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Date: October 1, 2022

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Reviewed by: Henry Stevens

TOPIC: Marginal Sump Drawdown Performance

Introduction

The City of Portland Bureau of Environmental Services uses perforated sumps throughout the city to dispose of stormwater by infiltrating it into the ground. The standard sump is a 30-feet deep maintenance hole with perforated sides and a three-foot deep solid bottom that serves as a sump for accumulated sediment. Typically, these sumps are designed to dispose of the peak flow rate for the 10-year design storm with a safety factor of two and are installed downstream of a sedimentation maintenance hole which provides water quality pre-treatment. In some locations in the city it is possible to install sump systems that dispose of a significant quantity of stormwater without meeting the specific design standard, these have been colloquially referred to as “marginal sumps.”

This report summarizes drawdown data for two marginal sumps installed downstream of infiltrating surface stormwater facilities within the combined system. From January 2015 to January 2017, HOBO water level data loggers (HOBOs) were deployed in two sumps to measure drawdown rates. The facilities were located at the intersections of SE 9th and Sandy Blvd and SE 57th and Pine. At the time of construction, flow tests conducted indicated that, while significant infiltration occurred, they did not dispose of the minimum flow BES requires for sumps. Construction documentation for the sump at SE 57th and Pine is included in Appendix C. Excepting brief interruptions to download data, the record is complete for the full two years the HOBOs were deployed. Paired with rainfall data from gauges in BES’s HYDRA network, HOBO data provide information on how these two marginal sumps functioned during some of Portland’s most intense rainfall events during the study period.

Methods

HOBOs use pressure transducers to measure water depth. They have a depth resolution of 1 mm with a maximum error of ± 10 mm. For this study, depth readings were taken at 4-minute intervals. Field Operations saved the data in spreadsheet format.

Analysis focused on large individual rain events. Previous experience analyzing HOBO data suggests that summary statistics of the whole record may not be meaningful. Rain events were initially screened by selecting the 10 days with the greatest cumulative rainfall in the data period, as measured at the nearest HYDRA rain gage. Gage 175 at 825 SE 51st Ave is approximately 1900 feet away from the SE 57th and Pine sump. Gage 181 at 501 SE Hawthorne Blvd is approximately 3000 feet from the SE 9th and Sandy sump. The data spreadsheet was then examined to find peak depths on those 10 days, and the drawdown rate examined. These storms and their return periods are included in Appendix B.

1-minute and 5-minute rainfall data from the HYDRA gauges nearest each sump were added to the HOBO data spreadsheet and plotted with the depth recorded by the HOBOs.

Results

The data were analyzed for several different performance measures. The maximum instantaneous drawdown rate provides a snapshot of the peak drawdown rate for a single 4-minute sample interval. Mean drawdown rates present the mean rate for each sump to drain the largest storm events over a relatively large depth range. Data comparing the drawdown rate to the depth confirms that the largest drawdown rates occur when the water-level in the sump is the deepest. Drawdown rates were looked at to observe if there was seasonality in rates but this data is complicated by the seasonal pattern of rainfall. Finally, the storm event that produced the deepest ponding in the sump is presented along with rainfall data and the drawdown rate to provide a visual example of sump performance over a specific event.

Maximum instantaneous drawdown rate

Using the highest rate is roughly analogous to a sump test where steady-state disposal rates are measured. Table 1 reports the highest draw down rate for each sump. These values represent the largest single change in ponded depth between any two successive data points for each sump. As the time resolution of the gauges is set to four minutes, these are four-minute averages rather than technically instantaneous rates.

Table 1. Maximum measured drawdown rates.

Location	Drawdown rate (in/hr)	Date
SE 57th and Pine	180.12 in/hr	October 14, 2016
SE 9th and Sandy	628.94 in/hr	October 31, 2015

The maximum drawdown rates occurred when the sumps were full or nearly so (Figures 7 and 9). This is consistent with maximum hydraulic head occurring when a sump is full. Vertical surface area available for water to leave the sump horizontally is also at a maximum when it is full. While it may seem possible, as discussed below in the section on limitations of HOBO data, these results cannot be translated into a flow rate.

Mean drawdown rates

Drawdown rates were estimated using the time for the ponded depth to fall across a selected range for each sump. The higher depth was chosen for each sump to select a depth that was reached frequently enough to maximize the number of events evaluated while minimizing the limitations of HOBO sample resolution by calculating the draw down rate over a relatively large range.

The SE 57th and Pine HOBO record was examined for events that ponded deeper than 12 feet. For those events, a drawdown rate was calculated by determining the time for the ponded depth to fall from 12 feet to 3 feet (Figure 1). The NE 9th and Sandy sump did not pond as frequently or as deeply as the SE 57th and Pine sump. Drawdown rates were calculated for the interval from 10 to 3 feet for the NE 9th and Sandy sump (Figure 2).

This analysis did not consider precipitation and no attempt was made to determine when inflow to the sump ended. The sumps' locations downstream of vegetated infiltrating stormwater facilities made it difficult to estimate when inflow to the sumps ended, even with rain gauges relatively nearby. This uncertainty is reflected in the large standard deviation of drawdown rates in both sumps (Table 2). Because the estimated rates include periods when inflow was ongoing, the drawdown rate without inflow is likely to be toward the higher end of the summary values.

Table 2. Summary of drawdown rates across selected ranges.

Location		SE 57th and Pine	SE 9th and Sandy
Range measured		12 ft – 3 ft	10 ft – 3 ft
Number of events		13	6
Drawdown rate (in/hr)	Min	3.4	16.4
	Mean	12.3	38.6
	Max	22.5	69.2
	StdDev	6.7	22.6

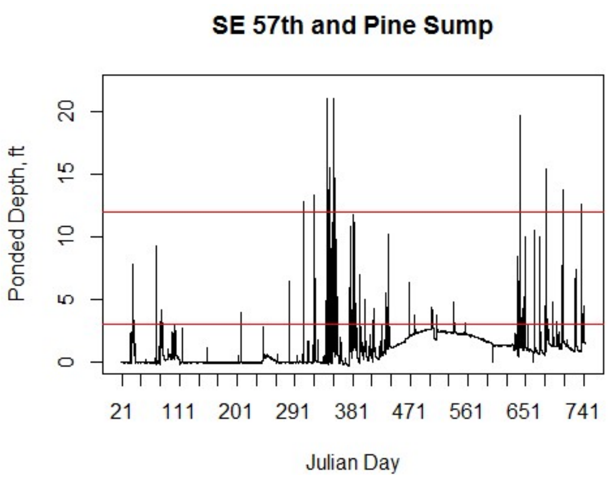

Figure 1. Ponded depth vs. Julian day (1/1/2015 = JDAY 1). Red lines show range used to summarize drawdown.

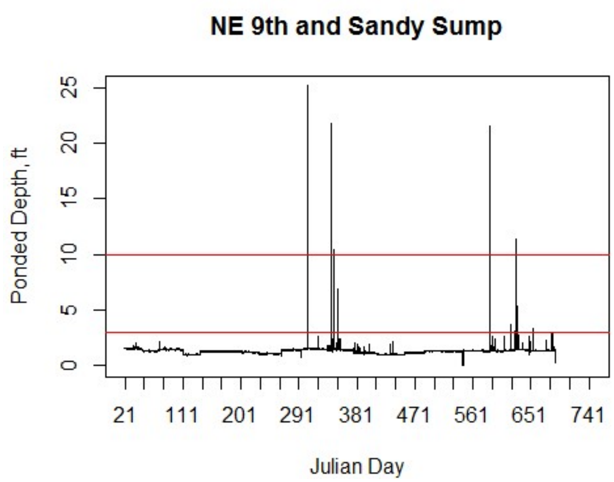

Figure 2. Ponded depth vs. Julian day (1/1/2015 = JDAY 1). Red lines show range used to summarize drawdown.

Drawdown rate variability with depth

To determine if there is a relationship between ponded depth in a sump and drawdown rate, an ordinary least squares linear regression was fit to each dataset with ponded depth as the predictor and drawdown rate as the response (Figures 3 and 4). If no water is ponded there can be no drawdown, so the regression intercept was set to zero. As in the estimation of mean rates above, this coarse analysis does not control for the impact of inflow to the sumps. For this reason, the influence of depth on drawdown rate may be underestimated.

The extremely low p values for both regressions indicate a high degree of confidence that a relationship between depth and drawdown rate exists (Table 3). Given the limitations regarding inflow mentioned above, the regression p values are more meaningful than the slope estimates.

Table 3. Ordinary least squares regressions fit to sump HOBO data. drawdown = depth x slope + ε.

Sump	Slope estimate	r^2	p value
SE 57th and Pine	2.43 in/hr/ft	0.55	<2e-16
SE 9th and Sandy	4.35 in/hr/ft	0.28	<2e-16

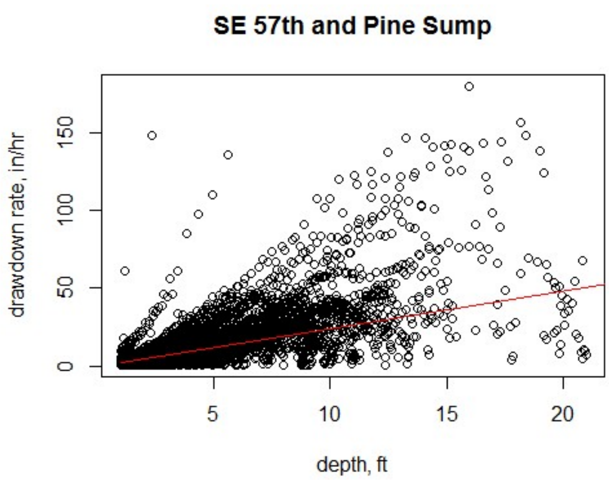

Figure 3. Drawdown rate vs. ponded depth with ordinary least squares linear regression.

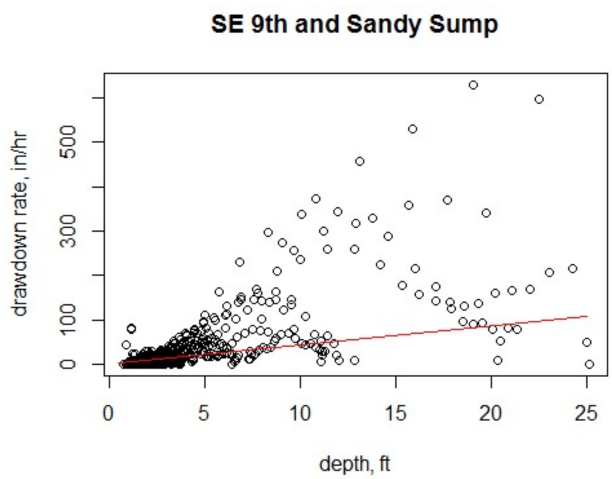

Figure 4. Drawdown rate vs. ponded depth with ordinary least squares linear regression.

Seasonal variation of drawdown rates

Figures 5 and 6 show drawdown rates plotted against the day of the year. Seasonal changes in drawdown rate are difficult to quantify. Again, it was not possible to control for inflow to the sumps. The deepest ponding events, which are expected to coincide with the highest drawdown rates, occurred exclusively in fall and winter seasons, further complicating seasonal comparisons.

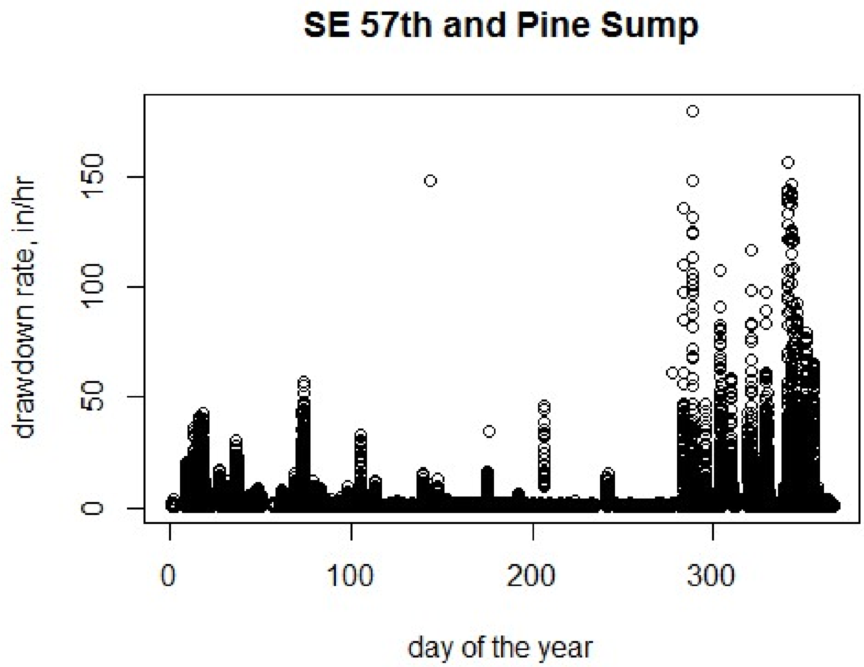

Figure 5. Drawdown rate vs. day of the year. Day 1 is January 1, day 365 is December 31.

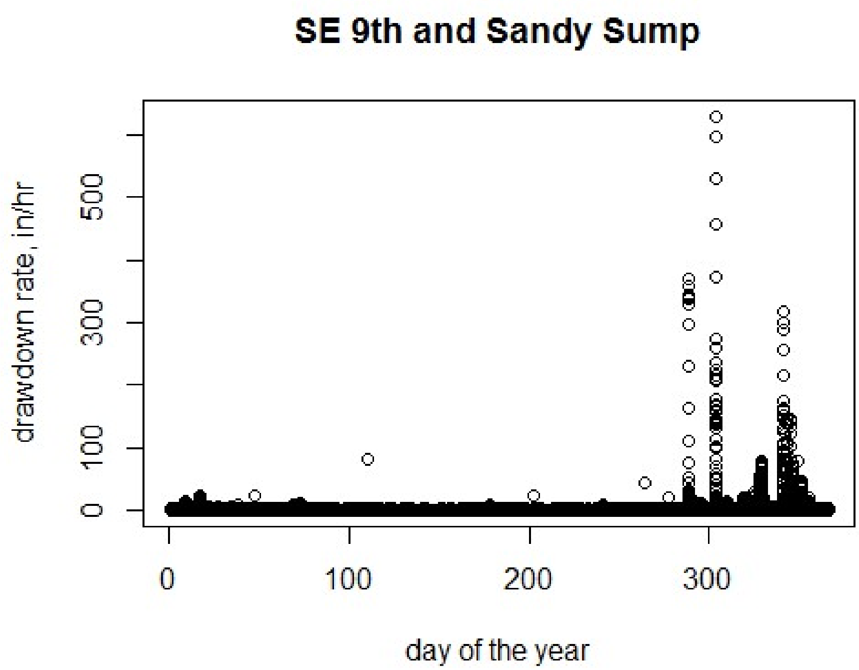

Figure 6. Drawdown rate vs. day of the year. Day 1 is January 1, day 365 is December 31.

Extremes

Figures showing the highest water level for each of the two sumps found in the record are presented here. The data are presented in two figures for each location: sensor depth with drawdown rate (the first derivative of sensor depth) (Figures 7 and 9), and sensor depth with 5-minute rainfall at the nearest HYDRA gauge (Figures 8 and 10).

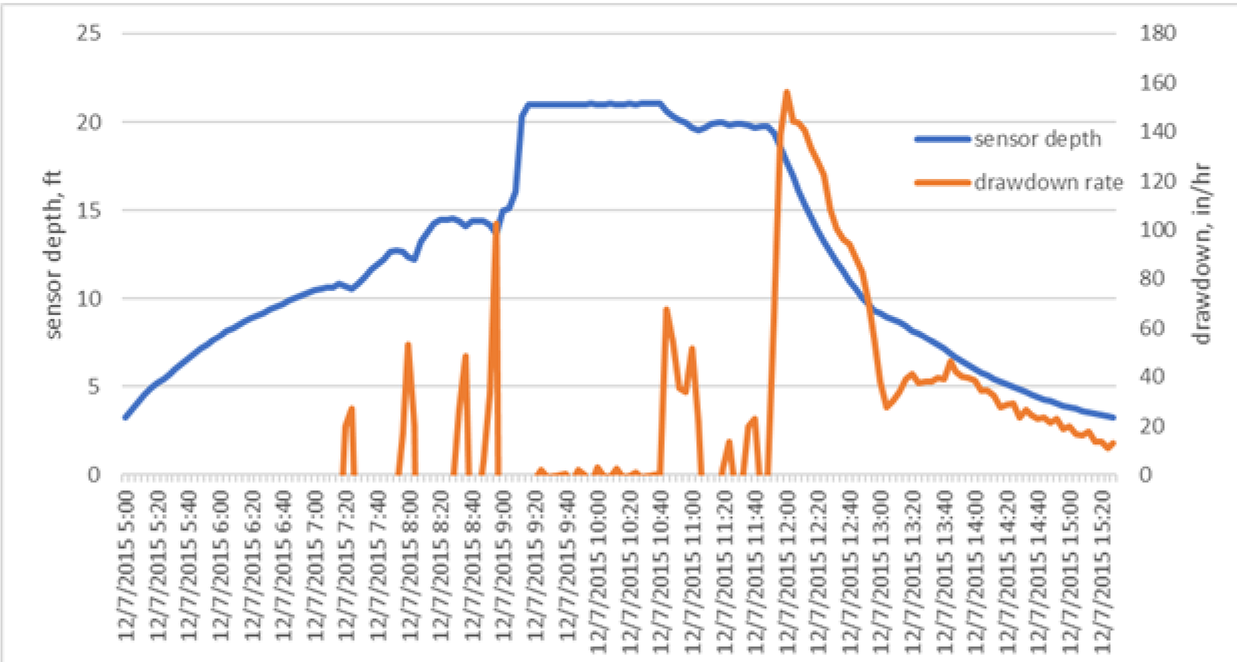

Figure 7. Sensor depth and drawdown rate in SE 57th and Pine sump on December 7, 2015.

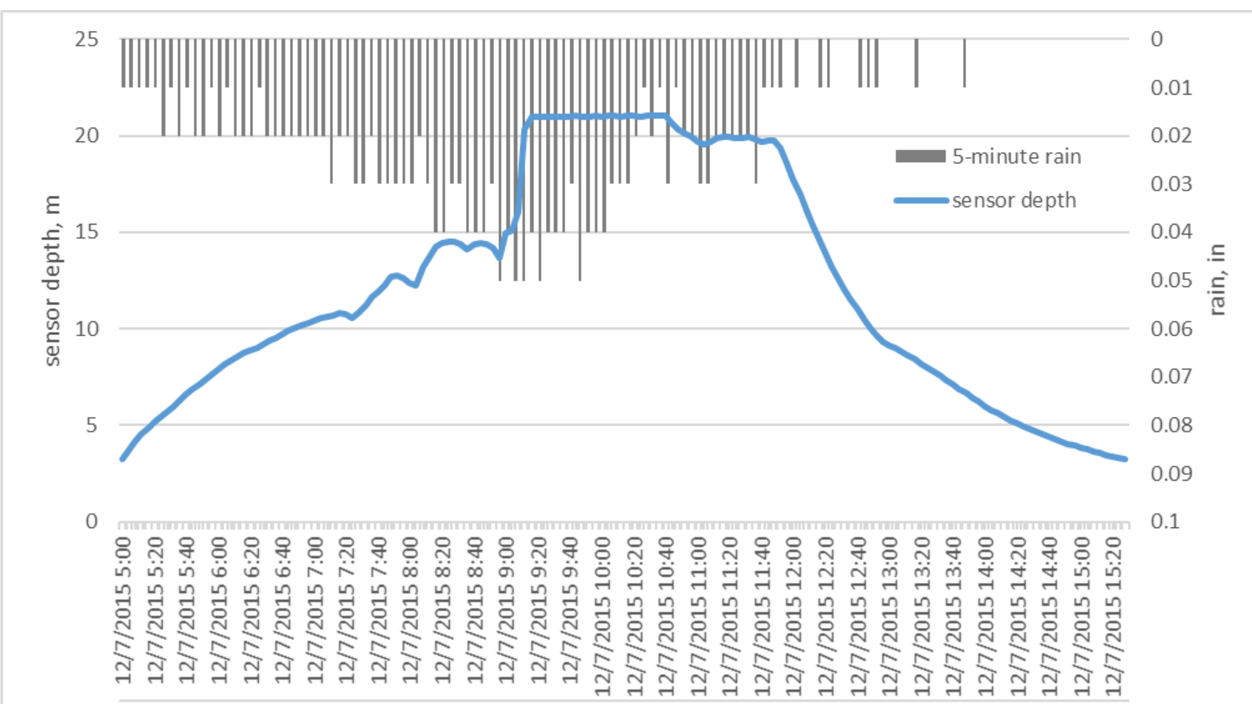

Figure 10. Sensor depth in SE 57th and Pine sump with Glencoe School HYDRA 5-minute hyetograph.

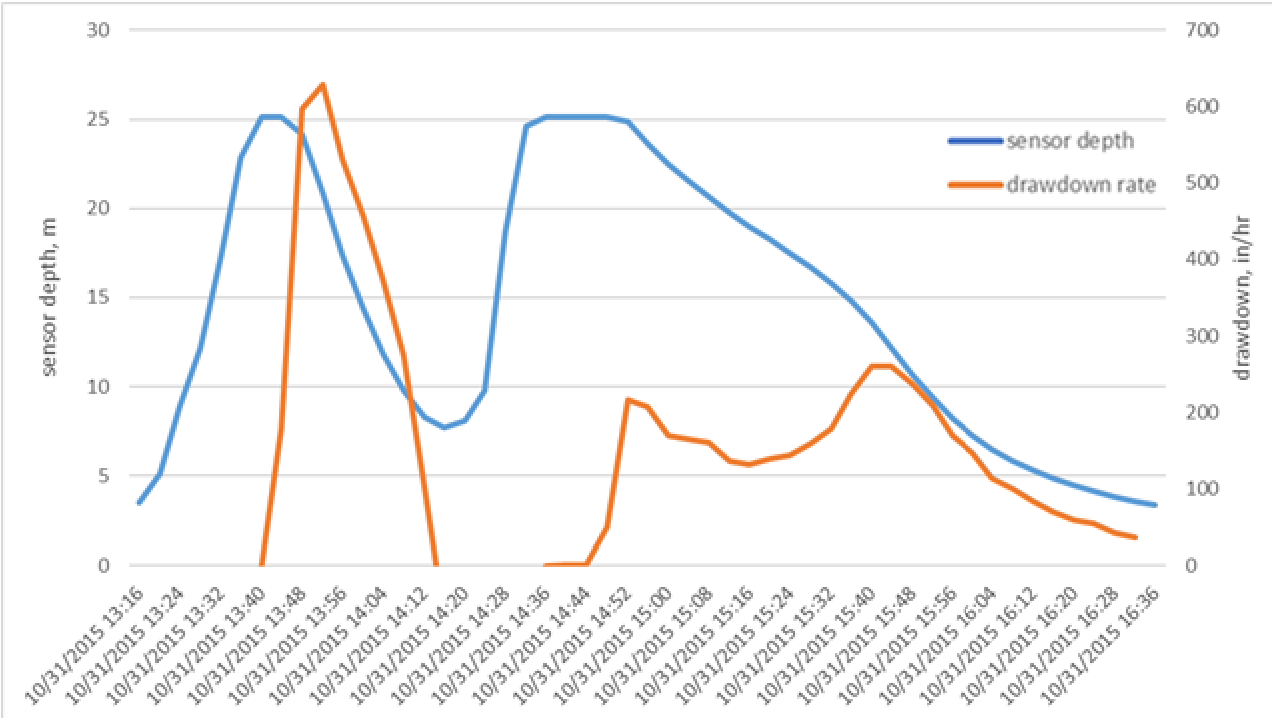

Figure 9. Sensor depth and drawdown rate in SE 9th and Sandy sump during October 31, 2015 rain event.

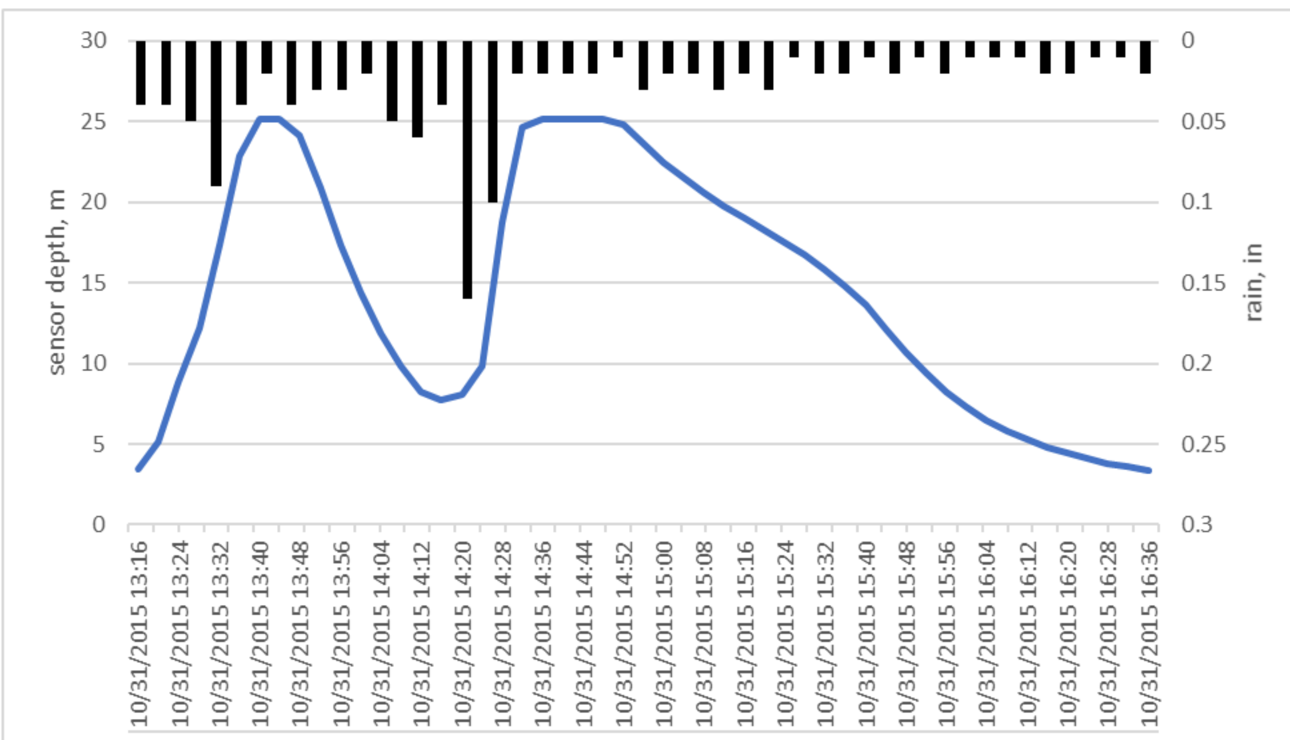

Figure 10. Sensor depth in SE 9th and Sandy sump with Multnomah HYDRA gage 5-minute hyetograph.

Time to empty
Following the rain events that caused the deepest ponding in each sump, the depth fell to three feet—indicating that capacity is restored—in well under 12 hours.

Conclusion

For each sump during the study period, the data indicates that the maximum capacity was reached for one storm in each location. This is indicated by a plateau in the maximum depth reading. Overall, this suggests that the stormwater systems in these locations including the sumps, disposed of the stormwater flowing into them without overflow back into the combined system in all but one rain event during the two-year monitoring period. Future monitoring would be needed to measure long-term performance or to confirm performance during other larger storm events.

Use of HOBO level loggers to measure performance was adequate to address basic questions such as how often the system is reaching capacity. However, the data cannot be used to calculate a disposal flowrate. In these two installations, it is not possible to back-calculate or estimate flowrates from rainfall because each sump was preceded by an infiltration basin whose performance for each event was also unknown.

Appendix

Appendix A: Note on limitations of HOBO data

Stormwater sumps are cylindrical with known diameter and depth making the internal volume of a sump easy to calculate. It would seem to follow, then, that the flowrate out of the sump could be calculated using the cross-sectional area and drawdown rate. While strictly true, this is, unfortunately, not a particularly useful number. The sump is hydraulically connected to the surrounding soil through perforations in the vertical walls, so a decrease in water level could easily represent outflow from the system an order of magnitude (or more) larger than the change in volume inside the sump. Figure 11 attempts to demonstrate this by showing the location of a hypothetical water table and "cone of impression." Figure 12 in the appendix may also help clarify this phenomenon. A cone of impression is analogous to the cone of depression found in the water table around wells when water is withdrawn. Instead of a depression or local decrease in the elevation of the water table, injecting water into a well—or in this case, a sump—creates an impression or local increase in the local water table elevation. Any change in water level in the sump would be coupled to a change in water level in the surrounding soil.

For this reason, a change in water volume within the sump is coupled to a greater change in volume of the system. If the shape of the water lens around the sump were known, the flowrate could be determined. That shape is not known, and determining it would be impractical.

Calculating runoff flowrates based on catchment area and rainfall data is an alternative for estimating disposal. However, the sumps investigated here are located downstream of infiltrating stormwater facilities, reducing the utility of such an estimate. The rate that water enters the sump could be measured directly and compared to the drawdown rate to determine the rate that water leaves the sump. This is similar to the sump tests conducted when sumps are built. Measuring flow into the sumps is resource intensive, however, and was not done for this study.

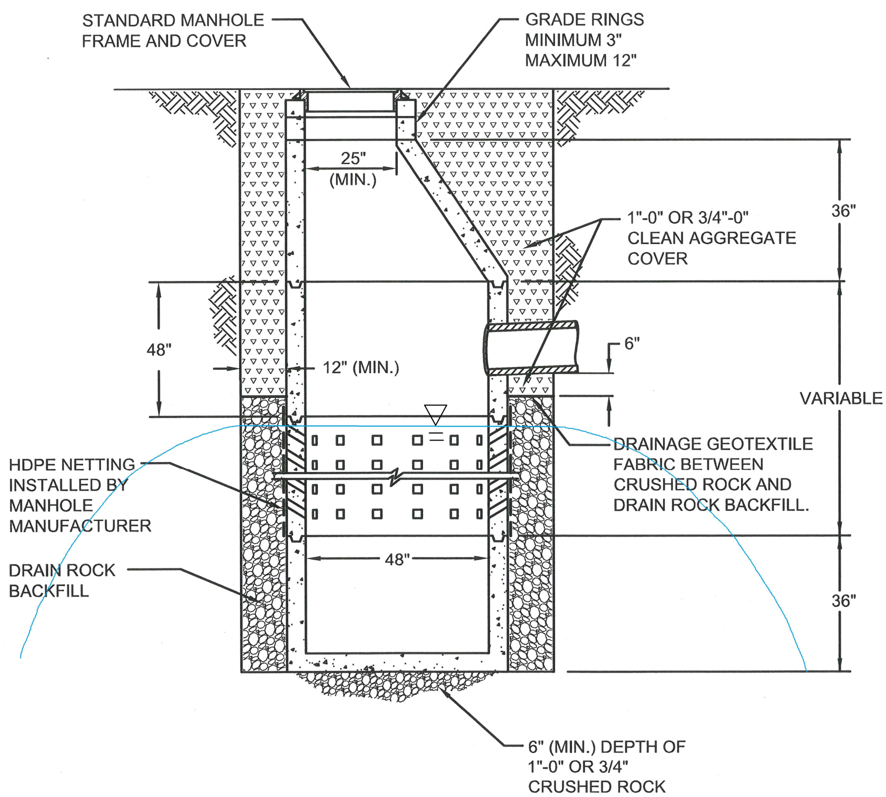

Figure 11. Water table surrounding a sump; or why HOBO data isn't adequate to calculate outflow.

The flow towards a well, situated in homogeneous and isotropic confined or unconfined aquifer is radially symmetric. Fig. 8(a) shows the cone of depression caused due to constant pumping through a single well situated at (0,0) in a confined aquifer. Fig. 8(b) shows the cone of impression caused due to constant recharge through the well.

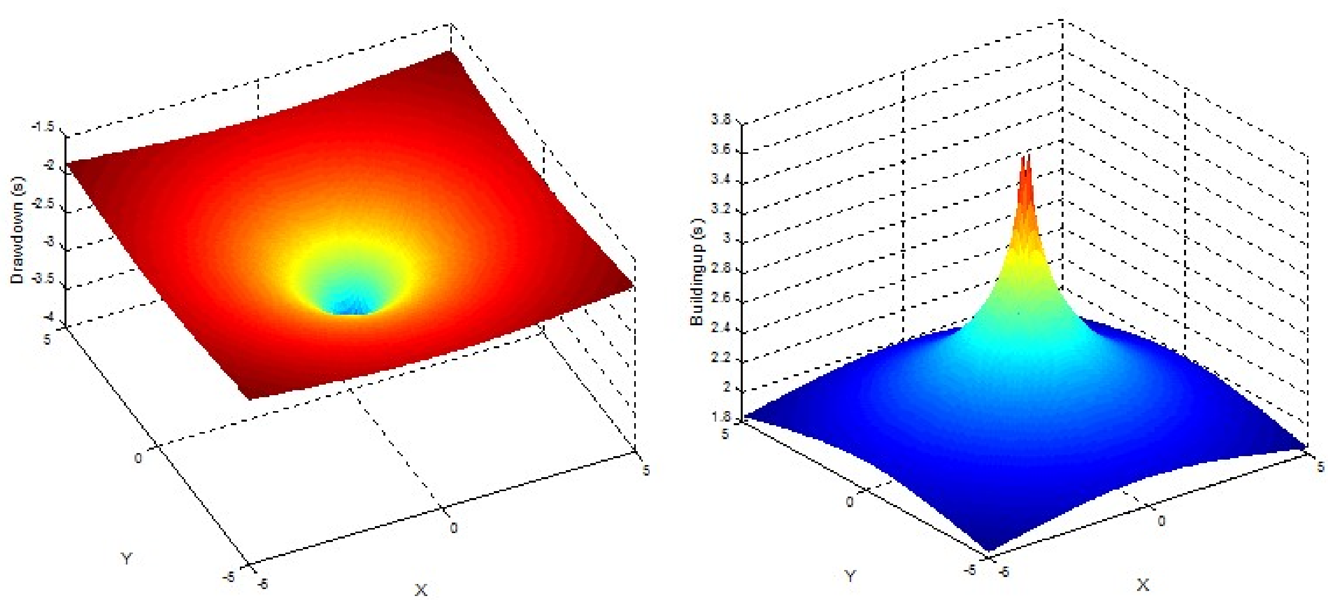

Figure 12. (a) Cone of depression (b) Cone of impression. From NPTEL.

Appendix B: Return periods for selected storms

Return Period	Oct 31 2015		Dec 7 2015		Oct 14 2016	
	SE 57th	*SE 9th*	*SE 57th*	*SE 9th*	*SE 57th*	*SE 9th*
5-min	7-yr	2-yr	-	-	7-yr	-
1-hr	18-yr	10-yr	3-yr	4-yr	>100-yr	4-yr
6-hr	7-yr	10-yr	9-yr	11-yr	4-yr	-
24-hr	2-yr	2-yr	6-yr	8-yr	-	-

Appendix C: Project Records for sump at SE 57th and Pine

BUREAU OF ENVIRONMENTAL SERVICES
TECHNICAL M E M O R A N D U M

Materials Testing & Geotechnical Services
1405 N. River St., Portland, OR 97227
Ph: (503) 823-2340 Fax: (503) 823-2342

DATE: 12/22/04

TO: Henry Stevens

FROM: Viola Lai 117/MTL

SUBJECT: Mount Tabor Middle School Sump Installation Field Observations

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I was onsite to visually observe the soil and groundwater conditions, today, while the City of Portland Bureau of Maintenance used a clamshell bucket to excavate the hole for installation of the sump in the street about 50 feet north of SE 57th Ave and SE Pine Street. The soil encountered consisted of about a 6" pavement section underlain by about 1 to 1.5 feet of base course material consisting of crushed gravel, sand, and coarse rounded gravel up to 3" diameter. Medium stiff to stiff sandy silt was encountered to about 9 feet. From 9 feet to 30 feet below ground surface, the soil consisted of medium dense poorly graded sand with trace silt, which caved only slightly during the entire excavation. Digging deeper than 30 feet below ground surface would probably not yield any more valuable information. No seepage was observed during excavation. Knowing the soil type unfortunately will not yield much information on ultimate sump performance, since many factors affect the ability of the formation as a whole to infiltrate water.

SUMP CAPACITY TEST

PROJECT NAME: Mt Tabor Basement Flooding Relief Project
TESTED BY: Terry Tice
TEST SUMP LOCATION: SE 57th Ave & Pine
TEST SUMP DEPTH: (before test) 29'3" (after test) 29'3"

PROJECT NUMBER: 7701
DATE: 12-23-04

METER READINGS:

	START	FINISH	WATER USE
A	452116	452346	23000 gal
B			

MAX STABLE FLOW RATE: 300 gpm
MAX STABLE FLOW RATE DICTATED BY:
max sump capacity X
max hydrant capacity ______
required flow rate unknown

TIME	ELAPSED TIME @ STABLE FLOW	METER A	METER B	TOTAL	DEPTH TO WATER SURFACE
9:00		500			—
9:05		↓			19'8"
9:10					15'8"
9:15					10'9"
9:20		↓			7'3"
9:29		400			1'3"
9:34		↓			9"
9:43		300			3'4"
9:48		↓			3'1"

TIME	ELAPSED TIME @ STABLE FLOW	METER A	METER B	TOTAL	DEPTH TO WATER SURFACE
Drawdown					
minutes					
1					4'3"
2					4'9"
3					5'2"
4					5'6"
5					5'11"
6					6'2"
7					6'6"
8					6'10"
9					7'1"
10					

Copy to: BES – Henry Stevens
cc: Viola Lai
2-27

Stevens, Henry

To: Henry, Don
Subject: Sump Performance Test (SE 57th and Pine)

Don: HE PUT 10,000 gallons in OVER 20 MINS.

The test resulted in ~~a constant~~ head infiltration rate of about 300 gpm. It took 20 minutes for Terry Tice (MTL) to fill it to the cone at a rate of 500 gpm. He than backed the rate down to roughly 300 gpm for the remainder of the test. He put a total of 23,000 gallons into it during the 50 minute test.

Henry

For a 10,000 ft^2 catchment the manual requires a rate of 530 gpm (2 x peak of 10 yr. storm).

SUMP INTERNAL VOLUME

$(\pi)(2^2)(12\ ft) = 150\ ft^3$

1st 15 MINUTES OF 25 YR STORM:

$(.48)\left(\frac{1''}{12''}\right)(10{,}000\ sf) = 400\ ft^3$

$(400\ ft^3)\left(\frac{7.48\ gal}{ft^3}\right) = 2992$ gallons