Detroit Water and Sewerage Department

Wastewater Master Plan

DWSD Project No. CS-1314

Summary of Footing Drain Flow Studies

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Summary of Footing Drain Flow Studies

1. Introduction

Footing drains connected to sanitary sewer systems are suspected of being the leading cause of excessive rainfall dependent inflow and infiltration (RDII) to sanitary sewer systems of communities in the Detroit Water and Sewerage Department (DWSD) service area. In *Report on SSO Controls in the DWSD Service Area* written as part of the DWSD Wastewater Master Plan (WWMP), CS-1314, all communities reporting SSOs to the Michigan Department of Environmental Quality (MDEQ) have footing drains connected to the local sanitary sewer. As part of the WWMP, footing drain flows are being monitored at individual houses using sump pump monitors. To further help understand footing drain flows this technical memorandum provides a summary of footing drain flow information collected from other reports, primary from SE Michigan communities, and data collected during the footing drain field monitoring program undertaken as part of the WWMP.

Prior to the mid 1980's, the connection of footing drains into sanitary collection systems for newly constructed homes was common practice in southeast Michigan. Also, where combined sewer systems were originally built, all sanitary and storm drainage was directed into a common sewer. As combined collection systems have been separated in some communities in response to CSO regulations, footing drains were not typically disconnected from the sanitary system. This was because it was perceived that the benefits of a complete separation program were not great enough to justify the expense and disruption to private property required to redirect footing drains to storm water collection systems or into backyards. However, as footing drains' impact on inflow becomes more apparent to many communities, footing drain disconnect programs are becoming more widespread. Footing drain disconnection is consistent with federal pollution prevention guidelines and is described in greater detail in the WWMP SSO Local Alternatives and Review of Footing Drain Disconnect Programs Technical Memoranda.

Over the years, building code requirements have evolved to the point that footing drains cannot be connected to sanitary collection systems for newly constructed / renovated buildings. Generally, prior to 1973, the connection of footing drains was allowable under the National Building Code and few communities had local requirements prohibiting connection to the sanitary system. Between 1973 and 1985, the connection of footing drains to sanitary collection systems was prohibited by individual community ordinances, but enforcement of this building code provision was not widespread. In the mid-1980s, enforcement became more rigorous and it is believed that most homes built after 1985 do not have footing drains connected to sanitary collection systems.

2. Footing Drain Flow Mechanics

Footing drains are constructed around the foundations of homes and other buildings with basements to drain water away from basement walls.

This is done to keep water from leaking through the walls and floor and maintain the structural stability of building foundations.

Water around basement walls can be the result of a high groundwater table that may fluctuate seasonally, or the results of rainwater that infiltrates into the soil after a rain event.

Based on inspections and information gathered from local plumbing inspectors in the Southeast Michigan area, Figure 1 shows how a residential footing drain system is typically connected into the sanitary sewer system. In this figure the footing drain pipes / tiles connect to the house sanitary lead inside the house. In this arrangement there are typically two cleanouts, one for the sanitary line and one for the footing drain line. In some homes this connection is made outside of the home.

The length of time for rain water entering the sanitary system through footing drains can be as short as five or 10 minutes and as long as 10 days, depending on site and soil conditions. In some cases, it is suspected that direct flow channels along or near foundation walls are formed, creating an immediate response to rainfall (less than 5 minutes).

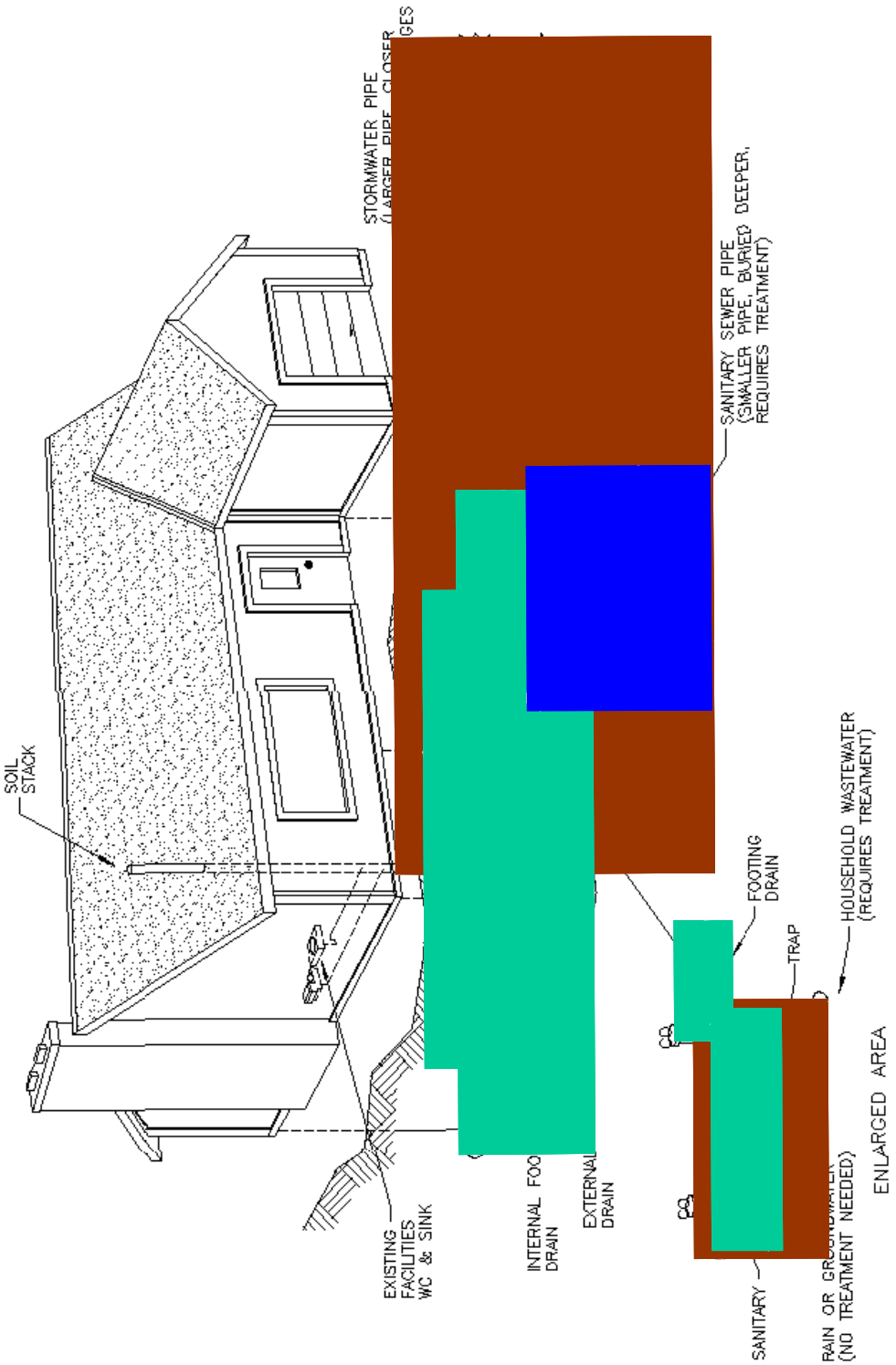
Based on a recent study performed by the City of Ann Arbor, Figure 2 shows an example of flow pathways for rainwater in a residential area with lot sizes approximately 60' x 110' and built in the 1960s. In this example, five percent of the rainwater enters the sanitary sewer through footing drains. Although this is a small amount relative to the amount that enters the storm sewer system (70 percent), it is a high amount relative to the capacity of the sanitary sewer system. This example is based on data from an extreme 4" total rainfall event. Therefore, the amount of surface runoff is higher than what would be expected for more common events. These percentages vary between locations and can be significantly different depending upon site-specific variables such as soil types, topography and construction standards used.

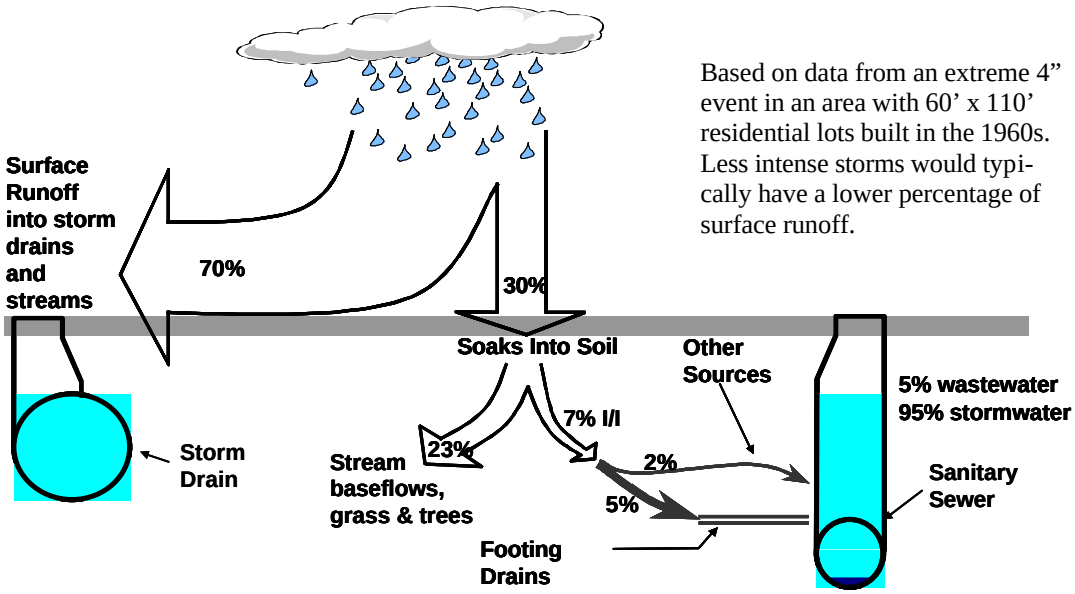
Site-specific variables potentially affecting footing drain flows include:

- **Soil types:** The type of soil around a footing drain controls both the volume of water and amount of time it takes for rainwater to infiltrate down to the footing drains. Less permeable soils such as clay can limit the amount of rainwater that infiltrates to a footing drain. However, direct flow paths through soil cracks and along the structure's foundation can significantly increase flows to footing drains in any type of soil. Soil types can also have an effect on the groundwater levels immediately surrounding the foundation. Foundations built in clay with sand backfill can act as a "bathtub," not allowing water to disperse through the clay away from the foundation.

This may cause an immediate and high response over a relatively short time. Alternatively, foundations built in sand allow water to flow more freely away from the foundation, potentially reducing the peak FD flow, but may allow for more long-term (days after an event) groundwater effects.

Figure 1. Typical Residential Footing Drain Connection





Note: Percentages can vary significantly between locations based on site-specific variables.

Figure 2. Example of Rainwater Flow Pathways for a High Intensity Event

- **Construction Standards.** The construction standards used to build footing drains, foundations, and backfill can all potentially affect footing drain flows. These standards include:
  - Depth of foundation and footing drains
  - Location of footing drains around foundation and effective drainage area
  - Size and type of footing drain materials used
  - Backfill soil types
- **Surface Drainage.** Surface grading and the location of downspouts around a house can potentially affect the amount of water that runs off to storm drainage (or at least away from the immediate area of the foundation) or infiltrates to the footing drain. For this reason, many communities either recommend or require that downspout leads be directed to at least five feet away from the house. Another common recommendation is to slope soil around the foundation to force more runoff away from the house, decreasing the amount of infiltration in these areas.

- **Groundwater Levels.** Groundwater is different from water that temporarily infiltrates by or backs up around the foundation. In some locations the groundwater level is higher than the footing drain level, causing a constant footing drain flow even without rain. After periods of rain, groundwater

levels may increase above footing drains for an extended period of time causing footing drain flows lasting days or weeks after a rain event is over.

Furthermore, seasonal variations can cause groundwater levels to be above footing drains at different times of the year. It is also possible that the presence of residential footing drains in some areas actually lowers the groundwater table by constantly draining it. In many cases, the groundwater table may be at the footing drain level.

- **Rainfall Characteristics and Antecedent Conditions.** As with all types of RDII into sewer systems, factors such as the duration and intensity of the storm will affect the amount of water that infiltrates into the soil and the amount that runs off to a storm sewer. Another important parameter is the antecedent moisture levels, which affects how much of the initial water that infiltrates will be stored in the soil.

- **Condition of the Footing Drain and House Lead.** It is possible at some locations that the footing drains and house lead pipes have collapsed or have blockages limiting flow. This may reduce the amount of footing drain flow; however, it could also lead to basement flooding from backups in the house lead or from water seeping through cracks in the walls because it is not being drained away properly.

Because of these variables, it is possible to have high footing drain flows from one house and smaller flows from the neighboring house. Furthermore, it is important to understand that some control measures may not be effective at all locations. For example, if the groundwater table is at the footing drain level of a foundation built in sand, improving drainage away from a house may have little effect on reducing flow. This is because infiltration on the entire property could raise the local groundwater table enough to cause a constant flow to the footing drain.

3. Summary of Existing and Proposed FD Flow Studies

This section gives a summary of existing and proposed studies to quantify the volume and rates of flows from footing drains.

3.1. Existing Studies

Existing studies on footing drain flows can be classified into two main types. Figure 3 lists the existing studies reviewed in this memo by type of study. The first type of study, sanitary sewer monitoring, measures sanitary sewer flows and compares peak flows in areas with and without footing drains. The comparison areas can either be different subdivisions with and without footing drain connections or the same area using flow data from before and after removal of footing drains. This type of study measures the effective peak flow in the sewer from all footing drain connections.

The second type of footing drain flow study is direct measurement of flows from residential house leads. This is done either by making individual measurements of flow or using a continuous monitor.

Individual measurements are taken by measuring flows during a rain event from a house lead that enters the sanitary system at a manhole.

Flow measurements are taken using a flow meter such as a calibrated weir or using a stopwatch and calibrated bucket lowered into the house lead discharge.

Sanitary Sewer Monitoring		Direct FD Flow Measurements	
Single Area: Pre/Post	**Different Areas**	**Individual Measurements**	**Continuous Monitoring**
Beverly Hills	Oakland County	Ann Arbor 2000	Ann Arbor 2002
Canton TWP	GDRSS	Dearborn Heights	DWSD WWMP
Auburn Hills		Troy	Toledo
West Lafayette		Southfield	SMSD
		Evergreen/Farmington	

Figure 3. List of Footing Drain Flow Studies by Type

Continuous monitoring uses a sump pump monitor which records pump on/off times. Even though these sump pumps are typically not connected to the sanitary sewer, they pump footing drain flows and are assumed to be representative of footing drain flows that drain by gravity to the sanitary sewer. Each sump pump that is monitored is typically calibrated by performing repeat draw down tests. Direct measurement studies can be extrapolated to the total number of homes in a subdivision.

Table 1 is a summary of key information from these footing drain studies. In many cases, in order to compare results in between studies in a uniform manner, obtaining values for this table required additional analysis of the original data. For each of the studies listed, a summary of the work performed and how the data was used to obtain the values in Table 1 are described below.

The summaries in this table represent measured values typically occurring during storms of less then 2" of total rainfall. Therefore, the results represent minimum values to expect. Where possible, extrapolation to a 4" rainfall event was done using linear and logarithmic curve fits. Both types of fits were made, because, many times, there is not enough data to determine which one is more appropriate. A logarithmic fit assumes that a maximum rate is approached at higher rainfall volumes. Some data suggest that this may not happen within 4" total rainfall, and the flow rate could actually accelerate with rainfall volume. This may be due to a ground saturation condition that forces surface runoff towards houses. Runoff would then infiltrate to

the footing drain quickly through channels in the soil that develop along the foundation.

Table 1. Summary of Footing Drain Flow Studies

Downstream System Metering	Wet Weather Sanitary Flow		Peak Footing Drain Flows			Projected Peak Footing Drain Flows (gpm/house)	
	Peak Flow with FD (cfs/1000)	Peak Flow Without FD (cfs/1000)	Flow (gpm/house)	Rainfall (inches)	RDII from FD (percent)	4" Linear	4" Log
Beverly Hills	1.56	0.38[5]	2.5	2.23"	76%	2.1	1.7
Oakland County 1967	1.76	0.53	1.8	1.86"	70%	3.8	3.0
1968 Study		---	2.1	---	---	---	---
Canton Township FD Removal	2.7	---	3.0[4]	2.50"[3]	---	3.0[4]	1.8[4]
GDRSS Data	2	0.63	1.5	2.0	69%	---	---
Clinton Township Data	3.3	---	3.3	---	---	---	---
Auburn Hills Data	1.8	---	1.1[3]	1.8 in / hr	70%	3.7	1.7
Center Line Data	1.7	---	1.7	---	---	---	---
West Lafayette, In	---	---	5[1]	---	---	---	---
Midland, MI	---	---	5[1]	---	---	---	---

Direct Measurement Metering	Wet Weather Sanitary Flow		Observed Footing Drain Flows				Projected Footing Drain Flows	
	Peak Flow with FD (cfs/1000)	Peak Flow Without FD (cfs/1000)	Average Flow (gpm/house)	Peak Flow (gpm/house)	Rainfall[2]	RDII from FD (percent)	4" Linear	4" Log
Ann Arbor 2000 FD Study	2.5	---	1.3	8.7	4.01"	60-90%	4.5	3.1
Dearborn Heights Study	3.0	---	0.55	1.0	0.87"	85-90%	2.2	1.1
WWMP Monitors	---	---	1.7	25.0	1.86"	---	3.0	1.7
Ann Arbor FD Monitoring 2002	----	---	1.0	8.5	1.81"	---	---	---
Toledo	---	---	0.3	3.3	1.72"	---	1.6	0.9
South Macomb Sanitary District:	---	---	---	3.2	1.73"	---	6.5	3.8
Simulated Rainfall Events	---	---	6.4	10.1	2.7 in / hr	---	--	---
Other Oakland County Studies	---	---	2.5 to 10	---	---	---	---	---

1 - Based on model calibration, not direct metering.
2 - Rainfall is displayed in total volume (") or intensity (in / hr)
3 - Based on interpolation of data.
4 - Actual flows are higher. These systems allowed up to 1 gpm to pass to the sanitary system

FD: Footing Drain
RDII: Rainfall Dependent I / I

5 - After removal of footing drain connections to sanitary sewer

3.1.1 Sanitary Sewer Monitoring Studies

Village of Beverly Hills, MI: The Village of Beverly Hills performed a study to measure the amount of wet weather flow removed after disconnecting approximately 63 connected footing drains from a subdivision with 83 homes. Complete results are documented in a report entitled "Sump Pump Removal Program Evaluation, Village of Beverly Hills". Sanitary sewer flows at the discharge point from the subdivision were monitored for about a year before and five years after the sump pumps were removed.

The amount of flow removed was evaluated by plotting the peak flows observed versus total rainfall. A logarithmic fit was made to the data points before and after the disconnection program. Figure 7 of the Beverly Hills report (Figure 1 of Appendix A) shows the peak-wet weather flows monitored before and after sump pump disconnections were made. The values in Table 1 were calculated using the values as shown on Figure 1 of Appendix A for a 4 " rain event. Based on the monitoring, the average peak FD flow removed was 1.7 gpm / house for a 4" rain event.

Similarly, a linear fit was made to the pre and post disconnection data sets. Using linear projections for a 4" rain event and average FD flow of 2.1 gpm / house is predicted.

It was estimated that individual homes in the study area produce 6,400 gallons annually through footing drains. The duration of rainfall was examined to see the effect on the duration of inflow to footing drains. In addition, the percent capture (fraction of rainfall that enters footing drains) was determined for pre and post disconnection periods.

Canton Township, MI. Canton Township performed flow monitoring before and after footing drain flow limiters were installed. These installations consisted of inserting a flow device to limit footing drain flows to approximately 1 gpm. A pump was installed to divert excess flows to the storm system. This work was done in an effort to eliminate basement flooding occurring from sanitary sewer backups. There is no written report, but graphs of the results were available for review. Sanitary sewer flows at the discharge point from the subdivision were monitored before any disconnections were performed and after each of three rounds of footing drains disconnections. The total number of homes in the subdivision is 530. Monitoring was performed after 100, 20, and 57 homes were disconnected in 1991, 1992, and 1994 respectively.

The amount of flow removed was evaluated by plotting the peak flows observed versus total rainfall. A logarithmic fit was made to the data points before and after the disconnection program. Based on an extrapolation of this data to a 2.5" rain event, an average of 3 gpm / house was removed (Figure 2 of Appendix A).

Actual footing drain flows would have been higher than this as 1 gpm / house was still allowed to discharge to the sanitary system. Since this work was done, there have been no further complaints of basement flooding in this area.

Additional analysis was completed using both linear and logarithmic projections for each of the three monitoring years. The peak inflow was calculated for a total of 17 rain events during the three monitoring periods. Using the peak inflow data from the rain events, linear and logarithmic projections to 4" were established for each of the three monitoring years. The difference between the projected values was attributed to the removed footing drains and the estimated flow per footing drain was subsequently determined using the number of disconnections completed between monitoring periods.

Using the linear projections, an estimated average peak flow of 3.3 gpm was removed per footing drain connection. The logarithmic projections indicated that peak footing drain flow was 1.8 gpm.

Auburn Hills, MI. The city of Auburn Hills is currently undergoing a footing drain disconnection program in a subdivision to prevent basement backups. Monitoring of flows before any disconnections were made are being compared to monitoring data after 25%, 50%, 75% and 100% of the homes are disconnected. A letter to the MDEQ from the city summarizing the conclusions of the 25% disconnect point was reviewed. Approximately 75% of the project has been completed over the past two years. Metering results indicate that a 60% reduction in I/I has been achieved with 50% of the disconnection completed. There are a total of 530 homes in the subdivision that will eventually be disconnected.

The amount of flow removed after 25% of the homes were disconnected was evaluated by plotting the peak flows observed versus total rainfall. A logarithmic fit was made to the data points before and after the disconnection program. Based on an extrapolation of this data to the 10-yr 1-hr rain event, an average of 1.1 gpm / house was removed from each of the homes disconnected (no graph available).

West Lafayette, IN. The city of West Lafayette, Indiana underwent a footing drain disconnect program to eliminate basement backups occurring due to RDII. Results are summarized in a report entitled "West Lafayette Tackles Gravity Foundation Drain Removal From Sewer System". The study area included approximately 500 homes. Initial estimates for the amount of RDII from residential footing drains were made based on model calibrations. Sanitary sewer flow monitoring was performed before and during the disconnect program.

The initial estimate based on the model calibration indicated that the average peak wet weather footing drain flow was 5 gpm / house.

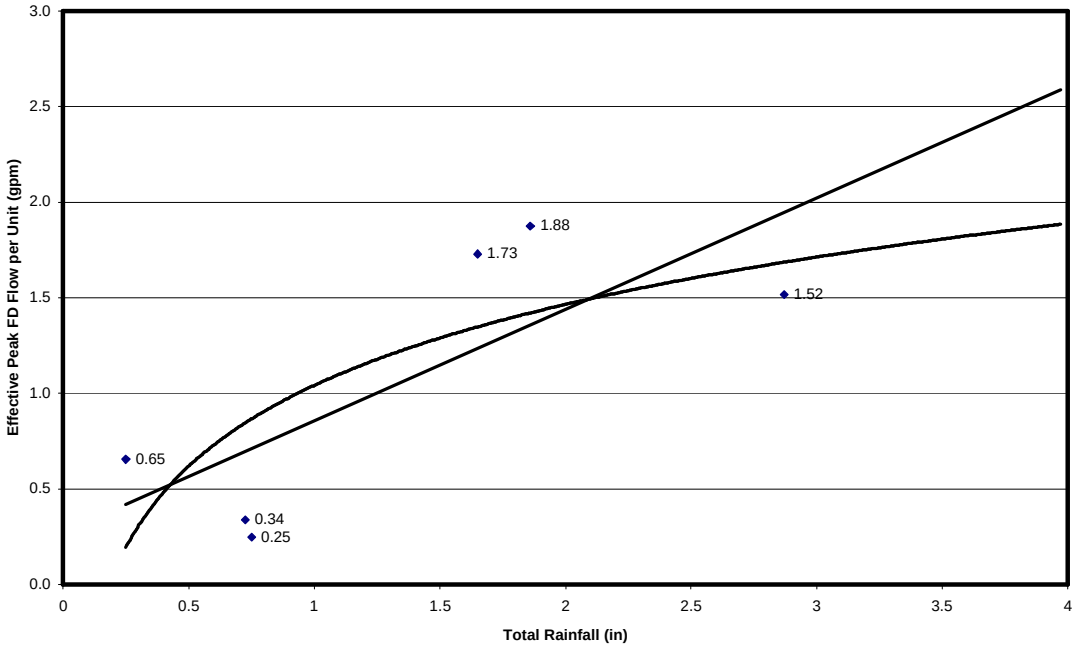
After disconnecting 144 footing drains, a comparison of the total monthly volume of flows between February 1993 and 1995 indicated a reduction of 60,000 gpd, or an average of 418 gpd / house (0.29 gpm / house).

Based on the study results it was concluded that peak flows from foundation drains are more related to rainfall depth than intensity. The subdivision was constructed on farm land and it is suspected that drainage tile left in place maybe interconnected with some footing drains.

Oakland County, MI Studies: An Oakland County D.P.W. report entitled "Drain Tile – Test Pilot Projects", August 16, 1967, compares sewer flow meter data from a housing subdivision with footing drains connected and one without footing drain connections. The data from the area without footing drains does not include any rainfall events over 0.37 inches, which is mostly taken up as initial soil abstraction (storage). Therefore that data is not summarized in this memo. The data from the area with footing drains covers 1.5 years and includes three events over 1" of total rainfall. A total of 613 houses with 2,146 people were tributary to the flow meter.

The original report calculates peak flow in cfs / 1000 people. However, using the data graphs presented in the report it is possible to estimate the effective peak footing drain flow in the sewer versus rainfall as shown in Figure 4. This is calculated by subtracting an estimate of 0.39 gpm peak flow per house for non-footing drain I / I from the peak RDII (peak flow minus dry weather flow). The non-footing drain RDII estimate is based on the 1968 study as described below, and serves as a rough estimate of the true amount.

Figure 4. Oakland County Study: Footing Drain Flow Versus Total Rainfall



The second report by Oakland County is "Footing-Drain Tile Report #2", January 9, 1968. This study expands upon the first report by comparing flows from six housing subdivisions with footing drains (ranging from 110 to 832 houses) to three housing subdivisions without footing drains (ranging from 290 to 377 houses). This report again calculates peak flow in cfs / 1000 people. No rainfall data is presented and only the flow data for a couple days before and after the peak flow for each site found over the study period is given. The values for Table 1 were estimated based on this limited data for each subarea and averaged. The values found for peak flow per 1000 people and amount attributed to footing drains was very consistent between the different sub areas as shown in Table 2.

Table 2. Summary of Oakland County Footing Drain Flow Study

Area No.	Drainage Area	Community	FDs Connected	Soil	Houses	Population*	WW Peak Flow (cfs/1000 people)	FD flows (gpm/unit)
1	13 Mile Rd. Arm	Farmington	100%	varies from sand to clay with spots pf peat and marl	450	1575	2.10	2.0
2	Olde Franklin Towne Sub	Farmington	100%	50% sand and 50% clay	150	525	1.76	1.6
3	Twyckingham Sub. #1	Southfield	100%	clay	110	385	1.06+**	na
4	Tarabusi Arm	Farmington	100%	sand and clay	832	2910	1.44	1.2
5	Bloomfield Orchards	Pontiac	100%	clay	554	1939	1.70	2.0
6	14 Mile Rd. Arm	West Bloomfield	100%	clay and sand	857	3000	1.80	2.1
7	Novi Trunk	Novi	0%	wet sand and gravel with some clay	337	1320	0.53	
8	Southfield Meadows	Southfield	10%	wet sandy soil	290	1015	0.53	
9	Sylvan Manor Sub.	West Bloomfield	0%	sandy soil	300	1050	0.50	

* based on units times 3.5 people/unit

** flows over maximum capacity of meter

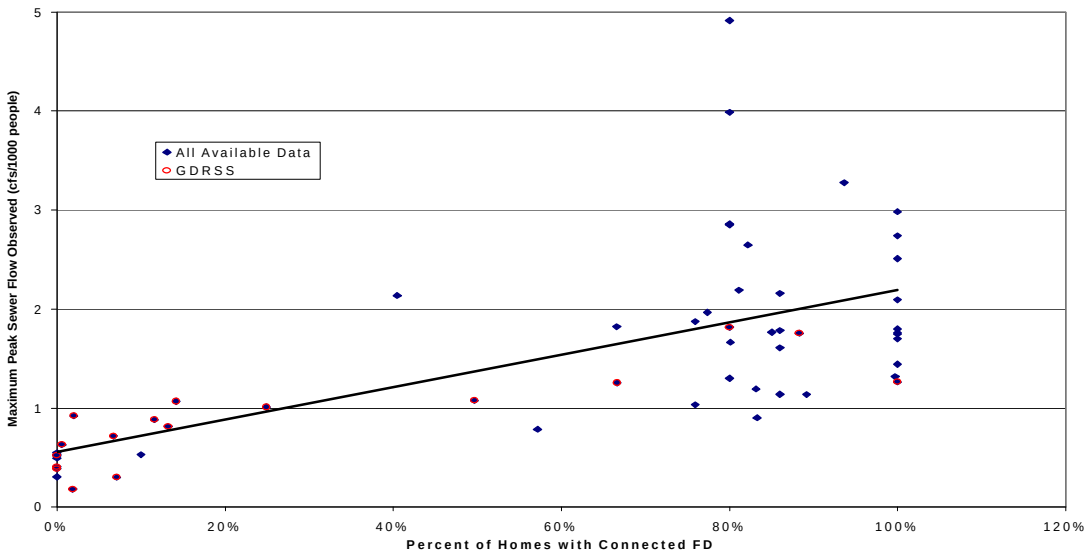
In general, homes without footing drains were also located in more permeable soils which may also have been a factor in the lower peak wet weather flows that were observed.

The average RDII per capita for areas with and without footing drains was found and the difference between them was attributed to footing drains. The average RDII for the non-footing drain areas (0.39 gpm per house) was used to estimate the footing drain flows for the values given in Tables 1 and 2. The conclusion of the report was that footing drains are a significant contributor of RDII and should not be allowed by code. The additional analysis performed as described above estimated that the average peak footing drain flow is 1.8 gpm / house in these areas. The peak flow of 2.0 gpm corresponded to a rainfall of 1.86 inches on June 7, 1967.

GDRSS Data and Peak Flow Comparisons. The Greater Detroit Regional Sewer System (GDRSS; CS-1249) project has been collecting digital meter data from billing meters since 1996 for meters classified as high volume (>5% of total WWTP flow) and since 2000 for the remaining low volume (< 5% of total WWTP flow) meters. This data goes through a very thorough review process. The top 10 peaks for each of the meters monitoring flows from sanitary sewer areas were found from the data set. GIS tools were used to find the total number of homes and population tributary to each meter for both with and without footing drains connected to the sanitary sewer system. This was done by intersecting census tract data with meter tributary areas and the footing drain areas map developed and described in the WWMP Final Report on SSO Characterization. The meter districts, in which the total number of connected footing drains was uncertain, were left out of the analysis.

Using this data a plot of peak observed flow in cfs / 1000 people versus percent of homes connected to the sanitary sewer is shown in Figure 5. This data is based on approximately a 2" total rainfall volume. Also plotted in this figure is similar data from I / I and footing drain flow reports reviewed for this memo. Using the total data set, the average wet weather maximum peak flows for areas with 20% or less FDs connected is 0.63 cfs / 1000 people. The average for areas with 50% or more FDs connections is 2.0 cfs / 1000 people. Assuming an average of 2.5 people per household, this gives an average of 1.5 gpm / house from footing drains This assumes there is no other significant contributor from the areas with footing drain connections.

Figure 5. Peak Observed Flows versus Percent of Connected Footing Drains (based on approximately 2" of total rainfall)

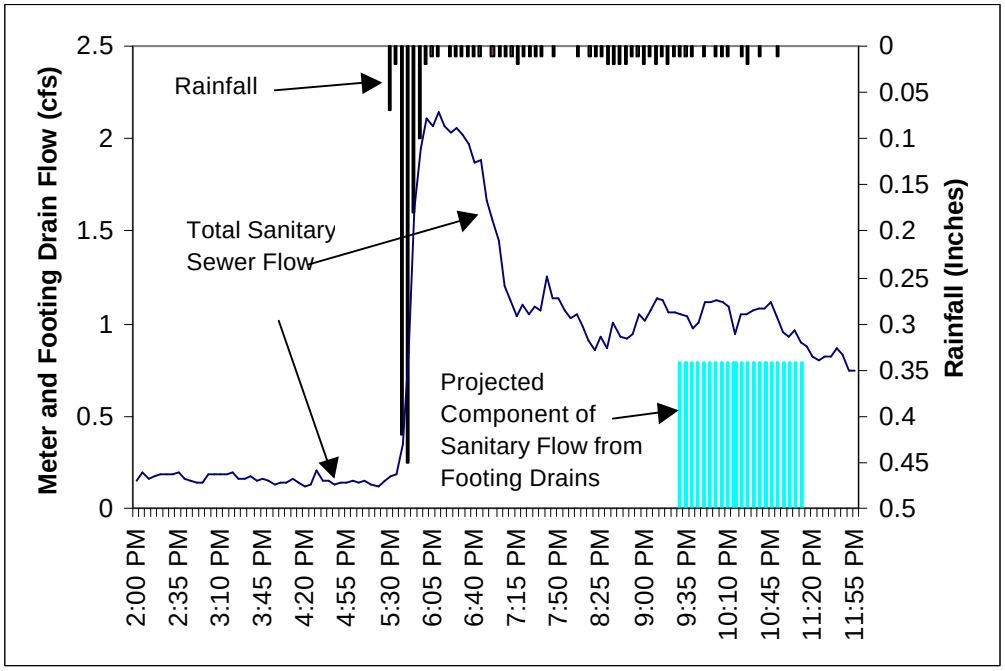


3.1.2 Direct Measurement Studies

Ann Arbor, MI: The city of Ann Arbor performed a basement flooding prevention study where direct measurements of footing drain flows during rain events were measured at house leads entering sanitary sewer manholes. Complete results are documented in a June 2001 report entitled "Sanitary Sewer Overflow Prevention Study". Footing drain flows were directly measured from house leads during a rain event using a calibrated bucket and stopwatch. Measurements were taken during a period of light rain (0.08 in / hr rainfall intensity) and higher flows are expected during more intense periods of flow. Under dry weather conditions, no flow was noted from these leads.

Footing drain measurements were taken from a total of 18 houses. The measured footing drain flows ranged from 0 to 2.7 gpm. The average footing drain flow (including readings of zero flow) is 1.4 gpm / house. The measurements were projected to the number of homes for five different metered areas and compared to sewer meter data to estimate the percent of flow attributed to footing drains. An example is shown in Figure 6 where sanitary flows and rainfall data are plotted. The projected FD flow was found using the average 1.4 gpm / house and is plotted for the time the FD measurements were taken.

Figure 6. Example of Sewer Flows Compared to Projected FD Flows (Bromley Area, 10" pipe, 282 houses)



Assuming that 70% to 90% of the peak flow observed during a three to four inch rain event was from footing drain flows, the average footing drain flow is between 1.9 and 2.4 gpm / house.

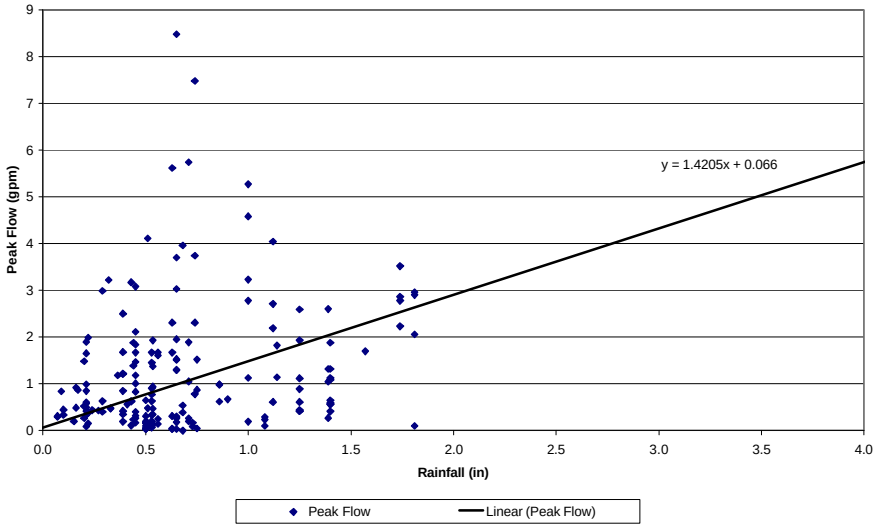
Based on the work from the 2001 report, the city started a city wide (approximately 30,000 homes) footing drain disconnection program, which includes continuous monitoring of sump pumps in homes that have undergone a footing drain disconnection. The program is ongoing and measurements are being taken using on / off recorders. Flows are calculated using pump run times and the rated capacity for each pump (found using draw down tests).

To date the largest storm event that has been recorded in 1.75 inches. During the monitoring period the average dry weather FD flow from the houses monitored is 80 gpd / house (0.056 gpm / house). Wet weather peaks have ranged from no response to 8.5 gpm, with an average of 1.4 gpm / house. Figure 7 show a plot of peak footing drain flow vs. rainfall.

A linear trend was added to the data set in order to predict the average response to larger storm events. The projected average footing drain flow for a 4" storm event is 5.7 gpm.

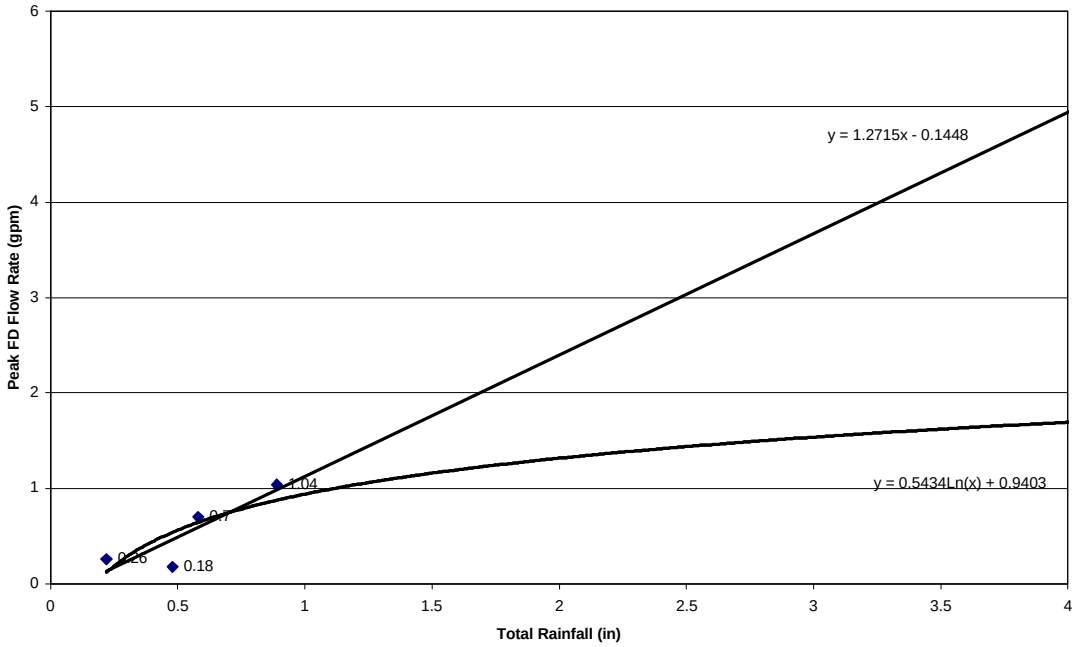
Dearborn Heights, MI: The city of Dearborn Heights performed a study where direct measurements of footing drain flows during rain events were measured at house leads entering sanitary sewer manholes. Complete results are documented in a June 1990 report entitled "City of Dearborn Heights SSES Supplemental Report, Footing Drain Inflow Study". This study also used direct measurement of flows from house leads in manholes using a calibrated bucket and stopwatch. The measurements were projected to the number of homes and compared to sewer meter data to estimate the percent of flow attributed to footing drains. These measurements were taken during a period of light rain.

Figure 7. Ann Arbor Study Peak Footing Drain Flow Rates.



Based on the results, the average footing drain flow was 1.0 gpm / house during light rain, which accounted for 85 to 90% of the RDII. Using the reported data to extrapolate to other peak flow data collected (rainfall totals unknown) as part of an SSES study for this same area, the average footing drain flow can be as high as 1.7 gpm / house using a logarithmic fit or 4.9 gpm / house using a linear fit. A logarithmic response would be valid in a situation where the soil becomes saturated as a rain event proceeds, resulting in higher runoff during the latter stages of the event. A linear response would be seen if infiltration was proportional to rainfall for all events. Real world responses likely have characteristics of both types of response.

Figure 8. Dearborn Heights Study, Peak Footing Drain Flow Rates.

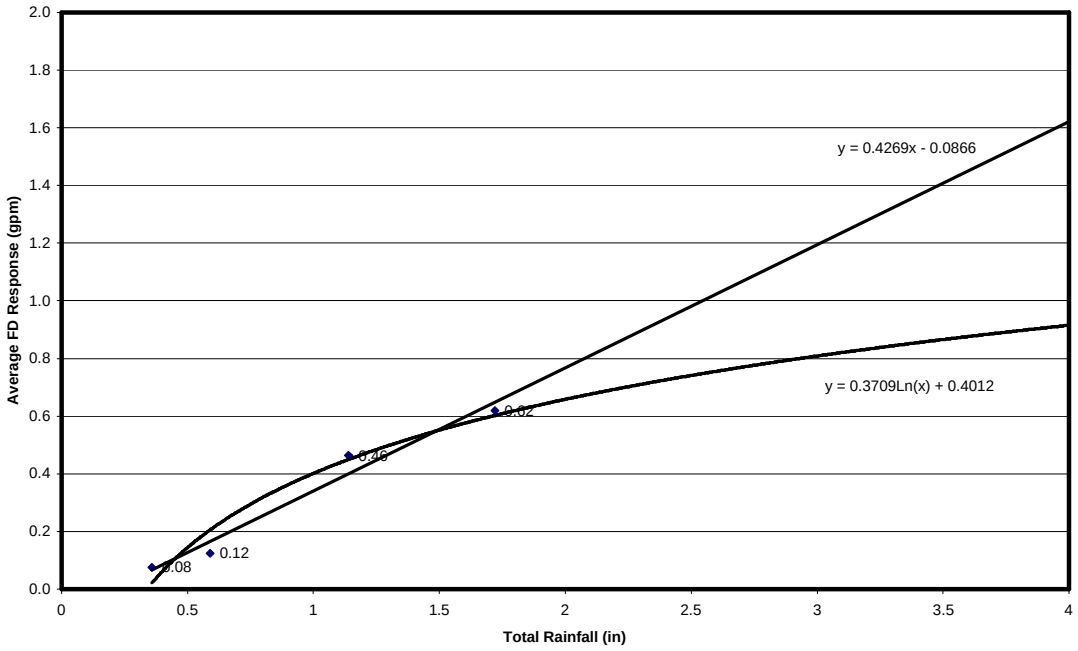


Toledo, OH: The city of Toledo performed continuous sump monitoring from seven homes as an estimate of what connected footing drains were contributing to the areas RDII. Complete results are documented in a report entitled City of Toledo, Ohio, River Road SSES. In this study, seven homes were monitored for two months using the same methods described for Ann Arbor above. Peak flows from four rain events ranging from 0.36 to 1.72 inches were analyzed.

Four of the seven homes monitored had no flow response for the 1.72" event, and the three other homes had peaks as high as 3.3 gpm. Based on this data, the average peaks from the homes that did respond were logarithmically extrapolated to the 10 yr-24 hr storm (3.6 inches) for an average of 3.2 gpm / house. The study assumed that half of the homes would respond on average at this rate and the other half would respond with 1 gpm, giving an overall average of 2.6 gpm / home.

A more conservative approach (relative to expected removal rates) would be to fit a logarithmic line to the average of the peak flows including the zero flow measurement versus the total rainfall as shown in Figure 9. The projected average FD flow for the 4" event is 0.9 gpm / house (1.6 gpm / house using a linear fit).

Figure 9. Average FD Flow versus Total Rainfall for Toledo Study



South Macomb Sanitary District, MI: As part of an SSES the South Macomb Sanitary District (SMSD) performed continuous sump pump monitoring in 1997 similar to the Toledo and Ann Arbor studies. Details of this work can be found in the South Macomb Sanitary District SSES 1997 report. A total of 10 homes were monitored in St. Clair Shores. Homes were selected to represent four of the five main soil types present in St. Clair Shores. Four rainfall events were reported.

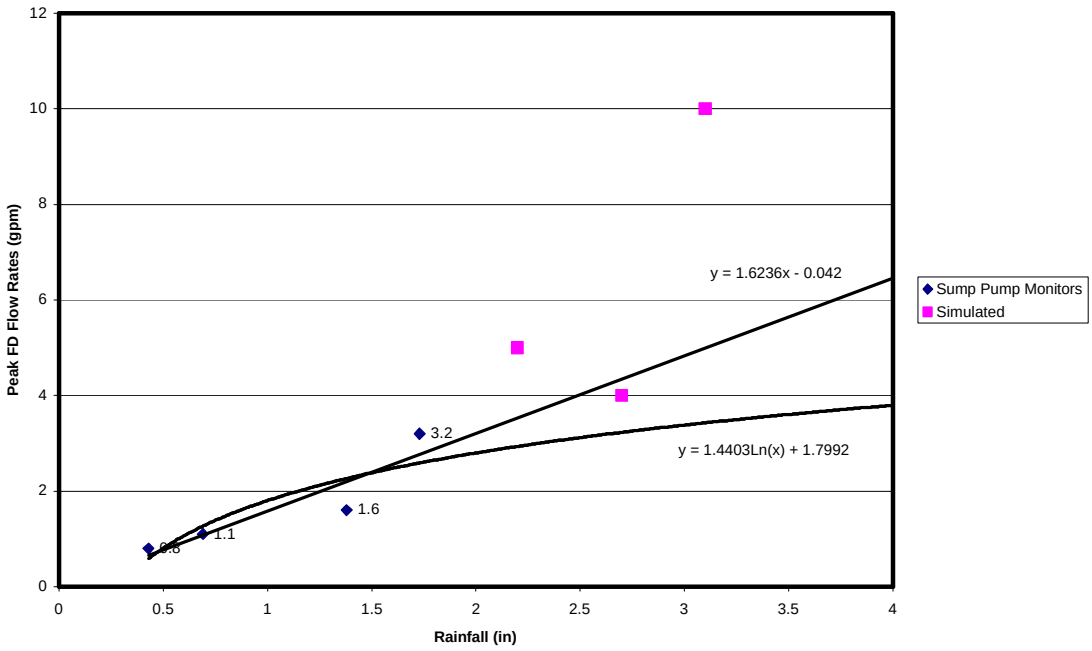
Three different homes were also used to measure footing drain flows from simulated rainfall events. This was done by applying water to the roof using hoses at a rate of 2 to 3" per hour, based on the area of the roof. Flows were measured from the house lead entering a sanitary manhole. The applied flow rate and house lead flow rate were measured using a calibrated bucket and stop watch.

The average measured footing drain flows from the 10 sump pump monitors and simulated rainfall events versus the total rainfall is shown in Figure 10.

Three of the seven homes monitored had no flow response for the 1.73 event. Based on this data, the average peaks from the homes that did respond were logarithmically extrapolated to the 25 yr-24 hr storm (4 inches) for an average of 3.8 gpm / house. Using a linear projection with the same data points an estimated FD response of 6.6 gpm / house is predicted. Since three out of the seven homes monitored had no FD response the average peak footing drain flow rate for the community as a whole would presumably be less than the projections shown in Figure 10.

The results of the simulated rainfall events were also added to Figure 10. With the addition of the simulated events, it appears that the linear fit provides a better prediction of FD response than the logarithmic fit.

Figure 10. South Macomb Sanitary District Footing Drain Flow Measurements



Others Studies: A report entitled "Evergreen-Farmington Sewage Disposal System, 1999 Phase 1 Study – Volume 1" summarizes several other footing drain flow studies performed in Troy, Southfield, and the Evergreen / Farmington district. Table 1 of Appendix A is a copy of this table, which indicates peak footing drain flow estimates of 2.5 to 10 gpm / house. These studies were done by simulating rainfall around a house and measuring footing drain flows.

3.2 Proposed / Ongoing Studies

Several SE Michigan communities have ongoing or planned studies to measure FD flows. Three of these studies were described above with preliminary results.

Ann Arbor and WWMP. The Ann Arbor and WWMP sump pump monitors were installed in late 2001 and early 2002. There have not been any extreme rain events since they were installed, with the largest recorded event at approximately 1.8 inches. Data collection from these studies will continue through the end of 2002. The WWMP study methodology and results are described in detail Chapter 4. Data collected during the Ann Arbor study is included in some of the WWMP data analysis since the studies are very similar.

Auburn Hills. Auburn Hills will perform monitoring at the sewer outlet point after 50, 75, and 100% of the footing drains in that subdivision are disconnected. Approximately 75% of the project has been completed over the past two years. Metering results indicate that at the 50% removal point, a 60% reduce in I/I has been realized.

Fraser. As part of their short-term measures for SSO control, the city of Fraser was planning a footing drain disconnect pilot study starting in the spring of 2002. This work includes disconnecting 32 homes along a single street, including 14 patio/area drains connected to the sanitary sewer. Four new storm lines will be installed to collect the disconnected footing and patio drain flows as shown in Table 3.

Table 3. New Storm Lines for Fraser Pilot Study

Storm Sewer ID	# Houses	Footing Drains	Patio Drains
1 North	8	8	0
1 South	8	8	8
2 North	8	8	0
2 South	8	8	6

The pilot street runs east/west with sanitary flows from the east half of the street flowing east and flows from the west half of the street flowing west. Pre- and post-disconnection monitoring will be performed in each of these sanitary sewers. Two flow monitors will also be used to measure flows in one of the new storm lines carrying footing drain flows only, and one of the lines carrying both footing and patio drains. The disconnections are scheduled to be completed in the spring of 2003, with post-monitoring following.

4. WWMP Footing Drain Flow Monitoring Field Program

One of the tasks under the Wastewater Master Plan (WWMP) is to measure footing drain flows at a number of locations within the DWSD service area. This data is being used in conjunction with information reported from other studies to support a regional assessment of potential solutions to Sanitary Sewer Overflows. The scope of this investigation is limited in both the number of locations being investigated and the duration of the study. As a result, the data set generated during the WWMP footing drain field investigation is intended to be used for planning activities of a regional scope. The data that was collected during the field-monitoring program indicates that the flow rates from footing drains in some SSO prone areas within the service area are significant and further studies by local communities are warranted.

Six communities within the DWSD service area agreed to become case studies for the SSO evaluation being undertaken as part of the WWMP. In the fall of 2001, the six communities were asked to provide the names of local residents who were willing to participate in the footing drain field-monitoring program. Volunteers were found in five of the six case study communities, as well as additional communities. In total, footing drain flows were monitored at fifteen single family homes in the region. The first flow monitor was installed October 31, 2001 and the most recent installation was completed on April 23, 2002. A summary of the installation information, including location and installation dates, is shown in Table 4.

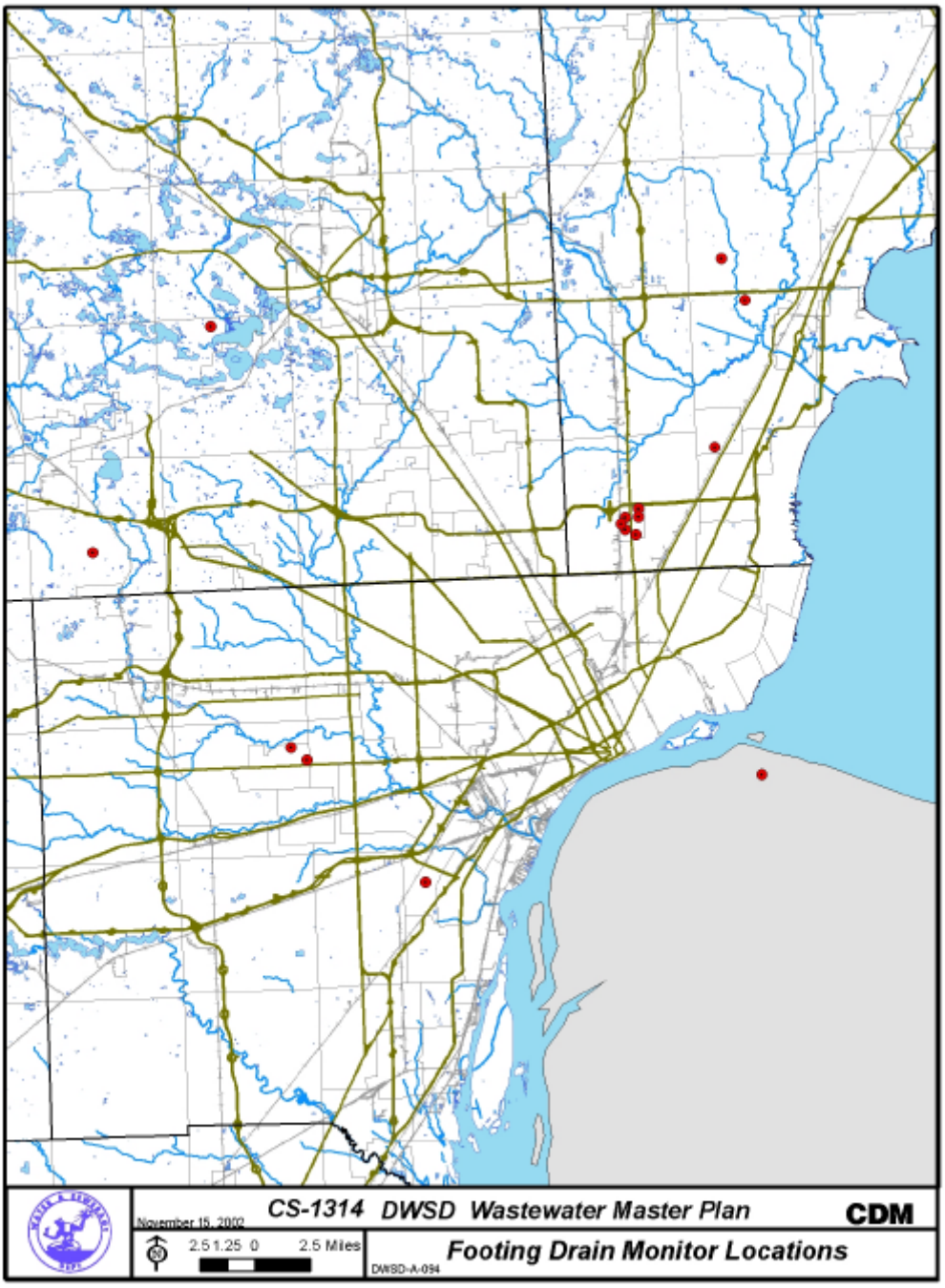
Table 4. Footing Drain Field Study Flow Monitor Locations

Installation	Address	Installation Date	Removal Date
1	15441 Jonas, Allen Park, MI	10/31/2001	12/27/2001
2	12760 Lanoue, Tecumseh, ON	2/20/2002	Active
3	28936 Bridge, Garden City, MI	11/01/2001	Active
4	6801 Braun, Center Line, MI	2/12/2002	Active
5	8458 Dale, Center Line, MI	2/12/2002	Active
6	8469 Mckinley, Center Line, MI	2/12/2002	Active
7	7201 Coolidge, Center Line, MI	2/12/2002	8/13/2002
8	44507 Manitou, Clinton Twp, MI	2/13/2002	Active
9	45635 Addington, Novi, MI	2/25/2002	Active
10	1825 Poppleton, West Bloomfield, MI	3/09/2002	Active
11	17883 Thomas, Macomb Twp, MI	3/09/2002	Active
12	7271 Dale, Center Line MI	3/12/2002	Active
13	8261 Sterling, Center Line, MI	3/12/2002	Active
14	16484 Vernetta, Fraser, MI	3/26/2002	Active
15	5948 Arcola, Garden City, MI	4/23/2002	Active

In addition, Figure 11 shows the geographic distribution of the footing drain flow monitor locations.

Flow monitors were installed in eight different communities within the DWSD service area. The largest number (six) was installed in Center Line, largely due to the cooperation received by that community during the selection of sites and installation of the monitors. Fourteen of the sites were located within the DWSD sanitary sewerage service area, with a single monitor installed in Ontario. The site in Ontario was initially selected as a temporary location, early in the study, in order to test the equipment setup. Early results for the site in Ontario yielded the highest peak footing drain flows and as a result the monitor was left in place for the duration of the study.

Figure 11. Flow Monitor Locations



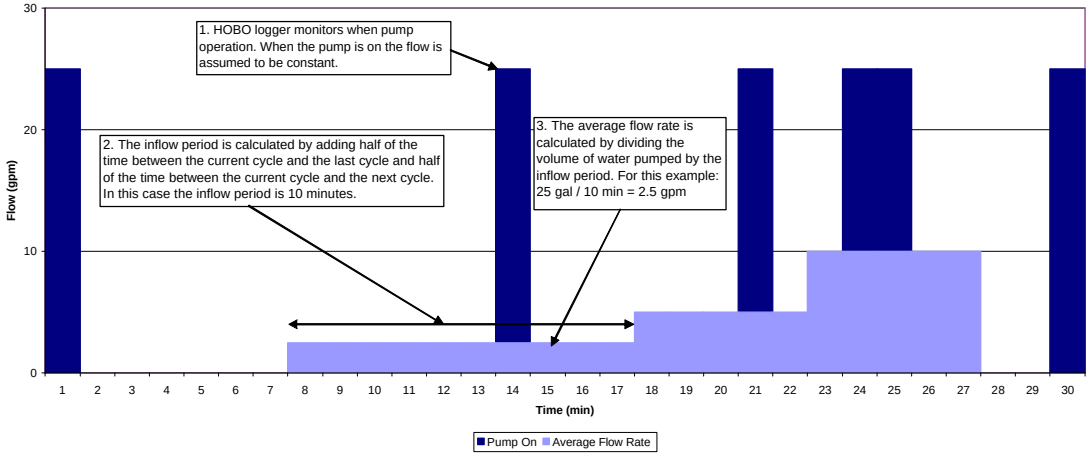
4.1 Methodology

The philosophy in developing the flow-monitoring program was to select an approach that was non-intrusive and cost effective. The equipment and methodology that were employed during this program met both of these goals.

The focus of this study was to collect representative footing drain flows, preferably from residences in areas with a history of SSOs. Typically, only footing drains that are connected to the sanitary sewer system are a concern. Despite this, the easiest point to access footing drains in a home is a basement sump and therefore only homes with accessible sumps were selected to be part of the field monitoring program. Home that are directly connected to sanitary or combined sewer systems normally do not have sumps but some sump pump systems may discharge into these types of sewer lines. Since the focus of this study was to collect information on footing drains flows, and not investigating the ultimate fate of water entering footing drain, the location of sump pump discharges, whether it was sanitary sewer, storm sewer or backyard, was not a key factor in site selection. However, care was taken to select sites where flow was not being recycled (i.e. discharge too close to foundation).

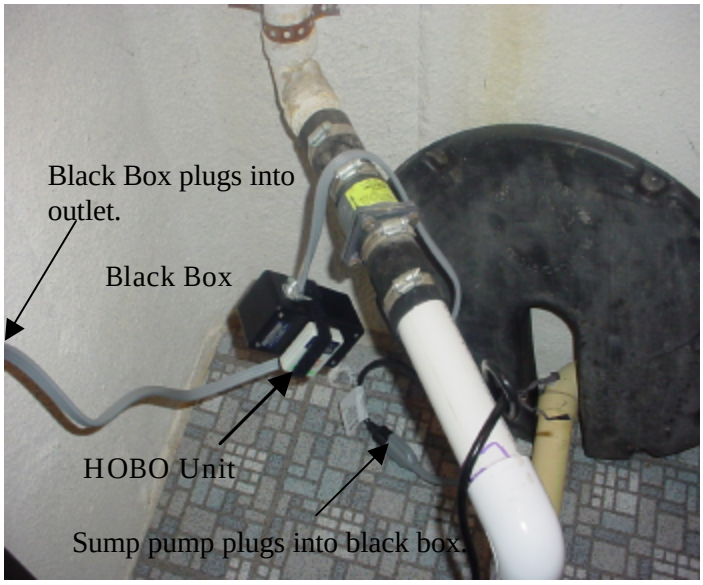
In the field-monitoring program, footing drain flow rates were not directly metered but calculated from sump pump operating data and the rated capacity of the pumps. A data logger was used to record each time the pump state changed (change from on to off). The total volume of water pumped during each cycle was calculated by multiplying the pump run time by the rated capacity of the pump. The rate of inflow from the footing drains was estimated by dividing the volume that was pumped in a cycle by the time between pump cycles. Figure 12 illustrates this methodology.

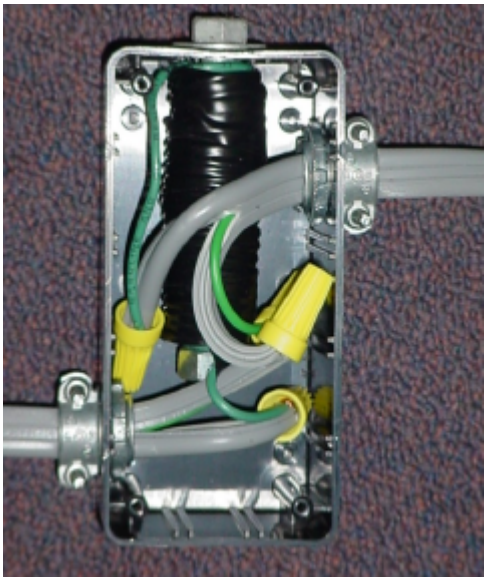
Figure 12. Estimating Footing Drain Flows Based on Sump Pump Cycle Time



A HOBO Model on/off data logger, manufactured by ONSET Computer Corporation, was used to record the time when a change of state occurred in a sump pump. These units are designed to determine when a dry motor (not submerged) is running based on the magnetic field generated when an electric motor operates. In order to use the HOBO units with submersible pumps a second device (dubbed a 'black box') was constructed which generated a magnetic field when a pump was operating. This 'black box' is an electrical box in which a copper wire has been coiled, in order to generate a magnetic field. It can be installed between an electrical outlet and a sump pump. The arrangement of the monitoring equipment is shown in Figure 13. The HOBO units contain enough memory to record 1,000 pump cycles.

Figure 13. Footing Drain Monitor Arrangement and Components of Black Box





As indicated above, the pump cycle information is used in conjunction with sump pump capacity in order to generate flow rates. The preferred approach to determining the rated pump capacity was to conduct draw down tests at each individual site. In a drawdown test, a known volume of water is pumped and the corresponding time is recorded. Using this approach, a detailed evaluation of discharge piping hydraulics and pump condition is avoided. Drawdown tests were repeated three times and the average resulting flow rate was used in subsequent analysis. Drawdown tests were not conducted for the two installations in Garden City, due to the design used in the footing drain disconnection program being conducted by that community. The rated capacity of the Garden City pumps was obtained by the local consultant for those installations.

The representative footing drain flows which were recorded during this study were used to prepare planning level cost effectiveness analysis for disconnection of footing drains from the sanitary sewer system. The methodology outlined in this section provides data that is suitable for this use.

4.2 Field Notes

Background information for each of the sites was collected to assist in the analysis of the monitoring results. The differences among the homes contribute to the variation in the results of the observed footing drain flows. Information included in the field notes that may significantly effect the flow characteristics are the age of the home and sump pump, the area enclosed by the lot, the area covered by the home, and the location and distance of the downspouts on the home. Also included in the field notes are photographs of the front and back of the home, date that the monitor was installed, information regarding data downloads, a street map showing the location of the home, and the sump pump capacity determined during draw down testing.

4.3 Results

Footing drain flow rates were calculated for each of the sites and plotted with respect to time. Rainfall was added to each of the plots to enable a visual comparison of the flows generated by rain events. After a storm event, the two key characteristics of these flow rate plots are the peak flow rate observed and the length of time during which the flow rates are elevated over normal base flow rates. Given the numerous variables between the sites' conditions and each of the rainfall events, the plots for each of the sites have unique characteristics. Figures 14 and 15 show the footing drain response plots for a site that exhibits large peaks which rapidly return to normal and a site where footing drain flow rates are elevated for an extended period of time after a rain event. These two sites represent extreme cases with most sites exhibiting characteristics similar to both of these sites.

Figure 14. Typical Footing Drain Flow vs. Rainfall – Rapid Response

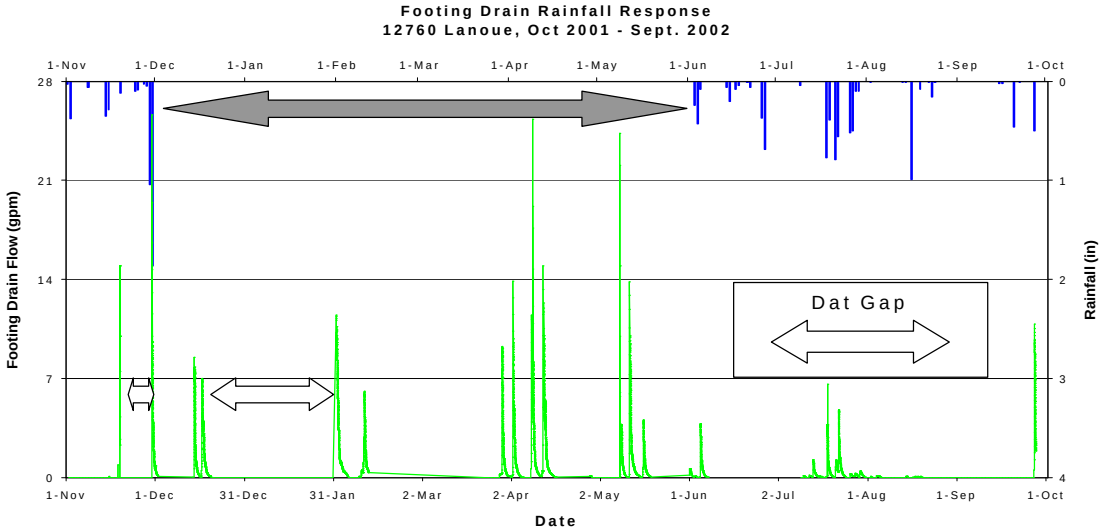
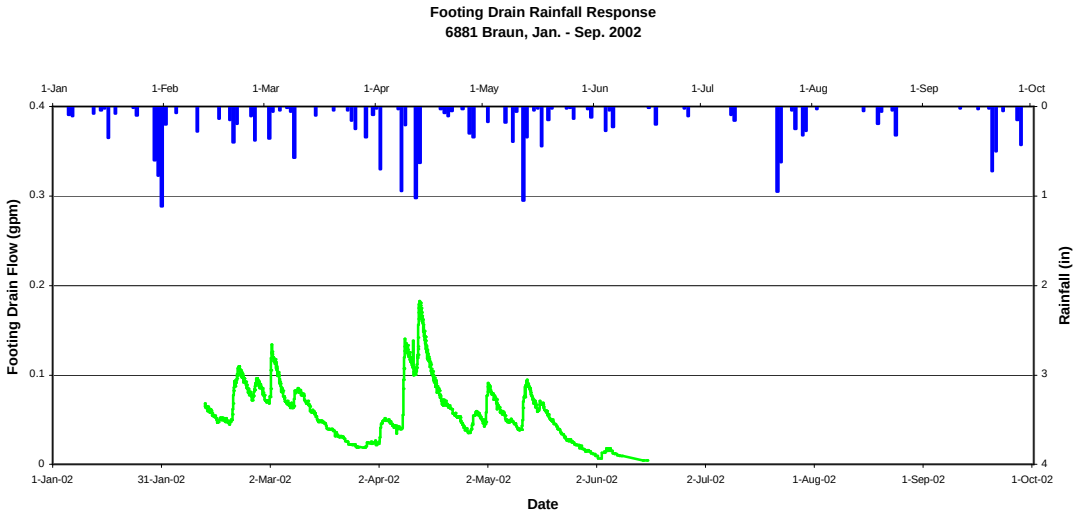


Figure 15. Typical Footing Drain Flow vs. Rainfall – Extended Infiltration



Analysis and interpretation of the footing drain flows were primarily focused on wet weather response but dry weather flow was also examined to a lesser extent, in order to characterize base flow at the sites. As expected, dry weather footing drain flows are a function of site characteristics, with some sites having no flow during dry weather and others having a continuous flow at all times. Most notably, during the spring the dry weather flow at 8548 Dale was approximately 1800 gallons per day. The average dry weather FD flow from the houses monitored is 172 gpd / house (0.12 gpm / house). This average includes 8548 Dale (it is possible there is a leak in the water line to the house). The average not including this extreme value is 91 gpd / house (0.063 gpm / house). As a comparison, the volume of wastewater generated from a typical single family home is 250 gallons per day.

The rainfall used in this study was obtained from two sources: the Midwest Climate Center (MCC) and AEW. The Midwest Climate Center operates five rain gages in southeast Michigan and AEW operates rain gages in both Center Line and Fraser. The MCC data contains only total daily rainfall numbers while 15 minute data was available from the AEW rain gages. Figure 16 shows the locations of the rain gauges.

Using the AEW gage information, a comparison can be made to both total daily rainfall and rainfall intensity. Typically, total precipitation less than half an inch over a twenty-four hour period does not result in significant runoff. For this study, data from all rainfall events was examined along with normal dry weather flows. The largest rainfall recorded during this study was 1.83 inches, reported from the MCC Farmington Hills rain gage on July 23, 2002.

For sites in Fraser and Center Line, two footing drain response plots were generated for each site – one using MCC rainfall and the second using AEW rainfall gage data. For these sites, the AEW rainfall is likely more accurate, due to the proximity of the gages to the sites. The MCC data has been provided as a reference for periods when data was not available from the AEW gages. The AEW gages are not heated and therefore data is not available during the winter months.

4.4 Analysis

Using this data an analysis of footing drain peak flows and volumes was made. The data was also analyzed for potential seasonal variations.

4.4.1 Peak Flows

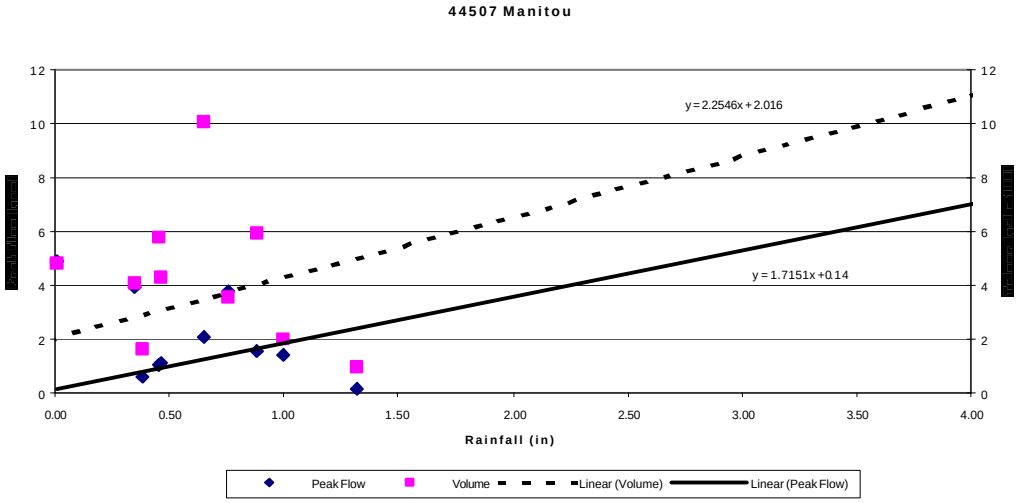
The peak footing drain flow rates generated during storm events were examined for each of the sites. Plots showing the peak footing drain response to storm events were generated individually for each site. Given the relatively small number of data points available, a linear trend line was added to each graph. This trend line was extrapolated to four inches of rain, which corresponds to the rainfall expected for a 25-year, 24-hour storm. For sites where rainfall intensity was also available, a second series was added to the plots.

Figure 16. Rain Gage locations



When the trend lines were added to the peak flow rate plots, they were forced to intersect the y-axis at the average dry weather flow rate. Figure 17 shows a typical plot of peak footing drain flow response to rainfall.

Figure 17. Typical Peak Footing Drain Flow Response to Rainfall



Due to the variations in site characteristics, storm events, and seasonal variability, it is difficult to establish any trends between each of the individual peak response plots. In order to establish an average peak flow response, the peak storm event flows for thirteen of the sites were plotted. The fifteenth site, in Ontario, was not used to develop the trend line since it is not located in the service area and the peak flows recorded at that site are significantly higher than any of the other sites. A plot of the peak flow responses is shown in Figure 18.

In the absence of any extreme storm events, a linear trend line was fit to the peak flow data set. The projected average peak flow, for a 4" storm event is 6.4 gpm. This average is based on the estimated peak flows, from the thirteen sites, for all storm events. Events that yielded no flow were included in the average.

The distribution of peak flows for the Waste Water Master Plan data set was also examined. The projected peak footing drain flow resulting from a 4" storm event was tabulated for all of the sites but Coolidge. The distribution of peak flows is shown in Figure 19 for both the monitoring performed under this project (WWMP) and a concurrent study in the city of Ann Arbor (AA). Approximately half of the homes monitored during this study are expected to have no, or extremely low, responses to a significant storm event. The median peak flow is projected to be approximately 0.5 gallons per minute. Approximately 40% of the homes are expected to generate peak flows above the average projected peak flow rate of 6.2 gpm.

Figure 18. Peak Footing Drain Flow Response to Rainfall – All Sites

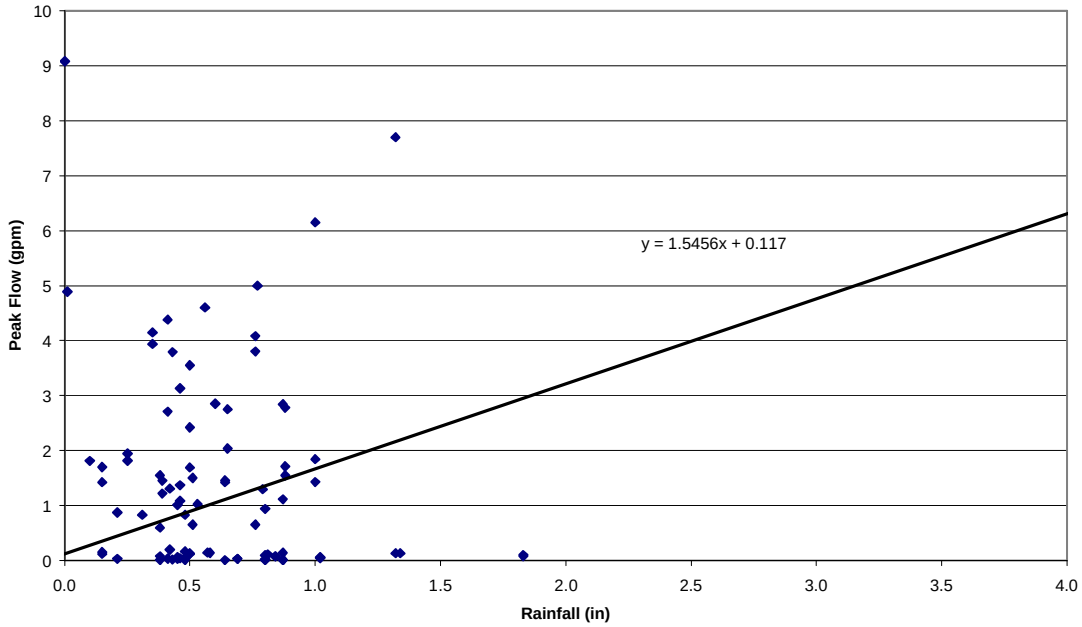
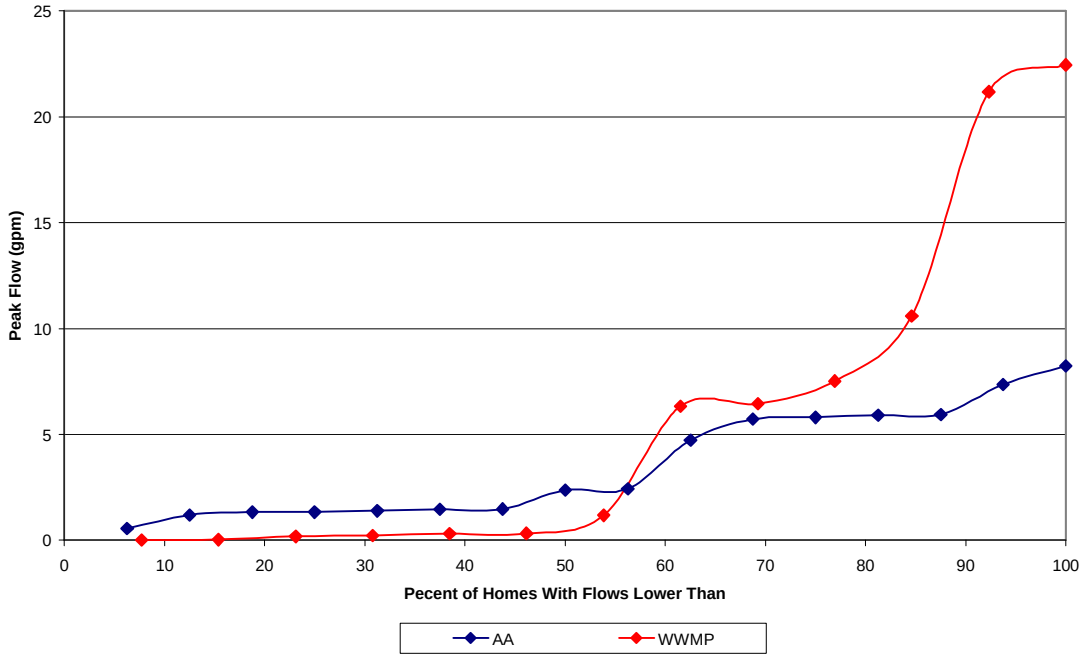


Figure 19. Distribution of Projected Peak Flows (4" event)



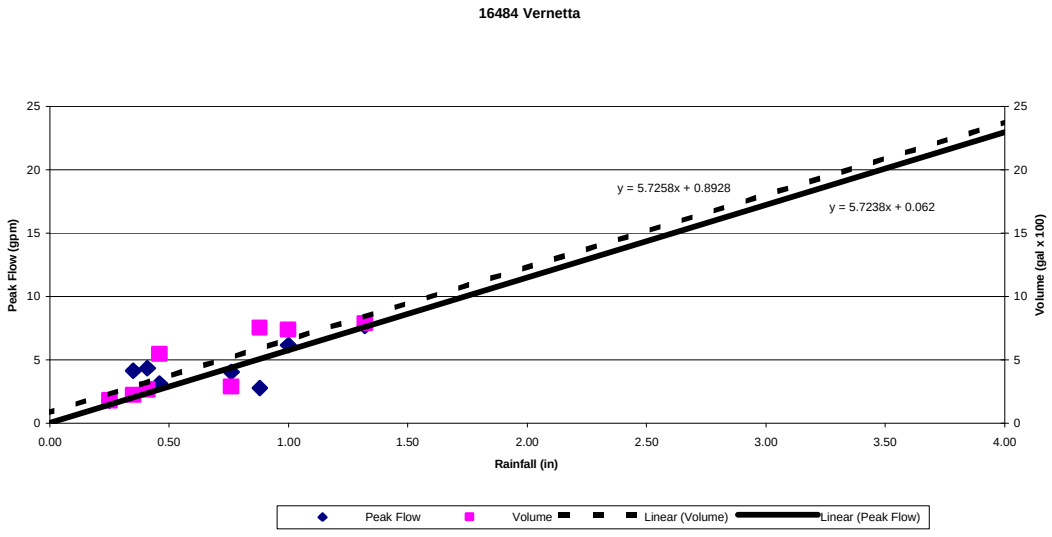
An examination of the distribution indicates that high footing drain flows appear to be strongly related to geographic location. The sites in Fraser, Clinton Township and Macomb Township all exhibited high peak flow rates. These sites are near areas that have historically had problems with SSOs.

4.4.2 Volume

In addition to peak flows, the volume of water carried by footing drains due to storm events was also examined. The volume of water added to sanitary sewer systems may be as or even more important than peak flow rates in larger systems with long transport times. To facilitate comparisons between the various sites and storm events, the total flow over a twenty-four hour period was selected as a basis. Some sites exhibited increased footing drain flows rates for days after storm events while others experienced high peak flow rates, which quickly returned to baseline levels.

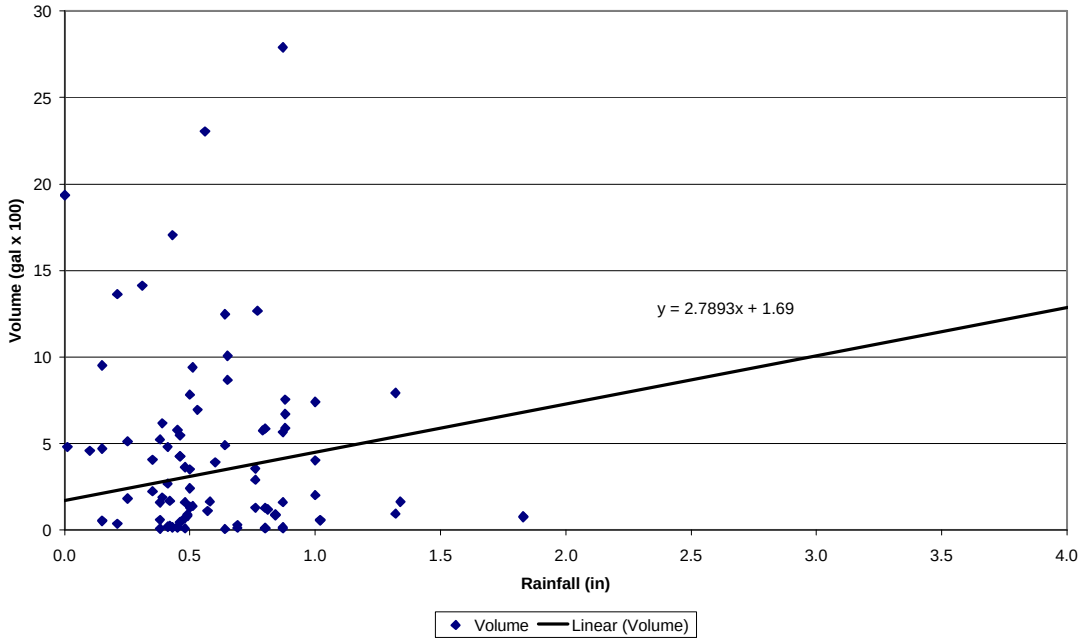
The clear water volume was determined for each site, for each storm event. Volume information is shown on the individual peak flow rate plots. Similar to the peak flow plots, a linear trend line was added to each plot, and projected to a 4" rainfall. A typical volume response plot is shown in Figure 20.

Figure 20. Volume of Flow From Footing Drain



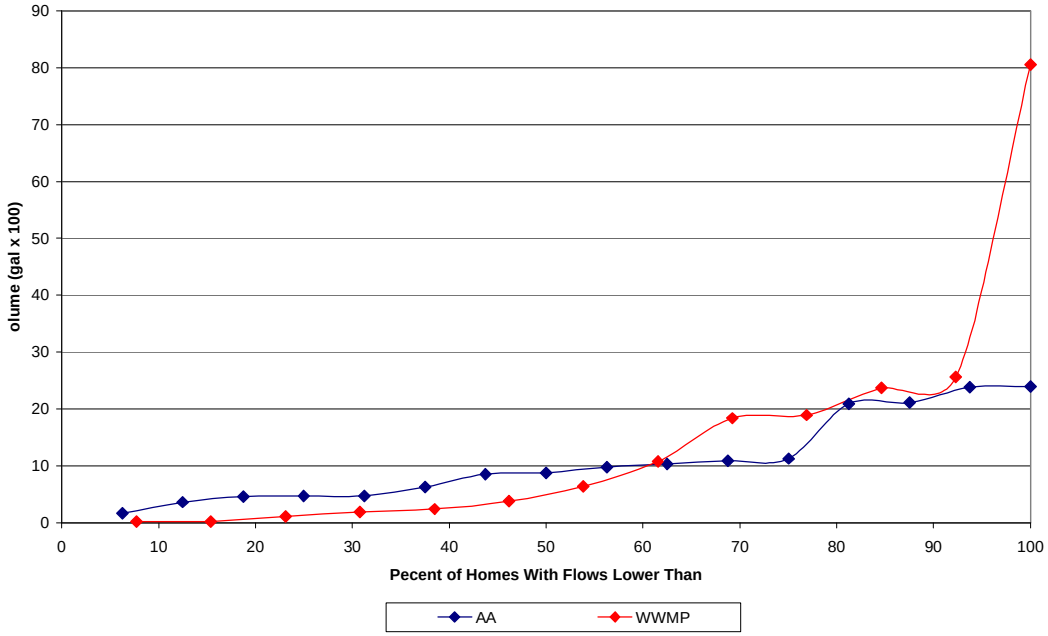
In addition to the individual plots, volume responses from the individual sites and storm events were consolidated onto one plot, shown in Figure 21. A linear trend line was added to the plot and projected to a 4" rainfall. The projected average volume generated during a 4" storm event is 1,250 gallons, over a 24 hour period. This is approximately 5 times the volume of sanitary wastewater that is typically generated in a single family home.

Figure 21. Volume of Flow From Footing Drains – All Sites.



The individual volume responses to a 4" storm event were tabulated for all of the sites. The distribution of those volume responses for the wastewater master plan (WWMP) and Ann Arbor (AA) studies is shown in Figure 22. Based on this distribution, it is estimated that 35% of homes in the study generate more than the projected average footing drain flow of 1,250 gallons expected from a 4" storm event. The median volume generated is approximately 500 gpd (0.35 gpm) or twice the typical sanitary wastewater volume for a single family home.

Figure 22. Distribution of Footing Drain Volumes



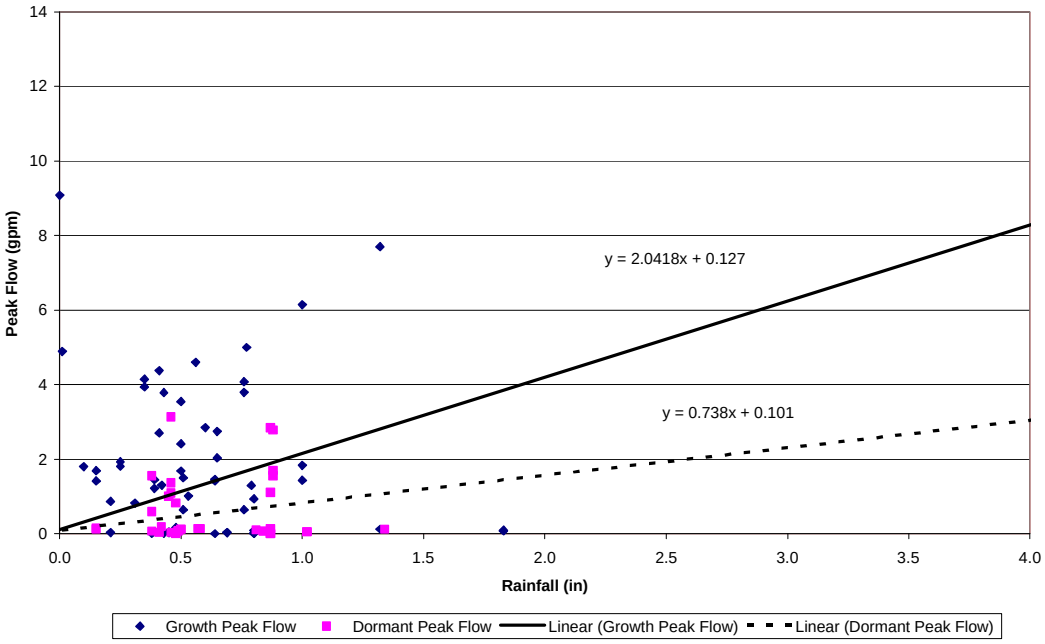
4.4.3 Seasonal Variation

The variation in footing drain response to storm events during the summer or winter is important for this study since the results are being used to support modeling efforts as detailed in the SSO Modeling and Calibration for SSO Case Studies Technical Memorandum. Runoff and storm characteristics are different for growth (summer) and dormant (winter) periods.

A preliminary assessment of the seasonal variation in footing drain response to wet weather was completed. The assessment should be considered preliminary since the majority of the data loggers have not been installed for a full year and, as a result, most of the collected data that has been classified resulted from summer storms. For our analysis, the beginning of April through November is classified as growth, while the remainder of the year is classified as dormant.

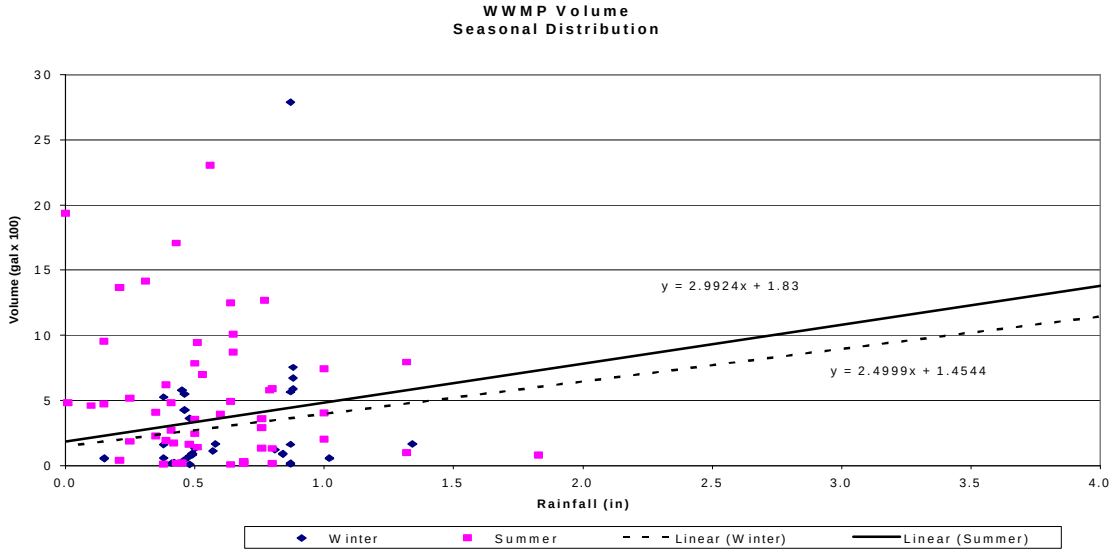
The peak footing drain flow rates that are shown in Figure 16 were categorized as summer or winter events and are included in Figure 23. Two linear trend lines were added to the plot, one for the dormant set and one for the growth set. The projected average flow generated from a growth event is 8.2 gpm while the projected flow from a dormant event is 2.5 gpm.

Figure 23. Seasonal Peak Footing Drain Response to Rainfall



Volume responses were also classified as resulting from either a growth or dormant storm event. The results are shown in Figure 24. The estimated average volume generated from an event during the growth season is 1,400 gallons and the estimated average volume generated during a dormant season event is 1,200 gallons.

Figure 24. Seasonal Footing Drain Volume Response to Rainfall



4.5 Conclusions

This section of the report contained a detailed assessment of the data collected during the footing drain field-monitoring program. Although a large amount of data was collected, there are a large number of factors that impact footing drain flows.

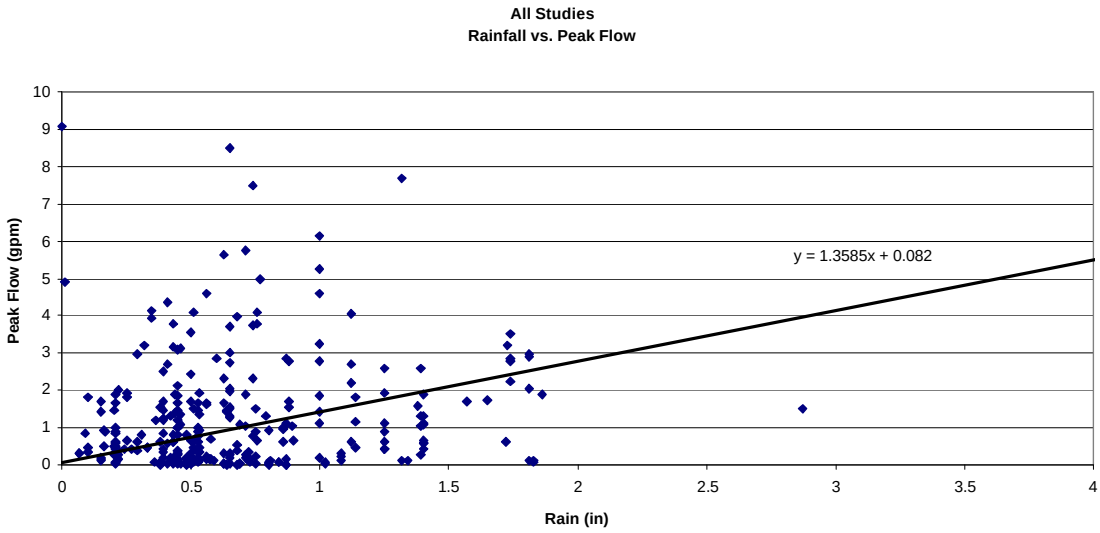
Key findings of the WWMP footing drain flow monitoring field program include:

- Approximately half of the homes monitored during this study are expected to have no, or extremely low, responses to a significant storm event. However, it is not possible to identify which houses are the high producers, as neighboring houses can have very different rates.
- 35% of homes in the study generate more than the projected average footing drain flow of 1,250 gallons expected from a 4" storm event over 24 hours.
- Approximately 40% of the homes are expected to generate peak flows above the average projected peak flow rate of 6.2 gpm.
- The median volume generated is approximately 500 gpd (0.35 gpm) or twice the typical sanitary wastewater volume for a single family home.
- The projected average flow generated from an event during the growth season is 8.2 gpm while the projected flow from an event during the dormant season is 2.5 gpm.
- The median peak flow is projected to be less than 0.5 gallons per minute.
- The estimated average volume generated during a 4" storm in the growth season is 1,400 gallons and the estimated average volume generated during the dormant season is 1,200 gallons.

5. Comparison of all Footing Drain Flow Rate Data

A large amount of information regarding footing drain flows, has been consolidated in this report. The sources of information used include: published study reports; a large data set from an ongoing study being conducted by Ann Arbor; and, the results of the WWMP footing drain field monitoring program. Figure 25 shows the peak footing drain flow rates from these studies on a single graph.

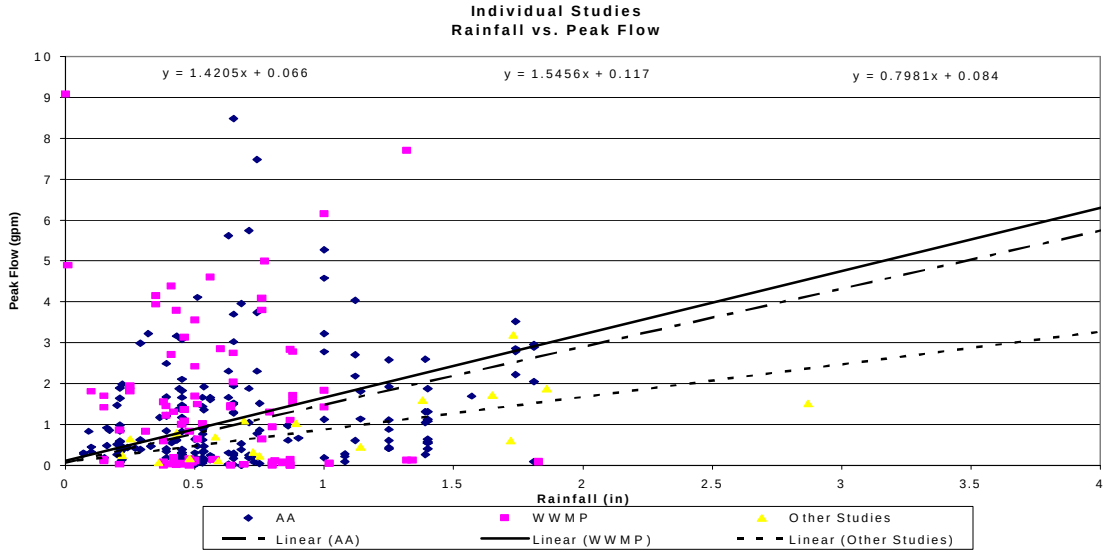
Figure 25. Reported Footing Drain Rainfall Responses



Considering the results from all of the studies, the projected peak footing drain flow rate is approximately 5.5 gpm for a 4" storm event. The results in Table 1 are very similar with consistent findings between the different studies in different areas.

A final comparison was made between the three data sets by plotting them as separate series on the same graph (Figure 26). A separate linear trend line was generated for each of the three sets. The trends for the Ann Arbor data set and the WWMP are in close agreement with projected flow rates for a 4" inch storm of 5.8 gpm and 6.2 gpm, respectively. The projection for the other studies is considerably less, at 3.2 gpm.

Figure 26. Reported Footing Drain Rainfall Responses



6. Conclusions

Key findings from the footing drain studies include:

- Areas with footing drains appear to have peaking factors that are 3-4 times higher than areas without footing drain connections.
- Peak wet weather flows range from 0.8 to 4.9 cfs / 1000 people. This is significantly higher than the typical design criterion of 0.4 cfs / 1000 people.
- Footing drains can account for 60-90% of wet weather flow in connected areas (as long as there are no other significant RDII problems).
- The effective wet weather peak in sewers attributed to footing drains depends on the amount of rainfall and other site-specific parameters. However, during large storms (greater than 3" total rainfall) average footing drain flows can range from 2.5 to 10 gpm per house. Individual houses can contribute significantly higher amounts (up to 25 gpm)

A summary of FD flows for a variety of storm events, ranging from the 1-month, 24-hour to a 100-yr, 24-hour event, are shown in Table 5. The flows listed below were generated using the linear fits, detailed in the proceeding chapter.

Table 5. Summary of Projected FD Flows for Storm Events.

Storm	Rainfall (in)	Footing Drain Flow (gpm)		
		WWMP	Ann Arbor	All Data
1-month, 24 hour	0.62	1.04	0.95	0.92
1-yr, 1-hour	1	1.60	1.49	1.43
10-yr, 1-hour	1.8	2.78	2.62	2.50
1-yr, 24-hour	2.2	3.37	3.19	3.03
10-yr, 24-hour	3.6	5.44	5.18	4.91
25-yr, 24-hour	4	6.03	5.75	5.45
100-yr, 24-hour	4.7	7.06	6.74	6.39