KEEPING WATER OUT OF SEWER SYSTEMS

A Simple Tool for Progressive
Sewer System Planning

DRAFT FINAL

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GENERAL INSTRUCTIONS
KEEPING WATER OUT OF SEWER SYSTEMS
A Simple Tool for Progressive Sewer System Planning

What is the "Keeping Water Out of Sewer Systems" Tool?

Keeping Water Out of Sewer Systems, or ***KWO***, is a simple planning tool for communities working to manage wastewater and stormwater issues and maintain their valuable sewer infrastructure. KWO is built on the simple premise that sewer systems in most urban areas are stressed. Implementation of management practices to keep excess water out of sewer systems can alleviate part of this stress, while mitigating downstream impacts at the wastewater treatment plant (WWTP) and/or receiving waterbody.

KWO allows communities to evaluate different scenarios for reducing flows to their sewer systems. It applies a holistic approach that addresses the interconnectivity among sanitary sewers, separate storm sewers, and combined sewers. All sewer systems are affected by precipitation, and KWO allows communities to consider all wastewater and all stormwater inputs to the system simultaneously. KWO accounts for flow reductions associated with user-designed planning scenarios, such as implementation of management practices that provide inflow and infiltration (I/I) control, stormwater runoff reduction, and water conservation.

KWO provides costs associated with these management practices and thus provides public works divisions, city managers, and community planners with information for their planning efforts. While KWO does not eliminate the need for good engineering analyses of the sewer system, it provides planning level data that can be used in public forums to build support for the sewer management program, or to determine if certain flow reduction elements are feasible or cost effective.

KWO consists of step-by-step general instructions that guide the user through a series of calculations to identify flow reduction opportunities with accompanying cost estimates. KWO can be applied at the local level or in a broader regional context, and can be used in communities that have separate sanitary, separate storm, or combined sewers, or any combination thereof.

Why Do I Need To "Keep Water out of Sewer Systems"?

Sewers are a very important part of urban infrastructure because they provide public health, environmental, and flood control benefits. However, it is difficult to manage sewer systems, particularly in older, urbanized areas. Increased imperviousness in urbanized areas increases runoff that can eventually end up in the storm sewer system. In addition, aging, leaky pipes and expanding populations increase flows in the wastewater system. These high flows can cause the pipes to overflow, causing public health and water quality problems. In the case of stormwater, the volume and erosive force of urban runoff conveyed in storm sewers also accelerates streambank erosion and destroys habitat. The challenges of managing these capacity issues and mitigating wet weather effects (e.g., CSOs, SSOs) place significant operational and financial demands on the communities that own and operate sewer systems and WWTPs.

Reducing the volume of water entering sewer systems through the elimination of I/I, control of precipitation-induced runoff, and water conservation provides the following benefits:

- Preservation of sewer system conveyance capacity
- Reduction of stress on existing sewer infrastructure
- Abatement of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs)
- Reduction of the volume of stormwater and associated pollutant loads delivered to waterbodies
- Lessening of public health, water quality, and environmental impairment attributable to urban runoff and sewer overflows
- Improvement of effluent quality from WWTPs due to lower loads during wet weather
- Better management of combined, sanitary, and separate storm sewer systems and permit programs

How Does KWO Fit in with Other EPA Programs?

Current regulatory approaches address municipal wet weather discharges under at least three separate national pollutant discharge elimination system (NPDES) programs (stormwater; CSO; and wastewater, which regulates SSOs and peak flows at WWTPs). These water management programs are generally designed to address only one type of wet weather discharge (e.g., CSOs, SSOs). Thus, there is often little coordination among program requirements, despite the functional commonalities among operations, maintenance, and management requirements for municipal wet weather discharges. As a result, communities often employ separate management strategies to address the different regulatory and programmatic requirements.

EPA is supportive of coordinated, cross-program efforts to achieve better water quality, and KWO is one of a suite of EPA tools and initiatives (including the watershed approach, watershed based permitting, and wet weather integration) to help communities integrate efforts to manage wet weather discharges and control water pollution. KWO is consistent with management measures required under the separate municipal wet weather programs that address stormwater and wastewater. For example, the tool incorporates water management techniques that can be used to meet requirements for the six minimum measures for municipal separate storm sewer systems (MS4s); the nine minimum controls (NMCs) for combined sewer systems; and the capacity, management, operations and maintenance (CMOM) programs for wastewater collection systems. Some of the management practices included in KWO may be required under current NPDES permits (e.g., I/I control, or low impact development (LID) as part of a CSO program).

Integrating wet weather programs (particularly their permitting elements - including monitoring, reporting, and training) across urban areas can provide efficiencies and reduce the prevalence and impacts of wet weather discharges. For example, KWO can help communities focus on their most pressing wet weather problems, and determine which wet weather management practices are best suited for their local situation. By targeting their most pressing problems more efficiently, municipalities can leverage their often-limited funding sources in order to make better progress in achieving water quality improvements in local waterbodies.

How Do I Use the KWO Tool?

KWO can be used to develop a baseline of all sewer flows (wastewater and stormwater) in an urban area. The tool can then be used to evaluate management practices and costs for "keeping the water out" of a community's sewer systems. KWO considers management practices that are especially useful in the developed areas of any sized community, from a small town to larger urbanized community. KWO is not designed for use with planned or new developments, because many of the tool's flow management measures would not be useful or necessary in these communities.

Using KWO, a given community may choose to evaluate one or more of the management practices provided. For example, a community may limit its evaluation to I/I reduction required by its NPDES permit, or it may couple this evaluation with a conceptual water conservation program or proposed stormwater runoff reduction project. The community is encouraged to use KWO to evaluate a range of scenarios that reduce flows to its sewer systems. KWO is also designed for iterative analysis, so the community can use the tool multiple times to evaluate the flow reductions, benefits, and costs of different management scenarios.

The management practices to reduce flows to sewer systems considered in KWO are summarized in Table 1.

Table 1. Management practices to reduce flows to sewer systems

Flow Component to be Reduced	Management Practices	Sewer System Affected
Stormwater Runoff	Reduce impervious cover; implement low impact development, (LID) including green roofs and pervious pavements	Combined and/or separate storm sewer systems
Inflow	Redirect roof leaders from the sewer systems	Combined and/or separate storm sewer systems
Infiltration	Implement sewer rehabilitation (e.g., grouting, lining, manhole repair, etc.)	Combined and/or separate sanitary sewer systems
Water Use (reducing consumptive water use in turn reduces flow to the sewer systems)	Implement water conservation techniques (low-flow fixtures and appliances)	Combined and/or separate sanitary sewer systems

KWO uses a format similar to that of an IRS form and includes line-by-line instructions and a calculation form. It describes flow reduction methods and provides guidance on their use. KWO contains default data for various management practices that can be used to generate planning level estimates of flow reduction if site-specific data are not available. Users of KWO should have a good understanding of the service area and demographics of their sewer systems in order to maximize its effectiveness.

Generalized cost data are provided in order to allow users to evaluate costs and benefits. The cost information is based on literature reviews and specific case studies. In general, costs are highly variable from one community to another. Actual costs can be highly influenced by site-specific conditions. It is recommended that site-specific costs be used where available. The default costs in KWO can be used for planning-level purposes with the understanding that the cited costs are an approximation of actual costs.

The sequence of calculations in KWO follows:

Quantify base sewer flow conditions

Wastewater (domestic and industrial flows plus infiltration)
Stormwater

Quantify flow reductions associated with the following practices

Stormwater runoff reduction
Inflow control
Infiltration control
Water conservation

Estimate costs associated with flow reduction

INSTRUCTIONS FOR FORM KWO

KWO is a quantitative planning tool for municipalities to estimate the following:

- Base wastewater and base stormwater flows generated for an urban area
- Volumetric reductions in flows to the sewer system that may be achieved through implementation of different management practices (stormwater runoff reduction, inflow reduction, infiltration reduction, and water conservation).
- Total reductions in municipal flows from ***Keeping Water Out of Sewer Systems***
- Planning level costs for implementing the mitigation measures

The line-by-line instructions below provide guidance to develop inputs for, and to evaluate outputs from, KWO. Although four types of flow reductions can be evaluated using the KWO (including reductions in inflow, infiltration, stormwater runoff, and consumptive water use), it is not necessary to estimate flow reductions in all four of these areas. A user can choose to evaluate any combination of the four management practices.

The principal data needs are as follows:

- Sewered service areas in acres (sanitary, separate storm, and combined)
- Wastewater sewer service population (number of people)
- Wastewater volume in gallons/year
- Infiltration (if this is not known, it can be calculated)
- Annual rainfall in inches

KWO provides default values and methods for estimating various inputs. Use of local flow rates, flow reduction information, and cost data is recommended, if available.

KWO is meant to be used in an iterative fashion. Users can test several different scenarios and can return to KWO to make changes to determine what actions (or combination of actions) will be most effective, best implemented, ort most cost-effective.

An example of how KWO could be used to evaluate several different potential flow reduction options is included in Appendix C.

Sewered Service Areas and Population

KWO requires some basic information about the community and its sewer systems, including the area of all sewer systems (sanitary, separate storm, and combined) and the wastewater service population. KWO uses this information in other parts of the tool, and so it is important that this information be as accurate as possible.

The total wastewater sewer area is calculated from the separate sanitary sewer service area and the combined sewer service area (if any). Likewise, the total stormwater sewer area is calculated by adding the total stormwater sewer area (also known as the municipal separate storm sewer system (MS4) area) and the combined sewer service area (if any). This does not double count wastewater and stormwater flow contributions, because these flows are calculated independently of the sewered area.

Line 1 – Total Wastewater Sewer Area. Enter the total wastewater service in acres. This is sanitary sewer service area added to combined sewer service area (if any).

Line 2 – Total Stormwater Sewer Area. Enter the total stormwater sewer area. If the service area includes combined sewer systems, include this acreage in the total.

Line 3 – Service Population for Wastewater. Enter a best estimate of the population (number of persons served) by the wastewater collection system.

Base Wastewater Flow (includes Infiltration)

Base wastewater flow is the average flow (in gallons/year) delivered to the WWTP from the total sewered area for wastewater (sanitary sewer and/or combined sewer service area). It consists of sewage generated from residences, commercial establishments, and industry. It also includes infiltration. It does not include stormwater inflow.

Base wastewater flow is usually measured with a flow meter as inflow to the WWTP or as WWTP discharge. It is sometimes measured at political or utility boundaries for satellite sanitary sewer systems that do not have their own WWTP.

Base wastewater flow is available through metered data or from other sources. However, if you do not know your base wastewater flow, you can estimate it.

If you know your total base wastewater flow, go to Line 4. If you don't know your total base wastewater flow, go to Line 5, where you can calculate it.

Known Base Wastewater Flow

Line 4 – Recorded Total Base Wastewater Flow. Enter the base wastewater flow value (gallons)—including domestic (the sum of residential and commercial flows) and industrial wastewater, plus infiltration.

Estimated Domestic and Industrial Wastewater Flow

Line 5 – Wastewater Generation Rate. Enter the daily per-capita generation rate for wastewater in your community. A daily per-capita wastewater generation rate may be available from previous studies, or it can be estimated from water usage. Metcalf and Eddy (1991) cite a range of 40-130 gallons/ person/day for domestic wastewater. A conservative average default value would be approximately 100 gallons/person/day.

Line 6 - Estimated Domestic Wastewater Flow. Multiply Line 3, the service population for wastewater, by Line 5, the daily per capita consumptive use rate, and then by 365 to calculate the estimated annual domestic wastewater flow.

Line 7 – Industrial Wastewater Flow. Enter best estimate of annual wastewater flows (gallons/year) from industries. Industrial (nondomestic) wastewater flowrates from industrial sources vary with the type and size of the facility, the degree of water reuse, and the onsite wastewater treatment methods, if any. If industry does not have a significant impact on wastewater flow in the community, enter zero.

Line 8 – Estimated Domestic and Industrial Wastewater Flow. Add Line 6, estimated domestic wastewater flow, to Line 7, industrial flow.

Infiltration

Infiltration, which can affect wastewater flows in both sanitary sewer and combined sewer systems, is defined as the stormwater and groundwater that enters a sewer system through defective pipes, pipe joints, connections, or manholes. Infiltration does not include inflow. The presence of infiltration results in leakage into the sewers and in an increase in the quantity of wastewater and the expense of treating it.

If you know your base wastewater flow and your annual infiltration, go to Line 9. If you have estimated your domestic and industrial wastewater flow, you must estimate your annual infiltration. Go to Line 12, where you can calculate it.

Known Annual Infiltration

Line 9 - Percent of Base Wastewater Flow that is Infiltration. Enter the percentage of base wastewater that is infiltration as a decimal fraction (i.e., 33% = 0.33). The percentage of base wastewater flow may be known from I/I studies. It can also be estimated from flow metering records. For example, some communities assume that the metered flow at 5 or 6 am is mostly infiltration.

Line 10 – Annual Infiltration. Multiply Line 9, the percent of base wastewater flow that is infiltration, by Line 4, the recorded total base wastewater flow, to determine the annual infiltration, in gallons/year.

Line 11 – Calculated Annual Infiltration Rate. Divide Line 10, the annual infiltration, by Line 1, the total wastewater sewer area, and then divide by 365 to determine an annual infiltration rate in gallons/acre/day.

Estimated Annual Infiltration

Line 12 – Estimated Annual Infiltration Rate. Enter the average daily rate of infiltration over the entire sewer area defined in Line 1, in gallons/acre/day The infiltration rate is a very site-specific value that depends on the age of the system, elevation of the water table, soils and topographic conditions, length of sewers, and population density (which affects the number and length of house connections). Infiltration may range from 20 to 3,000 gallons/acre/day or more (Metcalf and Eddy, 1991). For example, a study in Lawrence, Kansas found infiltration rates ranging from a low of 8 gallons/acre/day to a high of 220 gallons/acre/day during an I/I study for their Master Plan. The City of Issaquah, Washington, experienced an infiltration rate of 100-800 gallons/acre/day in some parts of the city (See Appendix A for references).

Line 13 – Estimated Annual Infiltration. Multiply Line 1, the total wastewater sewer area, by Line 12, the estimated annual infiltration rate, and then by 365.

Base Wastewater Flow

Line 14 – Base Wastewater Flow. If the base wastewater flow was known, copy this value from Line 4, the recorded total base wastewater flow. If the base wastewater flow was estimated, add Line 8, the estimated base wastewater flow, and Line 13, the estimated annual infiltration.

Base Stormwater Runoff

Stormwater runoff is derived from precipitation and snowmelt on roadways, parking lots, roof drains, and saturated soil. It flows over the surface of the ground and is generally collected in channels, conduits and sewer systems in urban areas. Base stormwater runoff is the annual volume of stormwater generated within defined areas that contribute to storm sewer systems and combined sewer systems. Base stormwater runoff is estimated with a calculation that uses annual rainfall and the simple method (Schueler, 1987). It assumes that most of the runoff generated on impervious surfaces such as roads, parking lots, and rooftops reaches storm or combined sewer systems.

Stormwater

Line 15 - Percent Imperviousness. Enter the percent of impervious area for the entire service area. The percent of the impervious cover of the existing mix of land uses in the service area may have been determined in earlier stormwater studies. It can also be quantified with GIS where coverages for impervious surfaces such as roads and rooftops are available. Typical ranges of imperviousness associated with different land use categories are presented in Table 2.

Line 16 - **Runoff Coefficient Calculation.** Calculate a runoff coefficient using the correlation provided in Schueler (1987) by multiplying Line 15, the percent imperviousness, by 0.9, and then adding 0.05. See Appendix A for references to the full calculation.

Line 17 – Annual Rainfall. Enter the average annual rainfall (inches) for the service area. The monthly average rainfall values for many U.S. cities can be found at the following website: http://countrystudies.us/united-states/weather/. The monthly averages can be added to determine the average annual rainfall for a given city.

Line 18 – Fraction of Annual Rainfall Events that Produce Runoff. Enter the fraction of annual rainfall events that produce runoff. This number accounts for the smaller rainfall events that do not result in measurable runoff due to surface storage effects. A value of 1 means every rain event produces measurable runoff. Enter the default value of 0.9, a number suggested for use in the eastern United States, unless local studies indicate that a different fraction is warranted.

Line 19 – Base Stormwater Runoff. Calculate total stormwater runoff by multiplying Line 2, the total stormwater sewer area; Line 16, the runoff coefficient; Line 17, the annual rainfall; and Line 18, the fraction of annual rainfall events that produce runoff, and then applying a conversion factor of 27,154 to convert acre-inches to gallons/year.

Total Municipal Flow

Line 20 – Total Municipal Flow. Add Line 14, the base wastewater flow, and Line 19, the base stormwater runoff, to calculate the total municipal flow in the system in gallons/year. Note that,

Table 2. Typical land use classifications and associated fraction imperviousness for use in Line 15.

Land Use	Imperviousness
Low density residential	10% - 30%
Medium density residential	20% - 50%
High density residential	50% - 90%
Commercial	30% - 70%
Industrial	50% - 80%
Forest	5% - 10%
Park	10% - 20%

depending on an individual community's infrastructure, this value will consist of base wastewater flow including infiltration (in sanitary sewer and/or combined sewer systems) and stormwater flow (in municipal storm and/or combined sewer systems).

Quantify Reduction in Stormwater Runoff

Runoff in developed urban areas can be reduced with implementation of best management practices (BMPS) including low impact development (LID) technologies. KWO includes a small subset of widely used runoff controls that can be retrofitted to existing development or included in the design for new development. These include:

- Conversion to green roofs
- Conversion to pervious pavement
- Removal of impervious area
- Disconnection of roof leaders

Some general information on the application of these individual stormwater runoff control measures and their cost is provided in this section. The costs reflected in this document reflect actual costs for retrofit applications. Actual costs are appropriate where conversion to a green roof or porous pavement is considered before the useful life of an existing roof or parking lot has been reached. However, the incremental cost of constructing a green roof or using porous pavement above and beyond standard replacement costs is appropriate when conversion is scheduled to coincide with the normal replacement period. These incremental differences in cost are noted in the cost discussion in Appendix A where appropriate. In all instances, users are encouraged to use local cost data where it is available.

The technologies used to accomplish runoff reduction are described in more detail in various EPA reference documents, including:

http://www.epa.gov/nps/lid/

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

http://www.epa.gov/owm/mtb/mtbfact.htm

Convert to Green Roofs

Green roofs employ a soil medium and plants instead of the standard roof material. They are designed to intercept rainfall, delay runoff peaks, and reduce runoff discharge rates and volume. Green roofs can be retrofitted into existing buildings, or they can be designed into new buildings during development or redevelopment. They are most commonly installed on flat-roofed commercial, institutional, or industrial buildings. Green roofs provide other benefits beyond runoff reduction. For example, they add insulation to buildings, and have the potential to reduce heating and cooling costs.

Although green roofs typically have a higher capital cost than standard roofs (green roofs are typically $7-$10 more per square foot than standard roofs), the overall life cycle costs for green roofs may be lower because of their longer life cycles (a typical green roof can last for 30-40 years, whereas a standard roof is designed to last for 15-25 years).

Line 21 – Total Area of Green Roofs. Enter an estimate of the total flat-roofed area (in acres, where one acre equals 43,560 ft^2) that could be converted to green roofs via retrofit programs. Roof areas in a community may be estimated using GIS, or by analyzing the mixture of building types in the community and then assigning average roof area values to the different building types.

Line 22 – Percent of Annual Rainfall Retained by Green Roofs. Enter the percent of annual rainfall retained by green roofs. Green roofs can retain anywhere from 25-90+ percent of the rainfall generated by a storm, depending on the type of green roof installed, the season, and the rainfall intensity (See Appendix A). If no local data exists on the percent of rainfall retained by green roofs, a default value of 60 percent can be used; 60 percent retention of rainfall in green roofs has been achieved in many communities, including Portland, OR and Toronto, Canada.

Line 23 – Depth of Annual Rainfall Retained per Unit Area of Green Roof. Multiply Line 17, the annual rainfall, by Line 22, the percent of annual rainfall retained by green roofs, to calculate the depth of annual rainfall retained per unit area of green roof.

Line 24 – Runoff Reduction from Converting to Green Roofs. Multiply Line 21, the total area of green roofs, by Line 23, the depth of annual rainfall retained per unit area of green roof, and then multiply by a conversion factor of 27,154 to convert acre-inches to gallons.

Line 25 – Unit Cost to Convert to Green Roofs. Enter the estimated cost per square foot to convert to green roofs. Default costs from the literature are typically in the $15-$20/ft^2 range (See Appendix A).

Line 26 – Estimated Cost to Convert to Green Roofs. Multiply Line 23, the total area of green roofs, by 43,560 to convert to ft^2, and then by Line 25, the unit cost to convert to green roofs.

Convert to Pervious Pavement

Pervious pavement is pavement that is specially designed to allow rainfall and snowmelt to pass through it to the soil underneath, thereby reducing runoff. Pervious pavement can be used to replace traditional impervious pavement to reduce runoff from paved areas. Pervious pavement is most often used in driveways, parking areas, walkways, and patios to minimize runoff. It can be used in roads and higher traffic areas under some circumstances.

The costs of pervious pavement are approximately the same as those for standard asphalt pavement. Therefore, replacement costs are equivalent.

Line 27 – Total Area of Pervious Pavement. Enter an estimate of the total paved area (in acres, where one acre equals 43,560 ft^2) that could be converted to pervious pavement.

Line 28 – Percent of Rainfall Infiltrating Pervious Pavement. Enter an estimate of the percent of runoff that infiltrates pervious pavement. While pervious pavement materials yield some surface runoff, it is much less than traditional paved surfaces. Research indicates that porous pavement may reduce site runoff by between 60 and 90 percent, depending on the application. Therefore, if no site-specific information is available, a conservative default value of 60 percent may be appropriate (See Appendix A).

Line 29 – Depth of Annual Rainfall Infiltrated per Unit Area of Pavement. Multiply Line 17, the annual rainfall, by Line 28, the percent of rainfall infiltrating pervious pavement, to calculate depth infiltrated per unit area of pervious pavement.

Line 30 – Runoff Reduction from Converting to Pervious Pavement. Multiply Line 27, the total area of pervious pavement, by Line 29, the depth of annual rainfall infiltrated per unit area of pavement, and then multiply by a conversion factor of 27,154 to convert acre-inches to gallons.

Line 31 – Unit Cost to Convert to Pervious Pavement. Enter the estimated cost per ft^2 to convert to pervious pavement. Default costs from the literature are typically in the $4/$ft^2$ range (See Appendix A).

Line 32 – Estimated Cost to Convert to Pervious Pavement. Multiply Line 27, the total area to be converted to pervious pavement, by 43,560 to convert to ft^2, and then by Line 32, the unit cost to convert to pervious pavement.

Remove Impervious Areas

Impervious areas are areas that are paved, built up, or otherwise impacted such that stormwater cannot infiltrate into the soil in that area. Removal of impervious area and replacement with pervious covers capable of allowing rainfall and snowmelt to infiltrate into the ground reduces runoff. Examples of practices that reduce impervious area are as follows:

- Reduce building footprints
- Reduce parking space size standards
- Use two-track driveway design
- Narrow road widths
- Use infiltration strips
- Use pervious walkway materials and interrupted walkways
- Use bio-retention and planting swales instead of berms
- Use dry-laid patios and walk ways instead of wet-laid.

Line 33 – Total Impervious Area Removed. Enter an estimate of the impervious area removed (in acres, where one acre equals 43,560 ft^2).

Line 34 – Runoff Coefficient for Impervious Areas. Copy from Line 16, the runoff coefficient for impervious areas.

Line 35 – Adjusted Rainfall. Multiply Line 17, the annual rainfall, by Line 34, the runoff coefficient for impervious areas.

Line 36 – Runoff Reduction from Removing Impervious Area. Multiply Line 33, the total impervious area removed, by a conversion factor of 27,154 to convert acre-inches to gallons, and then by Line 35, the adjusted rainfall.

Line 37 – Unit Cost to Remove Impervious Areas. Enter the estimated cost per ft^2 to remove impervious areas through installation of the practices discussed above. Default costs from the literature are typically in the $3-4/$ft^2$ range for residential areas. Costs will typically be higher for commercial areas (in the $10-$40/ft^2 range) because more drainage infrastructure is required (See Appendix A).

Line 38 – Estimated Cost to Remove Impervious Area. Multiply Line 33, the total impervious area removed, by 43,560 to convert it to ft^2, and then multiply by Line 38, the unit cost to remove impervious areas.

Disconnect Roof Leaders

Disconnecting roof leaders is one way to remove “inflow” from the sewer system. Inflow is the direct introduction of stormwater into a sewer system. Inflow can occur by design, through disrepair, or through illicit connections. The most common sources of inflow include roof leaders, basement sump pumps, foundation drains, and area drains in yards that are directly connected to sewer systems. Inflow also occurs due to cracked or broken manhole covers. Inflow does not include infiltration.

The disconnection of roof leaders is the only inflow reduction practice included in KWO. Flow reduction associated with other inflow reduction practices is valuable but difficult to quantify, and does not lend itself to the generalizations required in this planning tool.

Disconnection of roof leaders is well suited to detached single family homes in communities where local soil conditions are capable of achieving moderate rates of infiltration. Roof leader disconnection combined with the use of rain barrels can be effective where temporary storage is needed to complement inadequate infiltration.

Line 39 – Average Roof Area of Single Family Homes. Enter the average roof area (in ft^2) of single family homes. Typical roof areas can range from 1,000 ft^2 for small homes to 2,500 ft^2 for larger homes.

Line 40 – Number of Single Family Homes Participating in Roof Leader Disconnection. Enter an estimate of the number of households that would participate in a roof leader disconnection program. Success in communities that have implemented programs ranged from 40 percent of homeowners in Toronto to 90 percent in Niagara Falls (See Appendix A).

Line 41 – Total Roof Area of Single Family Homes Participating in Roof Leader Disconnection. Multiply Line 39, the average roof area of single family homes, by Line 40, the **n**umber of single family homes participating in roof leader disconnection.

Line 42 – Runoff Reduction from Disconnecting Roof Leaders. Multiply Line 41, the total roof area of single family homes participating in roof leader disconnection, by Line 17, annual rainfall, and then by a conversion factor of 0.623 to convert area in ft^2 and rainfall in inches to gallons.

Line 43 – Unit Cost to Disconnect Roof Leaders. Enter the estimated cost per building to disconnect roof leaders. Default costs from the literature are typically in the $15-$20 per roof leader range (See Appendix A).

Line 44 – Estimated Cost of Roof Leader Disconnection. Multiply Line 40, the number of single family homes participating in roof leader disconnection, by Line 43, the unit cost to disconnect roof leaders.

Total Reduction in Stormwater Runoff and Estimated Cost

Line 45 – Total Reduction in Stormwater Runoff. Add Line 24, runoff reduction from converting to green roofs; Line 30, runoff reduction from converting to pervious pavement; Line 36, runoff reduction from removing impervious area; and Line 42, runoff reduction from disconnecting roof leaders, to determine the total reduction in stormwater runoff.

Line 46 – Total Estimated Cost for Reduction in Stormwater Runoff. Add Line 26, estimated cost to convert to green roofs; Line 32 estimated cost to convert to pervious pavement; Line 38, estimated cost to remove impervious area; and Line 44, estimated cost of roof leader disconnection, to determine the total cost to reduce stormwater runoff.

Quantify Reduction in Wastewater Flows

Many communities are experiencing increased wastewater flows owing to aging, leaky pipes and expanding populations. These increased flows may exceed the design capacity of the sewer systems and contribute to problems such as overflows. Reducing wastewater flows can help a community manage these types of problems.

The two methods for reducing wastewater flows are:

- Removal of infiltration and
- Implementation of water conservation

Reduce Infiltration

Infiltration is the water - including groundwater - that enters a sewer system through broken or defective sewer pipes or manholes and bad sewer connections. It is largely a subsurface process.

The infiltration rate for any individual system is a very site-specific value that depends on the age of the system, elevation of the water table, soils and topographic conditions, length of sewers, and population density (which affects the number and length of house connections). Infiltration may range from 20 to 3,000 gallons/acre/day or more (Metcalf and Eddy, 1991). For example, a study in Lawrence, Kansas found infiltration rates ranging from a low of 8 gallons/acre/day to a high of 220 gallons/acre/day during an I/I study for their Master Plan. In contrast, the City of Issaquah, Washington, experienced an infiltration rate of 100-800 gallons/acre/day in some parts of the city (See Appendix A for references).

Reducing infiltration keeps water out of the sewer system and reduces the need to convey and treat what is essentially clean groundwater. While infiltration reduction efforts are appropriate for both sanitary and combined sewers, they are usually targeted to sanitary sewer systems because these systems tend to have more issues with capacity and potential overloading. KWO quantifies infiltration reduction as part of the flow reductions to the sanitary and/or combined sewer systems. It does not consider infiltration reductions for separate storm sewer systems.

A variety of technologies can be used to rehabilitate sewer mains and service laterals to reduce infiltration, including grouting, sliplining, pipebursting, and other technologies. The feasibility and potential effectiveness of each of these types of technologies must be determined on a case-by-case basis.

The technique chosen for sewer rehabilitation will also affect the cost. For example, traditional open cut trench and replace methods typically cost in the range of $100/linear ft of sewer replaced, while pipe bursting can cost between $115 and $260/linear ft depending on the diameter of the pipe being burst. Some example costs are provided in Appendix A.

Costs for sewer rehabilitation are typically provided as dollars per linear foot of sewer to be rehabilitated. However, KWO is based on the area of the system being rehabilitated, and thus these costs must be converted to costs per acre by multiplying the cost per linear foot of the chosen sewer rehabilitation technology by the mean length of pipe per acre of service area in the community. The mean length of pipe per acre of service area can be determined by the following equation:

$$\frac{\textit{Total sewer miles within the community (mi)}}{\textit{service area (sq. mi).}}$$

After completing this calculation, convert from miles per square mile to linear feet per acre.

If these data are not available, a default value can be used. Municipal data collected for the 2004 *Report to Congress on the Impacts and Control of CSOs and SSOs* (EPA 833-R-04-001) a previous EPA study indicate a mean of approximately 70 linear ft/acre. See Appendix A for a discussion of this calculation.

Line 47 – Infiltration Rate. Copy either Line 11, calculated annual infiltration rate, or Line 12, estimated annual infiltration rate, depending on how this value was determined.

Line 48 – Total Wastewater Sewer Area. Copy from Line 1.

Line 49 – Percentage of Sewered Area Targeted for Infiltration Reduction. Enter an estimate for the percentage of the sanitary and/or combined sewer service area for which various infiltration removal projects (sewer rehabilitation) are planned or feasible.

Line 50 – Estimated Effectiveness of Sewer Rehabilitation. Enter the percent of infiltration, on average, expected to be removed with rehabilitation projects. This is a very site-specific value that will depend on the type of sewer rehabilitation being planned. For example, King County, WA reported that sewer rehabilitation effectiveness in reducing I/I ranged from 17 to 90 percent during a large series of pilot projects that investigated various rehabilitation scenarios of trunks, sewers and laterals, as well as appurtenances (See Appendix A for a reference for this study).

Line 51 – Total Infiltration Reduction Due to Sewer Rehabilitation. Multiply Line 47, the infiltration rate, by Line 48, the total sewered area for wastewater, by Line 49, the percentage of sewered area targeted for infiltration reduction, by Line 50, the estimated effectiveness of sewer rehabilitation, and then multiply by 365 days to calculate total infiltration reduction (in gallons) due to sewer rehabilitation.

Line 52 – Unit Cost to Rehabilitate Sewers. Enter the best estimate of the unit cost to rehabilitate sewers (See Appendix A).

Line 53 – Estimated Cost to Reduce Infiltration. Multiply Line 48, the total sewered area for wastewater, by the Line 49, percentage of sewered area targeted for infiltration reduction, and then multiply this value by Line 52, the unit cost to rehabilitate sewers.

Implement Water Conservation

Water conservation consists of a number of types of practices that reduce water use. Water conservation helps to extend water supplies, conserve energy, and reduce water and wastewater treatment costs. The reduced use of water through water conservation keeps water out of the system and decreases the total volume of base sanitary sewage flowing through a wastewater collection system. Quantification of water conservation practices in KWO has been limited to indoor products for which good quantifiable water-reduction estimates are available.

Keys to successful water-conservation programs include the implementation of water-conservation ordinances, effective outreach, and fair financial incentives. Most communities promote the installation of water-conserving appliances in private homes by establishing rebate programs, and having individuals purchase and install the new appliances. Homeowners can collect rebates from the community when they show proof of purchase for approved water-conserving appliances. Unless otherwise noted, the unit costs cited in this section are average rebates provided by the community when the homeowner purchases and installs water-conserving appliances.

Install Low-Flow Toilets

Line 54 – Number of Low-Flow Toilets Installed. Enter an estimate of the number of low-flow toilets that could be installed in the service area. Previous studies have shown that participation in water conservation programs, such as programs to install low-flow toilets, can range from under 3 percent to more than 60 percent, with an average of approximately 30 percent (See Appendix A). Thus the number of low flow toilets installed can be calculated by assuming a certain percent participation in the program and multiplying that percentage by the community population.

Line 55 – Annual Flow Reduction per Low-Flow Toilet. Enter the estimated annual flow reduced by each low flow-toilet. Previous studies have shown that switching to low-flow toilets can reduce flow by approximately 11,000-15,000 gallons per low-flow toilet per year (See Appendix A).

Line 56 – Total Flow Reduction due to Installing Low-Flow Toilets. Multiply Line 54, the number of low-flow toilets installed, by Line 55, the annual flow reduction per low-flow toilet, to calculate the total flow reduction due to installing low-flow toilets.

Line 57 – Unit Cost to Install Low-Flow Toilets. Enter the estimated cost per toilet to install low-flow toilets. Default costs from the literature are approximately $100 per fixture (See Appendix A).

Line 58 – Estimated Cost to Install Low-Flow Toilets. Multiply Line 54, the number of low-flow toilets installed, by Line 56, the unit cost to install low-flow toilets, to determine costs for installing low-flow toilets.

Install Low-Flow Showers

Line 59 – Number of Low-Flow Showers Installed. Enter an estimate of the number of low-flow showers that could be installed in the community. Water conservation programs often target installation of low-flow toilets and installation of low-flow showerheads together, and it is reasonable to assume the same number of low-flow showerheads as low-flow toilets from Line 46 above.

Line 60 – Annual Flow Reduction per Low-Flow Shower. Enter the estimated annual flow reduced by each low-flow shower. Previous studies have shown that switching to low-flow showers can reduce flow by approximately 8,000 gallons per low-flow shower per year (See Appendix A).

Line 61 – Flow Reduction due to Installing Low-Flow Showers. Multiply Line 59, the number of low-flow showers installed, by Line 61, the annual flow reduction per low-flow shower, to calculate the total flow reduction due to installing low-flow showers.

Line 62 – Unit Cost to Install Low-Flow Showers. Enter the estimated cost per showerhead to install low-flow showers. Default costs from the literature are approximately $10 per showerhead (See Appendix A).

Line 63 – Estimated Cost to Install Low-Flow Showers. Multiply Line 59, the number of low-flow showers installed, by Line 62, the unit cost to install low-flow showers, to determine costs for installing low-flow showers.

Install Low-Flow Washers

Line 64 – Number of Low-Flow Washers Installed. Enter an estimate of the number of low-flow washers that could be installed in the community. Because washers are relatively expensive and rebate programs do not typically cover the full cost of an efficient washer, the number of low-flow washers installed will most likely be lower than the number of low-flow toilets or showerheads installed.

Line 65 – Annual Flow Reduction per Low-Flow Washer. Enter the estimated annual flow reduced by each low-flow washer. Previous studies have shown that switching to low-flow washers can reduce flow by approximately 6,600 gallons per washer per year (See Appendix A).

Line 66 – Total Flow Reduction due to Installing Low-Flow Washers. Multiply Line 64, the number of low-flow washers installed, by Line 65, the annual flow reduction per low-flow washer, to calculate the total flow reduction due to installing low-flow showers.

Line 67 – Unit Cost to Install Low-Flow Washers. Enter the estimated cost per unit for low-flow washers. Many municipalities use rebate programs to encourage residents to upgrade their appliances voluntarily. Default costs from the literature are approximately $550 per fixture (See Appendix A).

Line 68 – Estimated Cost for Installing Low-Flow Washers. Multiply Line 64, the number of low-flow washers installed, by Line 67, the unit cost for installing low-flow washers, to determine the estimated cost for installing low-flow washers.

Total Reduction in Wastewater Flows and Estimated Cost

Line 69 – Total Reduction in Wastewater Flows. Add Line 51, total infiltration reduction due to sewer rehabilitation; Line 56, flow reduction due to installing low-flow toilets; Line 61, flow reduction due to installing low-flow showers; and Line 66, total flow reduction due to installing low-flow washers, to determine the total reduction of flows to the wastewater system from infiltration reduction and water conservation.

Line 70 – Total Estimated Cost for Reduction in Wastewater Flows. Add Line 53, estimated cost to reduce infiltration; Line 58, estimated cost to install low-flow toilets; Line 63, estimated cost to install low-flow showers; and Line 68, estimated cost for installing low-flow washers, to determine the total cost for reduction of flows to the wastewater system from infiltration reduction and water conservation.

Summary – Total Flow Reductions

Line 71 – Total Municipal Flow. Copy from Line 20.

Line 72 –Total Reduction in Flow to all Sewer Systems. Add Line 45, total reduction in stormwater runoff, and Line 69, total reduction in wastewater flows.

Line 73 – Total Municipal Flow after Reductions. Subtract Line 72 from Line 71.

Line 74 – Percentage of Flow Reduced to the Sewer Systems. Divide Line 72 by Line 71.

Stormwater Runoff Reductions

Line 75 – Total Stormwater Runoff. Copy from Line 19.

Line 76 – Total Reduction in Stormwater Runoff. Copy from Line 45.

Line 77 – Total Stormwater Flow after Reductions. Subtract Line 76 from Line 75.

Line 78 – Percent Reduction in Stormwater Flow. Divide Line 76 by Line 75.

Wastewater Flow Reductions

Line 79 – Base Wastewater Flow. Copy from Line 14.

Line 80 – Total Reduction in Wastewater Flow. Copy from Line 69.

Line 81 – Total Wastewater Flow after Reductions. Subtract Line 80 from Line 79.

Line 82 – Percent Reduction in Wastewater Flow. Divide Line 80 by Line 79.

Appendix A

Back-Up Data for Setting Default Values for the "Keeping Water Out of the System" Tool

Line 12 – Estimated Annual Infiltration Rate

Infiltration rates are highly site-specific and depend on numerous factors, include the age and condition of the pipes, the depth of groundwater, and other factors. However, several examples of infiltration rates from published studies are provided below:

100-800 gal/acre/day – City of Issaquah, WA (reference: http://www.ci.issaquah.wa.us/page.asp?navid=448)

8.6 – 221.9 gal/acre/day – City of Lawrence, Kansas (reference: http://www.lawrenceks.org/Headlines/WasteWater/SectionI/I-3.0WastewaterFlows.pdf)

Line 18 - Fraction of Annual Rainfall Events that Produce Runoff

The fraction of annual rainfall events that produce runoff value is based on an equation derived by Tom Schueler and the Metropolitan Washington Council of Governments (MWCOG) in Appendix A of the Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs (Schueler/MWCOG, 1987). The value of Pj (the fraction of events producing runoff) has typically been set at 90 percent, although this specific value was originally developed for "regional" rainfall in the Chesapeake Bay region. However, this value of 0.9 for Pj has been used for other areas, including Michigan (http://www.deq.state.mi.us/documents/deq-wb-water-nps-gt04-BMPeffectiveness.ppt#271,15,Simple Method); Minnesota (http://www.pca.state.mn.us/publications/wq-strm8-14as.pdf); Nevada (http://www.ce.unlv.edu/~piechota/proceedings/reginato-piechota-ewri-portland-2002.pdf); and California (http://www.thecityofdixon.com/dixon/DixonDowns/appendixes/Appendix_H_Hydrology.pdf).

Line 22 – Percent of Annual Rainfall Retained by Green Roofs

Green roofs retain precipitation, thereby reducing overall runoff after rain events. Retention of rainfall in the green roof thereby "keeps water out of the system." There are a number of studies that have evaluated the percentage of precipitation retained by green roofs, and the average value for the percent of annual precipitation retained by green roofs is approximately 60 percent. Individual references are provided below:

The Whole Building Design Group website states that "Vegetated roof covers are particularly effective at controlling runoff on the large roofs typical of commercial and institutional buildings. They can be designed to achieve specified levels of storm water runoff control, including reductions in both total annual runoff volume (reductions of 50 to 60 percent are common) and peak runoff rates for storms" (reference: http://www.wbdg.org/design/greenroofs.php).

Storm Water Net indicates that green roofs can produce 40 to 71 percent retention, depending on roof-type and storm intensity (reference: http://www.lid-stormwater.net/greenroofs/greenroofs_benefits.htm).

Toronto (reference: http://www.toronto.ca/greenroofs/) and Portland, OR have used 60 percent as a baseline for planning purposes.

Line 25 – Unit Cost to Convert to Green Roofs

Green roofs typically have a higher capital cost than standard roofs (typically $15-$20 per square foot for green roofs versus $9 per square foot for standard roofs), but overall, the life cycle costs for green roofs may be lower than those for standard roofs because of their longer life cycles (a typical green roof can last for 30-40 years, whereas a standard roof is designed to last for 15-25 years (reference: http://www.rio3.com/proceedings/RIO3_461_U_Porsche.pdf).

Example costs for installation of green roofs:

$10-$15/sq ft. – Low Impact Development Center (reference http://www.lid-stormwater.net/greenroofs/greenroofs_cost.htm)

$10-$25/sq ft – *Report to Congress, Impacts and Control of CSOs and SSOs*, August, 2004 (EPA 833-R-04-001)

Line 28 - Percent of Rainfall Infiltrating Pervious Pavement

Pervious pavement allows the infiltration of rainfall into the soil, thereby reducing overall runoff after rain events. Infiltration of rainfall through pervious pavement thereby "keeps water out of the system." There are a number of studies that have evaluated the percentage of precipitation that infiltrates through pervious pavement, with a conservative value being approximately 60 percent. Individual references are provided below:

Studies by Gburek and Urban, 1980, cited by EPA suggest that 70 to 80 percent of annual rainfall will go toward ground water recharge (reference: http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/post_21.cfm)

Washington DOE (1992) reports 60 percent recharge (reference: http://www.dcr.virginia.gov/sw/docs/swm/Chapter_3-10.pdf

Line 31 – Unit Cost to Convert to Pervious Pavement

Many studies indicate that the overall costs of installing pervious pavement are approximately equivalent to the capital costs for installing standard pavement. For example, the increased costs incurred for laying a stone underbed for pervious pavement may be mitigated by the fact that pervious pavement does not require the underground piping structure required for typical asphalt paved areas (reference: http://www.betterroads.com/articles/nov04e.htm). However, while the costs are similar to installing a new asphalt-paved area, this tool focuses on retrofitting into existing areas, and there will be costs to retrofit an area so it is suitable for installing pervious pavement. Therefore, the costs cited in this tool are the costs associated with retrofitting an area for pervious pavement. The average cost for installing pervious pavement is approximately $4 per square foot. Individual references are provided below:

$1.50-$9 per square foot – Puget Sound (reference: http://www.psat.wa.gov/Publications/LID_studies/permeable_pavement.htm)

$1-$4 per square foot - Center for Watershed Protection

$2-$6.50 per square foot – Low Impact Development Center (reference: http://www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm)

Line 37 – Unit Cost to Remove Impervious Areas

The KWO tool includes calculations for retrofitting various types of BMPs – such as swales, grass strips, and green spaces - that reduce impervious area. As with installing pervious pavement, reducing impervious cover and replacing it with pervious cover allows infiltration of rainfall into the soil, thereby reducing overall runoff after rain events. Infiltration of rainfall through pervious areas thereby "keeps water out of the system." The costs associated with reducing impervious area will be costs for retrofitting impervious areas (such as islands in parking lots, or other paved or impervious areas that may not need to be paved) into pervious green areas. There are a number of studies that have evaluated the percentage of precipitation that infiltrates through pervious pavement, with a conservative value being approximately 60 percent. Individual references are provided below:

$3-$4 per square foot – Puget Sound (reference: http://www.psat.wa.gov/Publications/LID_studies/permeable_pavement.htm)

$0.50 per square foot - Stormwater Center (reference: http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Open%20Channel%20Practice/Grassed%20Channel.htm)

$3-$4 per square foot for residential areas, $10-$40 per square foot commercial for installing bioretention areas – Low Impact Development Center (reference: http://www.lid-stormwater.net/bioretention/bio_costs.htm)

Line 39 – Average Roof Area of Single Family Homes.

The average roof size will depend on the mix of housing stock in the area. Urbanized areas will tend to have more townhouses with smaller roof areas, while suburban and rural areas tend to have larger homes with larger roof areas. New suburban subdivisions with so-called "McMansions" will have even larger average roof areas. Many communities use GIS data to determine the percentage of area occupied by roofs in their localities. Several individual references are provided below:

The Greenbuilder.com website gave charts showing roof sizes from 1,000 – 2,500 square feet, which is a good range for residential roof area.

EPA's Heat Island pilot project measured average percentage of roof area in several cities. Baton Rouge, Louisiana had 20-24 percent roof area in the city. Chicago had 13 percent (far-out suburbs) to 34 percent (medium/high density urban residential) roof area, with medium/low density inner suburbs at 27 percent.

The city of Calgary used an average roof area of 100 square meters (1100 square feet) in their rainwater harvesting calculations.

Planners in the Nine Mile Run watershed in the Pittsburgh, PA, area used a mean of 1100 square feet and a median of 980 square feet during a study of rain barrels (reference: http://www.ninemilerun.org/programs/stewardship/Analysis report.pdf).

Line 40 – Number of Single Family Homes Participating in Roof Leader Disconnection

The easiest way to determine the number of single family homes participating in a roof leader disconnection program may be to determine the percentage of the community that would be expected to participate in the program. There is very little reported data regarding the percent participation that can be expected for roof leader disconnection programs. While there have been many reports on roof leader disconnection programs, these projects typically report the actual number of participants in the program, and not the percent of the community participating. The percent of a community participating in the program will depend on multiple factors, including the success with which the program is advertised, the financial incentive to participate, and the ease with which an individual homeowner can participate. Percent participation results from two example programs are cited below:

40 percent participation - Toronto (reference: http://www.toronto.ca/legdocs/2004/agendas/committees/wks/wks041109/it021.pdf)

90 percent participation - Niagara Falls, Ontario, Canada (reference: http://www.ene.gov.on.ca/envision/water/greatlakes/coa/Wastewater_EN.pdf)

Line 43 – Unit Cost to Disconnect Roof Leaders

Residential inflow reduction is handled in many different ways by different municipalities, leading to disparities in costs quoted for various reduction measures. Some communities rely on the homeowner to disconnect downspouts and then reimburse the homeowners for the disconnection (i.e., Milwaukee, Dearborn, Indianapolis), while other municipalities do the disconnection themselves (i.e., Detroit, Toronto). The costs used in the KWO tool reflect the costs to the municipality for conducting a downspout disconnection program, and they are comprised of either the cost of homeowner reimbursement if the municipality chooses that method for implementing their program; or the actual costs of having municipal workers disconnect the downspouts, if the municipality chooses that option. Program cost estimates tend to be lower for reimbursement programs than for municipalities that do the work themselves. Based on the literature, average costs for roof leader disconnection are approximately $100 per property if municipalities have residents do it themselves, and $250 per property if municipalities do it themselves. Costs for several roof leader disconnection programs are summarized below:

1. Dearborn, MI – up to $60 per household reimbursement for residents doing it themselves. (reference: http://www.rougeriver.com/restoration/projDetail.cfm?ProjectID=780&CategoryID=10)
2. Bremerton, WA - $25-$500 per household reimbursement for voluntary disconnection, depending on complexity (reference: http://www.ci.kenmore.wa.us/html/projects/SedimentaryStudy/Section6ManagementStrategies.pdf)
3. Portland, OR - $63 per roof leader.
4. Indianapolis encourages residents to do it for themselves and indicates it should cost less than $100 apiece (reference: http://www.indygov.org/eGov/City/DPW/Environment/CleanStream/Help/Residents/Connect/qa.htm)
5. Milwaukee MSD - $15 per roof leader (reference: http://www.mmsd.com/programs/downspout_disconnection.cfm)
6. Kenmore, WA - $150-$300 per roof leader if the city performs the work; $15 if the homeowner does it. (reference: http://www.ci.kenmore.wa.us/html/projects/SedimentaryStudy/Section6ManagementStrategies.pdf)
7. Lynn, MA - $20 per roof leader reimbursement (reference: http://www.cdm-mich.com/AA-SSO/Public/FinalReport_6_01/Appendix%20M.pdf)
8. Elkhart, IN - $150 (reference: http://elkhartindiana.org/content.php?id=12&c_id=63)
9. South Bend, Indiana - $150 per property (reference: http://www.ci.south-bend.in.us/Press/Releases_2004/052404_Downspout.htm)
10. Vancouver, BC – City provided $100 per roof leader disconnected (reference: http://www.cityfarmer.org/downspout96.html)
11. Detroit, Michigan - $243-$278 per property (reference: http://www.wadetrim.com/resources/pub_conf_downspout.pdf)
12. Toronto, Ontario - $180-$220 per property (reference: http://www.ene.gov.on.ca/envision/gp/4224e_2.htm)

Line 50 – Estimated Effectiveness of Sewer Rehabilitation

While there is a great deal of data available on sewer rehabilitation effectiveness, the data are very site specific, and depend on multiple factors, including the age and condition of the sewers being rehabilitated, the parts of the system being rehabilitated (e.g., laterals vs. main lines), and many other factors. In addition, there is a lack of consistency in the way that the data are reported, and therefore it is extremely difficult to draw generalized conclusions from the data. However, results from several sewer rehabilitation projects are provide below as background:

In a 2004 study, the City of Hamburg, NY assumed a 65 percent effectiveness for sewer rehabilitation measures in planning their sewer rehabilitation program (reference: http://villagehamburg.com/vertical/Sites/%7B2EFBC174-DCFC-435F-8DF3-DF9386B1FE7B%7D/uploads/%7BA57626F2-EF67-4680-9A5D-39445E48C7D1%7D.PPT)

King County, WA reported that sewer rehabilitation effectiveness in reducing I/I ranged from 17 to 90 percent during a large series of pilot projects that investigated various rehabilitation scenarios of trunks, sewers and laterals, as well as appurtenances (reference: http://dnr.metrokc.gov/WTD/i-i/pilotprojects.htm).

Line 52 – Unit Cost to Rehabilitate Sewers

The cost of rehabilitating sewers is dependent on the type of rehabilitation method chosen. The type of rehabilitation method chosen is itself dependent on multiple factors, including the diameter of the pipe, its present condition, whether or not the pipe diameter can be decreased while still maintaining the necessary flow rates, and other factors. Users should be knowledgeable about the feasible sewer rehabilitation techniques for their system before choosing a unit cost estimate for sewer rehabilitation for use in KWO. Once a realistic sewer rehabilitation method is identified, users can use the examples below as guidance for estimating unit costs for sewer rehabilitation.

Pipe Bursting and Associated Methods

$42-$260/linear ft (reference: *Report to Congress on the Impacts and Control of CSOs and SSOs* (EPA 833-R-04-001), http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm)

$73-$188/linear ft for pipe bursting 6" and 8" pipes (reference: King County Regional Inflow and Infiltration Control Program, Pilot Project Report, http://dnr.metrokc.gov/WTD/i-i/library/PilotProject/report.htm)

$114 - $216/linear ft for pipe bursting of 8" to 24" pipes (reference: research done for Los Altos, CA, http://www.ci.los-altos.ca.us/publicworks/sewerplan/Chapter%207.pdf)

Sliplining

$10-$560/linear ft (reference: *Report to Congress on the Impacts and Control of CSOs and SSOs* (EPA 833-R-04-001), http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm)

$89 - $202/linear ft for sliplining of 10" to 24" pipes (reference: research done for Los Altos, CA, http://www.ci.los-altos.ca.us/publicworks/sewerplan/Chapter%207.pdf)

$242/linear ft for sliplining 42" pipe with 36" pipe in Davis, CA (reference: http://www.city.davis.ca.us/pw/CIP/cip.cfm?cip=7B4C40AE-743C-4535-B7829C300E661FE8&ActiveTab=1#folder)

$282/linear ft for sliplining 42" pipe with 36" pipe in Orlando, FL (reference: http://www.cityoforlando.net/public_works/projects/viewdetails.asp?ID=109)

Cured in Place Pipe (CIPP)

$42-$1200/linear ft (reference: *Report to Congress on the Impacts and Control of CSOs and SSOs* (EPA 833-R-04-001), http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm)

$102 - $259/linear ft for 10" to 18" CIPP (reference: research done for Los Altos, CA, http://www.ci.los-altos.ca.us/publicworks/sewerplan/Chapter 7.pdf)

$205/linear ft for lining of 30" sanitary sewer, San Jose, CA (reference: http://www.sanjoseca.gov/clerk/Agenda/040406/040406_02.03.pdf)

$196/linear ft for sewer lining of 12"-16" sanitary sewer in Toronto (reference: http://www.toronto.ca/legdocs/2004/agendas/committees/wks/wks041109/it004.pdf)

$104/linear ft for lining of 8", 12", and 15" sanitary sewer in Hamilton County, OH (reference: http://www.hamilton-co.org/engineer/SCIP/Round20/PROJECT%20DESCRIPTIONS%20SCIP-20.pdf)

$165/linear ft for lining of 6" and 8" sewer lines in Long Beach, CA (reference: http://www.rinker.com/ULiner/PDFs/ch3.pdf)

$29.50/linear ft of 8" CIP pipe (reference: research done for Jefferson County, Alabama, http://jeffco.jccal.org/pls/portal/docs/PAGE/JEFFERSONCOUNTYDEPARTMENTS/ENVIRONME

NTALSERVICESPAGE/TRACKINGREPORTS/TAB53757541625423469854/UNIT PRICE TRACKING.PDF)

$63/linear ft for lining of 30" and 8" sewers, Durham, NC (reference: http://www.amwater.com/awpr1/commercial_services/underground_rehabilitation/case_studies/page6806.html)

$48/linear ft to line 6", 8", and 10" clay pipe in Concord, CA (reference: http://www.ci.concord.ca.us/CITYGOV/AGENDAS/council/2003/07-01-03/rpt07-01-03-3e.pdf)

Open Cut Trench and Replace

$84/linear ft for dig and replace of 5,370 linear ft of 6" and 8" sanitary sewer and 2,400 linear ft of 4" laterals, plus manholes, in Berkeley, CA (reference: http://www.ci.berkeley.ca.us/citycouncil/2006citycouncil/packet/030706/2006-03-07%20Item%2015%20Contract%20-%20Sanitary%20Sewer.pdf)

$107/linear ft for trench and replace of 8" ductile iron pipe (reference: research done for Jefferson County, Alabama, http://jeffco.jccal.org/pls/portal/docs/PAGE/JEFFERSONCOUNTYDEPARTMENTS/ENVIRONMENTALSERVICESPAGE/TRACKINGREPORTS/TAB53757541625423469854/UNIT%20PRICE%20TRACKING.PDF)

$114 - $216 for trench and replace of 8" to 24" pipes (reference: research done for Los Altos, CA, http://www.ci.los-altos.ca.us/publicworks/sewerplan/Chapter%207.pdf)

Sewer Density per Acre

Values for sewer density per acre were determined by analysis of data collected for the 2004 *Report to Congress on the Impacts and Control of CSOs and SSOs* (EPA 833-R-04-001). Data from 49 separate and combined sewer communities of different sizes located throughout the United States were analyzed for sewer density by dividing the total length of separate and/or combined sewers in that community by the service area. The mean sewer density value from this analysis was 70 linear ft/acre, with a range of 3 - 206 linear ft/acre for individual communities. There was no strong relationship between community size or population density and sewer density.

Line 54 – Number of Low-Flow Toilets Installed

One method for determining the number of low-flow toilets that could be installed is to determine the percentage of the community that would be expected to participate in the program. The percent of the population participating in any water conservation program (i.e., conversion to low-flow appliances, reducing residential water use, etc.) will depend on a number of things, including the effectiveness of promotion and outreach of the program; the incentives to participate; and the ease with which citizens can participate. Therefore, it is difficult to generalize about the percentage of a population that can be expected to participate in a low-flow toilet program. However, several examples of percent public participation in water conservation programs collected from the literature are provided below:

3 percent - Contra Costa, CA (reference: http://www.ccwater.com/files/ULFT.pdf)

24 percent – Seattle, WA, solicited homeowners to participate in a program for various conservation measures, and got 24 out of 102 homes to respond (reference: http://www.cuwcc.org/Uploads/product/Seattle-Final-Report.pdf)

30 percent – Los Angeles – several communities in Los Angeles reached 30 percent participation (reference: http://www.smartcommunities.ncat.org/success/toilet_replacement.shtml)

60 percent – Barrie, Ontario, Canada (reference: http://www.ene.gov.on.ca/programs/3659e.pdf)

Line 55 – Annual Flow Reduction per Low-Flow Toilet

An analysis of H.R. 859, a Bill to Amend the Energy Policy and Conservation Act to Eliminate Certain Regulation of Plumbing Supplies (http://www.monolake.org/waterpolicy/hr859-623analysishtm.htm#notes) cites "The Conserving Effect of Ultra Low Flush Toilet Rebate Programs. A Report to the Metropolitan Water District of Southern California, Los Angeles, California" (1992) by T.W. Chestnutt, A. Bamezia, and C. McSpadden. This paper summarizes empirical studies of seven years of data from 23,000 households in Los Angeles and Santa Monica that estimated mean savings of 28 gallons per day (gpd) per low-flow toilet in single family homes and 44 gpd per toilet in multi-family residences.

Chapter 3 of EPA's *Cleaner Water Through Conservation* document (EPA 841-B-95-002, April, 1995, http://www.epa.gov/water/you/intro.html) cites data from the City of San Pablo, CA, that showed a 34 percent decrease in water use through installation of low-flow toilets, from 225 gpd per household to 148 gpd per household, a savings of 77 gpd per household.

Flex Your Power website cites annual water savings of 14,800 gallons for new standard toilet vs. old standard toilet (40.5 gallons/day). (reference: http://www.fypower.org/com/tools/products_results.html?id=100139)

Line 57 – Unit Cost to Install Low-Flow Toilets

The cost for low-flow toilets is approximately equal to the cost for standard toilets, and most toilets manufactured today meet the requirements to be considered low-flow toilets. An inexpensive low-flow toilet can be purchased for approximately $100 (reference: http://www.fypower.org/com/tools/products_results.html?id=100139)

There are also multiple examples of rebate programs, in which municipalities provide a rebate to homeowners who have a proof of purchase of a low-flow appliance. Example rebate amounts include:

Austin, TX - Rebate of $100 (reference: http://www.ci.austin.tx.us/watercon/sftoilet.htm)

Contra Costa, CA – Rebate of $150 (reference: http://www.ccwater.com/conserve/c-comm_toilet_rebate.asp)

Line 59 – Number of Low-Flow Showers Installed

See the discussion of percent participation in conversion to low-flow toilets above. One example of percent participation in conversion to low-flow showers from the literature is provided below:

8.5 percent participation in the program – Sidney, Australia

Line 60 – Annual Flow Reduction per Low-Flow Shower

7,800 gallons - new low-flow showerhead vs. old standard showerhead (21.4 gallons/day). (reference: Flex Your Power website, http://www.fypower.org/res/tools/products_results.html?id=100160)

Line 62 – Unit Cost to Install Low-Flow Showers

The cost for low-flow shower heads is approximately equal to the cost for standard shower heads, and inexpensive low-flow showerheads can be purchased for under $10 (Department of Energy, reference http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13050). There are also multiple examples of rebate programs, in which municipalities provide a rebate to homeowners who have a proof of purchase of a low-flow appliance. Example rebate amounts include:

$8-$50 - eartheasy.com (reference: http://eartheasy.com/live_lowflow_aerators.htm)

Line 65 – Annual Flow Reduction per Low-Flow Washer

5,100 gallons/year (14 gallons/day savings) – Oxnard, CA (reference: http://www.oxnardwater.org/outreach/community/ulfts&washers.asp)

8,000 gallons/year (22 gallons/day) – West Basin, CA (reference: http://www.westbasin.com/saving_tips.php)

Line 67 – Unit Cost to Install Low-Flow Washers

Low-flow washers are typically more expensive than standard washers (an average standard washer would be in the $450 range, while an average low-flow washer would be in the $550 range), and therefore municipalities typically have to provide a good incentive for people to purchase low-flow washers. Example rebate amounts include:

$550 to purchase washer – Allen, TX (reference: http://www.cityofallen.org/commservices/Rebate/RebateItemFAQ.htm)

$300 rebate – Contra Costa, CA (reference: http://www.ccwater.com/conserve/c-commwashingmachine.asp)

$150 rebate - Los Angeles, CA (reference: http://www.ladwp.com/ladwp/cms/ladwp000399.jsp)

$125 rebate - Coastside Water, CA (reference: http://www.coastsidewater.org/water-conservation.html#CommercialWasherRebate)

$600 - $1000 to purchase washer in Pennsylvania (reference: http://www.hopi.nsn.us/wrp/docs/Water%20Audit%20Fact%20Sheet.pdf)

Appendix B

References

1. Analysis of H.R. 859, a Bill to Amend the Energy Policy and Conservation Act to Eliminate Certain Regulation of Plumbing Supplies, http://www.monolake.org/waterpolicy/hr859-623analysishtm.htm
2. Metcalf and Eddy, 1991. "Wastewater Engineering: Treatment, Disposal and Reuse." Third Edition, Irvin McGraw Hill, Boston, Massachusetts, 1991.
3. Schueler, T. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices*. MWCOG. Washington, D.C.
4. Sholz-Barth, K. 2001. "Green Roofs: Stormwater Management from the Top Down." Retrieved October 18, 2002. http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,18769,00.html
5. US EPA, 1995. *Cleaner Water Through Conservation*, Chapter 3, EPA 841-B-95-002, April 1995. http://www.epa.gov/water/you/intro.html
6. US EPA. 2004. *Office of Water. Report to Congress on the Impacts and Control of CSOs and SSOs.* EPA 833-R-04-001.

Appendix C

Example: Springfield, USA

Springfield, USA, is a small city (population 50,000) with a sanitary sewer system covering 5,120 acres in the municipality. Combined sewers serve approximately 320 acres in the older downtown area. The municipality also has a separate storm sewer area that encompasses 4,800 acres. About 34% of the City is impervious surface. The Springfield Wastewater Treatment Plant (WWTP) has an average daily flow of 10 MGD. I/I studies have determined that about 25% of the base flow is infiltration. The annual rainfall is 40 inches.

Springfield has problems with CSOs and has experienced peak flows at its WWTP. These problems have increased the potential for water quality degradation in the local receiving water. In addition, Springfield University has identified stormwater impacts in local waterbodies.

The City wants to develop a plan to address these issues. As a first step, Springfield used KWO to evaluate options for reducing flows to its sewer systems. The City is considering a sewer rehabilitation effort in the 200-acre Clover Hills subdivision. The City also wants to consider options to reduce base wastewater flows through water conservation. In addition, the City wants to consider some “low-hanging fruit” for reducing stormwater runoff.

The City used **KWO** to consider two options:

- ***Scenario 1****:* sewer rehabilitation only; and
- ***Scenario 2****:* sewer rehabilitation coupled with disconnecting roof leaders, adding pervious pavement and reducing imperviousness

See below for explanation of Springfield’s input data and KWO evaluation. Springfield’s completed **FORM KWO** is attached.

Explanation of Input Data

Using known information about Springfield’s sewer systems, its service population, and local rainfall, the City quantified base wastewater flow, base stormwater runoff, and total municipal flow (Lines 1-20 in **FORM KWO**).

Sewered Service Area and Population

- Sewered service areas in acres (sanitary, separate storm, and combined)
    - Total Wastewater Sewer Area
        - 5,120 acres sanitary sewer+ 320 acres combined sewer = 5,440 acres
    - Total Stormwater Sewer Area
        - 4,800 acres storm+ 320 acres combined = 5,120 acres.
- Wastewater sewer service population
    - 50,000 people

Base Wastewater Flow (Includes Infiltration)

- Wastewater volume in gallons/year
    - 10,000,000 gal/day * 365 days/yr = 3,650,000,000 gal/yr
- Infiltration
    - 25% of base flow is infiltration.

10 MGD * 25% = 2,500,000 gal/day * 365 days/yr = 912,500,000 gal/yr

Base Stormwater Runoff

- Percent imperviousness
    - 34%
- Annual rainfall in inches
    - 40 inches
- Fraction of events that produce runoff
    - 0.90 (KWO default value)

Scenario 1: Sewer Rehabilitation Only

Sewer Rehabilitation

- Percentage of Sewered Area Targeted for Infiltration Reduction
    - 200 acres targeted for rehabilitation/5,440 acres total sanitary sewer area = 4%

The City has some data on rehabilitation effectiveness and cost from previous sewer rehabilitation projects, and it used these in KWO:

- Estimated effectiveness of sewer rehabilitation = 75%
- Unit cost to rehabilitate sewers = $10,500/acre

Result: The City determined that sewer rehabilitation of the Clover Hills subdivision would only reduce wastewater flows by 1% at a cost of $2.3 million. While this type of sewer rehabilitation project is part of Springfield's ongoing capital improvement process, the City wants to explore other options for reducing flows to its sewer systems.

Scenario 2: Sewer rehabilitation coupled with disconnecting roof leaders, converting to pervious pavement, and reducing imperviousness

Sewer Rehabilitation

See Scenario 1.

<u>Disconnect Roof Leaders</u>

The Department of Public Works (DPW) believes that disconnecting roof leaders can significantly reduce flows to the storm sewer system, and so they want to explore this scenario using KWO. Based on the experience of a neighboring community, DPW feels that it is reasonable to get 4,000 homes (about 20% of the community) to participate in the program by offering a rebate of $20 per household. DPW doesn't have data on the average roof areas of homes in Springfield, so it chose a value of 1,500 sq. ft. based on the discussion in Appendix A of KWO.

- Average roof area of single family homes = 1,500 sq. ft
- Number of Single Family Homes Participating in Roof Leader Disconnection = 4,000
- Unit cost to disconnect roof leaders = $20/home

<u>Result:</u> KWO shows that disconnecting roof leaders at 4000 homes would reduce stormwater runoff by almost 150 million gallons/year at a cost of only $80,000.

Install Pervious Pavement

The City owns 50 acres of parking lots that it feels it could convert to pervious pavement, but it has no other data on pervious pavement, so it has chosen to use some reasonable default values from Appendix A of KWO. Thus, its inputs are:

- Total area of pervious pavement = 50 acres
- Percent of rainfall infiltrating pervious pavement = 60%
- Unit cost of installing pervious pavement = $4/sq. ft.

<u>Result:</u> KWO shows that installing 50 acres of pervious pavement would reduce stormwater runoff by approximately 32.5 million gallons at a cost of $8.7 million.

Reduce Impervious Areas

The City Planning Department has also identified approximately 50 acres of condemned buildings that it could replace with greenspace to reduce impervious areas. As with pervious pavement, the City has no other data on reducing impervious areas, so it has chosen to use some reasonable default values from Appendix A of KWO. Thus, its inputs are:

- Total impervious area removed = 50 acres
- Unit cost of removing impervious area = $4/sq. ft.

Result: KWO shows that reducing impervious areas by 50 acres would reduce stormwater runoff by approximately 19.3 million gallons at a cost of $8.7 million.

Overall Flow Reductions

KWO has allowed Springfield to explore various scenarios and potential options for reducing flows to their sewer systems. Springfield has an ongoing sewer rehabilitation program, but flow reduction strategies aimed at reducing runoff to the City's stormwater system can complement this work and reduce overall flows within the system. KWO has shown the City that a roof leader disconnection program can have a large impact on storm water runoff, and adding smaller projects to reduce impervious areas and add pervious pavement can help reduce flows further. Overall, Scenario 2 produced an 11 percent reduction in stormwater runoff and a 4 percent reduction in total flows in the sewer systems. Springfield can then use KWO to explore other scenarios to see if it can achieve further reductions in a cost-effective manner.

KWO United States Environmental Protection Agency
Keeping Water Out Of Sewer Systems

Community Information	Community Name City of Springfield, Scenario 1
	Street address 200 Main Street
	City, State, and ZIP Code Springfield, USA
	Contact John Q. Public, Public Works Department
	Telephone number: 555-1212 / Fax number: / E-mail address:
	Sewer Systems in your Community. Check all that apply. ☑ Combined Sewer System ☑ Sanitary Sewer System ☑ Separate Storm Sewer System

		Line	Value
SEWERED SERVICE AREA AND POPULATION			
	1 Total wastewater sewer area (acres)	1	5,440
	2 Total stormwater sewer area (acres)	2	5,120
	3 Service population for wastewater	3	50,000
BASE WASTEWATER FLOW (INCLUDES INFILTRATION)			
Known Base Wastewater Flow	4 Recorded total base wastewater flow, includes infiltration (gal/yr)	4	3,650,000,000
Estimated Domestic & Industrial Wastewater Flow	5 Wastewater generation rate (gal/person/day)	5	
	6 Estimated domestic wastewater flow (gal/yr). *Multiply Line 3 by Line 5, and then by 365.*	6	0
	7 Industrial wastewater flow (gal/yr)	7	0
	8 Estimated domestic and industrial wastewater flow (gal/yr). *Add Lines 6 and 7.*	8	0
Infiltration			
Known Annual Infiltration	9 Percent of base wastewater flow that is infiltration (percent)	9	25%
	10 Annual infiltration (gal/yr). *Multiply Line 4 by Line 9.*	10	912,500,000
	11 Calculated annual infiltration rate (gal/acre/day). *Divide Line 10 by Line 1, and then divide by 365.*	11	460
Estimated Annual Infiltration	12 Estimated annual infiltration rate (gal/acre/day)	12	
	13 Estimated annual infiltration (gal/yr). *Multiply Line 1 by Line 12, and then by 365.*	13	0
Base Wastewater Flow	14 Base wastewater flow (gal/yr). *Enter from Line 4, OR Add Line 8 to Line 13*	14	3,650,000,000
BASE STORMWATER RUNOFF			
	15 Percent imperviousness (percent)	15	34%
	16 Runoff coefficient. *Multiply Line 15 by 0.9 and then add 0.05*	16	0.356
	17 Annual rainfall (inches)	17	30
	18 Fraction of annual rainfall events that produce runoff.	18	0.9
Base Stormwater Runoff	19 Base stormwater runoff (gal/year). *Multiply Lines 2, 16, 17, and 18, and then multiply by 27,154.*	19	1,336,341,750
TOTAL MUNICIPAL FLOW			
	20 Total municipal flow (gal/yr). Add Lines 14 and Line 19	20	4,986,341,750

QUANTIFY REDUCTION IN STORMWATER RUNOFF			
Convert to Green Roofs	21 Total area of green roofs (acres)	21	
	22 Percent of annual rainfall retained by green roofs (percent). *Enter as a decimal fraction.*	22	
	23 Depth of annual rainfall retained per unit area of green roof (inches). *Multiply Line 17 by Line 22.*	23	0
	24 Runoff reduction from converting to green roofs (gal). *Multiply Line 21 by Line 23, then multiply by 27,154.*	24	0
	25 Unit cost to convert to green roofs ($/ft^2)	25	
	26 Estimated cost to convert to green roofs. *Multiply Line 21 by Line 25, then multiply by 43,560*	26	$0
Convert to Pervious Pavement	27 Total area of pervious pavement (acres)	27	
	28 Percent of rainfall infiltrating pervious pavement (percent). *Enter as a decimal fraction.*	28	
	29 Depth of annual rainfall infiltrated per unit area of pavement (inches). *Multiply Line 17 by Line 28.*	29	0
	30 Runoff reduction from converting to pervious pavement (gal). *Multiply Lines 27 and 29, then by 27,154*	30	0
	31 Unit cost to convert to pervious pavement ($/ft^2)	31	
	32 Estimated cost to convert to pervious pavement. *Multiply Line 27 by Line 31, and then multiply by 43,560.*	32	$0
Remove Impervious Areas	33 Total impervious area removed (acres)	33	
	34 Runoff coefficient for impervious areas. *Copy from Line 16.*	34	0.356
	35 Adjusted rainfall. *Multiply Line 17 by Line 34.*	35	11
	36 Runoff reduction from removing impervious area. *Multiply Line 33 by Line 35, then multiply by 27,154.*	36	0
	37 Unit cost to reduce impervious areas ($/ft^2)	37	
	38 Estimated cost to remove impervious area. *Multiply Line 33 by Line 37, then multiply by 43,560.*	38	$0
Disconnect Roof Leaders	39 Average roof area of single family homes (ft^2)	39	
	40 Number of single family homes participating in roof leader disconnection	40	
	41 Total roof area of single family homes participating in roof leader disconnection. *Multiply Line 39 by Line 40.*	41	0
	42 Runoff reduction from disconnecting roof leaders. *Multiply Line 17 by Line 41, then multiply by 0.623.*	42	0
	43 Unit cost to disconnect roof leaders ($/roof leader)	43	
	44 Estimated cost of roof leader disconnection. *Multiply Line 40 by Line 43.*	44	$0
TOTAL REDUCTION IN STORMWATER FLOW AND ESTIMATED COSTS			
	45 Total reduction in stormwater runoff (gallons). *Add Lines 24, 30, 36, and 42.*	45	0
	46 Total estimated cost for reduction in stormwater runoff. *Add Lines 26, 32, 38, and 44.*	46	$0
QUANTIFY REDUCTION IN WASTEWATER FLOWS			
Reduce Infiltration	47 Infiltration rate (gallons/acre/day). *Copy from Line 11 or 12, depending on method used for infiltration rate.*	47	460
	48 Total wastewater sewer area (acres). *Copy from Line 1.*	48	5,440
	49 Percentage of sewered area targeted for infiltration reduction (percent). *Enter as a decimal fraction.*	49	4%
	50 Estimated effectiveness of sewer rehabilitation (percent). *Enter as a decimal fraction.*	50	75%
	51 Total infiltration reduction due to sewer rehabilitation. *Multiply Lines 47 through 50, and then multiply by 365.*	51	27,375,000
	52 Unit cost to rehabilitate sewers ($/acre)	52	$10,500
	53 Estimated cost to reduce infiltration. *Multiply Line 48 by Line 49 and then by Line 52.*	53	$2,284,800
Implement Water Conservation			
Install Low-Flow Toilets	54 Number of low-flow toilets installed	54	
	55 Annual flow reduction per low-flow toilet (gallons/low-flow toilet/year)	55	
	56 Total flow reduction due to installing low-flow toilets (gallons/year). *Multiply Line 54 by Line 55.*	56	0
	57 Unit cost to install low-flow toilets ($/fixture)	57	
	58 Estimated cost to install low-flow toilets. *Multiply Line 54 by Line 57.*	58	$0
Install Low-Flow Showers	59 Number of low-flow showers installed	59	
	60 Annual flow reduction per low-flow shower	60	
	61 Total flow reduction due to installing low-flow showers (gallons/year). *Multiply Line 59 by Line 60.*	61	0
	62 Unit cost to install low-flow showers ($/fixture)	62	
	63 Estimated cost to install low-flow showers. *Multiply Line 59 by Line 62.*	63	$0
Install Low-Flow Washers	64 Number of low-flow washers installed	64	
	65 Annual flow reduction per low-flow washer	65	
	66 Total flow reduction due to installing low-flow washers (gallons/year). *Multiply Line 64 by Line 65.*	66	0
	67 Unit cost to install low-flow washers ($/fixture)	67	
	68 Estimated cost for installing low-flow washers. *Multiply Line 64 by Line 67.*	68	$0
TOTAL REDUCTION IN WASTEWATER FLOWS AND ESTIMATED COSTS			
	69 Total reduction in wastewater flows. *Add Lines 51, 56, 61, and 66.*	69	27,375,000
	70 Total estimated cost for reduction in wastewater flows. *Add Lines 53, 58, 63, and 68.*	70	$2,284,800

SUMMARY - TOTAL FLOW REDUCTIONS		
71 Total municpal flow. *Copy from Line 20.*	71	4,986,341,750
72 Total reduction in flow to all sewer systems. *Add Line 45 and Line 69.*	72	27,375,000
73 Total municipal flow after reductions. *Subtract Line 72 from Line 71.*	73	4,958,966,750
74 Percentage of flow reduced to sewer systems. *Divide Line 72 by Line 71.*	74	1%
STORMWATER RUNOFF REDUCTIONS		
75 Total stormwater runoff. *Copy from Line 19.*	75	1,336,341,750
76 Total reduction in stormwater runoff. *Copy from Line 45.*	76	0
77 Total stormwater runoff after reductions. *Subtract Line 76 from Line 75.*	77	1,336,341,750
78 Percent reduction in stormwater flow. *Divide Line 76 by Line 75.*	78	0%
WASTEWATER FLOW REDUCTIONS		
79 Total base wastewater flow. *Copy from Line 14.*	79	3,650,000,000
80 Total reduction in wastewater flow. *Copy from Line 69.*	80	27,375,000
81 Total stormwater flow after reductions. *Subtract Line 80 from Line 79.*	81	3,622,625,000
82 Percent reduction in wastewater flows. *Divide Line 80 by Line 79.*	82	1%

KWO

United States Environmental Protection Agency

Keeping Water Out Of Sewer Systems

Community Information	Community Name City of Springfield, Scenario 2
	Street address 200 Main Street
	City, State, and ZIP Code Springfield, USA
	Contact John Q. Public, Public Works Department
	Telephone number: 555-1212 | Fax number: | E-mail address:
	Sewer Systems in your Community. Check all that apply. ☑ Combined Sewer System ☑ Sanitary Sewer System ☑ Separate Storm Sewer System

SEWERED SERVICE AREA AND POPULATION			
	1 Total wastewater sewer area (acres)	1	5,440
	2 Total stormwater sewer area (acres)	2	5,120
	3 Service population for wastewater	3	50,000
BASE WASTEWATER FLOW (INCLUDES INFILTRATION)			
Known Base Wastewater Flow	4 Recorded total base wastewater flow, includes infiltration (gal/yr)	4	3,650,000,000
Estimated Domestic & Industrial Wastewater Flow	5 Wastewater generation rate (gal/person/day)	5	
	6 Estimated domestic wastewater flow (gal/yr). *Multiply Line 3 by Line 5, and then by 365.*	6	0
	7 Industrial wastewater flow (gal/yr)	7	0
	8 Estimated domestic and industrial wastewater flow (gal/yr). *Add Lines 6 and 7.*	8	0
Infiltration			
Known Annual Infiltration	9 Percent of base wastewater flow that is infiltration (percent)	9	25%
	10 Annual infiltration (gal/yr). *Multiply Line 4 by Line 9.*	10	912,500,000
	11 Calculated annual infiltration rate (gal/acre/day). *Divide Line 10 by Line 1, and then divide by 365.*	11	460
Estimated Annual Infiltration	12 Estimated annual infiltration rate (gal/acre/day)	12	
	13 Estimated annual infiltration (gal/yr). *Multiply Line 1 by Line 12, and then by 365.*	13	0
Base Wastewater Flow	14 Base wastewater flow (gal/yr). *Enter from Line 4, OR Add Line 8 to Line 13*	14	3,650,000,000
BASE STORMWATER RUNOFF			
	15 Percent imperviousness (percent)	15	34%
	16 Runoff coefficient. *Multiply Line 15 by 0.9 and then add 0.05*	16	0.356
	17 Annual rainfall (inches)	17	40
	18 Fraction of annual rainfall events that produce runoff.	18	0.9
Base Stormwater Runoff	19 Base stormwater runoff (gal/year). *Multiply Lines 2, 16, 17, and 18, and then multiply by 27,154.*	19	1,781,789,000
TOTAL MUNICIPAL FLOW			
	20 Total municipal flow (gal/yr). Add Lines 14 and Line 19	20	5,431,789,000

QUANTIFY REDUCTION IN STORMWATER RUNOFF			
Convert to Green Roofs	21 Total area of green roofs (acres)	21	
	22 Percent of annual rainfall retained by green roofs (percent). *Enter as a decimal fraction.*	22	
	23 Depth of annual rainfall retained per unit area of green roof (inches). *Multiply Line 17 by Line 22.*	23	0
	24 Runoff reduction from converting to green roofs (gal). *Multiply Line 21 by Line 23, then multiply by 27,154.*	24	0
	25 Unit cost to convert to green roofs ($/ft^2)	25	
	26 Estimated cost to convert to green roofs. *Multiply Line 21 by Line 25, then multiply by 43,560*	26	$0
Convert to Pervious Pavement	27 Total area of pervious pavement (acres)	27	50
	28 Percent of rainfall infiltrating pervious pavement (percent). *Enter as a decimal fraction.*	28	60%
	29 Depth of annual rainfall infiltrated per unit area of pavement (inches). *Multiply Line 17 by Line 28.*	29	24
	30 Runoff reduction from converting to pervious pavement (gal). *Multiply Lines 27 and 29, then by 27,154*	30	32,584,800
	31 Unit cost to convert to pervious pavement ($/ft^2)	31	$4.00
	32 Estimated cost to convert to pervious pavement. *Multiply Line 27 by Line 31, and then multiply by 43,560.*	32	$8,712,000
Remove Impervious Areas	33 Total impervious area removed (acres)	33	50
	34 Runoff coefficient for impervious areas. *Copy from Line 16.*	34	0.356
	35 Adjusted rainfall. *Multiply Line 17 by Line 34.*	35	14
	36 Runoff reduction from removing impervious area. *Multiply Line 33 by Line 35, then multiply by 27,154.*	36	19,333,648
	37 Unit cost to reduce impervious areas ($/ft^2)	37	$4.00
	38 Estimated cost to remove impervious area. *Multiply Line 33 by Line 37, then multiply by 43,560.*	38	$8,712,000
Disconnect Roof Leaders	39 Average roof area of single family homes (ft^2)	39	1500
	40 Number of single family homes participating in roof leader disconnection	40	4000
	41 Total roof area of single family homes participating in roof leader disconnection. *Multiply Line 39 by Line 40.*	41	6,000,000
	42 Runoff reduction from disconnecting roof leaders. *Multiply Line 17 by Line 41, then multiply by 0.623.*	42	149,520,000
	43 Unit cost to disconnect roof leaders ($/roof leader)	43	$20.00
	44 Estimated cost of roof leader disconnection. *Multiply Line 40 by Line 43.*	44	$80,000
TOTAL REDUCTION IN STORMWATER FLOW AND ESTIMATED COSTS			
	45 Total reduction in stormwater runoff (gallons). *Add Lines 24, 30, 36, and 42.*	45	201,438,448
	46 Total estimated cost for reduction in stormwater runoff. *Add Lines 26, 32, 38, and 44.*	46	$17,504,000

QUANTIFY REDUCTION IN WASTEWATER FLOWS			
Reduce Infiltration	47 Infiltration rate (gallons/acre/day). *Copy from Line 11 or 12, depending on method used for infiltration rate.*	47	460
	48 Total wastewater sewer area (acres). *Copy from Line 1.*	48	5,440
	49 Percentage of sewered area targeted for infiltration reduction (percent). *Enter as a decimal fraction.*	49	4%
	50 Estimated effectiveness of sewer rehabilitation (percent). *Enter as a decimal fraction.*	50	75%
	51 Total infiltration reduction due to sewer rehabilitation. *Multiply Lines 47 through 50, and then multiply by 365.*	51	27,375,000
	52 Unit cost to rehabilitate sewers ($/acre)	52	$10,500
	53 Estimated cost to reduce infiltration. *Multiply Line 48 by Line 49 and then by Line 52.*	53	$2,284,800
Implement Water Conservation			
Install Low-Flow Toilets	54 Number of low-flow toilets installed	54	0
	55 Annual flow reduction per low-flow toilet (gallons/low-flow toilet/year)	55	
	56 Total flow reduction due to installing low-flow toilets (gallons/year). *Multiply Line 54 by Line 55.*	56	0
	57 Unit cost to install low-flow toilets ($/fixture)	57	
	58 Estimated cost to install low-flow toilets. *Multiply Line 54 by Line 57.*	58	$0
Install Low-Flow Showers	59 Number of low-flow showers installed	59	0
	60 Annual flow reduction per low-flow shower	60	
	61 Total flow reduction due to installing low-flow showers (gallons/year). *Multiply Line 59 by Line 60.*	61	0
	62 Unit cost to install low-flow showers ($/fixture)	62	
	63 Estimated cost to install low-flow showers. *Multiply Line 59 by Line 62.*	63	$0
Install Low-Flow Washers	64 Number of low-flow washers installed	64	0
	65 Annual flow reduction per low-flow washer	65	
	66 Total flow reduction due to installing low-flow washers (gallons/year). *Multiply Line 64 by Line 65.*	66	0
	67 Unit cost to install low-flow washers ($/fixture)	67	
	68 Estimated cost for installing low-flow washers. *Multiply Line 64 by Line 67.*	68	$0
TOTAL REDUCTION IN WASTEWATER FLOWS AND ESTIMATED COSTS			
	69 Total reduction in wastewater flows. *Add Lines 51, 56, 61, and 66.*	69	27,375,000
	70 Total estimated cost for reduction in wastewater flows. *Add Lines 53, 58, 63, and 68.*	70	$2,284,800

SUMMARY - TOTAL FLOW REDUCTIONS		
71 Total municpal flow. *Copy from Line 20.*	71	5,431,789,000
72 Total reduction in flow to all sewer systems. *Add Line 45 and Line 69.*	72	228,813,448
73 Total municipal flow after reductions. *Subtract Line 72 from Line 71.*	73	5,202,975,552
74 Percentage of flow reduced to sewer systems. *Divide Line 72 by Line 71.*	74	4%
STORMWATER RUNOFF REDUCTIONS		
75 Total stormwater runoff. *Copy from Line 19.*	75	1,781,789,000
76 Total reduction in stormwater runoff. *Copy from Line 45.*	76	201,438,448
77 Total stormwater runoff after reductions. *Subtract Line 76 from Line 75.*	77	1,580,350,552
78 Percent reduction in stormwater flow. *Divide Line 76 by Line 75.*	78	11%
WASTEWATER FLOW REDUCTIONS		
79 Total base wastewater flow. *Copy from Line 14.*	79	3,650,000,000
80 Total reduction in wastewater flow. *Copy from Line 69.*	80	27,375,000
81 Total stormwater flow after reductions. *Subtract Line 80 from Line 79.*	81	3,622,625,000
82 Percent reduction in wastewater flows. *Divide Line 80 by Line 79.*	82	1%