Critical Turning Points

in the History of Water Reuse in the U.S.

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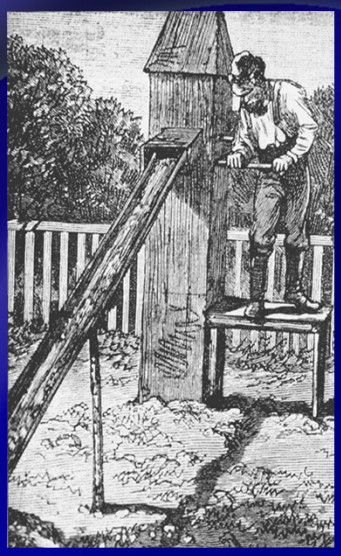
Critical Turning Points

- Extensive historical use of night soil on farms
- Advances in sanitation/treatment practices
- Evolution of "Land Treatment" from "disposal" to "sustainable land application practices"
- Lake Erie algae blooms/Cuyahoga River catching on fire … passage of the FWPCA Amendments of 1972 (the Clean Water Act); secondary treatment requirements; Construction Grants Program
- Development & implementation of established treatment technologies … reclaimed water projects & dual water distribution systems

- Water shortages … increasing demand for sustainable water supplies
- Establishment of State water reuse standards, EPA guidelines for water reuse, case study reports, white papers, etc.
- Funding (by EPA, BuREC, etc.) of full-scale reclamation projects (including indirect potable projects), research evaluations, NRC/NAS studies, national demonstration projects, NASA/space station interest in reuse, etc.
- High-end reuse projects and greater acceptance by the public
- Increasing awareness of nutrient impaired water bodies, establishment of nutrient standards, etc.

Extensive historical use of night soil on farms in Asia, sewage in Germany, UK, Scotland, Australia, and U.S.

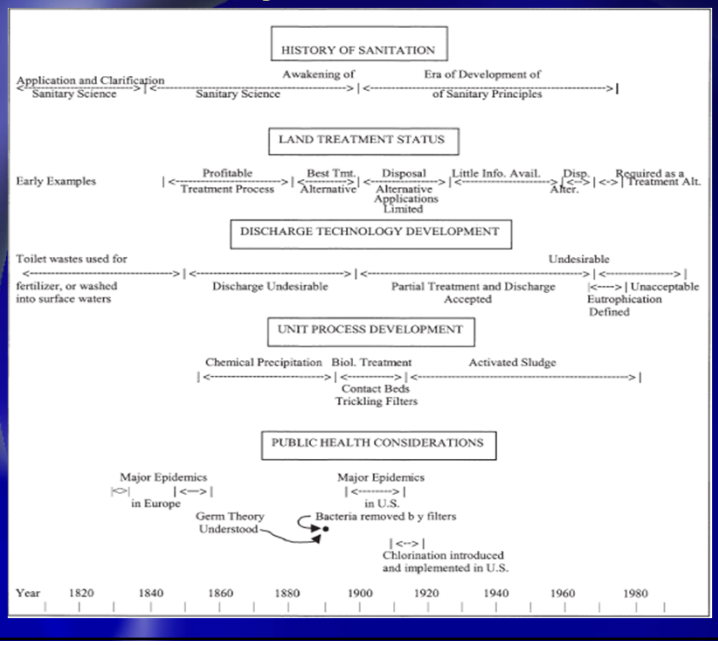
- Extensive historical use of night soil on farms in Asia, sewage in Germany, UK, Scotland, Australia, and U.S.
  - Viewed by some as the only adequate technology to help alleviate gross pollution impacts on surface waters
  - Nutrient value and improved crop productivity lead to promotion as a profitable practice
  - Pollutant and soil interactions considered to function as a purifying process
  - By the 1890's it was recognized that the "living system" had limitations and could be overloaded resulting in system failure



"Pumping Sewage on Crops for Fertilizer"
Source: *Harper's Weekly*, 1890, Photo IV.1;
from *The Search For The Ultimate Sink* by Joel A. Tarr,
The University of Akron Press, 1996

- Between 1840 and 1890, many of the basic wastewater treatment processes in use today were developed (e.g., chemical precipitation, activated carbon adsorption, trickling filters, biological contact beds, intermittent filtration)
- Introduction of chlorination in 1910 lead to the elimination of major epidemics of typhoid and cholera
- By late 1890s, discharge of partially treated wastewater effluents was considered to be a safe and cost-effective alternative

History of Sanitation



- By the late 1890's, previously promoted as profitable ventures, land treatment of raw sewage had been shown to be unprofitable
  - Many land treatment systems installed in the mid-1800's were used for 30 to 50 years without increasing their size in response to growing populations resulting in overloaded conditions
- Between 1890 to 1905, land treatment was considered the most effective alternative in the U.S. and was used by many communities
  - From the outset, American engineers considered sewage farming and other land application practices to be primarily "disposal" systems

- Land treatment for "disposal" was used by many food processors for many years (e.g., Seabrook Farms, Campbell Soup, WA & ID potato processors)
  - Such projects were generally designed to maximize the amount of waste applied per acre rather than to use conventional irrigation procedures and historically accepted practices for recycling animal manure back to the land to optimize their use as a source of water for irrigation and/or nutrients
- Similar practices were attempted by some cities as a means of disposal of municipal effluents and sewage sludge

- Land treatment for "disposal" often resulted in problems such as:
  - elevated nitrates in the underlying groundwater
  - high nitrate forage
  - severe erosion and runoff from application sites into nearby water bodies
  - poor cover crop performance
  - odors and other undesirable site conditions developed due to excess moisture, organic matter, and nutrient loadings
- Similar problems have resulted from excessive manure application rates to farmland in some areas of the country

The development of *Sustainable Land Application* Practices

- Modern "*Sustainable Land Application*" practices optimized for "treatment" and "reuse" while protecting the environment and/or use conventional irrigation procedures and historically accepted practices for recycling animal manure back to the land
  - Land treatment of municipal & industrial effluents
  - Reuse of treated effluents for irrigation

EPA430/9-79-012

April 1979

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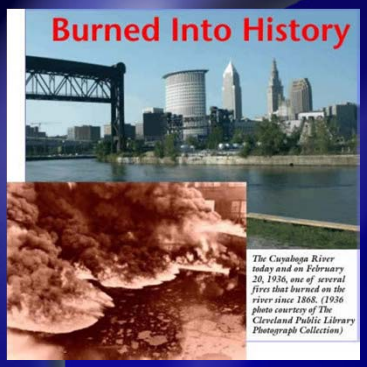
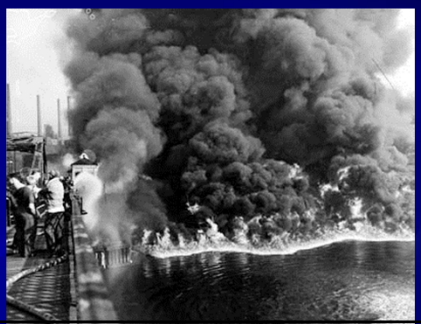
The Cuyahoga River Fire of 1969





Blue-green Algae Bloom circa 1970, Lake Erie

TP Loads to Lake Erie (1967 – 2001)

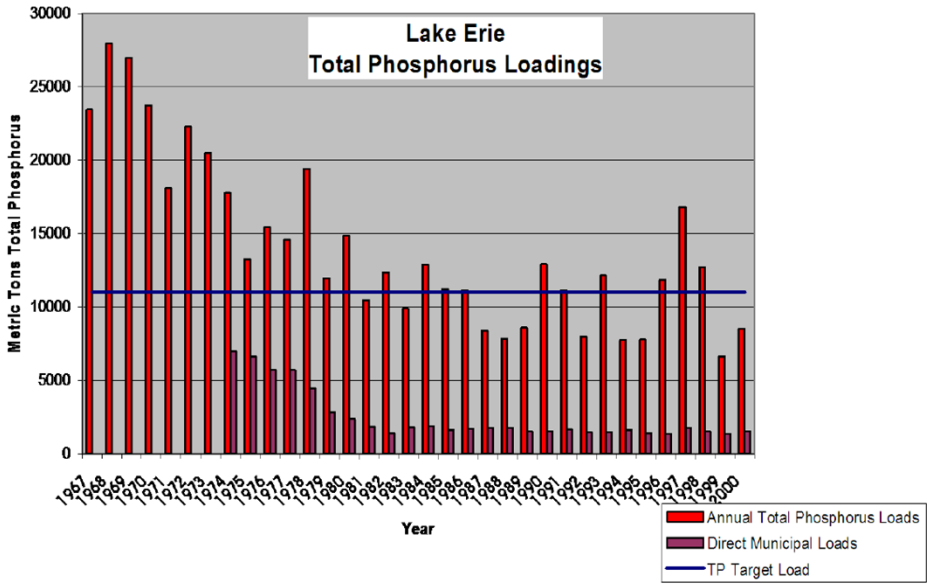


Table 2-13. Pollutant groups and related water resource issues.

Pollutant Group	Water Quality Conditions and Concerns	
Nutrients (nitrogen and phosphorus)	Eutrophication Ammonia toxicity Anoxia/ hypoxia; oxygen depletion Water clarity/transparency Reduced diversity/trophic structure	Nuisance algal blooms Toxic algal blooms Fish kills Shellfish bed closure/loss Loss of seagrass beds/habitat
Metals and Toxics	Fish body burden Shellfish body burden Mammals body burden	Birds body burden Sediment contamination Drinking water supply
Organic Matter	Anoxia/hypoxia; oxygen depletion Adsorption/desorption of toxic chemicals	Fish kills
Pathogens	Shellfish bed closure Recreational beach closure	Drinking water supply
Sediment	Anoxic sediments Damage to benthic biota	Habitat destruction/fish spawning Water clarity/ transparency
Hazardous materials	Oil spills Chemical spills	Fish kills

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FEDERAL WATER POLLUTION CONTROL ACT
[As Amended Through P.L. 107–303, November 27, 2002]

November 27, 2002 1

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FEDERAL WATER POLLUTION CONTROL ACT

(33 U.S.C. 1251 et seq.)

AN ACT To provide for water pollution control activities in the Public Health Service of the Federal Security Agency and in the Federal Works Agency, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—RESEARCH AND RELATED PROGRAMS

DECLARATION OF GOALS AND POLICY

SEC. 101. (a) The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this Act—

(1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;

(2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983;

(3) it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;

(4) it is the national policy that Federal financial assistance be provided to construct publicly owned waste treatment works;

(5) it is the national policy that areawide treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each State;

(6) it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone and the oceans; and

(7) it is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution.

(b) It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources, and to consult with the Administrator in the exercise of his authority under this Act. It is the policy of Congress that the States manage the construction grant program under this Act and implement the permit programs under sections 402 and 404 of

November 27, 2002 1

Progress in Water Quality: An Evaluation of the National Investment in Municipal Wastewater Treatment

(EPA-832-R-00-008; June 2000)

http://www.epa.gov/owm/wquality/wquality.pdf

United States Environmental Protection Agency
Office of Water (4204)
Washington, DC 20460
www.epa.gov/owm
EPA-832-R-00-008
June 2000

EPA

Progress in Water Quality

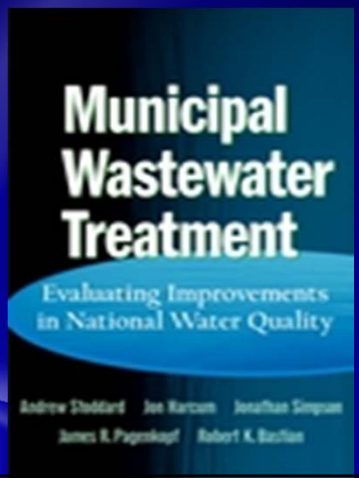
An Evaluation of the National Investment in Municipal Wastewater Treatment

Municipal Wastewater Treatment; Evaluating Improvements in National Water Quality

by Andrew Stoddard, Jon B. Harcum, Jonathan T. Simpson, James R. Pagenkopf, Robert K. Bastian

August 2002 Hardcover (E-Book also available)

http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471243604.html



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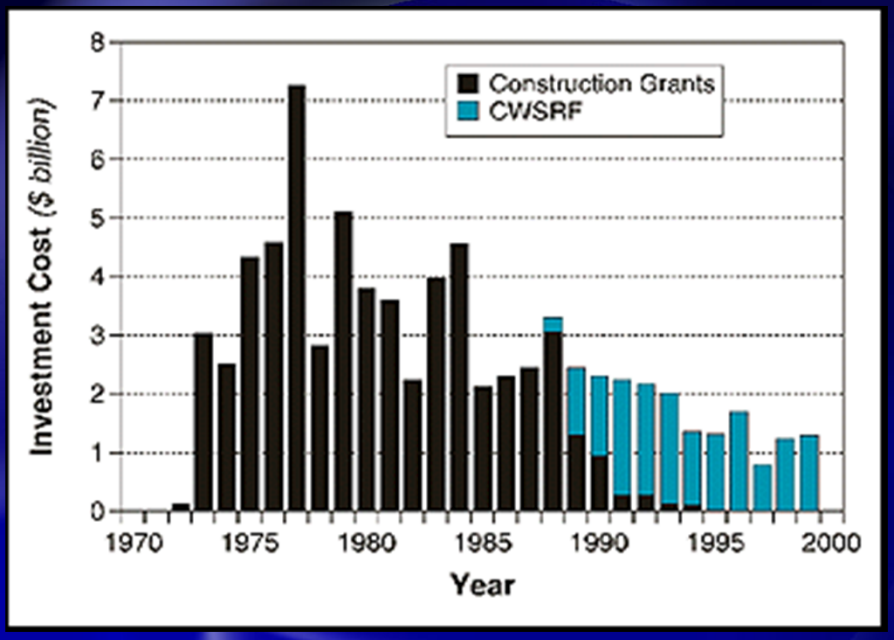

Table 2-4. Inventory of POTWs by wastewater treatment type, 1940 - 2000. *Source: U.S. Public Health Service Municipal Wastewater Inventories and USEPA Clean Water Needs Surveys.*

Inventory of POTWs

		TREATMENT TYPE				
Year	Total	Raw	Less than Secondary	Secondary	Greater than Secondary	No Discharge
1940	NA	NA	2,938	2,630	0	NA
1950	11,784	5,156	3,099	3,529	0	NA
1962	11,698	2,262	2,717	6,719	0	NA
1968	14,051	1,564	2,435	10,042	10	NA
1972	19,355	2,265	2,594	9,426 [a]	461	142
1978	14,850	91	4,278	6,608	2,888	985
1982	15,662	237	3,119	7,946	2,760	1,600
1988	15,708	117	1,789	8,536	3,412	1,854
1992	15,613	0	868	9,086	3,678	1,981
1996	16,024	0	176	9,388	4,428	2,032
2000	16,033	0	47	9,156	4,892	1,938

a This total excludes 4,467 oxidation ponds and 142 land application facilities classified as secondary treatment facilities in EPA's 1972 inventory of municipal wastewater facilities (USEPA, 1972). They were excluded because (1) EPA did not categorize oxidation ponds as secondary treatment facilities in any other year covered in this analysis and (2) land application facilities are classified as "no discharge" facilities in subsequent years and therefore (to be consistent) they were included in the no discharge facilities category for 1972.

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Table 2-5. Population served by and influent wastewater flow to POTWs by wastewater treatment type, 1940 - 2000. *Source: U.S. Public Health Service and USEPA Clean Water Needs Surveys.*

Population Served by POTWs (millions)

		TREATMENT TYPE				
Year	Total	Raw	Less than Secondary	Secondary	Greater than Secondary	No Discharge
1940	70.5	32.1	18.4	20.0	0.0	NA
1950	91.8	35.3	24.6	31.9	0.0	NA
1962	118.3	14.7	42.2	61.5	0.0	NA
1968	140.1	10.1	44.1	85.6	0.3	NA
1972	141.7	4.9	51.9	76.3	7.8	0.8
1978	155.2	3.6	44.1	56.3	49.1	2.2
1982	163.5	1.9	33.6	67.6	56.3	4.2
1988	177.5	1.4	26.5	78.0	65.7	6.1
1992	180.6	0.0	21.7	82.9	68.2	7.8
1996	189.7	0.0	17.2	81.9	82.9	7.7
2000	207.8	0.0	6.4	88.2	100.9	12.3

Influent Wastewater Flow to POTWs (mgd)

Year	Total	Raw	Less than Secondary	Secondary	Greater than Secondary	No Discharge
1940	11,682	5,313	3,053	3,317	0	NA
1950	15,141	5,819	4,059	5,263	0	NA
1962	19,520	2,409	6,963	10,148	0	NA
1968	23,117	1,667	7,277	14,124	50	NA
1972	23,384	815	8,560	12,585	1,288	136
1978	26,800	601	7,152	10,139	8,545	363
1982	27,203	310	5,301	11,010	10,092	491
1988	29,294	226	4,370	12,863	10,832	1,003
1992	29,801	0	3,583	13,680	11,258	1,281
1996	31,302	0	2,834	13,521	13,683	1,264
2000	34,467	0	818	14,671	17,588	1,390

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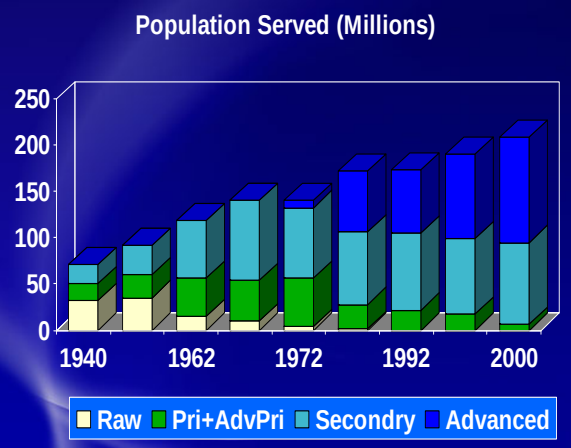
Increasing Proportion of the U.S. Population Served by POTWs

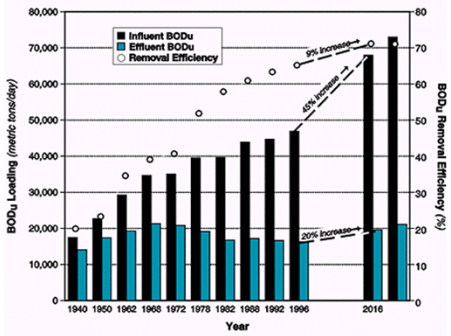


Assumptions:

Influent flow is a constant 165 gallon/capita-day[1] with a BOD_u of 396.5 mg/L

Projection Results

	1968	1972	1978	1996	2016	2025
Population served *(millions)*	140.1	141.7	155.2	189.7	275.0	295.0
Percent of total population	71%	69%	70%	72%	88%	88%
Design removal efficiency *(BOD_u)*	39%	41%	52%	65%	71%	71%
Effluent BOD_u *(metric tons/day)*	21,280	20,831	19,147	16,325	19,606	21,090



[1] 165 gal/capita-day is based on the mean of population served and wastewater flow data in the Clean Water Needs Surveys for 1978 through 1986 and accounts for residential, commercial, industrial, stormwater, and infiltration and inflow components.

Figure 3-1

Location of sample stations and minimum DO concentrations in the contiguous 48 states from 1957 to 1965.

Source: Gunnerson, 1966.

Table 3-1. Twenty-five RF1 river reaches with greatest improvements in worst-case (mean 10th percentile) DO after the CWA. *Source: USEPA STORET*

Rank	Reach ID	River Reach Name	Catalog Unit Name	Worst-case DO 1961-1965 *(mg/L)*	Worst-case DO 1986-1990 *(mg/L)*	DO Change *(mg/L)*	No. of Stations 1961-1965	No. of Stations 1986-1990
1	10170203037	Big Sioux R.	Lower Big Sioux, IA	0.0000	7.2200	7.2200	1	1
2	04100002001	River Raisin	Raisin, MI-OH	1.6000	8.3400	6.7400	2	2
3	04110002001	Cuyahoga R.	Cuyahoga, OH	0.2950	6.4967	6.2017	2	24
4	05030103007	Mahoning R.	Mahoning, OH-PA	1.0900	7.1600	6.0700	1	1
5	07070002034	Wisconsin R.	Lake Dubay, WI	0.8800	6.8400	5.9600	1	1
6	05120201004	White R.	Upper White, IN	0.6900	6.4240	5.7340	5	1
7	05080002008	Great Miami R.	Lower Great Miami, IN	0.2000	5.8600	5.6600	1	1
8	07120004018	Du Page R., E Br.	Des Plaines, IL	0.5750	5.9200	5.3450	4	3
9	07090001004	Rock R.	Upper Rock, IL	2.7600	8.0500	5.2900	1	1
10	05020006031	Casselman R.	Youghiogheny, MD	2.9600	8.0000	5.0400	1	1
11	04040002005	Root R.	Pike-Root, IL	0.9400	5.9400	5.0000	1	1
12	02040201011	Neshaminy R.	Crosswicks-Neshaminy	2.6000	7.5600	4.9600	1	1
13	04030101012	Manitowoc R.	Manitowoc-Sheboygan, WI	5.9500	10.9000	4.9500	1	1
14	03170006007	Pascagoula R.	Pascagoula, MS	0.0000	4.9200	4.9200	1	7
15	06010102004	Holston R, S Fk.	South Fork Holston,	1.6000	6.4800	4.8800	1	2
16	08030203006	Enid L.	Yocona, MS	0.0000	4.8673	4.8673	1	3
17	04040003001	Milwaukee R.	Milwaukee, WI	2.1800	6.9567	4.7767	2	3
18	04030104002	Oconto R.	Oconto, WI	0.5000	5.2000	4.7000	1	1
19	08030205018	Grenada L.	Yalobusha, MS	0.0000	4.6160	4.6160	1	4
20	05050008006	Kanawha R.	Lower Kanawha, WV	0.0000	4.5667	4.5667	2	3
21	04120102002	Cattaraugus Cr.	Cattaraugus, NY	3.3000	7.6000	4.3000	1	2
22	03050109053	Reedy R.	Saluda, SC	1.9500	6.2270	4.2770	4	10
23	07120004002	Des Plains R.	Des Plaines, IL	1.7620	6.0000	4.2380	2	1
24	05120201013	White R.	Upper White, IA	2.2267	6.3750	4.1483	3	2
25	03050103037	Catawba R.	Lower Catawba, NC	1.6780	5.8000	4.1220	5	1

Figure 3-12

Location map and distribution chart of the 25 RF1 reaches with the greatest after-CWA improvements in worst-case DO. *Source: USEPA STORET*

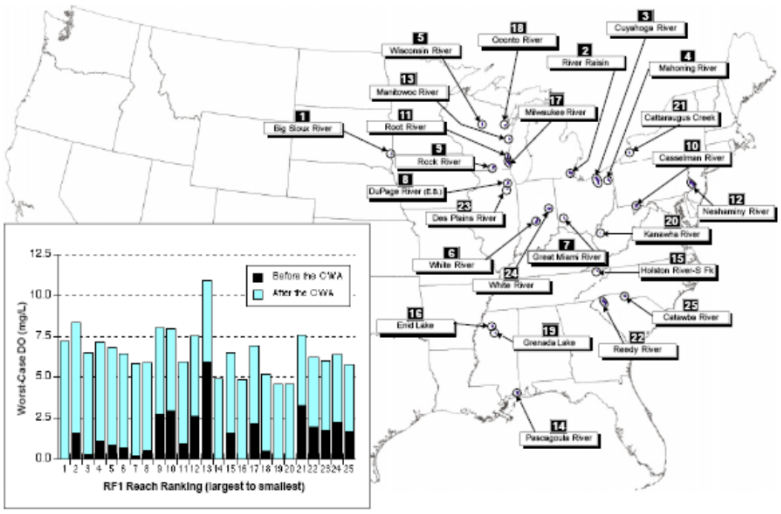


Table 3-2. Twenty-five catalog units with greatest improvements in worst-case (mean 10th percentile) DO after the CWA.
Source: USEPA STORET

Rank	Reach ID	Catalog Unit Name	Worst-case DO 1961-65 (mg/L)	Worst-case DO 1986-90 (mg/L)	DO Change (mg/L)
1	04030204	Lower Fox, WI	0.1600	7.2050	7.0450
2	04120102	Cattaraugus, NY	1.3230	7.6000	6.2770
3	04110002	Cuyahoga, OH	0.2950	6.5008	6.2058
4	17010307	Lower Spokane, WA	3.5000	9.7000	6.2000
5	07070002	Lake Dubay, WI	0.5800	6.6833	6.0033
6	18060005	Salinas, CA	3.1800	8.7500	5.5700
7	02050306	Lower Susquehanna, MD	0.5800	6.1980	5.3180
8	04030104	Oconto, WI	0.5000	5.8000	5.3000
9	05090002	Lower Great Miami, IN	1.1850	6.4675	5.2825
10	08030204	Coldwater, MS	0.0000	5.2062	5.2062
11	10170203	Lower Big Sioux, IA	0.0000	5.1433	5.1433
12	04040002	Pike-Root, IL	0.9400	5.9400	5.0000
13	08030203	Yocona, MS	0.0000	4.8543	4.8543
14	04040003	Milwaukee, WI	2.1800	6.9567	4.7767
15	05010104	Holston, TN	0.1570	4.8686	4.7116
16	08030205	Yalobusha, MS	0.0000	4.6295	4.6295
17	05010205	Upper Clinch, TN	1.6140	6.0819	4.4679
18	02040204	Delaware Bay, NJ	0.5300	4.9100	4.3800
19	04100002	Raisin, MI/OH	4.0588	8.3400	4.2812
20	11070207	Spring, KS/MO	1.6000	5.6250	4.0250
21	04040001	Little Calumet-Galle	0.5700	4.5553	3.9853
22	18090208	Mojave, CA	4.0200	7.9767	3.9567
23	07120007	Lower Fox, IL	3.7800	7.5764	3.7964
24	07130011	Lower Illinois, IL	1.9400	5.7225	3.7825
25	04100009	Lower Maumee, OH	2.0676	5.8471	3.7795

Figure 3-15

Location map and distribution chart of the 10 catalog units with the greatest before versus after-CWA improvements in worst-case DO. *Source: USEPA STORET*

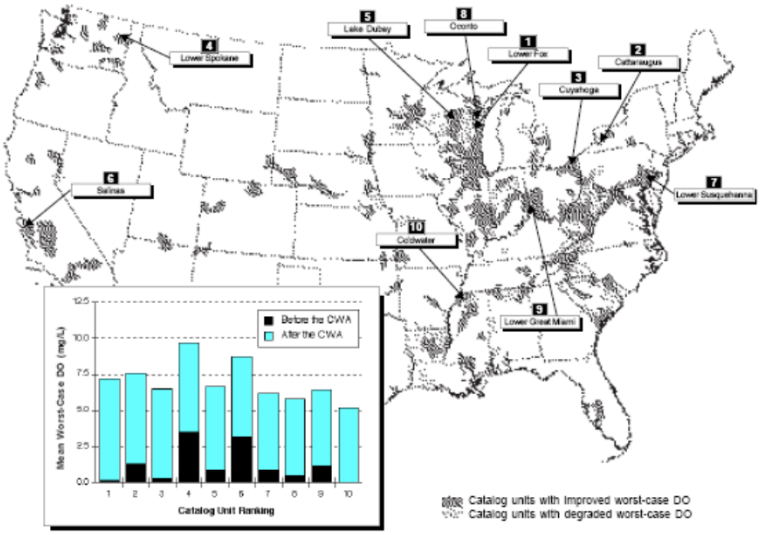
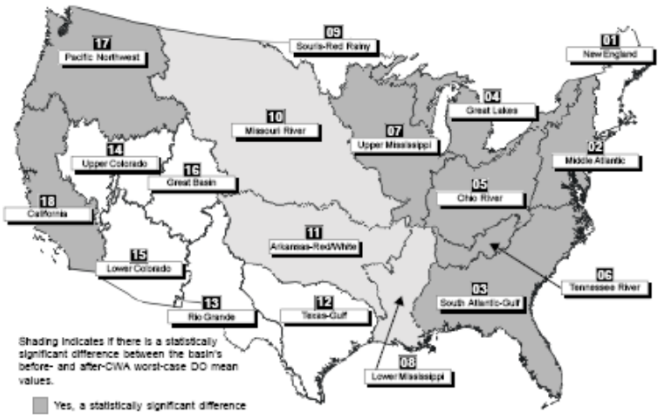


Figure 3-23

Statistical significance of the difference between before- and after-CWA worst-case DO mean values for the 18 major river basins in the 48 contiguous states. *Source: USEPA STORET*



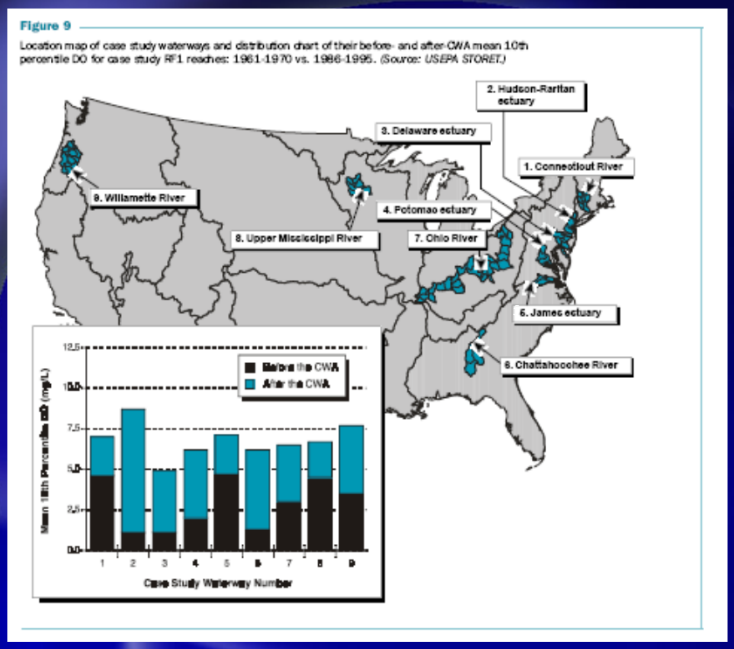
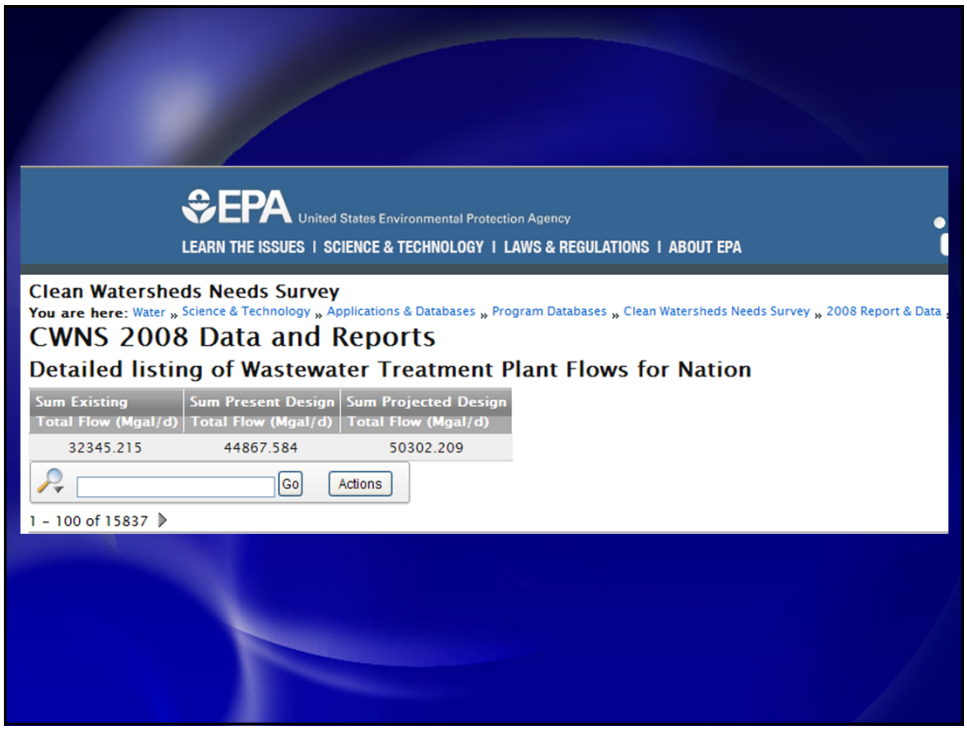


Figure 9
Location map of case study waterways and distribution chart of their before- and after-CWA mean 10th percentile DO for case study RF1 reaches: 1961-1970 vs. 1986-1995. (Source: USEPA STORET)
2. Hudson-Raritan estuary
3. Delaware estuary
1. Connecticut River
9. Willamette River
4. Potomac estuary
8. Upper Mississippi River
7. Ohio River
6. James estuary
5. Chattahoochee River
Before the CWA
After the CWA
Mean 10th Percentile DO (mg/L)
Case Study Waterway Number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CWNS 2008 Data and Reports
Detailed listing of Wastewater Treatment Plant Flows for Nation
Sum Existing Total Flow (Mgal/d)
Sum Present Design Total Flow (Mgal/d)
Sum Projected Design Total Flow (Mgal/d)
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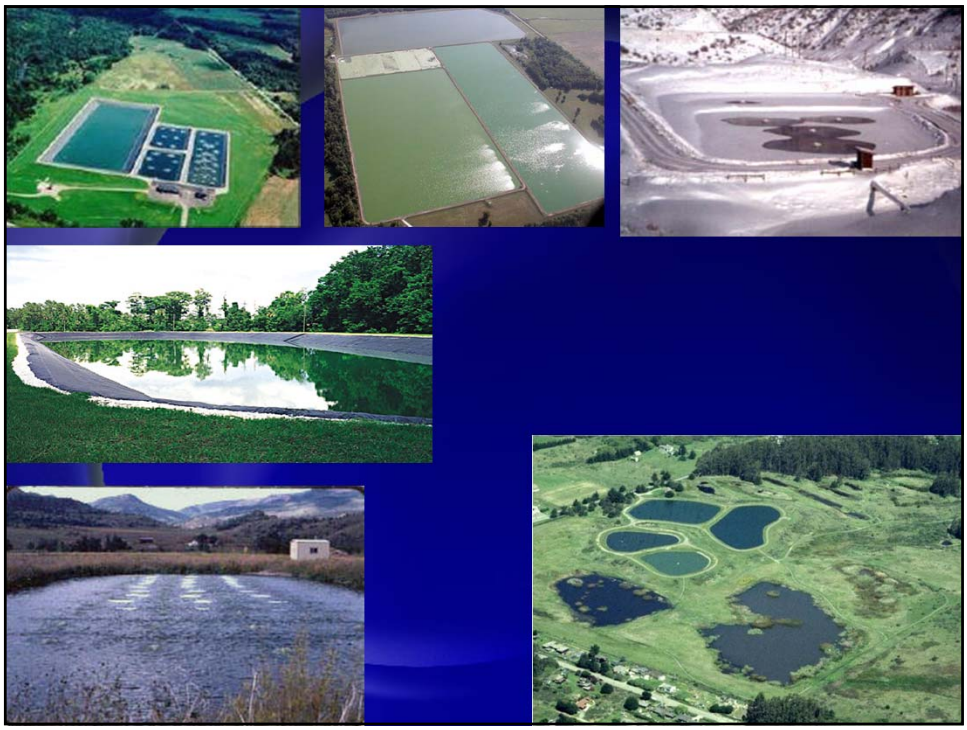
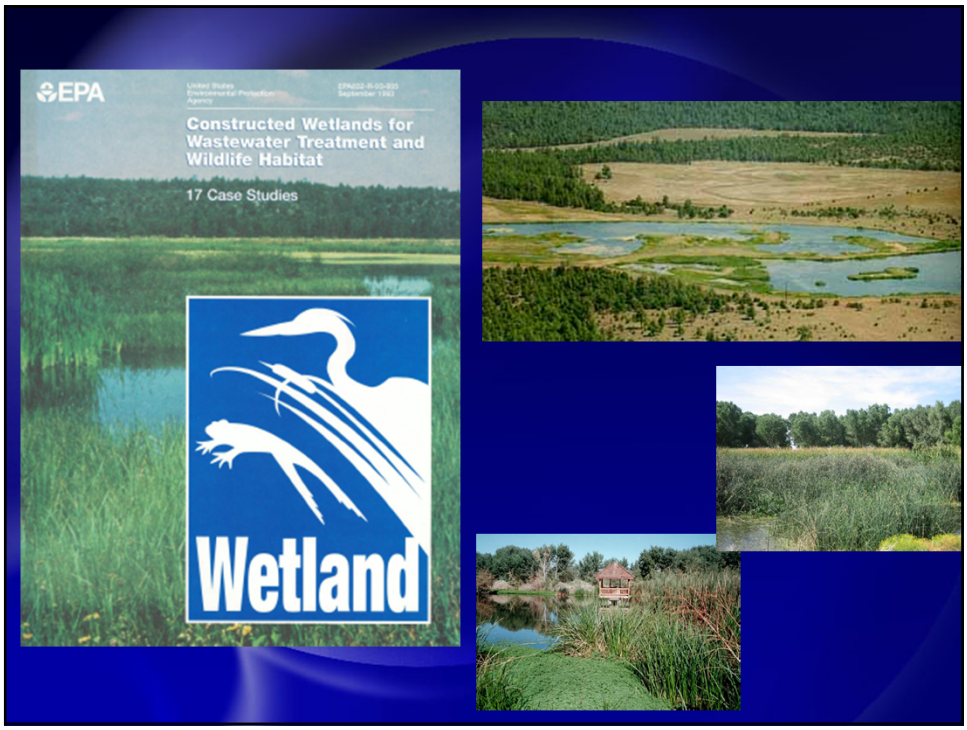
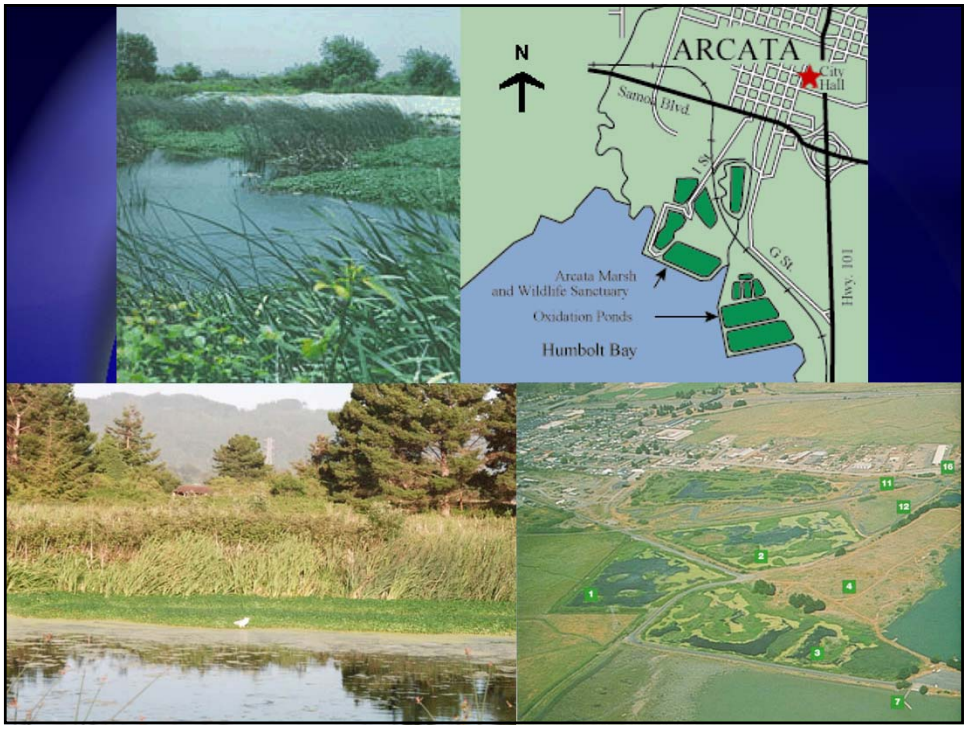
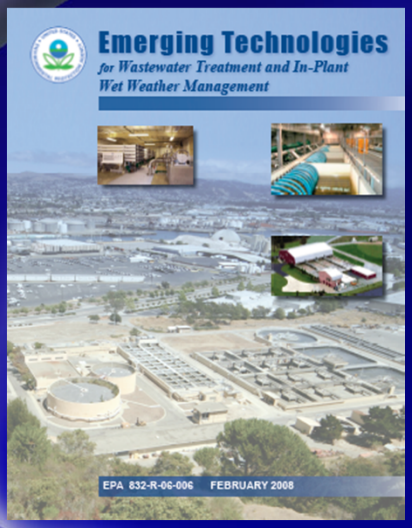


NO TRESPASSING
SEWAGE RECLAMATION AREA
COUNTY OF MUSKEGON
The Muskegon County Wastewater Management System
Is Cost Effective
Uses Wastewater for Food Production
Purifies Wastewater
Protects the Environment
27


EPA
Constructed Wetlands for Wastewater Treatment and Wildlife Habitat
17 Case Studies
Wetland



Wastewater Technology Publications



http://water.epa.gov/scitech/wastetech/publications.cfm

Established Technologies:

- Air Stripping
- Screening
  - Fine Screening
  - Micro Screening
  - Microsieves
  - Rotary Screening
  - Step Screening
- Vortex Separation
- Grit Removal
- Flocculation
- Chemical Precipitation*
  - Alum Addition
  - Zeolite
  - Iron Salts Addition
- Dissolved Air Flotation … including high rate
- Dispersed Air Flotation
- Enhanced/High Rate Clarification

  Ballasted Flocculation (Actiflo® and Microsep®)
  - Lamella Plate Settlers

Established Technologies (Cont'd):

- Chemically Enhanced Primary Treatment
- Solids Contact Clarifier for P Removal
- Ion-Exchange
- Chemical Oxidation*
  - Hydroxyl Radical
  - Oxygen (Atomic and Molecular)
  - Ozone
  - Hydrogen Peroxide
  - Hypochlorite/Chlorine/Chlorine Dioxide
- Advanced Oxidation Processes
  - Supercritical Water Oxidation
  - Catalytic Oxidation
  - Photo Catalysis (UV + TiO_2)
  - Fenton's Reagent (H_2O_2 + Ferrous Ion)

Established Technologies (Cont'd):

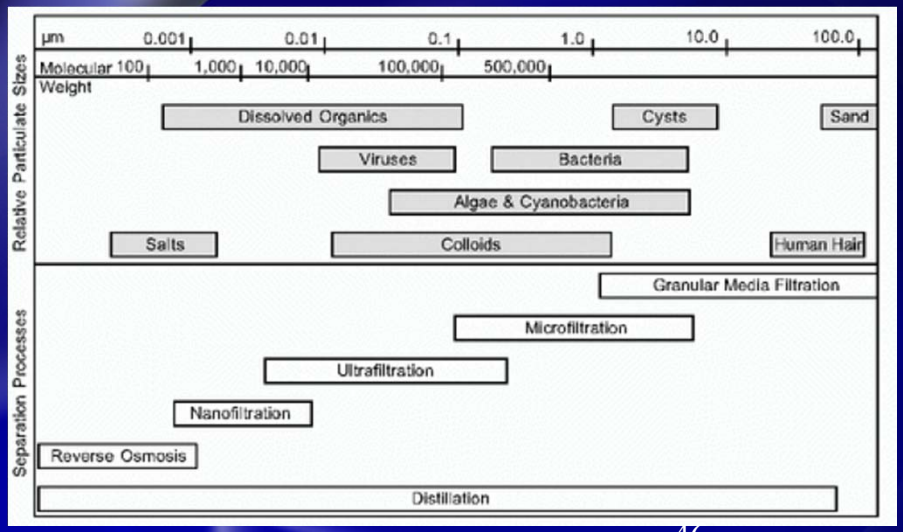
- Electrodialysis
- Membrane Filtration
  - Reverse Osmosis
  - Ultrafiltration
  - Microfiltration
- Media Filtration
  - Cloth Media

    [Disc Filter; Drum Filter; Diamond- Shaped Filters]
  - Silica Media (One- and Two-Stage)

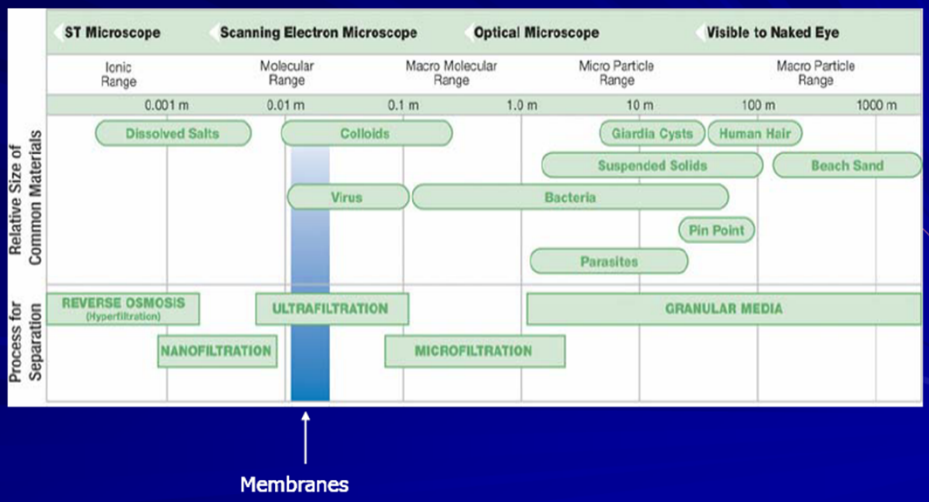
    [Conventional Downflow; Deep-Bed Downflow Filters

    Deep-Bed Upflow Continuous Backwash Filters]
  - Activated Alumina Media
  - Powdered Activated Carbon (PAC)
  - Granular-Activated Carbon (GAC)

Size ranges removed by various membrane types along the filtration spectrum



Membranes Provide a Physical Barrier Ensuring Reliable Filtration



Established Technologies (Cont'd):

- Denitrification Filters
- Automatic Backwash Filters (ABW®)
- Pulsed Bed Filter
- Disinfection
  - Ozone
  - Chlorine/Chlorine Dioxide/Liquid Chlorine/Dechlorination
  - Halogens (Bromine)
  - UltraViolet (UV) Disinfection

Established Technologies (Cont'd):

BOD Removal and Nitrification

- Aerated Lagoons
- Complete Mix-Activated Sludge Process
- Contact Stabilization
- Conventional Extended Aeration
- Countercurrent Aeration System
- High-Purity Oxygen
- Intermittent Cycle Extended Aeration System
- Oxidation Ditch
- Sequencing Batch Reactor (SBR)
- Staged Activated-Sludge Process
- Step Feed & Alternating Anoxic and Aerobic

Established Technologies (Cont'd):

Biological Nutrient Removal (BNR)

- Bardenpho® (Four Stage)
- Biodenitro™
- Ludzack-Ettinger
- Modified Ludzack-Ettinger
- Orbal™ Process
- Schreiber™ Process
- Simultaneous Nitrification Denitrification
- Step Feed BNR Process
- Wuhrman

Established Technologies (Cont'd):

Enhanced Biological Phosphorus Removal

- Anaerobic/Anoxic/Oxic (A2/O)
- Bardenpho® (Five Stage)
- Johannesburg Process
- Phoredox (Anaerobic/Oxic [A/O])
- Phostrip
- University of Cape Town (UCT)
- Virginia Initiative Plant (VIP)

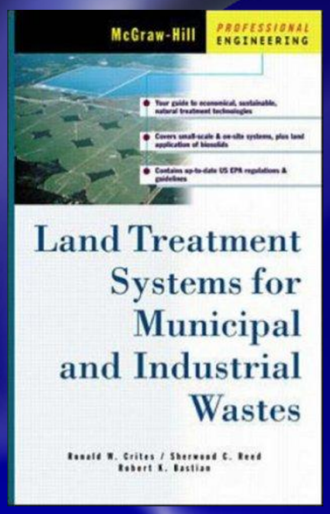
Established Technologies (Cont'd):

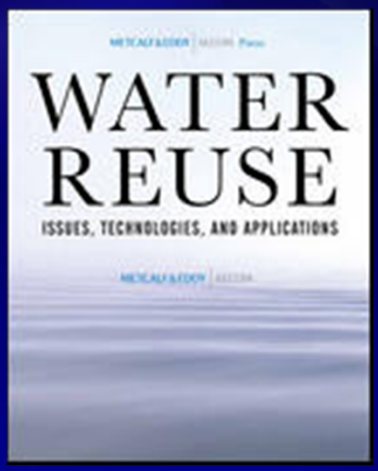
Other Biological Processes

- Fluidized Bed Bioreactor
- Rotating Biological Contractor (RBC)
- Submerged Rotating Biological Contactor
- Trickling Filter

Biological Aerated Filters

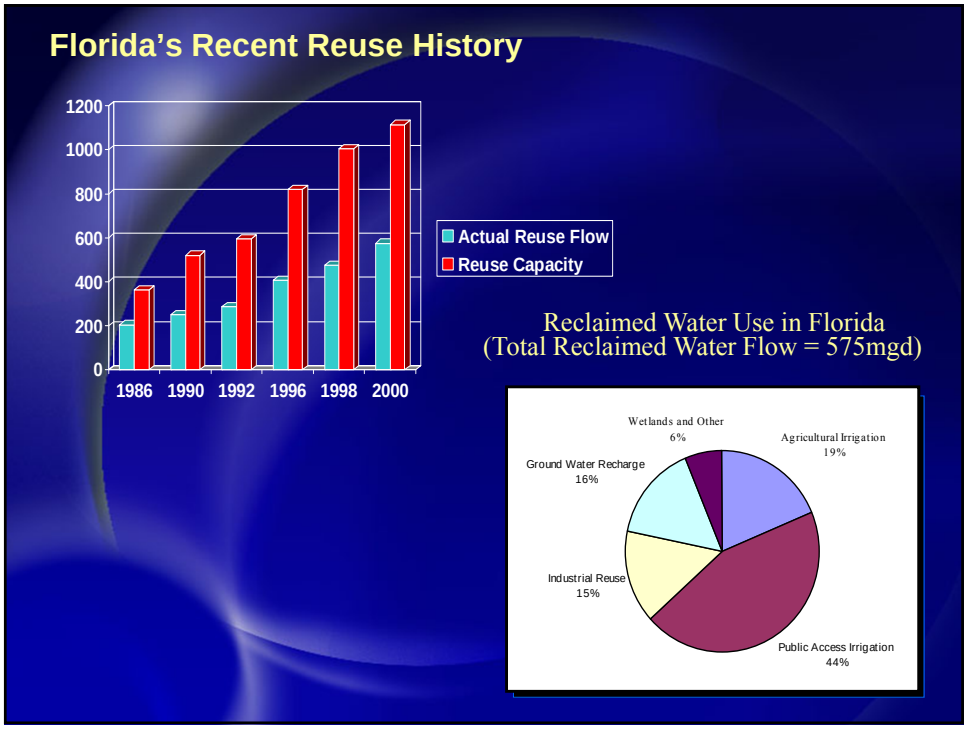
- Biofor®
- Biostyr®

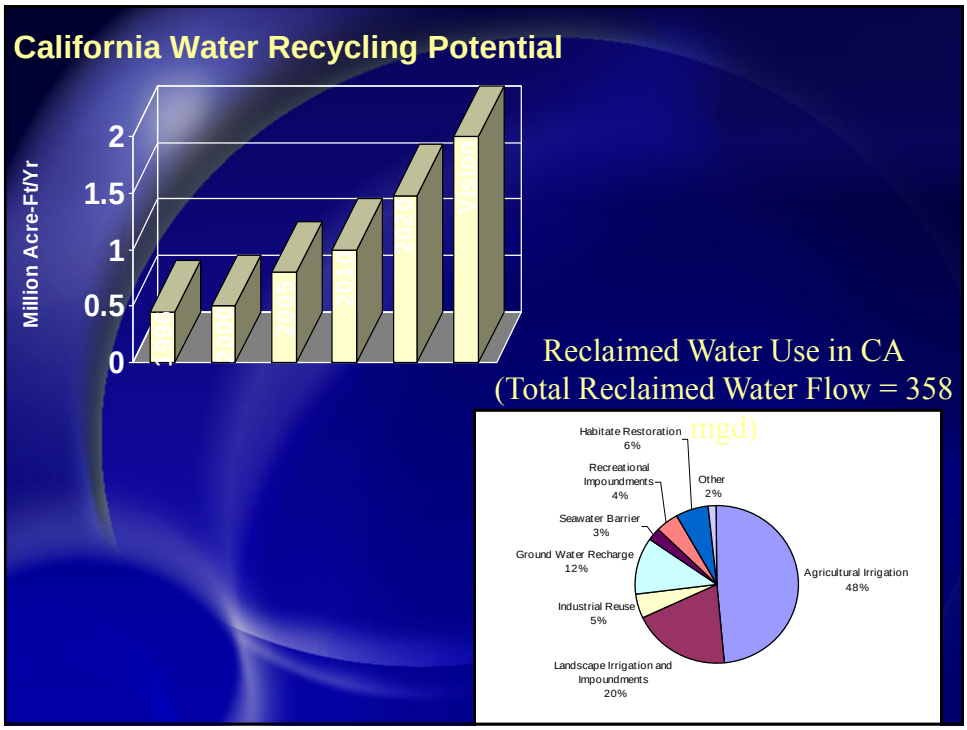

McGraw-Hill
PROFESSIONAL ENGINEERING
Land Treatment Systems for Municipal and Industrial Wastes
Ronald W. Crites / Sherwood C. Reed
Robert K. Bastian

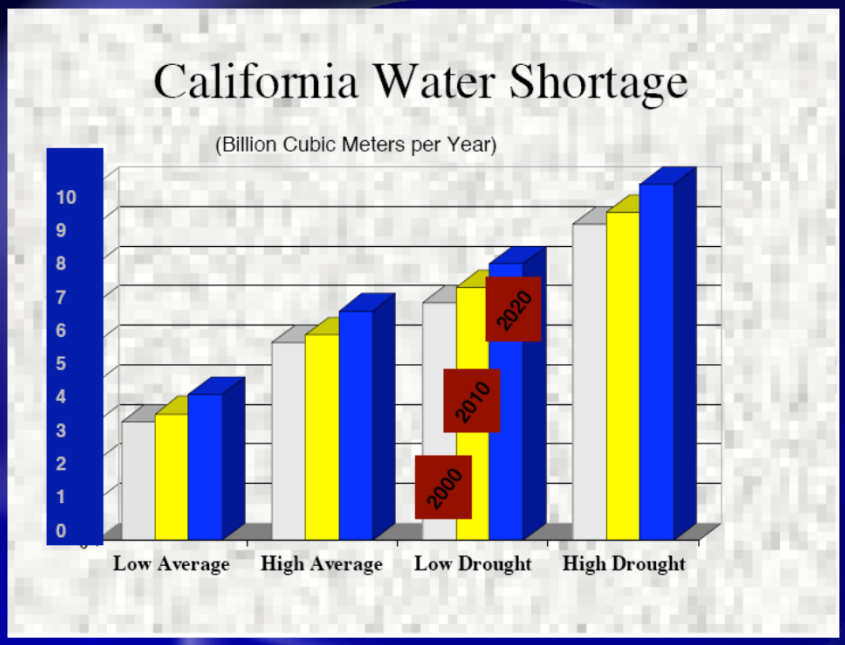

WATER REUSE
ISSUES, TECHNOLOGIES, AND APPLICATIONS

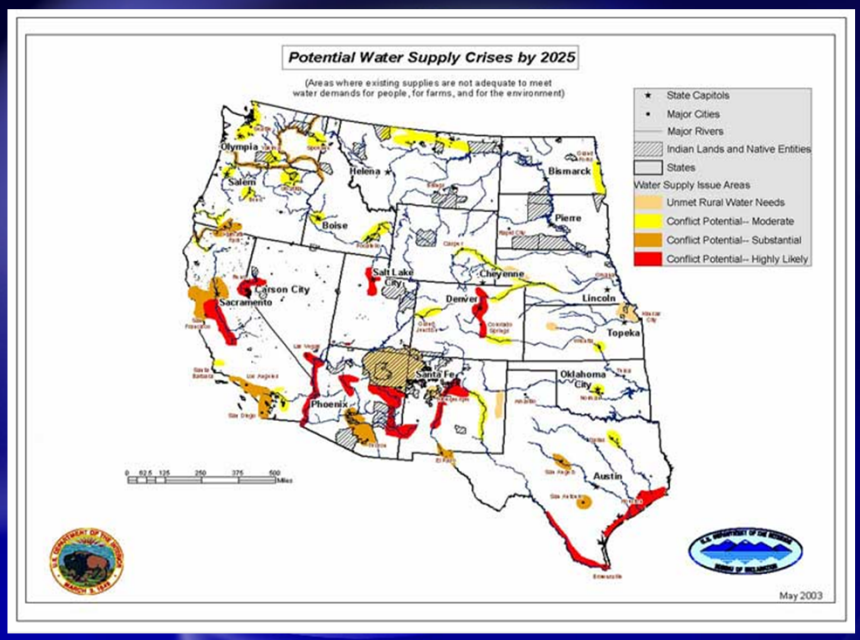
IRRIGATION WITH
RECLAIMED WATER
DO NOT DRINK
AVISO... AGUA RECICLADA
SE PROHIBE BEBER

56
IRRIGATION WATER
NOT FOR DRINKING
AGUA PARA RIEGO
NO PARA TOMAR


Florida's Recent Reuse History
1200
1000
800
600
400
200
0
1986
1990
1992
1996
1998
2000
Actual Reuse Flow
Reuse Capacity
Reclaimed Water Use in Florida
(Total Reclaimed Water Flow = 575mgd)
Wetlands and Other
6%
Agricultural Irrigation
19%
Ground Water Recharge
16%
Industrial Reuse
15%
Public Access Irrigation
44%

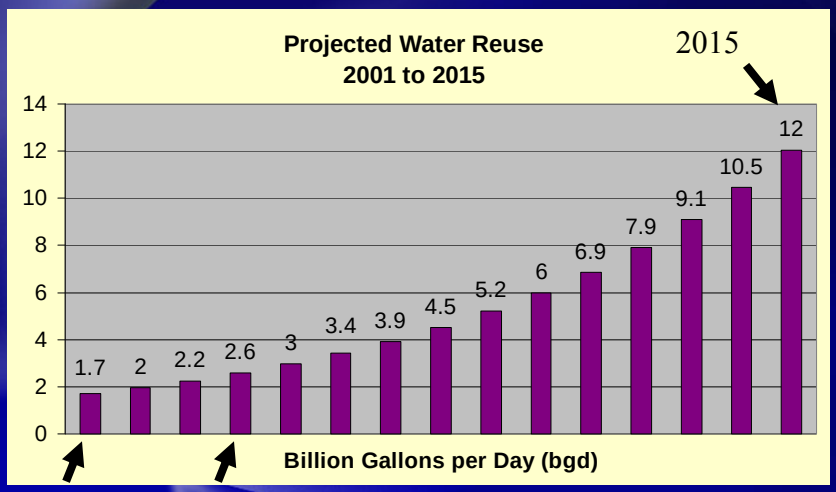

California Water Recycling Potential
Million Acre-Ft/Yr
2
1.5
1
0.5
0
1998
2000
2005
2010
2020
Potential
Reclaimed Water Use in CA
(Total Reclaimed Water Flow = 358
mgd)
Habitate Restoration
6%
Recreational
Impoundments
4%
Other
2%
Seawater Barrier
3%
Ground Water Recharge
12%
Agricultural Irrigation
48%
Industrial Reuse
5%
Landscape Irrigation and
Impoundments
20%

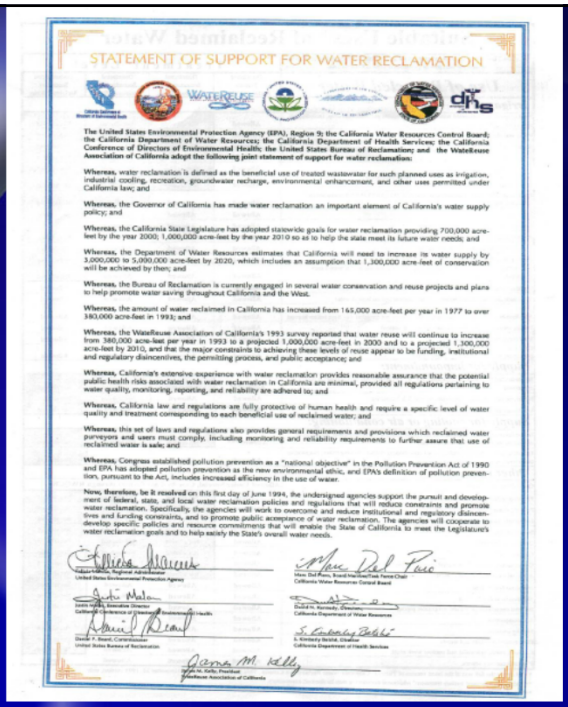




USBR 2025 Report – Map of areas with conflict potential

Projected Growth of Water Reuse in the U.S.





STATEMENT OF SUPPORT FOR WATER RECLAMATION

The United States Environmental Protection Agency (EPA), Region 9; the California Water Resources Control Board; the California Department of Water Resources; the California Department of Health Services; the California Conference of Directors of Environmental Health; the United States Bureau of Reclamation; and the WateReuse Association of California adopt the following joint statement of support for water reclamation:

Whereas, water reclamation is defined as the beneficial use of treated wastewater for such planned uses as irrigation, industrial cooling, recreation, groundwater recharge, environmental enhancement, and other uses permitted under California law; and

Whereas, the Governor of California has made water reclamation an important element of California's water supply policy; and

Whereas, the California State Legislature has adopted statewide goals for water reclamation providing 700,000 acre-feet by the year 2000; 1,000,000 acre-feet by the year 2010 so as to help the state meet its future water needs; and

Whereas, the Department of Water Resources estimates that California will need to increase its water supply by 3,000,000 to 5,000,000 acre-feet by 2020, which includes an assumption that 1,300,000 acre-feet of conservation will be achieved by then; and

Whereas, the Bureau of Reclamation is currently engaged in several water conservation and reuse projects and plans to help promote water saving throughout California and the West.

Whereas, the amount of water reclaimed in California has increased from 145,000 acre-feet per year in 1977 to over 380,000 acre-feet in 1993; and

Whereas, the WateReuse Association of California's 1993 survey reported that water reuse will continue to increase from 380,000 acre-feet per year in 1993 to a projected 1,000,000 acre-feet in 2000 and to a projected 1,300,000 acre-feet by 2010, and that the major constraints to achieving these levels of reuse appear to be funding, institutional and regulatory disincentives, the permitting process, and public acceptance; and

Whereas, California's extensive experience with water reclamation provides reasonable assurance that the potential public health risks associated with water reclamation in California are minimal, provided all regulations pertaining to water quality, monitoring, reporting, and reliability are adhered to; and

Whereas, California law and regulations are fully protective of human health and require a specific level of water quality and treatment corresponding to each beneficial use of reclaimed water; and

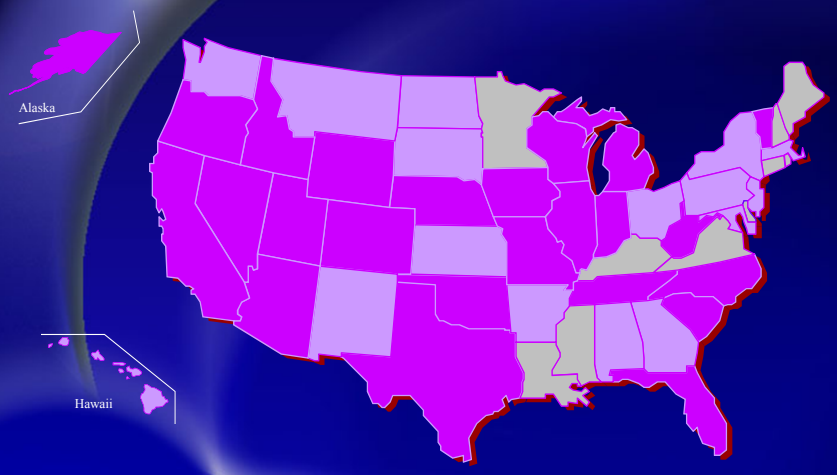
Whereas, this set of laws and regulations also provides general requirements and provisions which reclaimed water purveyors and users must comply, including monitoring and reliability requirements to further assure that use of reclaimed water is safe; and

Whereas, Congress established pollution prevention as a "national objective" in the Pollution Prevention Act of 1990 and EPA has adopted pollution prevention as the new environmental ethic, and EPA's definition of pollution prevention, pursuant to the Act, includes increased efficiency in the use of water.

Now, therefore, be it resolved on this first day of June 1994, the undersigned agencies support the pursuit and development of federal, state, and local water reclamation policies and regulations that will reduce constraints and promote water reclamation. Specifically, the agencies will work to overcome and reduce institutional and regulatory disincentives and funding constraints, and to promote public acceptance of water reclamation. The agencies will cooperate to develop specific policies and resource commitments that will enable the State of California to meet the Legislature's water reclamation goals and to help satisfy the State's overall water needs.

Government Actions and Policies

Status in 2003



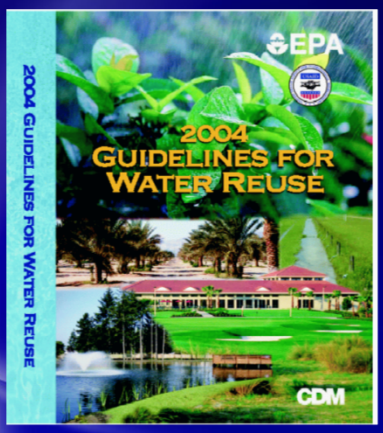
- Guidelines
- Regulations

2004 *Guidelines for Water Reuse*

EPA 625/R-04/108; August 2004

http://www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.pdf

http://www.epa.gov/ttbnrmrl/



Regulations and Guidelines Vary Depending on Type of Reuse

- Indirect potable reuse
- Agricultural Reuse on Food Crops
- Unrestricted Recreational Reuse
- Unrestricted Urban Irrigation Reuse
- Restricted Urban Irrigation Reuse
- Restricted Recreational Reuse
- Industrial Reuse
- Environmental Reuse
- Agricultural Reuse on Non-food Crops

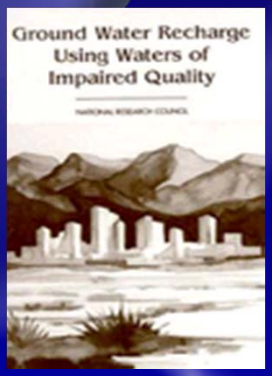
More Stringent Regulations

↓

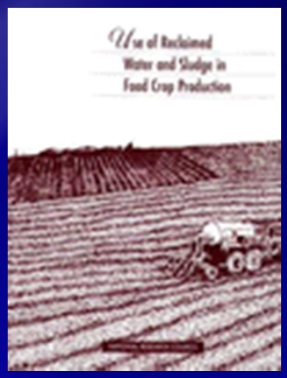
Less Stringent Regulations

NRC/NAS Reviews

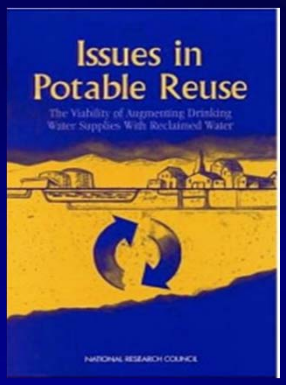
1994



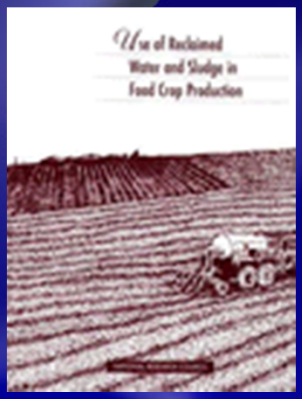
1996



1998



1996



20 *The Use of Reclaimed Water and Sludge in Food Crop Production*

TABLE 2.1 Composition of Secondary Treated Municipal Wastewater Effluents and Irrigation Water

Parameter	Secondary Effluent[a] Range	Typical	Colorado River[b]	Irrigation Water Quality Criteria[c]
Total Solids	U	425	U	NA
Total Dissolved Solids	200-1300	400	668.0	<2000
pH	6.8-7.7	7.0	7.9	6.5-8.4
Biochemical Oxygen Demand	2-50	25	U	NA
Chemical Oxygen Demand	25-100	70	U	NA
Total Nitrogen	10-30	20	U	<30
Ammonia Nitrogen	0.1-25	10	U	NA
Nitrate Nitrogen	1-20	8	0.1-1.2	NA
Total Phosphorus	5-40	10	<0.02	NA
Chloride	50-500	75	55-77	<350
Sodium	50-400	100	71-97	<70
Potassium	10-30	15	4-6	NA
Calcium	25-100	50	66-163	NA
Magnesium	10-50	20	23-28	NA
Boron	0.3-2.5	0.5	0.10-0.54	<3.0
Cadmium (ug/L)	<5-220	<5	<1-69	10
Copper (ug/L)	5-50	20	<10-10	200
Nickel (ug/L)	5-500	10	<1-4	200
Lead (ug/L)	1-200	5	<5	5000
Zinc (ug/L)	10-400	40	<3-12	2000
Chromium (ug/L)	<1-100	1	<1	100
Mercury (ug/L)	<2-10	2	<0.1-0.1	NA
Molybdenum (ug/L)	1-20	5	2-8	10
Arsenic (ug/L)	<5-20	<5	4-16	100

All units in milligrams per liter unless otherwise noted as micrograms per liter (ug/L). U: unavailable. NA: not applicable.

[a] Adapted from Asano et al., 1984 and Treweek, 1985

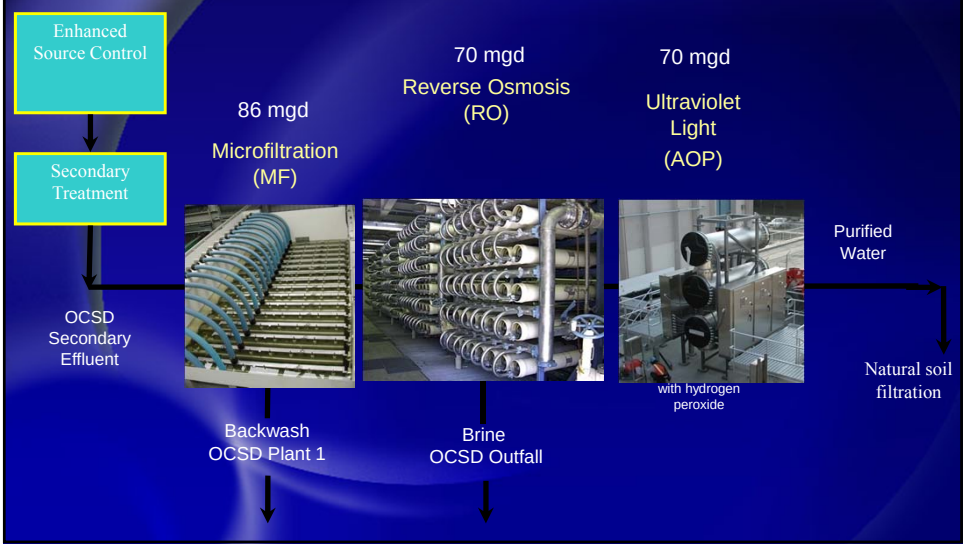
[b] Radtke, et. al., 1988

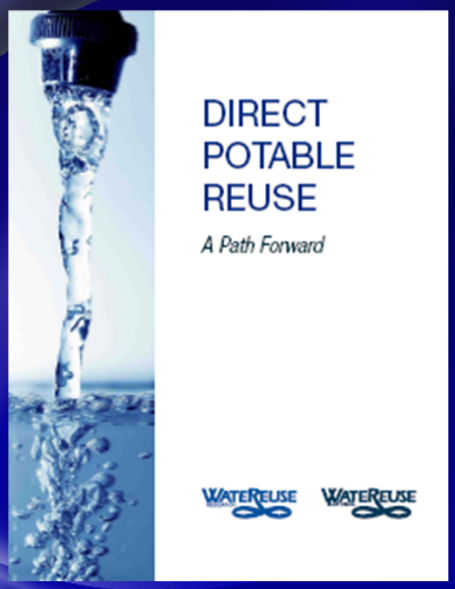
[c] from Westcot and Ayers, 1985 and National Academy of Sciences, 1973

NRC/NAS Reviews
2004
2008
2011
REVIEW OF THE
DESALINATION AND
WATER PURIFICATION
TECHNOLOGY ROADMAP
DESALINATION
A NATIONAL PERSPECTIVE
WSTB/NAS
Assessment of Water Reuse as an Approach for Meeting Future U.S. Water Supply Needs

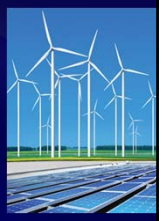
THIS FIXTURE USES
NON-POTABLE RECLAIMED
WATER-DO NOT DRINK

GWR System (OCWD and OCSD)
Advanced Water Treatment Flow Diagram



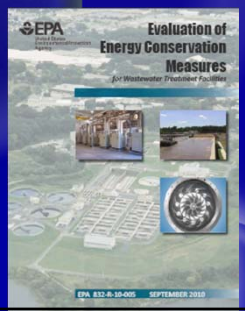


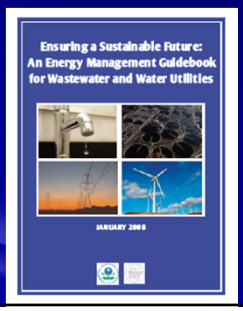
Current/Future Focus

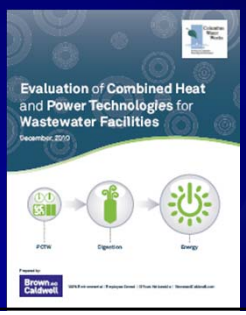


- ENERGY
  - IMPROVED ENERGY EFFICIENCY
  - ENERGY SELF SUFFICIENT
    - ONSITE HEAT & POWER PRODUCTION
    - ALTERNATIVE ENERGY SOURCES
  - NET EXPORTERS OF ENERGY?

ENERGY STAR
Portfolio Manager







Current/Future Focus

- CARBON FOOTPRINT / GHG EMISSIONS
  - REDUCED FOOTPRINT
  - ZERO CARBON FOOTPRINT
  - CARBON NEUTRAL THRU OFFSETS
- MULTIPLE BENEFITS / RESOURCE RECOVERY
  - WATER REUSE
  - WETLANDS / HABITAT RESTORATION
  - CARBON SEQUESTRATION
  - SOIL ENHANCEMENT
  - BIOFUELS, FERTILIZER RECOVERY
- INTEGRATED WATER RESOURCES MGNT.

Pearl® Process Operation

Precipitation chemistry

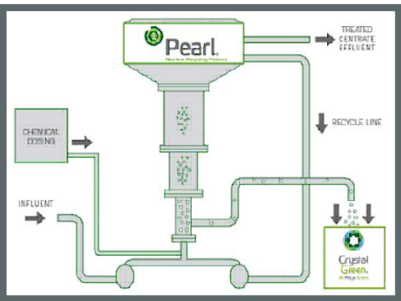
$Mg^{2+} + NH_4^+ + PO_4^{3-}$

pH

Crystal growth

Simple operation

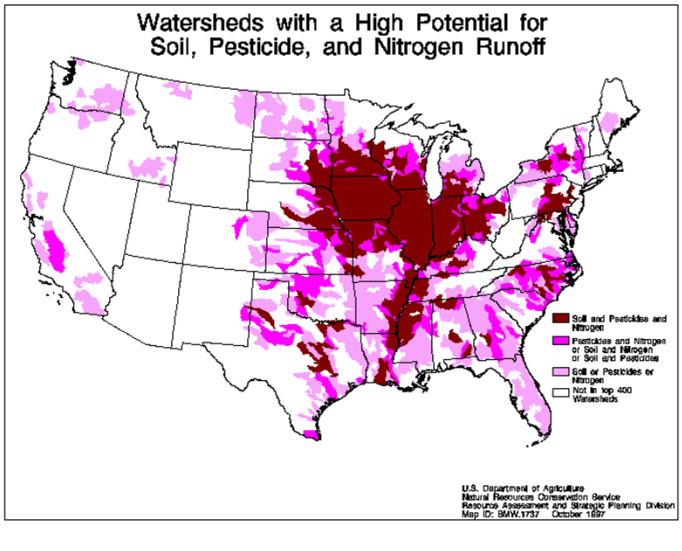
- Remote automation
- Material handling
- Sampling/analysis/calibration



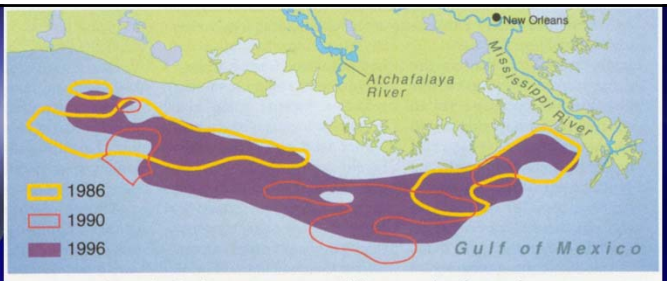
Crystal Green® fertilizer

Causes of Water Quality Impairment (303d listed waters)

General Impairment Name	Causes of Impairment Reported	Percent of Report
PATHOGENS	8563	13
MERCURY	8556	13
SEDIMENT	6858	10
METALS (OTHER THAN MERCURY)	6407	9
NUTRIENTS	5551	8
OXYGEN DEPLETION	4459	6
PH	3478	5
CAUSE UNKNOWN - BIOLOGICAL INTEGRITY	2813	4
TEMPERATURE	2786	4
HABITAT ALTERATION	2394	3
PCBS	2062	3
TURBIDITY	2009	3
CAUSE UNKNOWN	1405	2
PESTICIDES	1262	1
SALINITY/TDS/CHLORIDES	1075	1
FLOW ALTERATION	691	1
SULFATES	625	
ALGAL GROWTH	502	
AMMONIA	406	
OTHER TOXIC ORGANICS	320	
Total Causes of Impairment Reported Nationwide:	64,340	10

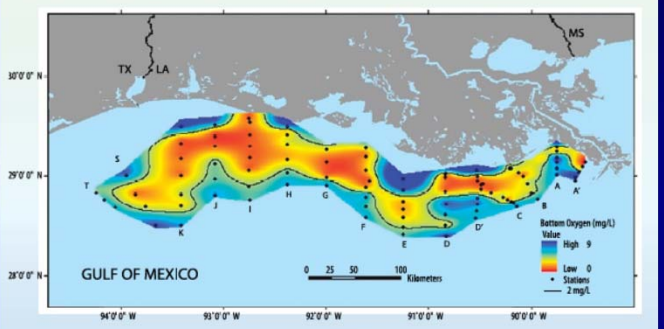


Map showing the extent of the Mississippi-Atchafalaya River basin.



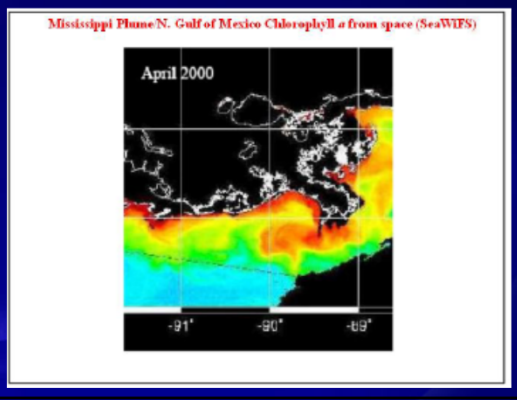
Hard to pin down. The dead zone encompasses different swaths of water from one summer to the next. Researchers are trying to find out which factors influence this shifting mosaic.

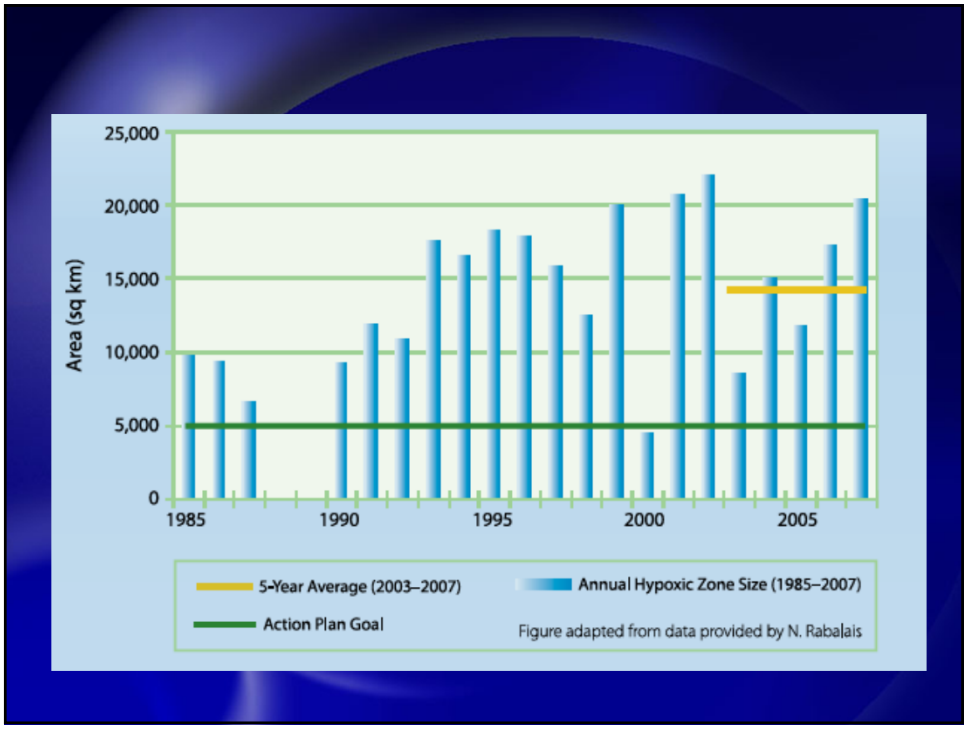
SCIENCE VOL 291 9 FEBRUARY 2001 965



Areal Extent of 2007 Hypoxic Zone

Data courtesy of N. Rabalais and A. Sapp




25,000
20,000
15,000
10,000
5,000
0
Area (sq km)
1985
1990
1995
2000
2005
5-Year Average (2003–2007)
Annual Hypoxic Zone Size (1985–2007)
Action Plan Goal
Figure adapted from data provided by N. Rabalais

Red Tides

@ PJS Franks

WHO GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER
VOLUME I POLICY AND REGULATORY ASPECTS
WHO GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER
VOLUME II WASTEWATER USE IN AGRICULTURE
WHO GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER
VOLUME III WASTEWATER AND EXCRETA USE IN AQUACULTURE
WHO GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER
VOLUME IV EXCRETA AND GREYWATER USE IN AGRICULTURE
NATIONAL WATER QUALITY MANAGEMENT STRATEGY
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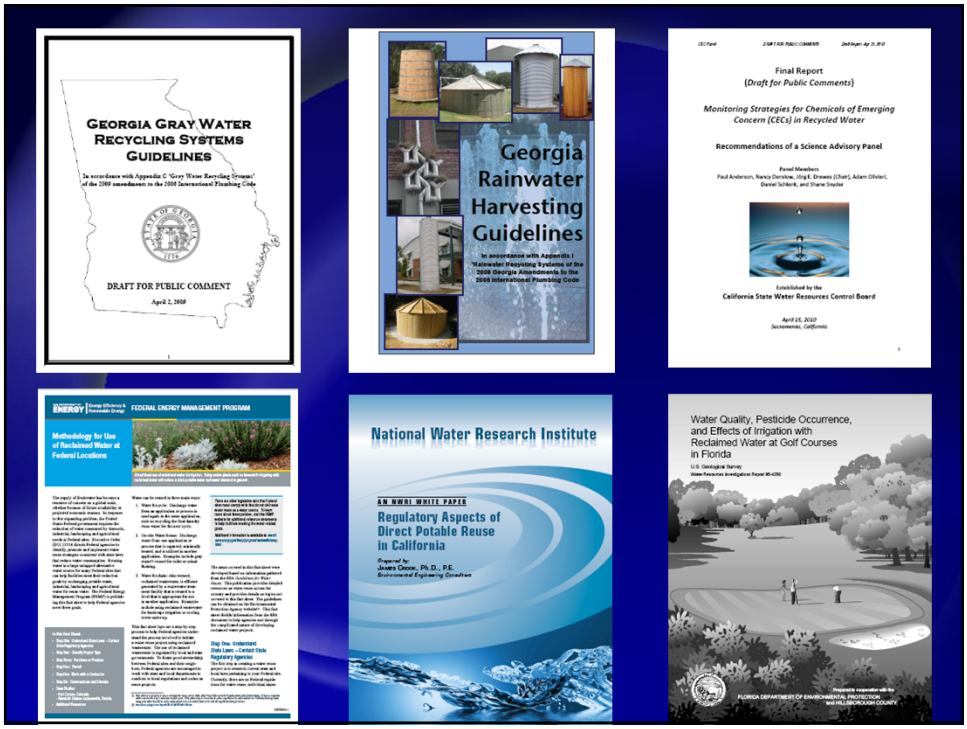
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