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Guide for Estimating Infiltration and Inflow

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Purpose

This Guide is intended to provide background and information for managers of wastewater collection systems on estimating the amount of infiltration and inflow (I&I) entering their collection system and for responding to National Pollutant Discharge Elimination System (NPDES) I&I permit reporting requirements.

This Guide provides methods for analyzing wastewater treatment plant influent flow data to estimate the I&I impact from the collection system as a whole. It will assist municipalities in ascertaining whether they have a significant I&I problem and, if so, what kind of problem they have. Areas (sewersheds) served by pump stations that are capable of recording flow can also be evaluated using these methods.

Background

There are three major components of wastewater flow in a sanitary sewer system, base sanitary (or wastewater) flow, groundwater infiltration and rainfall derived inflow and infiltration, more commonly referred to as inflow. Virtually every sewer system has some infiltration and/or inflow. Historically, small amounts of I&I are expected and tolerated. However, infiltration and inflow may be considered excessive when it is the cause of overflows or bypasses, or the cost to transport and treat exceeds the cost to eliminate it. In cases where the I&I may not be considered "excessive" from a cost-to-eliminate perspective but causes health or environmental risks, corrective actions are required.

Even where a system is not suffering from sanitary sewer overflows (SSOs), systems experiencing surcharging may be good candidates for further I&I investigation, as are systems where significant new growth is expected and existing collection system capacity may be inadequate or marginal for handling new customers.

State Revolving Loan Fund (SRF) applicants are generally required to evaluate the impacts of I&I on their overall system. This evaluation usually begins with an initial screening to determine whether a more complete I&I analysis will be required. The screening compares the sewered population to the treatment plant flow to determine gallons per day per person (gpdpp). The gpdpp is compared to a standard to determine if there is excessive infiltration. The states' standards vary between 100 and 150 gpdpp. The existing EPA guidance, which uses 120 gpdpp, was published in 1985 when 3.5 gallon-per-flush toilets were standard (the Energy Policy Act of 1992 required that toilets installed in new construction use a maximum of 1.6 gallon per flush (low-flow toilets)).

Some guidance documents use the term excessive infiltration/inflow. This can mean quantities of I&I which can be economically eliminated from a sewer system as determined in a cost-effectiveness analysis that compares the costs for correcting the I&I conditions to the total costs for transportation and treatment of the infiltration/inflow. I&I which causes SSOs is considered excessive.

Municipalities will be well served to understand the dimensions and nature of any I&I problems. A clear set of goals is important for keeping an I&I program focused.

The following is a sample of possible goals:

- To reduce ratepayer costs for transporting and treating wastewater by implementing all cost-effective I&I reduction projects within 10 years.
- To minimize liability from water pollution and public health risks by eliminating sanitary sewer overflows in storm events.
- To eliminate sufficient I&I to avoid the capital costs of wastewater treatment plant capacity expansion in anticipation of 10% population growth over the next 20 years.
- To eliminate sufficient I&I to avoid the capital costs of interceptor expansion which will be needed to support the build-out of certain neighborhoods.
- To eliminate enough I&I to offset the environmental and regulatory impact of sewer system expansion and increased water demand over the next 15 years.

In some cases, high levels of infiltration can lower groundwater levels and can cause significant hydrologic impacts to nearby streams. The health of tributary streams is critical to the health of main stem rivers, and reduced flows can impair the fish community by decreasing dissolved oxygen and available habitat, increasing water temperatures, and concentrating pollutant levels.

Finally, just as collection system capacity problems may indicate excessive inflow, the same can be said for treatment plant capacity problems. Your state agency can provide you with treatment plant design standards which can then be compared with your influent flow data. The Ten States Standards for Wastewater Facilities is also a good reference source.

Data Collection

To assess extraneous water entering your system at least a year of influent flow data to the treatment facility should be examined.

For infiltration analysis, flow data collected during the high groundwater periods is used. The Average Dry Weather (ADW) flow can be determined from analyzing a one to two week period during seasonal high water that is not influenced by rainfall. For the northeast, this is usually in the spring when the frost line is receding and the snow is melting. The ADW flow includes the sanitary flow plus infiltration, which can be separated into its individual components.

For inflow analysis, the Average Wet Weather (AWW) flow can be estimated from flow data for a one week period when there has been significant rain. If a single storm event is used to analyze wet weather inflow, it should be an event large enough to cause surface ponding and runoff.

Definitions of terms used in Calculating Inflow and Infiltration

Average Annual Flow - The total annual volume divided by 365 days. This value is approximated by the mean of the twelve monthly average flows.

Average Annual Infiltration - The average of the monthly minimum flows.

Average Annual Inflow - From the average annual flow, subtract the base sanitary flow and average annual infiltration.

Average Dry Weather Flow (ADW) - Flow during a period of extended dry weather (7 to 14 days) and seasonally high groundwater. Flow includes sanitary flow and infiltration, and excludes significant industrial and commercial flows (assumes no inflow during dry weather conditions).

Base Sanitary Flow (BSF) - The portion of wastewater which includes domestic, commercial, institutional, and industrial sewage and specifically excludes infiltration and inflow. (See Estimating Base Flow, below).

Delayed Inflow volume - The portion of total inflow which is generated from indirect connections to the collection system or connections which produce inflow after a significant time delay from the beginning of a storm. Delayed inflow sources include: sump pumps, foundation drains, indirect sewer/drain cross-connections, etc. Rainfall-induced infiltration cannot be distinguished from delayed inflow and is therefore included as part of delayed inflow. Delayed inflow sources have a gradual impact on the collection system and flow decreases gradually upon conclusion of the rainfall event, and after peak inflow caused by direct connections.

Direct Inflow Volume- The portion of total inflow volume which is from direct connections to the collection system such as catch basins, roof leaders, manhole covers, etc. These inflow sources allow stormwater runoff to rapidly impact the collection system.

Dry Weather Flow (DWF) - All flow in a sewer (includes sanitary flow and infiltration) except that caused directly by rainfall. Measured during a period of extended dry weather (7 to 14 days) and seasonally high groundwater.

Groundwater Infiltration (GWI) – Measured during average dry weather flow period (see above). The average of the low nighttime flows (midnight to 6 am) per day for the same time period, minus significant industrial or commercial nighttime flows.

Hydrograph - A graph showing stage (the height of a water surface above an established datum plane), flow, velocity, or other property of water with respect to time.

Infiltration - Water other than sanitary wastewater that enters a sewer system from the ground through defective pipes, pipe joints, connections, or manholes. Infiltration does not include inflow.

Inflow - Water other than sanitary wastewater that enters a sewer system from sources such as roof leaders, cellar/foundation drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, and catch basins. Inflow does not include infiltration.

Inflow volume - The total volume of inflow from a single storm event including both direct and delayed inflow. Total inflow is the area between the storm event hydrograph and the dry weather hydrograph.

Maximum Daily Flow - The highest flow during a 24 hour period.

Maximum Daily Infiltration - The highest daily flow at seasonal high groundwater after a dry period of three days or more minus the base sanitary flow.

Maximum Weekly Infiltration - The highest 7 day average flow at high groundwater after a dry period of three or more days minus the base sanitary flow.

Maximum Monthly Infiltration - The highest monthly average flow during dry or minimal rain period minus the base sanitary flow.

Maximum Daily Inflow - The highest daily wet weather flow minus the base sanitary flow and the infiltration prior to the rain event.

Maximum Weekly Inflow (includes delayed infiltration) - The highest 7 day average wet weather flow minus the base sanitary flow and the infiltration prior to the rain event.

Maximum Monthly Inflow - The highest monthly flow after subtracting the base sanitary flow and infiltration.

Peak Hourly Dry Weather Flow - The highest one hour flow after a dry period of three or more days.

Peak Hourly Inflow - The highest one hour flow rate during wet weather minus the base sanitary flow and the infiltration prior to the rain event.

Peak Hourly Wet Weather Flow – The highest one hour flow during a significant rain event.

Peak Infiltration- The highest nighttime (midnight to 6 am) flow during high groundwater (usually in early spring).

Peak Instantaneous Wet Weather Flow - The peak flow during a significant rain event day when the ground water is seasonally high.

Peaking Factor - The ratio of peak hourly flow to average daily flow.

Rainfall-Induced Infiltration - The short-term increase in infiltration which is the result of a rain event. Rainfall-induced infiltration is a portion of delayed inflow.

Wet Weather Flow- The highest daily flow during and immediately after a significant storm event. Includes sanitary flow, infiltration and inflow.

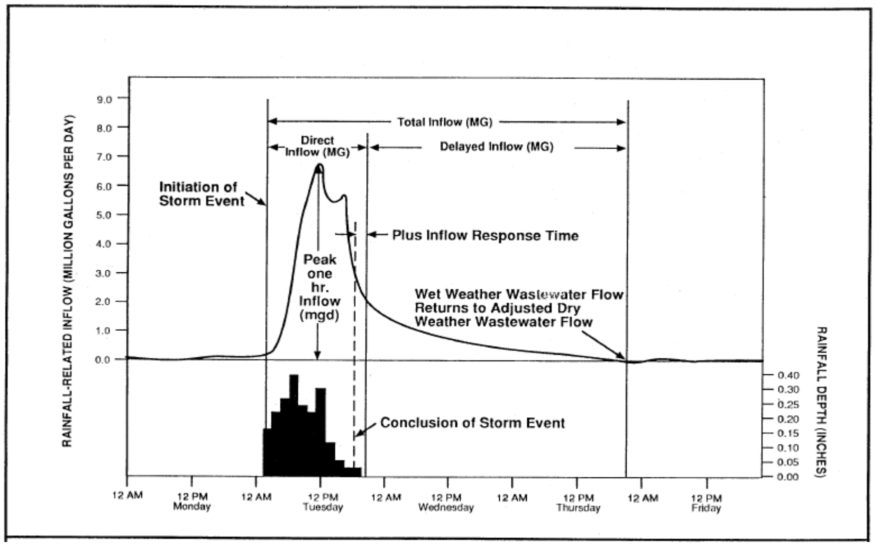

Figure 1: **Hydrograph helps visualize inflow as the response to wet weather flow (from MassDEP 1993)**

Estimating Base Sanitary Flow

The sanitary portion of the wastewater flow can be estimated through two methods, which can be used to 'check' each other - flow meter data and water consumption (if all sewer customers are on metered water).

The first method is to analyze the wastewater flow data at the treatment facility during a dry weather period of 7 to 14 days. It is useful to choose the dry weather period during seasonal high water as you will be able to determine the peak infiltration rate at the same time. From the flow data, calculate the average daily flow for the dry weather period (Average Dry Weather – ADW - flow). The base sanitary flow (BSF) can be estimated by subtracting the groundwater infiltration (GWI) flow from the average daily dry weather wastewater (ADW) flow. (See Estimating Infiltration below).

In the second method, water usage records can be used to estimate the base sanitary flow for the sewered population. The best time to estimate flow using this method would be when outdoor water uses are low and wastewater from a residential area can be assumed to be the same as the billed water use. In the northeast, this would typically be in the winter months prior to landscaping and swimming pool use. Groundwater infiltration can be estimated as the difference between the monitored wastewater flow and the billed water use.

Estimating Infiltration

Groundwater infiltration (GWI) can be estimated from influent flow data collected during a dry weather period at high groundwater. The dry weather period selected should be the same period as for estimating the BSF, however, it is more important to estimate GWI during high seasonal ground water. Dry weather is defined as when it has been at least three days without a rain event. During dry weather, inflow is expected to be zero.

During seasonal high groundwater, which usually occurs after snow melt and soil thaw, infiltration will be at its highest. During this period, the infiltration rate can be quantified by averaging the nighttime flows (midnight to 6 am) over several days, during dry weather conditions. The nighttime flows can be assumed to be mostly groundwater (after subtracting significant industrial or commercial nighttime flows).

In most cases, the GWI rate will approximate the maximum weekly infiltration. The maximum daily infiltration will be higher and maximum monthly infiltration will be lower.

Estimating Inflow

Inflow represents the influence of wet weather on the sewer system and is calculated by subtracting out the sanitary wastewater and infiltration flow during a time that the system has been influence by rain. Flow data during a significant storm event should be compared to the dry weather data immediately preceding the storm when groundwater conditions are similar. The rate and volume of inflow can be estimated by subtracting the base sanitary flow and infiltration flow data from the wet weather flow data.

The peak inflow rate and the total inflow volume can be calculated from the flow records. The peak inflow rate is the largest rate difference, over a one hour period, between the storm event flow data and the dry weather flow prior to the event. The total inflow volume from a storm event can be apportioned into two components: direct inflow and delayed inflow.

Direct inflow is the portion of the inflow which rapidly increases soon after the start of the storm and decreases swiftly upon conclusion of the event. The time it takes for inflow from the nearest sub-basin to reach the treatment facility can be estimated as the time difference between initiation of the storm event and the increase in observed flow. The direct inflow ends at a time after the conclusion of the storm approximately equal to the inflow response time from the furthest sub-basin.

Delayed inflow is the portion of the inflow which decreases gradually upon conclusion of the storm and after the peak inflow caused by direct connections. Delayed inflow is the inflow Beginning at the conclusion of direct inflow and ending at a time when dry weather flow resumes. It is expected that a portion of the delayed inflow includes rainfall-induced infiltration.

In some cases, a second storm will impact the flow data before dry weather flow resumes. When this occurs, the expected delayed inflow can be extrapolated from the flow data collected prior to the second storm.

Estimating Infiltration and Inflow (I&I)

Maximum monthly I&I rate can be estimated by subtracting the BSF from the maximum monthly average flow.

Average annual I&I rate can be estimated by subtracting the BSF rate from average annual flow rate.

Annual I&I volume can be estimated by multiplying the average annual I&I rate by 365 days.

Summary

Sewers and treatment facilities are designed around expected average and maximum flows. Excess storm and groundwater entering the sewer system through I&I robs the system of its valuable capacity, puts a burden on operation and maintenance, and reduces the life expectancy of the treatment facility. Sewer surcharging, back-ups and overflows all require emergency response and contribute to disruption of operations.

Integrating I&I investigation and corrective action into a municipality's normal public works budget can allow an incremental approach to continuous improvement and help defer capacity expansion projects.

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