Print version

CEE/EHS 597B

Background on Small and Disadvantaged Systems

Dave Reckhow

The Need

- **In the US**, there are about 150,000 public drinking water systems, of these 50,000 are considered community water systems.
- The vast majority of these systems are small (serving less than 3,300 people), underfunded, under staffed and experience almost **daily challenges** to meet the needs of their customers, and the regulatory agencies.
- This creates new **underserved populations** in communities that are often already disadvantaged; a situation that raises serious environmental justice concerns.
- Solving these problems requires a concerted effort by **interdisciplinary teams** including social scientists, engineers, political scientists, public health scientists, chemists and economists

597B Course Description

- Potable Water for Small and Disadvantaged Communities.
  - we will create several **interdisciplinary teams** of students who will work together over the semester to address problems experienced by a specific nearby public water system,
  - Each of the instructors will present **background** on public water supplies from the perspective of their academic disciplines and case studies from recent experience using the Res’Eau Community Circle program as well as other similar efforts .
  - The instructors will then work with each of the student teams to begin addressing the problems at **the assigned study sites**. This will include:
    - (1) documenting the system and its challenges based on existing records at the state offices and community files;
    - (2) identification of the key stakeholders,
    - (3) on-site or video meetings with those key stakeholders;
    - (4) development of a preliminary report on the system needs, problems, and solutions already proposed by the stakeholders;
    - (5) development of a plan and report including proposals for new, alternative solutions to the identified problems. Prerequisite: consent of the instructors.

Tentative schedule 1/2

Class #	Topic	Instructor/Leader
1	Overview of US water supply, types of systems, system sizes, demographics	Reckhow
2	Basics of water systems, physical components and treatment	Reckhow
3	Options for local case studies and Res'Eau community Circle approach	Reckhow
4	Waterborne disease risk	Ford
5	Wells and groundwater	Boutt
6	Water system economics	Milman
7	Short group reports on information needs	Student groups
8	Engineering technology for small systems	Reckhow
9	Regulatory requirements for small systems, and Res'Eau community Circle case studies	Reckhow
10	Water quality in distribution systems & biofilms	Kumpel & Ford
11	Water safety plans & sanitary surveys	Kumpel
12	Environmental justice	Milman

Tentative schedule 2/2

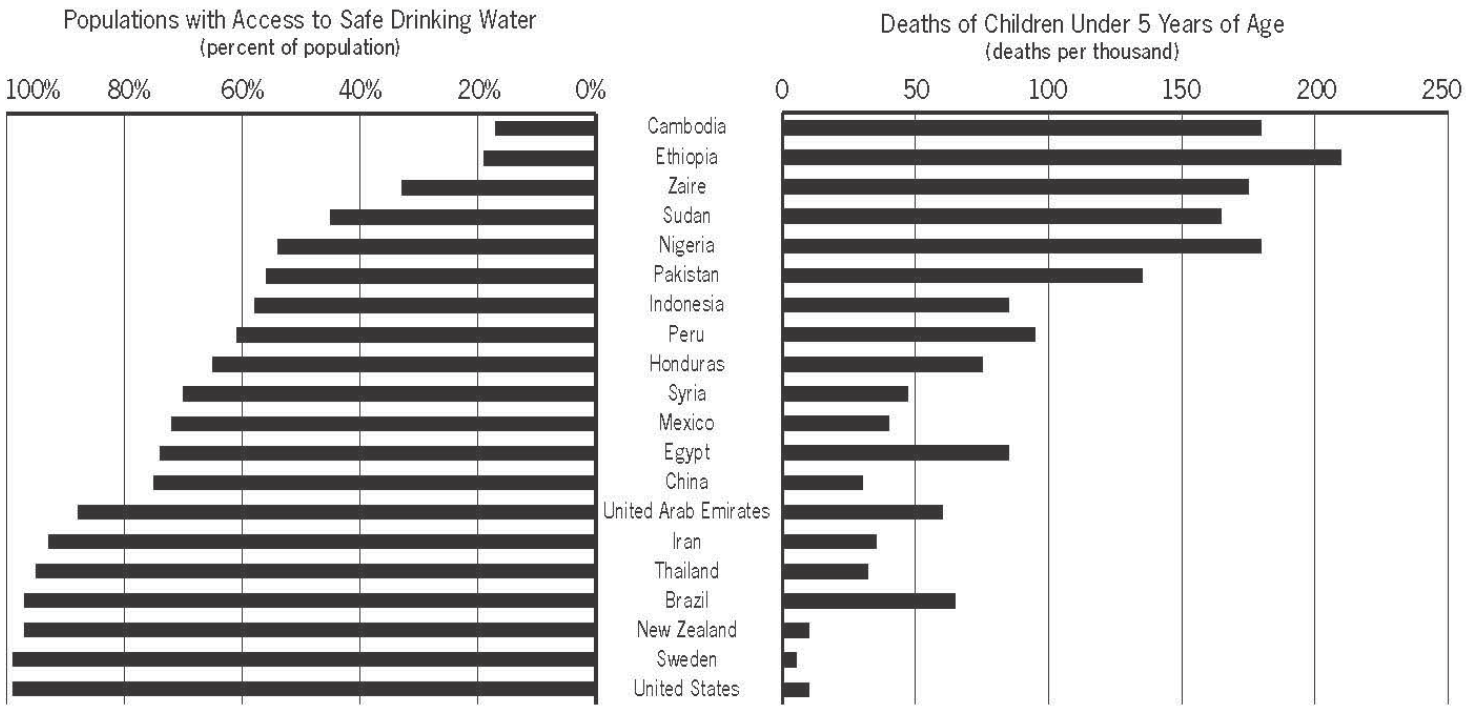
Class #	Topic	Instructor/Leader
13	Working with tribal systems	Ford
14	Group preliminary reports	Student groups
15	Policy implementation	Milman
16	Plant operations	TBD (WTP operator)
17	Politics of water provision	Milman
18	The regulatory perspective	TBD (from MA DEP)
19	The service provider perspective	TBD (from RCAP or MassRWA)
20	Case Studies from the US	Reckhow
21	Case Studies from Kenya	Gikonyo & Kumpel
22	Asset management; data flows and information and communication technologies	Kumpel & Wittbold
23	Assessing capacity for monitoring	Kumpel
24	Final project presentations	Student groups
25	Final project presentations	Student groups

SDGs – established 2015

Water and Disease across the world

- Child mortality is correlated to availability to safe water

Figure 3 Water quality and child survival



Sources: United Nations Children's Fund, *The State of the World's Children 1993*; Worldwatch Institute, *Worldwatch Paper 64: Investing in Children*, June 1985

Ford & Caldwell, 1996; A Global Decline in Microbiological Safety of Water: A Call for Action

But the U.S. is a wealthy country

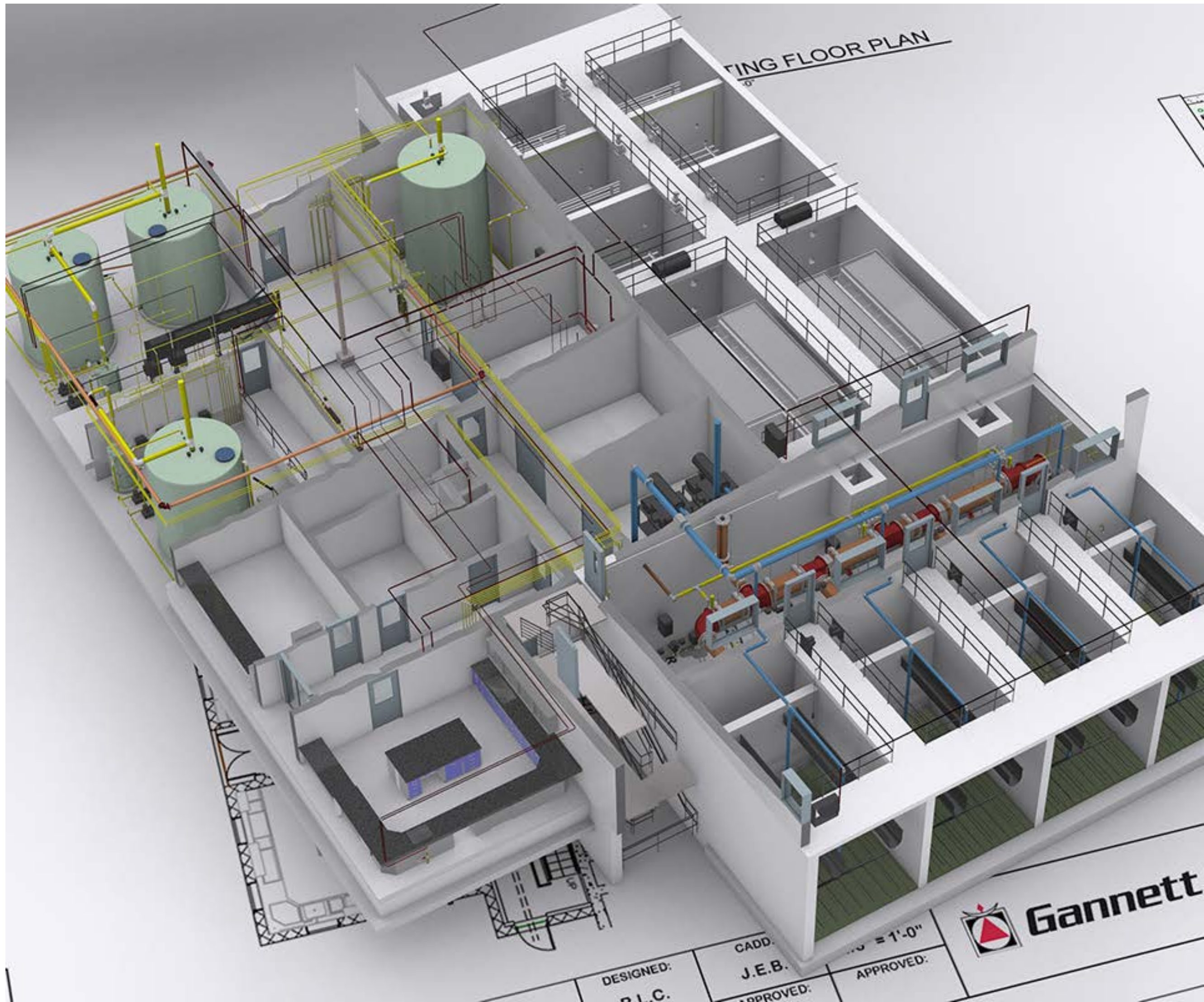
- We have magnificent treatment plants
  - The envy of the world

- Macon GA

- Cambridge MA

state-of-the-art process design

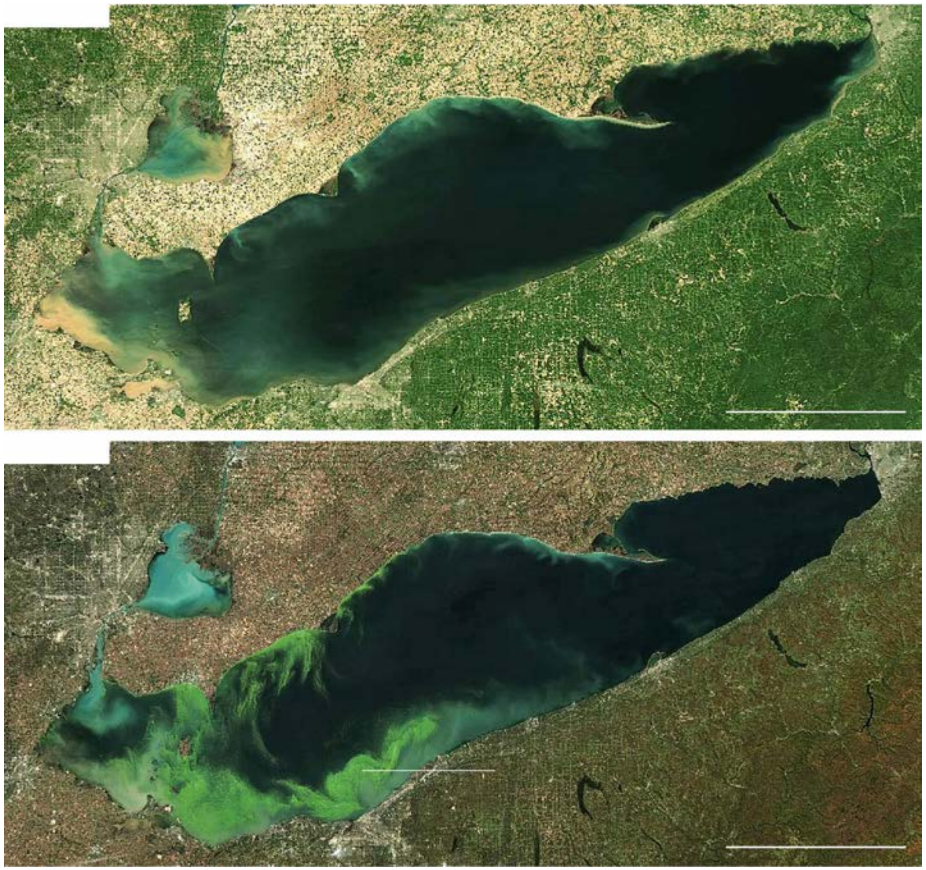
- York, PA



Yet, there remain challenges

- Even the large, wealthy US cities have problems with their water
- The smaller and poorer communities have many more problems

Lake Erie; western basin

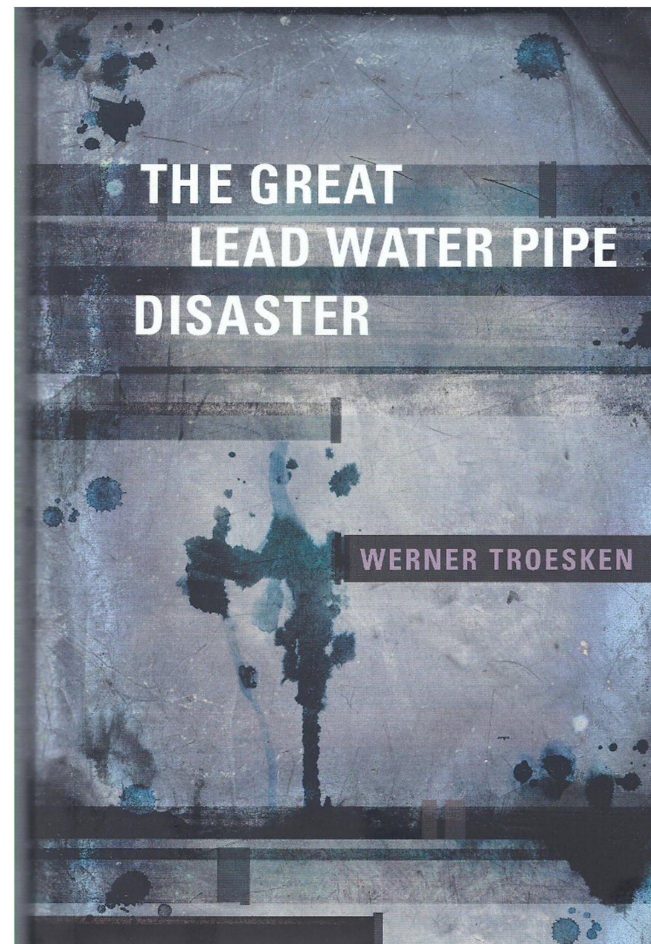


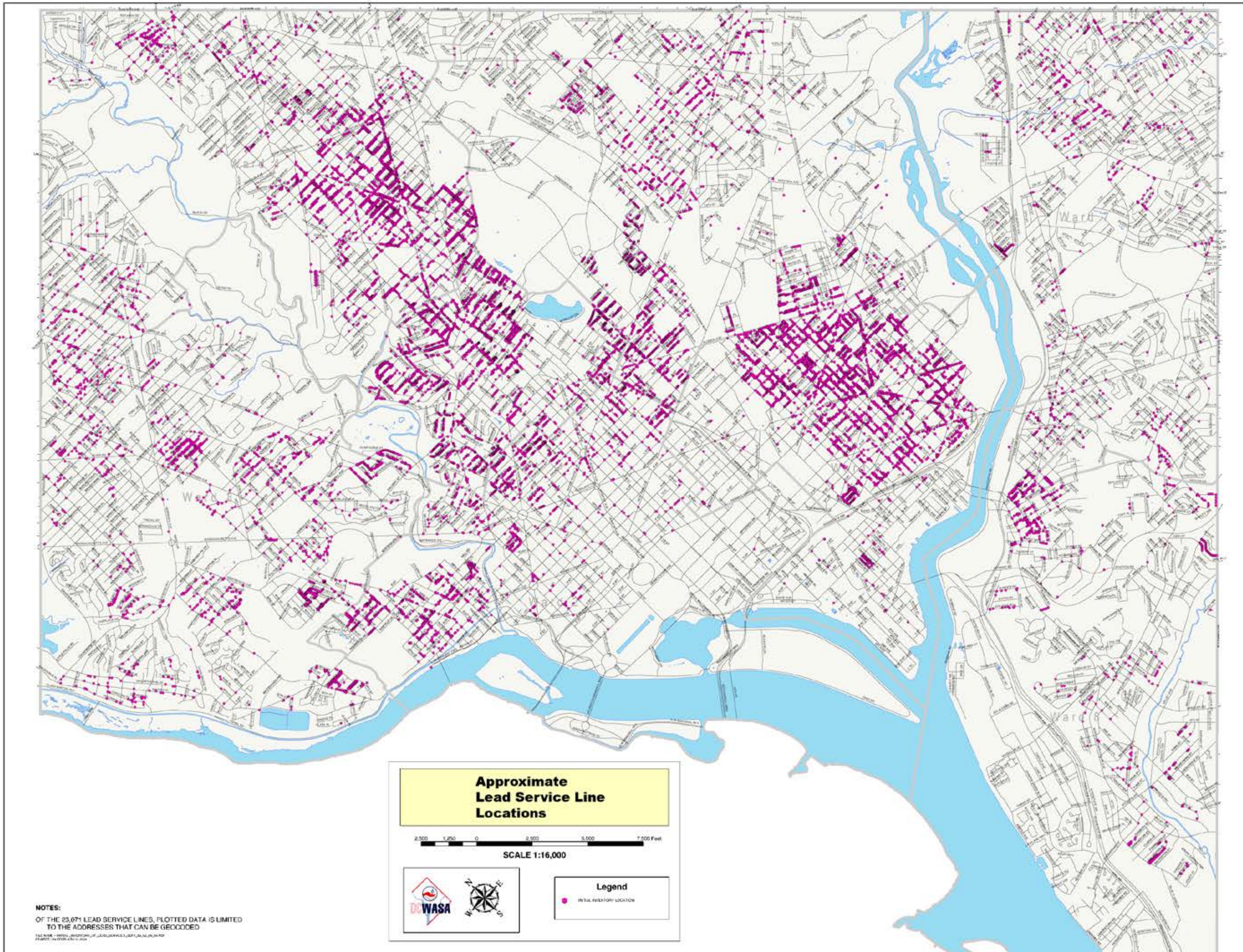
- The 2014 Toledo Ohio incident:
  - On-line reports
  - http://www.nytimes.com/2014/08/05/us/lifting-ban-toledo-says-its-water-is-safe-to-drink-again.html?_r=0
  - http://www.vox.com/2014/8/3/5963645/a-toxic-algae-bloom-has-left-400000-people-in-ohio-without-drinking

Pb & Public Outrage

- 2002 Washington DC

- The Great Lead Water Pipe Disaster
  - Werner Troesken
  - 2006 MIT Press





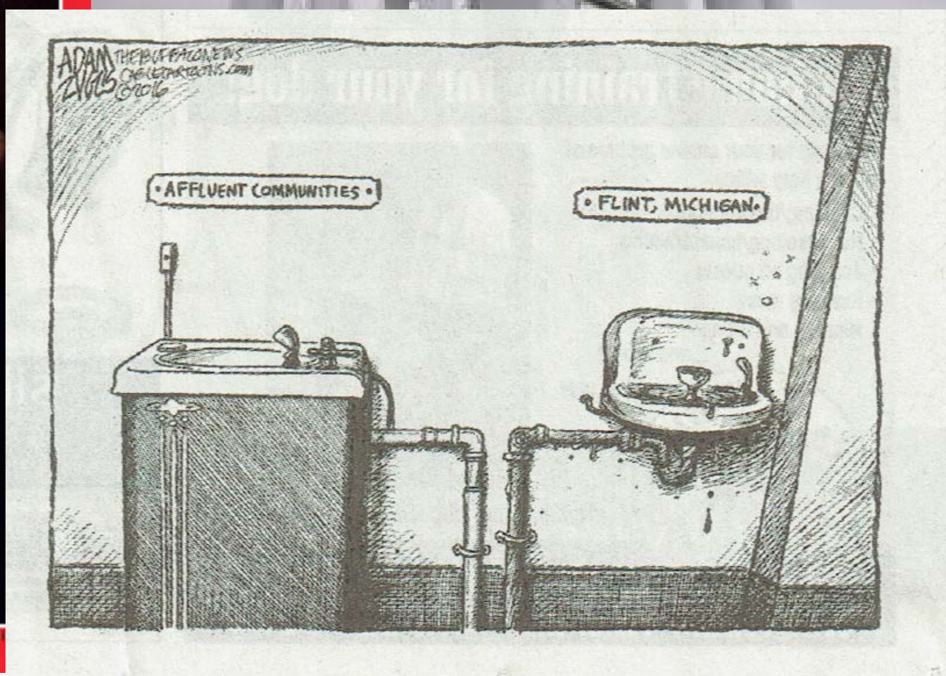
NOTES:

OF THE 23,071 LEAD SERVICE LINES, PLOTTED DATA IS LIMITED TO THE ADDRESSES THAT CAN BE GEOCODED

Then, Flint


FEBRUARY 1, 2016
TIME
The Poisoning Of An American City
Toxic water. Sick kids. And the incompetent leaders who betrayed Flint
By Josh Sanburn


FLINT WATER PLANT


• AFFLUENT COMMUNITIES •
• FLINT, MICHIGAN •


HAZARDOUS
CHEMICALS
UNAUTHORIZED
ENTRY
PROHIBITED

Challenges from Water contaminants

- Elements, mostly **metals**, and their aqueous forms
  - 91 elements with $t_{1/2}$>100 years
  - Each may have as many as 10 isotopes, 11 oxidation states, and many oxo-hydroxyl complexes
- Chemical compounds – most are **organic compounds**
  - 18.4 M in NIH's PubChem database (9.8 M in Beilstein)
    - ~100,000 new ones each year
  - 800,000 are in active use today
  - 85,000 are or have been readily available in commerce
  - 8,000 currently in high production

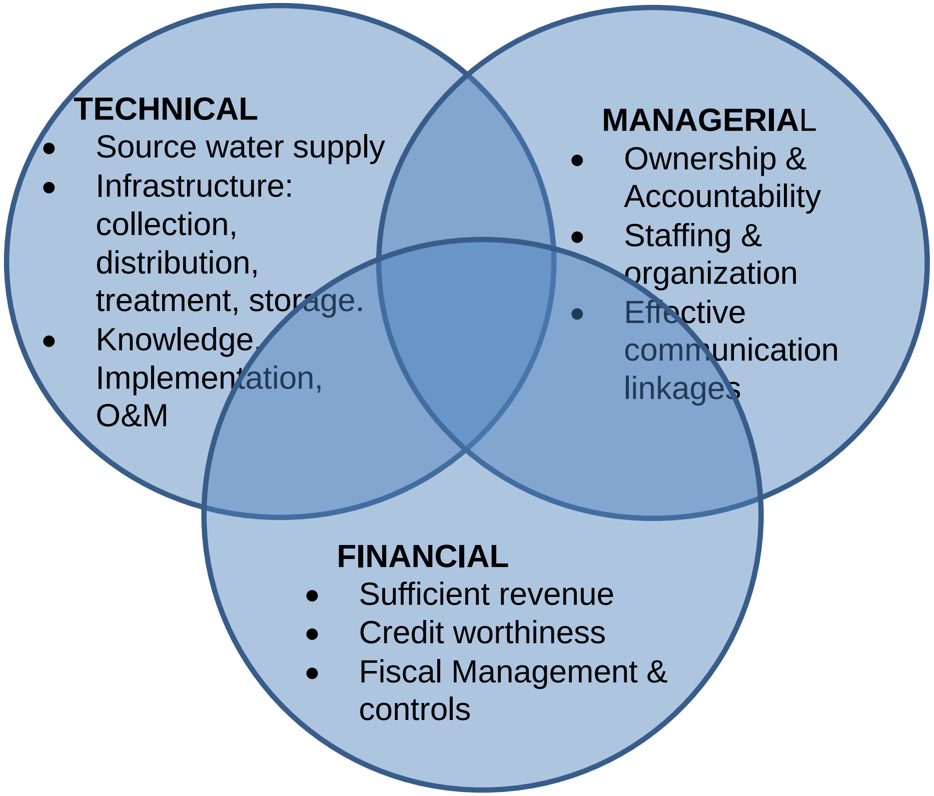
At 20 min/compound, presentation ends at 5:20 AM on October 18, 2716

- And then there are the microbial contaminants

In addition, there are serious inequities

- Both within the US and abroad
- Small systems in the US and around the world are especially challenged
  - Unfavorable economy of scale
    - Many constraints are nearly size-independent
      - Regulatory, treatment, monitoring, reporting, management
    - Yet $$ and # of personnel are linked to size
  - Difficulty in attracting highly qualified personnel to rural communities
  - Lack of political capital among small communities
  - Fewer alternative sources of income (e.g., industry)

Inequities span TMF spectrum



"Capacity"

CAPACITY, **adapted from USEPA,** http://www.epa.gov/dwcapacity/learn-about-small-drinking-water-systems#whatcd

Small Vs Large

Category	Small	Large
Equipment	• Often just disinfection • Many are package systems • High cost per connection • Manual, little automation • Little redundancy	• Can complex, multi-stage • Tailored design • Low cost per connection • Highly automated • Redundant units
Operations	• Part time operator • Low level of certification • Must do everything • Reactive maintenance • May not be year round • High flow variability	• Many full-time staff • High level of certification • Specialized staff • Preventive maintenance • Year round operation • Low flow variability
Management	• Volunteer board, many obligations • No capital improvement plans • Rates may not be well established	• Water specific board, may be compensated • Complex asset management program • Rates set by careful analysis

Engineering

- Small system

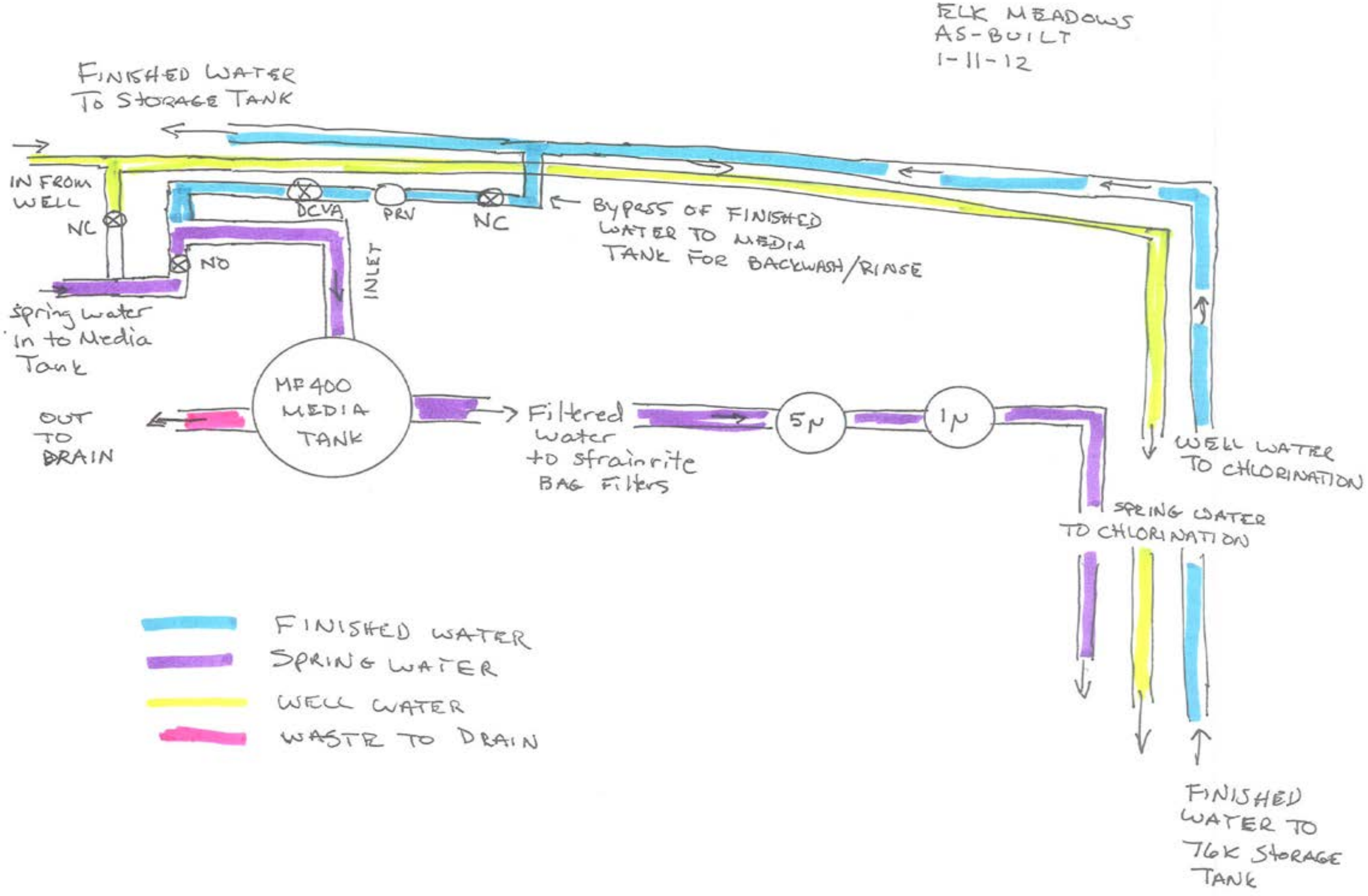
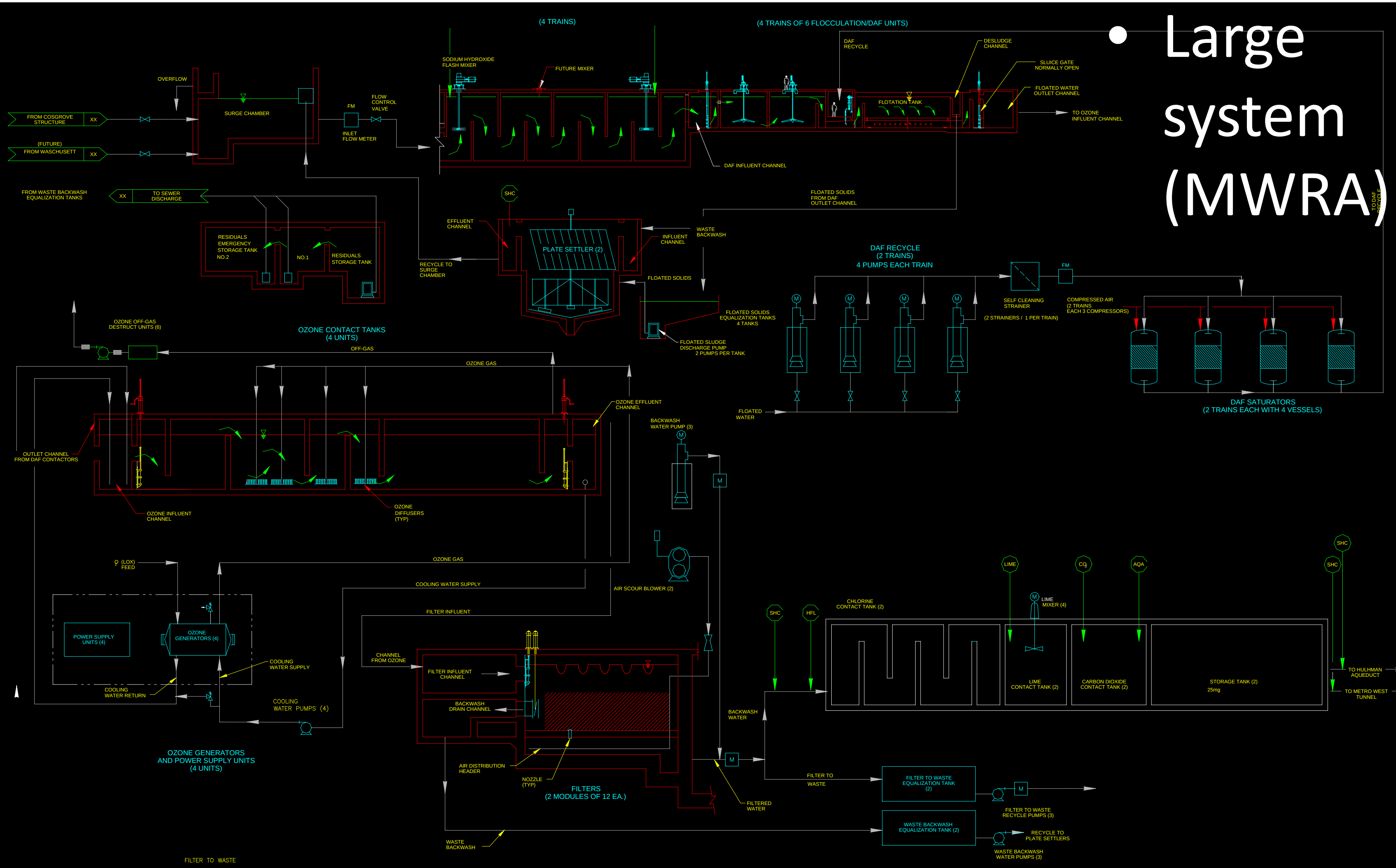


Image courtesy of Joy Barrett & Bill Hogrewe, RCAP

Engineering



- Large system (MWRA)

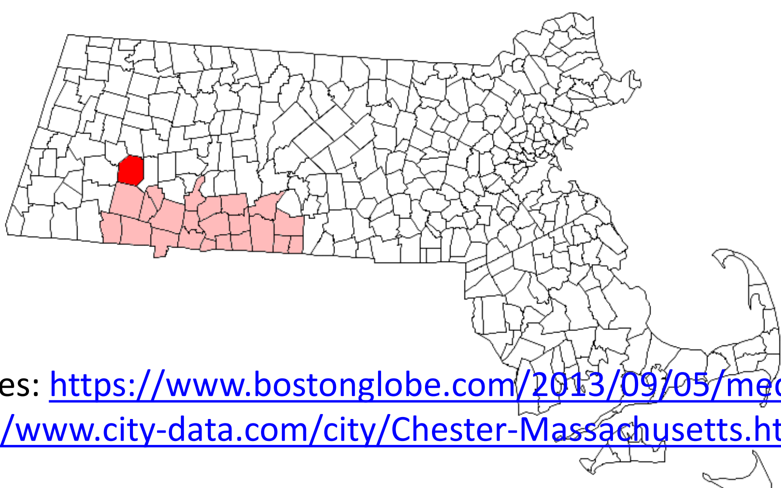
Small vs Large: Financial

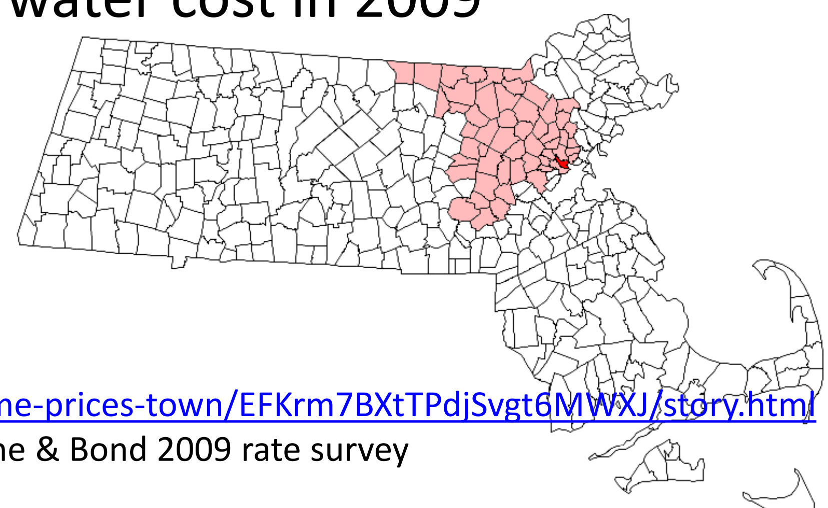
Chester MA

- $56,829 median household income in 2015
- $79,000 median home price in 2013
- $502 annual household water cost in 2009

Somerville MA

- $70,628 median household income in 2015
- $520,500 median home price in 2013
- $489 annual household water cost in 2009





Sources: https://www.bostonglobe.com/2013/09/05/median-home-prices-town/EFKrm7BXtTPdjSvgt6MWXJ/story.html
http://www.city-data.com/city/Chester-Massachusetts.html , Tighe & Bond 2009 rate survey

Small vs. Large: HR

Chester MA

- Town system
- 750 consumers
- 255 households
- Served by 1 part-time operator

Somerville MA

- Part of MWRA system
- 2,500,000 consumers
- 890,000 households
- Served by 1,205 employees

Small vs Large: Source Water

Chester MA

- Source: Horn Pond & Austin Brook Reservoir

Somerville MA

- Source: Quabbin & Wachusett Reservoirs

Small vs Large: treatment technology

Chester MA

- Slow sand filtration
  - 19th century technology

Somerville MA

- Ozonation
  - Cutting edge

Small vs Large: Disinfection

Chester MA

- chlorine

Somerville MA

- Ozone, UV, Chlorine & chloramines

Small system needs

In US and Canada

In low income countries

Without full plumbing in US?

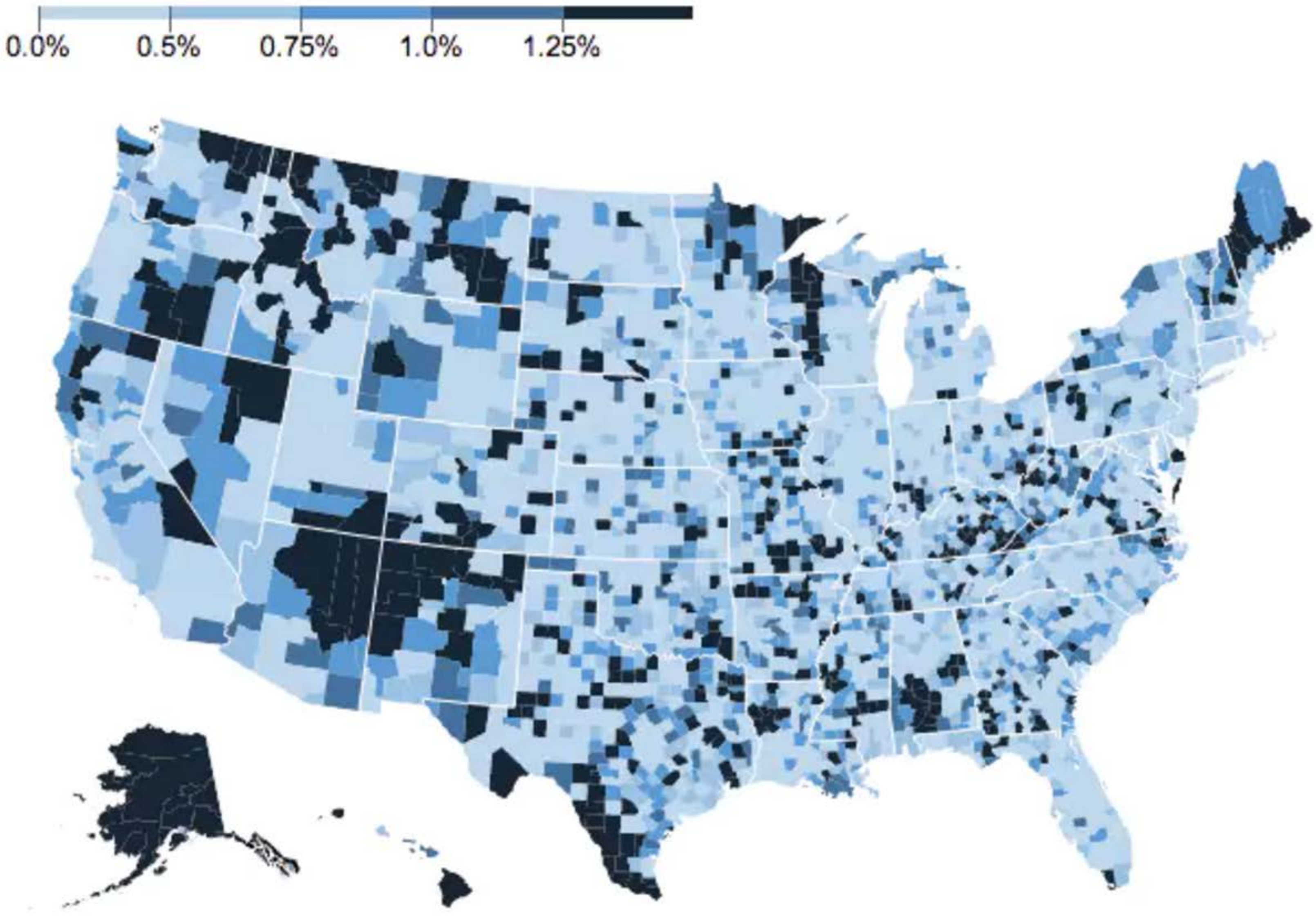
- In the US about 630,000 occupied households lack complete plumbing facilities
  - which means that they are without one or more of the following: a toilet, a tub or shower, or running water.
  - The Census Bureau says that the average household contains 2.6 individuals, which means that today (2014), in the wealthiest nation on Earth, upwards of 1.6 million people are living without full indoor plumbing.
- Middlesex county, MA
  - 0.404% lack complete plumbing facilities: Rank: 1883/3143
- Hampden County, MA
  - 0.806% lack complete plumbing facilities: Rank: 913/3143

Source:

Washington Post, Apr 23, 2014

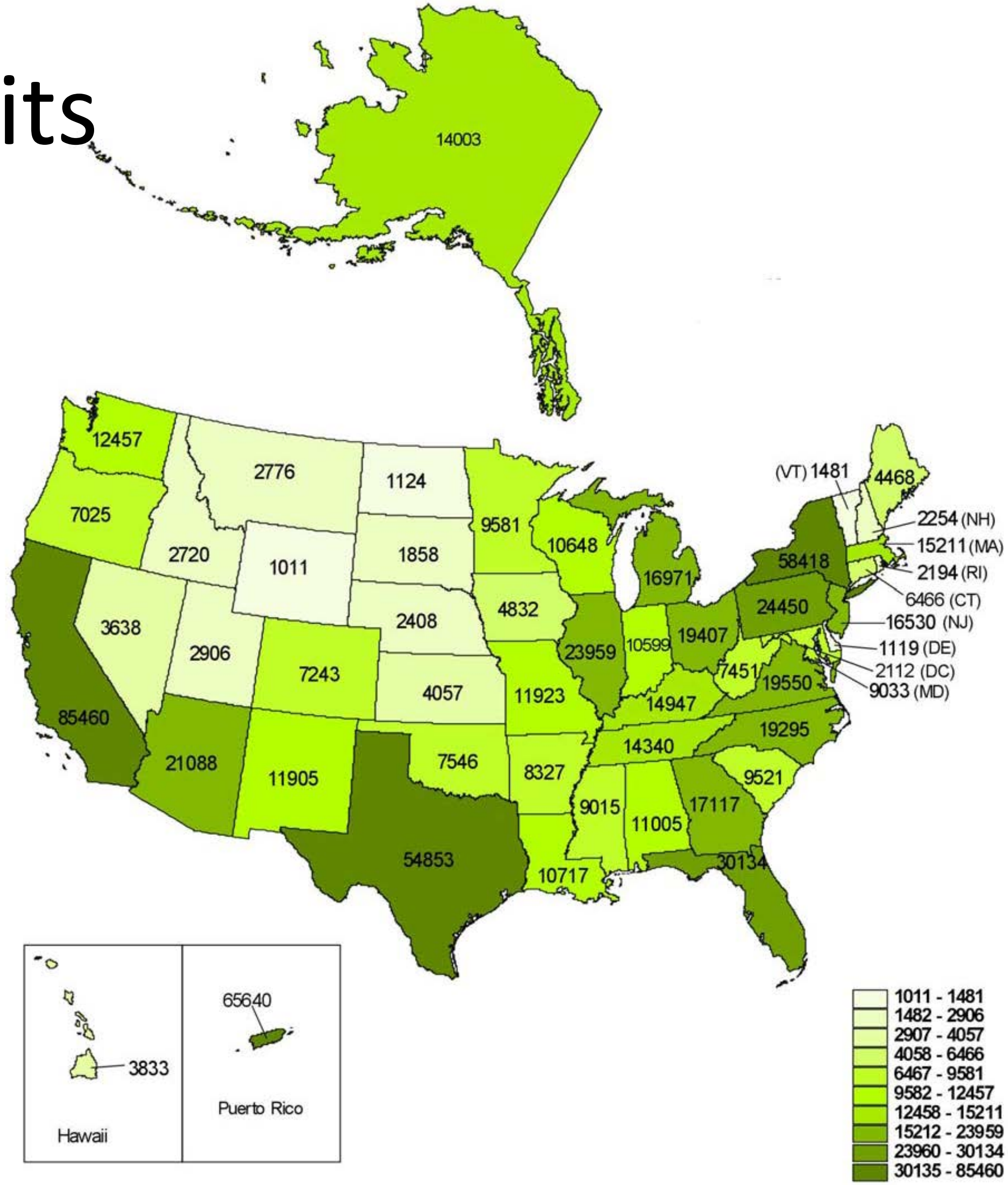
Interactive map: http://www.washingtonpost.com/wp-srv/special/national/county-plumbing-facilities/index.html

Percent of housing units lacking complete plumbing facilities



Housing Units

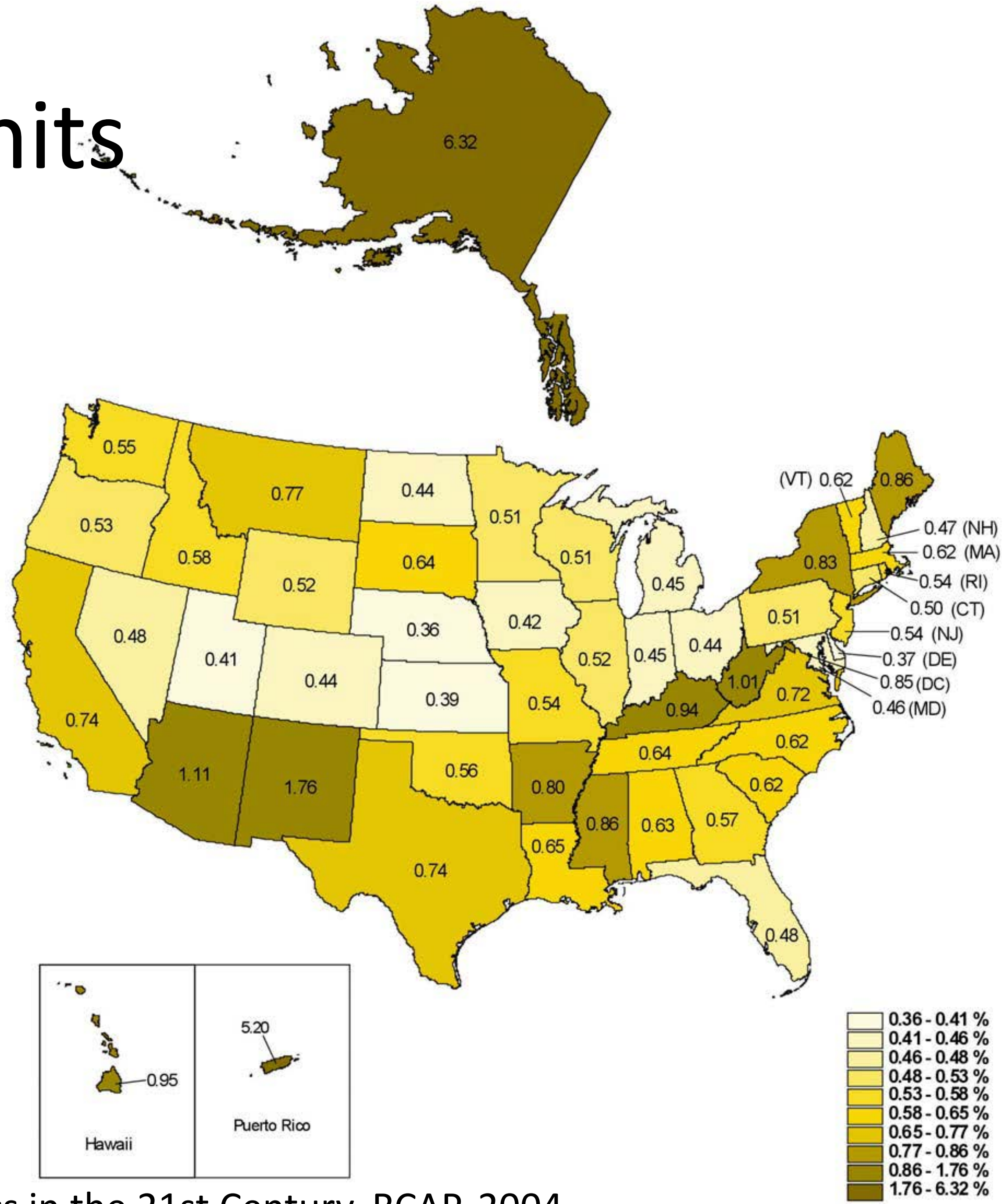
- Lacking complete indoor plumbing
  - 1.7 M people total in US



From: Still Living Without the Basics in the 21st Century, RCAP, 2004

% Housing Units

- Lacking complete indoor plumbing



From: Still Living Without the Basics in the 21st Century, RCAP, 2004

The National Challenge

- the costs of modernizing and sustaining the Country's water infrastructure is estimated in the hundreds of billions of dollars and worldwide in excess of $2 trillion.
- $380B estimated need over next 20 years in US for potable water alone.
  - See: http://water.epa.gov/grants_funding/dwsrf/upload/epa816r13006.pdf

Total National Need

The U.S. Environmental Protection Agency's (EPA's) fifth national assessment of public water system infrastructure needs shows a total twenty-year capital improvement need of $384.2 billion. This estimate represents infrastructure projects necessary from January 1, 2011, through December 31, 2030, for water systems to continue to provide safe drinking water to the public. The national total comprises the infrastructure investment needs of the nation's approximately 52,000 community water systems and 21,400 not-for-profit noncommunity water systems, including the needs of American Indian and Alaska Native Village water systems, and the costs associated with proposed and recently promulgated regulations. The findings are based on the 2011 Drinking Water Infrastructure Needs Survey and Assessment (DWINSA or Assessment) which relied primarily on a statistical survey of public water systems (approximately 3,165 responses).

$384.2 Billion is Needed

The nation's drinking water utilities need $384.2 billion in infrastructure investments over the next 20 years for thousands of miles of pipe as well as thousands of treatment plants, storage tanks, and other key assets to ensure the public health, security, and economic well-being of our cities, towns, and communities.

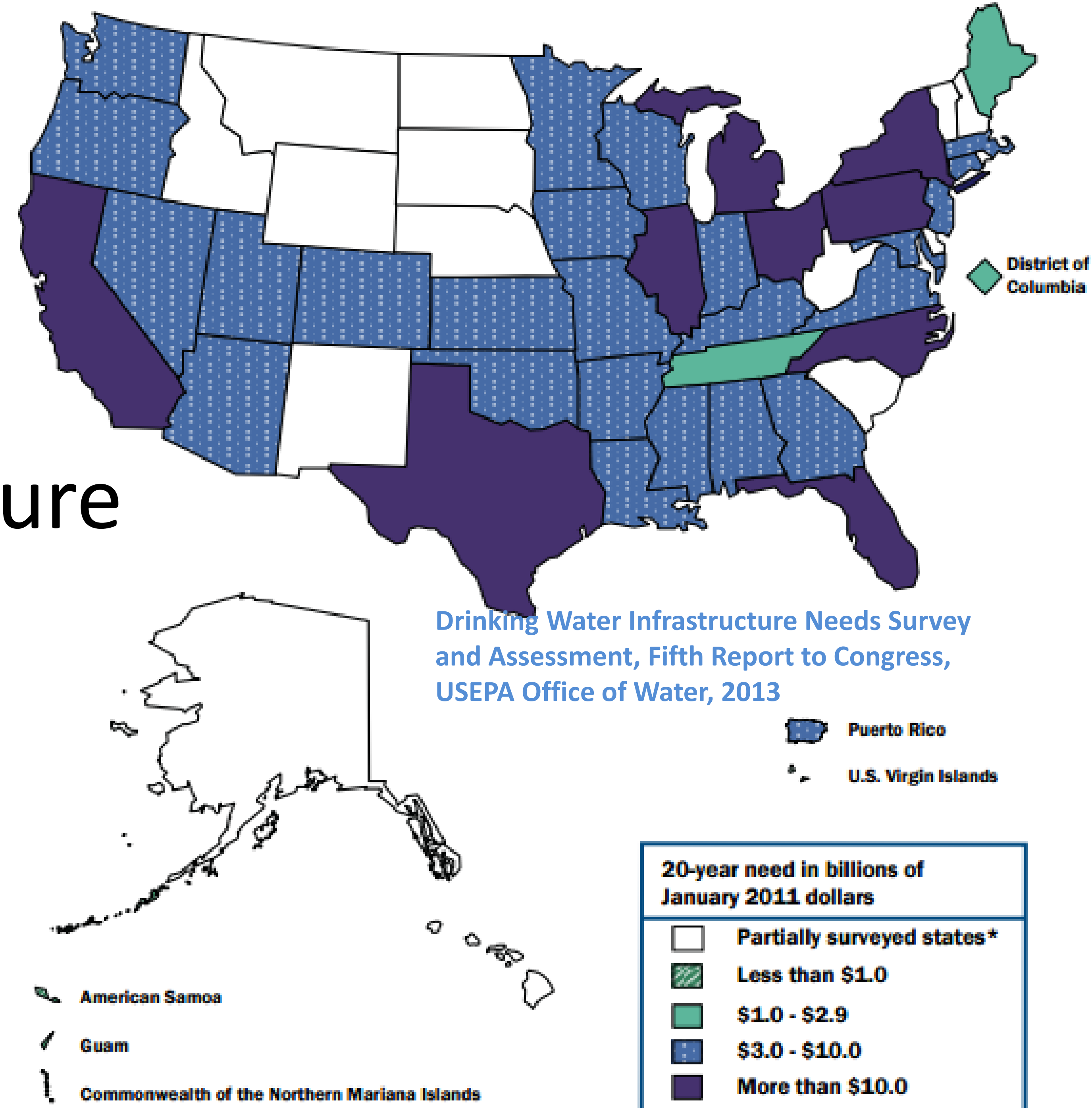
Authority, Purpose, and History

The 1996 Safe Drinking Water Act Amendments mandated that EPA conduct an assessment of the nation's public water systems' infrastructure needs every four years and use the findings to allocate Drinking Water State Revolving Fund (DWSRF) capitalization grants to states. The DWSRF was established to help public water systems obtain financing for improvements necessary to protect public health and comply with drinking water regulations. From 1997 to 2011, states loaned $21.7 billion to water systems for 9,188 projects

The estimate covers infrastructure needs that are eligible for, but not necessarily financed by, Drinking Water State Revolving Fund (DWSRF) monies (note - DWSRF is designed to supplement, not replace, investment funding by states and localities as well as rate payers). Projects eligible for DWSRF funding include the installation of new infrastructure and the rehabilitation, expansion, or replacement of existing infrastructure. Projects may be needed because existing infrastructure is deteriorated or undersized, or to ensure compliance with regulations. Cost estimates assume comprehensive construction

Drinking Water Infrastructure Needs Survey and Assessment, Fifth Report to Congress, USEPA Office of Water, 2013

Infrastructure needs



Drinking Water Infrastructure Needs Survey and Assessment, Fifth Report to Congress, USEPA Office of Water, 2013

Needs by State & System Size

Exhibit 2.2: State 20-year Need Reported by System Size (in millions of January 2011 dollars)

State	Large	Medium	Small	NPNCWSs	Total
Alabama	$1,570.2	$5,951.9	$423.3	$4.3	$7,949.8
Arizona	$3,987.1	$2,463.9	$968.7	$21.0	$7,440.7
Arkansas	$696.0	$4,354.9	$1,039.2	$8.3	$6,098.4
California	$27,369.9	$13,317.8	$3,710.3	$115.0	$44,513.0
Colorado	$2,708.2	$3,222.5	$1,191.8	$1.5	$7,124.0
Connecticut	$1,735.3	$1,137.7	$674.1	$31.2	$3,578.3
District of Columbia	$1,606.7	$0.0	$0.0	$0.0	$1,606.7
Florida	$8,258.6	$6,147.8	$1,919.7	$144.8	$16,471.0
Georgia	$3,283.0	$4,197.4	$1,772.2	$15.6	$9,268.2
Illinois	$8,640.7	$7,135.7	$3,083.7	$124.9	$18,984.9
Indiana	$1,791.2	$3,416.3	$1,139.3	$200.0	$6,546.9
Iowa	$447.9	$3,821.2	$1,640.3	$20.9	$5,930.2
Kansas	$1,045.3	$1,762.7	$1,382.8	$3.9	$4,194.7
Kentucky	$1,206.2	$4,662.0	$359.1	$1.2	$6,228.6
Louisiana	$1,196.1	$2,713.7	$1,395.9	$16.9	$5,322.6
Maine	$149.6	$501.6	$489.4	$39.1	$1,179.7
Maryland	$5,276.1	$939.7	$585.8	$111.4	$6,913.1
Massachusetts	$2,106.2	$5,104.4	$453.0	$37.3	$7,701.0
Michigan	$5,796.9	$5,649.7	$1,831.6	$535.6	$13,813.9
Minnesota	$738.7	$4,798.4	$1,521.1	$304.3	$7,362.6
Mississippi	$147.0	$1,648.5	$1,880.2	$10.9	$3,686.6
Missouri	$2,055.4	$4,365.6	$2,015.3	$44.4	$8,480.7
Nevada	$4,555.2	$726.3	$293.6	$16.2	$5,591.3
New Jersey	$3,402.9	$3,600.3	$680.5	$230.9	$7,914.5
New York	$13,801.7	$4,144.4	$3,951.9	$143.1	$22,041.1

Drinking Water Infrastructure Needs Survey and Assessment, Fifth Report to Congress, USEPA Office of Water, 2013

A Public Water System (PWS) ?

- <u>Candidates</u>: yes or no?
  - Well serving all 10 people in your duplex
  - Well used for watering a golf course
  - Well used for a campground
  - Surface water for small gas station
  - Water supply on a commercial airplane
  - Water supply for 100 people in Williamsburg
  - A convenience store that sells bottled water

PWS as defined by EPA

- Definitions
  - Water for human consumption
  - Delivered via pipes or other conveyances
  - Serving 25 or more people or with 15 or more connections
- Numbers
  - About 150,000 in US

PWS Categories

- Size, based on number of people served
  - Very Small 25-500 people
  - Small > 501-3,300 people
  - Medium > 3,301-10,000 people
  - Large > 10,001-100,000 people
  - Very Large > 100,000 people
- Source water
  - Groundwater (GW)
  - Surface water (SW)
  - Groundwater under the direct influence of surface water (GWUDI)
- Nature of service
  - Community water system (CWS)
    - To homes, year round
  - Non-transient, non-community water system (NTNCWS)
    - Service: 6-12 months
    - schools, factories, office buildings, and hospitals
  - Transient non-community water systems (TNCWS)
    - Service: short periods of time
    - Gas stations, campgrounds

US Community Water Systems

- Based on 2014 SDWIS
- Total systems: 153,138
  - Serving 322.46 M

Size (# served/system)	**Small & V. Small (<3.3K)**	**Medium (3.3-10K)**	**Large (10-100K)**	**V. Large (>100K)**
# Systems	143,611	5,192	3,902	433
Pop served	38.94 M	30.18 M	110.93 M	142.41 M

Sometimes called “small”

Categories based on SDWIS 2014

		<500	501-3,300	3,301-10,000	10,001-100,000	>100,000	Grand Total
CWS	Systems	18.28%	8.86%	3.23%	2.53%	0.28%	33.18%
	Population	1.46%	6.04%	8.95%	34.16%	43.48%	94.08%
NTNCWS	Systems	10.14%	1.66%	0.10%	0.01%	0.00%	11.90%
	Population	0.67%	0.84%	0.25%	0.14%	0.06%	1.97%
TNCWS	Systems	53.03%	1.82%	0.06%	0.01%	0.00%	54.92%
	Population	2.26%	0.82%	0.15%	0.10%	0.62%	3.96%
All PWS	Systems	81.44%	12.34%	3.39%	2.55%	0.28%	100.00%
	Population	4.38%	7.69%	9.36%	34.40%	44.17%	100.00%

Numbers of small systems by category

	<=100	101-500	501-1,000	1,001-3,300	3,301-10,000		Total small systems	% of small system
All PWS	79,881	41,814	9,269	9,574	5,151		145,689	97%
	53%	28%	6%	6%	3%			
Ground Water	77,077	38,943	7,942	6,935	2,890		133,787	92%
Surface Water	2,753	2,858	1,326	2,637	2,260		11,834	8%
CWS	12,264	15,511	5,524	8,094	4,920		50,452	35%
NTNCWS	8,576	6,534	1,636	879	137		17,778	12%
TNCWS	59,041	19,769	2,109	601	94		81,627	56%
Private	66,591	29,417	3,748	2,016	620		102,392	70%
Local gov't	5,465	7,924	4,336	6,431	4,088		28,244	19%
Federal Gov't	2,255	930	168	156	98		3,607	2%
Native American	236	323	129	155	66		909	1%
Public Private	2,856	1,800	408	402	133		5,599	4%
State Gov't	2,478	1,420	480	414	146		4,938	3%
Private								% of Private
CWS	10,326	9,341	1,562	1,324	519		23,072	23%
NTNCWS	7,142	4,041	723	401	72		12,379	12%
TNCWS	49,123	16,035	1,463	291	29		66,941	65%

Data extracted from SDWIS 2013 by Joy Barrett & Bill Hogrewe, RCAP

Revenue and # of Consumers

- Impact of alternative sources of income

SYSTEM SIZE	% REVENUE FROM RESIDENTIAL USERS
VERY SMALL (25 -500)	**89%**
SMALL (501 -3,300)	**84%**
MEDIUM (3,301 - 10,000)	**74%**
LARGE (10,001 - 100,000)	**67%**
VERY LARGE (>100,001)	**50%**

Source: RCAP 2005

Health Violations

- During FY 2014 (from sdwis fed)
  - Many more non-health violations

Reason	All Sizes		Serving < 10K	
	# systems	population	# systems	population
Coliform Bacteria	6,179	9.89 M	6,000	2.64 M
DBPs	789	9.54 M	689	1.24 M
Arsenic	550	0.69 M	538	0.30 M
Nitrates	555	0.37 M	552	0.13 M
Other Inorganics	98	0.29 M	92	0.06 M
Volatile Organics	21	0.06 M	20	0.01 M
Synthetic Orgs.	12	0.05 M	10	0.003 M
Radioactive	288	0.49 M	278	0.019 M
Lead & Copper	8,542	17.94 M	8,193	6.05 M

End of Class #1

- To next Lecture