Day 3: Conventional Design of Combined Sewers

Regulations and Emerging Technology

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Two Categories of Sewer Systems

- Separate Sewer Systems
- Combined Sewer Systems

Captured floatable debris from combined sewer outfalls at Brooklyn, NY, study area.

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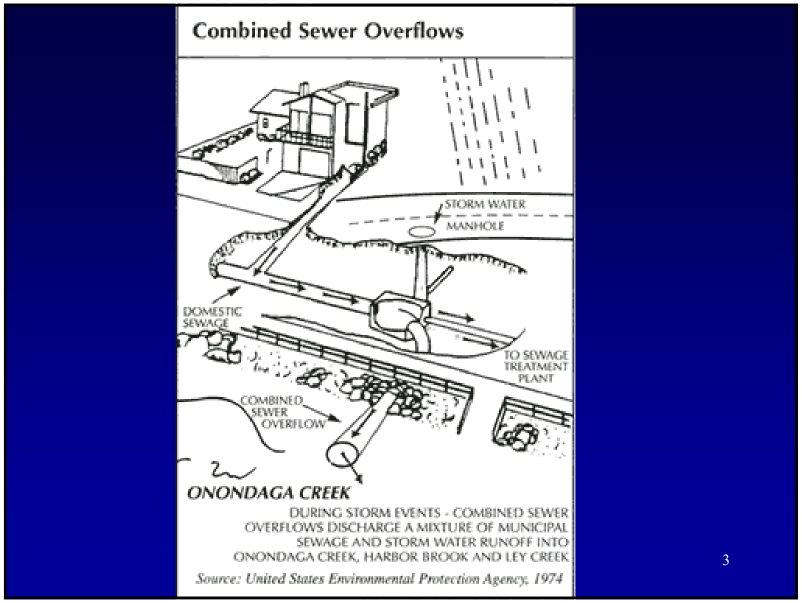

Combined Sewer Overflows

DURING STORM EVENTS - COMBINED SEWER OVERFLOWS DISCHARGE A MIXTURE OF MUNICIPAL SEWAGE AND STORM WATER RUNOFF INTO ONONDAGA CREEK, HARBOR BROOK AND LEY CREEK

Source: United States Environmental Protection Agency, 1974

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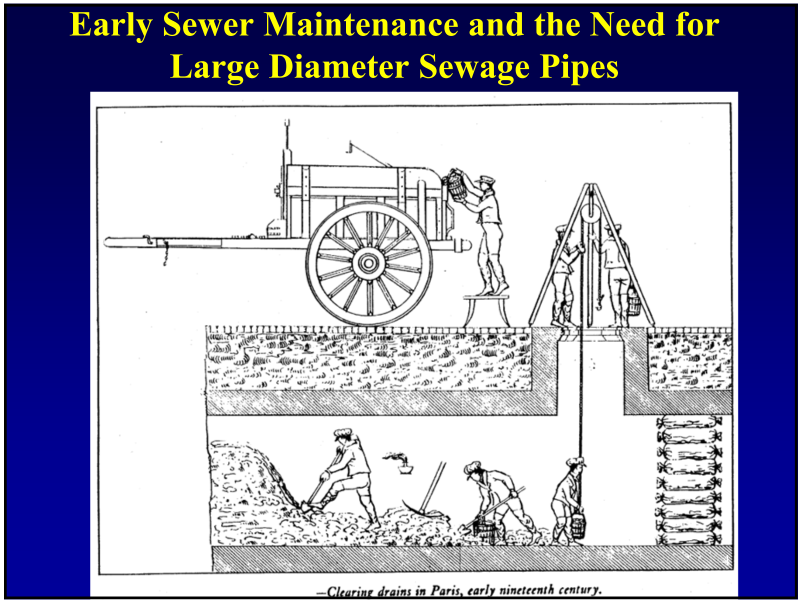
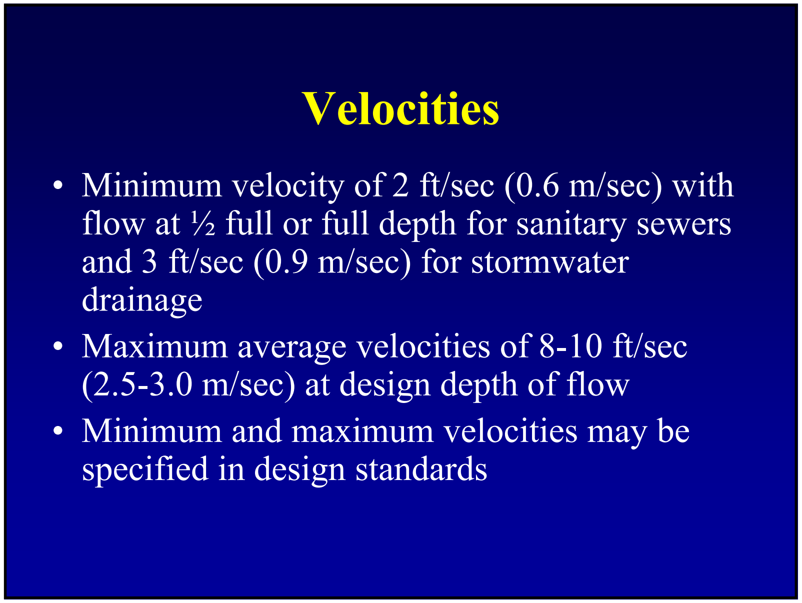


Early Sewer Maintenance and the Need for Large Diameter Sewage Pipes

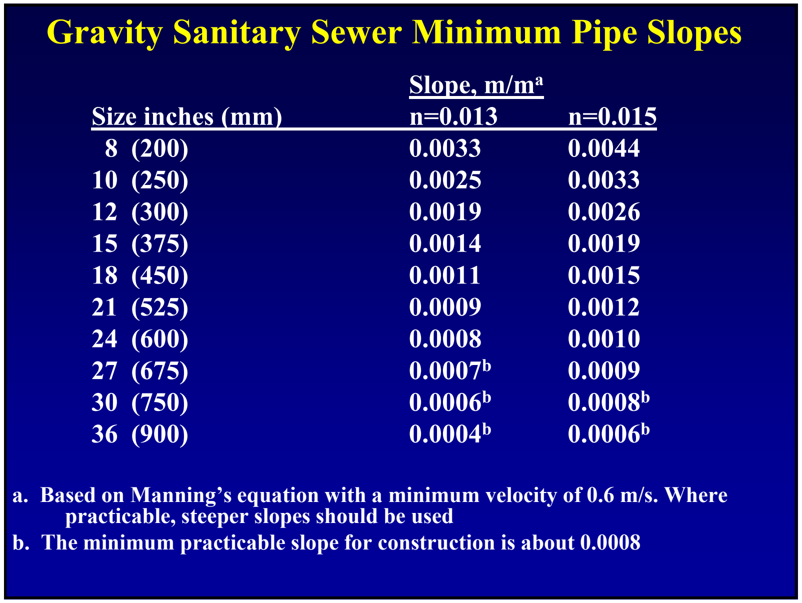
—*Clearing drains in Paris, early nineteenth century.*

4



Velocities

- Minimum velocity of 2 ft/sec (0.6 m/sec) with flow at ½ full or full depth for sanitary sewers and 3 ft/sec (0.9 m/sec) for stormwater drainage
- Maximum average velocities of 8-10 ft/sec (2.5-3.0 m/sec) at design depth of flow
- Minimum and maximum velocities may be specified in design standards

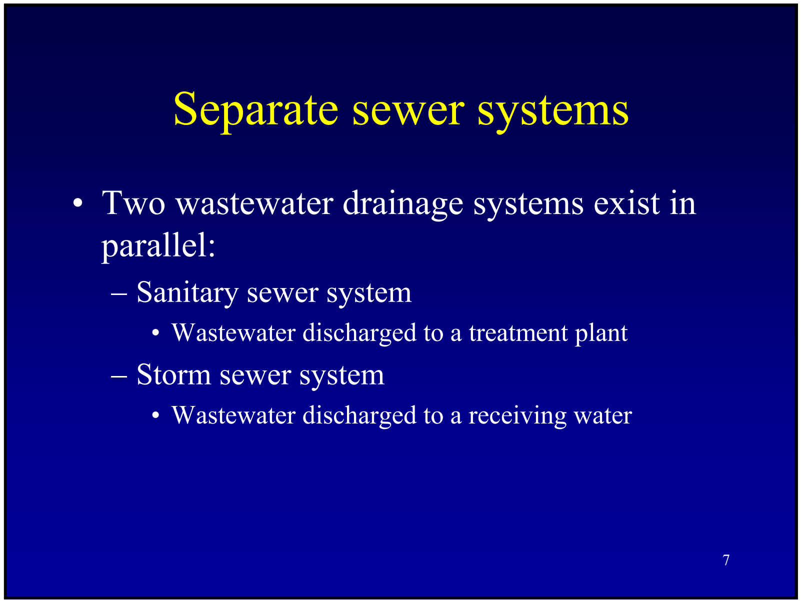


Gravity Sanitary Sewer Minimum Pipe Slopes

	Slope, m/m[a]	
Size inches (mm)	n=0.013	n=0.015
8 (200)	0.0033	0.0044
10 (250)	0.0025	0.0033
12 (300)	0.0019	0.0026
15 (375)	0.0014	0.0019
18 (450)	0.0011	0.0015
21 (525)	0.0009	0.0012
24 (600)	0.0008	0.0010
27 (675)	0.0007[b]	0.0009
30 (750)	0.0006[b]	0.0008[b]
36 (900)	0.0004[b]	0.0006[b]

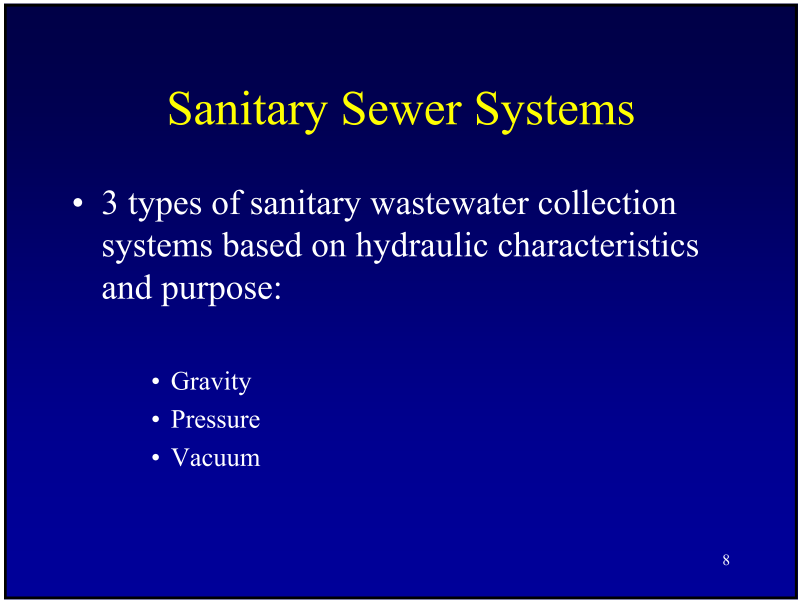
[a] Based on Manning's equation with a minimum velocity of 0.6 m/s. Where practicable, steeper slopes should be used

[b] The minimum practicable slope for construction is about 0.0008



Separate sewer systems

- Two wastewater drainage systems exist in parallel:
  - Sanitary sewer system
    - Wastewater discharged to a treatment plant
  - Storm sewer system
    - Wastewater discharged to a receiving water



Sanitary Sewer Systems

- 3 types of sanitary wastewater collection systems based on hydraulic characteristics and purpose:
    - Gravity
    - Pressure
    - Vacuum

Gravity Sanitary Sewer

- Most common
- Wastewater transported by gravity
- Used to collect wastewater from residential, commercial, industrial, and institutional sources.
- Conveyance capacity allowances must be made for groundwater infiltration and unavoidable inflow

Pressure (Pumped) Sanitary Sewer

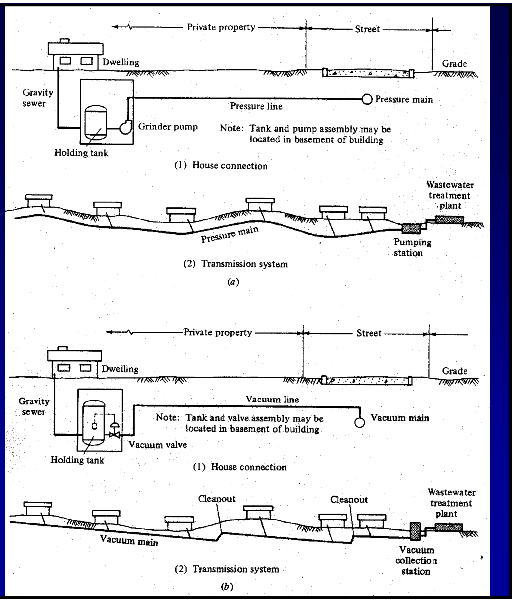
- Wastewater transported under pressure
- Used principally to collect wastewater from residential sources in locations unsuitable for the construction and/or use of gravity sewers
- They are also used to collect wastewater from commercial sources, but only rarely from industrial sources because of the large volumes that may be involved.
- These systems are usually small and are designed to exclude groundwater infiltration and stormwater inflow.

Vacuum Sanitary Systems

- Wastewater transported in a vacuum
- Otherwise, same as for pressure systems

Pressure Sewer System

Vacuum Sewer System



Industrial Wastewater Collection Options

- Discharge to sanitary sewer for treatment at a publicly owned wastewater treatment plant
- Partial treatment on site, followed by discharge to sanitary sewer for treatment at a publicly owned wastewater treatment plant (pre-treatment)
- Complete treatment to permit specifications on site, followed by release to receiving water

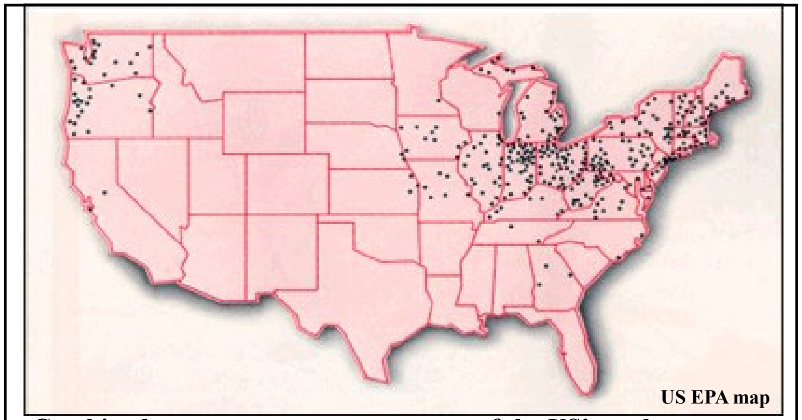
Storm Sewer Systems

- Almost always gravity-flow systems due to large quantities of stormwater
- Collect stormwater from streets, roofs and other sources
- Sanitary wastewater is (in theory) totally excluded
  - Plumbing cross connections
  - Leaking sanitary sewers
  - Sanitary sewer overflows
  - Failing septic tanks

Storm drains flow directly to receiving waters

Combined Sewer Systems

- About 15% of communities in the U.S. have a single sewer system that handles both sanitary wastewater and stormwater in the same piping system.
- Most of these are found in older cities with populations of over 100,000.
- Most regulations now permit the construction of separate sewers only, and expensive projects to separate, or provide partial treatment to combined sewage, is required.
- Combined systems still commonly constructed outside of the US, many include integrated storage and treatment systems



US EPA map

Combined sewer systems are remnants of the US's early infrastructure and are therefore usually found in older communities. Combined sewer systems serve almost 800 communities having about 40 million people (and about 10,000 CSO outfalls). Most are located in the Northeast and Great Lakes regions, and the Pacific Northwest

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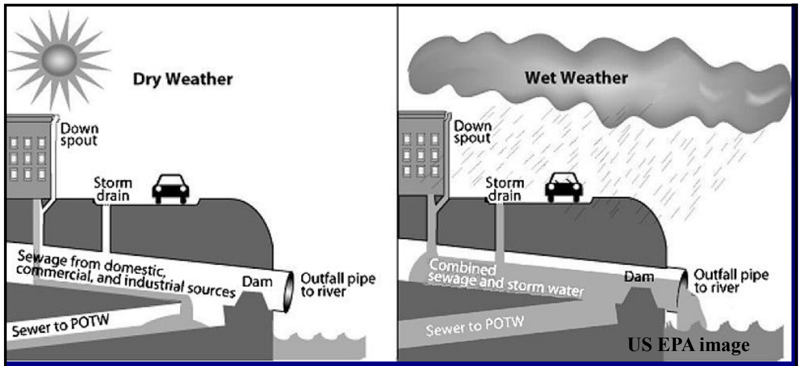


US EPA image

Simple combined sewer and overflow controlled by an outfall weir as commonly found in the U.S.

POTW: Public Owned Treatment Works

Sanitary Sewer Overflow (SSO)

SSO water mixing with receiving water

CSO discharge location at a public swimming beach

Report to Congress: *Impacts and Control of Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)* (2004)

http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm

- EPA estimates that about 850 billion gallons of untreated wastewater and stormwater are released as CSOs each year in the United States.
- Because CSOs contain raw sewage along with large volumes of stormwater and contribute pathogens, solids, debris, and toxic pollutants to receiving waters, CSOs can create significant public health and water quality concerns. CSOs have contributed to beach closures, shellfish bed closures, contamination of drinking water supplies, and other environmental and public health concerns

What recommendations does the Report to Congress make?

- Providing adequate funding for maintenance and improvement of the nation’s wastewater infrastructure;
- integrating of wastewater programs and activities at the watershed level;
- improving monitoring and reporting programs to provide better data for decision-makers; and
- supporting stronger partnerships among federal and state agencies, municipalities, industry, non-governmental organizations, and citizens.

Combined Sewer Overflows Nine Minimum Controls (1994)

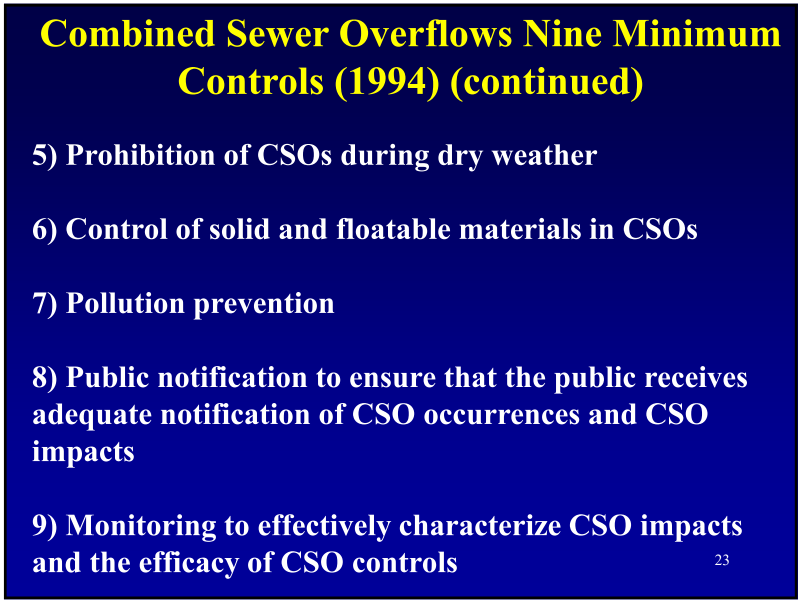
http://cfpub.epa.gov/npdes/cso/ninecontrols.cfm?program_id=5

1) Proper operation and regular maintenance programs for the sewer system and the CSOs

2) Maximum use of the collection system for storage

3) Review and modification of pretreatment requirements to assure CSO impacts are minimized

4) Maximization of flow to the publicly owned treatment works for treatment



Combined Sewer Overflows Nine Minimum Controls (1994) (continued)

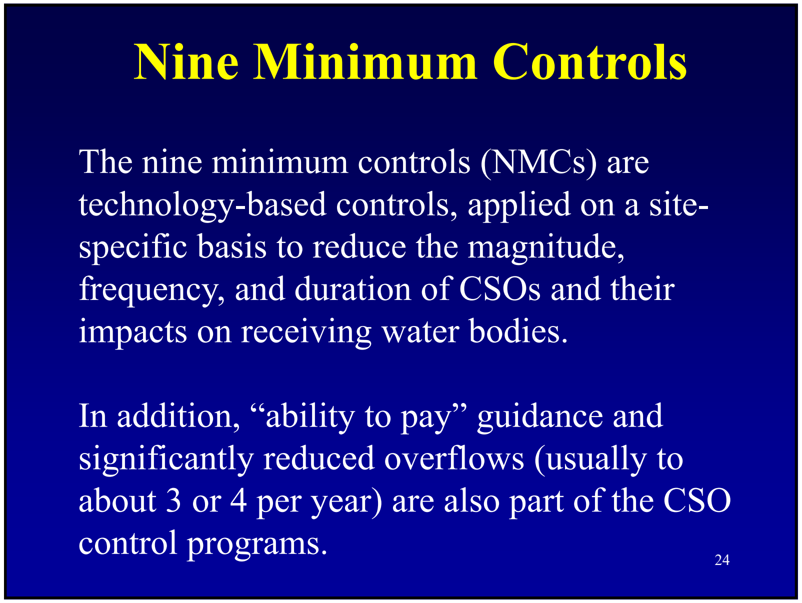
5) Prohibition of CSOs during dry weather

6) Control of solid and floatable materials in CSOs

7) Pollution prevention

8) Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts

9) Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls



Nine Minimum Controls

The nine minimum controls (NMCs) are technology-based controls, applied on a site-specific basis to reduce the magnitude, frequency, and duration of CSOs and their impacts on receiving water bodies.

In addition, “ability to pay” guidance and significantly reduced overflows (usually to about 3 or 4 per year) are also part of the CSO control programs.

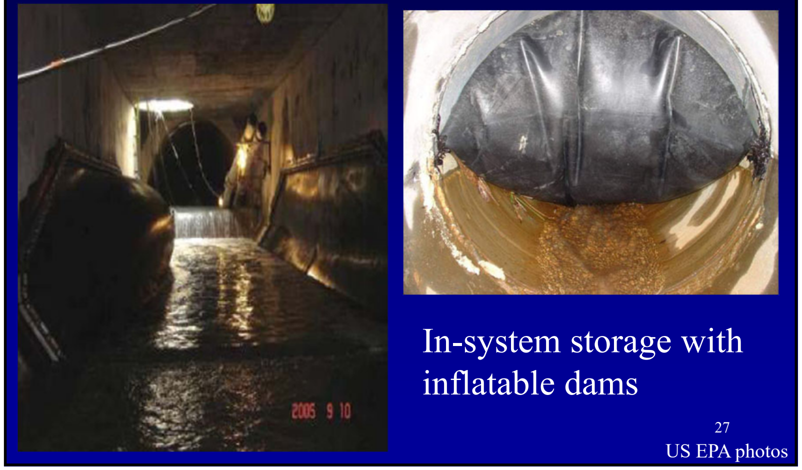
1) Proper operation and regular maintenance programs for the sewer system and the CSOs

Sealing and inspections to ensure minimal infiltration and inflow (I&I)

EPA photos

Re-lining of a large sanitary sewer to reduce infiltration

2) Maximum use of the collection system for storage



In-system storage with inflatable dams

US EPA photos

3) Review and modification of pretreatment requirements to assure CSO impacts are minimized

King County, Washington and Akron, Ohio, web pages describing industrial pre-treatment and local hazardous waste management programs

County closures: Fri, Sept. 4, many county offices will be closed and staff will be on unpaid furlough. Please note exceptions, such as courts and the Office of the Public Defender. All offices are closed Mon, Sept. 7 for Labor Day.

King County Industrial Waste Program (KCIW)

You're in: Industrial Waste Program

The King County Industrial Waste Program (KCIW) administers regulations that allow it to give approval to discharge industrial wastewater to the King County sewer system.

Our regulations are designed to prevent businesses from discharging substances that can degrade the wastewater treatment process, harm workers or facilities, or impact surface-water quality. Since 1969, the KCIW has required many industries to pretreat wastewater before discharging it into the sewer.

Protecting water quality is a sound business investment. The region is committed to improving its natural resources, including water. This means that businesses and regulators must work together to find better ways to manage waste.

The program's mission statement: The mission of the Industrial Waste Program is to

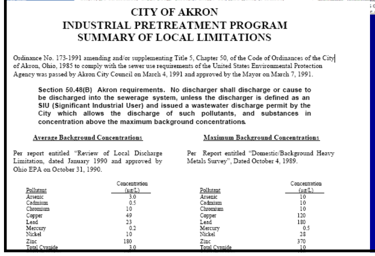
Related King County agency

Wastewater Treatment Division

KCIW updates:

(8/24/09) KCIW will hold a free industrial user workshop on Weds. Oct. 7 for wastewater dischargers with active permits and discharge approvals...

(7/10/09) Collection of sewer charges for certain discharges: In 2008 -09 KCIW has been working with local sewer agencies to ensure more consistent collection of sewer charges for contaminated industrial stormwater, groundwater remediation



CITY OF AKRON
INDUSTRIAL PRETREATMENT PROGRAM
SUMMARY OF LOCAL LIMITATIONS

Ordinance No. 173-1991 amending and/or supplementing Title 5, Chapter 50, of the Code of Ordinances of the City of Akron, Ohio, 1985 to comply with the sewer use requirements of the United States Environmental Protection Agency was passed by Akron City Council on March 4, 1991 and approved by the Mayor on March 7, 1991.

Section 50.48(B) Akron requirements. No discharger shall discharge or cause to be discharged into the sewerage system, unless the discharger is defined as an SIU (Significant Industrial User) and issued a wastewater discharge permit by the City which allows the discharge of such pollutants, and substances in concentration above the maximum background concentrations.

Average Background Concentrations

Per report entitled "Review of Local Discharge Limitation, dated January 1990 and approved by Ohio EPA on October 31, 1990.

Pollutant	Concentration (µg/L)
Arsenic	3.0
Cadmium	0.5
Chromium	10
Copper	49
Lead	23
Mercury	0.2
Nickel	10
Zinc	180
Total Cyanide	3.0

Maximum Background Concentrations

Per Report entitled "Domestic/Background Heavy Metals Survey", Dated October 4, 1989.

Pollutant	Concentration (µg/L)
Arsenic	10
Cadmium	10
Chromium	10
Copper	120
Lead	180
Mercury	0.5
Nickel	28
Zinc	370
Total Cyanide	10

Welcome to the home page for the Local Hazardous Waste Management Program in King County, Washington. We are a regional program of local governments working together to protect public health and environmental quality by reducing the threat posed by the production, use, storage, and disposal of hazardous materials.

We offer information and services to help 1.8 million residents and 54,000 businesses and other groups reduce toxic and hazardous materials, safely use and store hazardous materials and properly dispose of hazardous wastes. For more information, click below:

- Health Update
- Household services
- Services for businesses and other groups
- Services for schools and youth
- Agencies working together

Events Calendar

Wastemobile Collection Event - Burien/SeaTac
Sep 11 - Sep 13

Wastemobile Collection Event - Covington/Maple Valley/Black Diamond
Sep 18 - Sep 20

Wastemobile Collection Event - Redmond
Sep 25 - Sep 27

Northwest Children's Environmental Health Forum and Fair
Oct 1 - Oct 2

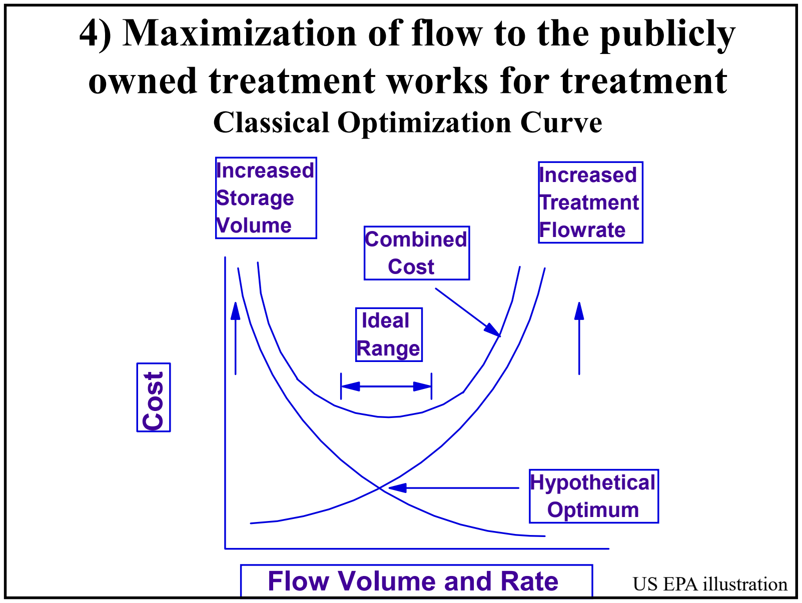
More Events »

Program Highlights

New hazardous waste collection service offered in South King County

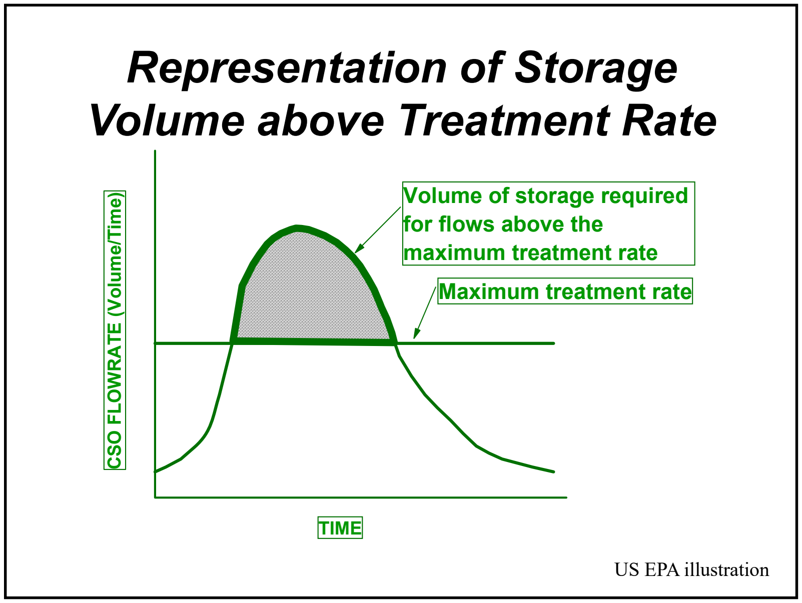
4) Maximization of flow to the publicly owned treatment works for treatment

Classical Optimization Curve



US EPA illustration

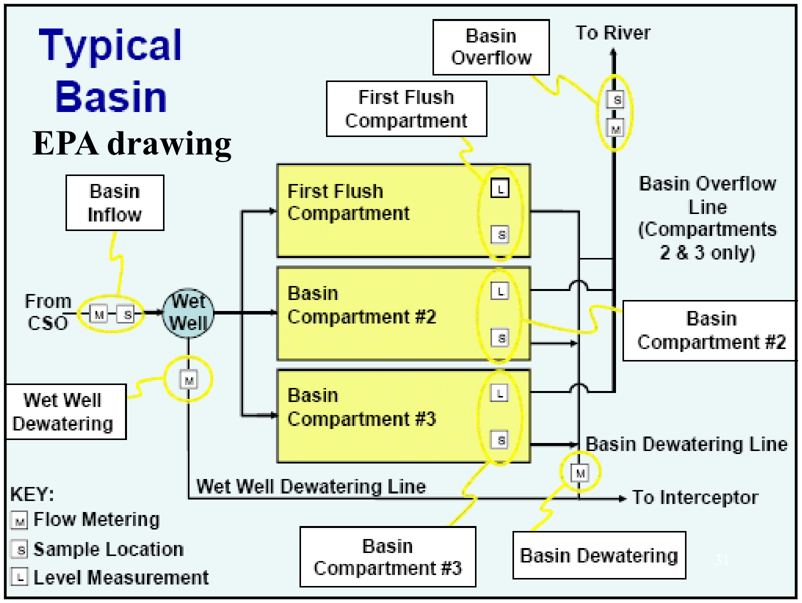
Representation of Storage Volume above Treatment Rate



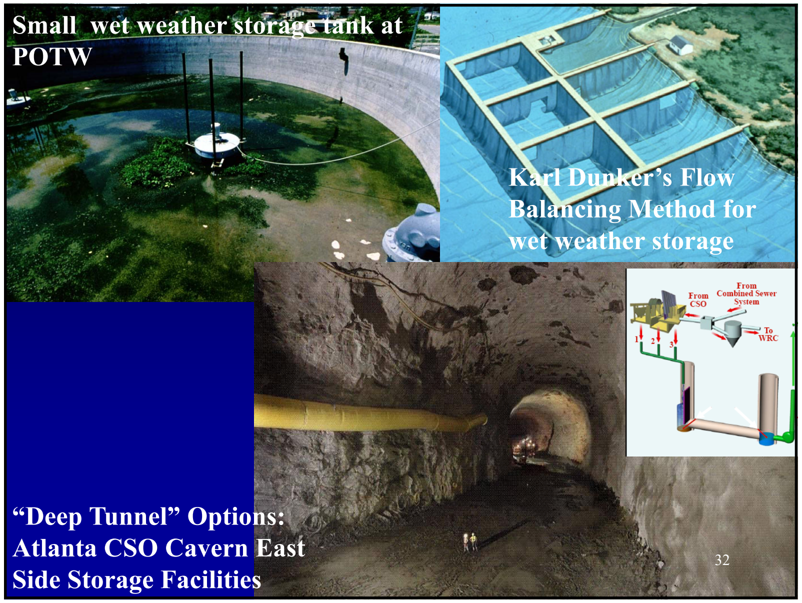
US EPA illustration

Typical Basin

EPA drawing



KEY:
- M Flow Metering
- S Sample Location
- L Level Measurement

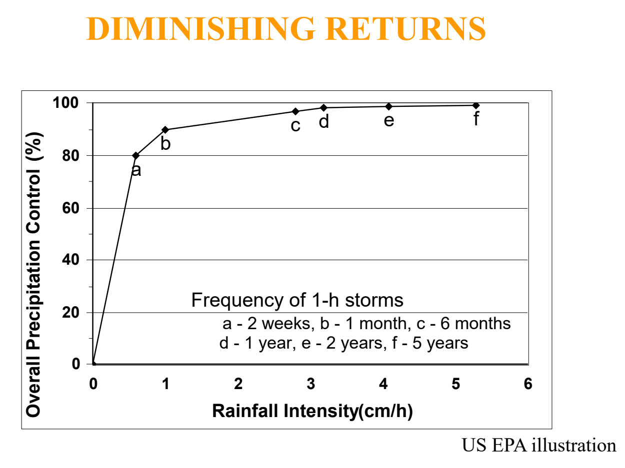


Small wet weather storage tank at POTW

Karl Dunker's Flow Balancing Method for wet weather storage

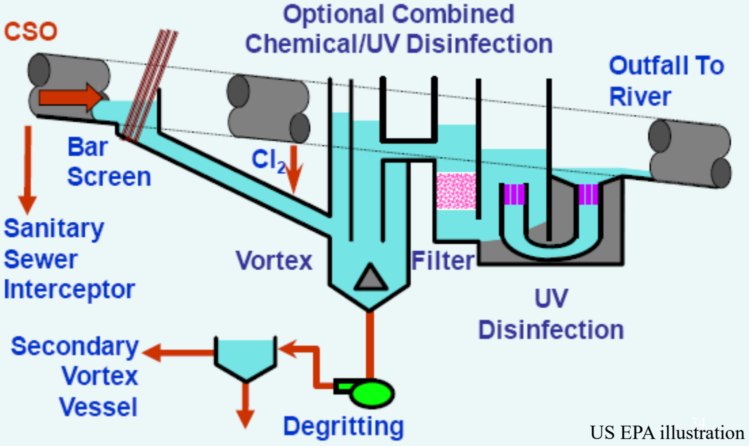
"Deep Tunnel" Options: Atlanta CSO Cavern East Side Storage Facilities

Enhanced Treatment at High Flow Rates

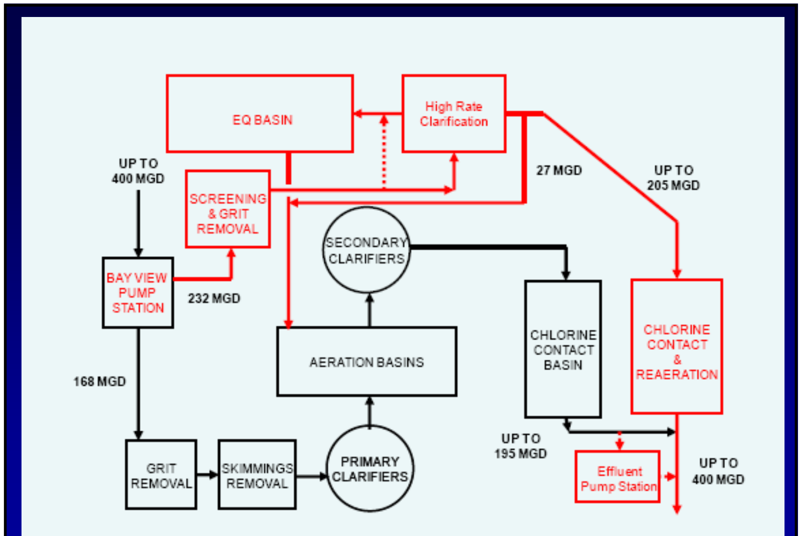


US EPA illustration

High Quality Treatment After Storage Capacity Is Exceeded



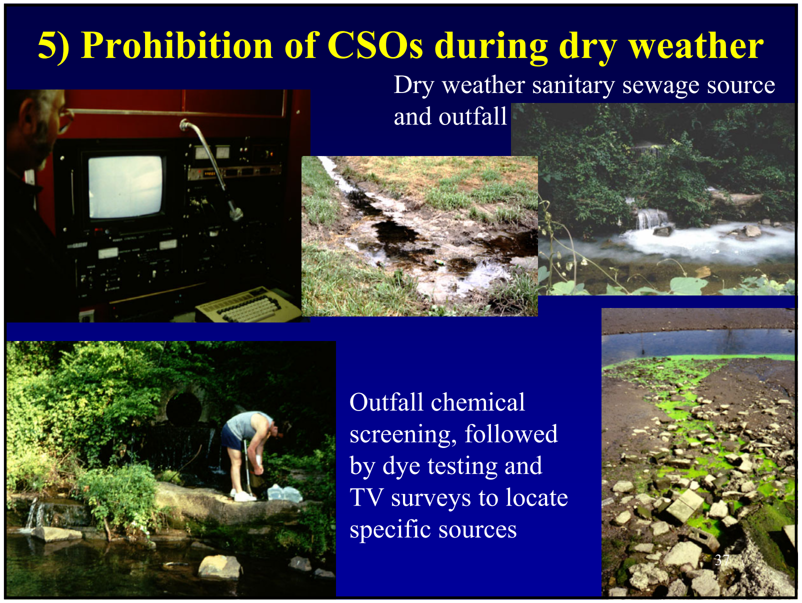
US EPA illustration



NEW WET WEATHER FACILITIES

US EPA illustration

Wetland Treatment of CSO discharges; Rouge River National Demonstration Project, Detroit, Michigan



5) Prohibition of CSOs during dry weather

Dry weather sanitary sewage source and outfall

Outfall chemical screening, followed by dye testing and TV surveys to locate specific sources

6) Control of solid and floatable materials in CSOs

Large-scale CSO screening facility

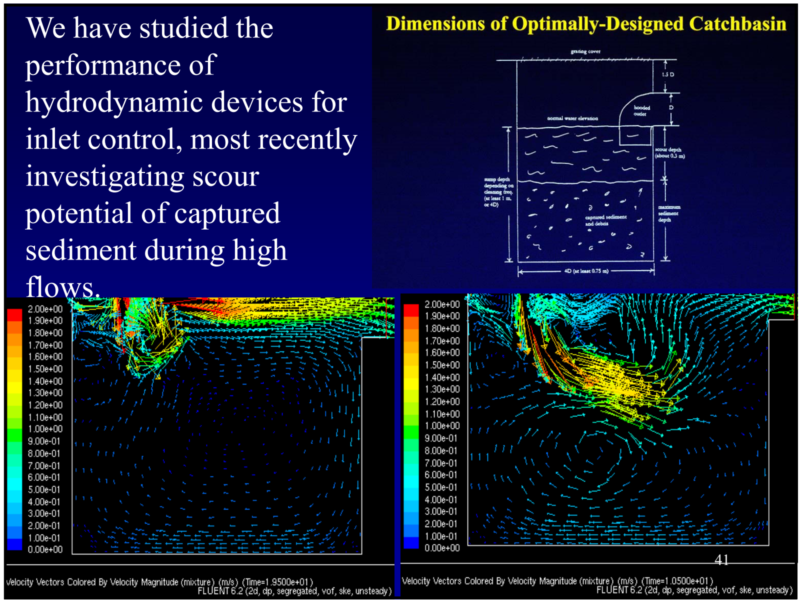
Typical CSO floatables in receiving water

Floating booms and screening nets to capture CSO floatables

7) Pollution prevention

Street cleaning, inlet screening, materials substitution, and stormwater controls are included under this category.

Street and catchbasin cleaning, and inlet controls most effective for smaller rains in heavily paved areas.

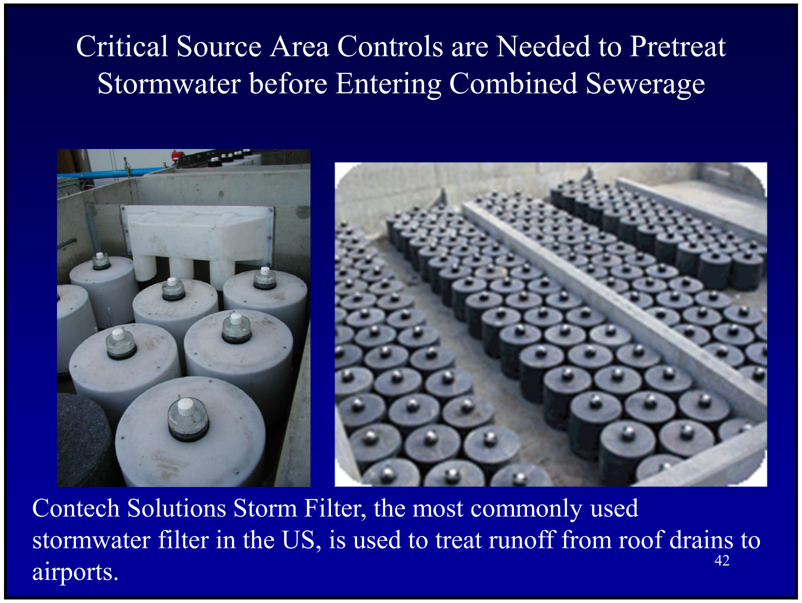


We have studied the performance of hydrodynamic devices for inlet control, most recently investigating scour potential of captured sediment during high flows.

Dimensions of Optimally-Designed Catchbasin

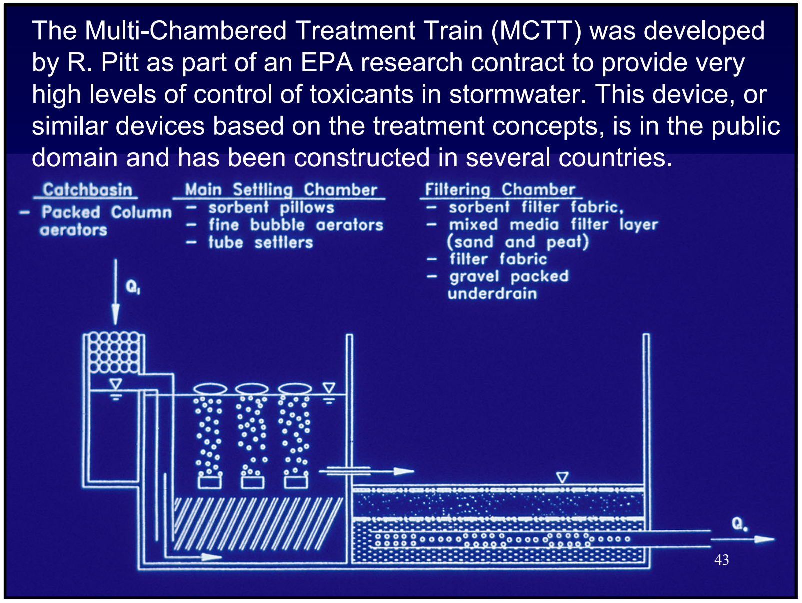
Velocity Vectors Colored By Velocity Magnitude (mixture) (m/s) (Time=1.9500e+01)
FLUENT 6.2 (2d, dp, segregated, vof, ske, unsteady)

Velocity Vectors Colored By Velocity Magnitude (mixture) (m/s) (Time=1.0500e+01)
FLUENT 6.2 (2d, dp, segregated, vof, ske, unsteady)



Critical Source Area Controls are Needed to Pretreat Stormwater before Entering Combined Sewerage

Contech Solutions Storm Filter, the most commonly used stormwater filter in the US, is used to treat runoff from roof drains to airports.



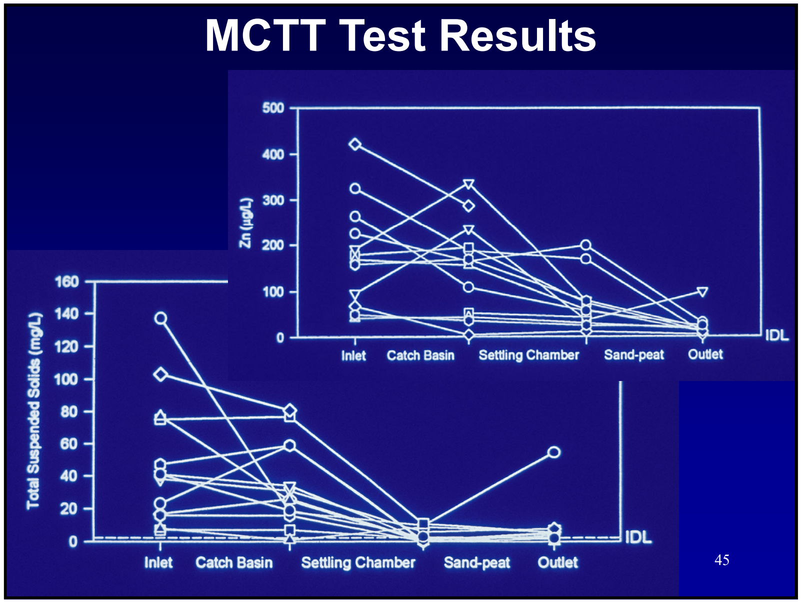
The Multi-Chambered Treatment Train (MCTT) was developed by R. Pitt as part of an EPA research contract to provide very high levels of control of toxicants in stormwater. This device, or similar devices based on the treatment concepts, is in the public domain and has been constructed in several countries.

Catchbasin
- Packed Column aerators

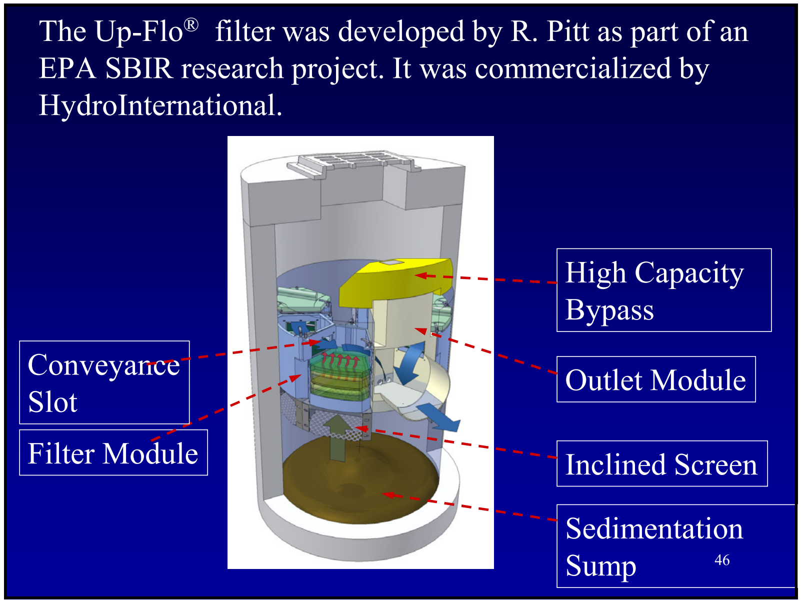
Main Settling Chamber
- sorbent pillows
- fine bubble aerators
- tube settlers

Filtering Chamber
- sorbent filter fabric,
- mixed media filter layer (sand and peat)
- filter fabric
- gravel packed underdrain

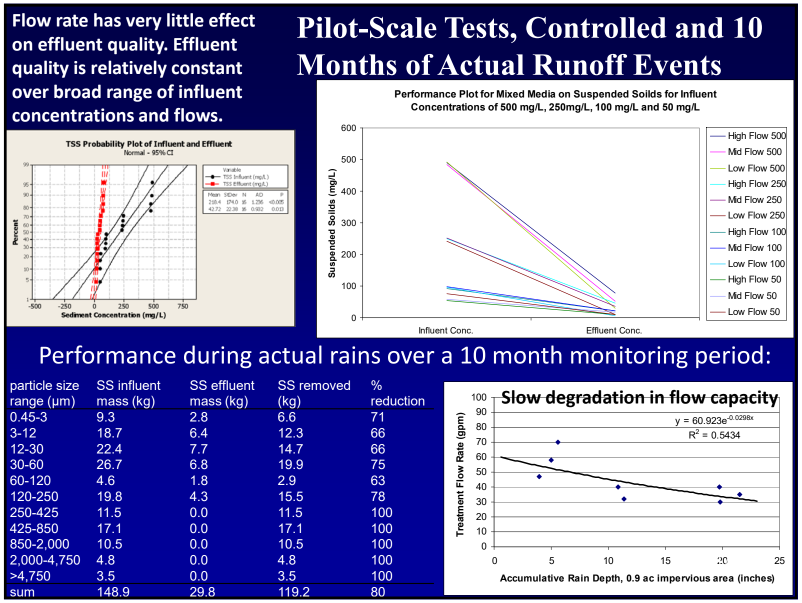
Minocqua, WI, MCTT Installation



MCTT Test Results



The Up-Flo® filter was developed by R. Pitt as part of an EPA SBIR research project. It was commercialized by HydroInternational.



Flow rate has very little effect on effluent quality. Effluent quality is relatively constant over broad range of influent concentrations and flows.

Pilot-Scale Tests, Controlled and 10 Months of Actual Runoff Events

Performance during actual rains over a 10 month monitoring period:

particle size range (µm)	SS influent mass (kg)	SS effluent mass (kg)	SS removed (kg)	% reduction
0.45-3	9.3	2.8	6.6	71
3-12	18.7	6.4	12.3	66
12-30	22.4	7.7	14.7	66
30-60	26.7	6.8	19.9	75
60-120	4.6	1.8	2.9	63
120-250	19.8	4.3	15.5	78
250-425	11.5	0.0	11.5	100
425-850	17.1	0.0	17.1	100
850-2,000	10.5	0.0	10.5	100
2,000-4,750	4.8	0.0	4.8	100
>4,750	3.5	0.0	3.5	100
sum	148.9	29.8	119.2	80

Slow degradation in flow capacity

High Zinc Concentrations have been Found in Roof Runoff for Many Years at Many Locations

- Typical Zn in stormwater is about 100 µg/L, with industrial area runoff usually several times this level.
- Water quality criteria for Zn is as low as 100 µg/L for aquatic life protection in soft waters, up to about 5 mg/L for drinking waters.
- Zinc in runoff from galvanized roofs can be several mg/L

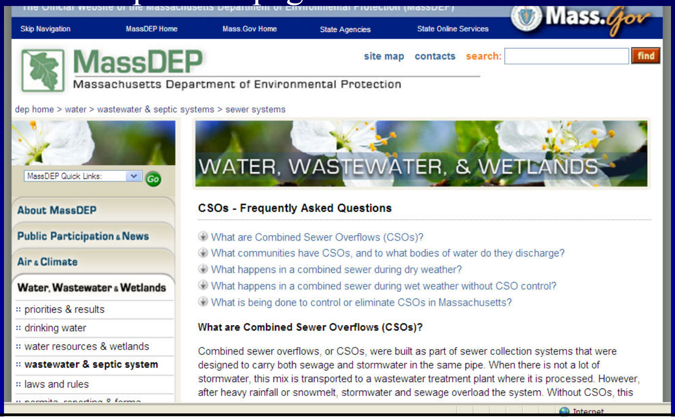
• Other pollutants and other materials also of potential concern.

• A cost-effective stormwater control strategy should include the use of materials that have reduced effects on runoff degradation.

Penn State – Harrisburg test facility

8) Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts

Example web page from Massachusetts



The Official Website of the Massachusetts Department of Environmental Protection (MassDEP)

CSOs - Frequently Asked Questions

- What are Combined Sewer Overflows (CSOs)?
- What communities have CSOs, and to what bodies of water do they discharge?
- What happens in a combined sewer during dry weather?
- What happens in a combined sewer during wet weather without CSO control?
- What is being done to control or eliminate CSOs in Massachusetts?

What are Combined Sewer Overflows (CSOs)?

Combined sewer overflows, or CSOs, were built as part of sewer collection systems that were designed to carry both sewage and stormwater in the same pipe. When there is not a lot of stormwater, this mix is transported to a wastewater treatment plant where it is processed. However, after heavy rainfall or snowmelt, stormwater and sewage overload the system. Without CSOs, this

Public Education Activities

Fish consumption warning

Presentations at schools

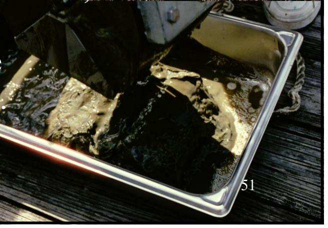
Aquarium exhibit

Signage at in-stream aeration system

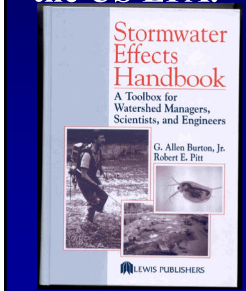
Volunteer stream monitoring

9) Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls

Many in-stream and CSO discharge attributes need to be monitored, including rainfall and runoff quantity, chemical and physical characteristics, and biological conditions in the receiving waters.



Monitoring guidance is provided in the following book that was prepared with partial assistance from the US EPA.



Burton, G.A. Jr., and R. Pitt. *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

Due to partial EPA support, this book is also freely available at:
http://www.epa.gov/ednnrmrl/publications/books/handbook/index.htm

Design Approach to Wastewater

- Where does the wastewater come from?
- How much wastewater flow is there going to be?
- How is the wastewater going to be removed and treated?

Where does the wastewater come from?

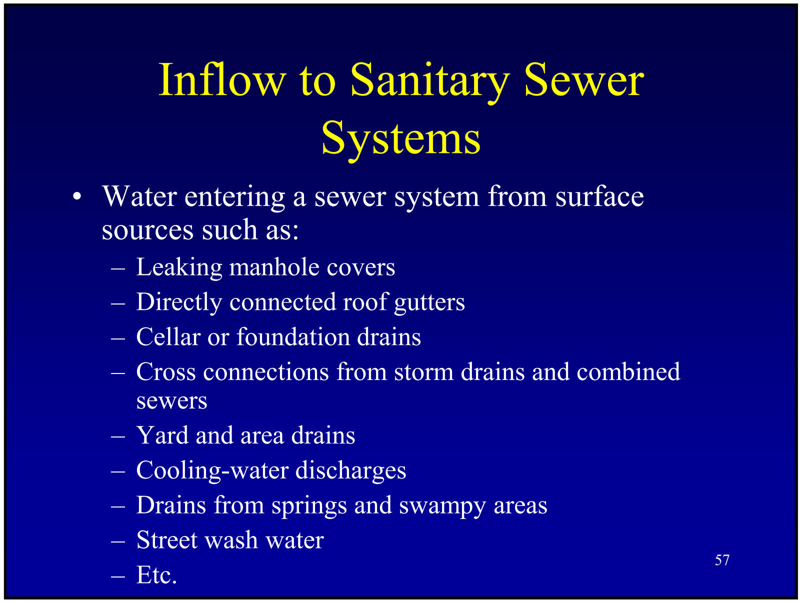
- Two main categories:
  - Sanitary Wastewater
    Wastewater from residential, commercial, institutional and industrial sources.
  - Stormwater Runoff
    Wastewater resulting from rainfall running off streets, roofs, and other impervious surfaces.
- Today in the U.S., these wastewaters are generally handled separately and in very different ways.

Components of a Community's Wastewater

- *Domestic (sanitary) wastewater* – wastewater discharged from residences and from commercial, institutional and similar facilities.
- *Industrial wastewater* – wastewater in which industrial wastes predominate.
- *Infiltration/Inflow (I/I)* – extraneous water that enters the sewer system from the ground through various means, and storm water that is discharged from sources such as roof leaders, foundation drains, and storm sewers.
- *Stormwater* – runoff resulting from rainfall and snowmelt.

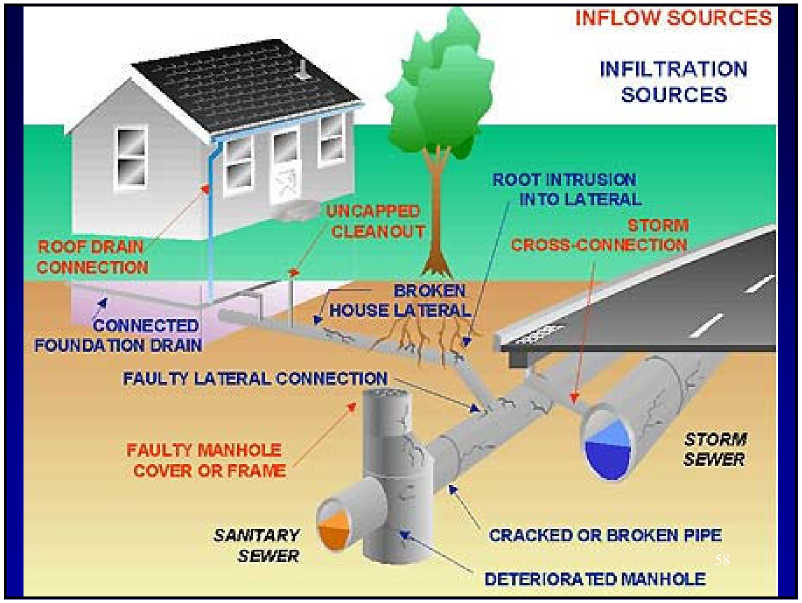
Infiltration to Sanitary Sewer Systems

- Groundwater/percolating water in the subsurface entering a sewer system through:
  - Defective pipes
  - Leaking pipe joints
  - Poor connections
  - Cracked manhole walls
  - etc.



Inflow to Sanitary Sewer Systems

- Water entering a sewer system from surface sources such as:
  - Leaking manhole covers
  - Directly connected roof gutters
  - Cellar or foundation drains
  - Cross connections from storm drains and combined sewers
  - Yard and area drains
  - Cooling-water discharges
  - Drains from springs and swampy areas
  - Street wash water
  - Etc.



Inflow and Infiltration Locations

Engineered by-pass in Five-Mile Creek, Birmingham, AL

Engineered Sanitary Sewer Overflows

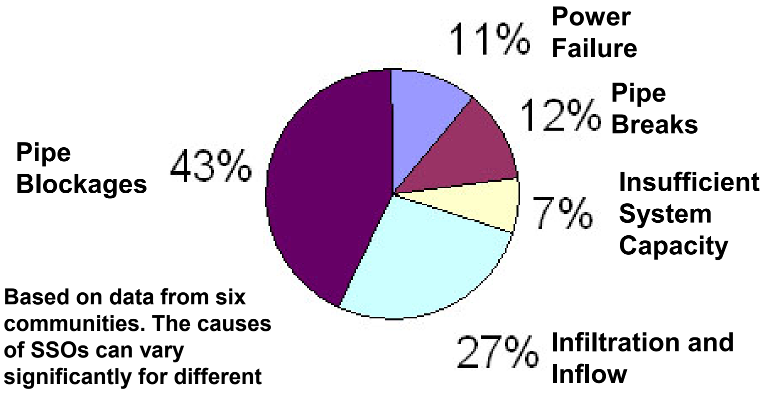
- In the Birmingham area, Jan.-March heaviest rain months of the year. In 1995, over 271 million gal of raw/untreated sewage discharged during these months. SSOs occur in many communities.
- Heavy rains overload the system though inflow and infiltration into cracks, ill-fitting joints, and leaky manholes.
- To prevent hydraulic overload of treatment plants, the excessive sewage bypasses the plant and is discharged without treatment.

Is this legal?

- The Clean Water Act of 1972 only allows bypasses in the cases of emergencies
- Typically, a rain storm is not considered an emergency
- Jefferson County lost a major lawsuit to the EPA, ADEM, and citizens and is required to correct the sanitary sewer system and expand treatment capacity, and spend about $30 million to purchase stream corridors buffers.

Sanitary Sewer Overflows (SSOs) in Separate Sanitary Sewer Systems

Causes of Sanitary Sewer Overflows (other than through engineered by-passes)



Based on data from six communities. The causes of SSOs can vary significantly for different communities.

Effects of SSOs

Environmental

- Nutrients and toxicants may cause algal blooms and harm wildlife. Algal blooms remove O_2 from water, smothering aquatic life.
- Decrease in water quality reduces number and range of plants and fish.

Public Health

- Direct contact with water containing sewage can cause skin and ear infections and gastroenteritis, and cuts become infected.
- Illnesses result from eating fish/shellfish that swim in sewage contaminated waters.
- Inhalation and skin absorption can also cause disease.

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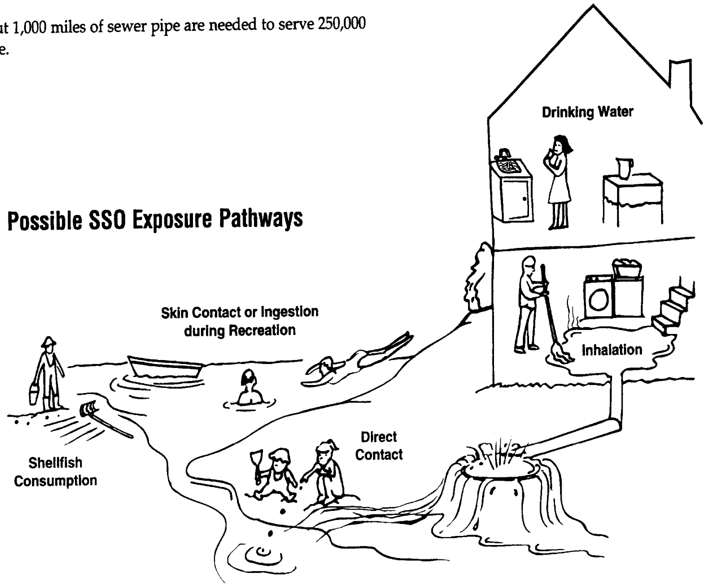
*About 1,000 miles of sewer pipe are needed to serve 250,000 people.

Possible SSO Exposure Pathways



Sewer Corrosion is an Important Cause of Sewerage Failure – Acid Attack

- Takes place when low pH waste, usually industrial wastewater comes in contact with the concrete sewer structure.
- Corrosion is easily identifiable due to its propensity of attacking below the wastewater level or anywhere the wastewater contacts the cement structure on a regular basis.

Sewer Corrosion – Hydrogen Sulfide

- **Sulfide attack, hydrogen sulfide corrosion or simply sulfide corrosion**.
  - Extremely costly problem.
  - Closely related to acid attack in that they both involve sulfuric acid attacking the structures.
  - However, hydrogen sulfide corrosion can be found above the wastewater surface, usually in the crown of the pipe and is caused mainly by biological processes.
  - Slow moving sewage allows anaerobic bacteria to reduce sulfate ions to sulfide ions.
  - Corrosion occurs when the produced H_2S gas condenses on the sewer crown.
  - Condensate oxidized by aerobic bacterium into H_2SO_4.
  - The resulting sulfuric acid destroys the concrete above the normal wastewater level in the pipe.

Sewer Corrosion Problems

– Biggest Problem: Loss of structural integrity. When the concrete is eroded more and more over time the walls can become very thin, and even disappear in some cases.
  - Vero Beach, FL (1990). Sulfide levels in the sewage were averaging 12-15 mg/L and gaseous H_2S readings in excess of 900 parts per million. A 12-ft vertical drop located in a wastewater-treatment-plant influent channel was constructed. In four months time this newly constructed structure lost four inches of concrete.
  - St. Louis (1987). “12 in. thick concrete baffle walls virtually disappeared”.

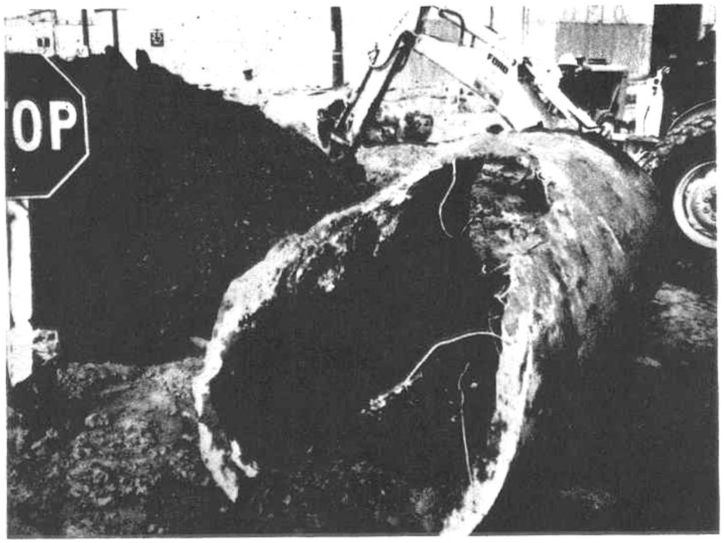


Figure 7-8 Sewer pipe corroded by hydrogen sulfide. (*Courtesy E. Rogers*)

Sewer Corrosion Causes Leaking Sewer Lines

- Poorly constructed/maintained collection lines allow large amounts of groundwater seepage.
- Amount of groundwater infiltration often enough to overload treatment plants.
- During storms, rainwater inflow also overloads a system.
- Surges in volume of wastewater from these inflows often enough to overload systems even when infiltration is relatively low.
- Combined effects of I&I may result in sustained flows far higher than plants were designed to handle and peak flows many times greater still.
- These usually cause some sort of bypass into a receiving water.
- I & I can cause raw sewage in collection systems to backup into homes, streets and yards.

Calculation/Estimation of Infiltration/Inflow (I&I)

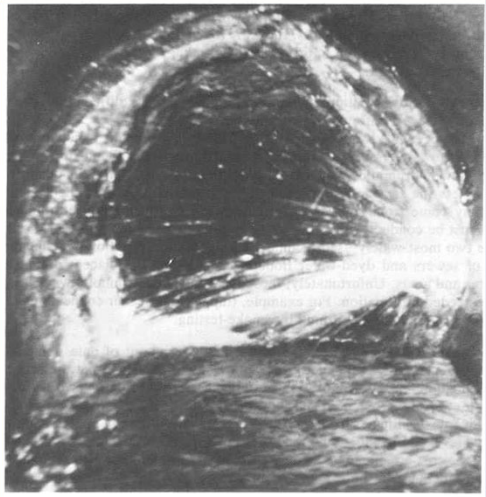


Figure 6-8 Photograph of sewer pipe interior taken during I/I analysis.

Graphical Identification of I&I

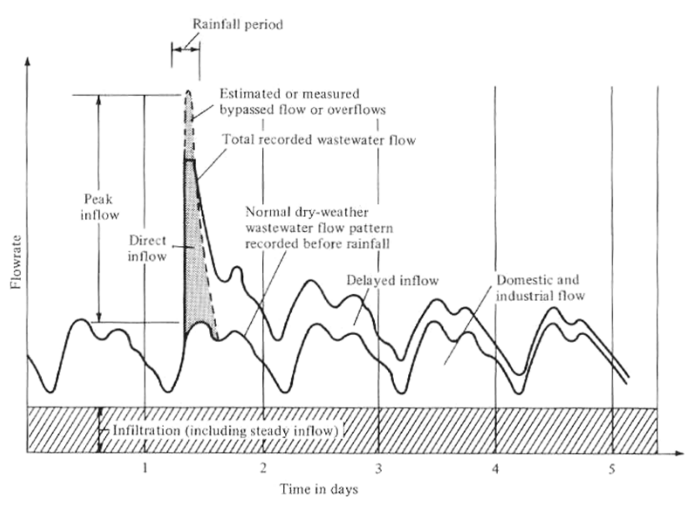


Figure 6-1 Graphic identification of infiltration/inflow.

Smoke Testing to Identify Inflow Locations

Design Approach to Wastewater

- Where does the wastewater come from?
- How much wastewater flow is there going to be?
- How is the wastewater going to be removed and treated?

Sources and Rates of Domestic Wastewater Flows

- Small residential districts – wastewater flows determined based on population density and average per capita contribution of wastewater.
- Large residential districts – wastewater flows developed based on land use areas and anticipated population density (typically rates are based on wastewater flows from nearby areas).
- If data is unavailable, estimate 70% of the domestic water-withdrawal rate is returned to the sanitary sewer system.
- In all cases, should try to obtain local wastewater flows for a similar area.

Example Relationship between Water and Wastewater Flows

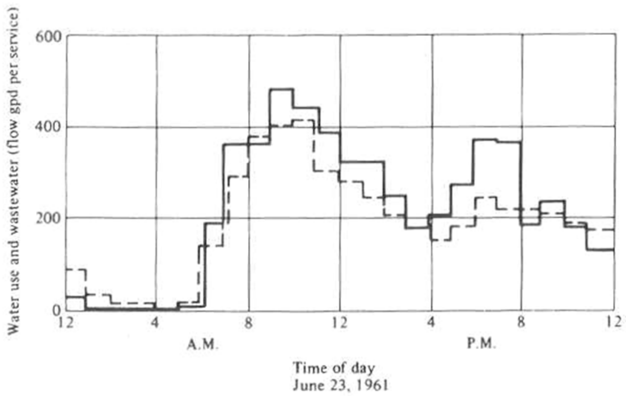
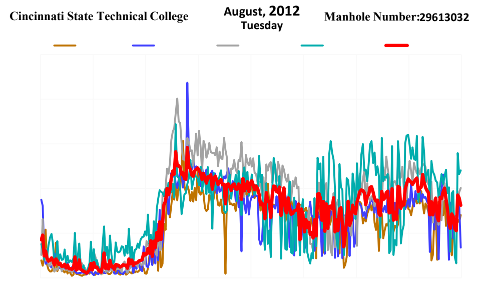
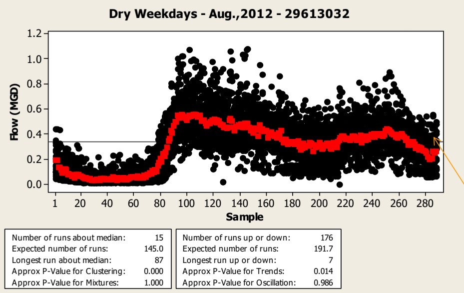


Figure 4.14 Comparison of water use (solid line) and wastewater flow (dashed lines) on days when little sprinkling occurred. (From Residential Water-Use Research Project, Johns Hopkins University and Federal Housing Administration, 1963.)

Base Flow Analyses of Dry Weather Combined Sewer Flow Data to Subtract from Combined Wet Weather Flow Data to Obtain Direct Runoff Hydrographs





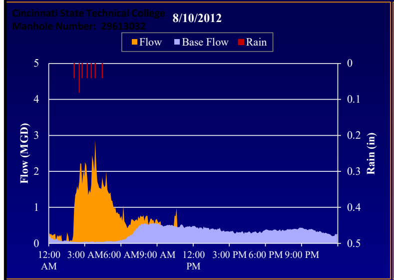
Number of runs about median:	15
Expected number of runs:	145.0
Longest run about median:	87
Approx P-Value for Clustering:	0.000
Approx P-Value for Mixtures:	1.000

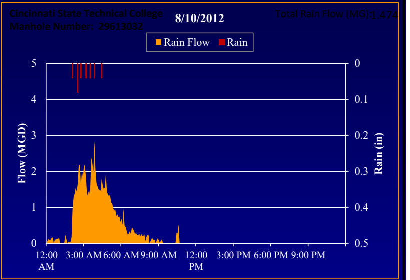
Number of runs up or down:	176
Expected number of runs:	191.7
Longest run up or down:	7
Approx P-Value for Trends:	0.014
Approx P-Value for Oscillation:	0.986

These dry weather flow analyses were done for each day of the week for each month. All week days were combined and the weekends were combined for use for the specific month's wet weather record.

Average base flow time series used for all August 2012

Base flow analyses of combined sewer flow data to obtain direct runoff (did this for all Kansas City and Cincinnati data)

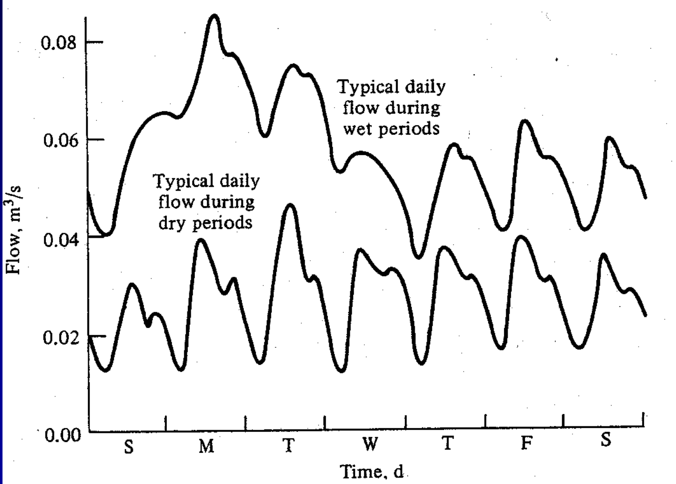




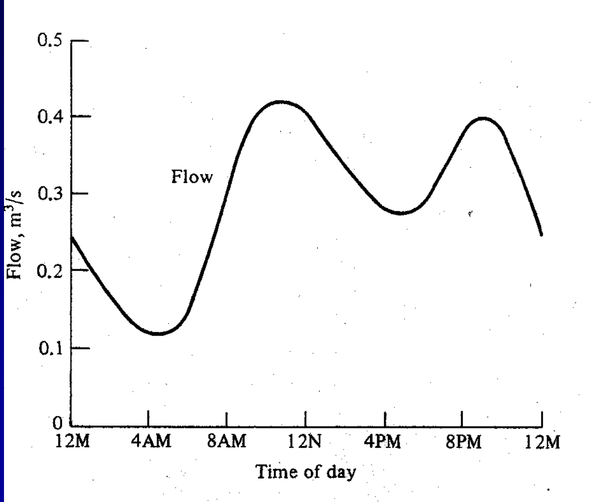
Prepared individual storm event summaries that are coordinated with the rain data for each monitoring point, including:

- start/end time of rain,
- rain duration,
- antecedent dry days,
- total rain,
- peak and average rain intensity,
- pipe-flow start/end time,
- total pipe-flow discharge volume,
- total runoff,
- peak and average flow discharge rates,
- R_v (the ratio of runoff to rainfall depth).

Example Daily/Weekly Variations in Residential Wastewater Flows for Dry and Wet Periods



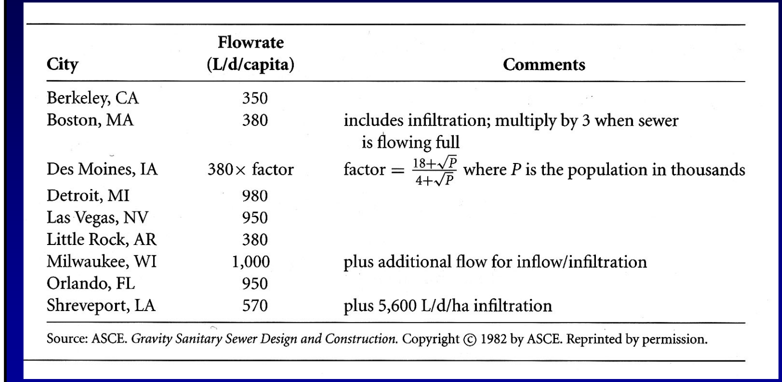
Typical Hourly Variations in Residential Area Wastewater Flows



Average Wastewater Flows from U.S. Residential Sources

Source	**Unit**	**Flow, L/unit-day**	
		Range	**Typical**
Apartment	Person	200 – 340	260
Hotel, resident	Resident	150 – 220	190
Individual Dwellings			
Average Home	Person	190 – 350	280
Better Home	Person	250 – 400	310
Luxury Home	Person	300 – 550	380
Semimodern Home	Person	100 – 250	200
Summer Cottage	Person	100 – 240	190

Average per-capita wastewater domestic flowrates in the U.S.



City	Flowrate (L/d/capita)	Comments
Berkeley, CA	350	
Boston, MA	380	includes infiltration; multiply by 3 when sewer is flowing full
Des Moines, IA	380× factor	factor = $\frac{18+\sqrt{P}}{4+\sqrt{P}}$ where *P* is the population in thousands
Detroit, MI	980	
Las Vegas, NV	950	
Little Rock, AR	380	
Milwaukee, WI	1,000	plus additional flow for inflow/infiltration
Orlando, FL	950	
Shreveport, LA	570	plus 5,600 L/d/ha infiltration

Source: ASCE. *Gravity Sanitary Sewer Design and Construction.* Copyright © 1982 by ASCE. Reprinted by permission.

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Water Reduction Measures: Per Capita Wastewater Flows from Conventional Domestic Devices

Device	**Wastewater Flow**	
	L/capita-day	**Percent**
Bathtub Faucet	30.3	12
Clothes Washing Machine	34.1	14
Kitchen Sink Faucet	26.5	11
Lavatory Faucet	11.4	5
Shower Head	45.4	19
Toilet	94.6	39

Design Approach to Wastewater

- Where does the wastewater come from?
- How much wastewater flow is there going to be?
- How is the wastewater going to be removed and treated?

Sanitary Sewer:
Basic Design Considerations

- Wastewater flow
- Hydraulic-design equation
- Sewer pipe materials
- Minimum pipe sizes
- Minimum and maximum velocities
- Slopes and cover
- Evaluation of alternative alignments or designs
- Selection of appropriate sewer appurtenances

Types of Sewer Pipes in a Typical Separate Sanitary Collection System

- Sanitary sewers must be laid near all occupied buildings in order to collect wastewater.
- Building Connecting Pipes
  - Connects the building plumbing to the public sanitary wastewater collection system.
  - Convey wastewater from the buildings to lateral or branch sewer, or any other sewer except another building sewer.
  - Normally begins outside the building foundation

Types of Sewer Pipes in a Typical Separate Sanitary Collection System (cont.)

- Lateral or Branch Sewers
  - Forms the first element of a wastewater collection system.
  - Usually in streets or special utility easements.
  - Used to collect wastewater from one or more building sewers and convey it to a main sewer.
- Main Sewers
  - Main sewers are used to convey wastewater from one or more lateral sewers to trunk sewers or to intercepting sewers

Combination Gravity and Pressure Sanitary Sewer System

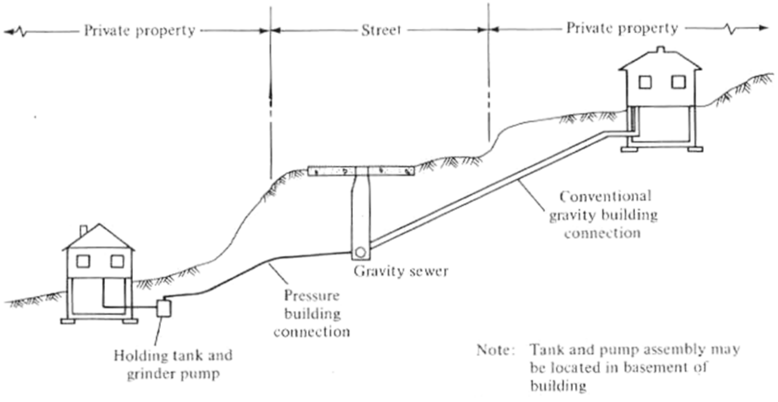

Figure 4-13 Typical pressure connection to gravity sewer from isolated low building site.

Conclusions

- Combined sewer overflows and sanitary sewer overflows have been recognized as significant water pollutant sources in the US for many years.
- Regulations have been in place for several decades describing the minimum efforts needed to reduce these discharges, and the US EPA has prepared associated guidance documents.
- Numerous large-scale CSO and SSO control programs have been conducted throughout the country, documenting their success.
- The large costs of these conventional programs have lead to the current implementation of "green infrastructure" solutions that also promise many social benefits.
- Numerous new projects are demonstrating these benefits of green infrastructure in combined sewered areas.