Chapter 13

Spatial and Seasonal Characterization of Infiltration/Inflow for a Regional Sewer System Model

Benjamin J. Sherman, Philip N. Brink, and Mark J. TenBroek

The most recent release of the City of Detroit regional sewer collection system SWMM model includes improvements made to the previous characterization of rainfall-dependent inflow/infiltration (RDII). These improvements included a method to account for seasonal variation in RDII C factors, initial abstractions, and initial abstraction recovery rates. Furthermore, a correlation was developed which describes spatial variation of the seasonally varied RDII C factors as a function of construction age. The GIS tools and the correlations were used to establish RDII C factors throughout the separate sewer areas of the system. The initial abstraction term showed significant seasonal variation; however, spatial variation was not discernible. To support the RDII characterization method and to quantify a reasonable value for the initial abstraction recovery rate, a RUNOFF model was developed for three separate sewer service areas for which flow and rainfall data had been collected. The calibration results for the initial abstraction recovery rates support seasonal variation in this parameter.

13.1 Introduction

The City of Detroit, Michigan, has developed a regional sewer collection system SWMM model to assist in developing the best approach to reduce CSO discharges. The collection system includes the City of Detroit and the surrounding communities, covers over 900 square miles (2,300 square kilometers), and serves nearly three million people. The Greater Detroit Regional Sewer System (GDRSS) model has been under development since 1988.

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While the system is dominated by runoff from combined sewer tributary areas during wet weather, wet weather inflows from suburban separate sewer tributary areas were also found to be significant. As part of the current model refinement process, RDII was investigated for separate sewer service areas. The investigation provided insight into the spatial and seasonal variation of RDII. It should be noted that the model estimates flows from separate sewer areas using a different method than for combined sewer areas. Storm runoff from separate sewer areas is not included in this model. Also, RDII estimates were not developed for the combined sewer areas as storm runoff dominates in these systems.

The purpose of this chapter is to present the most recent improvements in the characterization of RDII. Previous phases of model development and evaluation resulted in modifications to the SWMM RUNOFF block source code to allow RDII calculations for separate sewer areas. Those modifications are included in the official EPA Version 4.3 SWMM RUNOFF. During the current project, this RDII representation has been improved by analyzing a significant amount of additional data collected from many separate sewer areas within the model tributary area. The model updates included a method to account for seasonal variation in the RDII parameters. The data also provided insight into spatial variation of the RDII parameters. Using GIS tools, the spatial variation of the RDII response was correlated to construction age. The GIS tools, along with the correlations, were used to spatially distribute RDII parameters.

To investigate the RDII characterization method, a model using a modified version of RUNOFF was developed for three separate sewer service areas for which flow and rainfall data were collected for this project. These models were run in a continuous simulation mode for a period of four months. A multi-linear regression technique was used to describe the relationships between the parameter input and the RDII volume response of the RUNOFF models. The parameters were statistically optimized to minimize the difference between the model output volume and the measured volume from each subarea for the period of record. The optimization/calibration procedures and results are also presented in this chapter.

13.2 Review of RDII

13.2.1 Definitions

Infiltration - The water entering a sewer system and/or service connections from the ground, through such means as defective pipes, pipe joints, connections, manholes, etc. Infiltration does not include inflow.

Inflow - The water discharged into a separate sewer system, including service connections, from such sources as roof leaders, cellar drains, yards and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm and combined sewers, etc. Inflow does not include infiltration.

Initial Abstraction (V_0) - The amount of rainfall below which no wet weather response is observed from a separate wastewater collection system. This initial abstraction represents a combination of depression storage for inflow and soil storage for infiltration.

Rainfall-Dependent Inflow/Infiltration (RDII) C factor – The fraction of rainfall that enters the collection system during or following a rainfall event either by inflow or infiltration. RDII represents the wet weather response in a separate sewer.

Seasons - For the purpose of this study, a growth season is defined as taking place from the beginning of June until the end of September. A dormant season is defined as occurring from November through April. The months of May and October are defined as transition months. It should be noted that these seasons reflect conditions determined for Detroit, Michigan.

13.2.2 Literature Review

To understand alternative methods that have been used to represent response from sanitary sewer systems, a thorough literature search was performed by the members of the study team. This literature search yielded a number of publications that described the application of the different components of the SWMM model. Other than papers by Walch et al. (1996) and Miles et al. (1996), this search identified little work relative to the wet weather modeling of the RDII component. For this current study, Sherman et al. (1997) discuss RDII parameter distribution using a geographic information system. Through the SWMM-USERS internet group (SWMM-USERS@listserv.uoguelph.ca), information regarding modeling of RDII by manipulating combined area parameters was discussed. During this discussion, little was mentioned regarding the EPA SWMM 4.3 method for modeling RDII volume and hydrograph shape. Furthermore, information on previous work addressing the seasonal variation of RDII could not be identified. In addition, this search did not identify statistical techniques that would facilitate calibration of the GDRSS hydrologic model.

13.2.3 Historical Data Review

To better understand local hydrology, the members of the study team contacted local community representatives, or their engineering consultants, to compile the available RDII information. This review showed that many different

communities had investigated wet weather response and could provide a significant amount of data to the GDRSS project. These data were initially collected to aid in the management of various sanitary and stormwater projects including: project performance certification, sewer system evaluation survey, basis of design, system analyses, and infiltration/inflow studies. For this project, the data were used to develop a consistent RDII characterization methodology, to estimate ranges for RDII values, and to identify time periods that define seasonal variation.

13.3 RDII Characterization

13.3.1 Development of RDII Characterization

RDII C is the fraction of rainfall that enters a sanitary sewer system during a rainfall event, after accounting for V_o . This representation of RDII was included in the official EPA Version 4.3 SWMM in 1994. In previous GDRSS modeling efforts, RDII was described as a ratio of the inflow to the total precipitation, without considering the impact of V_o . The RDII C factor is a capture coefficient represented by the slope for an inflow/infiltration vs. rainfall plot, as presented in Figure 13.1. In addition, previous work did not quantify the temporal variation in RDII; therefore, it was assumed that the response-rainfall relationship remained constant throughout the year.

Figure 13.1 Previous model characterization of RDII.

Based on the wet weather flow analysis results obtained from sources throughout the wastewater collection system, it was found that there is an initial abstraction volume, termed V_o , which must be satisfied before a response is

observed. The phenomenon of initial abstraction is thought to be due to depression storage for inflow and soil storage for infiltration. Initial abstraction has now been included in the official EPA Version 4.3 SWMM.

Furthermore, it was observed that V_0 and RDII C varied seasonally. As one might expect in a temperate zone, the highest RDII typically occurs during the late fall and spring months (dormant period) and the lowest RDII typically occurs during the summer months (growth period). This observation can be attributed to the groundwater fluctuations that occur due to natural recharge, as well as changes in soil moisture caused by evapotranspiration. The variation of the V_0 and the RDII C terms have been defined during dormant and growth seasons. In general, the variation in both V_0 and RDII C is presented in Figure 13.2. The ability to vary these terms seasonally is currently not included in the EPA Version 4.3 SWMM RUNOFF. However, the GDRSS project version of SWMM RUNOFF includes the capability to model the seasonal variation of these terms.

Figure 13.2 Current model characterization of RDII.

For the current model development, the RDII C factor has been defined as the slope of the response versus precipitation line as shown in Figure 13.2. This response line can be estimated by dividing the measured RDII by the quantity of rainfall minus V_0 for a number of selected rainfall events.

This analysis also showed that the RDII C factor exhibits significant spatial variability. This variability is expected for a complex system with significant variability in construction materials and methods, soil conditions, groundwater fluctuations, sewer network age distribution, and the presence of system specific structural features.

13.3.2 RDII Data Analysis

Flow and precipitation data were collected from a total of 70 areas that ranged from approximately 25 acres (10 ha) to 12,000 acres (5,000 ha) in size. Flow data were obtained from meters within sewer pipes with known tributary areas. Precipitation volumes were determined from rain gages, where possible. Additional precipitation data were gathered from other gages in the area to understand precipitation variability and to supplement cases where the on-site precipitation records were suspect or unavailable. The precipitation was expressed as inches (mm) per each recorded event.

Once rain data and flow data were collected, rainfall events were identified. Representative dry weather flows (base flows) were determined for each metered location and superimposed on the wet weather flow hydrograph. The volume of response for a given storm event was then determined as the area between the wet weather and superimposed dry weather hydrographs. This analysis was performed for each storm event, per site. For each event analyzed, a point was plotted as the volume of RDII response versus rainfall.

In some cases, the total response volume used for the analysis was the result of multiple precipitation events. To define the total response volume, dry weather flow was used to bound the response. For analysis purposes, an event period was defined as the time when precipitation began through the time the sewer system response ended. However, it should be noted that a minimum interevent time period of 24 hr was used. Longer term groundwater elevation changes were not considered as part of the response volume. Furthermore, data quality was evaluated. Unreliable or questionable data were identified and either reevaluated for use in determining RDII or discarded. The following flow and rainfall data selection criteria were used for the RDII C factor analysis:

- data having precipitation below the respective V_o values were excluded;
- extreme value data (growth season data that falls above a preliminary regression line through dormant season data, and dormant season data that falls below a preliminary regression line through growth season data) were excluded;
- where volumetric raingage readings included multiple events, the sum of the event response volumes was considered to be one data point; and
- data with high rainfall variability between gages were excluded when data were not collected within the tributary area.

Early during the data collection, plots of RDII versus precipitation were generated for thirteen metered drainage areas. To verify the seasonally distinct periods, the plotted data were segregated into two regions. These regions were defined by taking the bisect of two preliminary regression lines. These regression

lines were drawn through data that fell before June first for one set and after June first for the second set. The regression lines were forced through the respective V_0 values.

One should note that these initial regression lines were established as a consistent approach to determine the position of the bisect line and for the exclusion of extreme values. As will be discussed later, the data is regressed a second time with extreme values excluded to determine RDII C factors. Figure 13.3 shows the initial regression lines, the bisect, and an excluded extreme value data point. The data were then tabulated by the month in which the event occurred, as well as by the graphic region (above or below the bisection line) in which the data were plotted. A total of 151 data points from the thirteen sites were analyzed. Non-response events were not used in the regression analyses. The data presented in Figure 13.4 shows two distinct seasonal periods. From this figure, June was chosen to define the beginning of the growth season.

Figure 13.3 Evergreen-Farmington seasonal and extreme value analysis.

Figure 13.4 displays some data that do not correspond well with the seasonal division. Therefore, only two seasons were identified. May and October were designated as transitional months. RDII parameters for the transition months consist of average values of those determined for the dormant and growth periods.

It is important to note the significance of characterizing seasonal variation in RDII for continuous modeling. The weak seasonally dependent data show that some growth period events behave as a dormant event and vice versa. However, without considering that RDII is higher during the dormant period, the model could be significantly underestimating overflow volume contributed from separate sewer areas.

Figure 13.4 Seasonal time periods.

In determining the RDII response, V_o was first determined for both dormant and growth seasons. Average V_o values for both dormant and growth seasons were determined from the data collected from detailed study areas and the suburban metering analysis. Regional averages were also determined to minimize error associated with identifying these values. The flow data analysis indicated that, even by region, there is very little difference in V_o values within the greater Detroit wastewater collection system.

For each region, a linear regression was performed to obtain a growth season regression line and a dormant season regression line. These regressions were forced through the growth and dormant period V_o values, respectively. The RDII C factor for each season was then determined as the slope of the respective regression lines. After the initial regression analyses, dormant season data falling below the growth season regression line and growth season data falling above the dormant season regression line were considered extreme values and eliminated from the parameter determination. Subsequently, the two regression analyses for each site were repeated without the extreme values to obtain final estimates of the RDII C factors. Examples of regression analyses for three sites are shown in Figure 13.5 with the corresponding regression statistics listed in Table 13.1.

13.3.3 RDII Spatial Variation

Despite the extensive analysis of RDII data throughout the modeled region, there remained many areas in which parameters had yet to be determined. Correlations were established to estimate the RDII C factors in areas where data were not available. The 1990 U.S. Census GIS coverage statistic for median

Figure 13.5 RDII C factor regression analyses for three sites.

Table 13.1 Regression results for three sites - including initial abstraction.

Site ID	Regression Results (Dormant)				Regression Results (Growth)			
	RDII C (slope as %)	Intercept (in. (mm))	R ²	Vo (in. (mm))	RDII C (slope as %)	Intercept (in. (mm))	R ²	Vo (in. (mm))
DBH2	23	-0.044 (-1.1)	0.90	0.19 (4.8)	8.8	-0.027 (-0.69)	0.99	0.31 (7.9)
RED1	13	-0.025 (-0.64)	0.81	0.19 (4.8)	7.0	-0.022 (-0.56)	1.0	0.31 (7.9)
SCS1	13	-0.021 (-0.53)	0.67	0.13 (3.3)	5.7	-0.014 (-0.36)	0.95	0.25 (6.4)

building age was used as a surrogate measure of the sewer system age. This GIS coverage provides an estimate for sewer system age at the census block group level. Correlations were developed for the RDII C factors for both the dormant and growth seasons.

Figure 13.6 shows the results of these correlation analyses. No extrapolation from these correlations was permitted. For subbasins with greater than a 40-year construction age, 15% and 8% RDII C factors were used for the dormant and growth periods, respectively. Where data were available, the measured RDII C factors supersede the correlation. Equations 13.1 and 13.2 describe the best fit correlations for the dormant and growth period RDII C factors to the construction age surrogate, respectively.

$$\text{Dormant: RDII C (\%)} = 0.12 \cdot e^{(0.14 \cdot (\text{age}-6))} + 1.2 \quad R^2=0.79 \quad (13.1)$$

$$\text{Growth: RDII C (\%)} = 0.033 \cdot e^{(0.16 \cdot (\text{age}-6))} + 0.3 \quad R^2=0.70 \quad (13.2)$$

Figure 13.6 RDII correlation to surrogate for construction age.

Figure 13.7 shows the distribution of the growth period RDII C factors throughout the separate sewerage drainage areas of the model. It is important to note that the U.S. Census median housing unit age was weighted by census block group area for each subbasin. In hindsight, the correlation would have likely been improved if the median age were weighted by number of housing units in each block group for each subbasin, rather than by the block group area.

Figure 13.7 Distribution of growth period RDII C factors.

13.3.4 RDII Response Shape

The RDII C factor and V_0 are the parameters used to relate total RDII volumes to precipitation. To better quantify how this response volume is temporally distributed in the collection system, the response hydrograph was divided into two components. An example of these component hydrographs is shown in Figure 13.8 along with the resultant composite hydrograph compared to the measured wet weather response. Parameters used to describe these component hydrographs are T, K and the fraction of RDII C applied to each component. The parameter T represents the time to the peak of a component

hydrograph and K is the ratio of the time to recession to the time to peak. The fraction of RDII C applied to each component is proportional to the volume of each of the components. In most cases, the T and K parameters were determined for both the inflow (direct response) component hydrograph and the infiltration (delayed response) component hydrograph. However, some tributary area responses were best described by a single hydrograph. Some limitations to determining the T and K parameters that were not addressed for these analyses are as follows:

- the inflow component hydrograph can vary with rainfall volume, intensity, and spatial and temporal distribution;
- the inflow component hydrograph is a function of tributary area size and network density (travel time); and
- the infiltration component hydrograph can vary seasonally.

Figure 13.8 Inflow and infiltration hydrographs and measured and composite hydrographs at detailed study area DBH2.

Despite these limitations, the importance of quantifying the response behavior is warranted. For example, if the infiltration component (the tail portion of the response hydrograph) is not considered, all of the response volume (100% of the RDII C factor) would be applied as inflow, most likely resulting in simulated peak flows which could be substantially greater than observed peak flows.

T , K , and fraction of RDII C for each component hydrograph were determined as follows:

- isolate one-event responses;
- use events greater than 0.3 in. (7.6 mm) precipitation;
- estimate T and K for the inflow component;
- determine inflow component peak (in excess of baseflow);
- estimate T and K for the infiltration component;
- determine infiltration component peak (in excess of baseflow);
- calculate volume of component hydrographs and total volume;
- determine fraction of RDII C for the two component hydrographs;
- average up to four analyses per site to give final parameters.

This methodology was applied in a consistent manner for all data reviewed.

13.4 Sensitivity Analysis and Results

RUNOFF models were developed for three small separate sewer study areas within the GDRSS service area. These RUNOFF models were developed to provide insight into some of the parameters required for the system-wide GDRSS model. A four month continuous rainfall record was used for each simulation. The RUNOFF models' sensitivity to the following six parameters was determined for the three separate sewer areas:

- dormant and growth season RDII C factors (C_{dorm} & C_{grow});
- dormant and growth season initial abstractions (V_o dorm & V_o grow); and
- dormant and growth season recovery rate of the initial abstraction ($DREC_{dorm}$ & $DREC_{grow}$).

As might be expected, the models were most sensitive to the RDII C factors for the two seasons. One particularly interesting finding was that the dormant season V_o and recovery terms had no effect on model sensitivity for the parameter range considered for all three areas. This finding was not the case for the growth season V_o and recovery terms which accounted for as much as 14% of the overall sensitivity effects in one study area RUNOFF model. This result further supports the need to isolate and adequately model seasonal effects.

13.5 RDII Calibration

13.5.1 Introduction

The RUNOFF models developed for the three small separate sewer study areas within the GDRSS service area were used for calibration of the RDII parameters. The objectives of the calibration were:

- use a number of events in a continuous simulation mode for calibration; this would minimize the impact of error due to inaccuracies in rainfall volume/distribution for any given event;
- minimize differences between simulated and measured RDII;
- maintain consistency in calibrating the models for the different areas for subsequent comparison; and
- extrapolate results to the system-wide GDRSS model.

Past approaches used to select the numerous hydrologic parameters included in the RUNOFF model required fixing many of these parameters based on literature values or engineering judgment. With most parameters fixed, the best fit was determined by varying only those parameters with the greatest impact on the model results. Using this interactive manual approach was often more art than science.

Therefore, a metamodeling approach to calibrate the EPA's SWMM RUNOFF model was developed. A metamodel is a simple statistical model of the input/output relationship of a more complex predictive model (Bettonvil, 1994). Metamodeling allows the user to describe the behavior of the hydrologic RUNOFF model for several hydrologic parameters under a large number of parameter combinations. This approach allows consideration of more parameters than would be practical to consider under typical calibration approaches.

To implement this innovative approach, RUNOFF model simulations were performed for many combinations of RDII hydrologic parameters. Simulated discharges from the sewershed were then described by a statistical regression equation, known as a metamodel. Lastly, the metamodel was optimized over the parameter ranges to obtain sets of parameters that reduced the differences between modeled and measured volumes.

13.5.2 Methodology

RDII C factors, V_o , and DREC for dormant and growth periods were used as independent variables in a multi-linear regression analysis. Multi-linear regression was used to model the relationships between the hydrologic parameter input and the RDII volume output of the RUNOFF models. The multi-linear regression equation is of the following form:

$$y = \sum_{i=1}^n m_i \cdot x_i + b \quad (13.3)$$

where:

- y = the calibration statistic,
- m_i = the rate of change for the i -th parameter,
- x_i = the value of the i -th parameter, and
- b = the intercept.

A calibration statistic was identified to optimize the hydrologic parameters. A calibration statistic is a measure of the difference between simulated and field measured values such as runoff or RDII volume. The calibration statistic considered for the first approximation was defined as follows for n events:

$$\text{Volume Ratio} = \frac{\sum_{i=1}^n V_{\text{simulated}_i}}{\sum_{i=1}^n V_{\text{measured}_i}} \quad (13.4)$$

The volume ratio was used as the calibration statistic, due to the monotonic response surface describing the statistic and the parameter values; i.e. multi-linear regression yielded a reasonable fit. However, using the volume ratio as a calibration statistic is not ideal due to the cancellation of differences between calibration events. Consequently, a statistic value equal to one may not necessarily mean an optimal match. Therefore, the volume ratio statistic was used in the regression model only to obtain a first approximation of the optimal values for the hydrologic parameters being reviewed.

Once the multi-linear regression equation is developed, the regression results are entered into an optimization routine. This routine evaluates millions of combinations of the multiple parameters as input to the regression model. Since multiple solutions result from this optimization approach, sets of parameters that yielded the lowest values for the calibration statistic are used as a first approximation to calibration.

13.5.3 Analysis

Flow and rainfall data were processed into a four-month continuous format. These data were compared to isolate event time periods. The number of events used for calibration depended on the quality of both the flow and the rainfall data. An average of thirteen events per study area were selected.

Next, the hydrologic parameters and their expected ranges were selected. By establishing reasonable ranges over which the parameters were allowed to vary during calibration, one ensured that the deterministic nature of the model was maintained. Otherwise, the calibration would have been reduced to a fitting process and the parameters would have become merely empirical constants.

The RDII parameters that affect the volume of the response are the RDII C factors, the V_o volumes, and the DREC recovery rates for the two seasons. These six parameters were varied to develop the regression model. A preprocessor was used to generate RUNOFF input files for all parameter combinations defined by the parameter range limits. There were 64 different combinations for the six

parameters. These input files were created and run in batch mode. A post-processor extracted and tabulated the runoff volume for each preselected event from the RUNOFF model output. The tabulated output was used to generate the calibration statistic that was used to develop the multi-linear regression equations.

Once the initial calibration conditions were established, by optimizing the metamodels, further refinement was added by manually adjusting the T and K values and the fraction of RDII C assigned to the inflow component hydrograph. These five parameters were varied to improve the calibration results, in terms of hydrograph shape, with emphasis on peak flow and overall duration of response. After the shape parameters were adjusted, the steps to create a new set of metamodels were applied and the optimization routine performed again to check and refine the results.

Throughout the various stages of the calibration, an overall check of the total absolute volume difference statistic was evaluated to ascertain the improvement. This calibration statistic is defined as:

$$\text{Total Absolute Volume Difference} = \sum_{i=1}^n |V_{\text{simulated}_i} - V_{\text{measured}_i}| \quad (13.5)$$

This statistic gives a true measure of how the simulated flows differ from the measured flows in terms of volume differences. Event hydrographs and a RDII versus rainfall plot for each area were evaluated while improving the second statistic.

13.5.4 Results and Application

The calibration results confirmed the values determined for RDII C and V_o from the wet weather flow analysis. The average V_o values for dormant and growth season were found to be 0.15 and 0.28 inches (3.8 and 7.1 mm), respectively. These values were used throughout the system. The RDII C factors that were determined from the wet weather flow analysis, field investigations, and the study area calibration results were used in the system-wide model where applicable. Tables 13.2 and 13.3 list the results for the RDII response shape and volume parameters, respectively for three detailed study areas. For all other areas, the RDII C factors were calculated using the correlations with construction age, as discussed previously.

To further investigate the RDII parameter DREC, the individual regression models for each small area were combined using weighting factors equal to the number of events used to calibrate each site. The combined metamodels, the megametamodel, was optimized to provide a composite parameter set. This approach is based on the field and model statistical results for 48 events from three separate sewer area data sets. The megametamodel provided greater insight into DREC, a parameter for which no textbook or field data are available. The overall

Table 13.2 Calibration results for RDII shape parameters.

Site ID	T _{inflow} (hr)	K _{inflow}	T _{infiltration} (hr)	K _{infiltration}	Fraction of RDII C to Direct Response
DBH2	1.5	1	3	4	0.5
RED1	0.5	1	3	11	0.1
SCS1	1	2	7	5	0.59

Table 13.3 Calibration results for RDII volume parameters.

Site ID	Dormant Period RDII Parameters			Growth Period RDII Parameters		
	RDII C (%)	V _o (in. (mm))	DREC (in./day (mm/day))	RDII C (%)	V _o (in. (mm))	DREC (in./day (mm/day))
DBH2	17.0	0.15 (3.8)	0.11 (2.8)	5.0	0.22 (5.6)	0.08 (2.0)
RED1	14.0	0.15 (3.8)	0.06 (1.5)	5.0	0.34 (8.6)	0.20 (5.1)
SCS1	15.0	0.10 (2.5)	0.10 (2.5)	8.0	0.30 (7.6)	0.19 (4.8)

regression model yielded a dormant season DREC of 0.06 in/day (1.5 mm/day) and a growth season DREC of 0.40 in/day (10.2 mm/day). Intuitively, the values obtained through calibration for DREC seem high; therefore, further investigation of the parameter is recommended. For comparison, evaporation was expressed as 0.17, 0.23, 0.26 and 0.28 in/day (4.3, 5.8, 6.6 and 7.1 mm/day) for April, May, June and July, respectively.

13.6 Conclusions

The representation of RDII in the GDRSS model has been elaborated based on the analysis of a significant amount of additional data collected throughout the tributary area. These improvements include a method to account for seasonal variation in RDII C factors, V_o volumes, and initial abstraction recovery rates.

In addition to characterizing seasonal variation, the analyses provided insight into spatial variation. Using GIS tools, seasonally varied RDII C factors were correlated to construction age. The correlations and GIS tools were used together to distribute RDII C factors throughout the system. Spatial variation in the V_o term was not discernible.

To investigate the RDII characterization method, and to quantify reasonable values for DREC, a RUNOFF model was developed for the three separate sewer service areas for which flow and rainfall data had been collected. These models were run in a continuous simulation mode for a period of four months. A

multi-linear regression technique was used to describe the relationships between the parameter input and the RDII volume response of the RUNOFF models. The parameters were statistically optimized to minimize the difference of model volume output to measured volume output from each subarea for the period of record. The optimization/calibration results for DREC support seasonal variation of this parameter. The data were insufficient to determine spatial variation of this parameter.

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