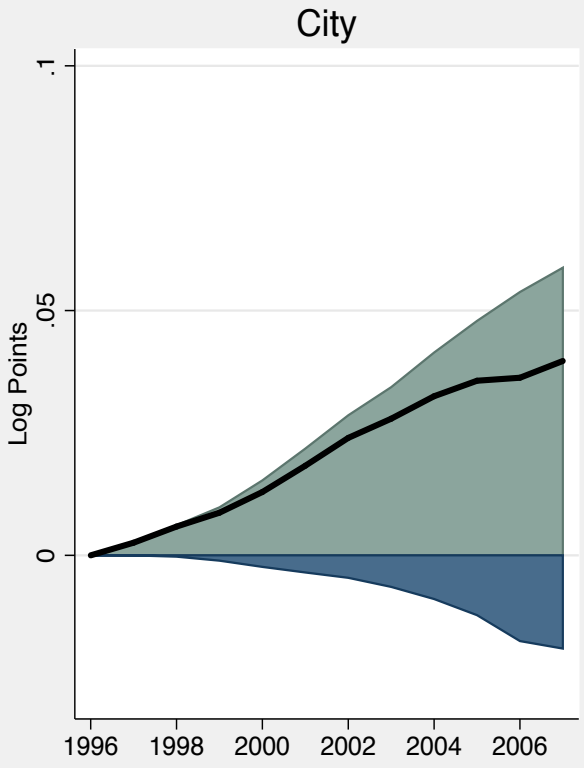
3. How did population growth and new construction influence household water consumption?

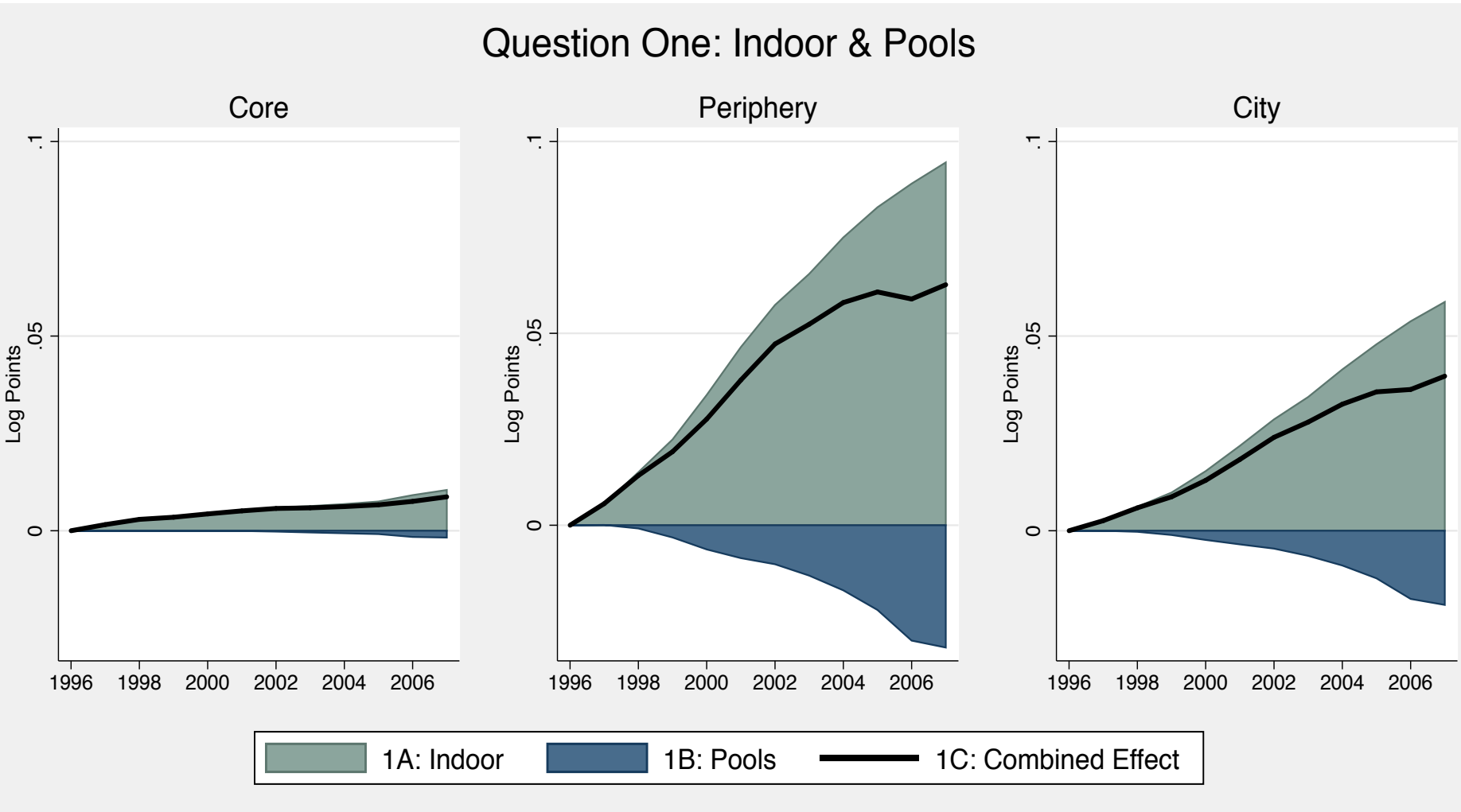
4. How did behavior change in response to the 2004 drought alert influence household water consumption?

Example

- Pool ownership rates declined by a small amount in both the periphery and core between 1996 and 2007.
- The estimated coefficient on pool ownership is large and positive: in a given neighborhood, an increase in pool ownership from 0 to 100% increases average household consumption there by 52%
- In the pools scenario, we estimate what household consumption would have been if pool ownership rates stayed at the higher 1996 level:
  - The observed decline in pool ownership caused a decline in household consumption.

Household Infrastructure



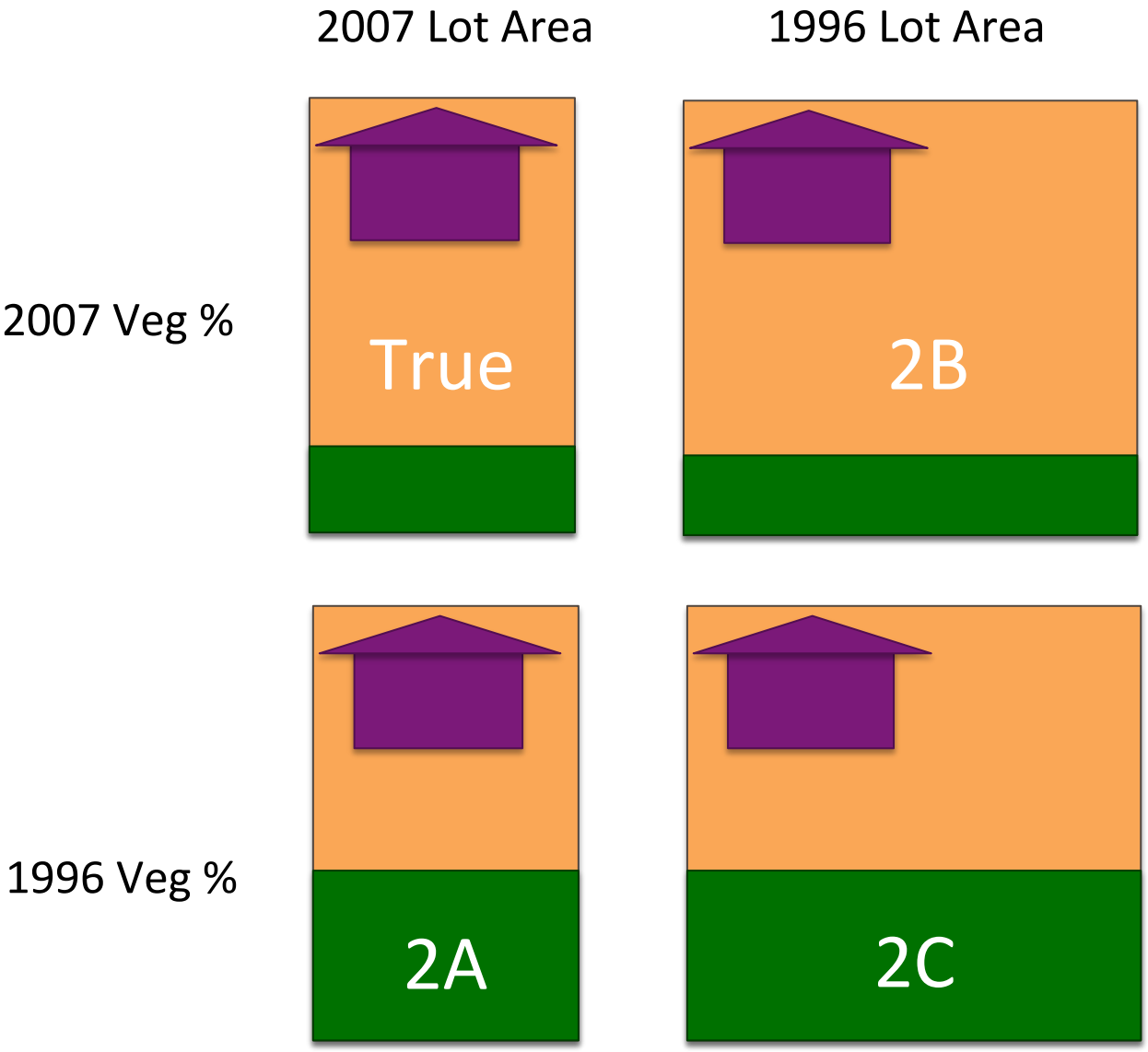

Question One: Indoor & Pools
Core
Periphery
City
Log Points
0
.05
.1
1996
1998
2000
2002
2004
2006
1A: Indoor
1B: Pools
1C: Combined Effect

1. How did changing household infrastructure characteristics like house size, number of bedrooms or plumbing fixtures, and pool prevalence influence household water consumption?

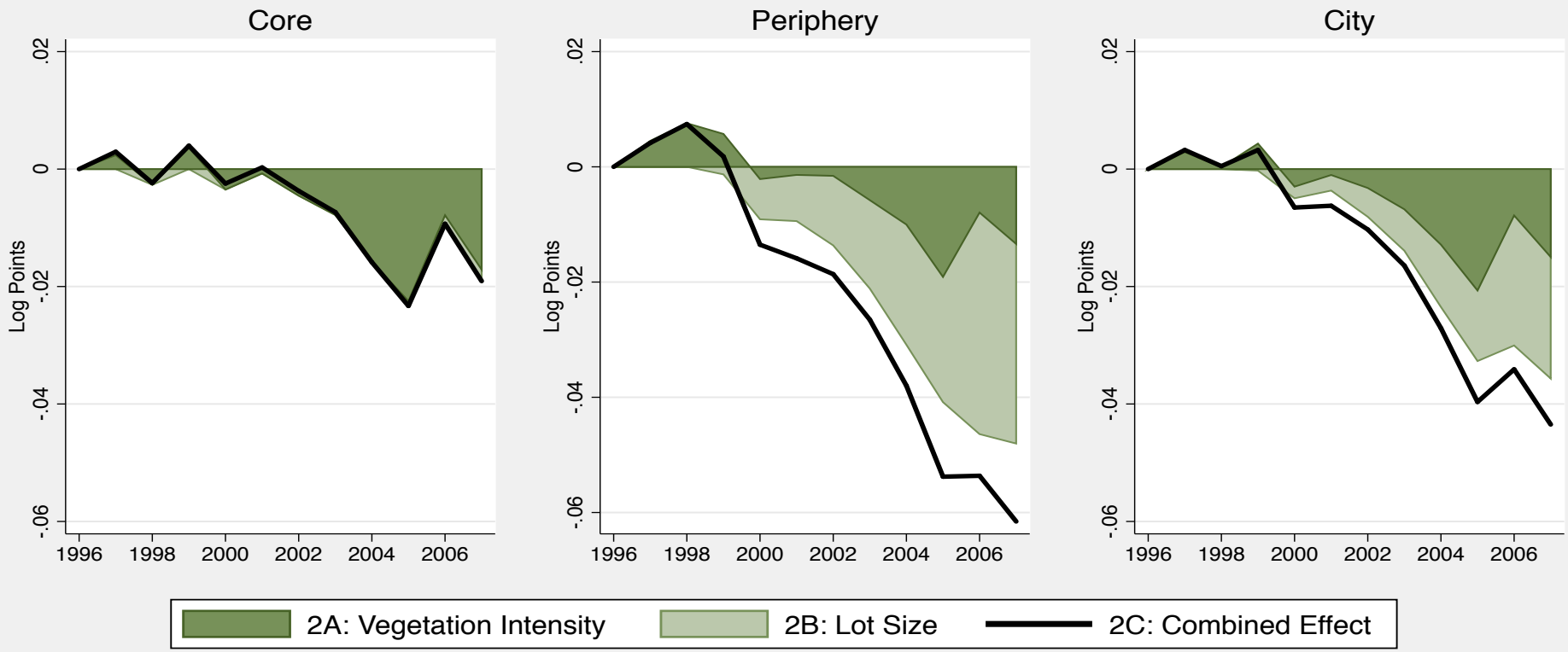
2. **How did changing vegetation area per household influence household consumption?**

3. How did population growth and new construction influence household water consumption?

4. How did behavior change in response to the 2004 drought alert influence household water consumption?


2007 Lot Area
1996 Lot Area
2007 Veg %
1996 Veg %
True
2B
2A
2C

Question Two: Lot Size and Composition



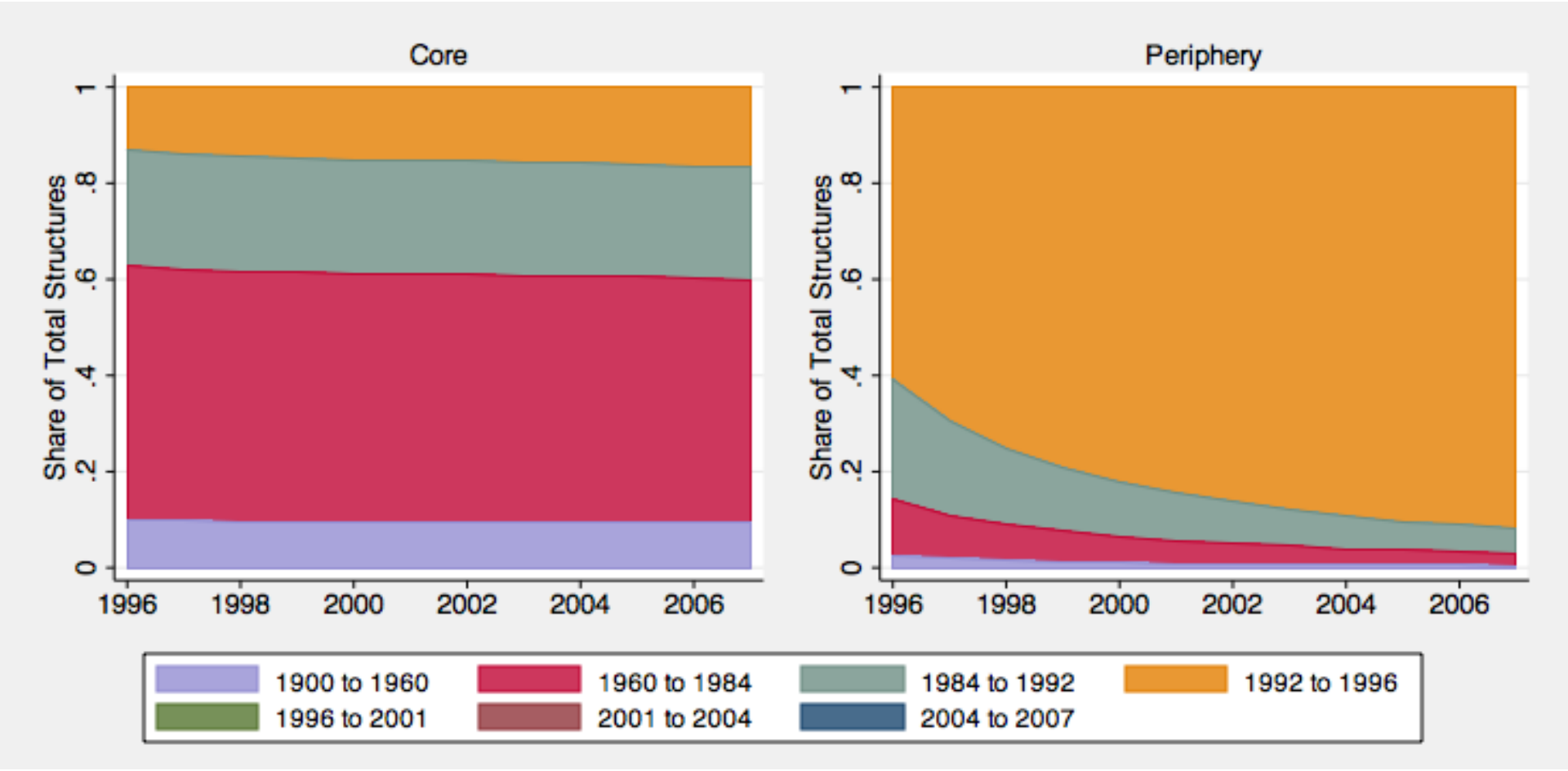
1. How did changing household infrastructure characteristics like house size, number of bedrooms or plumbing fixtures, and pool prevalence influence household water consumption?

2. How did changing vegetation area per household influence household consumption?

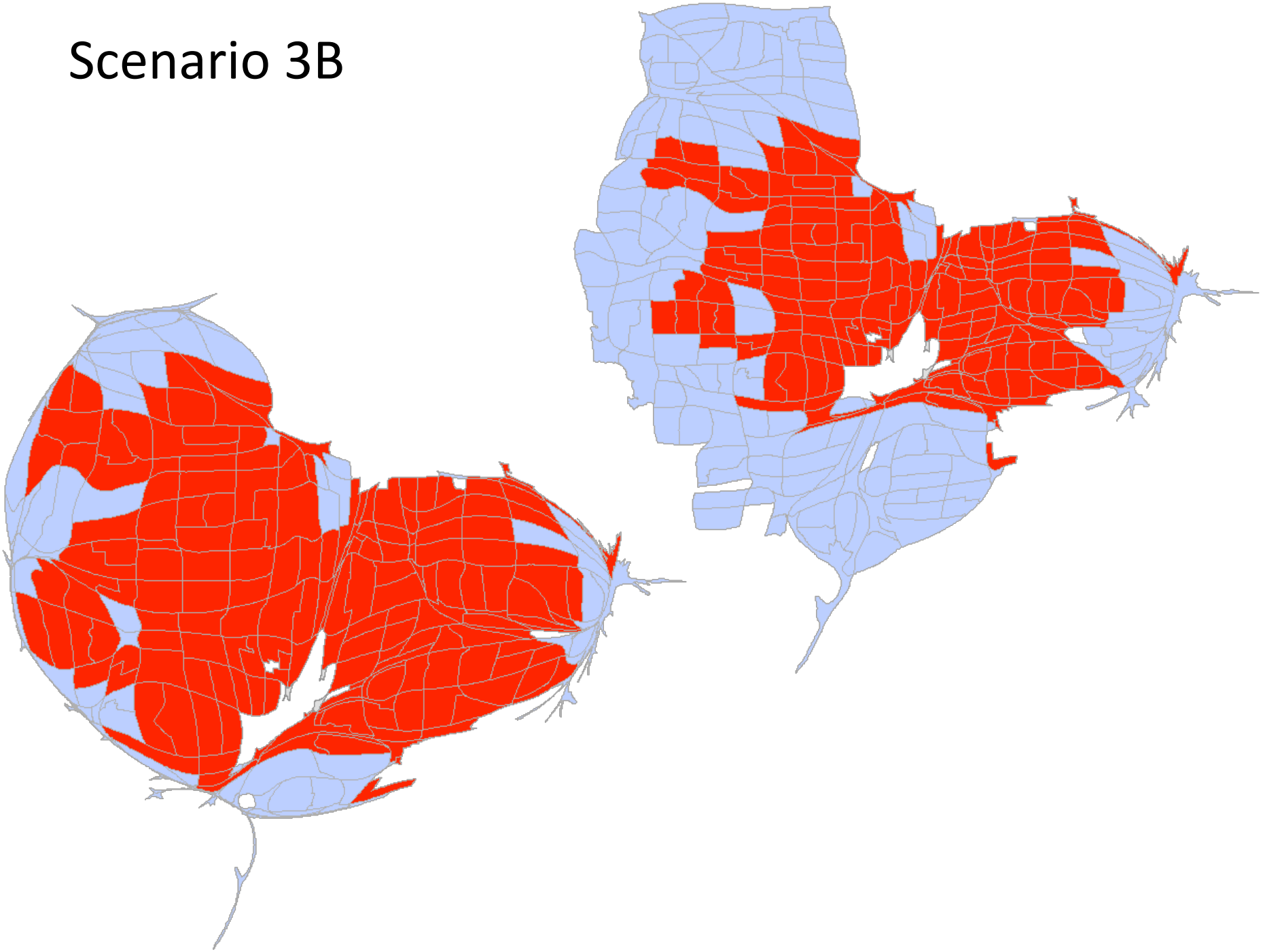
3. **How did population growth and new construction influence household water consumption?**

4. How did behavior change in response to the 2004 drought alert influence household water consumption?

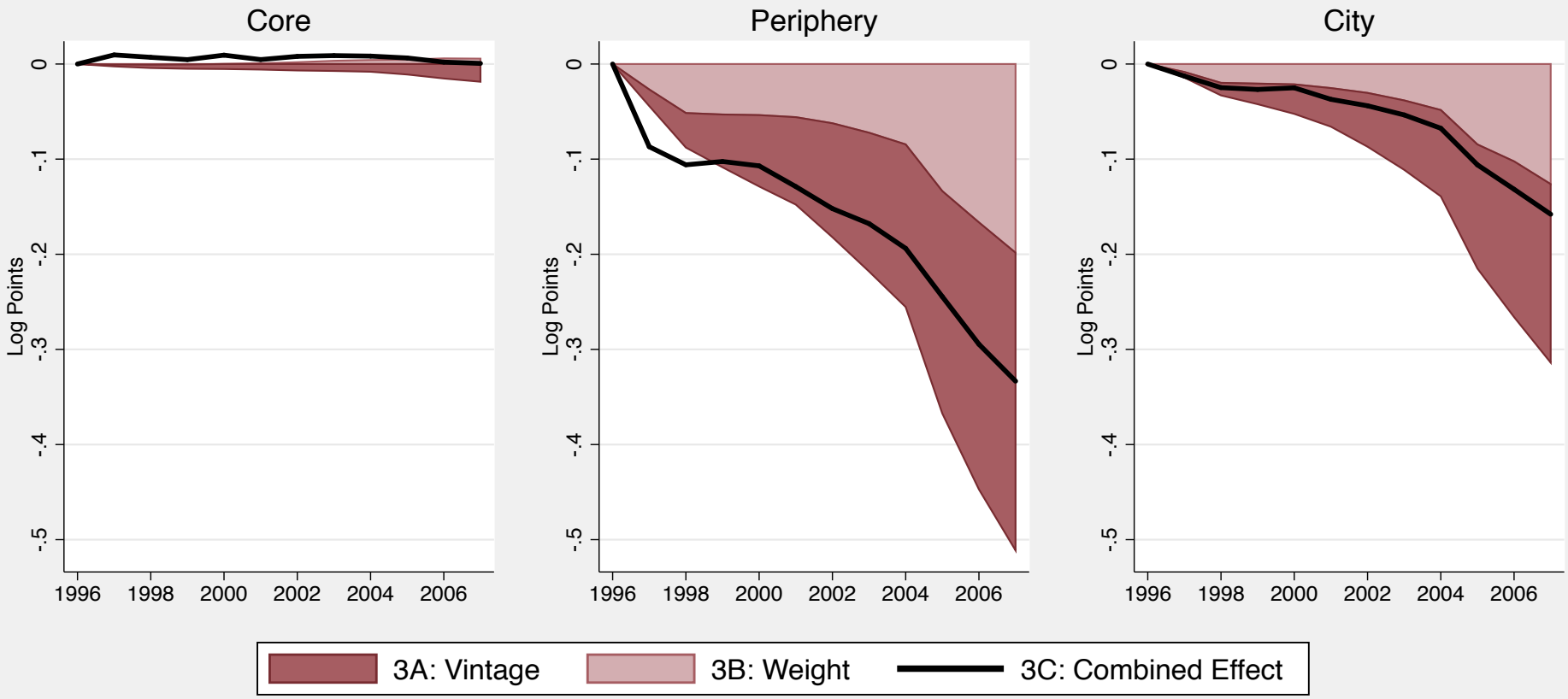
Scenario 3A


Core
Periphery
Share of Total Structures
0
.2
.4
.6
.8
1
1996
1998
2000
2002
2004
2006
1900 to 1960
1960 to 1984
1984 to 1992
1992 to 1996
1996 to 2001
2001 to 2004
2004 to 2007

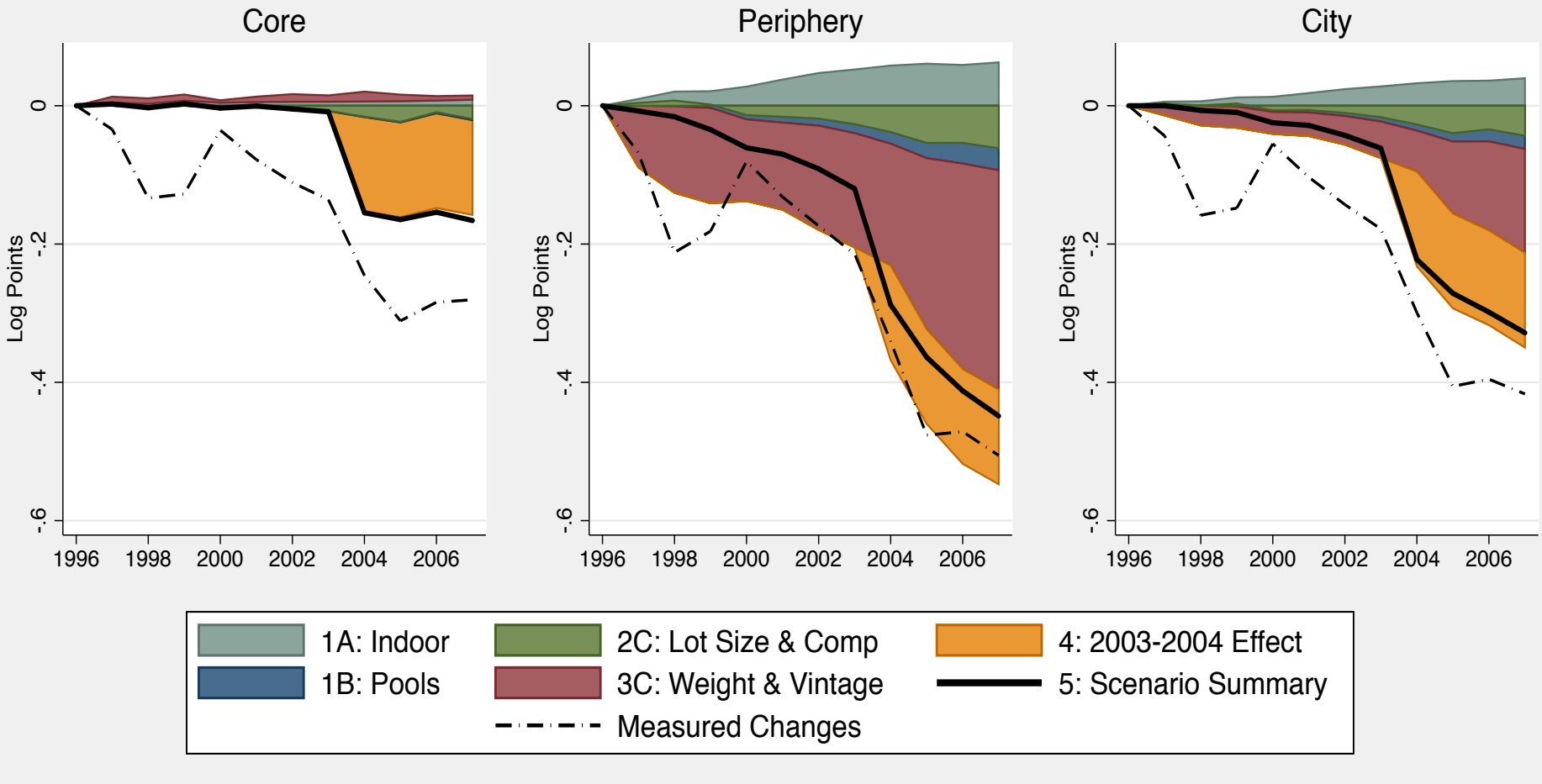
Scenario 3B



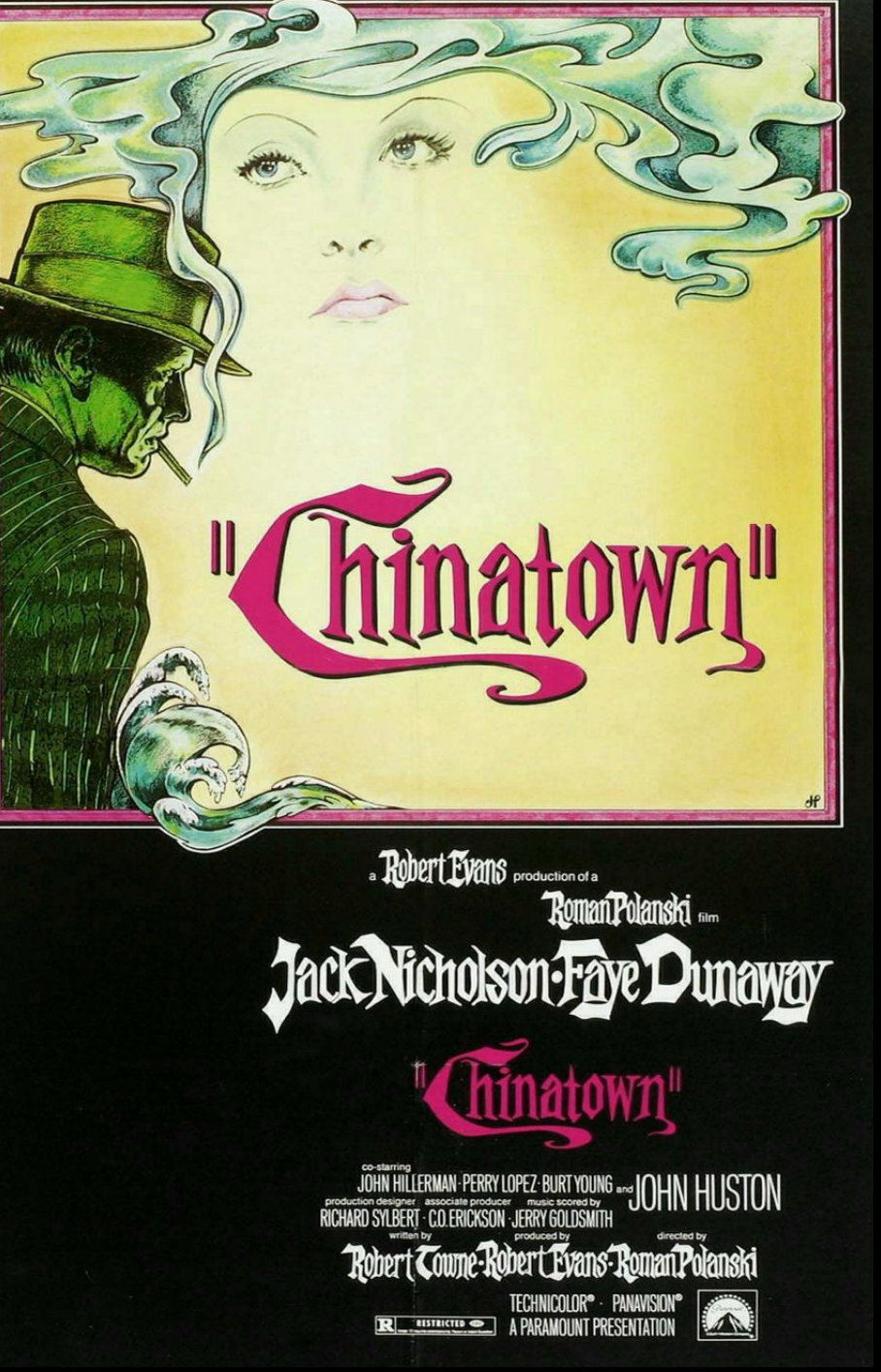
Question Three: Vintage and Weight



Summary


Core
Periphery
City
Log Points
0
-.2
-.4
-.6
1996
1998
2000
2002
2004
2006
1A: Indoor
1B: Pools
2C: Lot Size & Comp
3C: Weight & Vintage
Measured Changes
4: 2003-2004 Effect
5: Scenario Summary

christabrelsford.com christa@santafe.edu

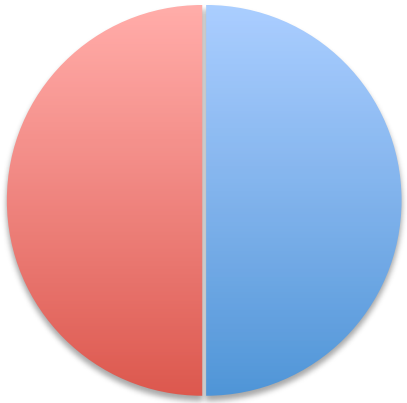


What's going on in California?

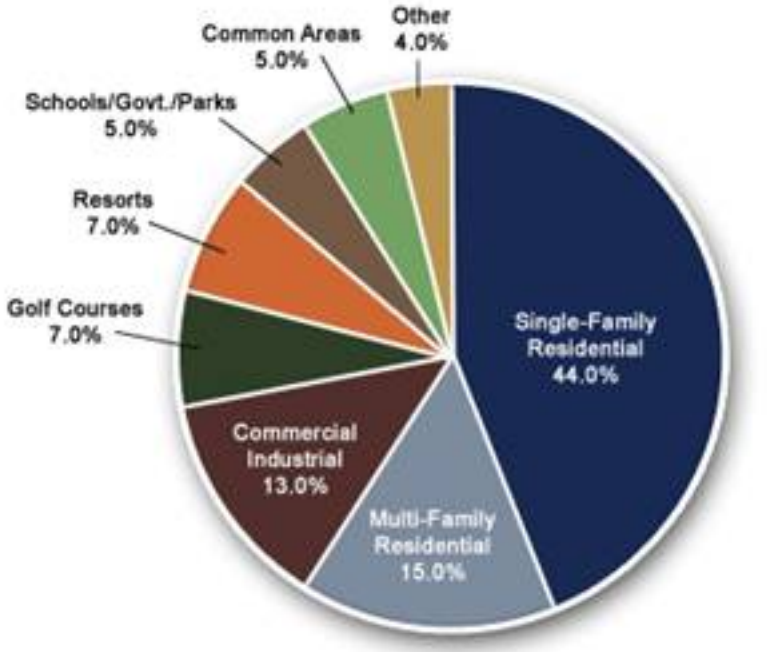
Indoor Residential Water Use

epa.gov

Residential Water Use



Consumptive Water Use in Southern Nevada

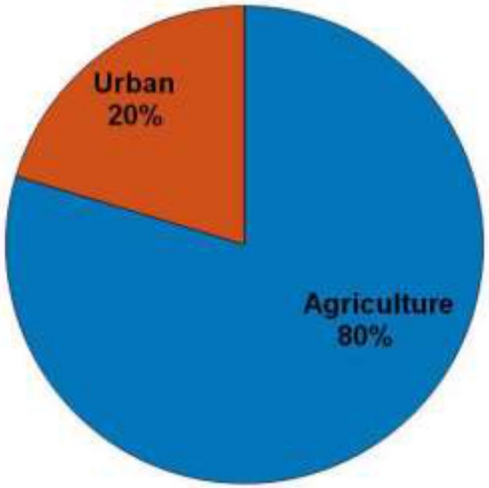


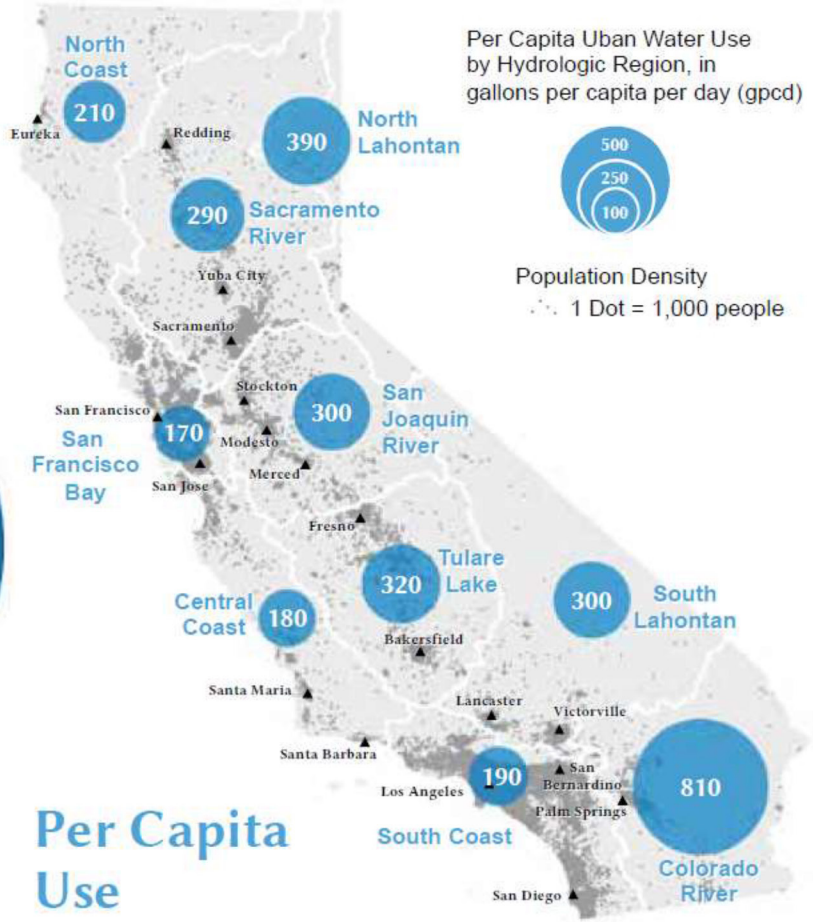
Based upon 2006 municipal metered potable and non-potable water use in the Southern Nevada Water Authority's metered service area.

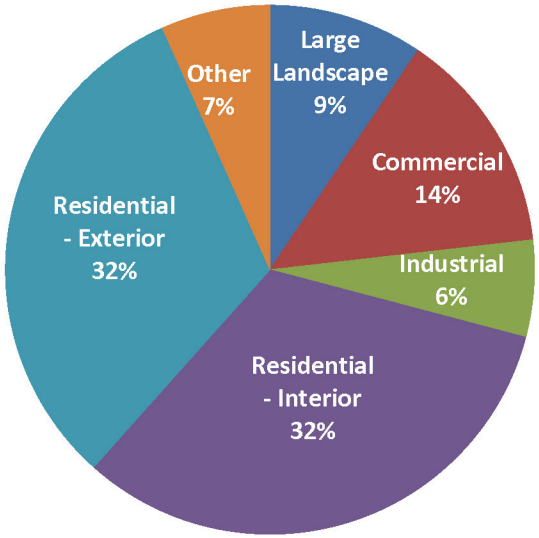
SNWA estimates of water use

Water Use in California

Human Water Use:
44 million acre-feet per year



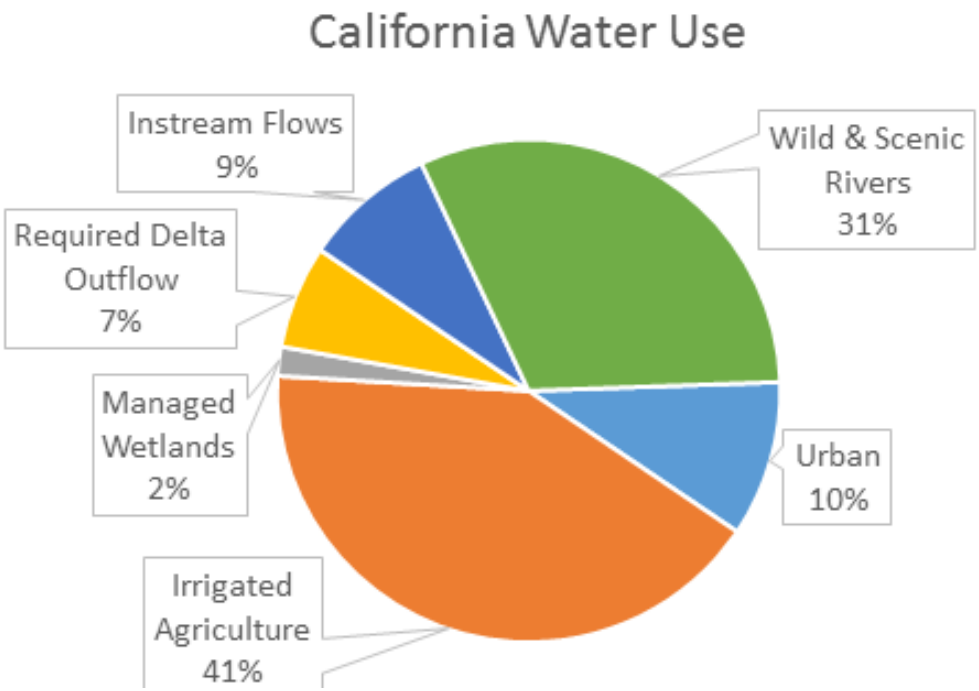




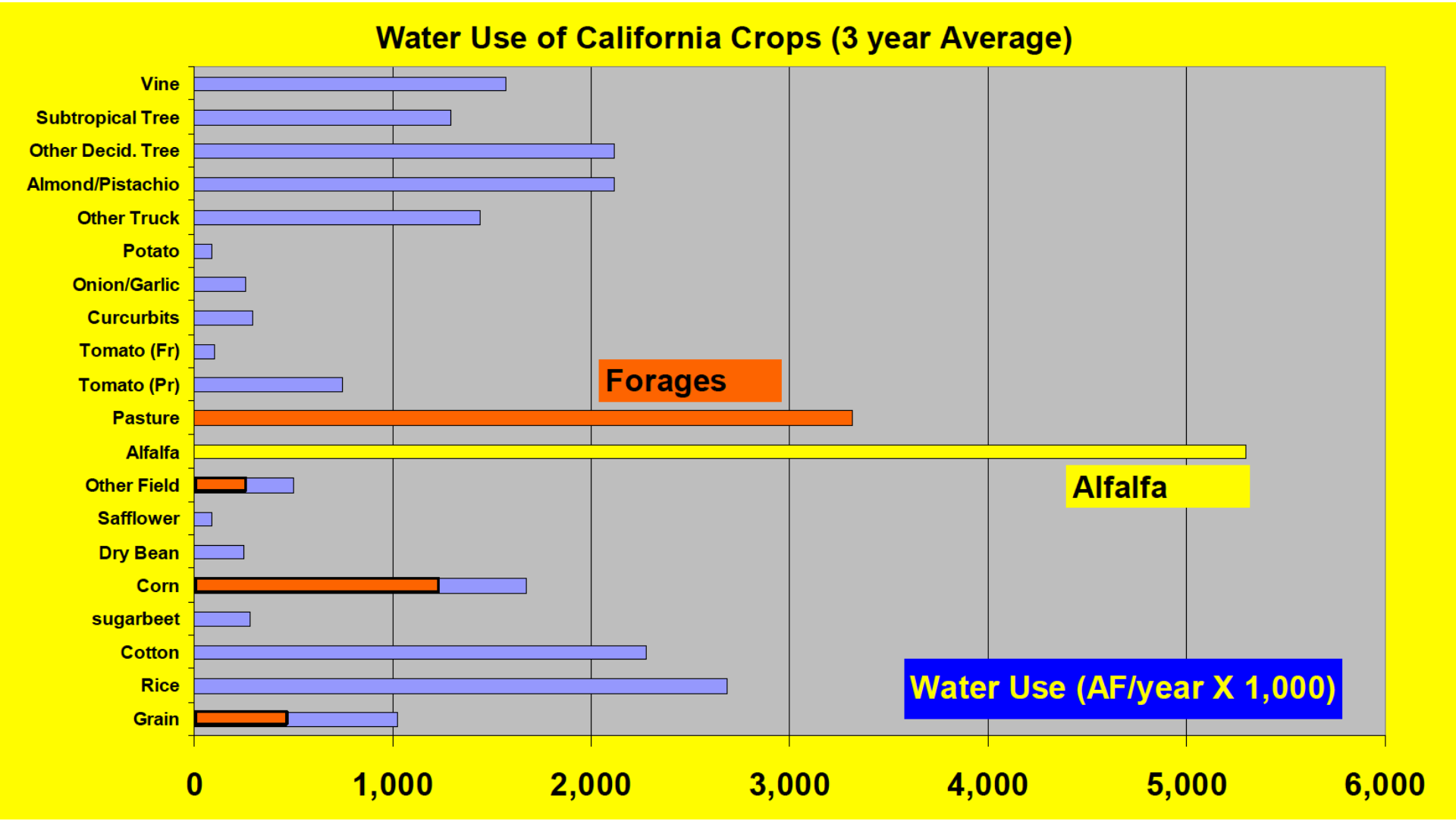
Average from 2001-2010: 230 gpcd

NRDC

PACIFIC INSTITUTE



norcalwater.org



Blaine Hanson, Dept. of Ag and Resource Economics at UC Davis
in talk to California EPA in 2012