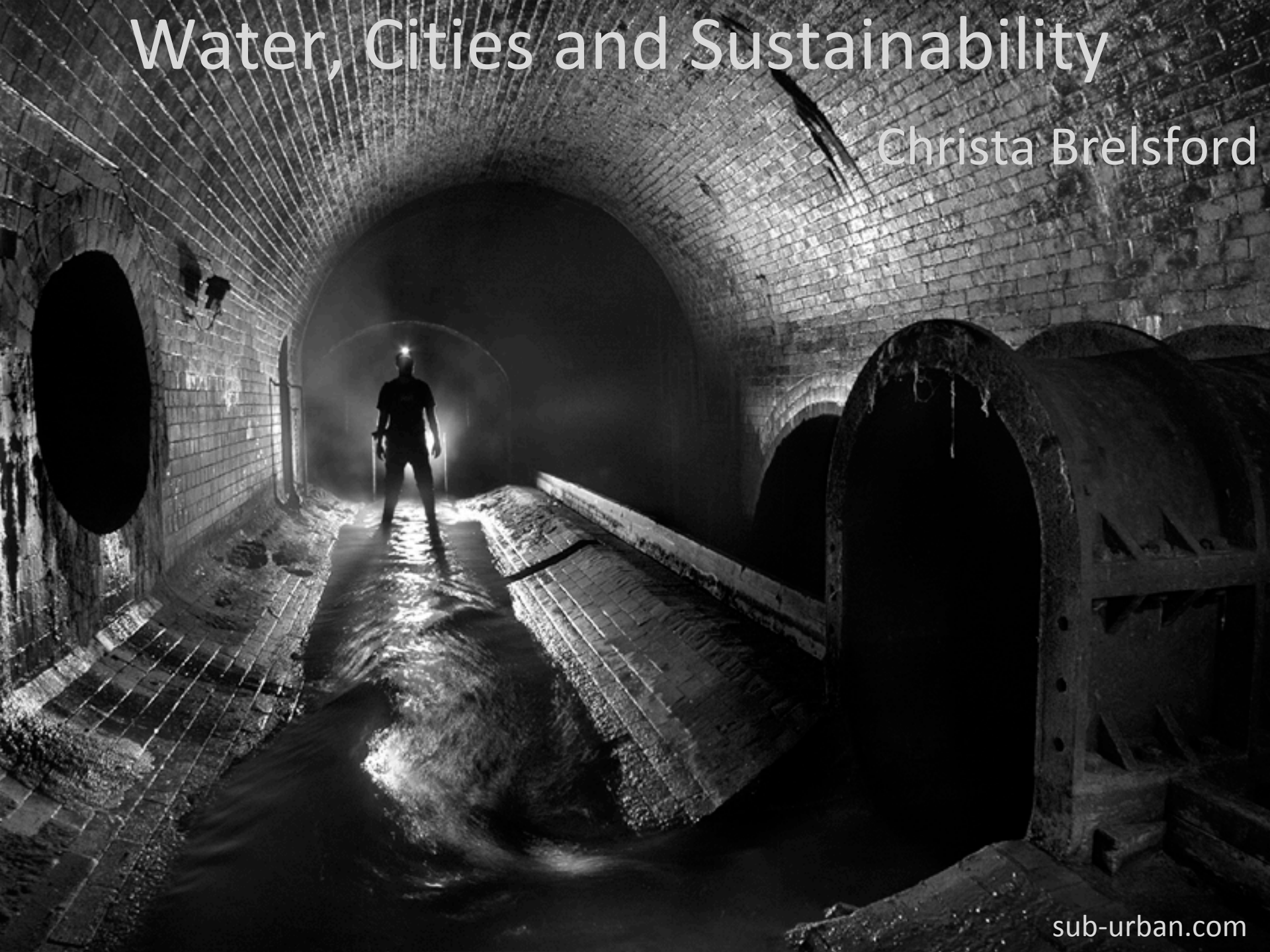
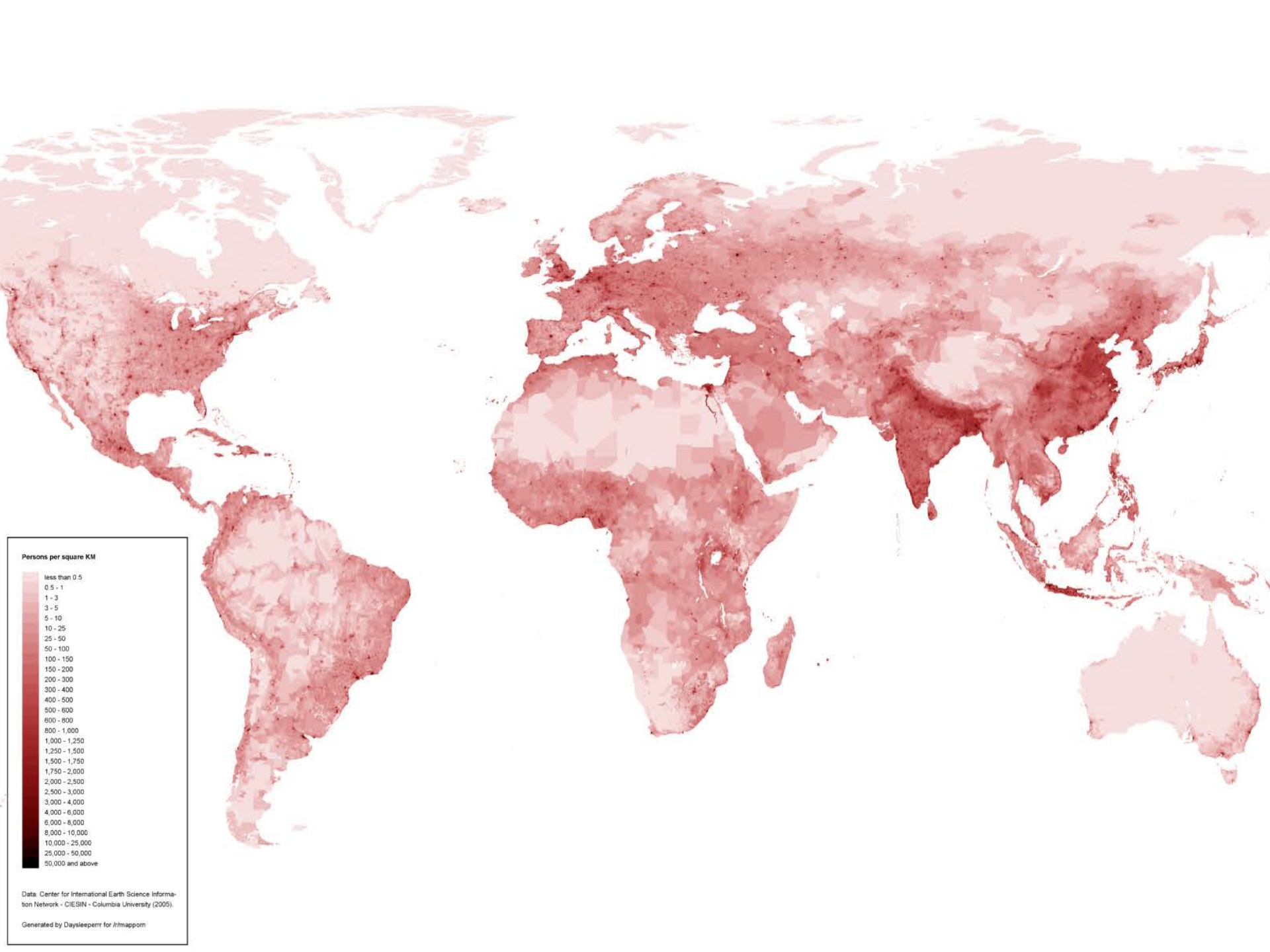
Water, Cities and Sustainability

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
Seattle
WASHINGTON
Portland
OREGON
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
MISSOURI
IOWA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
CONNECTICUT
RHODE ISLAND
NEW JERSEY
DELAWARE
MARYLAND
VIRGINIA
NORTH CAROLINA
TENNESSEE
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
SOUTH CAROLINA
FLORIDA
LOUISIANA
TEXAS
OKLAHOMA
CALIFORNIA
ARIZONA
NEW MEXICO
Snake River
Columbia River
Platte River
Missouri River
Arkansas River
Ohio River
Tennessee River
Canadian River
Colorado River
Red River
Mississippi R.
Brazos River
Grande Rio
Susquehanna River
Connecticut River
Chattahoochee River
San Joaquin River
Milwaukee
Chicago
Detroit
Columbus
Baltimore
Washington
Philadelphia
New York
Boston
Denver
Oklahoma City
Memphis
Charlotte
Fort Worth
Austin
San Antonio
Houston
Jacksonville
El Paso
Phoenix
Los Angeles
San Diego
San Francisco
San Jose
Mexico
100
200mi

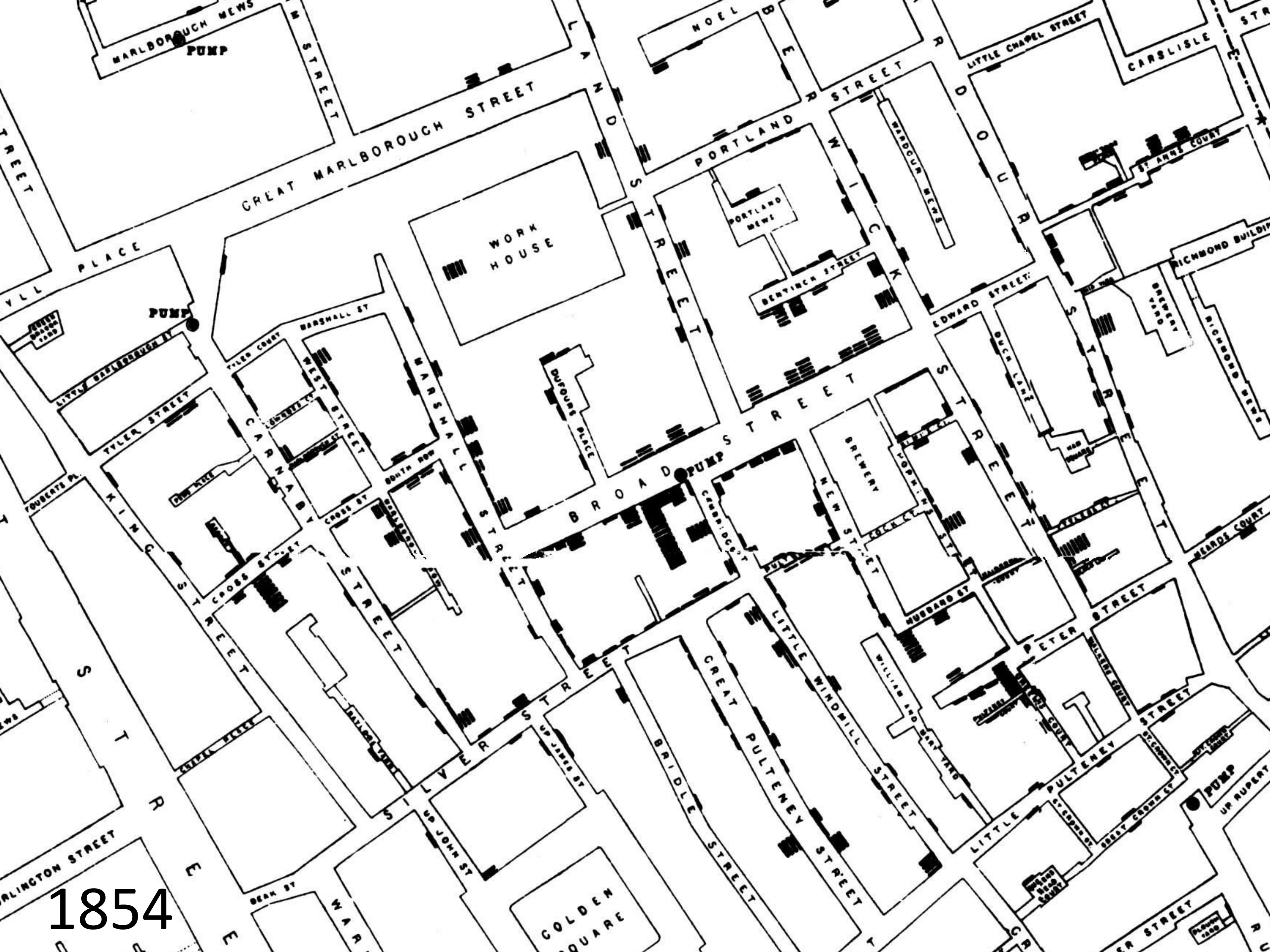

Persons per square KM
less than 0.5
0.5 - 1
1 - 3
3 - 5
5 - 10
10 - 25
25 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 800
800 - 1,000
1,000 - 1,250
1,250 - 1,500
1,500 - 1,750
1,750 - 2,000
2,000 - 2,500
2,500 - 3,000
3,000 - 4,000
4,000 - 6,000
6,000 - 8,000
8,000 - 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

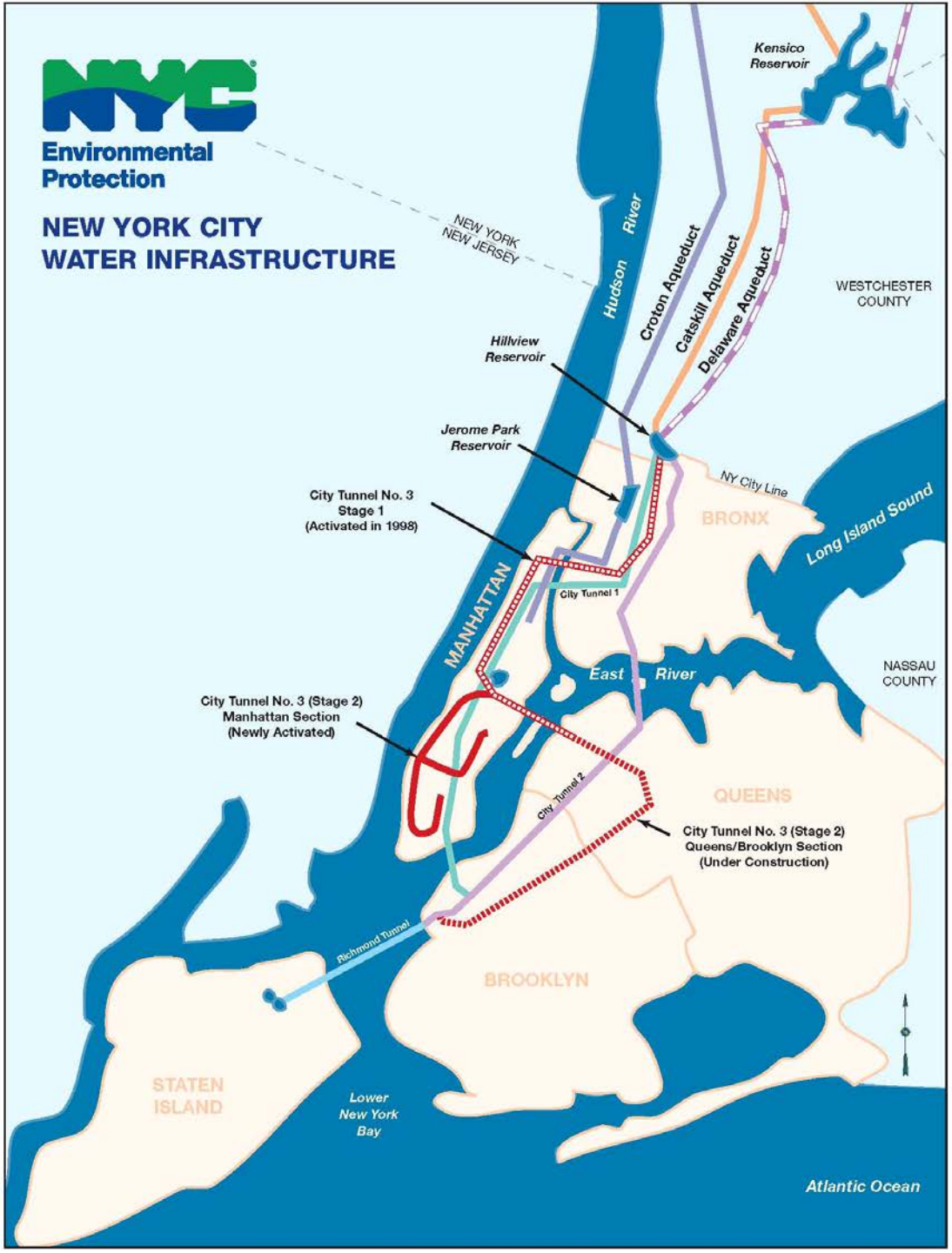

SLEEPY'S
SLEEPY'S
SLEEPY'S
SLEEPY'S
SLEEPY'S
Canal St
Google

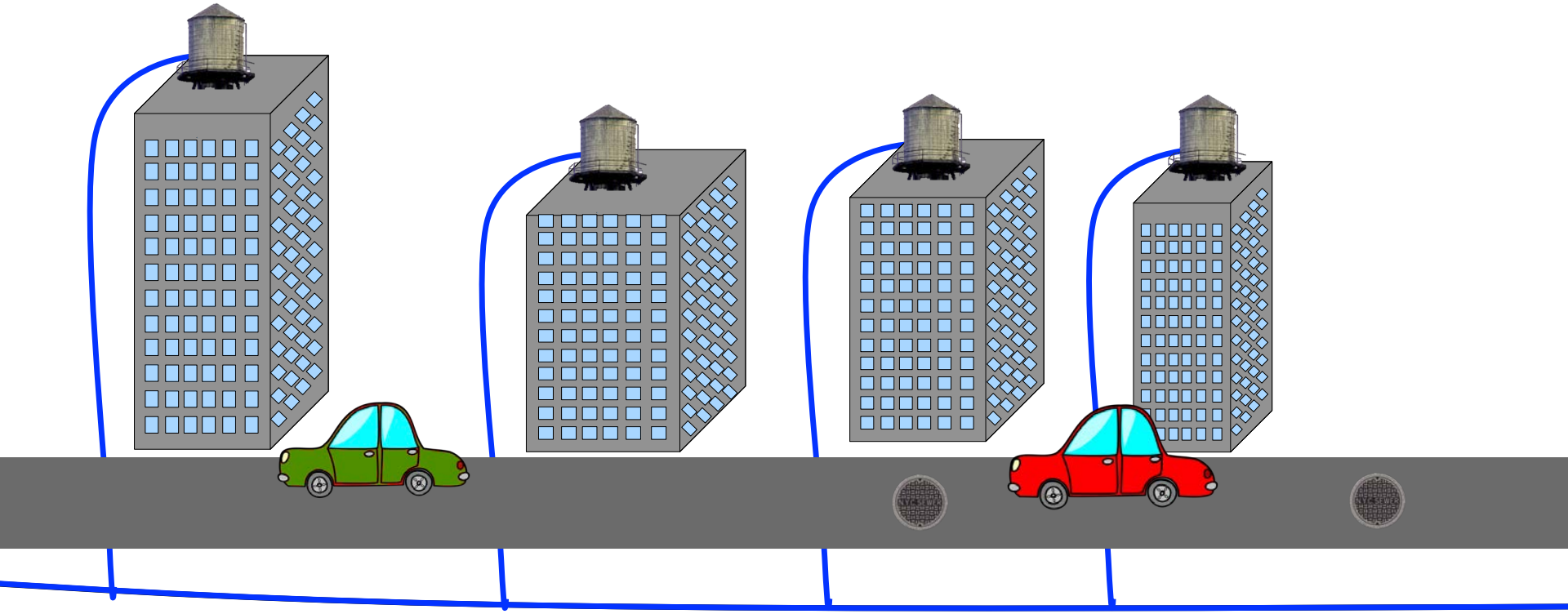


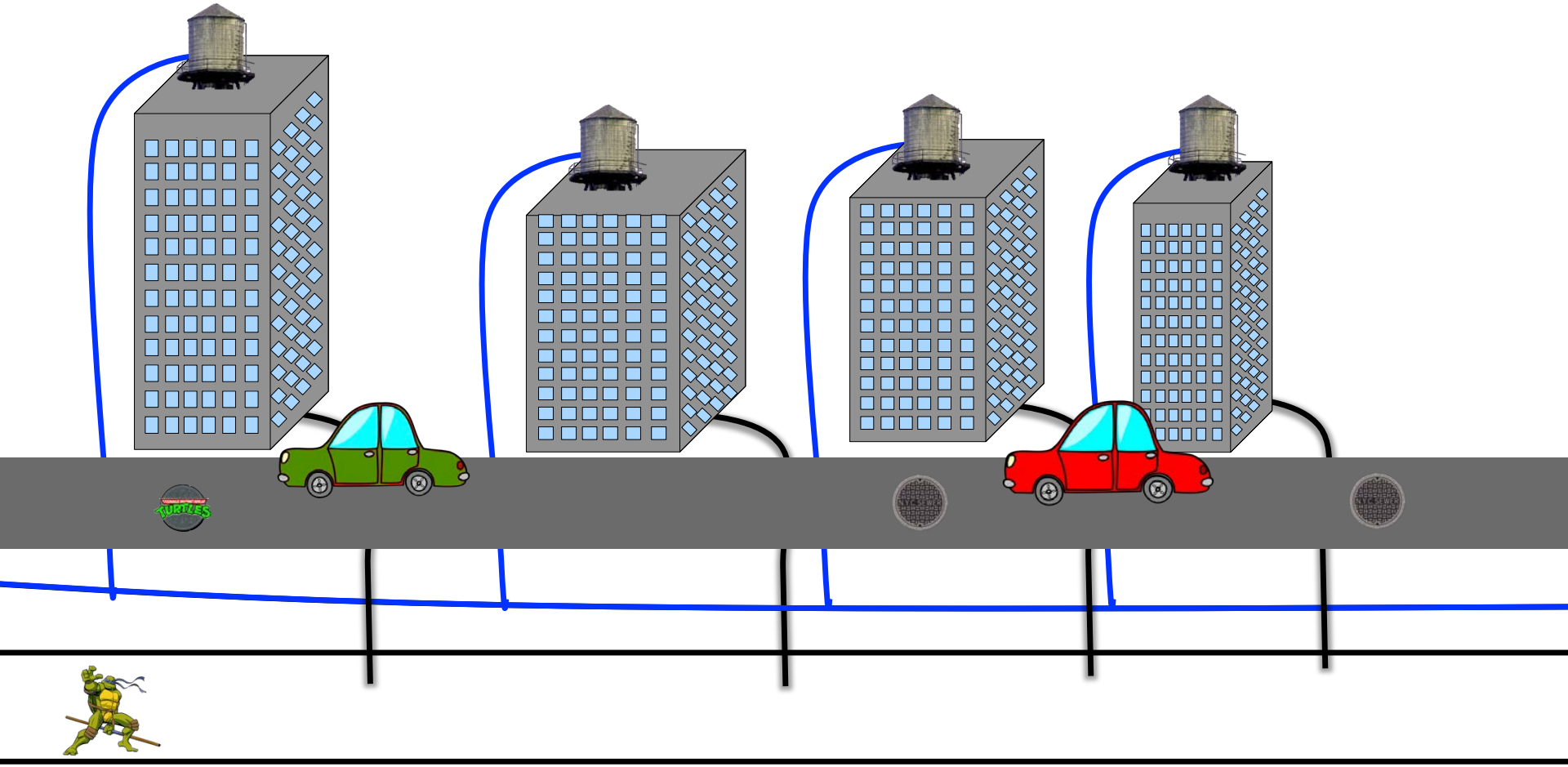
MARLBOROUGH MEWS
PUMP
GREAT MARLBOROUGH STREET
NOEL
PORTLAND STREET
LITTLE CHAPEL STREET
CARLISLE
ST ANNS COURT
PORTLAND MEWS
WARDOUR MEWS
WORK HOUSE
BENTINCK STREET
RICHMOND BUILDI
EDWARD STREET
BREWERY YARD
RICHMOND MEWS
DUCK LANE
MARSHALL ST
TYLER COURT
WEST STREET
MARSHALL STREET
DUFOURS PLACE
BROAD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

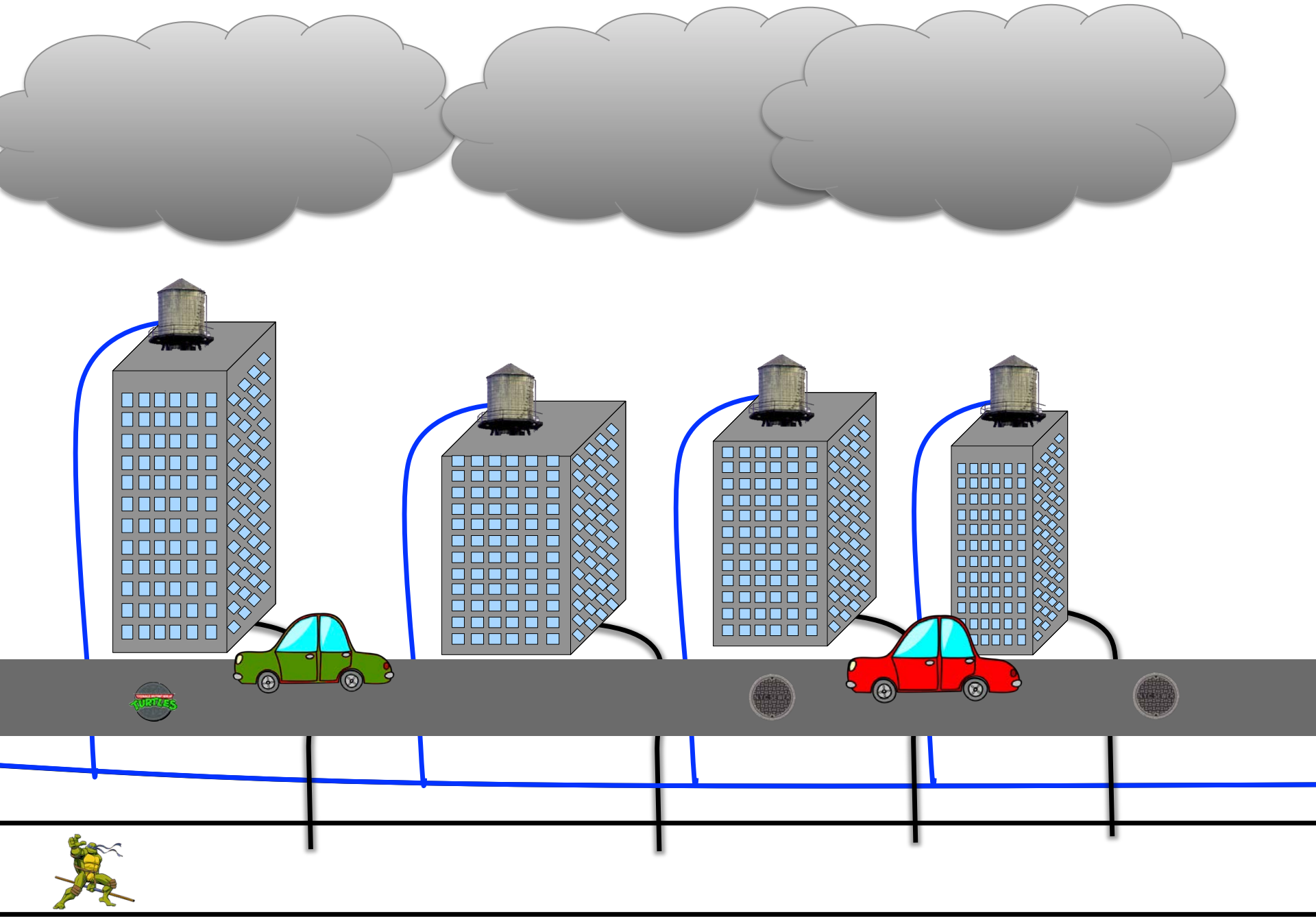
1854

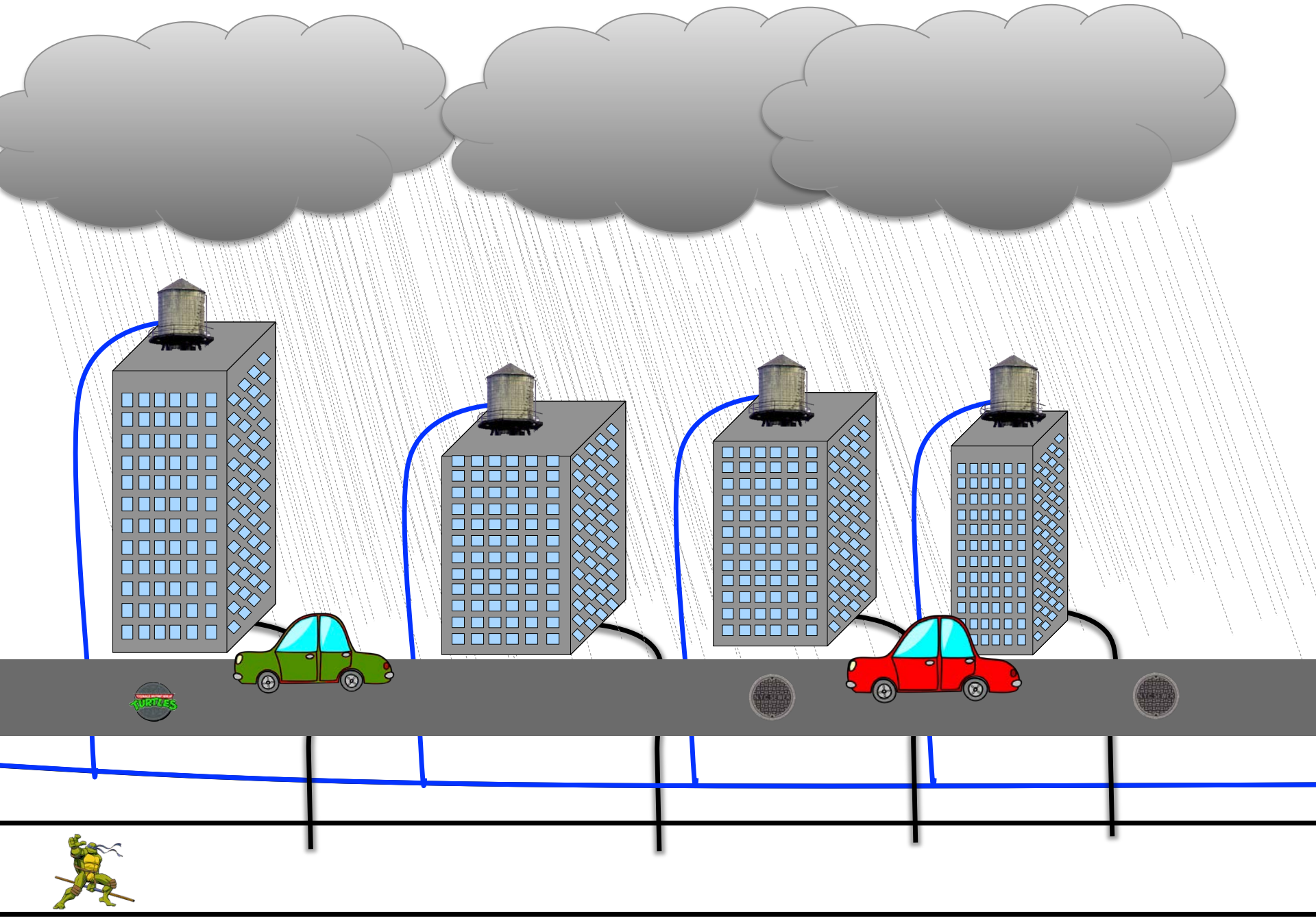

Catskill/Delaware Watersheds
Schoharie Reservoir
Pepacton Reservoir
Cannonsville Reservoir
Ashokan Reservoir
Neversink Reservoir
Rondout Reservoir
West Branch Delaware
East Branch Delaware
Esopus Creek
Schoharie Creek
Stamford Tunnel
West Delaware Tunnel
East Delaware Tunnel
Neversink Tunnel
Delaware 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

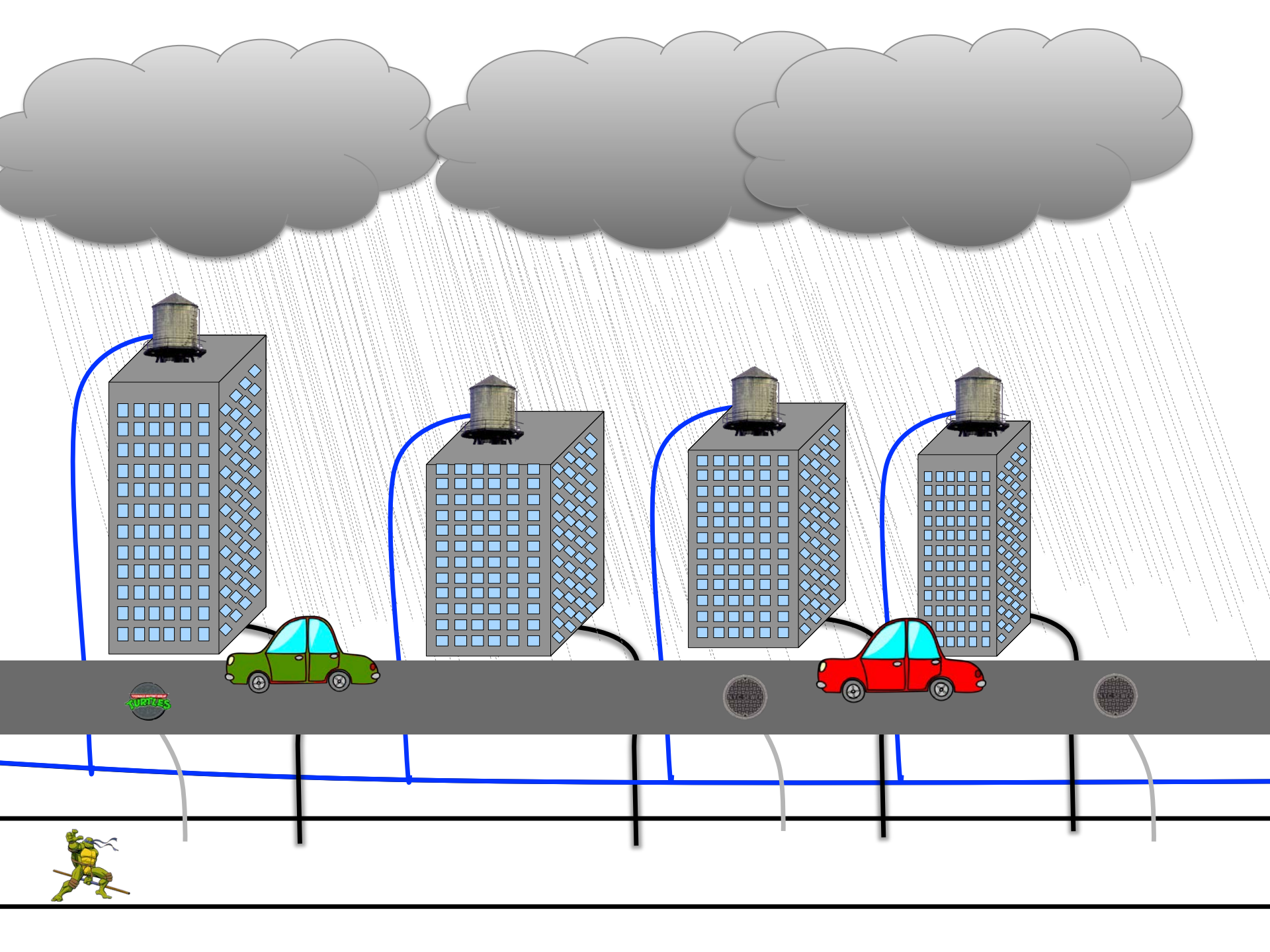

NYC Environmental Protection
NEW YORK CITY WATER INFRASTRUCTURE
NEW YORK
NEW JERSEY
Hudson River
Kensico Reservoir
Croton Aqueduct
Catskill Aqueduct
Delaware Aqueduct
WESTCHESTER COUNTY
Hillview Reservoir
Jerome Park Reservoir
City Tunnel No. 3 Stage 1 (Activated in 1998)
NY City Line
BRONX
Long Island 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

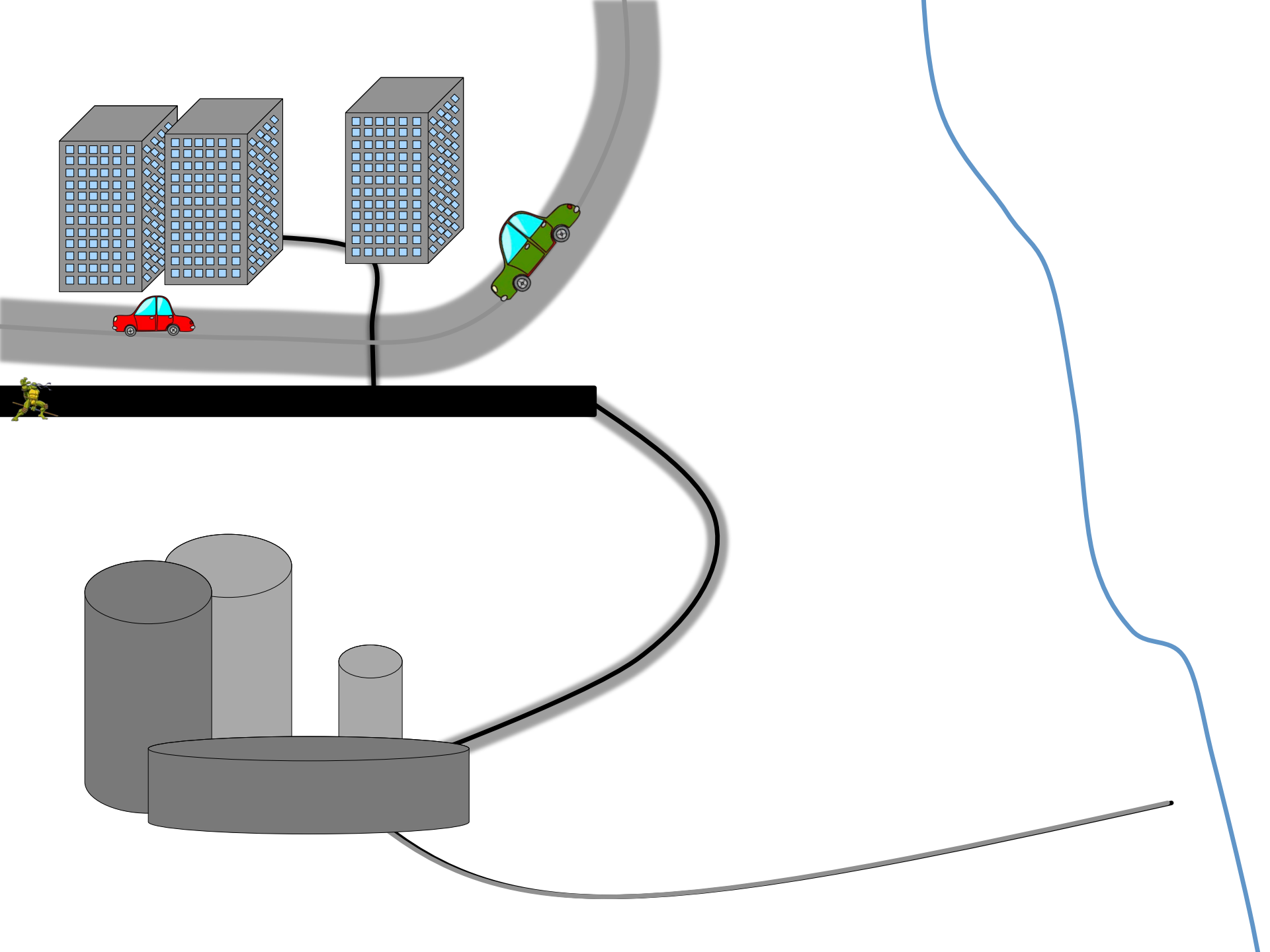


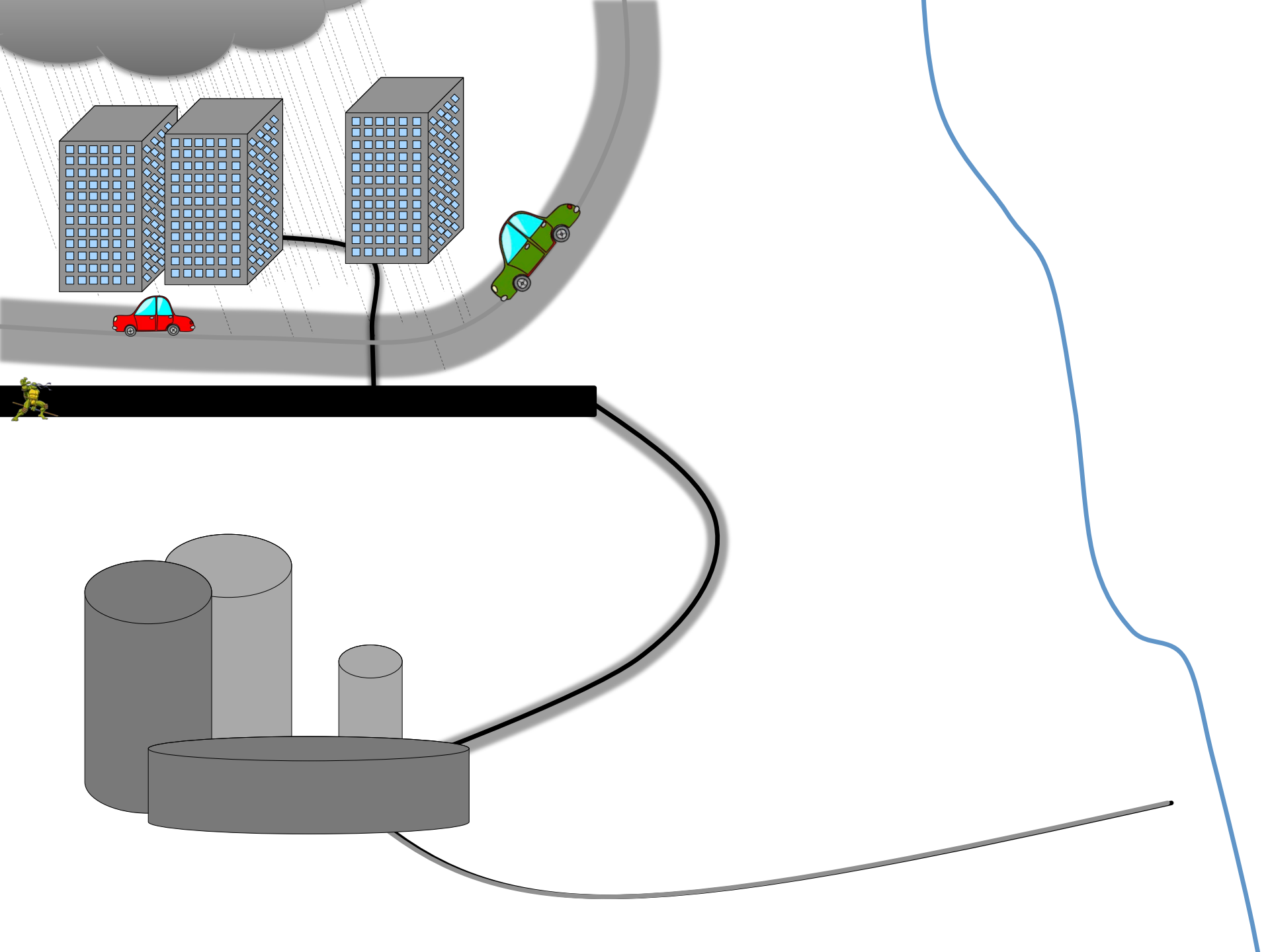


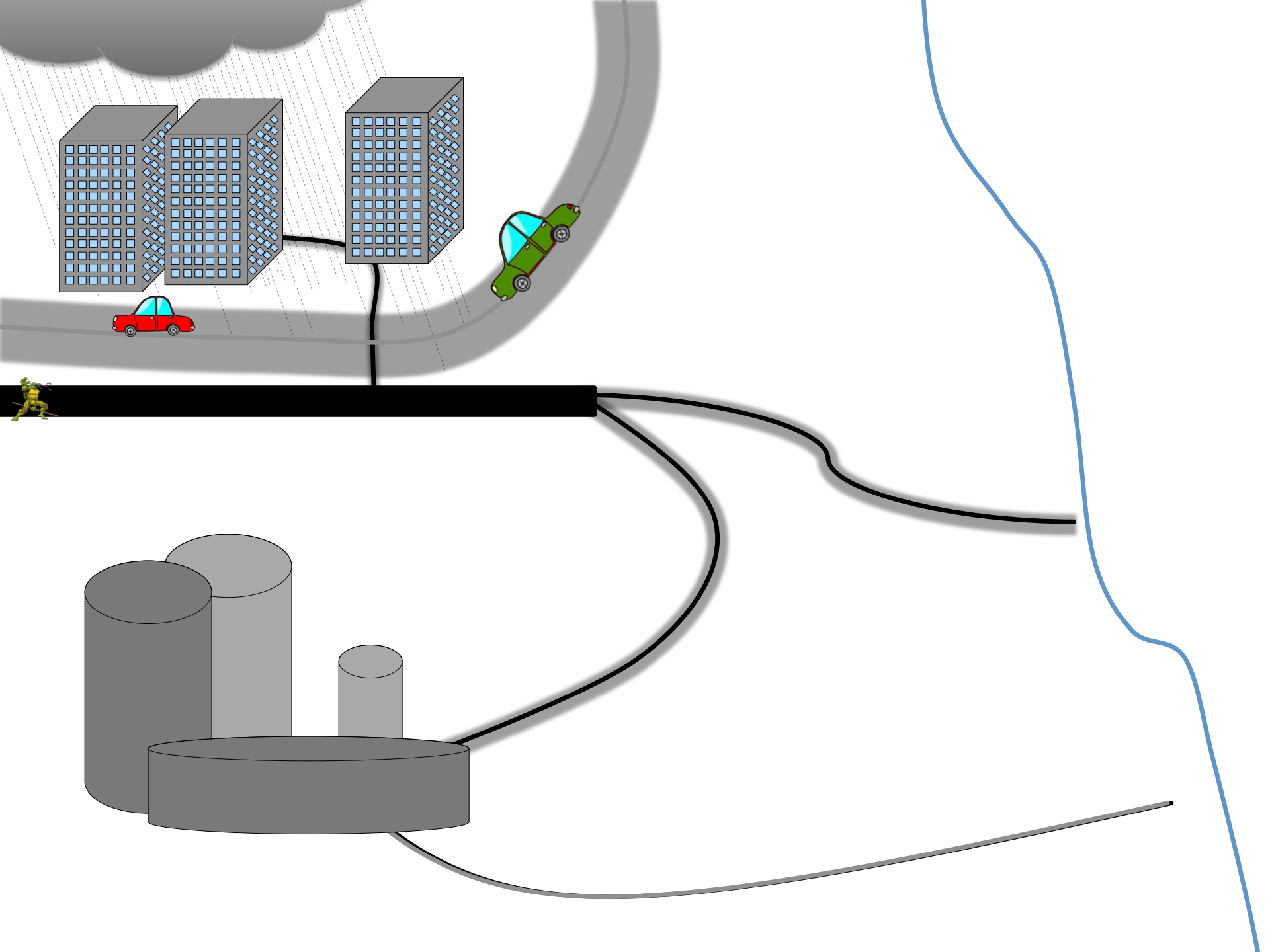

TURTLES



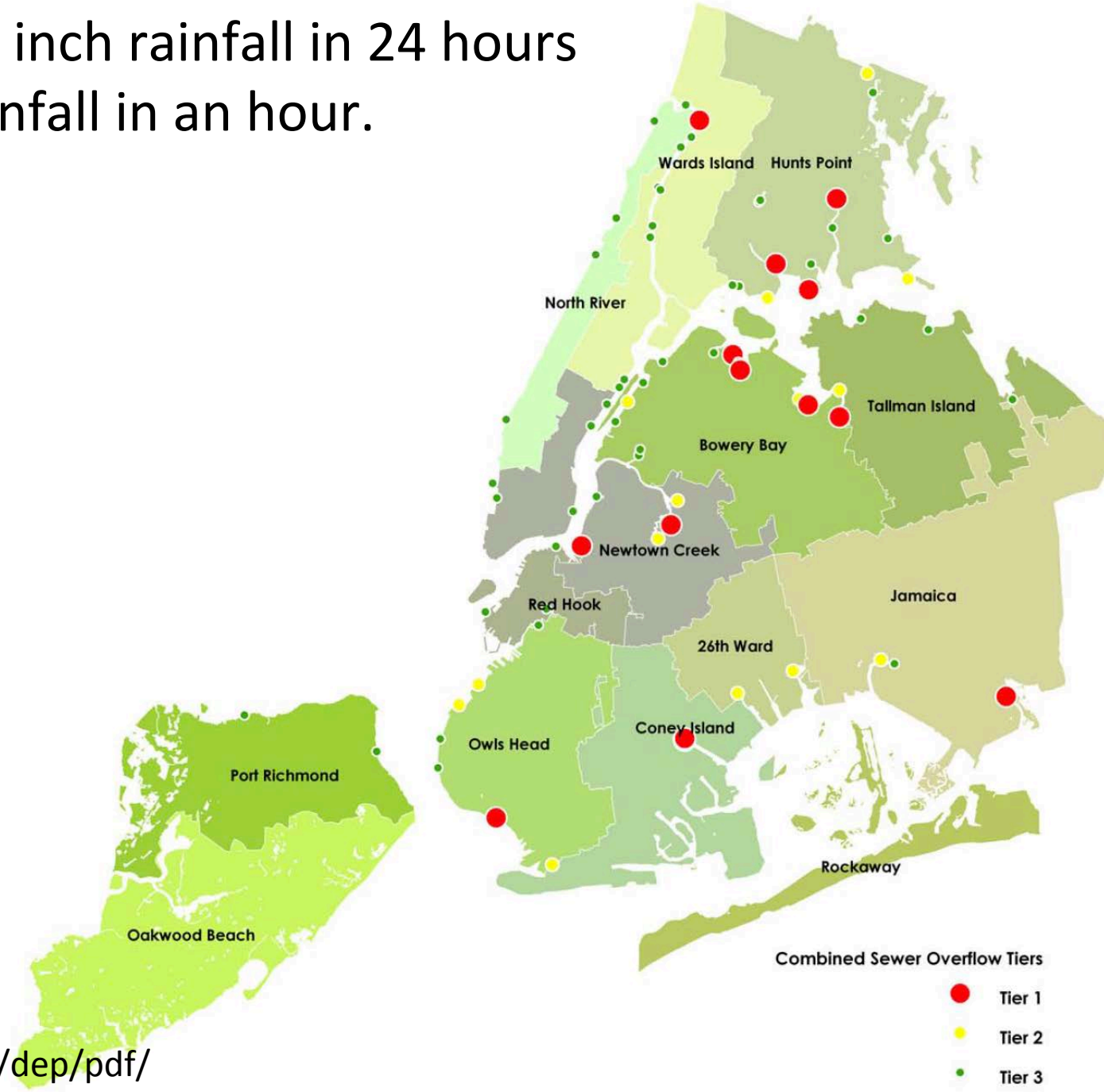






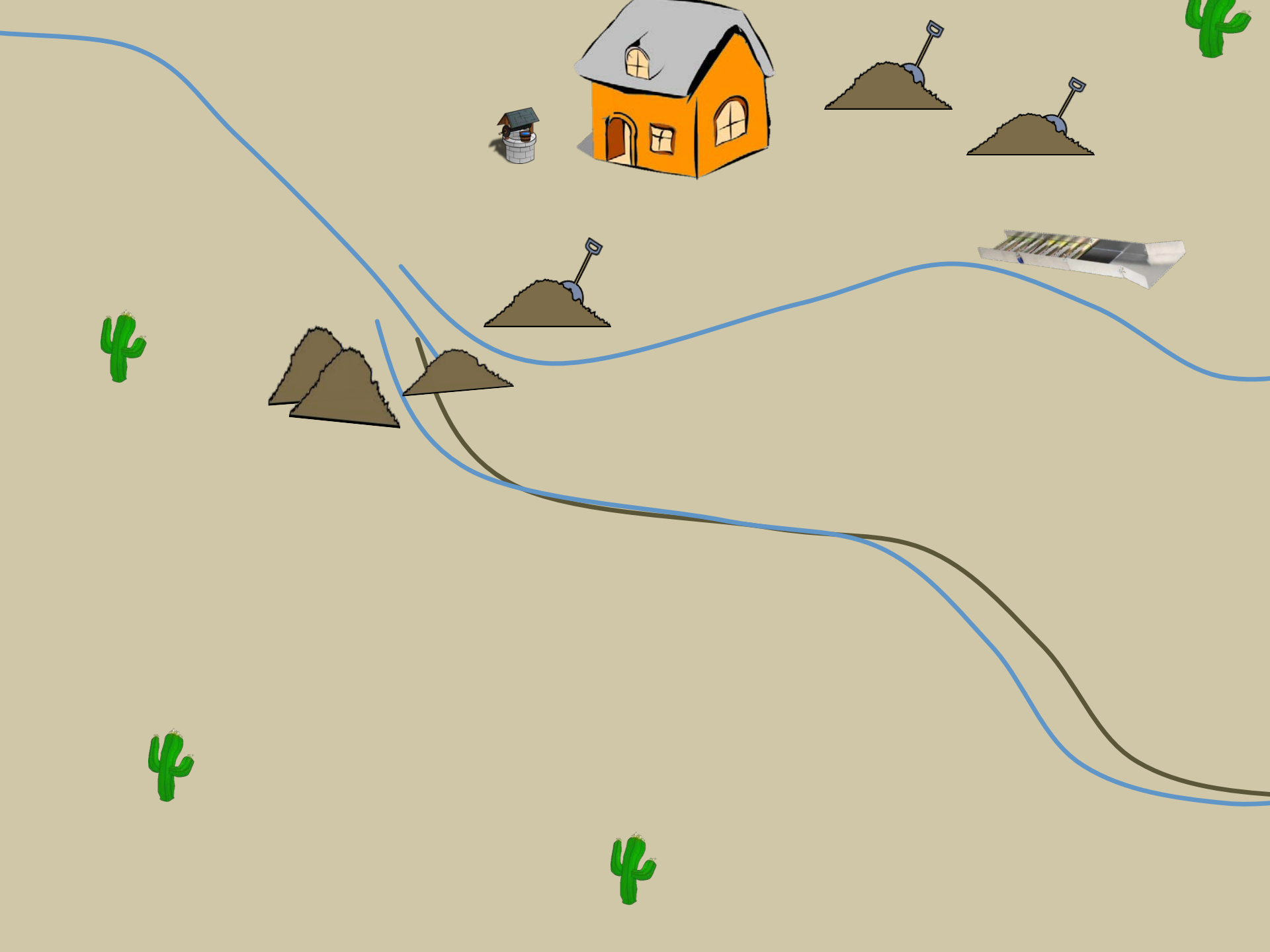


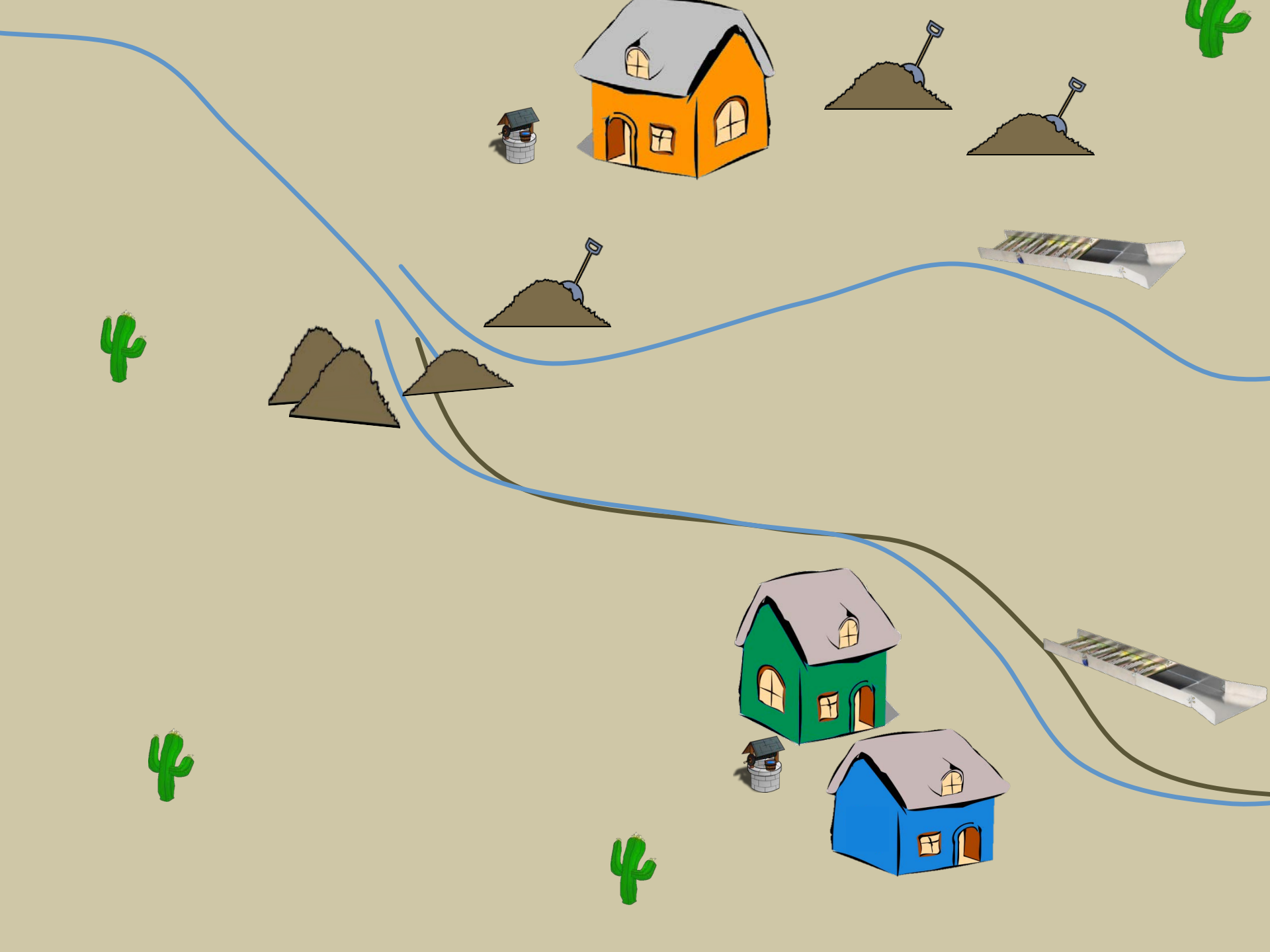
CSO's at about ½ inch rainfall in 24 hours or 1/10th inch rainfall in an hour.

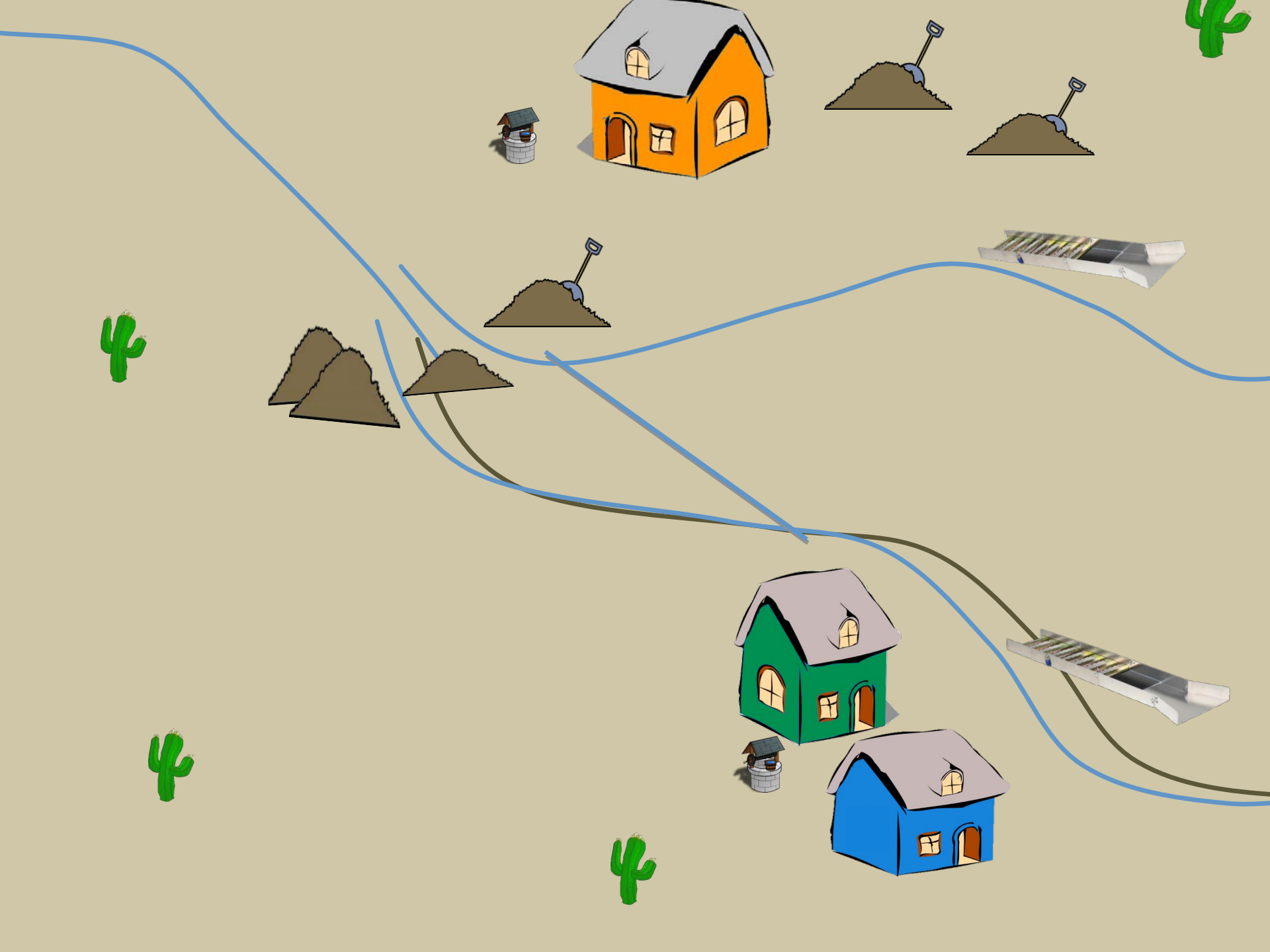


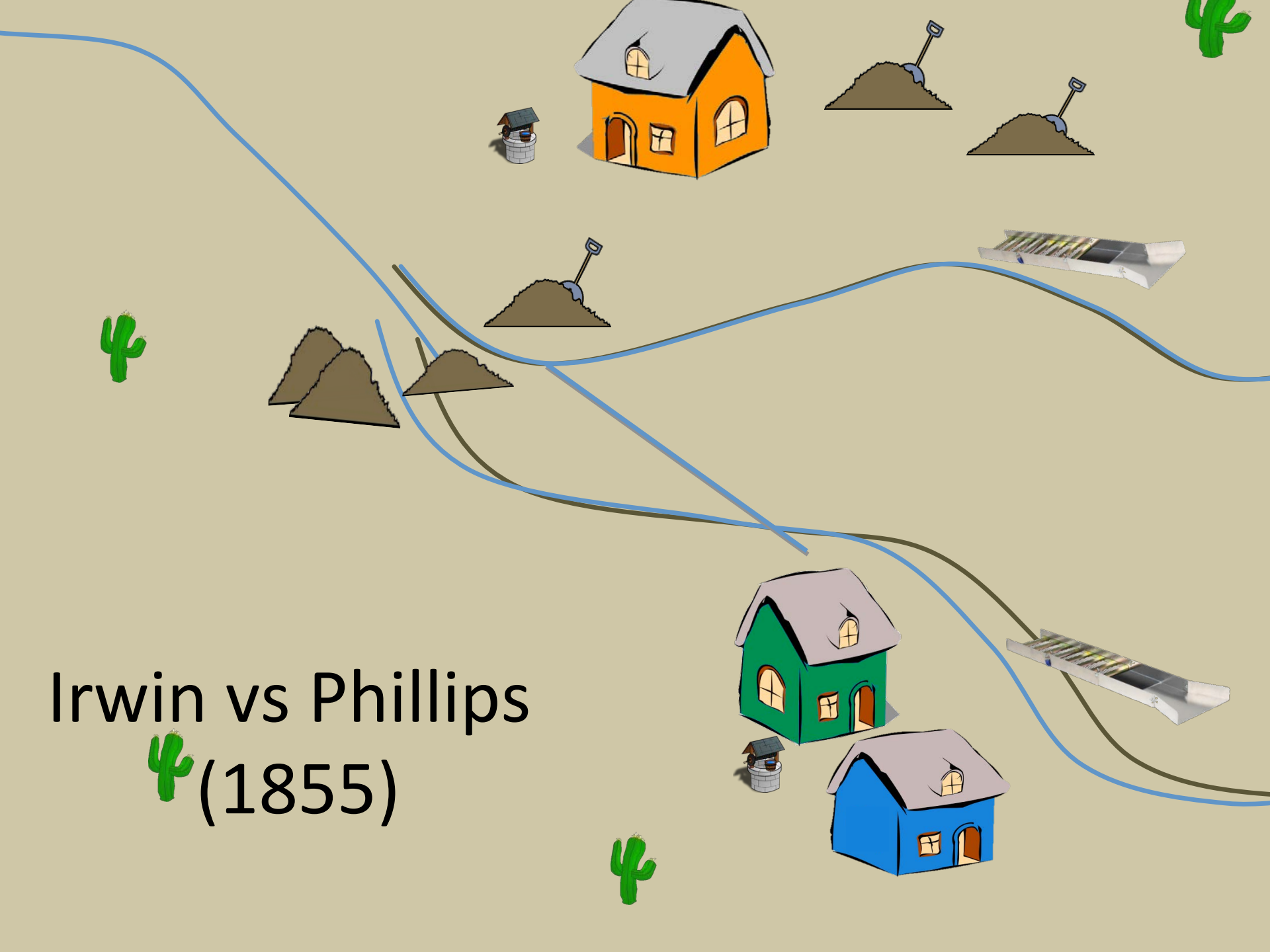
http://www.nyc.gov/html/dep/pdf/green_infrastructure/cso_outfalls_map.pdf

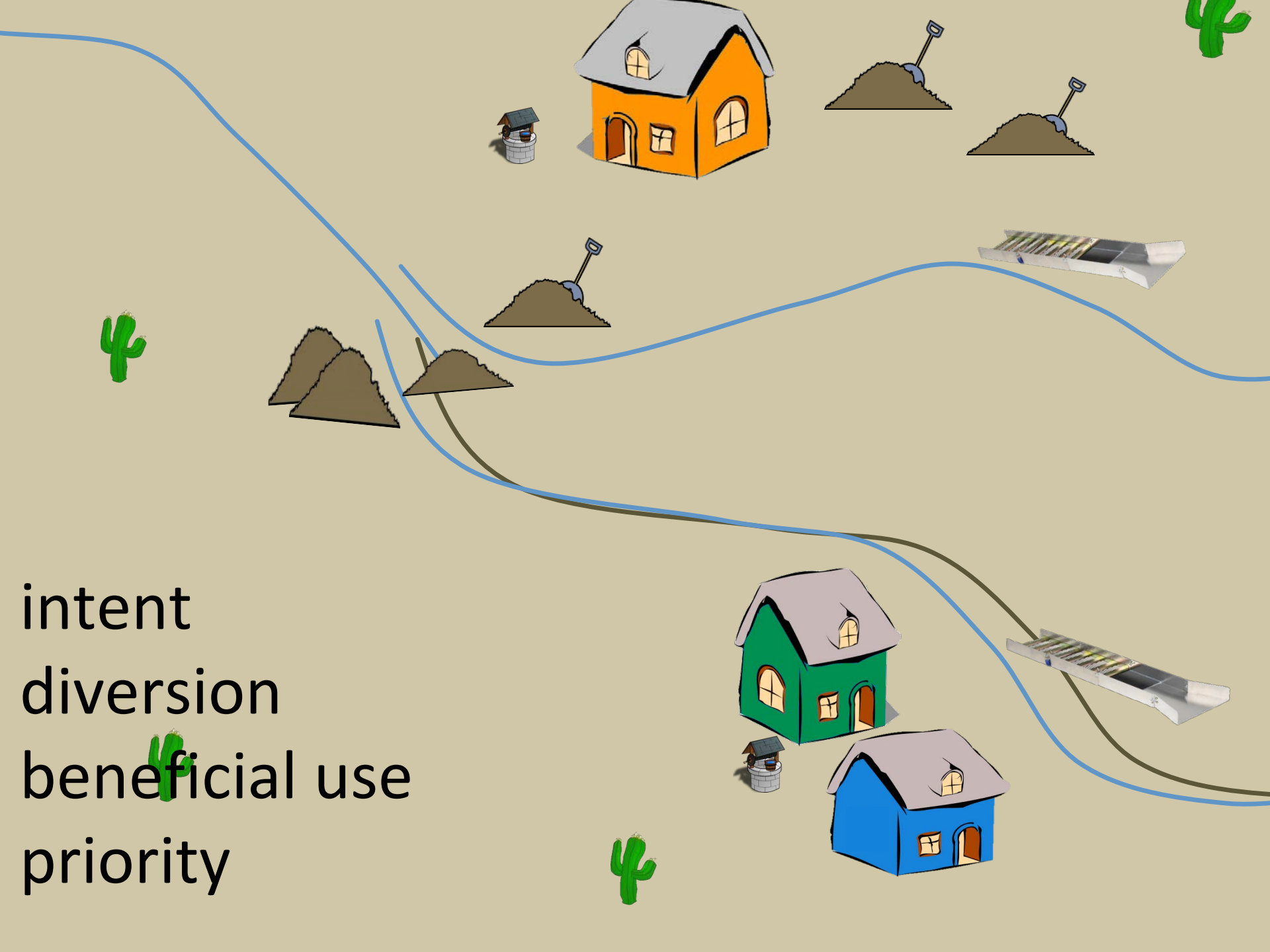
Riparian Water Law








Irwin vs Phillips
(1855)



intent
diversion
beneficial use
priority

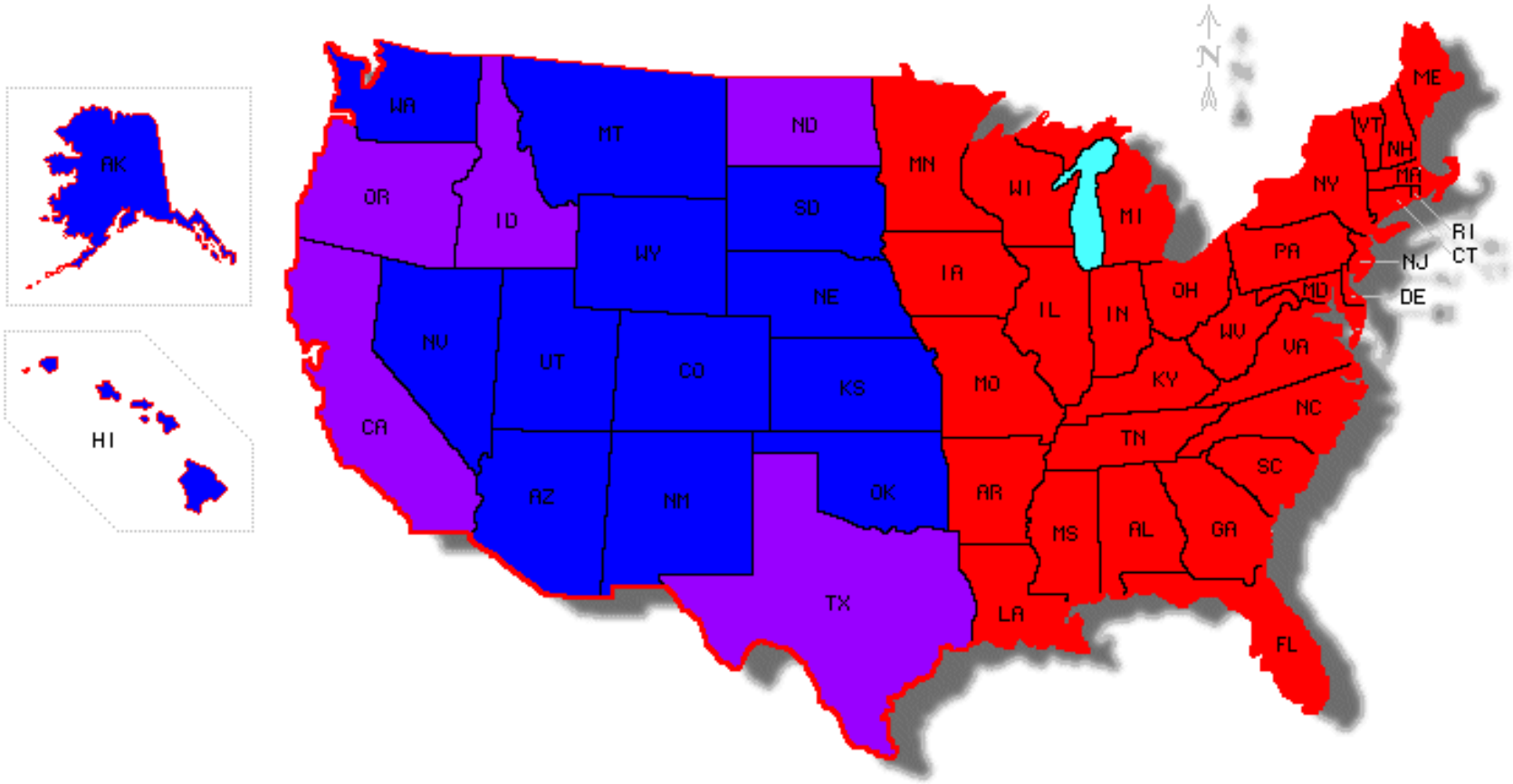
Doctrine of Prior Appropriation

Raquel Baranow


Cobalt123

allocation systems

- Prior Appropriation
- Riparian
- Combined

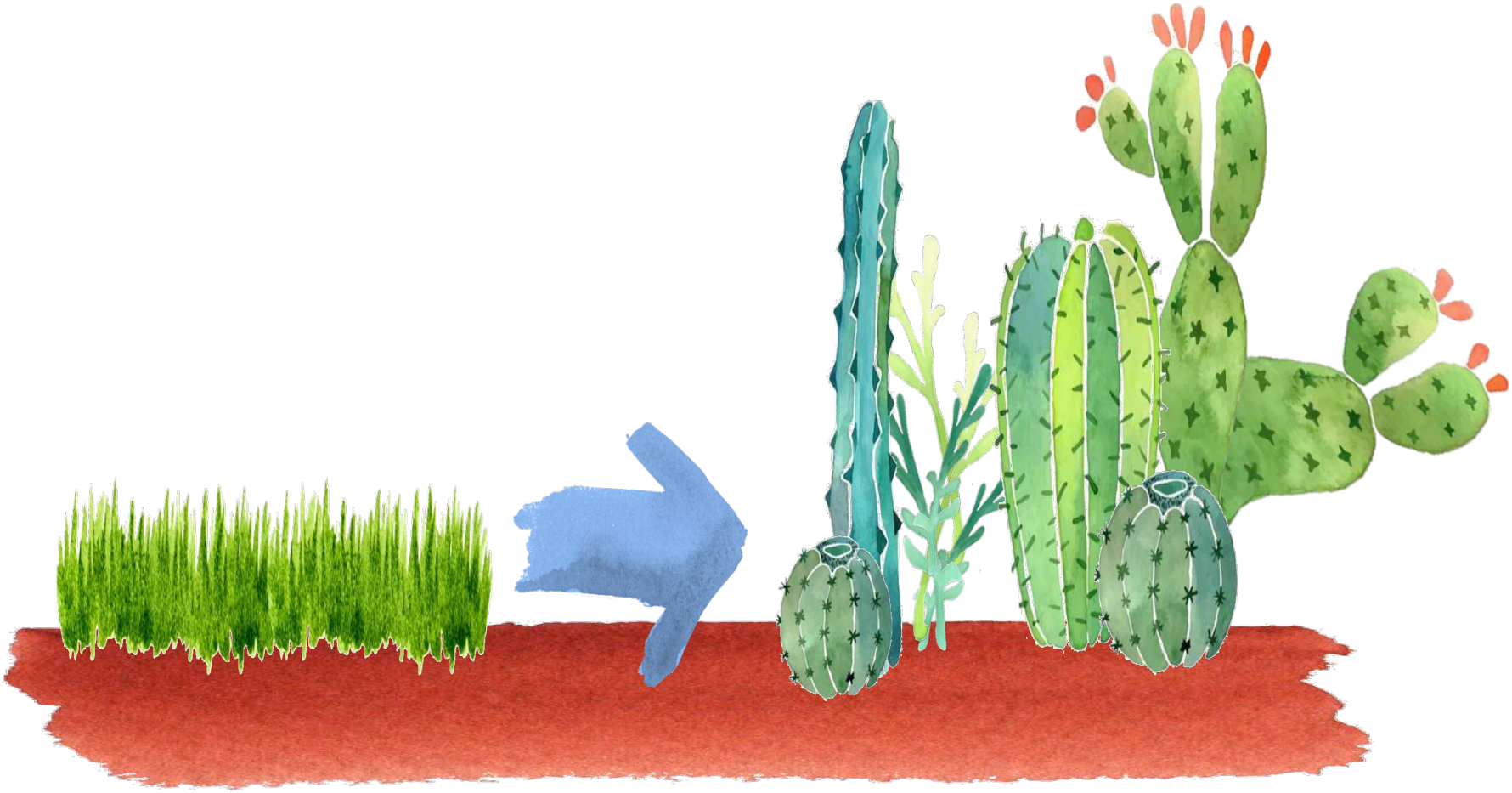


Source: diymaps.net (c)

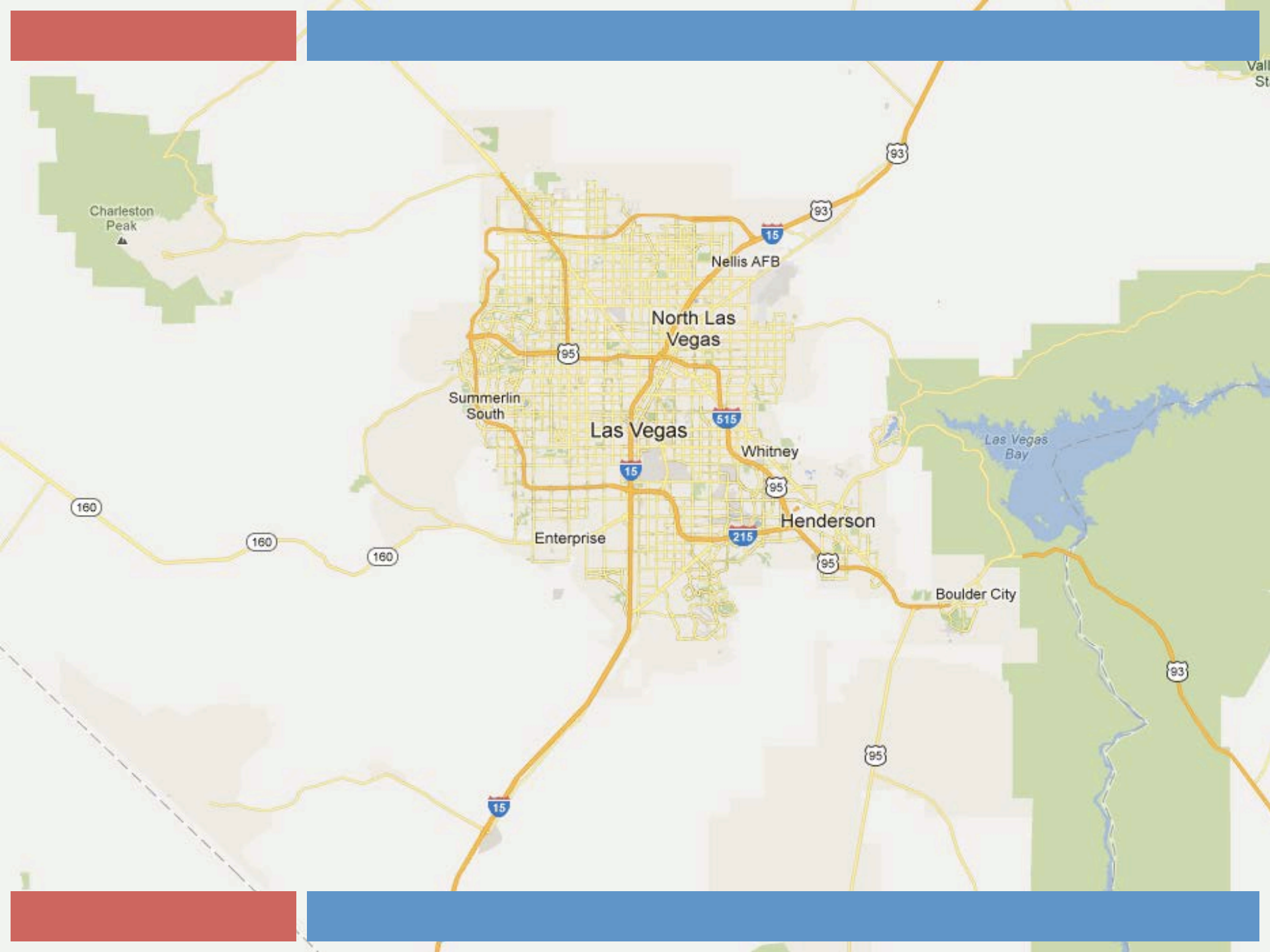

Topo
Imagery Topo
Imagery
Hydro-NHD
Hill Shade
HUC 2 - 09
HUC 2 - 17
HUC 2 - 04
HUC 2 - 01
HUC 2 - 10
HUC 2 - 07
HUC 2 - 16
HUC 2 - 14
HUC 2 - 11
HUC 2 - 05
HUC 2 - 06
HUC 2 - 18
HUC 2 - 15
HUC 2 - 03
HUC 2 - 13
Seattle
WASHINGTON
Portland
OREGON
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
MISSOURI
IOWA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
CONNECTICUT
RHODE ISLAND
NEW JERSEY
DELAWARE
MARYLAND
VIRGINIA
NORTH CAROLINA
TENNESSEE
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
SOUTH CAROLINA
FLORIDA
LOUISIANA
TEXAS
OKLAHOMA
CALIFORNIA
ARIZONA
NEW MEXICO
Snake River
Columbia River
Platte River
Missouri River
Arkansas River
Ohio River
Tennessee River
Canadian River
Colorado River
Red River
Mississippi R.
Brazos River
Grande Rio
Susquehanna River
Connecticut River
Chattahoochee River
San Joaquin River
Milwaukee
Chicago
Detroit
Columbus
Baltimore
Washington
Philadelphia
New York
Boston
Denver
Oklahoma City
Memphis
Charlotte
Fort Worth
Austin
San Antonio
Houston
Jacksonville
El Paso
Phoenix
Los Angeles
San Diego
San Francisco
San Jose
Mexico
100
200mi

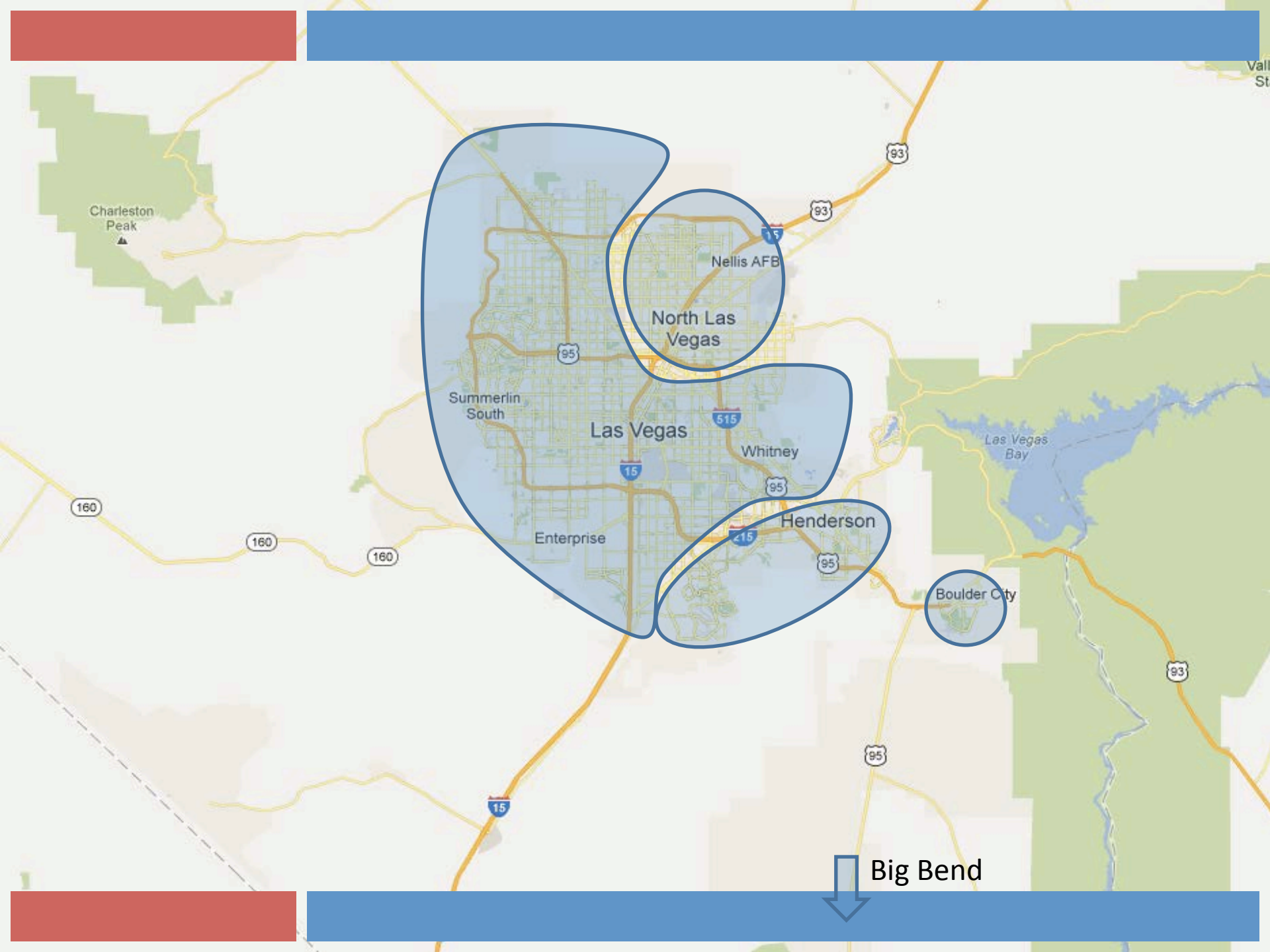

Whiskey is for Drinking;
Water is for Fighting Over
matching fixed supply with growing demand

Water Conservation in Las Vegas

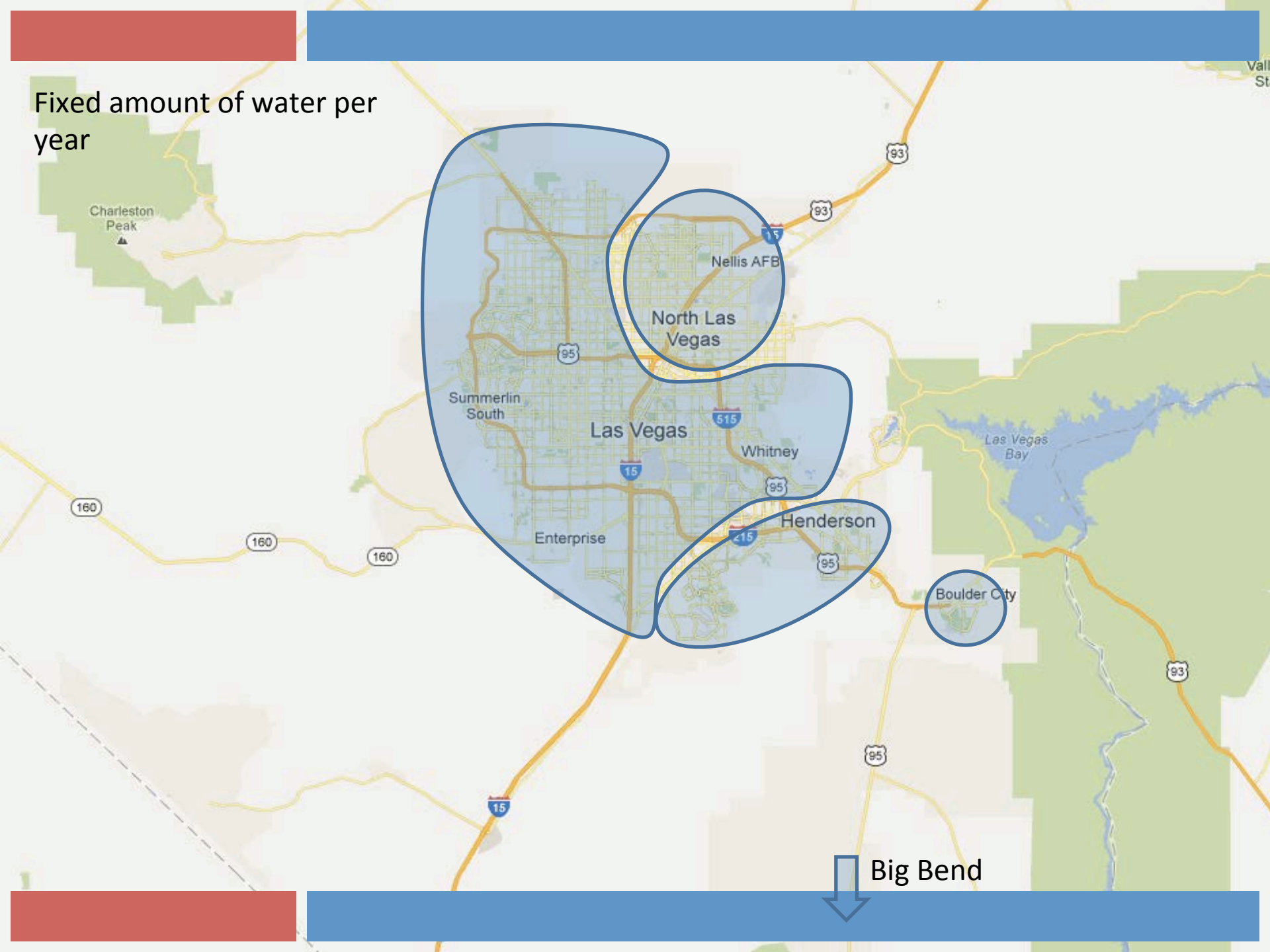


Brelsford & Abbott, *Ecological Econ.* 2016
Brelsford & De Bacco, *NETS.* 2018
Brelsford & Abbott, [in review]


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

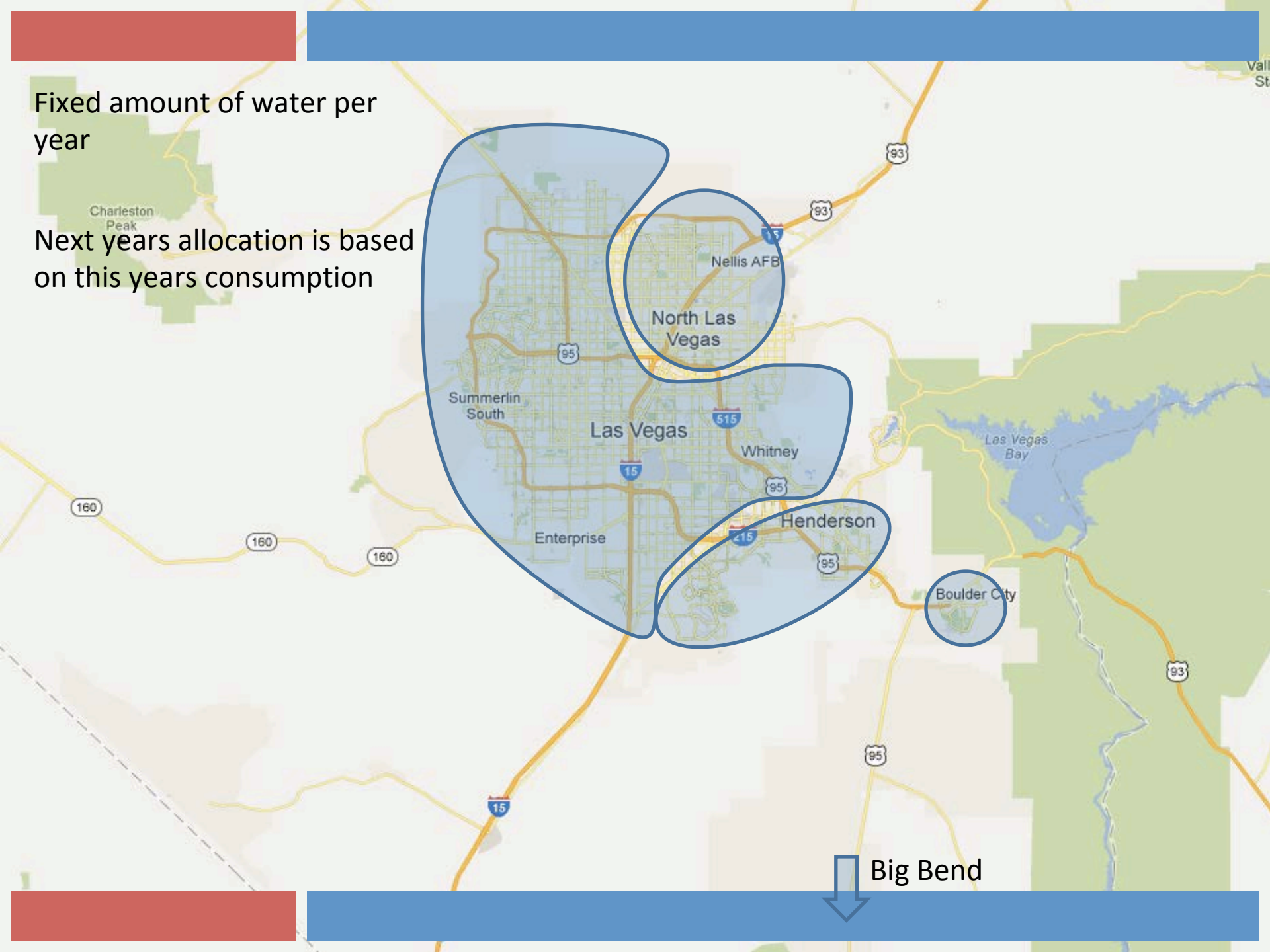
Fixed amount of water per year



Big Bend

Fixed amount of water per year

Next years allocation is based on this years consumption

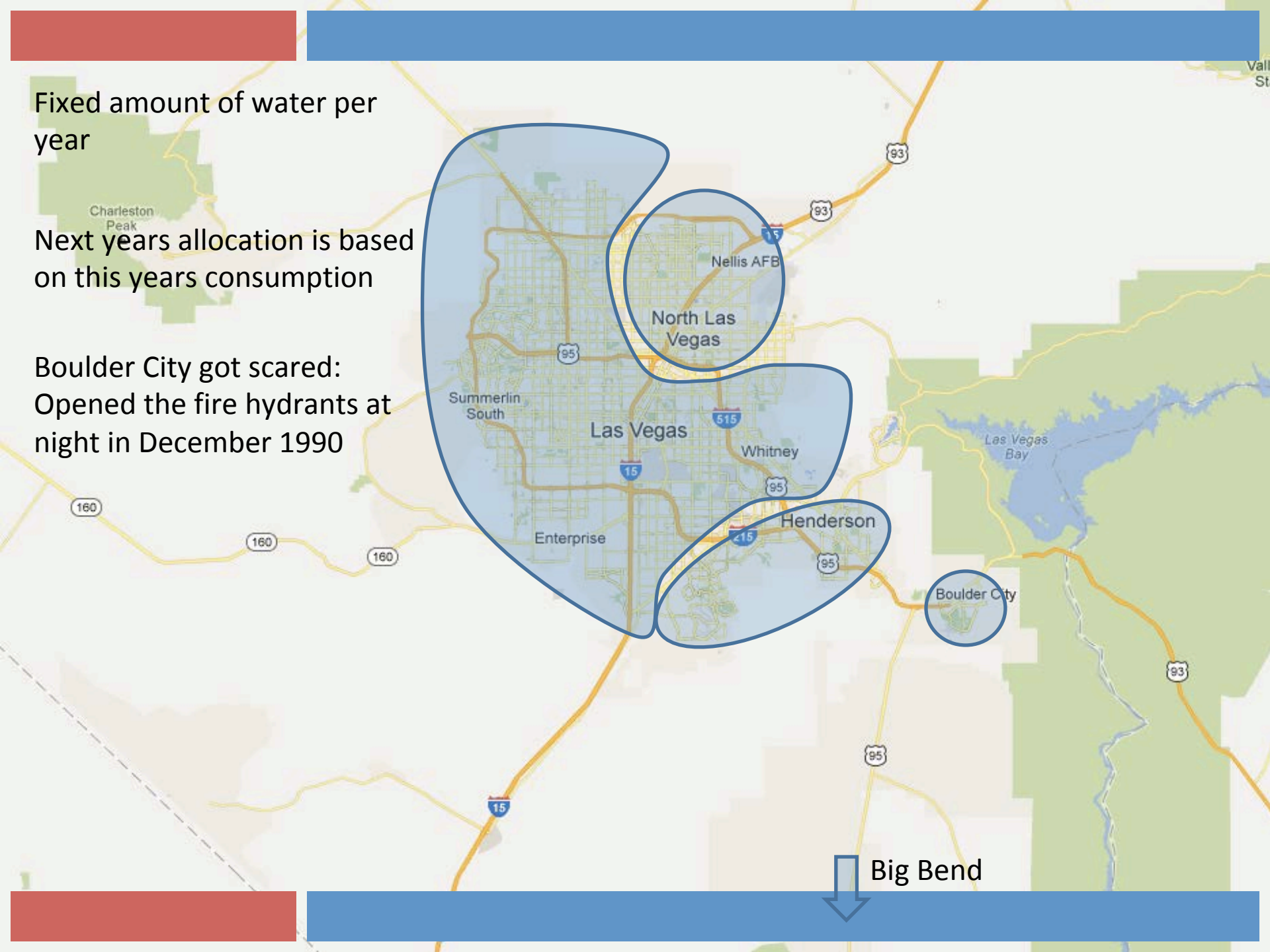


Big Bend

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



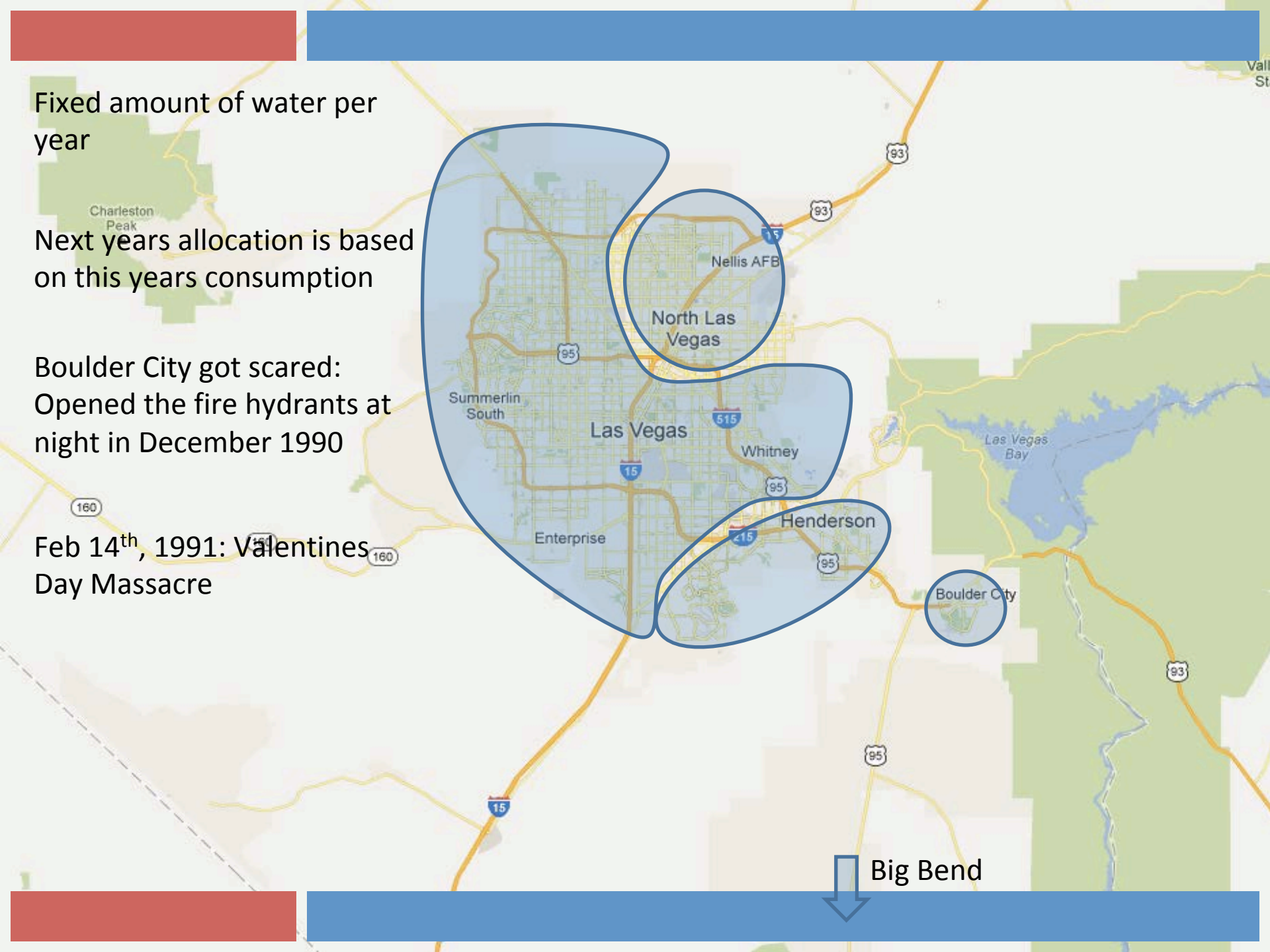
Big Bend

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

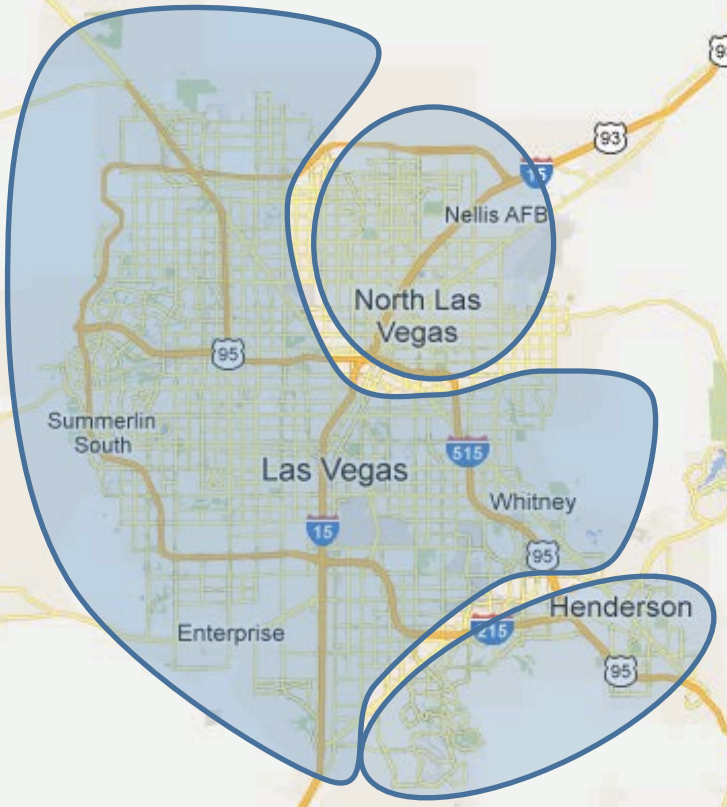
Fixed amount of water per year

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.



Big Bend

Fixed amount of water per year

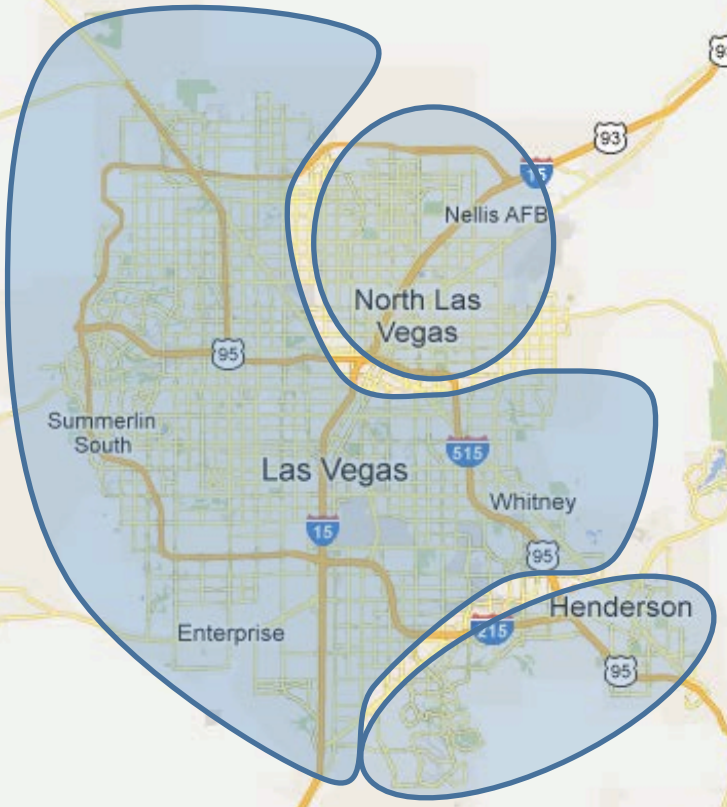
Next years allocation is based on this years consumption

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

Feb 14th, 1991: Valentines Day Massacre

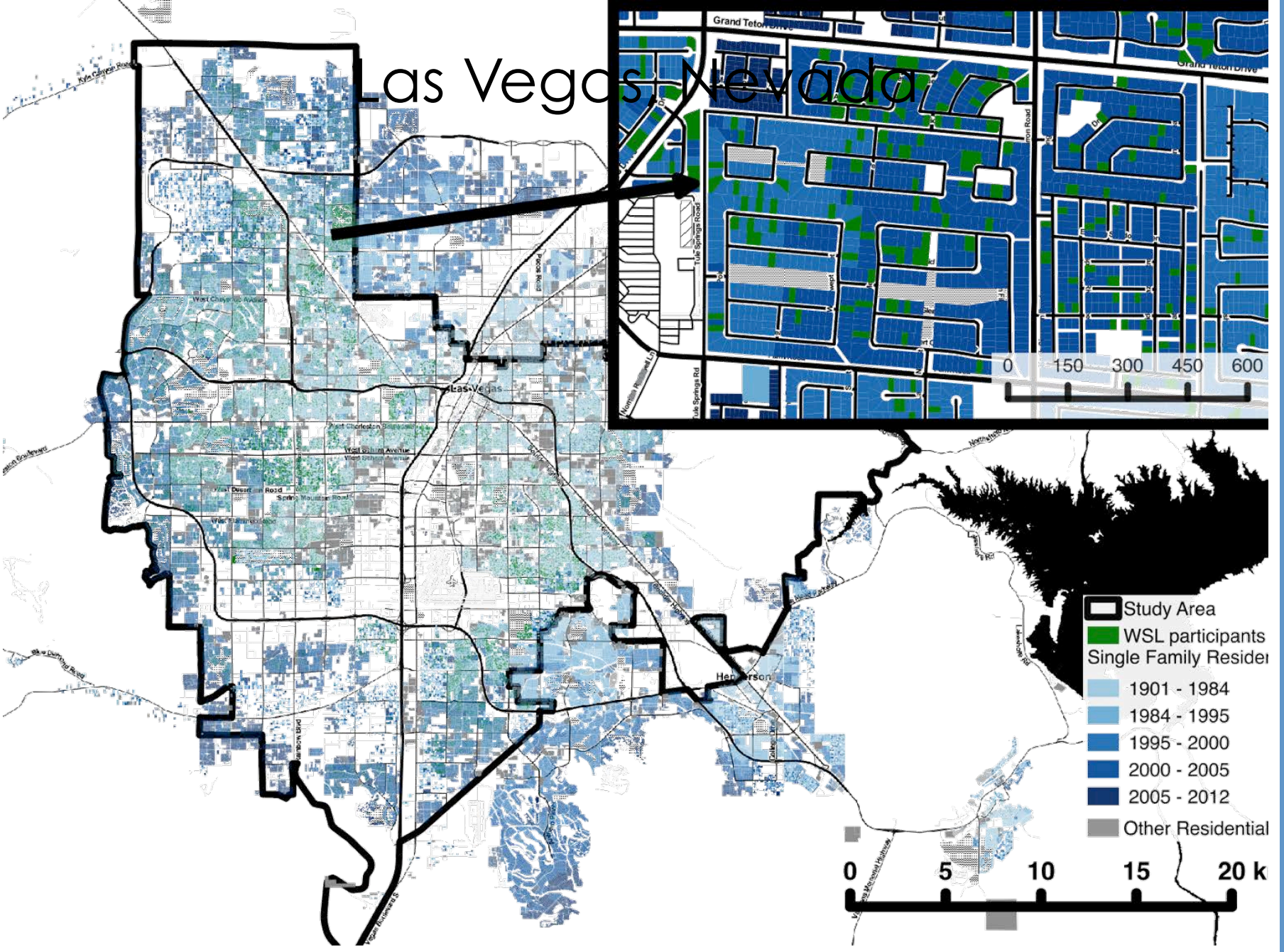
June 27th, 1991: Southern Nevada Water Authority was created.

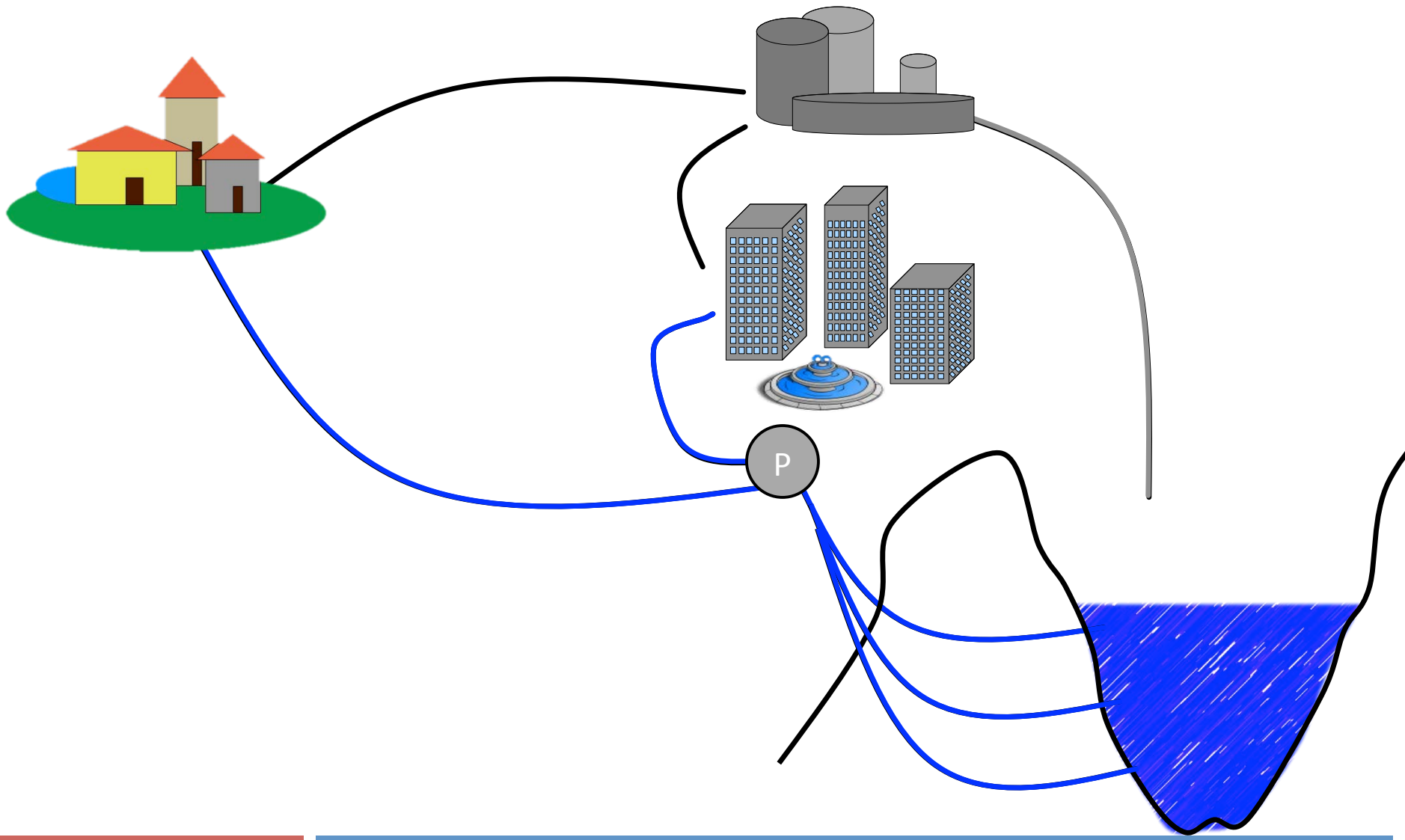
1993: Return Flow Credit Established



Big Bend

Las Vegas, Nevada




P

LAS VEGAS WASH COORDINATION COMMITTEE

SEARCH: Go

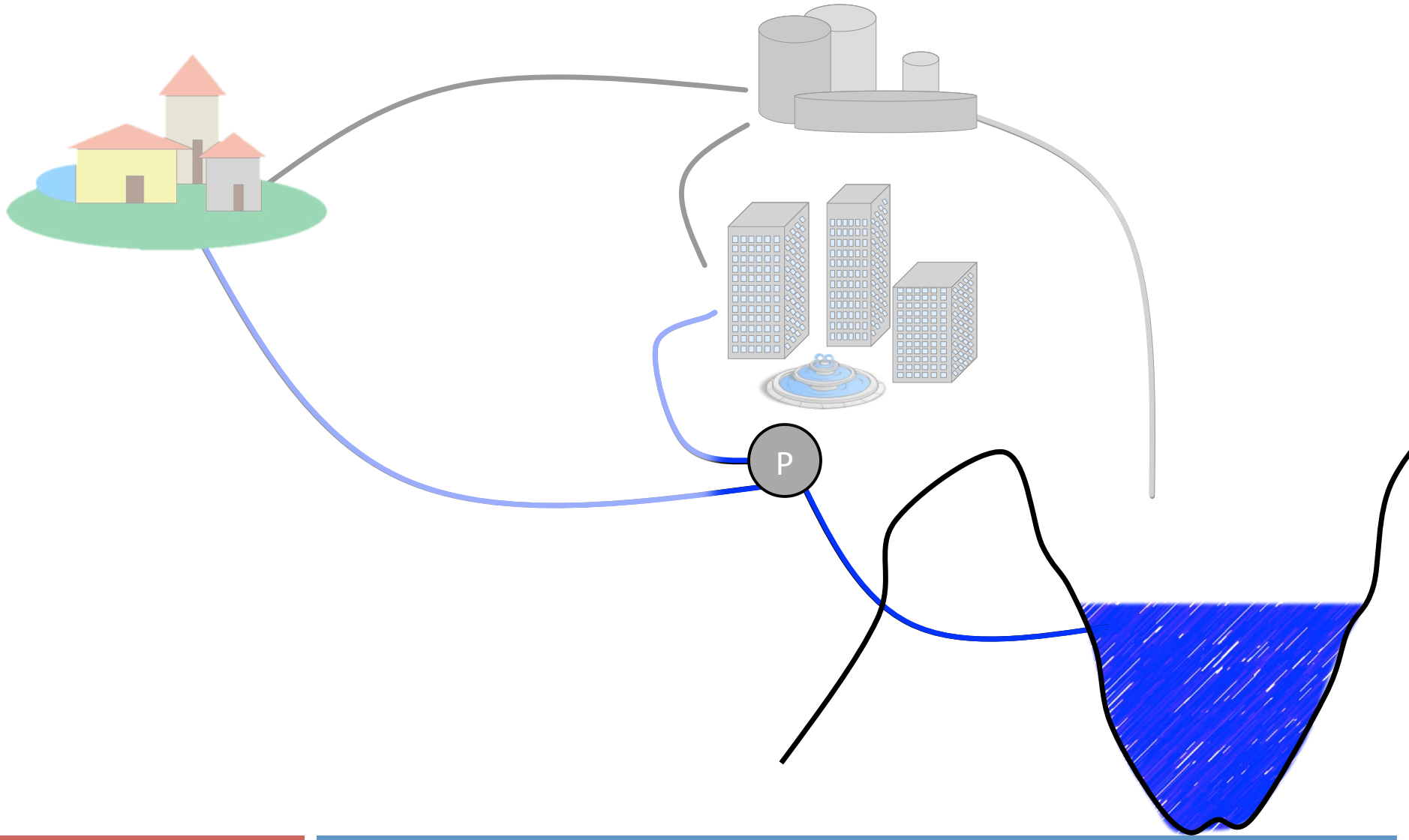
WORKING TO STABILIZE AND ENHANCE THE VALUABLE ENVIRONMENTAL RESOURCES OF THE LAS VEGAS WASH

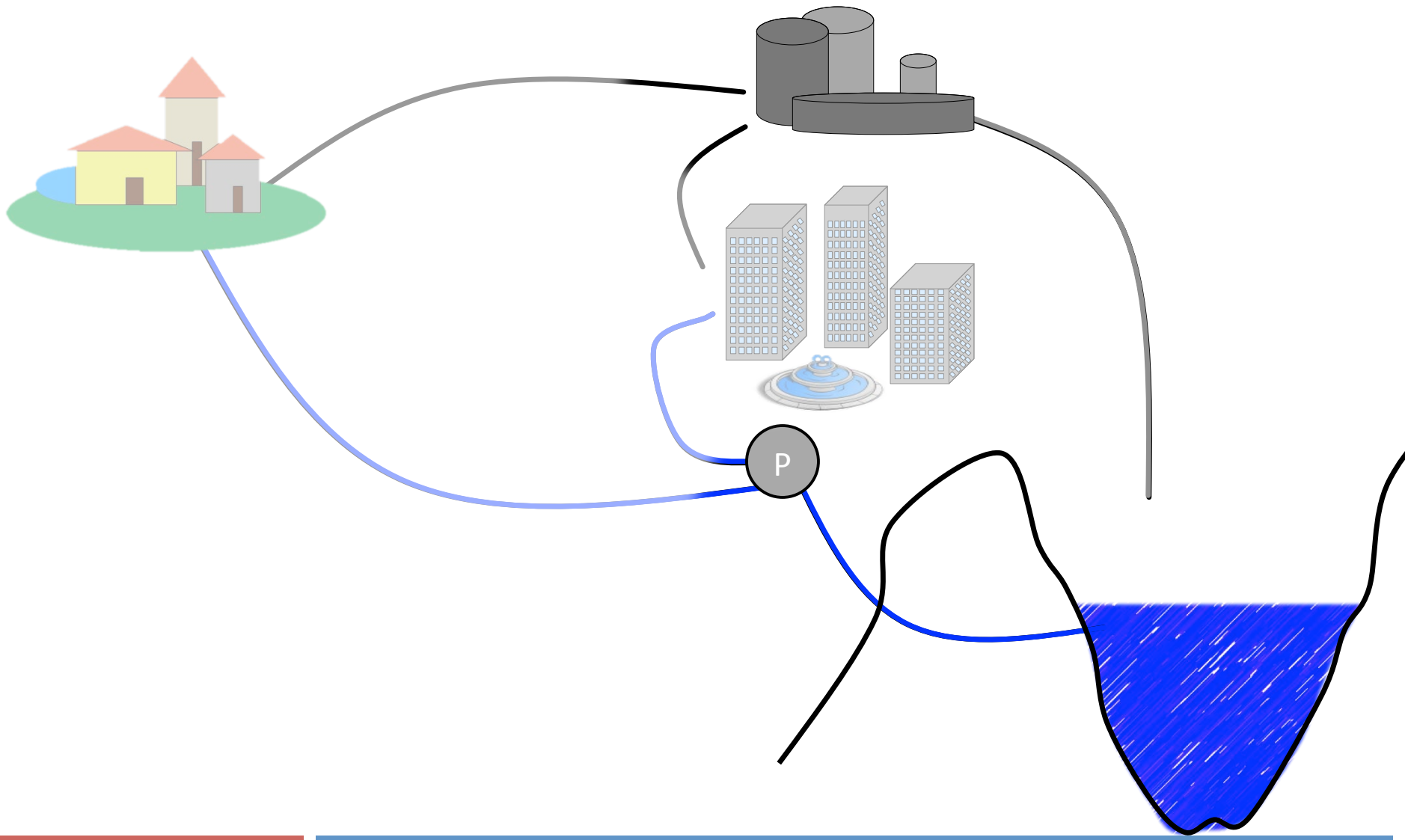
What is "the Wash"? Why is "the Wash" important? What is being done? What can I do to help?

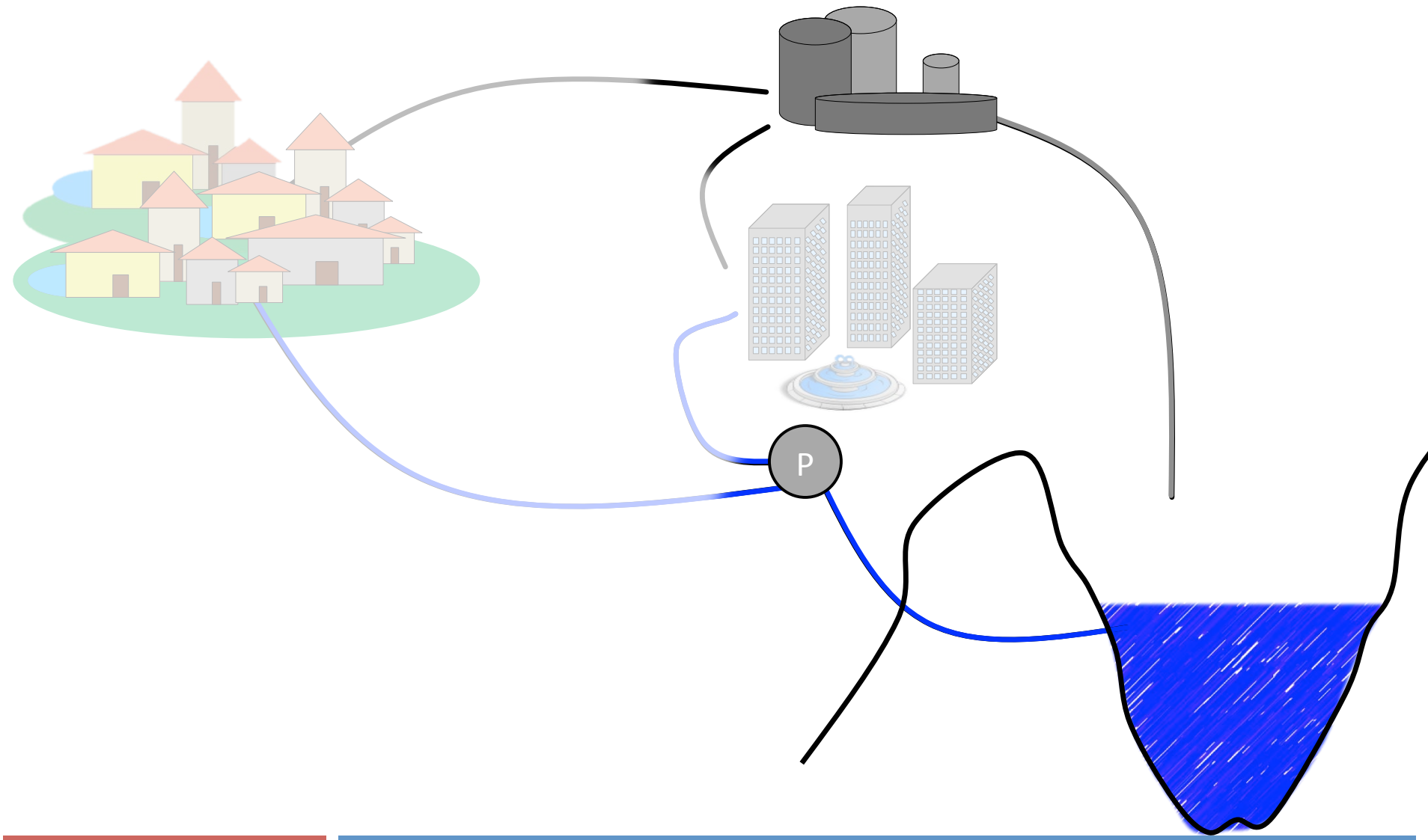
Annual bird surveys begin

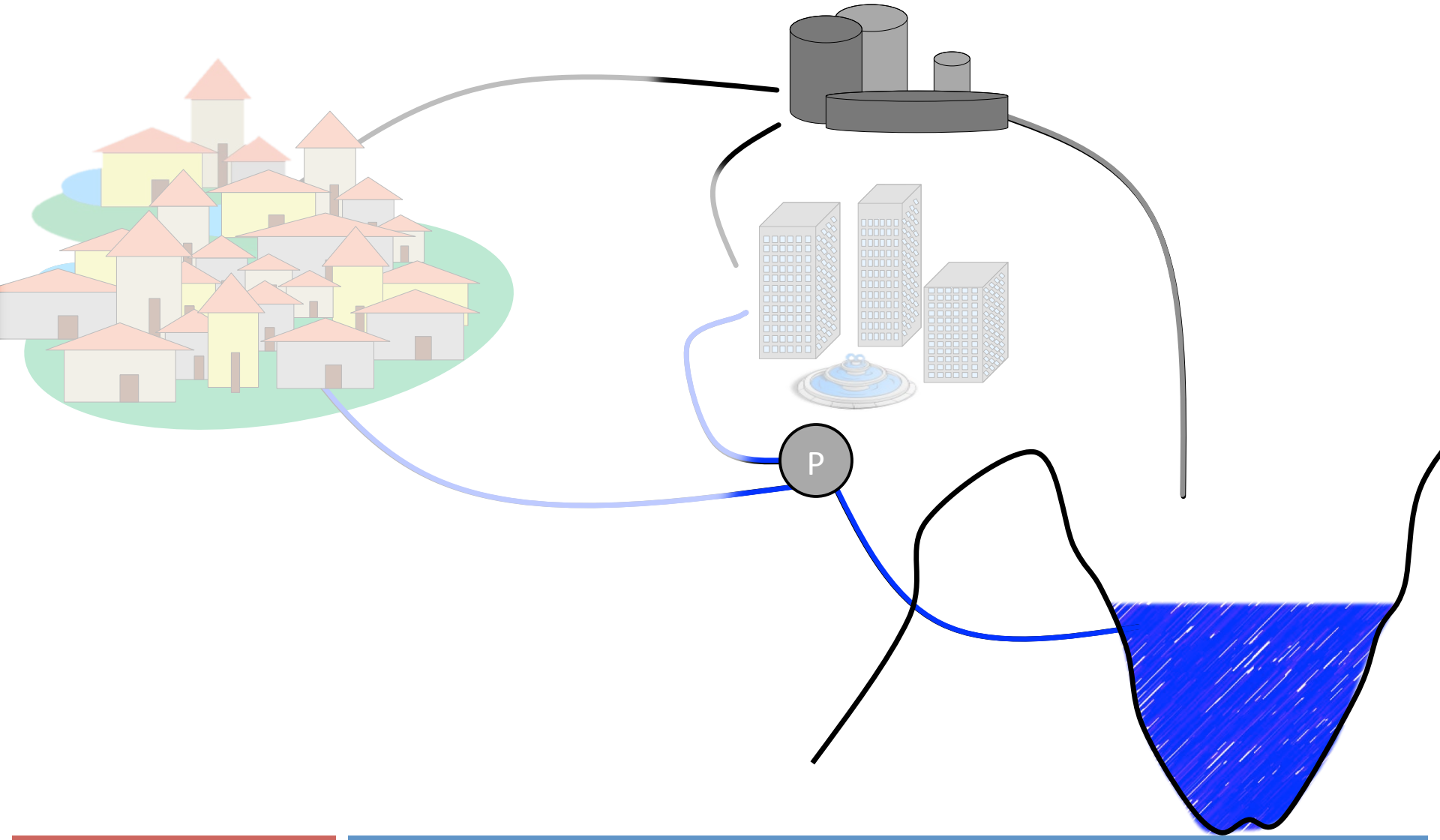
Fast Track

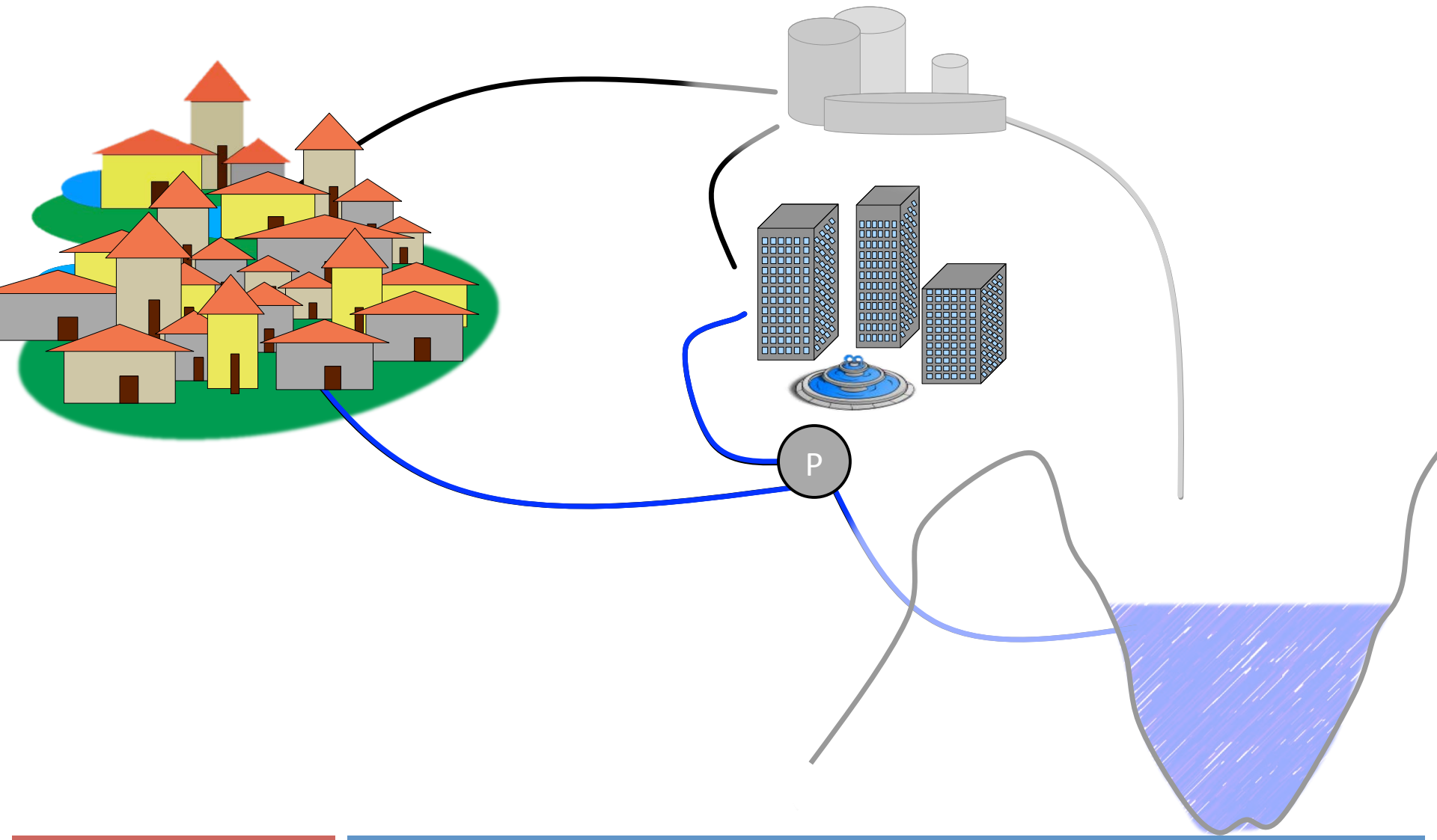
- Meetings & Events


P


P

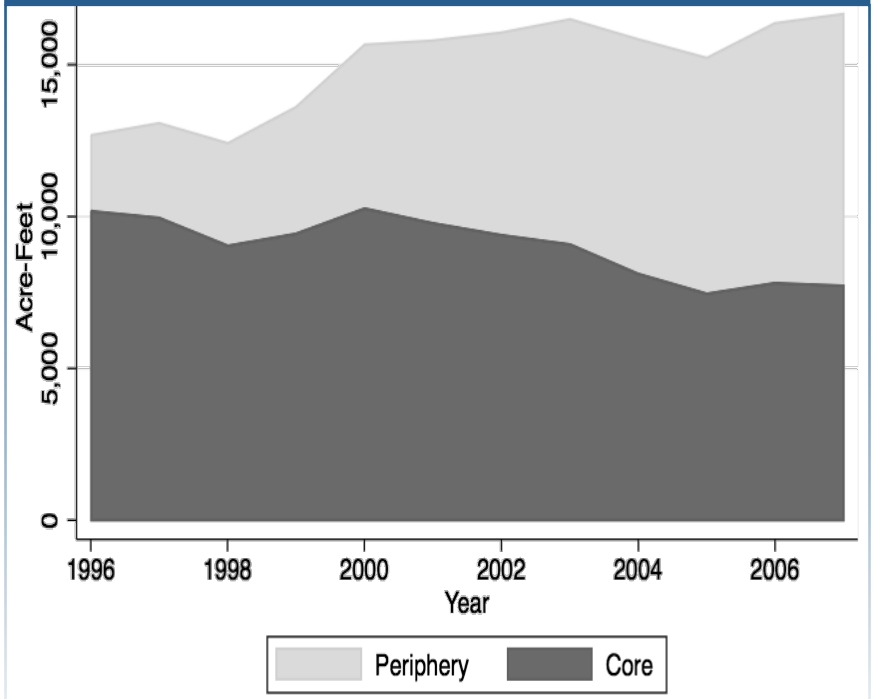

P


P

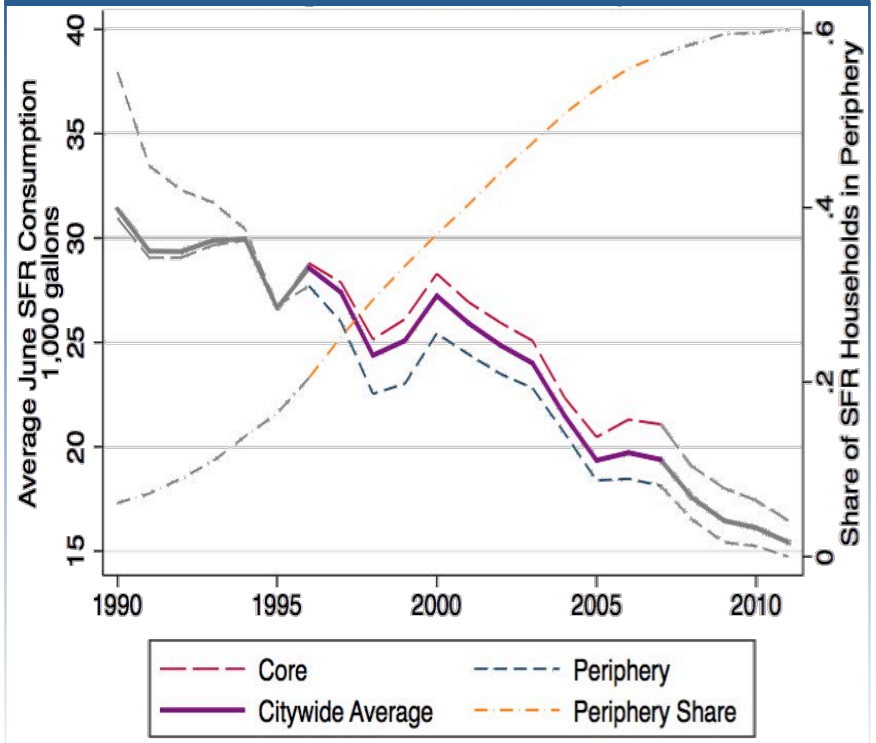

P

Las Vegas' per capita water consumption fell dramatically in the 1990s and 2000s.

Total June Water Consumption Single Family Residential



Average Household Consumption



How can we identify the most important drivers of our observed decline in water consumption?

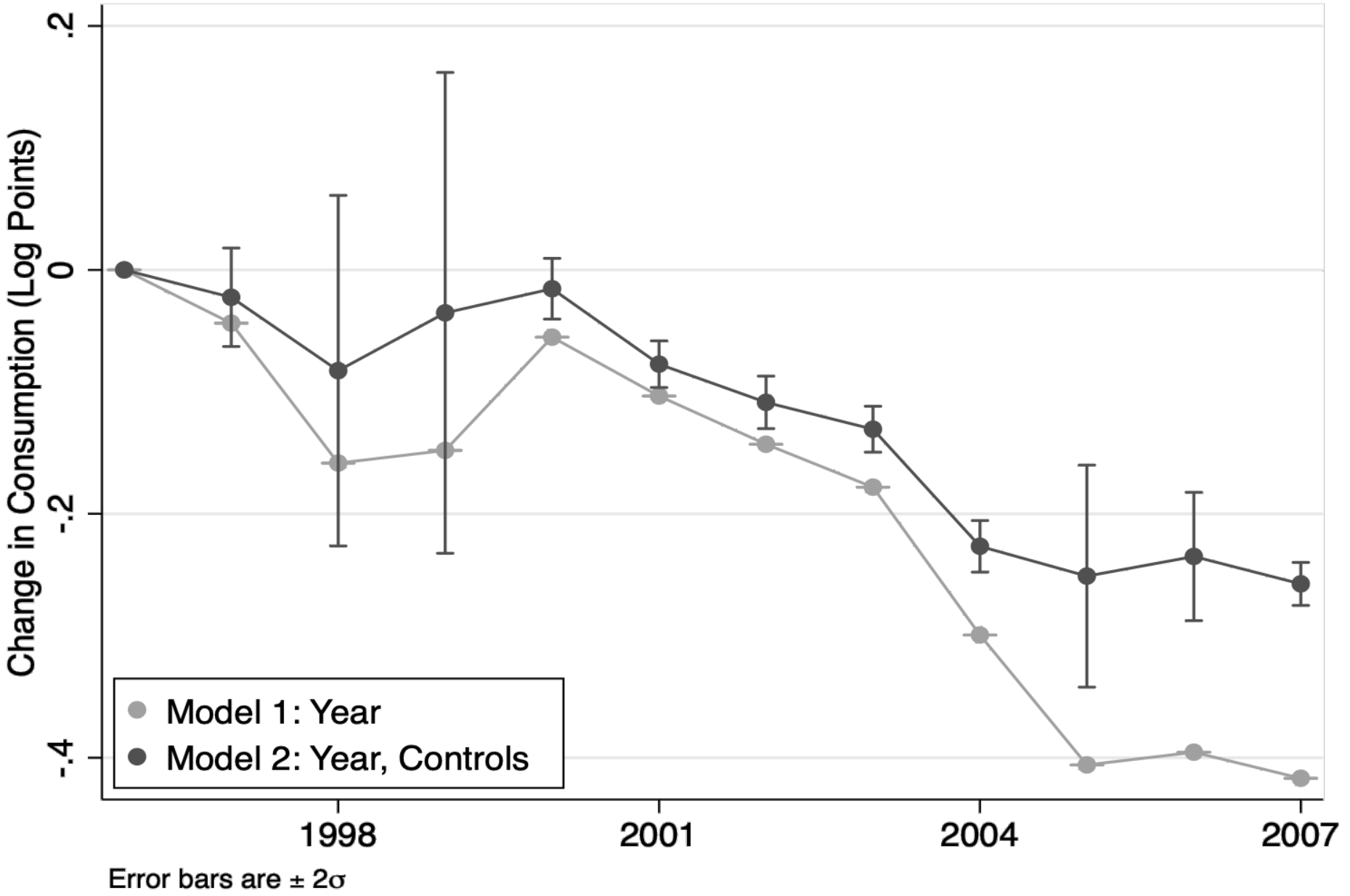
Semi Log Regressions

with a rich set of fixed effects, temporal dummy variables and controls related to home characteristics, weather, and neighborhood

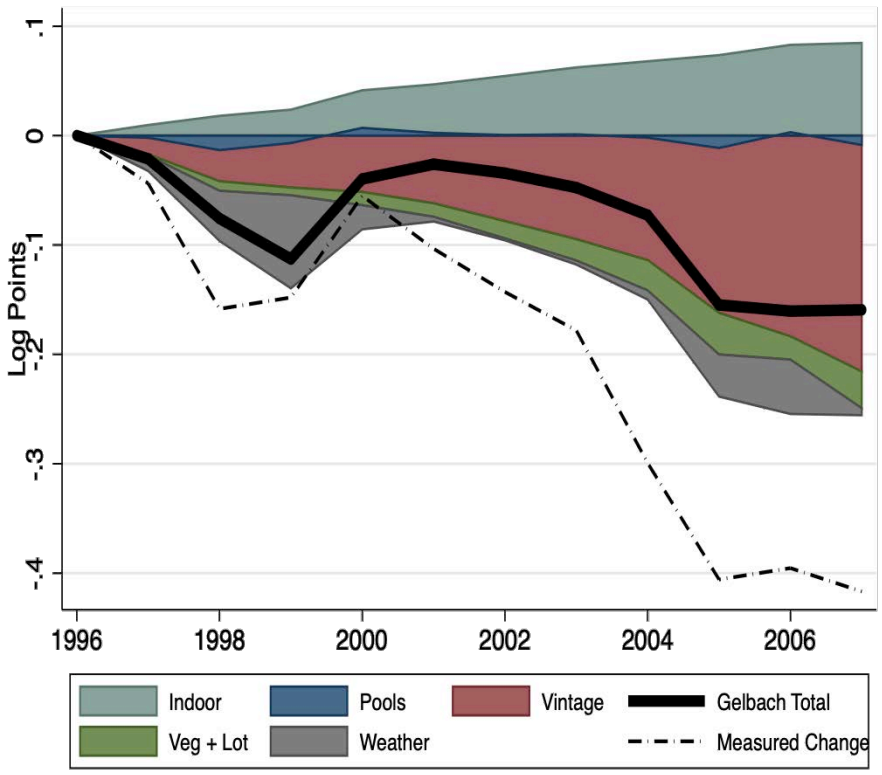
Gelbach's Decomposition

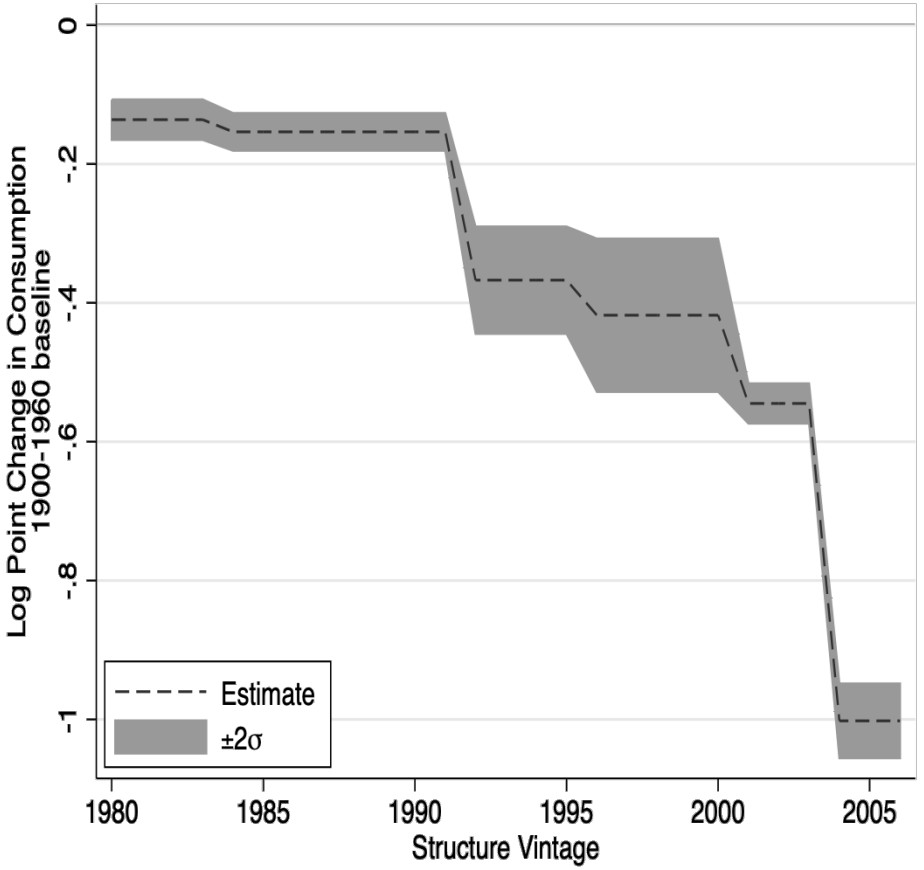
uses estimates of omitted variable bias to define the relative importance of various covariates

through scenario development


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

What did we find?





Building efficient infrastructure during new construction is the single biggest driver of reduced consumption.

How do we measure how effective the WSL program is?

Event Study

- Used to ensure that WSL driven water savings accrue at the time of the landscape change
- This compares the seasonal water comparison for the new landscape, age τ to water consumption the year it was installed.

$$c_{it} = a + \sum_{k=-15}^{k=11} \beta_k [\tau_{it} = k]_{it} + \gamma_t + \zeta_b + \epsilon_{it}$$

Difference in Differences

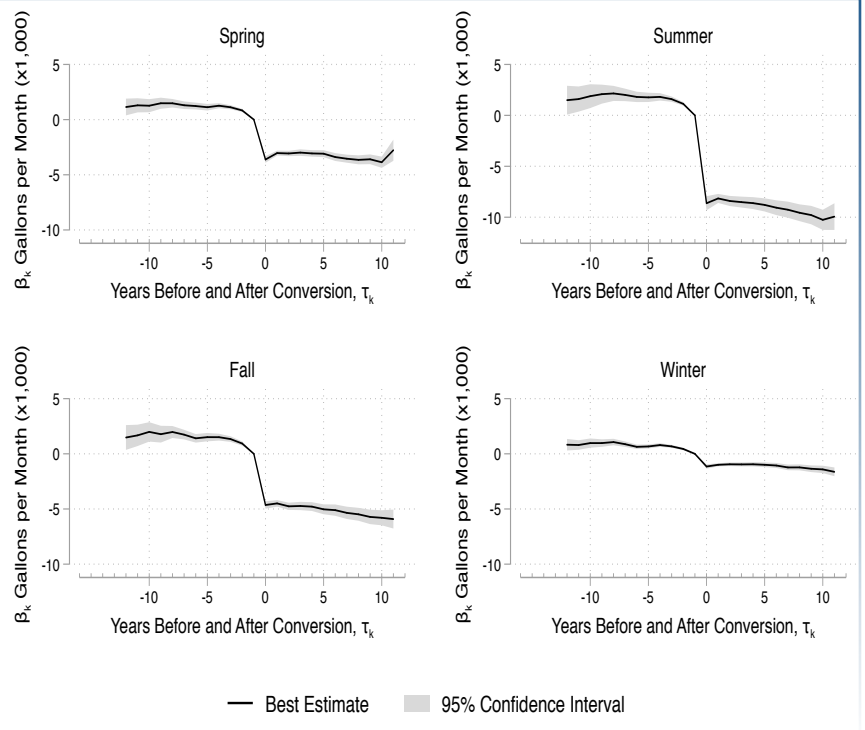
- Used to estimate the gallons saved per meter converted.
- This compares CHANGES in consumption during the landscape change to CHANGES in consumption for households with static landscapes.

$$c_{it} = \zeta_i + \gamma_t + \beta_0 a_{it} + \beta_1 \kappa_{it} + \epsilon_{it}$$

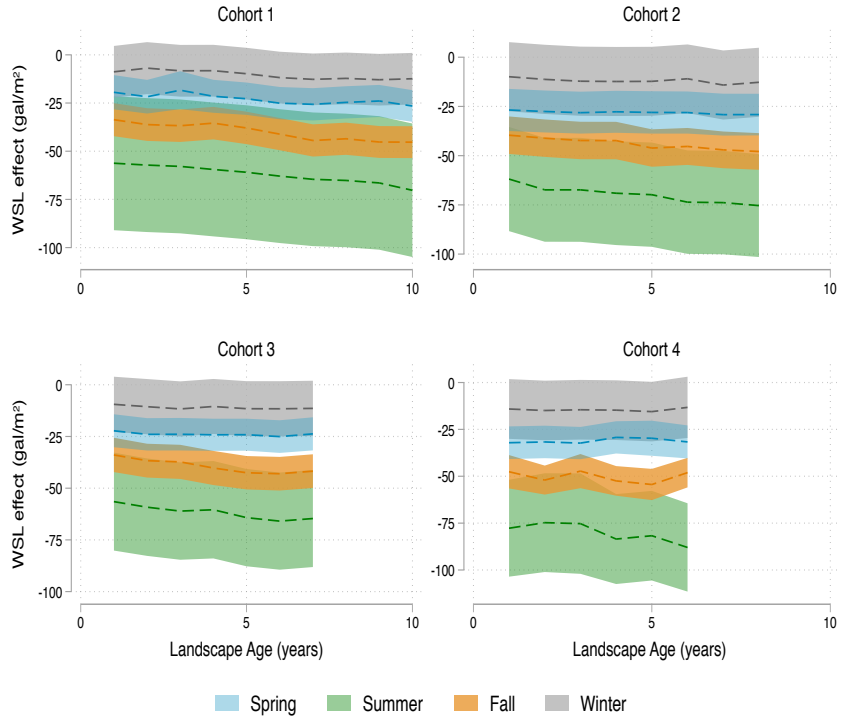
through quasi-experimental econometric methods.

What did we find?

Event Study



Difference in Differences



Large and durable water savings across seasons.

How can we test for the existence of Peer Effects in WSL Participation?

1) WSL participants

$$P(t_{iE} = t_i > 0 | \alpha, \mu, \{t_{kE}\}_{k \in \partial i}) = I_{x_i^0 = S} \left[\prod_{t=1}^{t_i - 1} (1 - \mu_i^t) \prod_{k \in \partial i | t_{kI} < t_i - 1} (1 - \alpha)^{t_i - \tau_{kiI} - 1} \right] \times \left[1 - (1 - \mu_i^{t_i})(1 - \alpha)^{n_i} \right]$$

2) Non-Participants

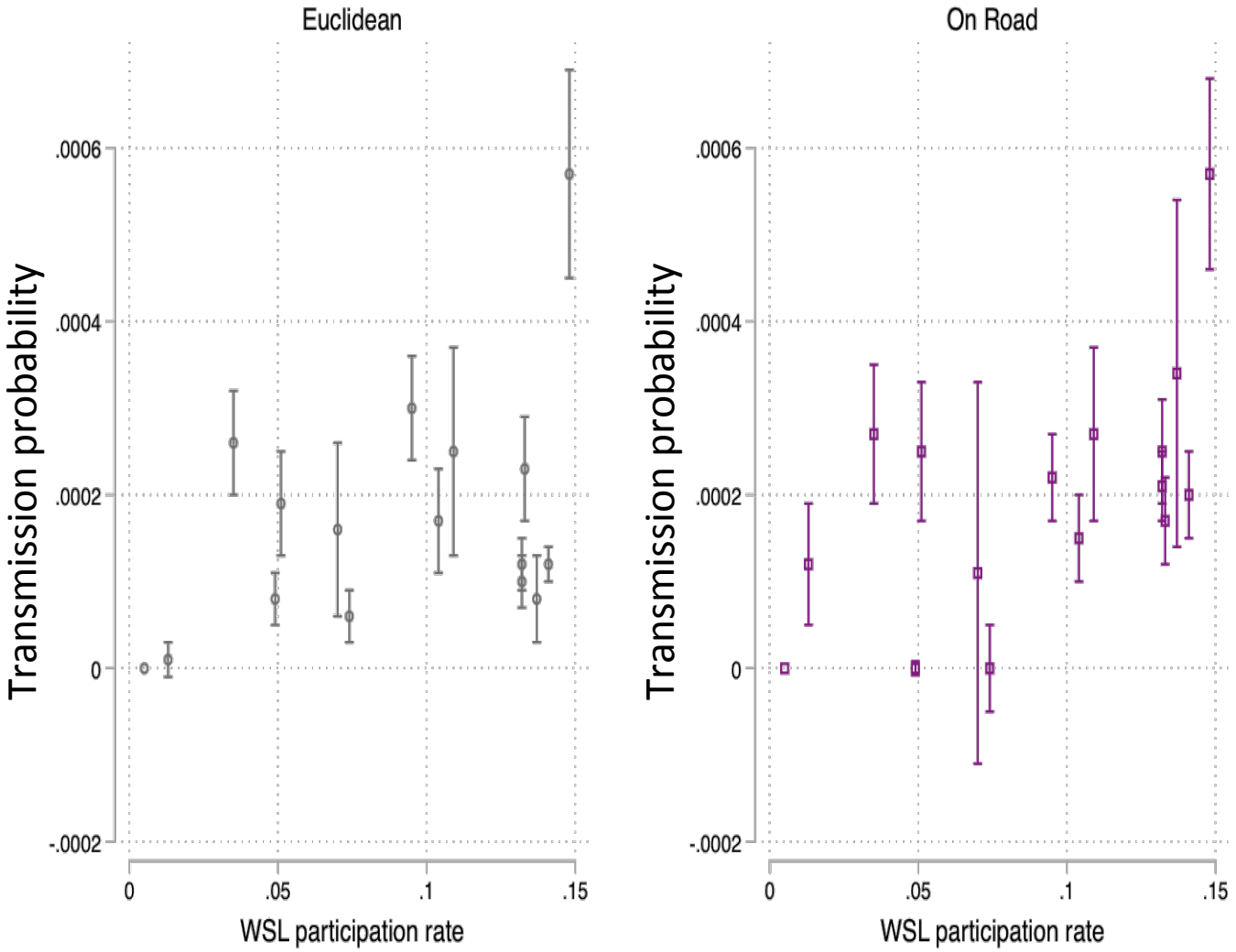
$$P(t_{iE} = \infty | \alpha, \mu, \{t_{kE}\}_{k \in \partial i}) = \mathbb{I}_{x_i^0 = S} \prod_{t=1}^{T} (1 - \mu_i^t) \prod_{k \in \partial i | t_{kI} < T} (1 - \alpha)^{T - \tau_{kiI}}$$

3) Joint Probability for All Homes

$$P(\bar{t} | \alpha, \mu) = \prod_{i \in V | x_i^T = S} P(t_{iE} = \infty | \alpha, \mu, \{t_{kE}\}_{k \in \partial i}) \prod_{i \in V | x_i^T \neq S} P(t_{iE} = t_i > 0 | \alpha, \mu, \{t_{kE}\}_{k \in \partial i})$$

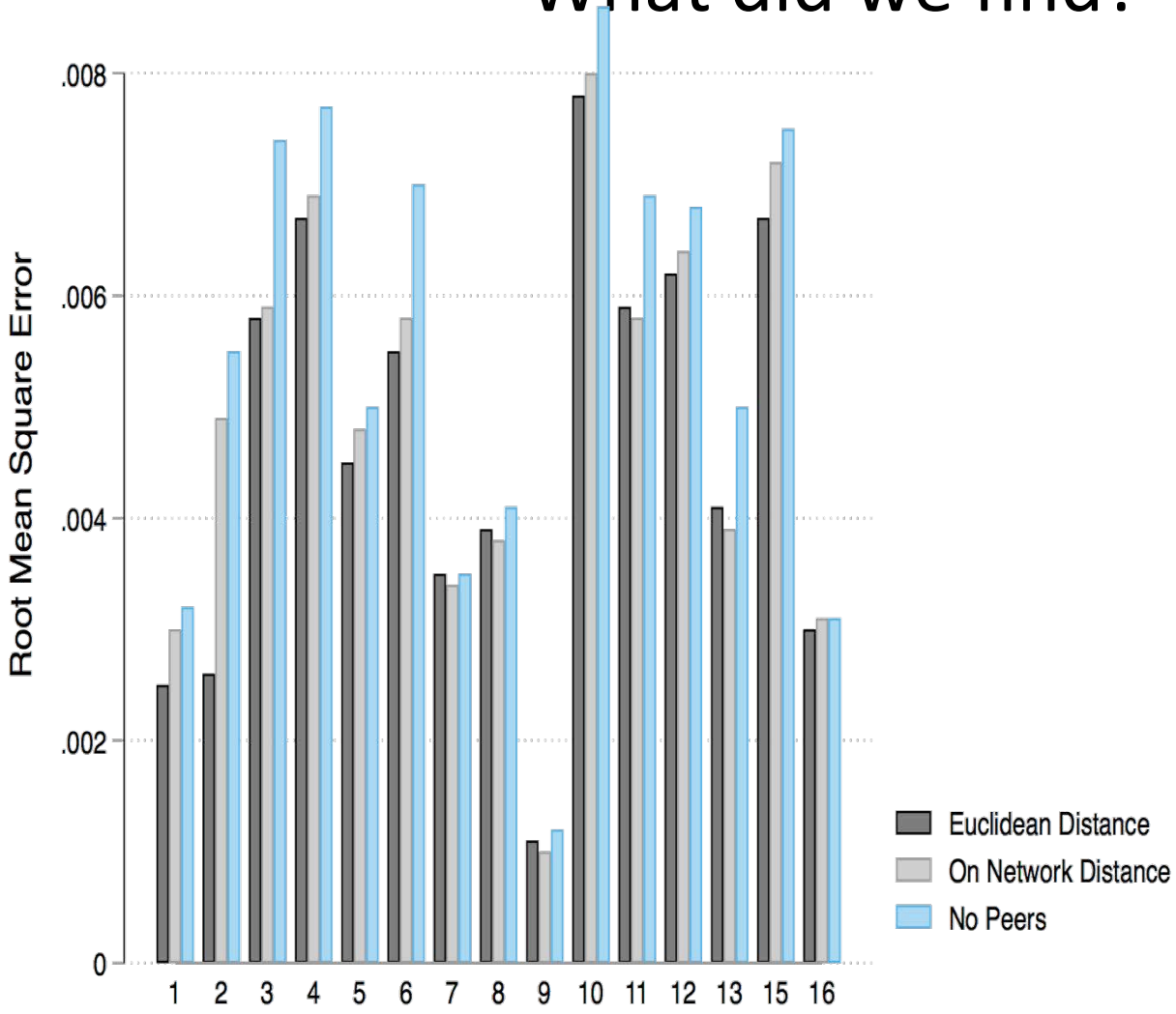
We model participation like it's an epidemic

What did we find?



Non-zero transmission probabilities across most neighborhoods

What did we find?



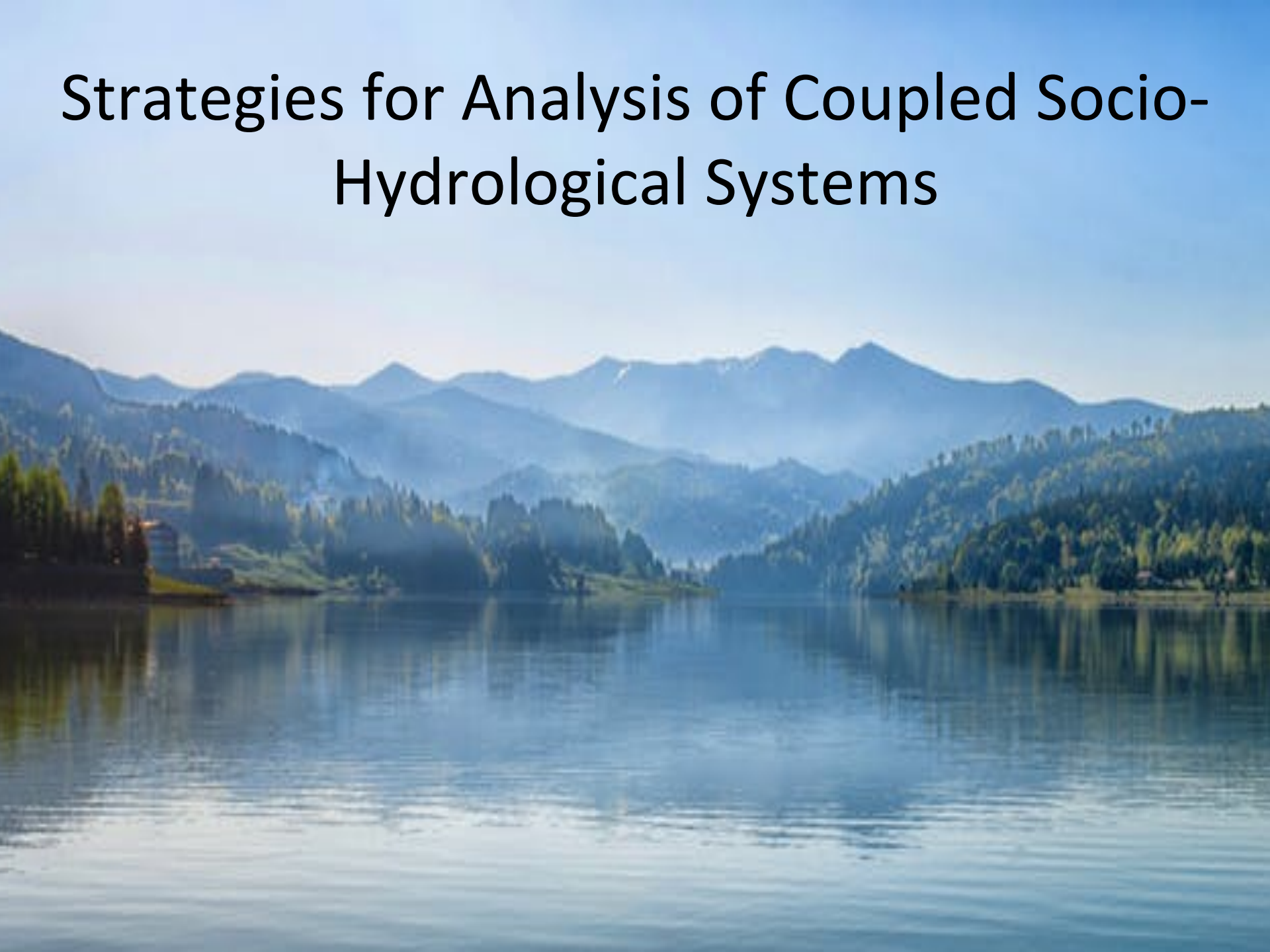
Models that allow peer effects fit the data better than models which don't

- Landscape change is a small but measureable component of Las Vegas' overall decline in residential water consumption.

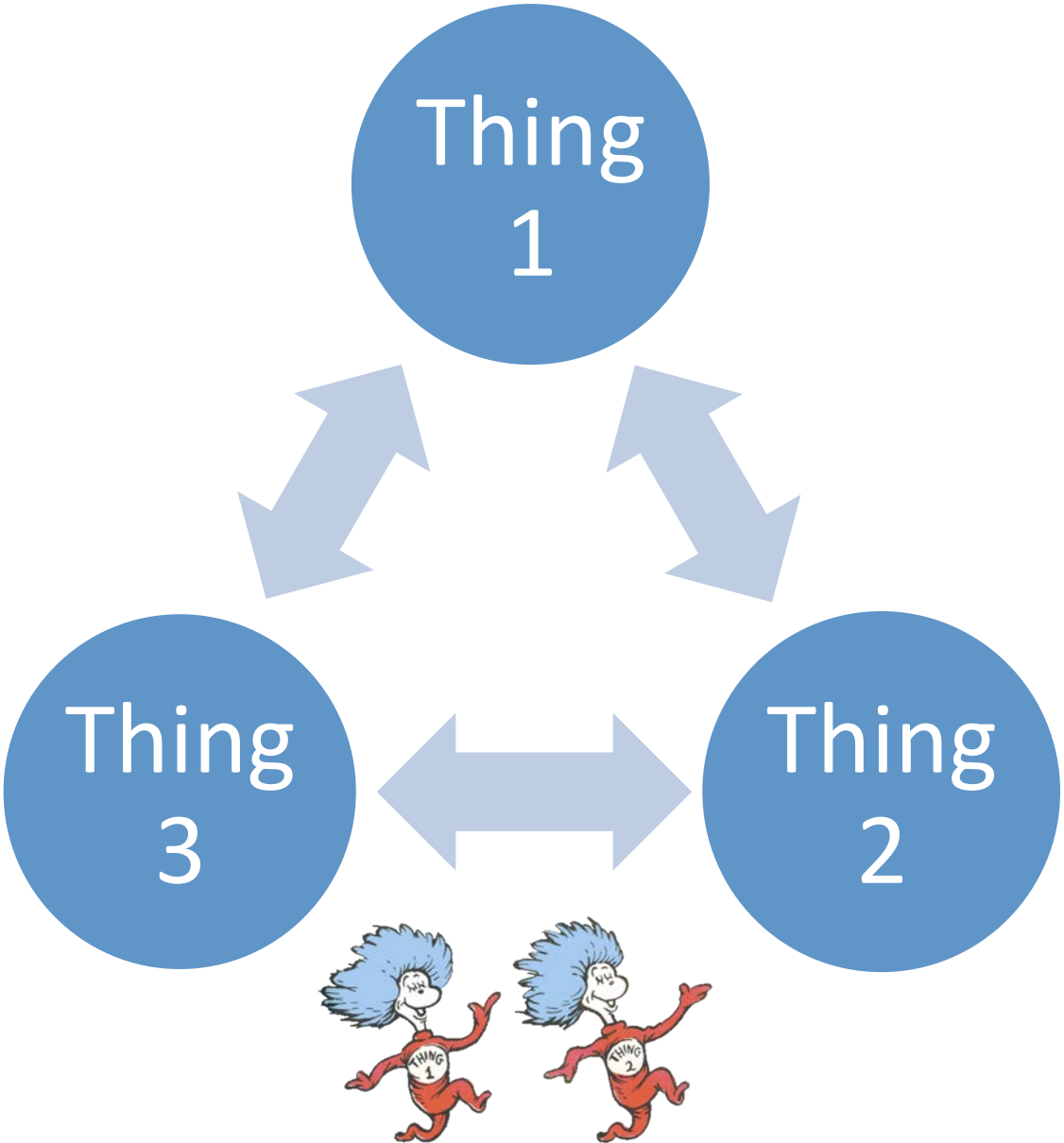
- WSL landscape conversions save meaningful amounts of water.

- There is evidence of a peer influence in WSL participation.

Strategies for Analysis of Coupled Socio-Hydrological Systems




ELLICOTT


Thing 1
Thing 3
Thing 2
THING 1
THING 2

More Things

Thing 1

More Things

Thing 3

Thing 2

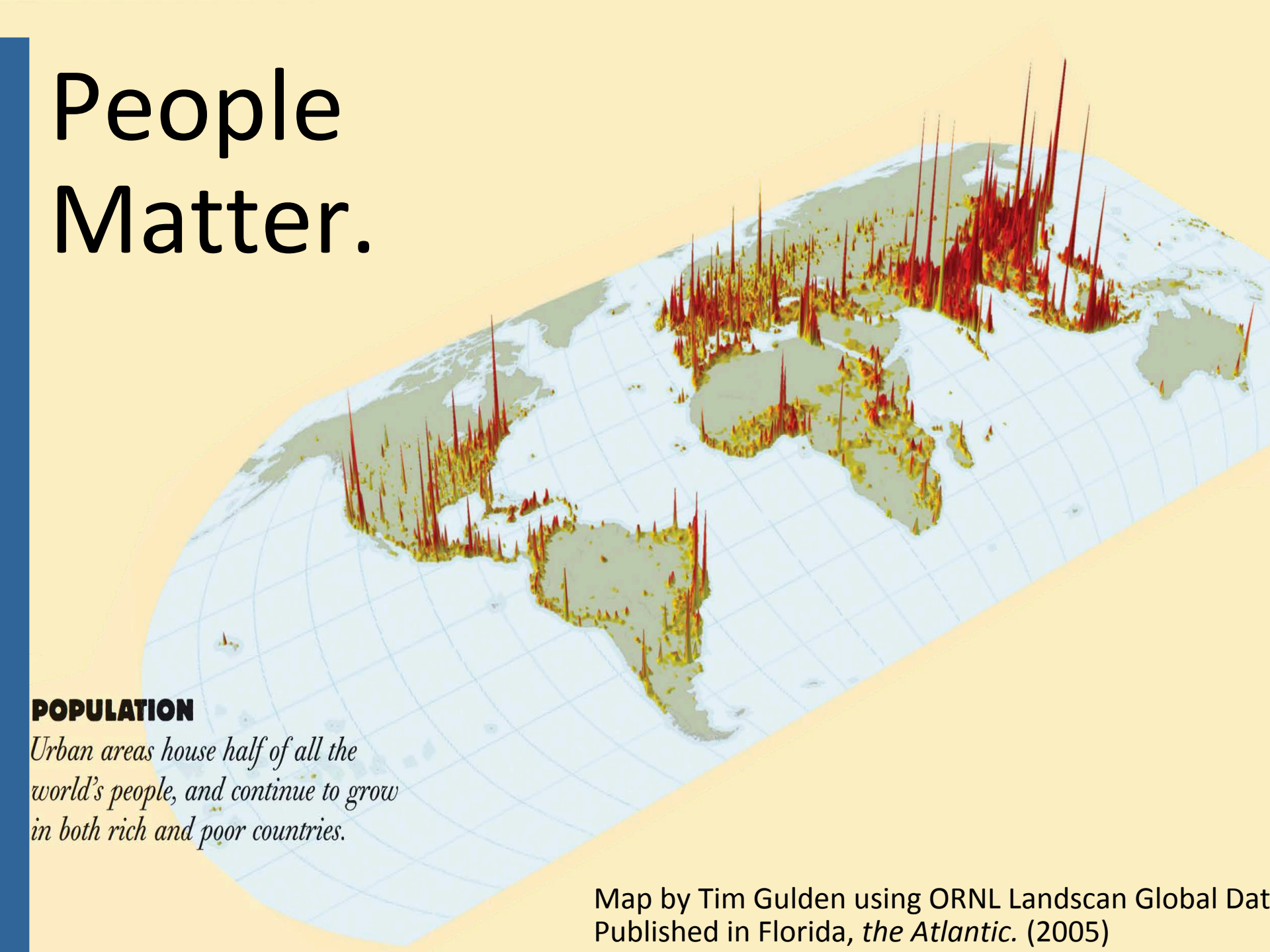

Water
Scarcity


Water
Excess


Quality

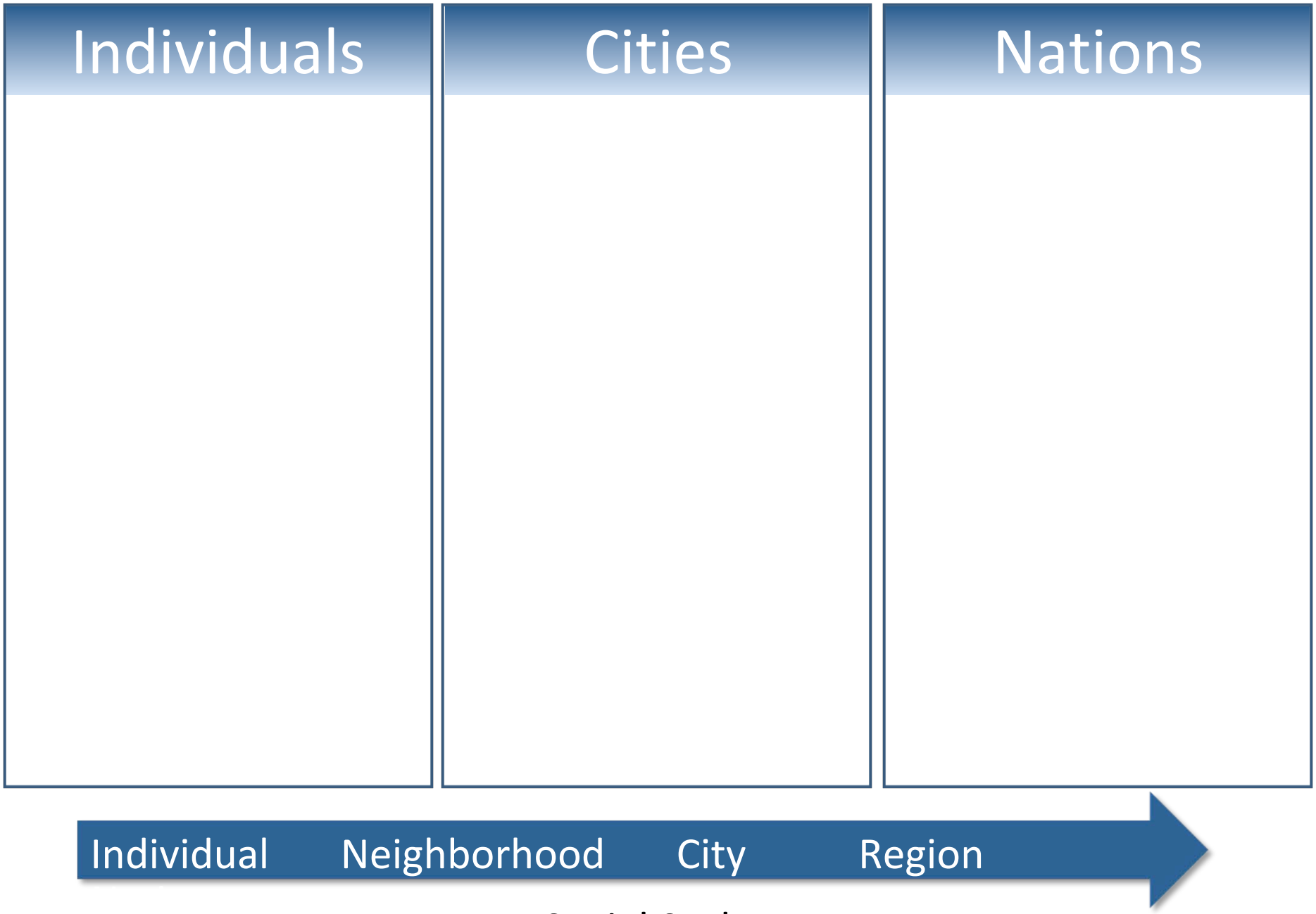

Adaptive
Capacity

People Matter.



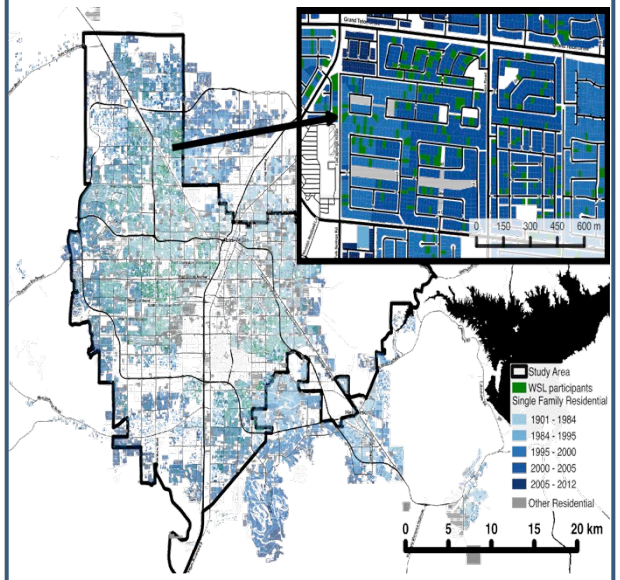
Map by Tim Gulden using ORNL Landscan Global Dat
Published in Florida, *the Atlantic.* (2005)

Social Scale


Individuals
Cities
Nations
Individual
Neighborhood
City
Region
Social Scale

Individuals

Probabilistic, Empirical or Agent Based Models



Brelsford & De Bacco. NETS (2018)

Cities

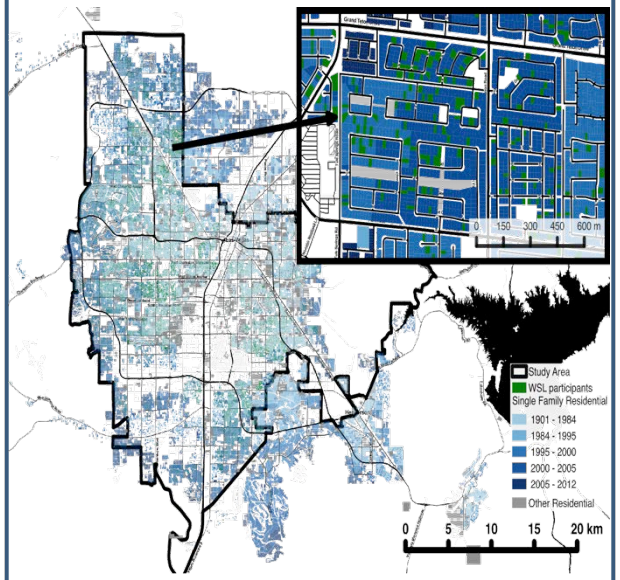
Nations

Individual Neighborhood City Region

Social Scale

Individuals

Probabilistic, Empirical or Agent Based Models

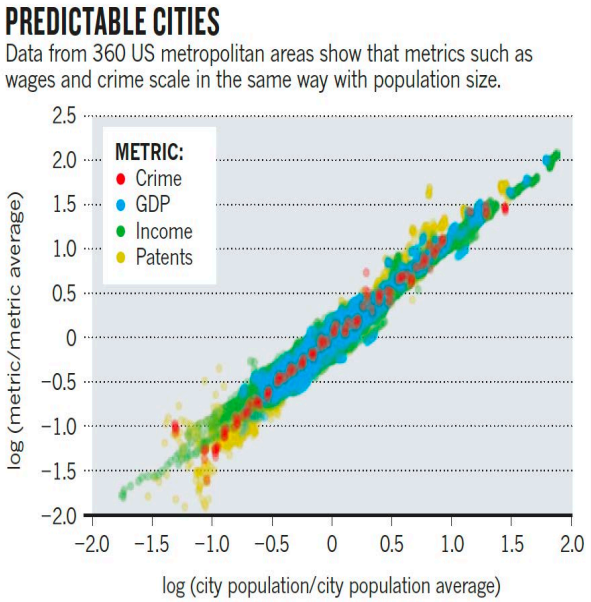


Brelsford & De Bacco. NETS (2018)

Cities

Nations

Urban Scaling Theory



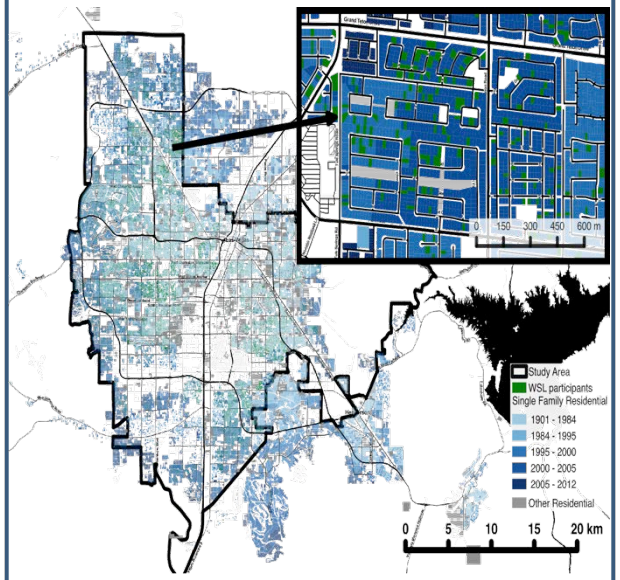
Bettencourt & West. Nature (2010)

Individual Neighborhood City Region

Social Scale

Individuals

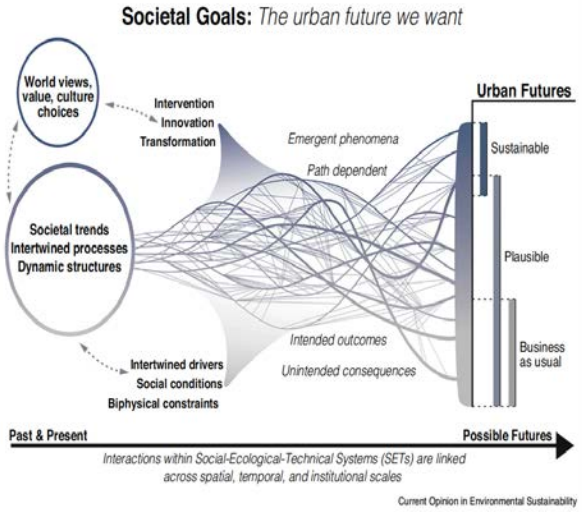
Probabilistic, Empirical or Agent Based Models



Brelsford & De Bacco. NETS (2018)

Cities

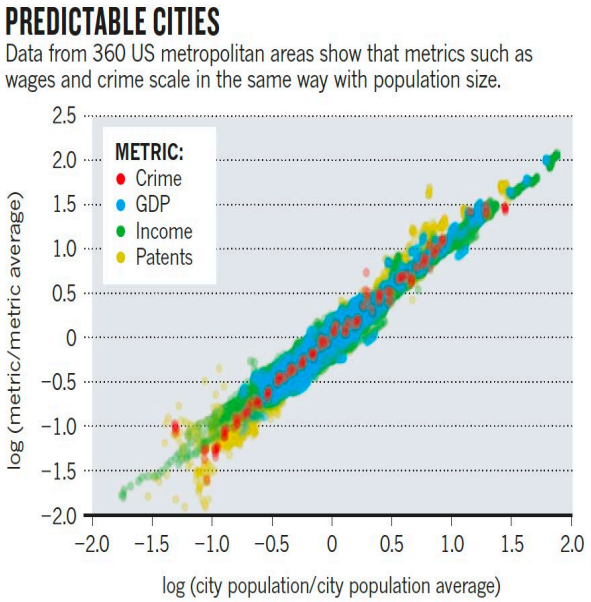
Urban Analysis and Stakeholder Engagement



McPhearson, Iwaniec, & Bai. Crnt. Opn. in Envi. Sust. (2016)

Nations

Urban Scaling Theory



Bettencourt & West. Nature (2010)

Individual Neighborhood City Region

Social Scale

christabrelsford.com brelsfordcm@ornl.gov