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Lincoln, Nebraska, Standard Land Use Characteristics and Pollutant Sources

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Standard Land Use Development Characteristics

The Lincoln, NE, project team conducted detailed site surveys for representative land uses within the lower Antelope Creek drainage area. From five to ten homogeneous neighborhoods were surveyed in low density residential, medium density residential <1960, 1960-80, >1980, light industry, strip malls, shopping centers, schools; churches, and hospitals and use areas. The site survey information was organized and presented in both Appendix A and in associated WinSLAMM *.dat files. Table 1 summarizes the breakdown of these categories into directly connected impervious areas (DCIA), partially connected impervious areas, and pervious areas, plus shows the percentage of the roofs that are directly connected to the drainage system for each of these nine areas.

Table 1. Summary of Major Land Use Characteristics in Lincoln, NE (average and COV)

Land Use Category	Percent of roofs that are directly connected	Total directly connected impervious areas (DCIA)	Total partially connected impervious areas	Total pervious areas
Low density res	12	18	16	66
Med density res <1960	16	22	20	58
Med density res 1960 - 1980	24	18	19	63
Light industry	55	58	27	15
Commercial - strip mall	100	86	0	14
Commercial - shopping center	100	88	0	12
Institutional - school	100	56	0.5	44
Institutional - church	37	44	10	46
Institutional - hospital	80	62	5.4	33

The directly connected impervious percentages are most closely related to the runoff quantities. The partially connected impervious areas contribute runoff at later portions of larger rains, while the pervious areas may only contribute flows after substantial rain has occurred. These nine averaged areas were statistically analyzed and evaluated using WinSLAMM, the Source Loading and Management Model, briefly described below.

WinSLAMM Background Information

WinSLAMM version 9.5 was used to analyze the water quality (stormwater pollution loading) and runoff volume for the land used found in the Antelope Creek study area. WinSLAMM was developed to evaluate stormwater runoff volume and pollutant loadings in urban areas using small storm hydrology. The model determines the runoff based on local rain records and calculates runoff volumes and pollutant loadings from each individual source area within each land use category for each rain. Examples of source areas include: roofs, streets, small landscaped areas, large landscaped areas, sidewalks, and parking lots.

The model can use any length of rainfall record as determined by the user, from single rainfall events to several decades of rains. The rainfall file used in these calculations were developed from hourly data from the EarthInfo CDROMs, using the four years from 1996 through 1999. The model can apply a series of stormwater control practices, such as infiltration/biofiltration (as used in rain gardens and green roofs), water tanks for stormwater beneficial use, street cleaning, wet detention ponds, grass swales, porous pavement, catchbasins, or various proprietary settling devices. The model will evaluate the practices and determine how effectively these practices remove runoff volume and pollutants. Since its beginnings in the 1970’s, the program’s use has extended across North America and overseas.

WinSLAMM is based largely upon research and studies conducted in the United States and Canada (mostly funded by the US EPA and Environment Canada, plus various state and local agencies and industries), and by studies conducted through the Wisconsin Department of Natural Resources (WDNR) and the United States Geological Survey (USGS). WinSLAMM is licensed by PV & Associates.

WinSLAMM does not use a percent imperviousness or a curve number to general runoff volume or pollutant loadings. The model applies runoff coefficients to each “source area” within a land use category. Each source area has a different runoff coefficient equation based on factors such as: slope, type and condition of surface, soil properties, etc., and calculates the runoff expected for each rain. The runoff coefficients were developed using monitoring data from typical examples of each site type under a broad range of conditions. The runoff coefficients are continuously updated as new research data becomes available.

Each source area also has a unique pollutant concentration (event mean concentrations - EMCs - and a probability distribution) assigned to it. The EMCs for a specific source area vary depending on the rain depth. The source area’s EMCs are based on extensive monitoring conducted in North America by the USGS, Wisconsin DNR, University of Alabama, and other groups. These monitoring efforts isolated source areas (roofs, lawns, streets, etc.) for different land uses and examined long term data on the runoff quality. The pollutant concentrations are also continuously updated as new research data become available.

For each rainfall in a data set, WinSLAMM calculates the runoff volume and pollutant load (EMC x runoff volume) for each source area. The model then sums the loads from the source areas to generate a land use or drainage basin subtotal load. The model continues this process for the entire rain series described in the rain file. It is important to note that WinSLAMM does not apply a “unit load” to a land use. Each rainfall produces a unique load from a modeled area based on the specific source areas in that modeled area.

The model also is used to predict stormwater management practice effectiveness (to be examined during the next project activities). The model replicates the physical processes occurring within the practice. For example, for a wet detention pond, the model incorporates the following factors for each rain event:

1. Runoff hydrograph, pollution load, and sediment particle size distribution from the drainage basin to the pond,
2. Pond geometry (depth, area),
3. Hydraulics of the outlet structure,
4. Particle settling time and velocity within the pond based on retention time

Stokes Law and Newton’s settling equations are used in conjunction with conventional surface overflow rate calculations and modified Puls-storage indication hydraulic routing methods to determine the sediment amounts and characteristics that are trapped in the pond. Again, it is important to note that the model does not apply “default” percent efficiency values to a practice. Each rainfall is analyzed and the pollutant control effectiveness will vary based on each rainfall and the pond’s antecedent condition.

The model’s output includes:

1. Runoff volume, pollutant loadings and EMCs for a period of record and/or for each event.
2. The above data pre- and post- for each stormwater management practice.
3. Removal by particle size from stormwater management practices applying particle settling.
4. Other results can be selected related to flow-duration relationships for the study area, impervious cover model expected biological receiving water conditions, and life-cycle costs of the controls.

A full explanation of the model's capabilities, calibration, functions, and applications can be found at www.winslamm.com. For this project, the parameter files were calibrated using the local Lincoln MS4 monitoring data, supplemented by additional information from regional data from the National Stormwater Quality Database (NSQD), available at:
http://www.unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

Observed Stormwater Quality in Lincoln, Nebraska

Local Lincoln, NE, NPDES MS4 monitoring data are available from the master's thesis prepared by M.K. Vegi at the University of Nebraska, February 2008 (*Estimation of Stormwater Pollutant Loads from the City of Lincoln, Nebraska*). Twenty-seven runoff events were monitored at three study areas representing residential, commercial, and industrial areas. These were monitored from April to the end of August, 2008. Table 2 (from the thesis) describes the monitored locations.

Table 2. Wet Weather Monitoring Locations (Higgins, 2007).

Monitoring Point Designation	**Site# 2**	**Site# 5**	**Site# 3**
Name Designation	Tipperary	N Street Storm Drain	W.Commerce Way
Predominant Land Use	Residential	Commercial	Industrial
Location Description	400 ft west of 27th St. & Tipperary Trail	1st & N Sts.	400 ft west of NW 15th & W. Commerce Sts.
Latitude	40° 45' 56.4"	40° 48' 13.9"	40° 50' 52.1"
Longitude	96° 41' 2.27"	96° 43' 13.9"	96° 44' 30.6"
Receiving Stream	Beal Slough	Salt Creek	Oak Creek
Watershed Area	126.6 acres (51 ha)	358.0 acres (145 ha)	48.5 acres (20 ha)
Percent Imperviousness	38 %	85%	72%

Tables 3 through 5 show the monitored concentrations for these events in Lincoln, along with the average concentrations for each land use as calculated using the locally calibrated WinSLAMM model for Lincoln.

Table 3. Lincoln, NE, Residential Area Monitoring Data (Site #2, 27th and Tipperary Trail)

	Rain depth (in)	Average rain intensity (in/hr)	E. coli (#/100 mL)	TSS (mg/L)	TP (mg/L as P)	TKN mg/L as N	Cu (µg/L)	Zn (µg/L)
4/6/2006	0.50	0.17	123,900	135	0.18	3.4	110	50
7/21/2006	0.94	0.13	16,705	38	0.33	1.6	110	800
8/17/2006	0.43	0.07	127,000	15	0.30	1.1	140	50
9/21/2006	0.42	0.04	6,140	43	0.33	1.3	60	<50
4/24/2007	2.08	0.16	3,880	178	0.18	1.2	150	130
7/19/2007	0.92	0.23	128,000	49	0.48		150	130
7/29/2007	0.31	0.06	24,200	41	0.13		200	100
8/8/2007	1.70	0.34	41,000	36	0.27		30	40
8/20/2007	0.63	0.16	242,000	107	0.37	1.3	40	120
Average	0.88	0.15	79,203	71	0.29	1.65	110	178
Standard deviation	0.62	0.09	81,062	55	0.11	0.87	57	254
COV	0.7	0.6	1.0	0.8	0.4	0.5	0.5	1.4
Minimum	0.31	0.04	3,880	15	0.13	1.1	30	40
Maximum	2.08	0.34	242,000	178	0.48	3.4	200	800
Count	9	9	9	9	9	6	9	8
WinSLAMM Average Residential Area Concentrations			78,000	86	0.31	1.67	110	180

Table 4. Lincoln, NE, NPDES Industrial Monitoring Data (Site #3, 15th and W. Commerce)

	Rain depth (in)	Average rain intensity (in/hr)	E. coli (#/100 mL)	TSS (mg/L)	TP (mg/L as P)	TKN (mg/L as N)	Cu (µg/L)	Zn (µg/L)
3/30/2006	0.99	0.17	185	590	0.45	1.4	240	600
7/21/2006	0.97	0.14	52,500	61	0.13	1.2	120	120
8/17/2006	0.63	0.08	1,730	22	0.16	1.5	120	120
9/21/2006	1.43	0.11	3,450	41	0.20	1.1	100	100
4/24/2007	2.60	0.17	880	267	0.42	0.7	160	270
7/29/2007	0.33	0.08	173,000	45	0.02		120	120
8/8/2007	0.97	0.14	2,190	78	0.26		<30	120
8/20/2007	0.24	0.12	700	180	0.36	1.1	60	170
9/10/2007	0.23	0.03	3,200	23	0.11		80	260
Average	0.93	0.11	26,426	145	0.23	1.17	125	209
Standard deviation	0.75	0.04	57,479	186	0.15	0.28	55	160
COV	0.8	0.4	2.2	1.3	0.6	0.2	0.4	0.8
Minimum	0.23	0.03	185	22	0.02	0.7	60	100
Maximum	2.6	0.17	173,000	590	0.45	1.5	240	600
Count	9	9	9	9	9	6	8	9
WinSLAMM Average Industrial Area Concentrations			30,000	91	0.19	1.20	110	150

Table 5. Lincoln, NE, NPDES Commercial Data (Site #5, 1st St. and N. St)

	Rain depth (in)	Average rain intensity (in/hr)	E. coli (#/100 mL)	TSS (mg/L)	TP (mg/L as P)	TKN (mg/L as N)	Cu (µg/L)	Zn (µg/L)
3/30/2006	1.01	0.17	4,495	1,056	1.50	1.6	380	1400
7/21/2006	0.95	0.12	1,160	772	0.72	4.7	520	1000
8/17/2006	0.50	0.07	46,200	88	0.39	2.0	120	190
9/21/2006	0.56	0.04	43,600	113	0.36	0.4	90	70
4/24/2007	2.50	0.18	19,900	675	0.46	1.0	265	660
7/19/2007	0.79	0.20	44,000	347	0.46		265	660
7/29/2007	0.36	0.06	32,600	114	0.36		990	1140
8/8/2007	1.07	0.13	6,375	151	0.36		60	270
8/20/2007	0.73	0.37	8,445	362	0.33	1.3	80	330
Average	0.94	0.15	22,975	409	0.55	1.8	308	636
Standard deviation	0.63	0.10	18,752	348	0.38	1.5	299	463
COV	0.7	0.7	0.8	0.9	0.7	0.8	1.0	0.7
Minimum	0.36	0.04	1,160	88	0.33	0.4	60	70
Maximum	2.50	0.37	46,200	1,056	1.50	4.7	990	1400
Count	9	9	9	9	9	6	9	9
WinSLAMM Average Commercial Area Concentrations			23,000	410	0.51	1.8	310	640

The National Stormwater Quality Database Compared to Lincoln, Nebraska MS4 Data

The characteristics of stormwater discharges vary considerably. Geographical area and land use have been identified as important factors affecting base flow and stormwater runoff quality, for example. Many studies have investigated stormwater quality, with the EPA's Nationwide Urban Runoff Program (NURP) being the best known and earliest effort to collect and summarize these data. Unfortunately, NURP was limited in that it did not represent all areas of the US or all important land uses. More recently, the National Stormwater Quality Database (NSQD) compiled runoff characteristics information from more than 8,000 events from throughout the US. Most of these data were from the EPA's NPDES stormwater permit program for Phase 1 communities. These permits are needed for all large municipal areas having >250,000 in population. The Phase II permit program requires permits from small communities.

As a condition for these permits, municipalities were required to establish a monitoring program to characterize their local stormwater quality for their most important land uses discharging to the municipal separate storm sewer system (MS4). Although only a few samples from a few locations are required each year from these communities, the ten plus years of MS4 data included in the NSQD comprise a suitable number of samples from many locations. Recently, version 3 of the NSQD was completed, and besides expanding to include additional stormwater NPDES MS4 permit holders, most of the older NURP data, and some of the International BMP database information was also added, along with data from some USGS research projects. A number of land uses are represented in these data, with most data from residential, commercial, and industrial areas, and less data from freeways, institutional and open space areas. These observations were all obtained at outfall locations and do not include snowmelt or construction erosion sources. This version contains the results from about one fourth of the total number of communities that participated in the Phase I NPDES stormwater permit monitoring activities. The database is located at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml.

Figure 1 is a map showing the EPA Rain Zones in the US (not to be confused with EPA administrative regions), along with the locations of the communities containing data in the NSQD, ver 3. Recent revisions to the database have included additional quality control evaluations. In the near future, additional supplemental data from under-represented regions (especially southern California, plus some additional information from recent stormwater research projects) will also be added to the database.

Appendix B summarize the data observations for selected stormwater characteristics (volumetric runoff coefficient, TSS, TDS, COD, TKN, NO_3+NO_2, TP, dissolved P, Cu, Pb, Zn, and fecal coliforms, plus for limited data for E. coli bacteria). These data are separated by the six land uses represented and geographical areas (shown by EPA Rain Zones). Rain Zones 8 and 9 have very few samples, and institutional and open space areas are poorly represented. However, residential, commercial, industrial, and freeway data are plentiful, except for the few EPA Rain Zones noted above. Lincoln, NE, is close to the arbitrary dividing line between Rain Zones 1 and 9, and is also close to Rain Zone 4. The yellow high-lighted cells indicate rain zone-land use combinations having at least 40 events represented, a value expected to result in more reliable concentration estimates than for conditions having very few data observations.

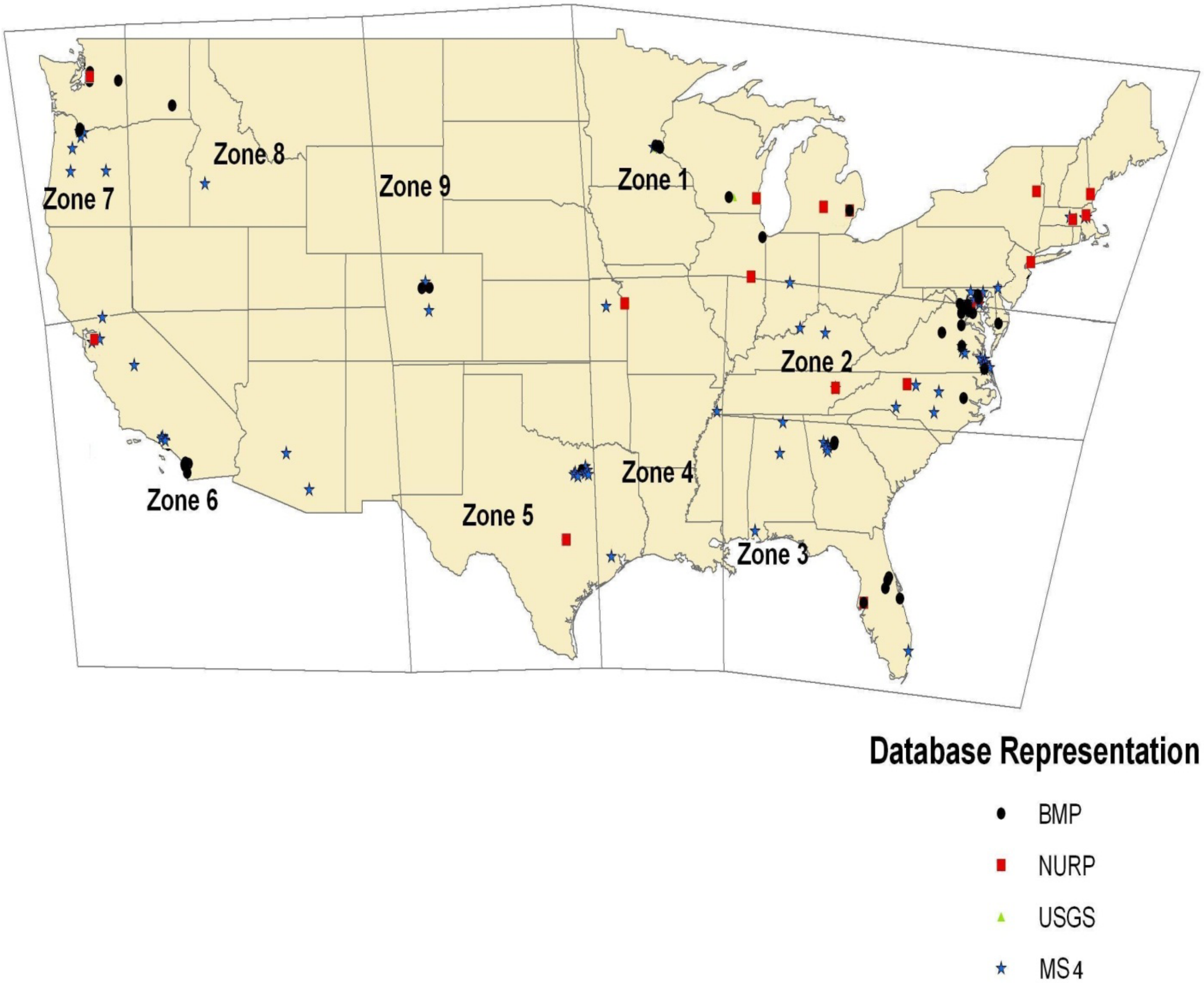


Figure 1. Sampling Locations for Data Contained in the National Stormwater Quality Database, version 3.1.

The values on the tables in Appendix B are the averages, the coefficient of variation, and the number of observations for the observed data (above the detection limits). Besides each land use and rain zone combination, overall land use and overall rain zone values are also shown, along with the overall database values. The average values are shown instead of the median, as the averages better represent long-term mass discharges. Median values artificially reduce the effects of the periodic unusually high concentrations that do occur in stormwater. In most cases, the detection limits are exceeded for more than 90% of the observations. If substitutions were made, then the average values would be slightly smaller, while the medians would likely change very little. Applying substitutions for non-detectable values can cause other artifacts when conducting statistical analyses, especially for paired analyses. No substitutions were therefore made in these analyses for the non-detected values, since the detected percentages were high, and these other statistical artifacts were not desired. Some of the other constituents included in the NSQD (such as filtered forms of metals and organic toxicants) can have much larger fractions of non-detected values, and special procedures are needed when analyzing those data.

Figure 2 is a plot showing the calculated ratios of the average concentrations to the median concentrations for all of the cells represented in the data set summarized in the tables (but including the few E. coli data). The average values are all larger than the median values, with the ratios ranging from 1 up to about 10. This plot shows how this ratio generally increases as the coefficient of variation (COV) values increase. The coefficient of variation is the ratio of the standard deviation to the average value (another reason why the average values are shown on these tables).

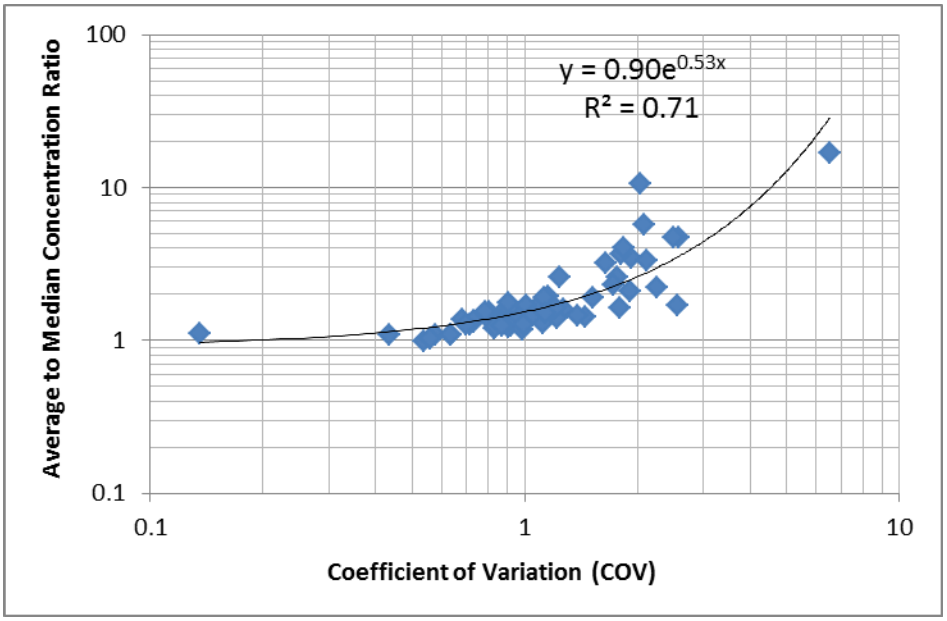


Figure 2. Relationship between the average to median concentration ratios and the COV values.

Stormwater concentrations usually have a log-normal distribution, with a concurrent positive bias, resulting in the average values being larger than the median values. The greater the difference, the greater the positive bias (and the larger the COV). If the COV is less than about 0.5, there is little difference between the median and the average values. However, most of the stormwater concentration COV values are in the range of 0.5 to 2, as indicated on Figure 2, with some much larger. The fecal coliform observations have the largest variations in each sample subgroup, while the Rv, COD, and TKN observations have the smallest variations.

In most cases, the COV values are smaller for the subgroups compared to the overall group values, indicating that the land use and geographical combinations help explain some of the large variability commonly found with stormwater concentrations. Detailed analyses have been conducted using the complete database to statistically identify significant subgroupings. In most cases, the complete matrix of 54 combinations of land use and location is reduced by missing data and by combining similar conditions, resulting in many fewer significant subgroups. The Appendix B tables do not reflect these statistical groupings, as these data are being used to compare the regional NSQD observations with the local Lincoln observations in this report. Actual data for the areas closest in character to the standard land use file locations are desired for these comparisons; therefore, the data in high-lighted cells are compared to the local values. If a cell is not high-lighted, then the land use high-lighted value is used. If that is not high-lighted, then the overall value is compared. These NSQD data are also used to compare the modeled results when local data are not available.

Statistical Groupings of NSQD Data into Significantly Different Data Subsets

During her Ph.D. research, Bochis (2010) examined all 2-way interactions between the geographical regions and the land use categories for selected constituents in the NSQD. She found that the national data could be combined into a reasonable number of significantly different subsets having similar characteristics. These groups of data have concentrations that are more similar within the group than between the groups. These groupings of the data can be used to assist local stormwater managers in estimating likely stormwater concentrations for similar local conditions. Examining 3-way interactions, by adding seasonal data to the geographical regions and land use information, did not result in many additional category distinctions associated with seasonal effects on stormwater concentrations. Table 6 shows the combined categorical groupings of the national data, with the limited seasonal distinctions identified. At the national level, EPA Rain Zones 1, 3, and 5 were found to have statistically significant differences in land use categories only for total suspended solids. EPA Rain Zones 1 and 2 were found to also have statistically significant differences in land use categories only for total suspended solids. Also, EPA Rain Zones 2 and 5 were not found to have statistically significant differences in land use categories, except for total copper, and EPA Rain Zones 6 and 9 were not found to have statistically significant differences in land use groups, except for metals (total zinc and total copper).

Table 6. Summary of Homogeneous Land Uses and Seasonal Clusters

<table>
<tr><td>Stormwater Constituent</td><td>All EPA Rain Zones
Land Use</td><td>Mean (COV)</td></tr>
<tr><td rowspan="3">Total Suspended Solids</td><td>1-RE,CO,ID
4-RE,CO,ID
6-RE,CO
9-CO,ID</td><td>199
(1.9)</td></tr>
<tr><td>2-RE
3-RE,CO,ID</td><td>76
(1.6)</td></tr>
<tr><td>2-CO,ID
5- RE,CO,ID
7- RE,CO,ID
9-RE</td><td>78
(1.9)</td></tr>
<tr><td rowspan="4">Total Zinc</td><td>1-RE</td><td>59
(1.9)</td></tr>
<tr><td>1-CO,ID
2-RE
3-RE,CO,ID
5-RE,CO,ID</td><td>92
(1.6)</td></tr>
<tr><td>2-ID
7-RE,CO,ID
9-RE,CO,ID</td><td>163
(2.3)</td></tr>
<tr><td>2-CO
4-RE,CO,ID
6-RE,CO</td><td>261
(1.2)</td></tr>
</table>

Table 6. Summary of Homogeneous Land Uses and Seasonal Clusters (cont.)

Total Copper	1-RE,ID 3-RE,CO,ID 5-RE,CO,ID 6-RE,CO	11 (2.3)
	2-RE,ID 7-RE,CO,ID	25 (1.9)
	1-CO 2-CO 9-RE,CO,ID	36 (1.2)
	4-RE,CO,ID	86 (1.9)
Total Phosphorous	1-CO 3-RE,ID 5-CO	0.17 (1.2)
	1-RE,ID 2-RE,CO,ID 3-CO 4-RE,CO,ID 5-RE,ID	0.38 (1.7)
	7-RE,CO,ID	0.3 (1.2)
	6-RE,CO 9-RE,CO,ID	0.52 (0.67)
Total Kjeldahl Nitrogen	1-RE,CO,ID 2-RE,CO,ID 3-CO,ID 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO) (FA,SU), ID	1.8 (0.99)
	3-RE 7-(RE,CO) (SP,WI)	0.97 (0.90)
	6-RE,CO 9-RE,CO,ID	3.6 (0.73)

Table 6. Summary of Homogeneous Land Uses and Seasonal Clusters (cont.)

Fecal Coliform	1-(RE,CO,ID) (FA,SP,WI) 2-(RE,CO,ID) (SP,WI) 3-(RE,CO,ID) (SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID) (SP)	29120 (8.2)
	1-(RE,CO,ID) (SU) 2-(RE,CO,ID) (FA,SU) 3-(RE,CO,ID) (FA,SU) 4-RE,CO 5-RE,CO,ID 6-RE 9-(RE,CO,ID) (FA,SU)	40286 (3.0)

Comparison of Local Lincoln MS4 NPDES Data with Regional NSQD Data

Tables 7 through 9 summarize the observed Lincoln MS4 monitored data compared to regional data from the NSQD. The Lincoln data compare well with the regional data from the three adjoining EPA Rain Zones that are close to the city, with the exception of the E. coli bacteria data. There are few E. coli observations available in the NSQD, so those data are not very reliable. Generally, the Lincoln E. Coli values are about 5 to 10 times larger than the reported NSQD observations. Lincoln residential and industrial area TSS concentrations are also substantially smaller (2 to 5 times) than the regional data, while the commercial TSS data are about twice the regional average. The nutrient and zinc observations are quite close, while the Lincoln copper observations are 2 to 5 times larger than the regional averaged copper data. Because of the large variability of stormwater quality data as reflected in the moderate to large COV values, these differences are not unexpected. As an example, Figure 3 shows that with a COV of 1, the ratio of the 90^{th} and 10^{th} percentile concentrations is about 10, while this range ratio is still about 5 for a COV of 0.5. Therefore, these Lincoln observations are not likely statistically dissimilar from the regional data, although further statistical analyses are planned in the future after current NSQD updates are completed.

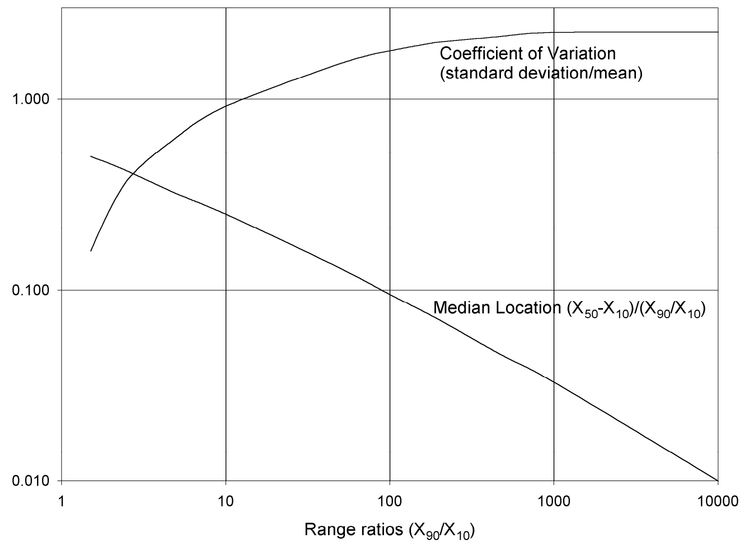


Figure 3. Determination of Coefficient of Variation from Range of Observations (Burton and Pitt, 2001).

Table 7. Residential Area Comparisons

	Lincoln MS4		**NSQD RZ9**		**NSQD RZ4**		**NSQD RZ1**	
	average	COV	average	COV	average	COV	average	COV
E. coli (#/100 mL)	79,203	1.0	6,580	1.9	6,580	1.9	6,580	1.9
TSS (mg/L)	71	0.8	528	2.5	374	1.8	135	1.2
TP (mg/L as P)	0.29	0.4	0.81	1.1	0.7	1.2	0.4	1.1
TKN (mg/L as N)	1.7	0.5	3.8	0.7	2.3	1.5	1.9	0.9
Cu (µg/L)	110	0.5	27	1.8	52	1.8	34	1.8
Zn (µg/L)	178	1.4	139	1.0	264	2.3	132	1.2

Table 8. Commercial Area Comparisons

	Lincoln MS4		**NSQD RZ9**		**NSQD RZ4**		**NSQD RZ1**	
	average	COV	average	COV	average	COV	average	COV
E. coli	22,975	0.8	4,620	2.4	4,620	2.4	4,620	2.4
TSS	409	0.9	133	1.7	232	1.9	201	1.5
TP as P	0.55	0.7	0.37	2.0	0.38	1.6	0.25	2.2
TKN as N	1.8	0.8	1.9	0.9	1.8	0.9	1.5	1.1
Cu	308	1.0	37	2.3	69	1.2	58	0.8
Zn	636	0.7	197	1.4	270	0.9	196	1.4

Table 9. Industrial Area Comparisons

	Lincoln MS4		NSQD RZ9		NSQD RZ4		NSQD RZ1	
	average	COV	average	COV	average	COV	average	COV
E. coli	29,706	2.0	5,240	2.1	5,240	2.1	5,240	2.1
TSS	90	1.0	360	1.9	164	1.4	177	1.4
TP as P	0.21	0.6	0.39	1.5	0.36	1.2	0.33	0.8
TKN as N	1.2	0.2	1.9	1.2	1.6	0.6	1.9	0.9
Cu	109	0.3	46	1.0	99	2.3	25	1.8
Zn	160	0.4	486	0.9	512	2.9	106	1.2

Calibrations of WinSLAMM to Simulate Local Observed Stormwater Conditions

All models need to be calibrated to result in the most effective information. WinSLAMM calibrations for Lincoln were based on a multi-step process. Much source area monitoring data are available from different locations (mainly from California, Alabama, Ontario, and Wisconsin). These data are summarized in a series of peer-reviewed chapters in modeling monographs:

- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. “Sources of pollutants in urban areas (Part 1) – Older monitoring projects.” In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 465 – 484 and 507 – 530. 2005.
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. “Sources of pollutants in urban areas (Part 2) – Recent sheetflow monitoring results.” In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 485 – 530. 2005.
- Pitt, R., D. Williamson, and J. Voorhees. “Review of historical street dust and dirt accumulation and washoff data.” Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp 203 – 246. 2005.

These data have been used to create calibrated WinSLAMM models in several locations that have since been verified using outfall data. The most extensive data are from the Birmingham, AL area and from the state of Wisconsin. Land use (and stormwater) data from throughout the nation are also available from many research reports. These data were separated into several regional groups. The Lincoln area is included in the Central US area and was originally based on the Wisconsin calibration and verification model sets. The Central model files were then modified based on outfall data from the Central US region as contained in the NSQD. Finally, these Central US files were further modified using the events monitored in Lincoln as part of their MS4 monitoring program.

As noted earlier, the Lincoln rain file was used to calculate long-term stormwater conditions. The four year period from 1996 through 1999 was used. A longer period was not possible due to missing observations. Winter conditions were also defined as being from December 20 to February 10 of each year. During these winter periods, no stormwater calculations were made.

During the Lincoln calibration process, the calculated long-term averaged modeled concentrations were compared to the monitored concentrations for each site. Factors were applied uniformly to each land use in the Lincoln pollutant and particulate solids parameter files to adjust the long-term modeled concentrations to best match the monitored/observed values. The runoff parameter file was not modified as it has been shown to compare well to observed conditions under a wide range of situations.

Sources of Stormwater Flows and Pollutants and Control Strategy

The locally calibrated WinSLAMM parameter files and averaged land use files were then used to identify the major source areas of each pollutant and flow. This is critical information needed when designing a stormwater management program for an area. Table 10 summarizes the detailed plots presented in Appendix C. Table 10 includes summaries of the major flows and pollutant sources for each of the nine land use categories. The major sources are shown for each flow and constituent, for three different rain event categories: small (<0.5 inches), intermediate (0.5 to 2 inches), and large (>2 inches).

The small category generally includes most of the rain and runoff events by number, but produces a small fraction of the annual runoff mass. This category of events if therefore of greatest interest when the number of events is of concern. If regulatory limits have numeric effluent standards, then the number of runoff events is of the greatest concern, and stormwater control strategies would focus on eliminating as many of the runoff events as possible. Relatively small rains are associated with most of the runoff events, by number (although the total runoff volume from these rains is relatively small). For many locations, typical numeric standards for bacteria and total recoverable heavy metals would be frequently exceeded. Therefore, runoff volume, bacteria, and heavy metals would be of the greatest interest for removal from the small rain category.

The intermediate category generally includes most of the runoff pollutant discharges by mass; frequently more than 75% of the annual pollutant discharges, by mass, occur during these rains. It is therefore greatly desired to remove as much of the runoff from this rain category. However, site soil and development conditions will likely prevent the elimination of all runoff from this category. Therefore, stormwater treatment will be needed for the constituents of concern for runoff that cannot be totally eliminated by site beneficial use or infiltration. Flow, as noted, will always be of interest, but further treatment of stormwater to reduce bacteria, nutrient, and /or heavy metal discharges will also likely be a suitable goal.

The largest rain category includes events that are channel-forming with dramatic effects on habitat conditions. Therefore, volume reductions during some portions of these large rains will provide some benefit, but reductions in runoff energy discharges will also need to be considered. Runoff energy reductions are most effectively associated with flow-duration modifications of the discharge hydrographs. The largest rains in this category (not included in the 4-year rainfall period examined) are associated with drainage design and public safety. Flow sources are therefore of the greatest concern, and like for energy reductions, basin-wide hydraulic analyses would be needed to result in the most effective stormwater management and drainage options. It is unlikely that pollutant discharges would be of great concern during these large events, as they contribute relatively small fractions of the amortized annual flows, and any treatment method that could manage these large flows would be extremely costly and inefficient.

As shown on Table 10, most of the flows originate from the directly connected impervious areas (DCIA), but undeveloped or landscaped areas can contribute large portions of the flows if these areas are very large (such as in the residential areas). For these areas, the landscaped/undeveloped areas can produce significant flows (about 40% of the total flows) during the large rains. The goal of any stormwater management program should therefore be to reduce/eliminate runoff from the DCIA areas. However, there are many conditions where large-scale infiltration of stormwater may not be desirable (mainly in areas having severely limited soils hindering infiltration, shallow groundwater, or other factors that would not adequately mitigate pollutant movement to the groundwater). In most cases, roof runoff, being the least contaminated DCIA source water, should be preferentially infiltrated or used on site for beneficial uses.

In residential areas, the roof runoff comprises about 15% of the total annual runoff amount, mainly because most of the roofs are disconnected. Streets can comprise the majority of the total flows in residential areas during small to intermediate events. A typical strategy in residential areas would therefore apply rain gardens, or otherwise disconnect the roof drainage, for roof runoff control (for currently directly connected roofs). If possible, soil amendments and other strategies to reduce soil compaction to improve infiltration in the landscaped areas could eliminate much of the runoff from those areas. Street and driveway runoff would remain and are significant flow and pollutant sources. If the area was drained using grass swales, it is likely that most of the total area runoff would be eliminated. If drained by conventional curbs and gutters, curb-cut bioinfiltration areas could be retrofitted to eliminate almost all of the runoff (and associated pollutants). In residential areas having loamy soils that are not compacted and are drained by grass swales, especially if most of the impervious areas are disconnected and drain to pervious areas, no additional stormwater controls may be needed in residential areas. High-density residential areas having larger amounts of impervious areas would obviously require additional effort.

Commercial areas have most of their runoff originating from paved parking areas, streets, and roofs. These are also the main sources for most of the pollutants examined. Few opportunities exist to utilize rain gardens for roof runoff control in most commercial areas, so bioinfiltration areas that collect runoff from mixed sources may be an appropriate approach. In many parking areas, islands or landscaped edges can be retrofitted with infiltration devices for significant runoff volume reductions. Curb-cut biofilters would need to extend out into the street in most cases due to lack of suitable space near the street edge in most commercial areas. Treatment of commercial area stormwater runoff would therefore be needed, as complete infiltration is not likely to be achieved. Critical source area treatments in areas of major automobile activity, plus pollution prevention to reduce the use of galvanized metals are other strategies. Because of the lack of space in most commercial areas, stormwater treatment may need to be situated in adjacent areas, or in underground chambers.

Industrial areas have most of their flows and pollutants originating from paved parking and storage areas. Roofs and streets are lesser, but still important sources. Infiltration in these areas is of greater concern as the runoff from industrial areas is more likely to lead to groundwater contamination. Critical source area controls (such as media filtration and biofilters using specialized media as part of treatment trains) will likely be necessary, along with pollution prevention to reduce the exposure of metals (especially galvanized) and other materials. In some industrial areas, stormwater can be used for dust suppression. If a relatively large site, wet detention ponds could also be located on available land to collect and further treat any remaining surface runoff.

Some institutional areas are predominately landscaped, with less directly connected impervious areas and larger landscaped or undeveloped areas for stormwater management. Designing stormwater management features that take advantage of the topography in these areas can result in significant runoff discharge reductions. Most institutional areas in the Antelope Creek drainage have large parking areas with long-term parking that can benefit from parking lot island or perimeter bioinfiltration areas.

The summaries in Table 10 and Appendix C can be used to illustrate the likely maximum level of control for different stormwater management approaches applied to source areas. If lots of attention were applied to roof rain gardens in residential areas, it is obvious that there will still be significant runoff from other sources, for example. Modeling of the different scenarios can be used to quantify how the different control approaches can (or cannot) meet desired objectives. These summary tables and the figures can however be used to indicate where management strategies should be focused.

Table 10. Summary of Major Sources of Flows and Pollutants, Lincoln, NE Land Uses

	Commercial – Strip Mall	**Commercial – Shopping Center**	**Light Industrial**
Flows			
Small	Paved parking (56%) Streets (23%) Roofs (21%)	Paved parking (58%) Roofs (22%) Streets (20%)	Park/stor (55%) Streets (20%) Driveways (19%)
Intermediate	Paved parking (50%) Roofs (30%) Streets (19%)	Paved parking (51%) Roofs (32%) Streets (17%)	Park/stor (53%) Streets (18%) Driveways (14%)
Large	Paved parking (51%) Roofs (28%) Streets (17%)	Paved parking (52%) Roofs (30%) Streets (15%)	Park/stor (49%) Streets (15%) Driveways (14%)
Total Suspended Solids			
Small	Paved parking (83%) Roofs (12%)	Paved parking (84%) Roofs (12%)	Park/stor (78%) Streets (11%) Driveways (10%)
Intermediate	Paved parking (83%) Roofs (13%)	Paved parking (84%) Roofs (13%)	Park/stor (74%) Driveways (12%)
Large	Paved parking (64%) Roofs (23%)	Paved parking (66%) Roofs (24%)	Park/stor (87%) Driveways (4%)
Chemical Oxygen Demand			
Small	Paved parking (67%) Roofs (28%)	Paved parking (67%) Roofs (29%)	Park/stor (73%) Streets (15%) Driveways (10%)
Intermediate	Paved parking (63%) Roofs (31%)	Paved parking (63%) Roofs (32%)	Park/stor (69%) Streets (13%) Driveways (10%)
Large	Paved parking (44%) Roofs (42%) Streets (11%)	Paved parking (44%) Roofs (44%) Streets (10%)	Park/stor (81%)
Total Phosphorus			
Small	Paved parking (61%) Roofs (31%)	Paved parking (61%) Roofs (33%)	Park/stor (53%) Streets (24%) Driveways (20%)
Intermediate	Paved parking (53%) Roofs (31%)	Paved parking (54%) Roofs (33%)	Park/stor (48%) Streets (22%) Driveways (20%)
Large	Landscaping (39%) Paved parking (36%) Roofs (25%)	Landscaping (34%) Paved parking (31%) Roofs (28%)	Park/stor (59%) Streets (16%) Driveways (10%) Landscaping (12%)

	Commercial – Strip Mall	Commercial – Shopping Center	Light Industrial
Total Kjeldahl Nitrogen			
Small	Paved parking (64%) Roofs (29%)	Paved parking (64%) Roofs (30%)	Park/stor (64%) Driveways (18%) Streets (13%)
Intermediate	Paved parking (58%) Roofs (33%)	Paved parking (58%) Roofs (34%)	Park/stor (56%) Driveways (18%) Streets (10%)
Large	Roofs (38%) Paved parking (34%) Landscaping (19%)	Roofs (41%) Paved parking (35%) Landscaping (16%)	Park/stor (64%) Landscaping (11%) Roofs (10%)
Nitrites + nitrates			
Small	Paved parking (48%) Roofs (27%) Streets (25%)	Paved parking (49%) Roofs (29%) Streets (22%)	Park/stor (50%) Streets (24%) Driveways (16%)
Intermediate	Paved parking (41%) Roofs (37%) Streets (21%)	Paved parking (42%) Roofs (40%) Streets (18%)	Park/stor (50%) Streets (21%) Driveways (14%)
Large	Paved parking (42%) Roofs (36%) Streets (18%)	Paved parking (43%) Roofs (38%) Streets (16%)	Park/stor (55%) Streets (18%) Driveways (12%)
Total Copper			
Small	Paved parking (79%) Roofs (16%)	Paved parking (80%) Roofs (14%)	Park/stor (63%) Roofs (31%)
Intermediate	Paved parking (77%) Roofs (16%)	Paved parking (78%) Roofs (16%)	Park/stor (52%) Roofs (31%) Streets (10%)
Large	Paved parking (62%) Roofs (25%) Streets (11%)	Paved parking (63%) Roofs (26%) Streets (10%)	Park/stor (58%) Roofs (33%)
Total Lead			
Small	Paved parking (75%) Roofs (22%)	Paved parking (75%) Roofs (23%)	Park/stor (76%) Driveways (16%)
Intermediate	Paved parking (74%) Roofs (24%)	Paved parking (73%) Roofs (25%)	Park/stor (73%) Driveways (16%)
Large	Paved parking (53%) Roofs (40%)	Paved parking (53%) Roofs (42%)	Park/stor (87%)

	Commercial – Strip Mall	Commercial – Shopping Center	Light Industrial
Total Zinc			
Small	Paved parking (68%) Roofs (27%)	Paved parking (68%) Roofs (28%)	Park/stor (76%) Streets (10%)
Intermediate	Paved parking (67%) Roofs (29%)	Paved parking (66%) Roofs (31%)	Park/stor (70%) Roofs (15%)
Large	Paved parking (48%) Roofs (46%)	Paved parking (48%) Roofs (47%)	Park/stor (78%) Roofs (15%)
Fecal Coliform Bacteria			
Small	Paved parking (70%) Streets (25%)	Paved parking (74%) Streets (23%)	Driveways (68%) Streets (25%)
Intermediate	Paved parking (69%) Streets (23%)	Paved parking (73%) Streets (22%)	Driveways (65%) Streets (24%)
Large	Paved parking (70%) Streets (21%)	Paved parking (74%) Streets (19%)	Driveways (58%) Streets (21%)
E. Coli Bacteria			
Small	Paved parking (70%) Streets (25%)	Paved parking (75%) Streets (23%)	Driveways (58%) Streets (36%)
Intermediate	Paved parking (70%) Streets (24%)	Paved parking (74%) Streets (22%)	Driveways (55%) Streets (34%)
Large	Paved parking (71%) Streets (22%)	Paved parking (75%) Streets (20%)	Driveways (49%) Streets (30%) Park/stor (10%)

Small events: <0.5 inches of rain
Intermediate events: 0.5 to <2.5 inches of rain
Large events: 2.5 and greater inches of rain

Table 10. Summary of Major Sources of Flows and Pollutants, Lincoln, NE Land Uses (cont.)

	Institutional - Schools	Institutional - Churches	Institutional - Hospitals
Flows			
Small	Paved parking (52%) Roofs (32%) Streets (11%)	Paved parking (46%) Streets (33%) Roofs (15%)	Paved parking (63%) Roofs (24%) Streets (11%)
Intermediate	Roofs (42%) Paved parking (41%)	Paved parking (44%) Streets (31%) Roofs (13%)	Paved parking (53%) Roofs (33%)
Large	Paved parking (39%) Roofs (37%) Landscaping (11%)	Paved parking (40%) Streets (24%) Landscaping (15%) Roofs (10%)	Paved parking (51%) Roofs (30%) Landscaping (10%)
Total Suspended Solids			
Small	Paved parking (48%) Streets (40%)	Streets (78%) Paved parking (18%)	Paved parking (48%) Streets (46%)
Intermediate	Paved parking (53%) Streets (19%) Roofs (14%)	Streets (56%) Paved parking (30%)	Paved parking (59%) Streets (24%)
Large	Paved parking (47%) Landscaping (30%) Roofs (11%)	Paved parking (37%) Streets (26%) Landscaping (25%)	Paved parking (59%) Landscaping (20%) Streets (10%)
Chemical Oxygen Demand			
Small	Roofs (42%) Paved parking (37%) Streets (17%)	Streets (56%) Paved parking (25%) Roofs (14%)	Paved parking (46%) Roofs (30%) Streets (22%)
Intermediate	Roofs (53%) Paved parking (29%)	Streets (37%) Paved parking (32%) Roofs (16%) Landscaping (10%)	Roofs (43%) Paved parking (40%) Streets (10%)
Large	Roofs (44%) Paved parking (26%) Landscaping (24%)	Landscaping (32%) Paved parking (28%) Streets (18%) Roofs (14%)	Roofs (40%) Paved parking (38%) Landscaping (15%)

	Institutional - Schools	Institutional - Churches	Institutional - Hospitals
Total Phosphorus			
Small	Paved parking (43%) Roofs (27%) Streets (16)	Streets (49%) Paved parking (29%) Driveways (12%) Roofs (10%)	Paved parking (54%) Streets (20%) Roofs (20%)
Intermediate	Landscaping (30) Paved parking (25%) Roofs (25%)	Landscaping (39%) Streets (22) Paved parking (22%)	Paved parking (36%) Landscaping (30%) Roofs (22%)
Large	Landscaping (56) Paved parking (12%) Roofs (12%)	Landscaping (74%) Paved parking (11%)	Landscaping (62%) Paved parking (20%) Roofs (12%)
Total Kjeldahl Nitrogen			
Small	Roofs (40%) Paved parking (36%) Streets (19)	Streets (58) Paved parking (35%) Roofs (14%)	Paved parking (44%) Roofs (40%) Streets (24)
Intermediate	Roofs (46%) Paved parking (25%) Streets (14) Landscaping (14%)	Streets (35) Paved parking (25%) Landscaping (18%) Roofs (13%)	Roofs (39%) Paved parking (35%) Landscaping (14%) Streets (11)
Large	Landscaping (36%) Roofs (30%) Paved parking (18%)	Landscaping (46%) Paved parking (18%) Streets (15)	Landscaping (37%) Roofs (28%) Paved parking (27%)
Nitrites + nitrates			
Small	Paved parking (43%) Roofs (41%) Streets (12)	Streets (37) Paved parking (39%) Roofs (19%)	Paved parking (55%) Roofs (31%) Streets (12)
Intermediate	Roofs (52%) Paved parking (33%)	Paved parking (38%) Streets (34) Landscaping (15%) Roofs (14%)	Paved parking (44%) Roofs (42%) Streets (10)
Large	Roofs (46%) Paved parking (31%) Landscaping (11%)	Paved parking (34%) Streets (27) Landscaping (18%) Roofs (14%)	Paved parking (42%) Roofs (38%) Landscaping (10)
Total Copper			
Small	Paved parking (51%) Streets (28%) Roofs (17%)	Streets (68%) Paved parking (25%)	Paved parking (54%) Streets (33%) Roofs (11%)
Intermediate	Paved parking (50%) Roofs (28%) Streets (15%)	Streets (50%) Paved parking (37%)	Paved parking (59%) Roofs (20%) Streets (18%)
Large	Paved parking (52%) Roofs (27%)	Paved parking (45%) Streets (32%) Landscaping (10%)	Paved parking (62%) Roofs (19%) Streets (10%)

	Institutional - Schools	Institutional - Churches	Institutional - Hospitals
Total Lead			
Small	Paved parking (51%) Streets (25%) Roofs (21%)	Streets (66%) Paved parking (26%)	Paved parking (55%) Streets (31%) Roofs (13%)
Intermediate	Paved parking (49%) Roofs (33%) Streets (10%)	Streets (44%) Paved parking (40%)	Paved parking (58%) Roofs (23%) Streets (14%)
Large	Paved parking (48%) Roofs (30%) Landscaping (12%)	Paved parking (47%) Streets (21%) Landscaping (17%)	Paved parking (60%) Roofs (23%) Landscaping (10%)
Total Zinc			
Small	Paved parking (43%) Roofs (33%) Streets (22%)	Streets (64%) Paved parking (25%) Roofs (10%)	Paved parking (49%) Streets (28%) Roofs (22%)
Intermediate	Roofs (49%) Paved parking (39%)	Streets (45%) Paved parking (37%) Roofs (12%)	Paved parking (48%) Roofs (36%) Streets (13%)
Large	Roofs (47%) Paved parking (41%)	Paved parking (46%) Streets (25%) Roofs (15%)	Paved parking (51%) Roofs (36%)
Fecal Coliform Bacteria			
Small	Paved parking (73%) Driveways (16%)	Paved parking (58%) Driveways (21%) Streets (18%)	Paved parking (83%) Driveways (10%)
Intermediate	Paved parking (71%) Driveways (15%)	Paved parking (57%) Driveways (21%) Streets (17%)	Paved parking (82%) Driveways (10%)
Large	Paved parking (69%) Driveways (12%)	Paved parking (57%) Driveways (18%) Streets (15%)	Paved parking (80%)
E. Coli Bacteria			
Small	Paved parking (73%) Driveways (16%)	Paved parking (58%) Driveways (21%) Streets (18%)	Paved parking (83%) Driveways (10%)
Intermediate	Paved parking (71%) Driveways (15%)	Paved parking (57%) Driveways (21%) Streets (17%)	Paved parking (82%) Driveways (10%)
Large	Paved parking (70%) Driveways (13%)	Paved parking (57%) Driveways (18%) Streets (15%)	Paved parking (81%)

Table 10. Summary of Major Sources of Flows and Pollutants, Lincoln, NE Land Uses (cont.)

	Residential – Low Density	**Residential – Medium Density (<1960)**	**Residential – Medium Density (1960 - 1980)**
Flows			
Small	Streets (73%) Driveways (15%) Roofs (12%)	Streets (68%) Driveways (16%) Roofs (16%)	Streets (55%) Roofs (28%) Driveways (16%)
Intermediate	Streets (60%) Landscaping (15%) Driveways (12%) Roofs (11%)	Streets (59%) Driveways (15%) Roofs (14%) Landscaping (11%)	Streets (47%) Roofs (24%) Driveways (15%) Landscaping (14%)
Large	Landscaping (40%) Streets (38%) Roofs (14%)	Streets (40%) Landscaping (32%) Roofs (16%) Driveways (11%)	Landscaping (37%) Streets (29%) Roofs (16%) Driveways (11%)
Total Suspended Solids			
Small	Streets (92%)	Streets (92%)	Streets (90%)
Intermediate	Streets (86%)	Streets (88%)	Streets (86%)
Large	Streets (47%) Landscaping (44%)	Streets (53%) Landscaping (35%)	Streets (48%) Landscaping (40%)
Chemical Oxygen Demand			
Small	Streets (84%) Driveways (11%)	Streets (71%) Driveways (11%)	Streets (77%) Driveways (11%)
Intermediate	Streets (77%) Landscaping (11%)	Streets (79%)	Streets (73%) Landscaping (10%)
Large	Landscaping (45%) Streets (40%)	Streets (45%) Landscaping (36%)	Landscaping (41%) Streets (37%) Roofs (10%)
Total Phosphorus			
Small	Streets (88%) Driveways (10%)	Streets (87%) Driveways (10%)	Streets (85%) Driveways (10%)
Intermediate	Streets (58%) Landscaping (36%)	Streets (64%) Landscaping (29%)	Streets (58%) Landscaping (34%)
Large	Landscaping (81%) Streets (15%)	Landscaping (75%) Streets (20%)	Landscaping (79%) Streets (15%)
Total Kjeldahl Nitrogen			
Small	Streets (79%) Driveways (14%)	Streets (76%) Driveways (14%)	Streets (69%) Driveways (14%)
Intermediate	Streets (52%) Landscaping (37%)	Streets (57%) Landscaping (29%)	Streets (49%) Landscaping (34%)
Large	Landscaping (78%) Streets (14%)	Landscaping (71%) Streets (18%)	Landscaping (75%) Streets (14%)

	Residential – Low Density	Residential – Medium Density (<1960)	Residential – Medium Density (1960 - 1980)
Nitrites + nitrates			
Small	Streets (73%) Driveways (12%)	Streets (68%) Roofs (17%) Driveways (13%)	Streets (53%) Roofs (34%) Driveways (13%)
Intermediate	Streets (60%) Landscaping (16%) Roofs (14%) Driveways (10%)	Streets (59%) Roofs (17%) Landscaping (12%) Driveways (11%)	Streets (45%) Roofs (28%) Landscaping (14%)
Large	Landscaping (41%) Streets (36%) Roofs (15%)	Streets (38%) Landscaping (33%) Roofs (19%) Driveways (14%)	Landscaping (38%) Streets (28%) Roofs (25%)
Total Copper			
Small	Streets (65%) Driveways (17%)	Streets (74%) Driveways (18%)	Streets (53%) Driveways (18%)
Intermediate	Streets (74%) Driveways (13%)	Streets (74%) Driveways (13%)	Streets (68%) Driveways (15%) Roofs (10%)
Large	Streets (42%) Landscaping (33%) Driveways (13%) Roofs (10%)	Streets (45%) Landscaping (25%) Driveways (14%) Roofs (11%)	Streets (37%) Landscaping (29%) Driveways (14%) Roofs (14%)
Total Lead			
Small	Streets (75%) Driveways (15%) Roofs (10%)	Streets (73%) Driveways (15%) Roofs (12%)	Streets (65%) Roofs (21%) Driveways (14%)
Intermediate	Streets (70%) Landscaping (13%) Driveways (10%)	Streets (71%) Driveways (10%)	Streets (65%) Roofs (14%) Landscaping (11%) Driveways (10%)
Large	Landscaping (49%) Streets (28%) Roofs (12%) Driveways (11%)	Landscaping (40%) Streets (32%) Roofs (15%) Driveways (12%)	Landscaping (42%) Streets (27%) Roofs (18%) Driveways (11%)
Total Zinc			
Small	Streets (80%) Roofs (12%)	Streets (77%) Roofs (14%)	Streets (67%) Roofs (24%)
Intermediate	Streets (76%) Roofs (10%)	Streets (76%) Roofs (11%)	Streets (68%) Roofs (18%)
Large	Streets (43%) Landscaping (33%) Roofs (17%)	Streets (46%) Landscaping (25%) Roofs (20%)	Streets (37%) Landscaping (28%) Roofs (24%)

	Residential – Low Density	Residential – Medium Density (<1960)	Residential – Medium Density (1960 - 1980)
Fecal Coliform Bacteria			
Small	Driveways (59%) Streets (41%)	Driveways (61%) Streets (38%)	Driveways (66%) Streets (32%)
Intermediate	Driveways (53%) Streets (37%)	Driveways (56%) Streets (34%)	Driveways (59%) Streets (29%)
Large	Driveways (41%) Streets (28%) Landscaping (21%)	Driveways (44%) Streets (27%) Landscaping (15%)	Driveways (44%) Streets (21%) Landscaping (19%)
E. Coli Bacteria			
Small	Driveways (58%) Streets (41%)	Driveways (61%) Streets (38%)	Driveways (66%) Streets (32%)
Intermediate	Driveways (53%) Streets (37%)	Driveways (56%) Streets (34%)	Driveways (59%) Streets (29%)
Large	Driveways (43%) Streets (30%) Landscaping (18%)	Driveways (46%) Streets (29%) Landscaping (13%)	Driveways (47%) Streets (23%) Landscaping (16%)

Appendix A. Lincoln, NE, Land Use Site Descriptions

Land Use	**land use**	**Pitched Roofs to Impervious Areas - connected (%)**	**Pitched Roofs to Pervious Areas - disconnected (%)**	**Flat Roofs to Impervious Areas – connected (%)**	**Flat Roofs to Pervious Areas – disconnected (%)**
Low density res	resid	1.8	13.1		
Med density res <1960	resid	2.8	14.7		
Med density res 1960 - 1980	resid	4.4	13.7		
Light industry	indus			5.6	4.6
Commercial - strip mall	commer			25	
Commercial - shopping center	commer			27.1	
Institutional - school	instit			24	
Institutional - church	instit	4.6	2.2	0.7	6.7
Institutional - hospital	instit			19.9	5

Land Use	**Parking paved – connected (%)**	**Parking unpaved – disconnected (%)**	**Storage paved – connected (%)**	**Storage unpaved – disconnected (%)**	**Playground unpaved (%)**	**Driveways paved – connected (%)**
Low density res						2.7
Med density res <1960		1.5				3.5
Med density res 1960 - 1980	0.1	2.1				3.1
Light industry	8.3	5.5	24.8	16.7		9.2
Commercial - strip mall	45.7					0.3
Commercial - shopping center	47.7					0.1
Institutional - school	25.5					1.5
Institutional - church	22.6				0.2	2.3
Institutional - hospital	35.6				0.2	1.1

Land Use	**Driveways paved - disconnected (%)**	**Walkways - connected (%)**	**Walkways - disconnected (%)**	**Street Area (%)**	**Curb Miles (per 100 acres)**	**Street Width (ft)**
Low density res	2.7		0.4	13.2	7.9	28
Med density res <1960	3.5	0.1	0.4	15.1	10	25
Med density res 1960 - 1980	3.1		0.3	10.4	8.4	23
Light industry				10	5.9	28
Commercial - strip mall				15	4.8	54
Commercial - shopping center				13.4	3.8	58
Institutional - school		0.5	0.5	4.5	1.8	42
Institutional - church	0.3	0.4	0.5	13.5	8.5	26
Institutional - hospital			0.2	5.1	2.9	29

Land Use	**Large Turf Areas (%)**	**Small Landscaping Areas (%)**	**Isolated Areas (%)**	**Total (%)**
Low density res		66.1		100
Med density res <1960		58.4		100
Med density res 1960 - 1980		62.5	0.3	100
Light industry		15.3		100
Commercial - strip mall		14		100
Commercial - shopping center		11.7		100
Institutional - school	34.8	8.7		100
Institutional - church	40	6		100
Institutional - hospital	16.4	16.5		100

Appendix B. NSQD Regional and Land Use Stormwater Characteristics

Volumetric Runoff Coefficients, Rv, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	n/a	0.59 (0.5) 66	0.59 (0.9) 64	0.32 (0.7) 14	0.68 (0.5) 114	0.65 (0.4) 34	n/a	0.48 (0.1) 2	0.59 (0.5) 16	0.62 (0.6) 310	100%
Freeways	n/a	0.31 (0.3) 37	n/a	n/a	0.46 (0.3) 20	0.67 (0.6) 158	n/a	n/a	n/a	0.58 (0.7) 215	100%
Industrial	0.28 (0.6) 9	0.43 (1.0) 54	0.34 (0.7) 50	0.36 (0.2) 7	0.72 (0.2) 110	0.34 (0.9) 69	n/a	n/a	0.30 (0.8) 23	0.48 (0.7) 322	100%
Institutional	n/a	0.04 (1.8) 14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.04 (1.8) 14	100%
Open Space	n/a	0.15 (0.6) 16	n/a	0.16 (1.1) 9	0.33 (0.8) 69	0.06 (0.5) 2	n/a	n/a	0.30 (0.6) 7	0.29 (0.9) 103	100%
Residential	0.30 (2.4) 88	0.28 (1.7) 403	0.18 (1.2) 209	0.34 (0.6) 30	0.33 (0.7) 184	0.20 (0.7) 51	0.23 (1.2) 30	0.55 (1.0) 5	0.24 (1.0) 54	0.27 (1.5) 1054	100%
all land uses	0.30 (2.3) 97	0.32 (1.4) 705	0.28 (1.2) 322	0.31 (0.6) 60	0.50 (0.6) 497	0.51 (0.8) 314	0.28 (1.4) 37	0.50 (1.3) 8	0.31 (0.9) 100	0.39 (1.1) 2115	100%
% detect	100%	100%	100%	100%	100%	100%	100%	100%	100%		

TSS Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	201 (1.5) 310	101 (1.7) 669	56 (2.0) 55	232 (1.9) 67	108 (1.6) 100	132 (1.0) 41	87 (0.9) 61	98 (0.8) 7	247 (1.2) 32	133 (1.7) 1342	98%
Freeways	24 (0.3) 3	80 (1.6) 225	36 (1.4) 13	n/a	144 (1.1) 12	183 (2.8) 105	n/a	n/a	n/a	114 (2.5) 381	100%
Industrial	177 (1.4) 100	97 (1.6) 375	105 (1.2) 105	164 (1.4) 68	155 (1.7) 106	385 (1.2) 95	164 (1.2) 30	n/a	360 (0.9) 39	160 (1.6) 918	97%
Institutional	91 (0.7) 8	86 (1.0) 46	68 (1.4) 15	n/a	n/a	n/a	n/a	n/a	n/a	83 (1.0) 69	99%
Open Space	176 (2.4) 128	98 (1.5) 107	n/a	370 (0.8) 18	202 (1.6) 67	330 (n/a) 1	n/a	n/a	846 (0.4) 7	182 (1.9) 329	98%
Residential	135 (1.2) 507	102 (1.7) 1893	102 (1.6) 207	374 (1.8) 140	129 (0.9) 203	162 (1.0) 75	130 (1.8) 315	140 (0.9) 16	528 (2.5) 116	137 (2.4) 3472	99%
all land uses	156 (1.6) 1132	97 (1.7) 3468	93 (1.6) 395	293 (1.8) 293	141 (1.5) 488	235 (1.7) 318	126 (1.7) 443	140 (1.0) 24	460 (2.3) 194	135 (2.2) 6682	99%
% detect	99%	99%	98%	99%	99%	90%	100%	100%	99%		

TDS Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	388 (2.7) 84	172 (2.9) 404	72 (0.6) 29	159 (1.0) 45	64 (0.6) 99	119 (0.7) 26	226 (2.0) 61	172 (0.5) 5	131 (0.6) 32	178 (2.9) 785	100%
Freeways	210 (0.3) 3	582 (0.5) 20	n/a	n/a	175 (0.4) 12	94 (0.8) 83	85 (1.0) 12	n/a	n/a	178 (1.3) 127	99%
Industrial	510 (2.5) 76	171 (4.0) 290	108 (1.1) 86	175 (1.2) 50	82 (0.6) 106	132 (0.5) 73	69 (0.6) 30	n/a	248 (1.4) 39	182 (3.3) 752	99%
Institutional	138 (0.5) 6	66 (0.7) 18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	84 (0.7) 24	100%
Open Space	n/a	101 (0.6) 101	n/a	199 (0.6) 18	214 (1.3) 67	35 (n/a) 1	n/a	n/a	789 (2.1) 6	171 (2.0) 193	99%
Residential	416 (3.8) 172	100 (1.7) 832	121 (1.3) 126	165 (0.8) 96	100 (1.0) 160	106 (0.6) 50	66 (0.7) 69	203 (0.7) 15	162 (1.3) 45	142 (3.9) 1565	99%
all land uses	423 (3.3) 341	132 (3.0) 1754	111 (1.2) 241	169 (0.9) 209	107 (1.2) 444	111 (0.6) 233	123 (2.2) 183	188 (0.7) 21	212 (2.1) 122	159 (3.3) 3548	99%
% detect	100%	99%	100%	99%	100%	99%	98%	100%	100%		

COD Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	79 (0.8) 249	97 (1.0) 495	69 (1.4) 55	75 (0.8) 98	59 (0.7) 105	232 (0.6) 36	66 (0.9) 61	161 (0.6) 7	197 (0.4) 7	91 (1.0) 1065	99%
Freeways	88 (0.3) 3	68 (0.7) 114	67 (0.8) 14	n/a	82 (1.0) 265	149 (1.0) 56	99 (1.3) 11	n/a	n/a	87 (1.0) 460	100%
Industrial	111 (1.2) 66	65 (0.9) 293	44 (0.9) 112	78 (1.2) 48	50 (0.8) 108	252 (0.7) 60	97 (0.7) 30	n/a	226 (0.4) 14	84 (1.2) 731	99%
Institutional	31 (0.4) 7	75 (0.9) 18	44 (0.7) 15	n/a	n/a	n/a	n/a	n/a	n/a	55 (0.9) 95	95%
Open Space	26 (0.3) 11	37 (1.0) 95	n/a	66 (1.6) 18	41 (0.7) 66	59 (n/a) 1	n/a	n/a	336 (0.7) 7	52 (1.6) 198	92%
Residential	61 (0.9) 277	73 (1.0) 1225	38 (0.9) 202	93 (1.1) 89	69 (0.7) 203	138 (0.6) 71	40 (0.8) 24	216 (0.8) 16	141 (0.7) 54	70 (1.0) 2456	99%
all land uses	72 (1.0) 617	76 (1.0) 2327	45 (1.1) 398	83 (1.1) 205	67 (0.9) 747	186 (0.8) 224	56 (0.9) 445	204 (0.7) 24	177 (0.7) 82	77 (1.1) 5069	99%
% detect	98%	99%	99%	99%	98%	99%	100%	100%	100%		

Total Phosphorus Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	0.25 (2.2) 311	0.37 (1.3) 641	0.39 (1.1) 141	0.38 (1.6) 50	0.64 (3.0) 112	0.57 (0.7) 37	0.35 (1.3) 84	0.57 (0.6) 7	0.34 (0.7) 16	0.37 (2.0) 1399	96%
Freeways	0.43 (0.5) 3	0.95 (1.3) 186	0.16 (0.7) 14	n/a	0.22 (0.7) 245	0.49 (1.6) 135	0.35 (0.6) 24	n/a	n/a	0.50 (1.7) 604	99%
Industrial	0.33 (0.8) 100	0.36 (1.6) 370	0.20 (0.9) 108	0.36 (1.2) 49	0.25 (1.2) 108	1.3 (0.9) 63	0.33 (0.9) 76	n/a	0.46 (0.7) 23	0.39 (1.5) 897	95%
Institutional	0.21 (0.4) 8	0.24 (0.8) 45	0.19 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	0.23 (0.17) 68	99%
Open Space	0.18 (1.7) 139	0.33 (1.1) 106	n/a	0.31 (0.6) 17	0.40 (1.0) 67	0.65 (0.3) 2	n/a	n/a	0.60 (0.5) 7	0.29 (1.2) 338	96%
Residential	0.40 (1.1) 565	0.43 (1.7) 1956	0.20 (1.4) 410	0.70 (1.2) 91	0.47 (0.9) 206	0.54 (1.1) 70	0.30 (1.2) 331	0.85 (0.7) 15	0.81 (1.1) 75	0.71 (1.5) 3719	98%
all land uses	0.32 (0.4) 1203	0.42 (1.7) 3572	0.24 (1.3) 688	0.51 (1.3) 207	0.38 (2.2) 738	0.68 (1.3) 307	0.31 (1.1) 539	0.74 (0.8) 23	0.67 (1.1) 121	0.40 (1.7) 7295	97%
% detect	97%	97%	95%	98%	99%	97%	99%	100%	100%		

Dissolved Phosphorus Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	0.14 (0.5) 81	0.24 (1.9) 386	0.13 (1.7) 43	0.25 (1.2) 30	0.09 (1.0) 103	0.42 (0.8) 26	0.20 (2.3) 13	n/a	0.17 (0.6) 16	0.21 (1.8) 698	77%
Freeways	n/a	0.14 (0.8) 18	0.06 (1.3) 14	n/a	0.04 (0.9) 11	0.78 (2.1) 22	n/a	n/a	n/a	0.34 (3.1) 65	85%
Industrial	0.085 (0.9) 70	0.20 (2.1) 275	0.10 (1.2) 97	0.15 (0.7) 33	0.11 (1.0) 109	0.30 (0.9) 52	0.06 (0.7) 8	n/a	0.24 (0.9) 22	0.17 (1.8) 666	82%
Institutional	0.054 (0.6) 5	0.13 (0.5) 17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.11 (0.6) 22	86%
Open Space	n/a	0.17 (1.1) 100	n/a	0.20 (0.7) 18	0.15 (1.2) 67	0.18 (n/a) 1	n/a	n/a	0.19 (0.5) 6	0.17 (1.1) 192	84%
Residential	0.16 (1.2) 149	0.21 (1.1) 797	0.13 (1.3) 148	0.29 (0.6) 66	0.20 (0.7) 164	0.24 (0.7) 26	0.30 (1.8) 26	n/a	0.26 (0.7) 12	0.21 (1.1) 1388	83%
all land uses	0.14 (1.2) 305	0.21 (1.5) 1675	0.11 (1.4) 302	0.24 (0.8) 147	0.14 (0.9) 454	0.39 (1.9) 127	0.23 (2.0) 47	n/a	0.22 (0.8) 56	0.20 (1.6) 3113	81%
% detect	62%	79%	74%	96%	93%	98%	81%	n/a	100%		

Total Kjeldahl Nitrogen Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	1.5 (1.1) 185	2.0 (0.9) 625	1.2 (0.7) 41	1.8 (0.9) 47	1.1 (0.6) 112	4.3 (0.7) 39	1.6 (1.0) 61	3.7 (0.7) 5	2.6 (0.6) 16	1.9 (0.9) 1131	97%
Freeways	3.6 (0.3) 3	2.4 (1.1) 100	n/a	n/a	2.0 (0.9) 204	3.3 (1.4) 122	1.7 (0.6) 24	n/a	n/a	2.4 (1.2) 450	99%
Industrial	1.9 (0.9) 100	1.8 (1.5) 338	1.5 (0.8) 99	1.6 (0.6) 46	1.2 (0.9) 109	4.2 (0.8) 76	1.9 (0.6) 33	n/a	2.5 (0.6) 23	1.9 (1.2) 824	96%
Institutional	0.79 (0.6) 7	1.6 (0.8) 46	1.4 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	1.5 (0.8) 68	97%
Open Space	0.79 (0.7) 100	1.2 (0.8) 77	n/a	1.9 (0.7) 18	1.7 (0.9) 67	1.8 (0.2) 2	n/a	n/a	3.3 (0.6) 7	1.3 (1.0) 271	91%
Residential	1.9 (0.9) 434	1.8 (1.1) 1783	1.0 (0.9) 335	2.3 (1.5) 74	2.1 (0.9) 183	3.2 (2.7) 74	1.1 (0.9) 318	5.7 (0.8) 15	3.8 (0.7) 64	1.8 (1.1) 3280	98%
all land uses	1.6 (0.9) 834	1.9 (1.1) 3067	1.2 (0.9) 490	2.0 (0.7) 185	1.7 (0.9) 675	3.6 (1.0) 313	1.3 (0.9) 460	5.0 (0.8) 21	3.3 (0.7) 110	1.9 (1.1) 6095	97%
% detect	100%	97%	93%	97%	96%	99%	98%	100%	100%		

Nitrate plus Nitrite Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	0.81 (0.7) 213	0.89 (1.0) 536	0.31 (1.5) 109	0.89 (0.7) 29	0.54 (0.5) 112	1.3 (0.7) 33	0.44 (1.0) 80	1.0 (n/a) 1	1.2 (0.7) 16	0.77 (1.0) 1129	98%
Freeways	0.67 (0.8) 3	2.2 (2.0) 86	n/a	n/a	0.72 (0.7) 11	n/a	0.51 (1.2) 25	n/a	n/a	1.8 (2.2) 122	99%
Industrial	0.67 (0.57) 98	0.79 (0.8) 335	0.71 (1.6) 81	0.82 (0.6) 31	0.67 (0.6) 109	1.8 (0.5) 62	0.37 (0.6) 30	0.26 (n/a(1	1.0 (0.4) 23	0.83 (0.9) 769	97%
Institutional	1.0 (0.5) 7	0.63 (0.7) 46	0.37 (0.5) 14	n/a	n/a	n/a	n/a	n/a	n/a	0.61 (0.7) 67	99%
Open Space	0.41 (0.8) 138	0.81 (0.9) 106	n/a	0.78 (1.0) 17	0.84 (0.7) 67	1.0 (0.6) 2	n/a	n/a	1.2 (0.4) 7	0.66 (0.9) 337	96%
Residential	0.78 (0.6) 434	1.1 (2.5) 1583	0.35 (1.7) 357	0.88 (0.7) 75	0.79 (0.9) 202	1.1 (0.4) 66	0.82 (1.2) 77	1.5 (1.0) 2	1.4 (1.0) 54	0.94 (2.3) 2850	99%
all land uses	0.73 (0.8) 969	1.0 (2.2) 2890	0.39 (1.8) 561	0.86 (0.7) 152	0.72 (0.8) 501	1.4 (0.6) 163	0.59 (1.2) 223	1.1 (0.9) 4	1.2 (0.9) 100	0.88 (2.0) 5506	98%
% detect	98%	99%	97%	100%	99%	100%	90%	100%	100%		

Total Copper Concentrations, µg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	58 (0.8) 141	33 (1.2) 502	7.4 (1.4) 106	69 (1.2) 47	61 (3.5) 109	21 (1.1) 40	29 (1.1) 84	42 (1.2) 7	46 (1.6) 32	37 (2.3) 1068	88%
Freeways	54 (0.1) 3	28 (2.0) 103	1.1 (0.5) 13	n/a	7.4 (1.7) 117	62 (1.4) 101	32 (0.8) 26	n/a	n/a	30 (2.0) 360	98%
Industrial	25 (1.5) 83	22 (1.3) 257	18 (1.0) 106	99 (2.3) 49	17 (0.7) 107	78 (0.9) 93	42 (0.8) 34	n/a	46 (1.0) 39	36 (2.0) 768	86%
Institutional	33 (0.4) 7	25 (0.7) 45	7.3 (0.6) 15	n/a	n/a	n/a	n/a	n/a	n/a	21 (0.8) 67	85%
Open Space	9 (0.1) 6	9 (0.8) 58	n/a	20 (0.8) 12	12 (0.9) 70	119 (1.1) 2	n/a	n/a	28 (0.7) 7	14 (1.5) 155	84%
Residential	34 (1.8) 333	30 (1.6) 1340	10 (2.6) 396	52 (1.8) 111	16 (1.8) 164	36 (1.4) 66	13 (0.7) 24	22 (0.4) 15	28 (0.9) 103	27 (1.8) 2613	88%
all land uses	33 (1.6) 644	29 (1.5) 2339	10 (2.1) 636	65 (2.1) 219	23 (4.3) 567	56 (1.4) 302	26 (1.1) 253	28 (1.0) 23	35 (1.2) 181	30 (2.1) 5087	88%
% detect	78%	89%	79%	89%	98%	99%	93%	90%	83%		

Total Lead Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	17 (1.3) 101	34 (1.7) 438	9.1 (1.5) 71	63 (1.0) 45	37 (1.2) 111	32 (2.2) 42	44 (1.4) 84	65 (1.2) 7	75 (0.7) 16	34 (1.6) 915	80%
Freeways	n/a	57 (0.8) 100	n/a	n/a	81 (0.8) 138	72 (1.5) 112	55 (1.3) 26	n/a	n/a	71 (1.1) 376	98%
Industrial	15 (0.8) 77	21 (2.3) 327	22 (1.1) 89	113 (2.0) 48	35 (1.4) 108	148 (0.9) 101	45 (0.8) 74	n/a	157 (1.2) 23	55 (1.9) 847	76%
Institutional	22 (0.8) 6	32 (1.5) 46	n/a	n/a	n/a	n/a	n/a	n/a	n/a	30 (1.5) 52	92%
Open Space	n/a	11 (1.2) 107	n/a	140 (n/a) 17	27 (2.4) 70	80 (1.2) 2	n/a	n/a	225 (0.5) 7	30 (2.2) 203	67%
Residential	65 (2.3) 287	19 (2.1) 1052	9.6 (3.5) 317	25 (1.7) 96	25 (1.5) 183	45 (1.0) 56	30 (1.3) 85	22 (0.8) 15	29 (1.2) 51	26 (2.6) 2142	77%
all land uses	45 (2.7) 546	25 (1.9) 2104	11 (2.8) 477	57 (2.3) 206	43 (1.3) 610	89 (1.3) 313	39 (1.3) 293	38 (1.3) 23	81 (1.4) 97	37 (2.0) 4694	78%
% detect	59%	76%	74%	60%	92%	93%	98%	83%	100%		

Total Zinc Concentrations, µg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	196 (1.4) 225	237 (1.2) 513	60 (1.4) 136	270 (0.9) 51	116 (0.8) 111	343 (2.0) 42	138 (1.0) 84	434 (1.1) 7	217 (0.7) 32	197 (1.4) 1201	99%
Freeways	368 (0.1) 3	185 (1.3) 203	7.5 (0.9) 14	n/a	89 (1.2) 267	304 (1.1) 99	211 (0.8) 25	n/a	n/a	159 (1.4) 608	99%
Industrial	106 (1.2) 84	172 (0.9) 326	166 (1.3) 107	512 (2.9) 54	169 (1.1) 107	1720 (2.0) 100	306 (2.9) 81	n/a	486 (0.9) 39	382 (3.5) 898	99%
Institutional	169 (0.2) 7	254 (0.9) 46	90 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	210 (1.0) 68	100%
Open Space	53 (0.8) 10	93 (0.8) 109	n/a	98 (1.0) 17	100 (1.3) 69	225 (1.0) 2	n/a	n/a	439 (0.4) 7	109 (1.1) 214	91%
Residential	134 (1.2) 351	125 (3.6) 1471	61 (1.2) 384	264 (2.3) 120	95 (0.9) 183	260 (1.2) 76	120 (0.8) 328	185 (0.6) 15	139 (1.0) 100	125 (2.8) 3028	97%
all land uses	138 (1.4) 752	162 (2.3) 2711	78 (1.5) 656	310 (2.7) 242	107 (1.1) 737	746 (2.8) 319	152 (2.4) 542	264 (1.1) 22	242 (1.2) 178	178 (3.3) 6036	97%
% detect	98%	97%	95%	98%	100%	97%	100%	100%	94%		

Fecal Coliforms, count/100 mL, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

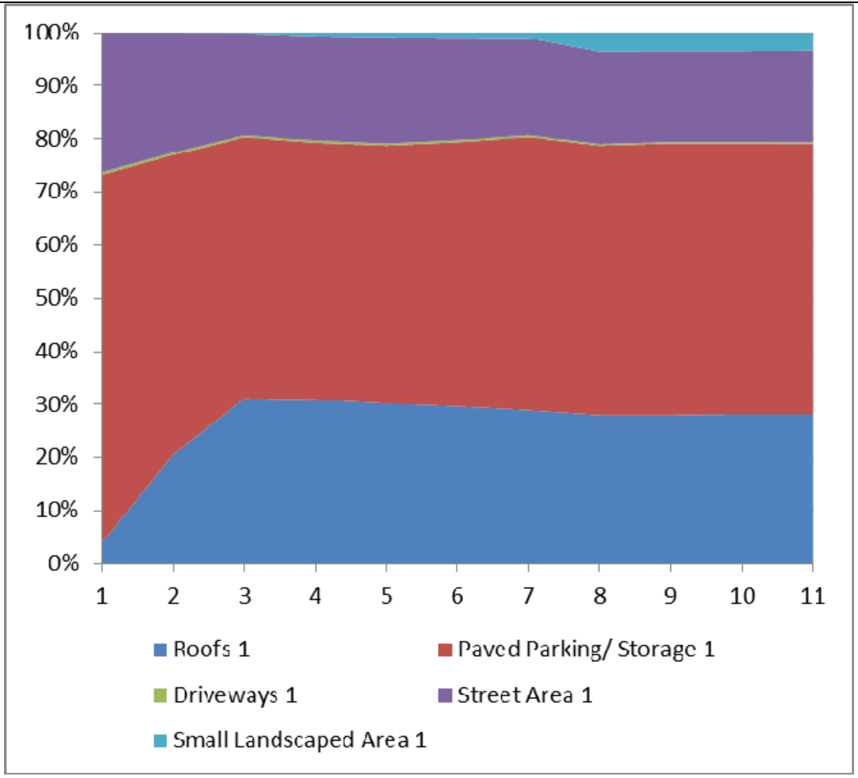
Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	5,160 (2.2) 43	14,200 (2.2) 154	3,220 (1.0) 6	54,500 (1.9) 44	41,000 (2.8) 103	9,500 (1.5) 7	34,000 (4.0) 57	3,500 (1.3) 4	21,600 (1.3) 11	27,400 (3.2) 429	91%
Freeways	<1 (n/a) 3	11,400 (3.3) 18	n/a	n/a	9,000 (2.0) 13	7,900 (2.1) 26	7,060 (1.8) 23	n/a	n/a	8,600 (2.5) 80	100%
Industrial	100,000 (5.7) 44	14,000 (2.5) 150	5,500 (1.8) 65	83,400 (4.2) 46	50,200 (4.9) 109	4,190 (1.0) 22	15,100 (3.5) 34	n/a	24,200 (1.8) 15	35,900 (6.6) 485	90%
Institutional	3,100 (0.4) 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3,100 (0.4) 3	100%
Open Space	14,300 (1.7) 6	11,100 (3.1) 24	n/a	17,900 (1.0) 16	39,900 (2.1) 67	2,500 (n/a) 1	n/a	n/a	480 (0.6) 2	29,100 (2.4) 116	97%
Residential	210,000 (3.3) 156	33,100 (2.7) 380	20,300 (6.5) 90	41,700 (1.0) 91	88,500 (1.8) 165	5,970 (1.7) 10	25,400 (2.8) 68	17,800 (2.1) 10	25,600 (1.0) 8	69,600 (4.4) 978	91%
all land uses	140,000 (4.2) 301	24,100 (2.9) 731	13,700 (7.2) 161	52,600 (3.4) 197	59,300 (2.8) 457	6,520 (1.9) 66	25,000 (3.6) 191	13,700 (2.3) 14	22,400 (1.5) 36	48,400 (5.0) 2102	91%
% detect	80%	88%	91%	87%	100%	97%	95%	100%	100%		

***E. coli*, count/100 mL, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)**

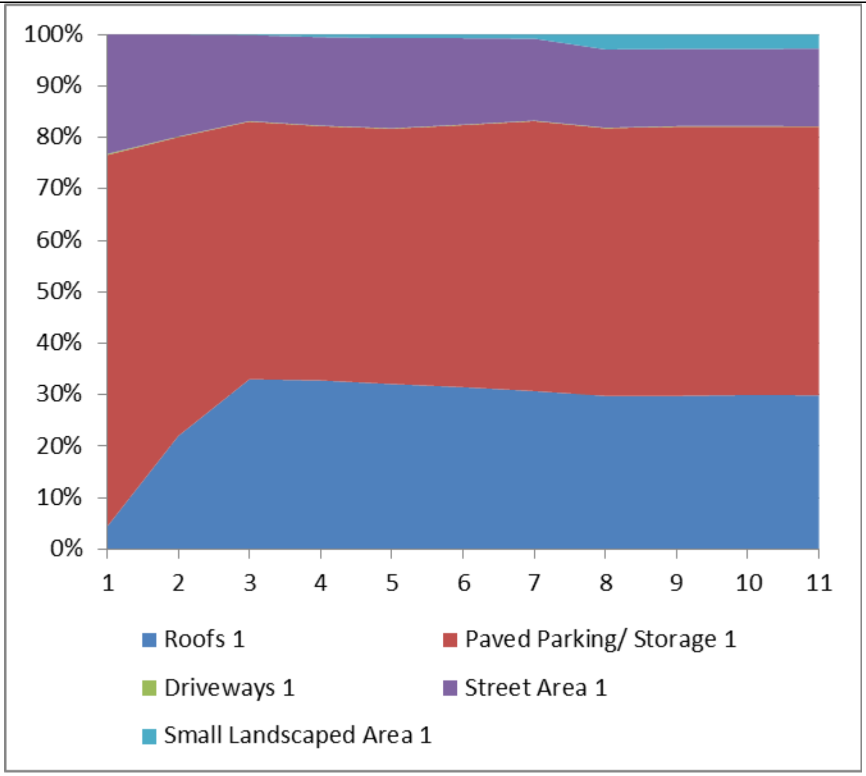
Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	3930 (1.8) 32	n/a	n/a	n/a	n/a	n/a	8340 (2.3) 12	1010 (1.1) 6	n/a	4620 (2.4) 50	90%
Freeways	n/a	n/a	n/a	n/a	n/a	n/a	6000 (2.2) 13	n/a	n/a	6000 (2.2) 13	100%
Industrial	3030 (2.1) 20	n/a	n/a	n/a	n/a	n/a	3230 (0.4) 4	n/a	n/a	3060 (1.9) 24	79%
Institutional	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Open Space	1560 (1.2) 5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1560 (1.2) 5	100%
Residential	7300 (1.7) 36	n/a	n/a	n/a	n/a	n/a	4380 (1.5) 12	6560 (2.6) 13	n/a	6580 (1.9) 61	95%
all land uses	4990 (1.9) 93	n/a	n/a	n/a	n/a	n/a	5750 (2.1) 47	4560 (3.0) 20	n/a	5240 (2.1) 155	92%
% detect	89%	n/a	n/a	n/a	n/a	n/a	94%	100%	n/a		

Appendix C. Sources of Stormwater Flows and Pollutants

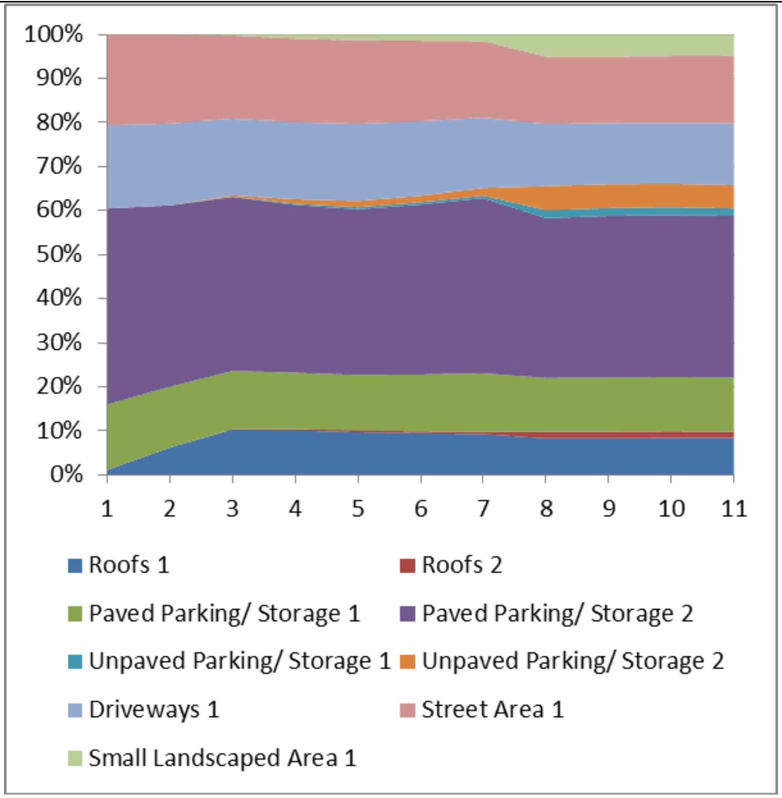
Flow Contributions



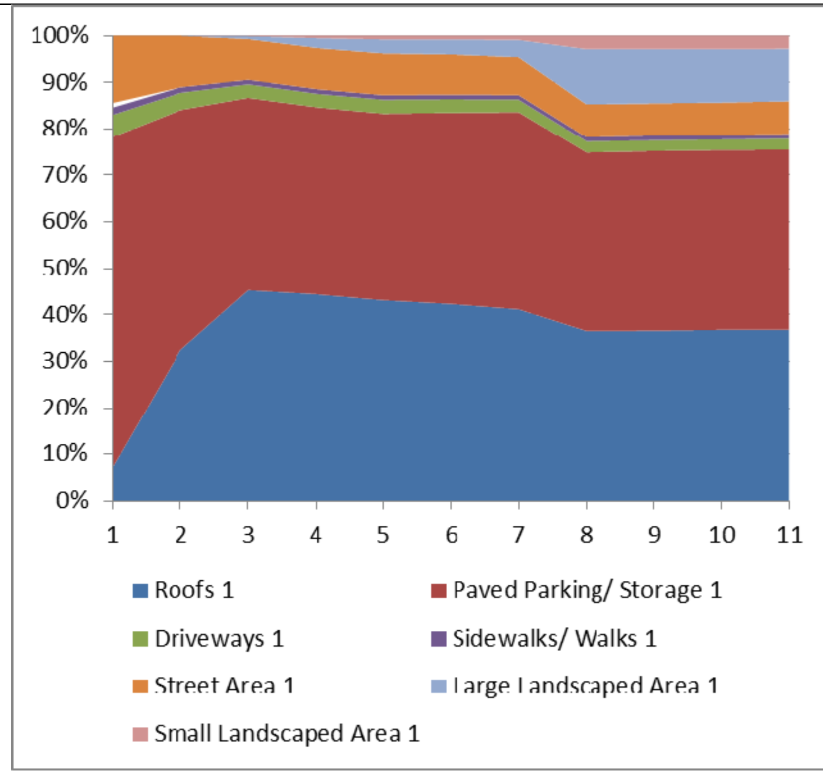
Commercial – Strip Mall Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



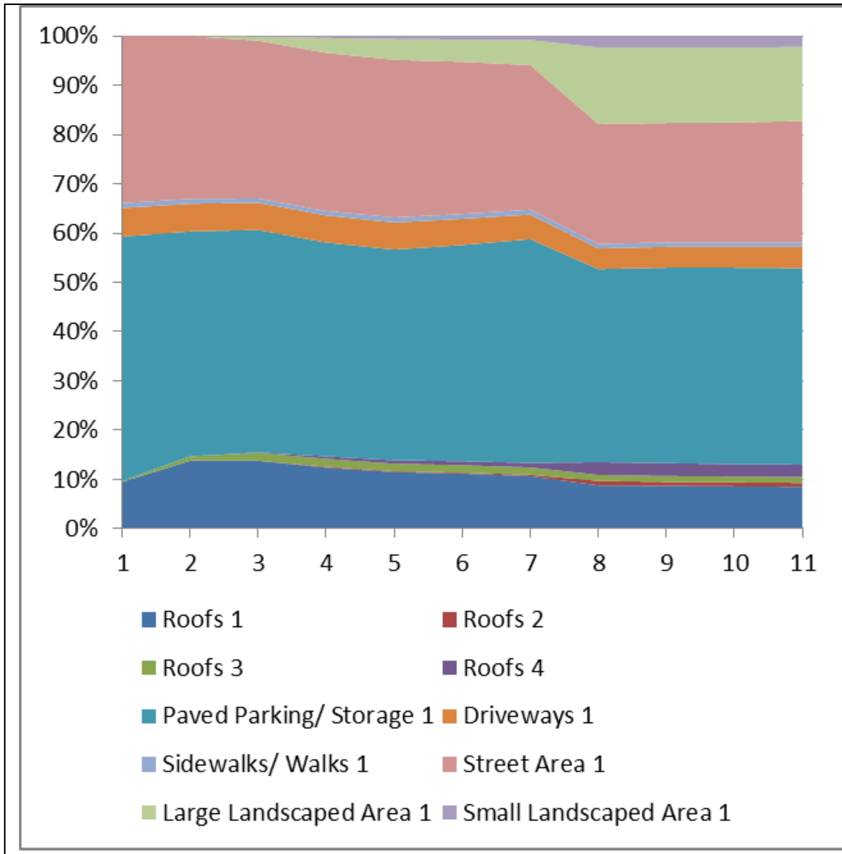
Commercial – Shopping Center Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



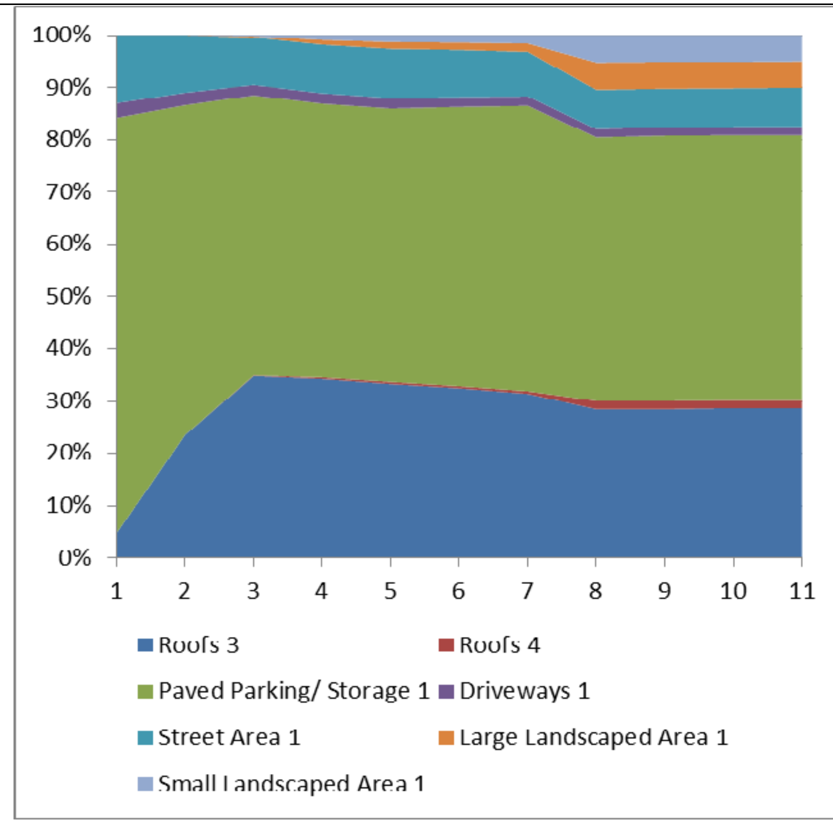
Light Industrial Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



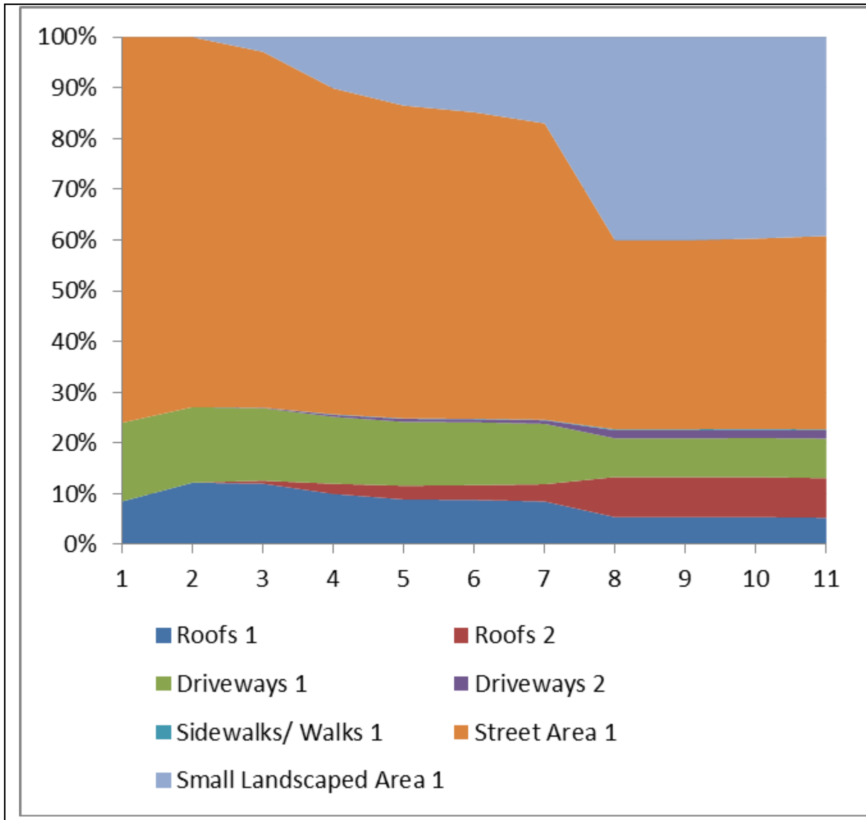
Institutional - School Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



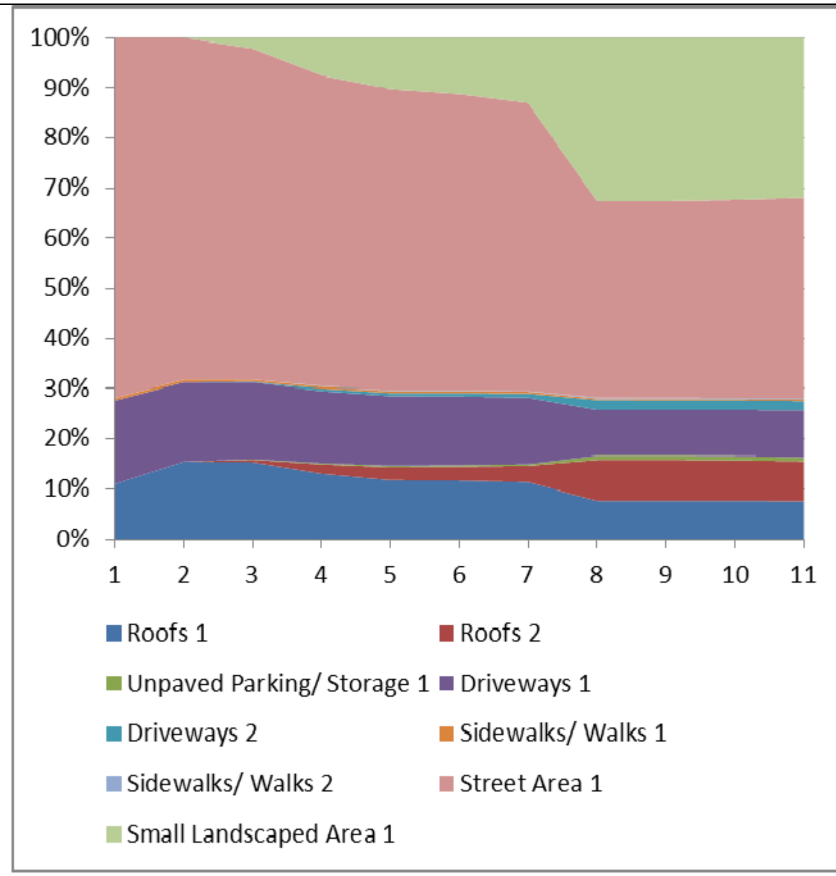
Institutional – Church Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



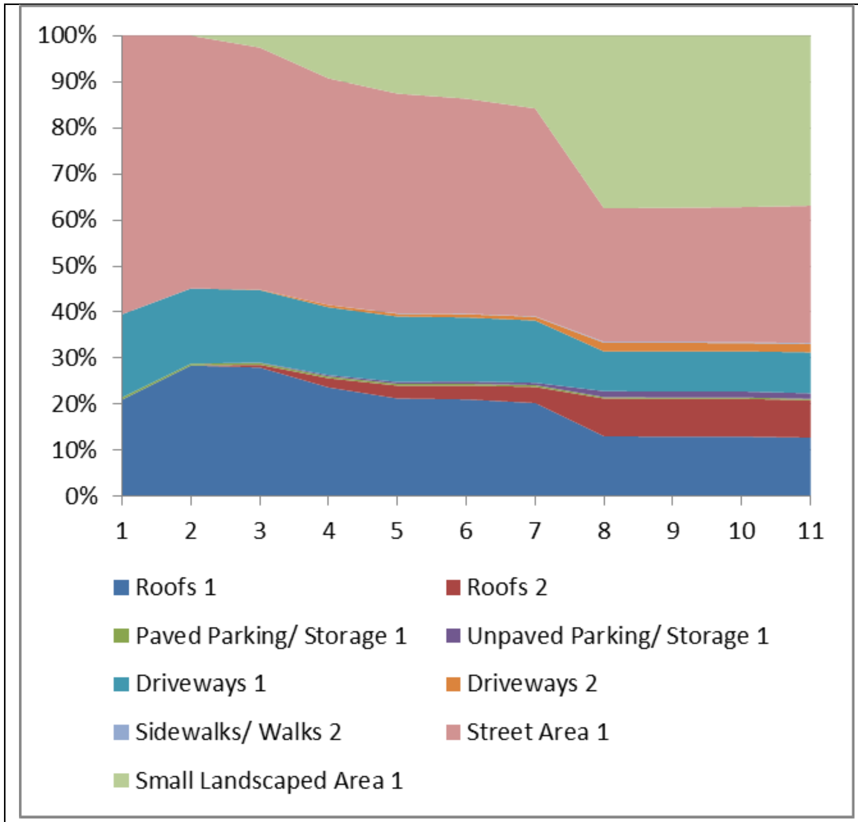
Institutional - Hospital Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

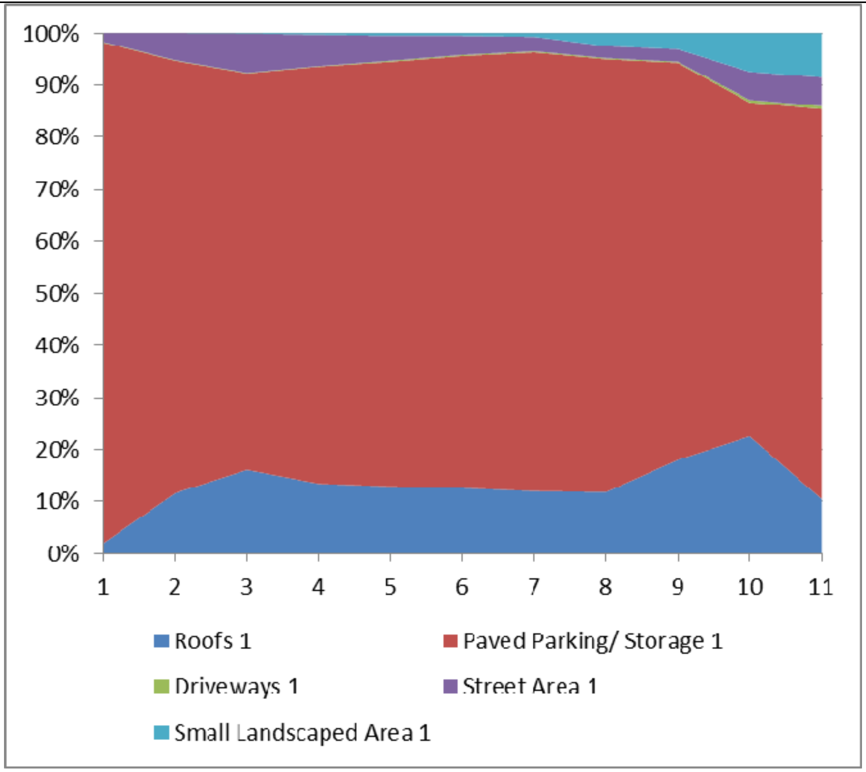


Medium Density Residential Area (<1960) Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

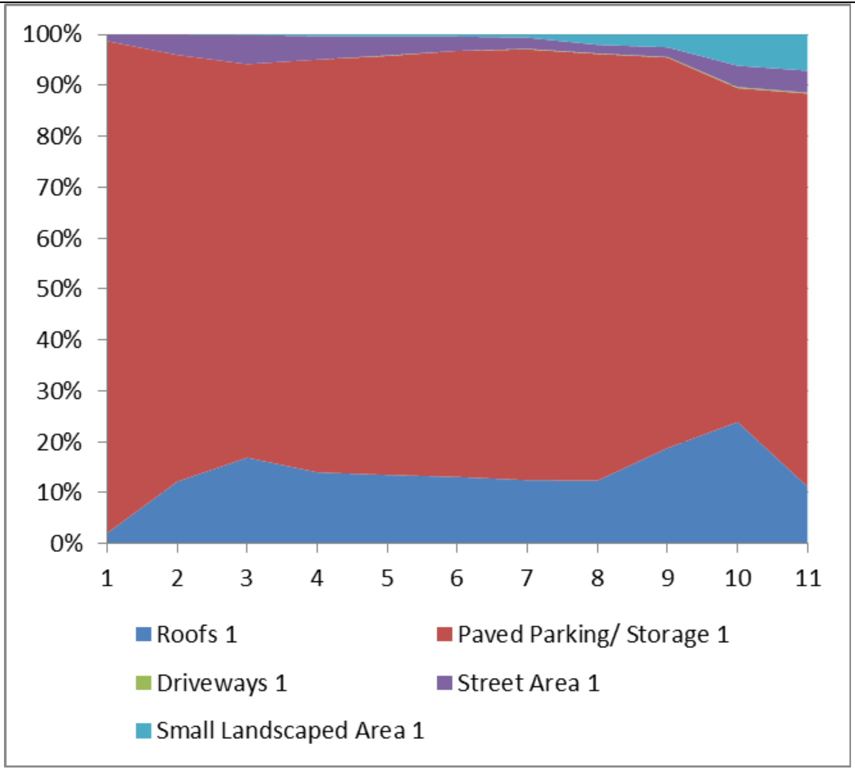


Medium Density Residential Area (1960 - 1980) Flow Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"

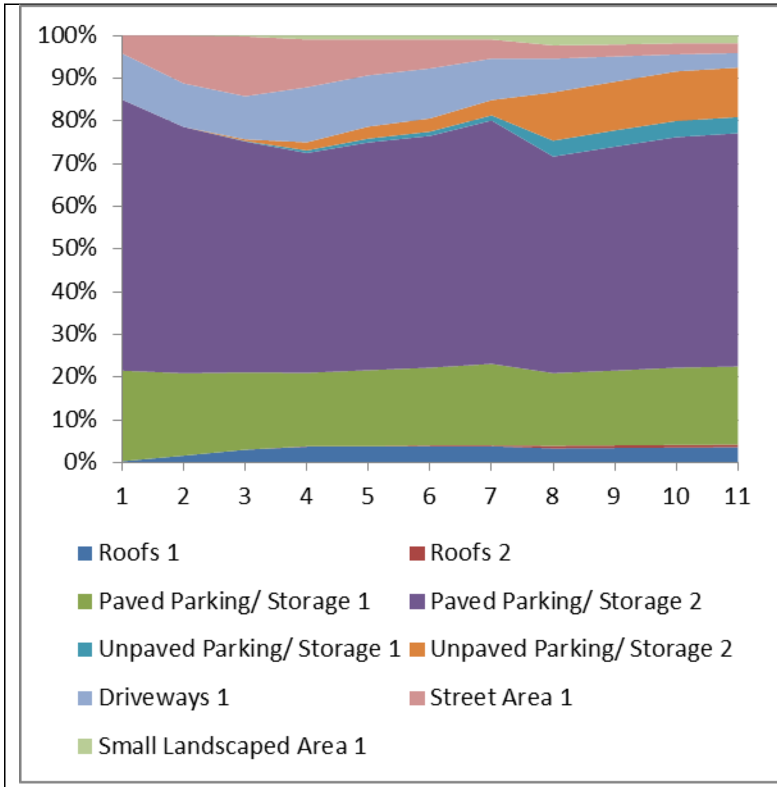
Total Suspended Solids Mass Contributions



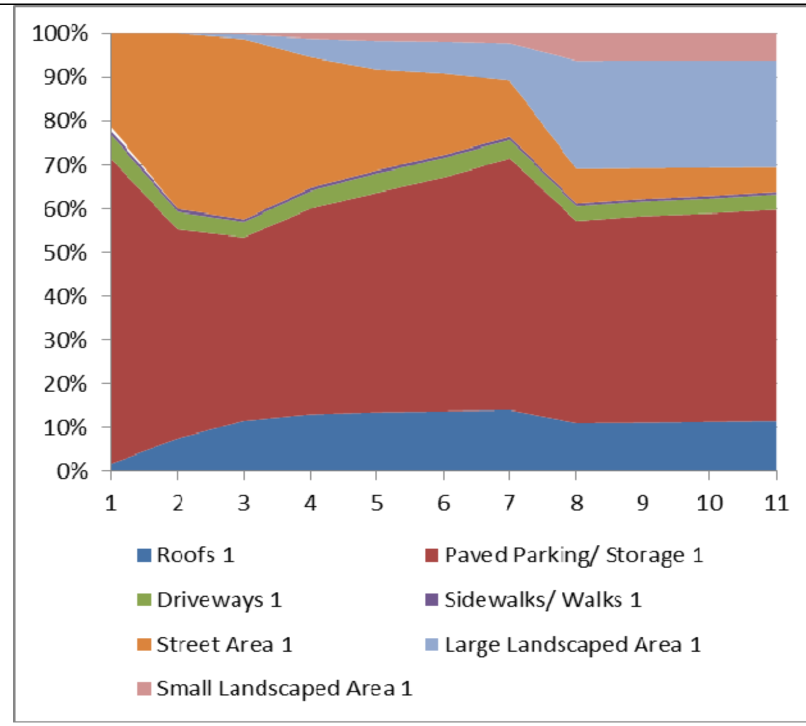
Commercial – Strip Mall Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



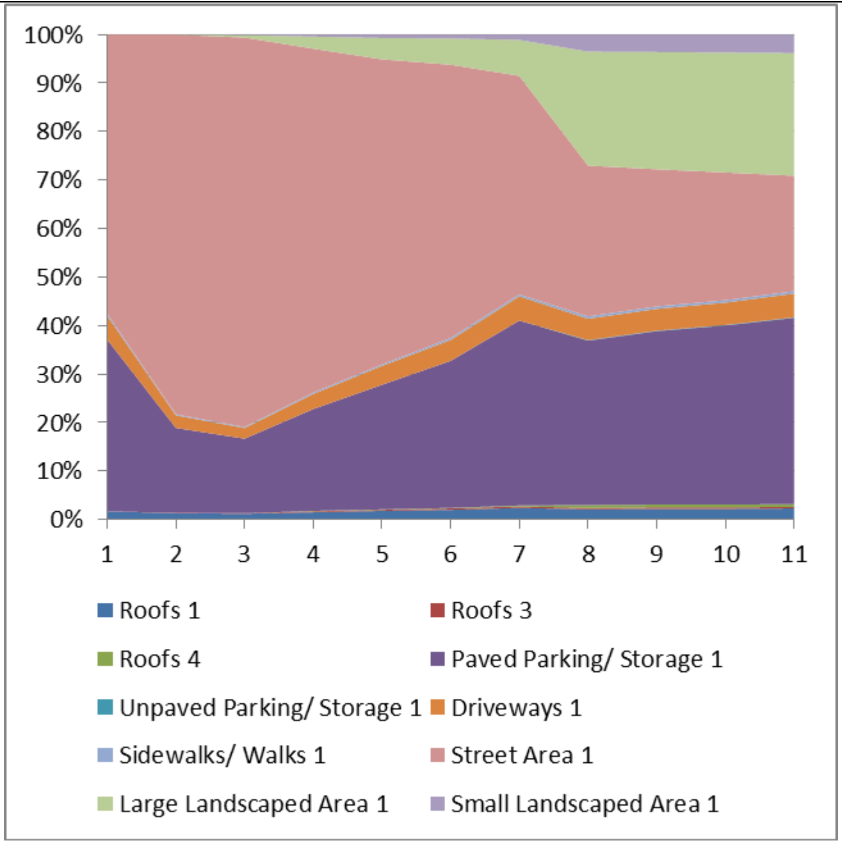
Commercial – Shopping Center Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



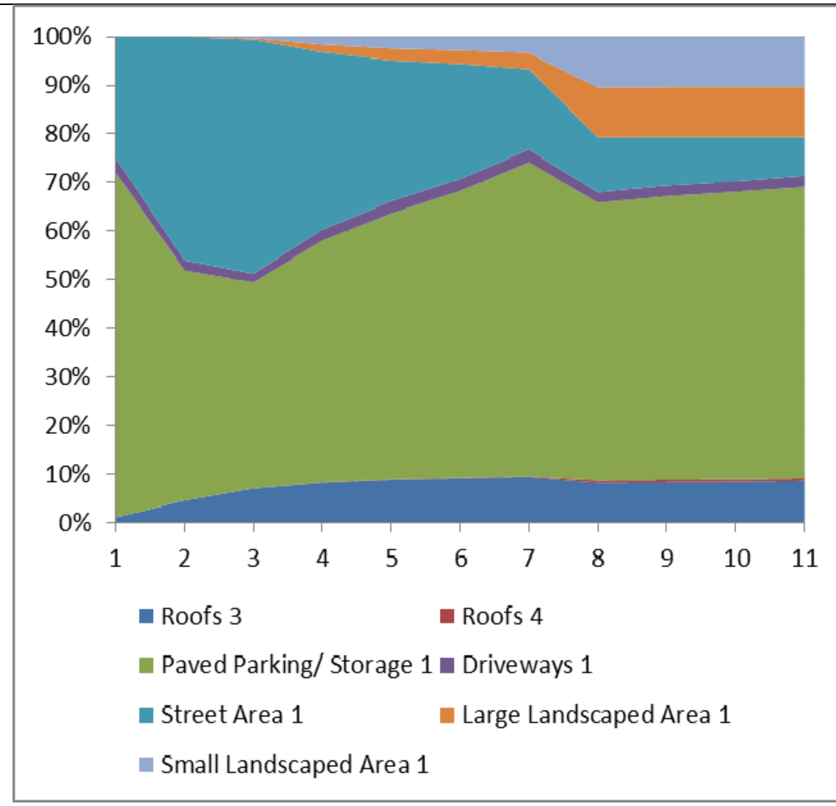
Light Industrial Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



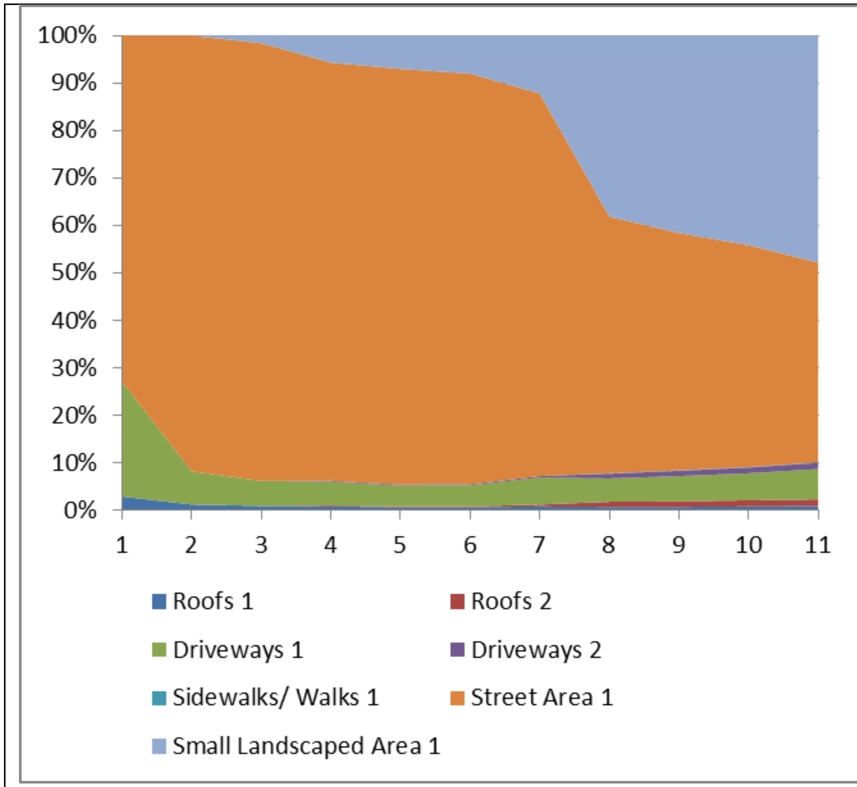
Institutional - School Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



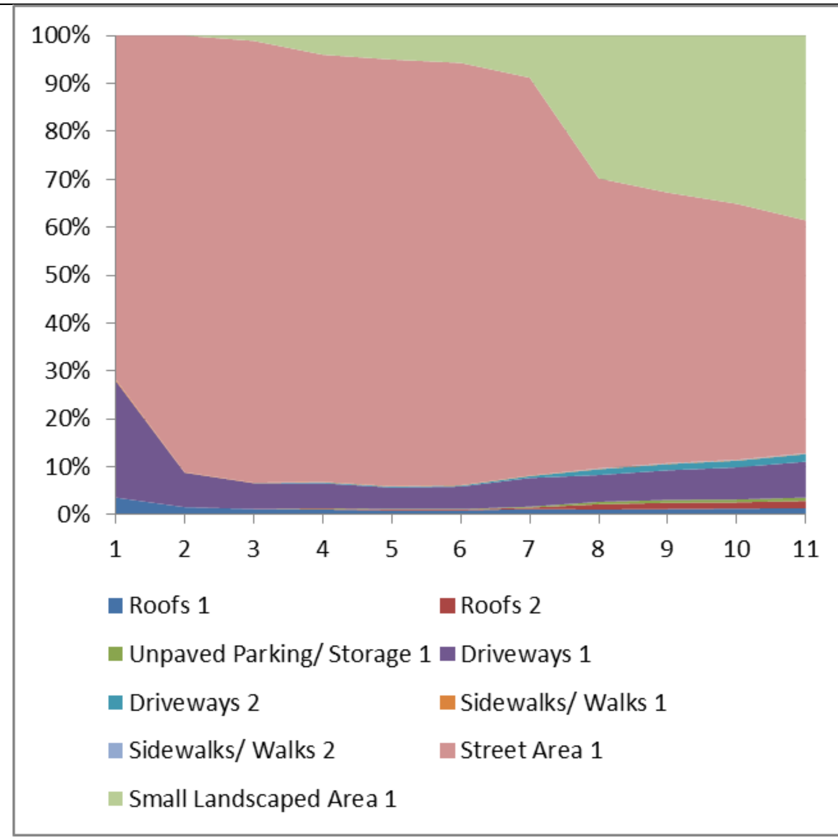
Institutional – Church Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



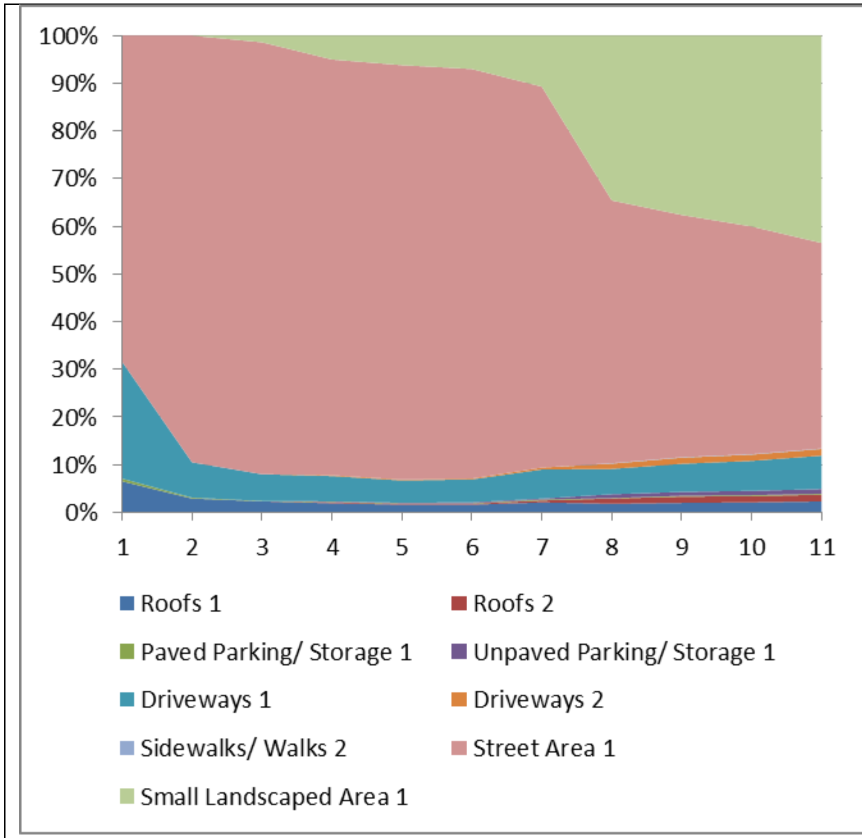
Institutional - Hospital Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

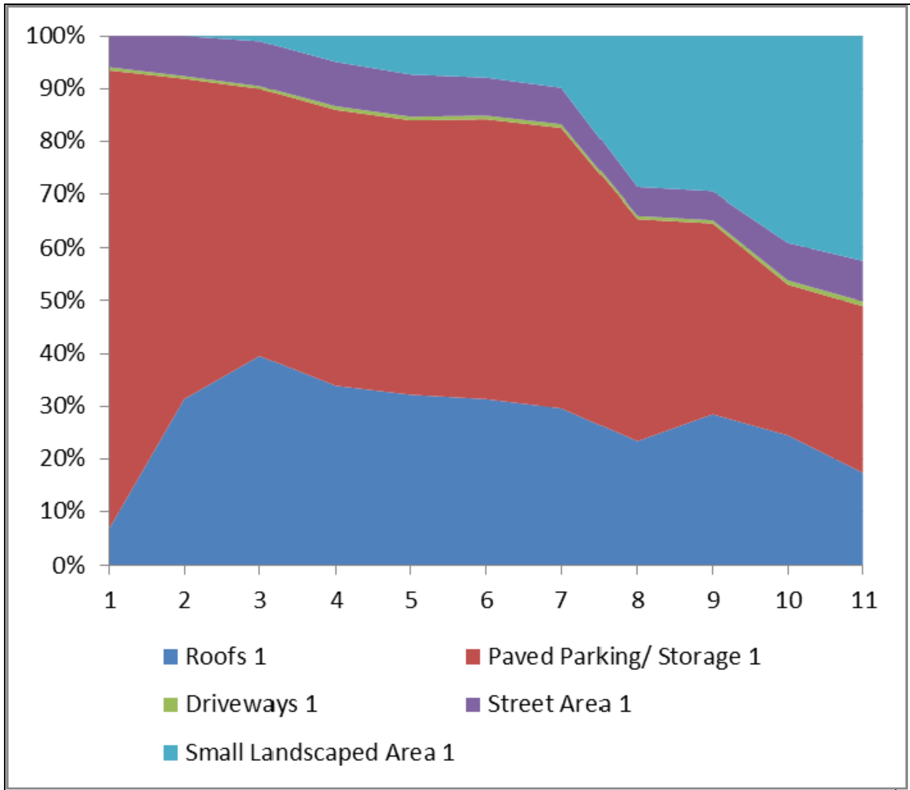


Medium Density Residential Area (<1960) TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

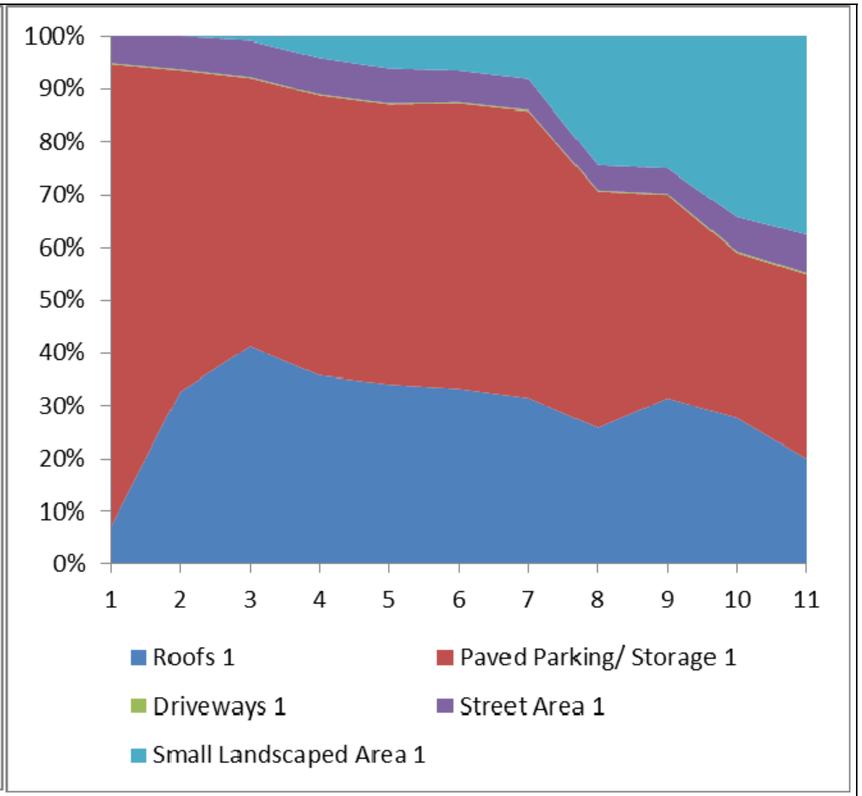


Medium Density Residential Area (1960 - 1980) TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

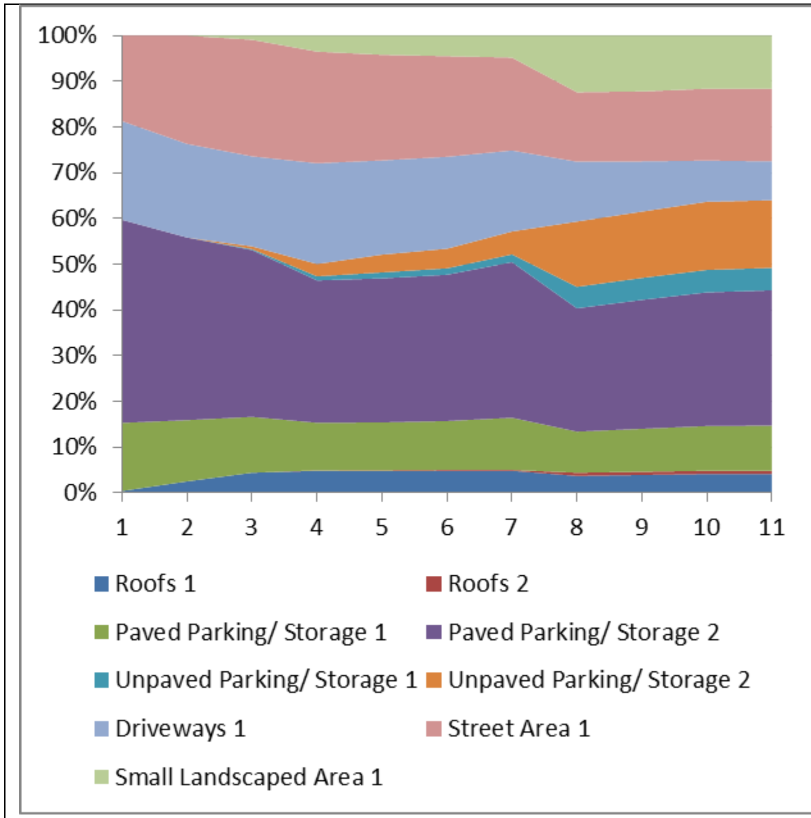
Total Phosphorus Mass Contributions



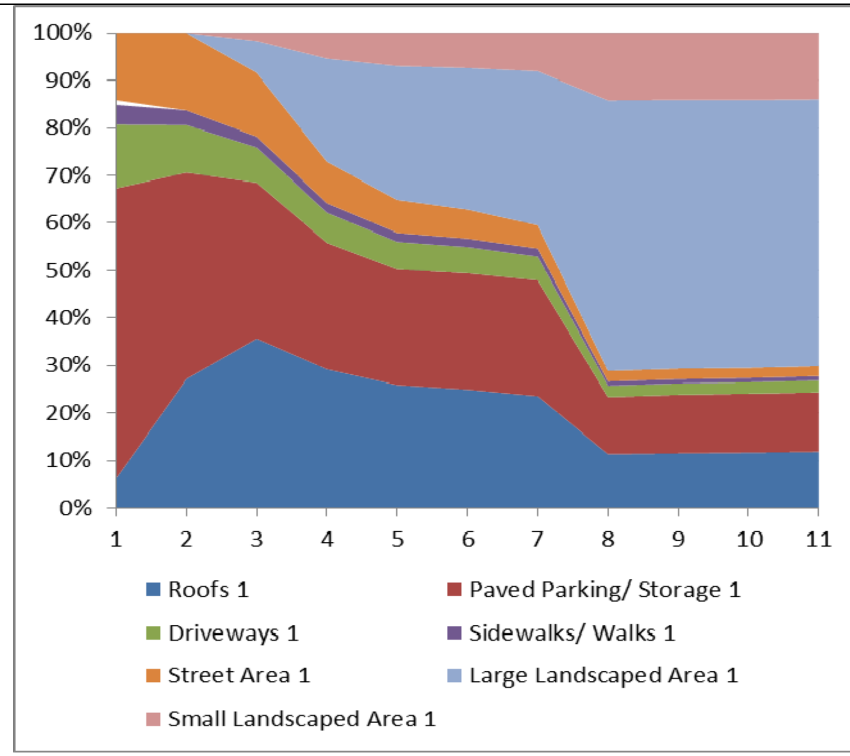
Commercial – Strip Mall Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



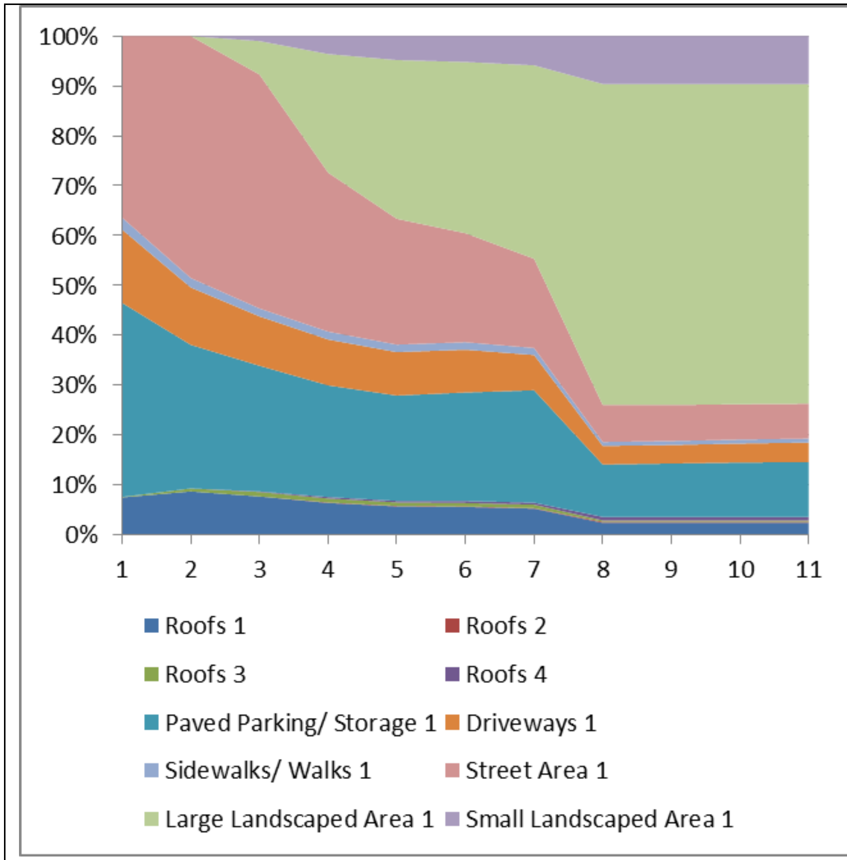
Commercial – Shopping Center Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



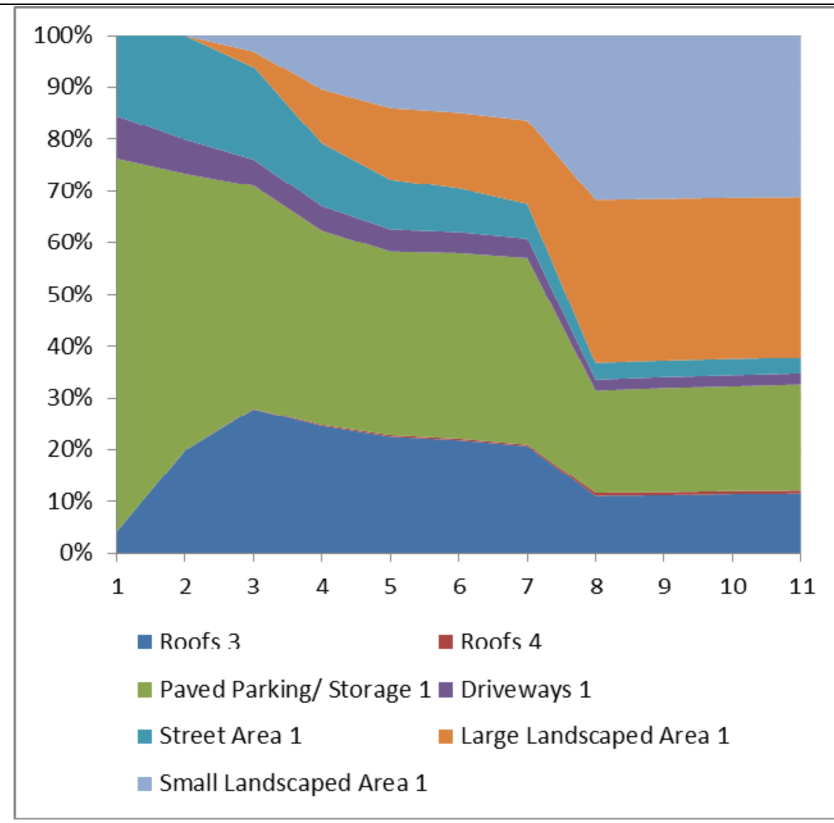
Light Industrial Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



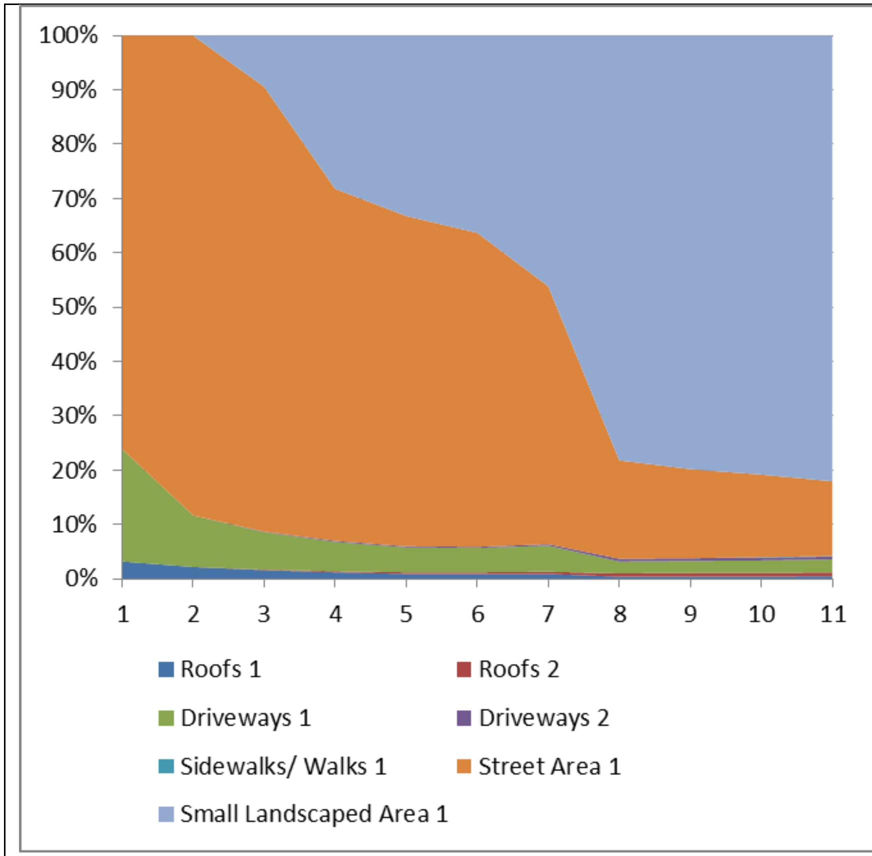
Institutional - School Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



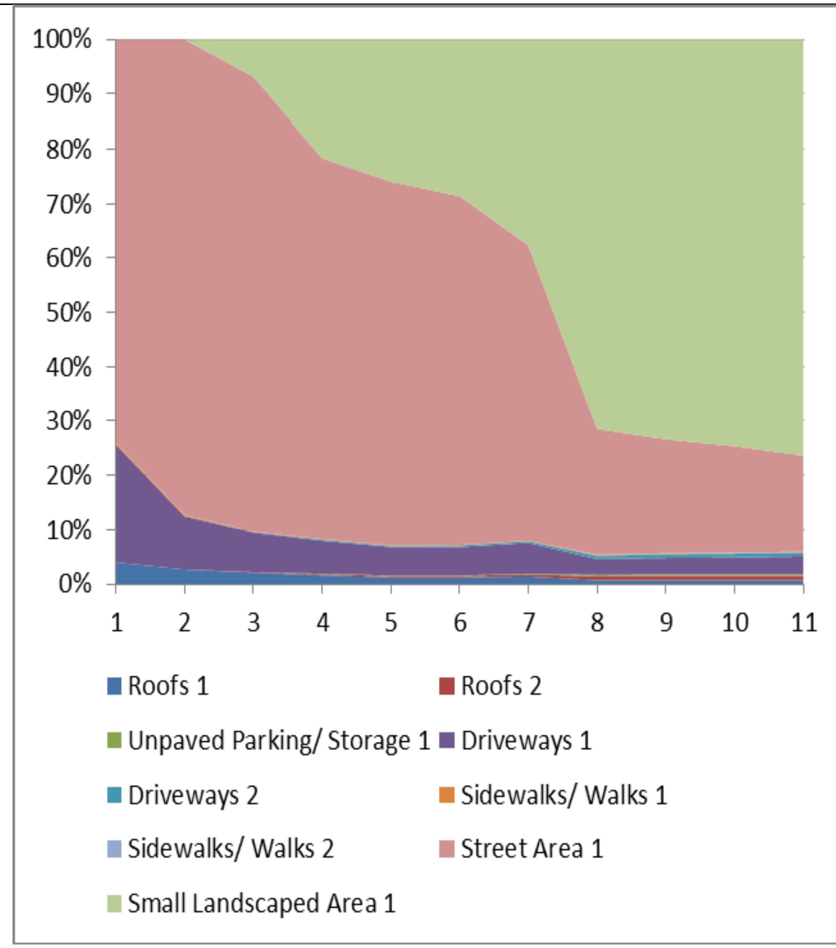
Institutional – Church Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



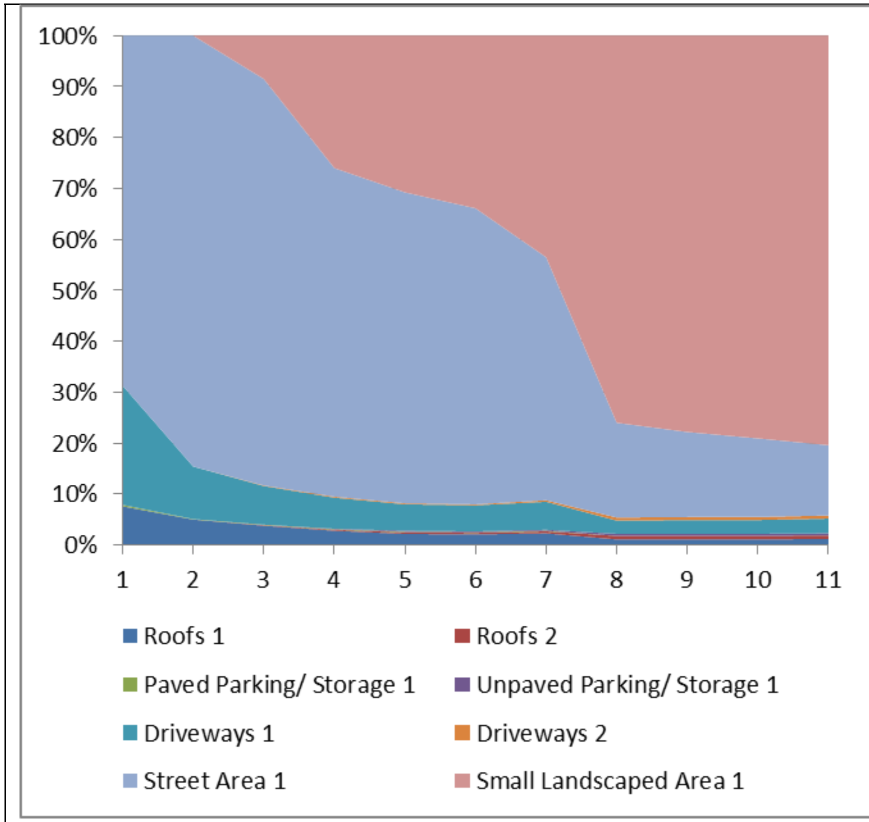
Institutional - Hospital Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

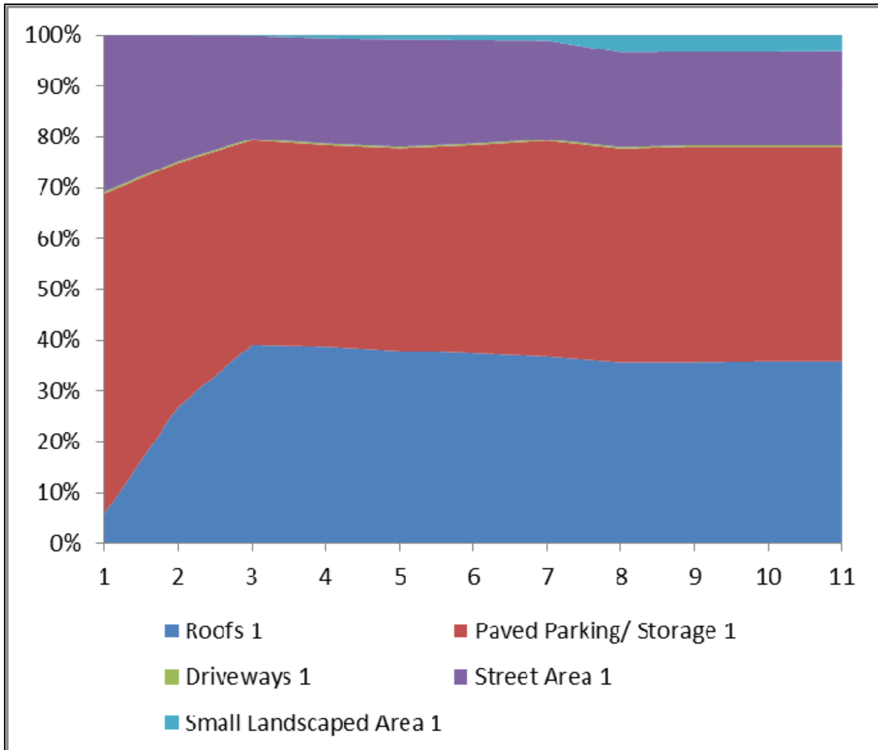


Medium Density Residential Area (<1960) TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

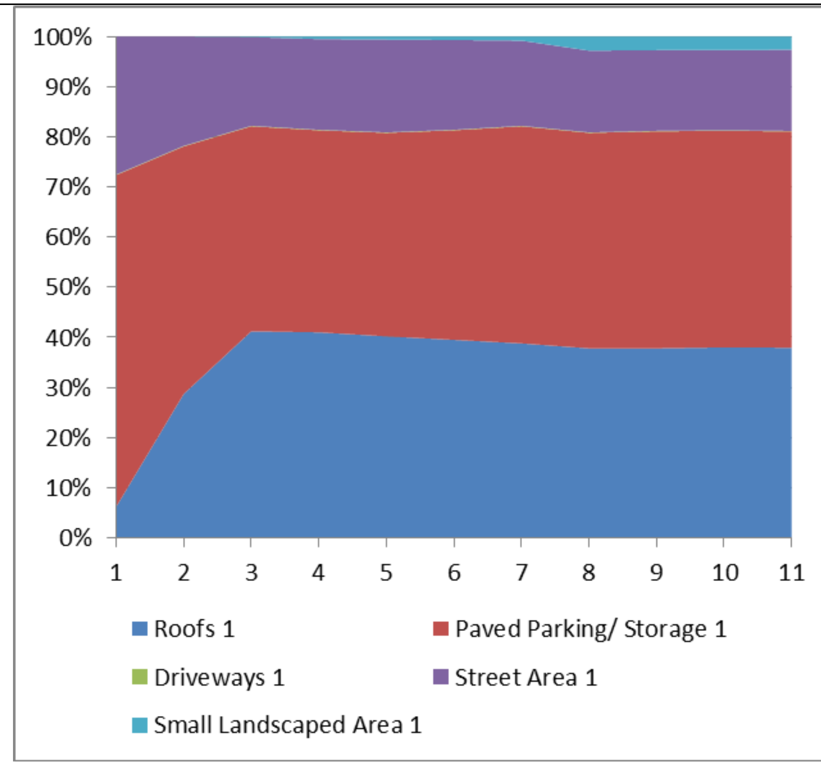


Medium Density Residential Area (1960 - 1980) TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

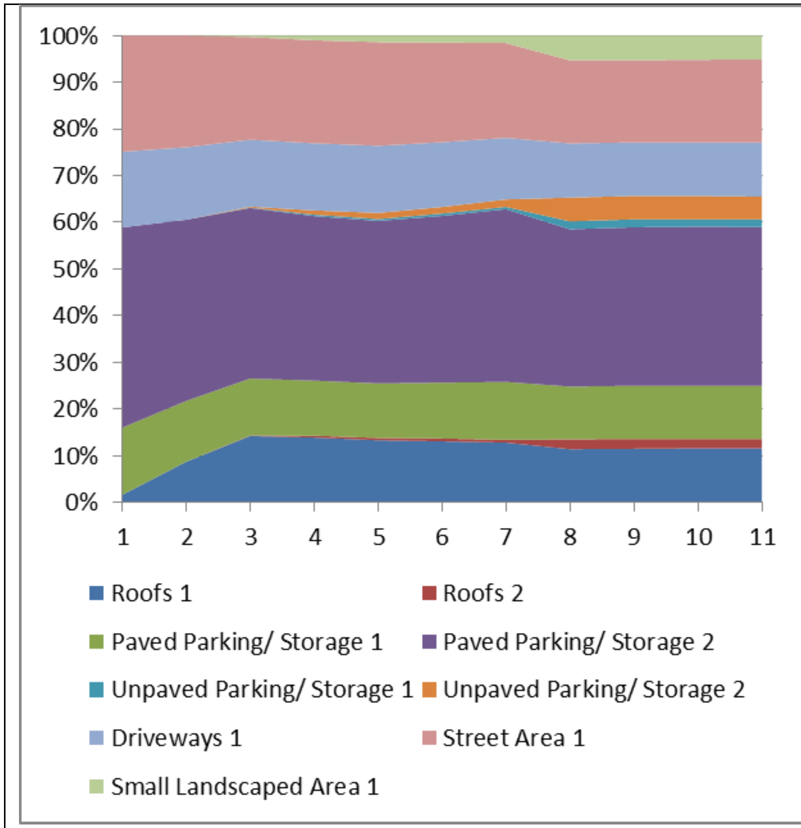
Nitrite plus Nitrate Mass Contributions



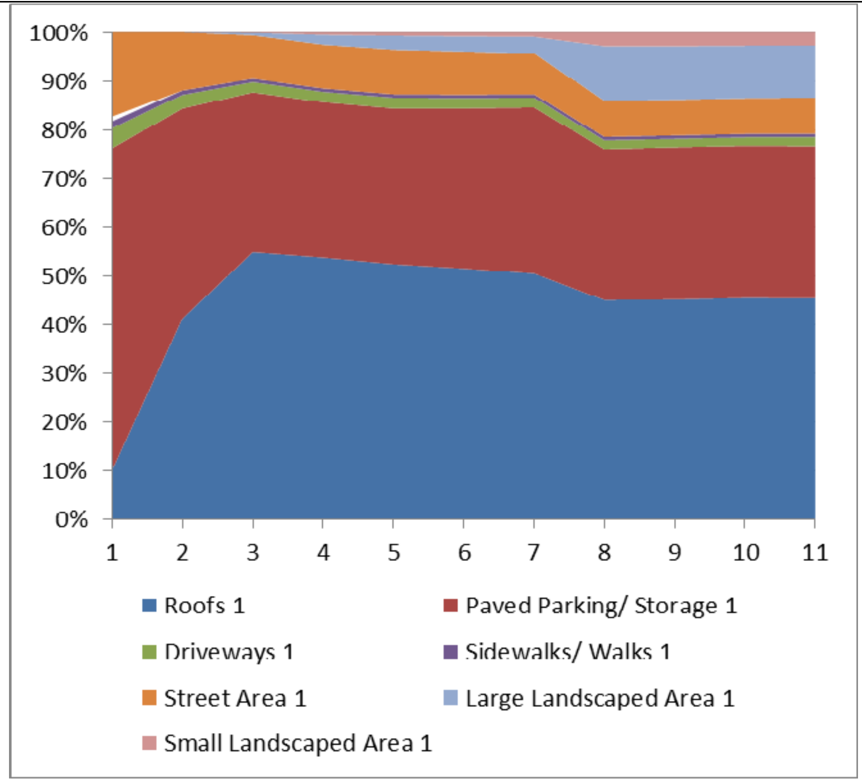
Commercial – Strip Mall Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



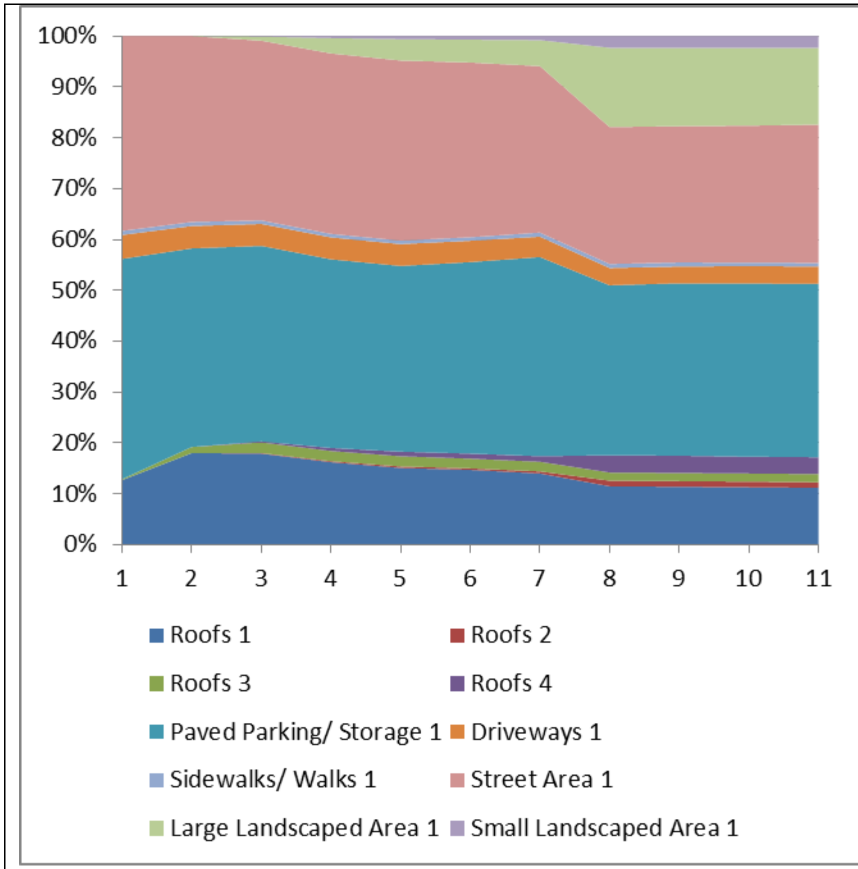
Commercial – Shopping Center Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



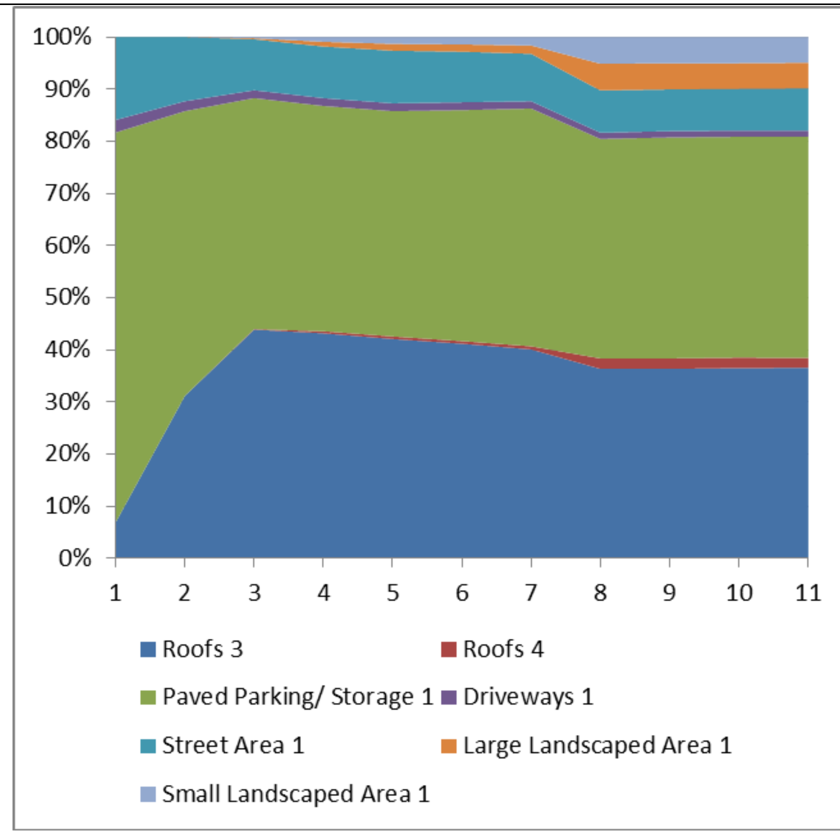
Light Industrial Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



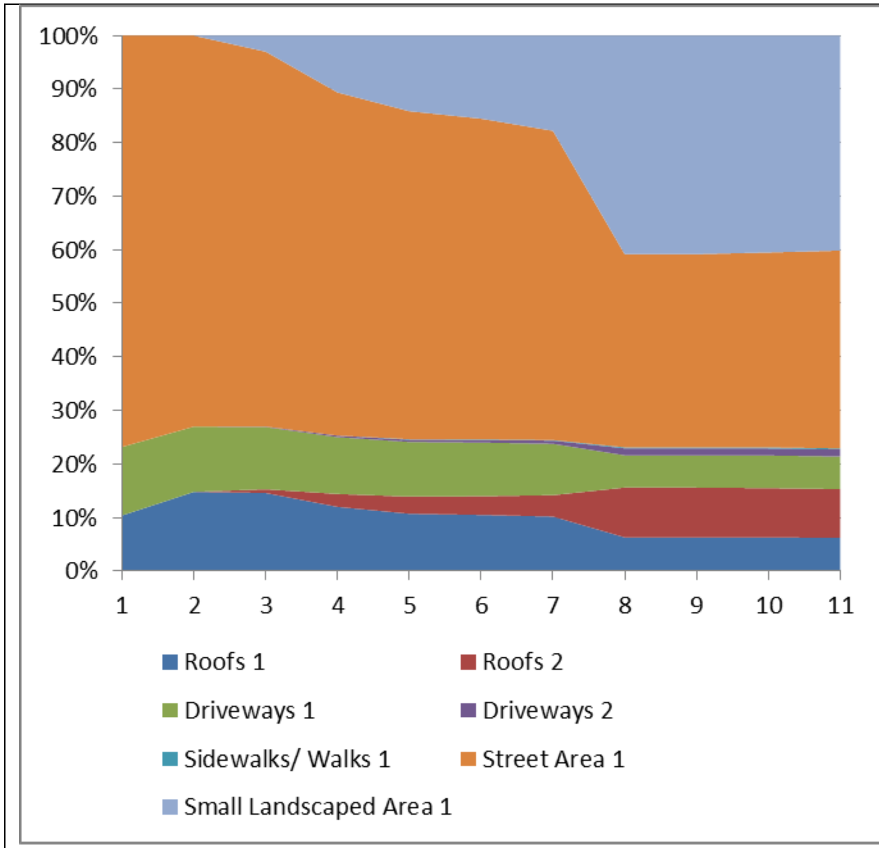
Institutional - School Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



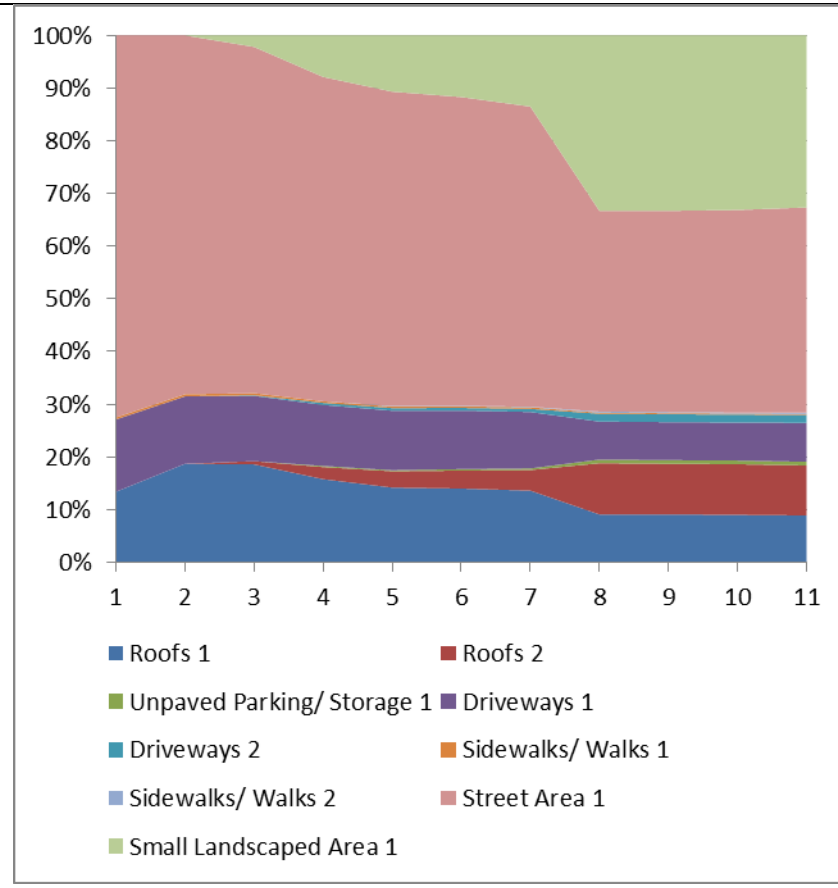
Institutional – Church Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



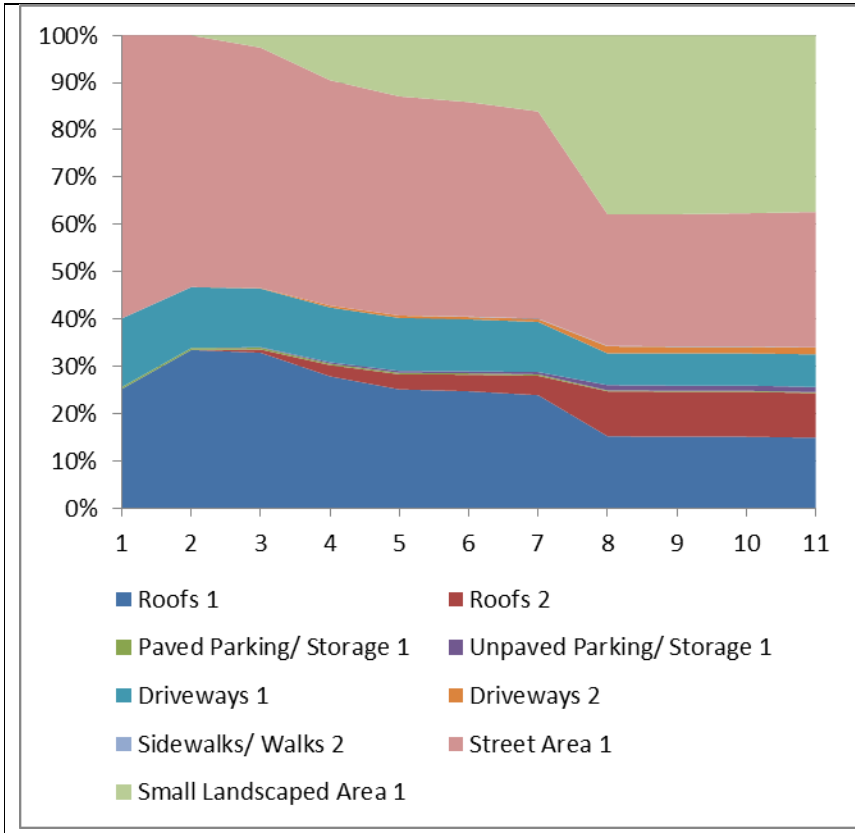
Institutional - Hospital Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



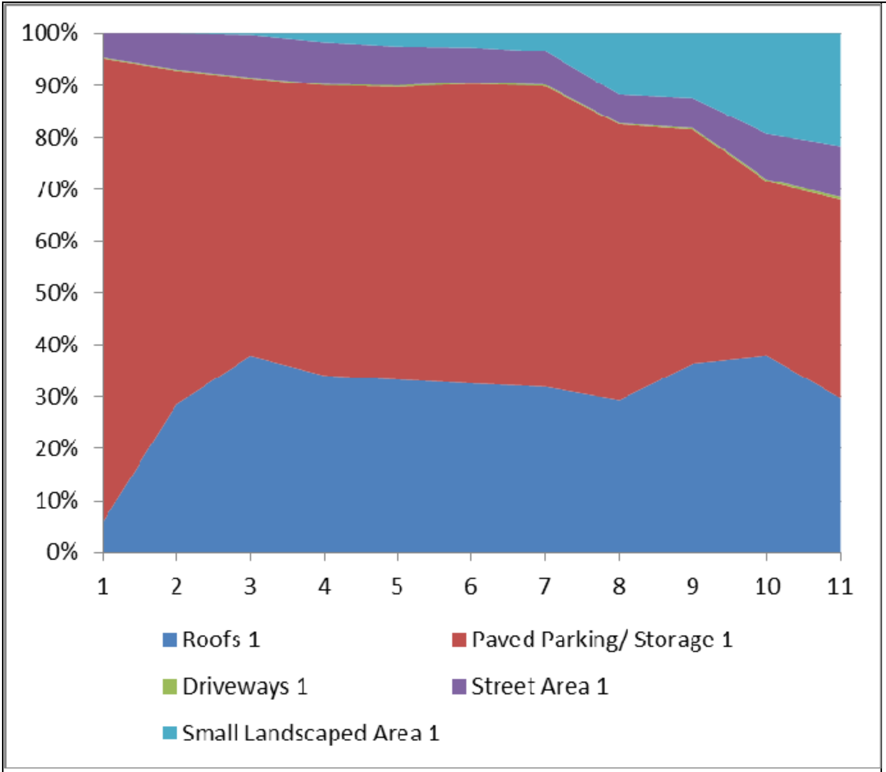
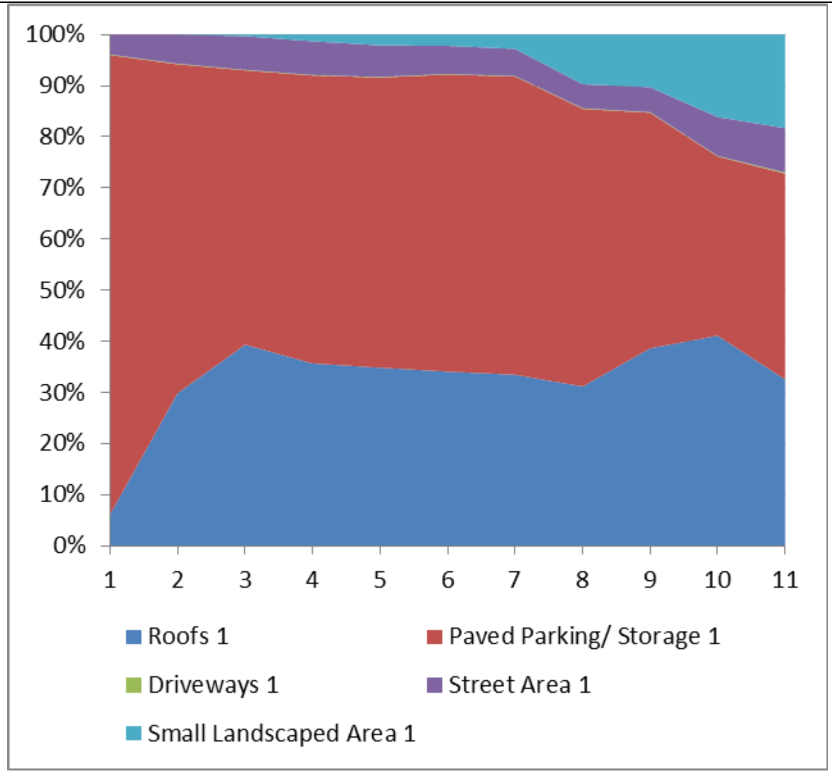
Medium Density Residential Area (<1960) NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

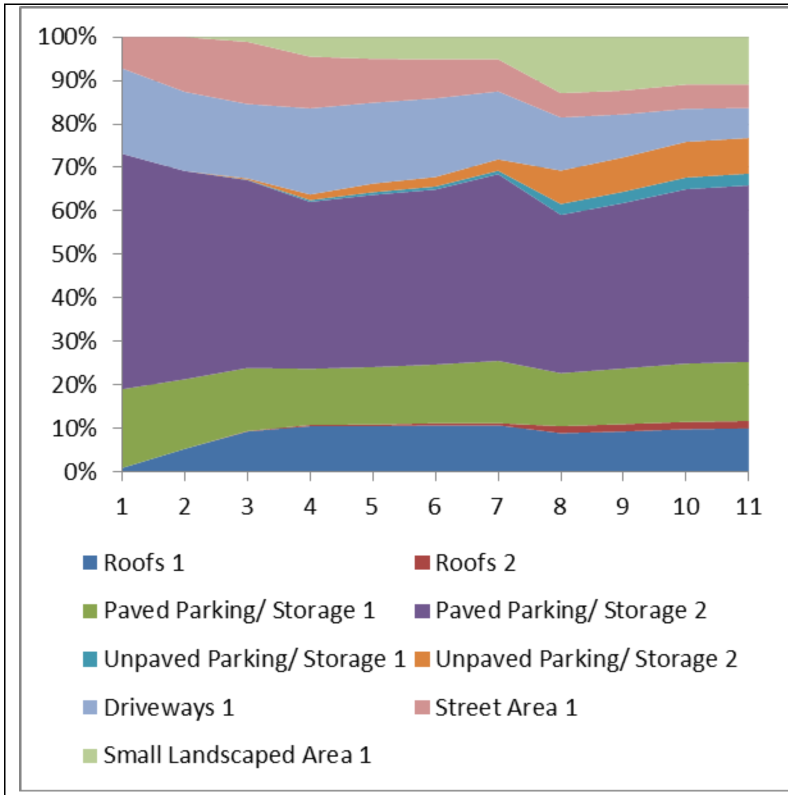


Medium Density Residential Area (1960 - 1980) NO_2+NO_3 Contributions

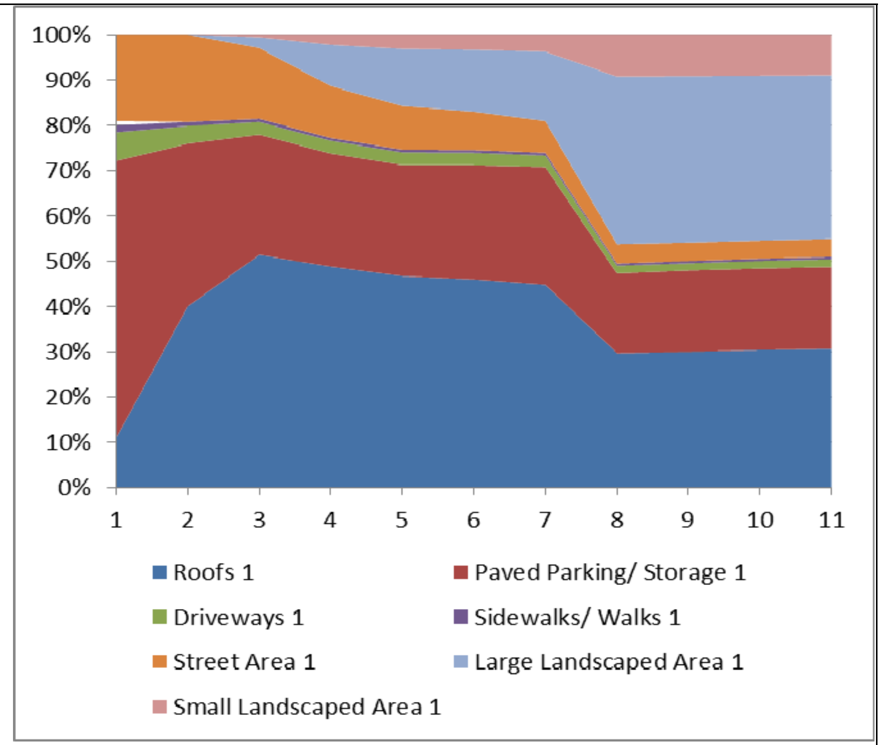
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

Total Kjeldahl Nitrogen Mass Contributions

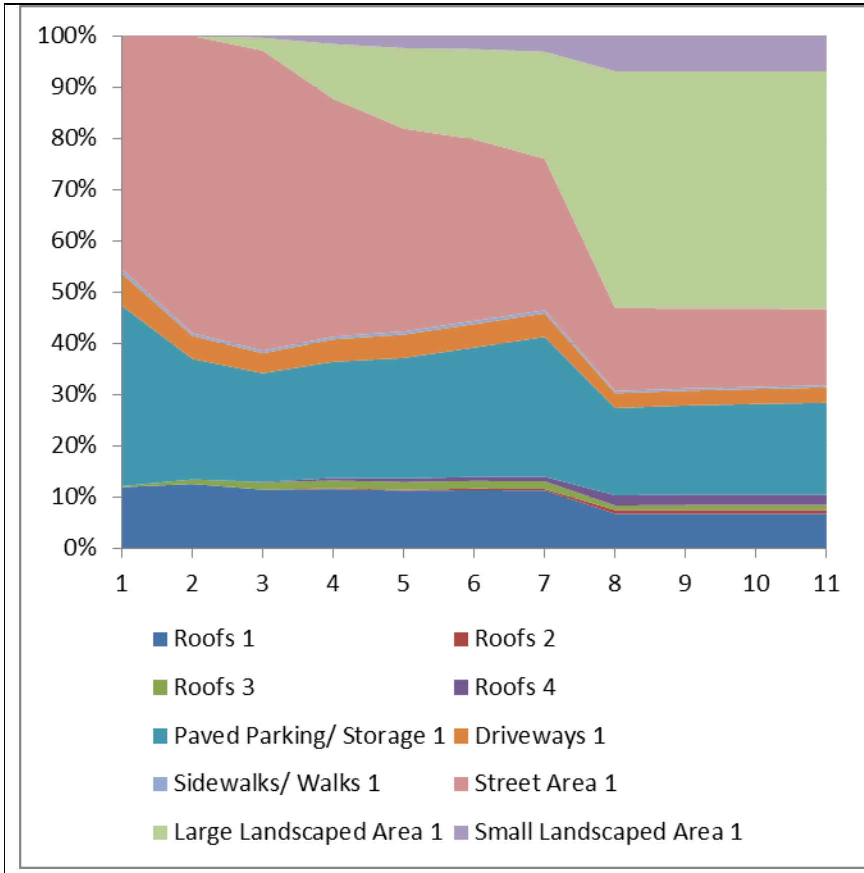
	
Commercial – Strip Mall Area TKN Contributions Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”	Commercial – Shopping Center Area TKN Contributions Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



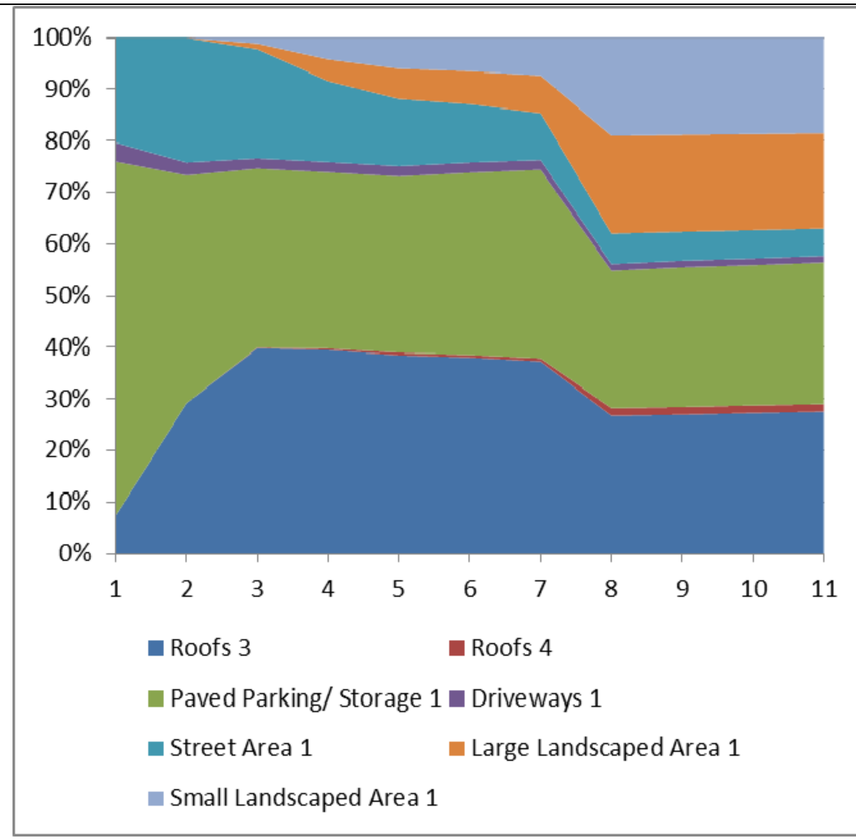
Light Industrial Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



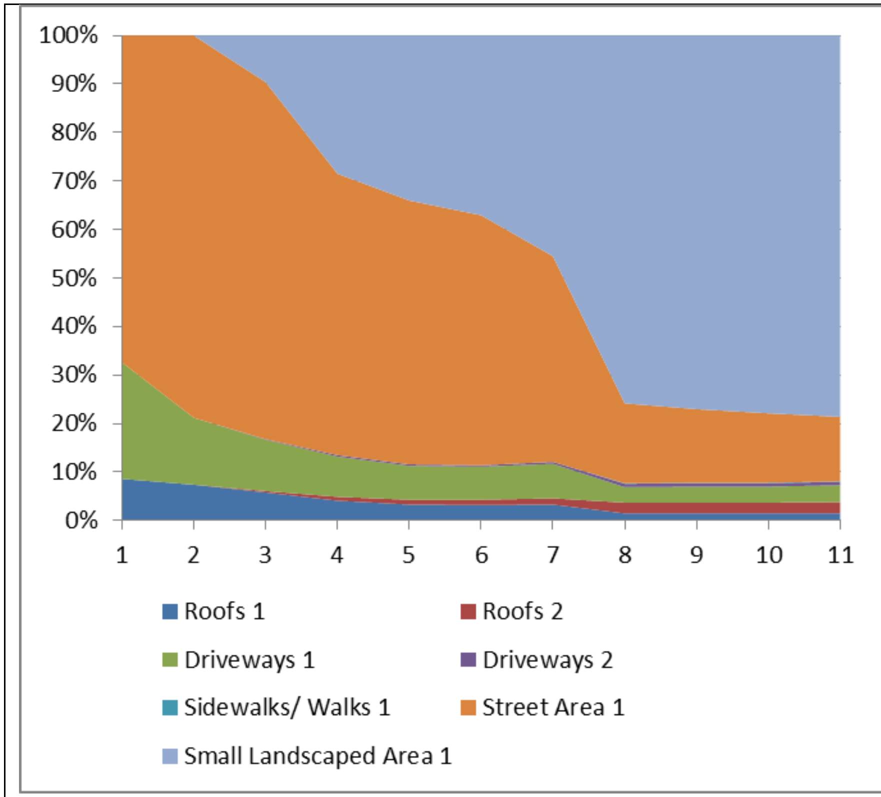
Institutional - School Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



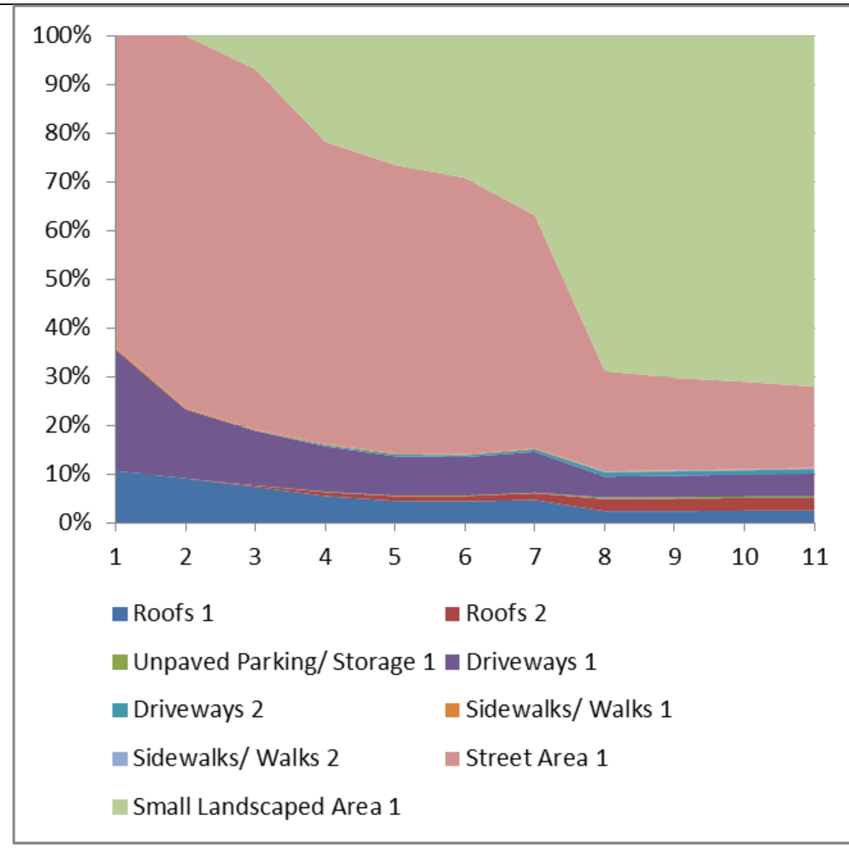
Institutional – Church Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



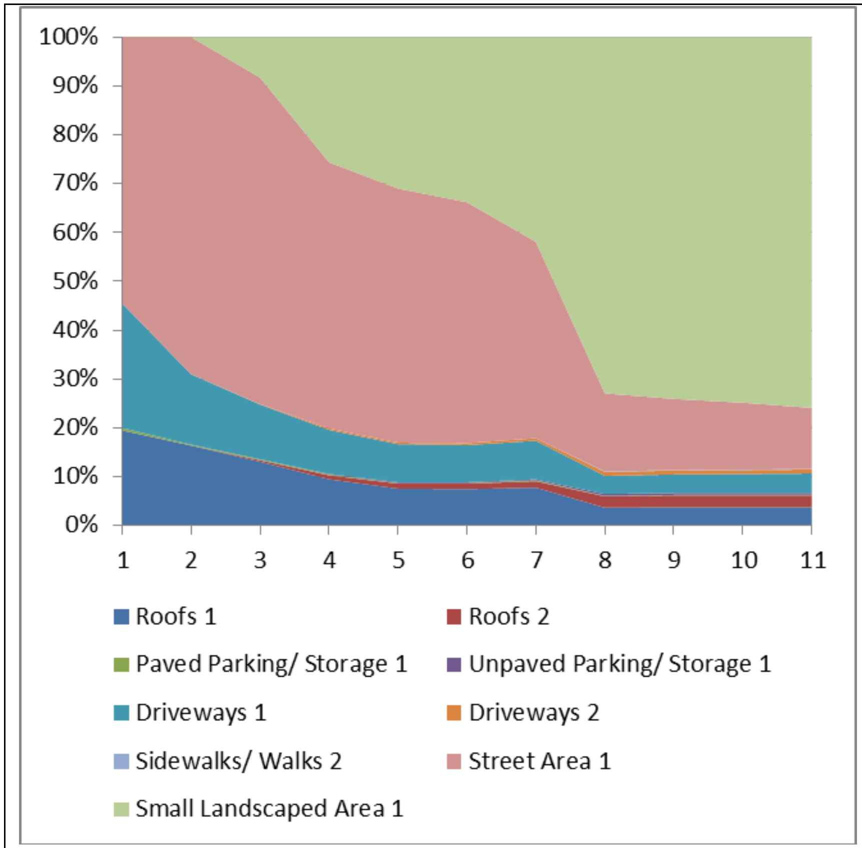
Institutional - Hospital Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

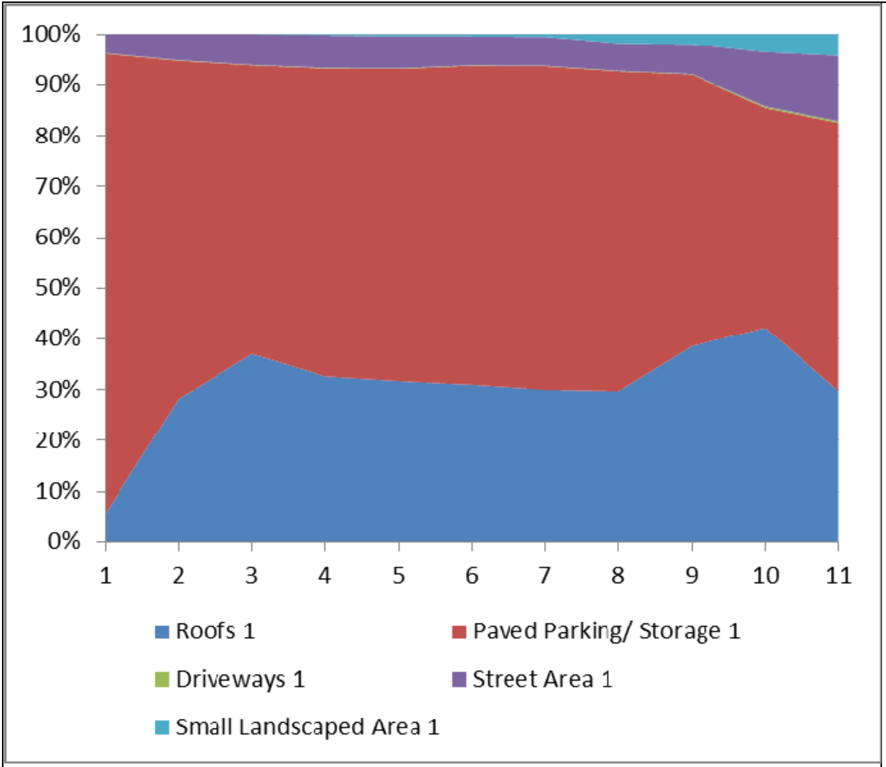


Medium Density Residential Area (<1960) TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

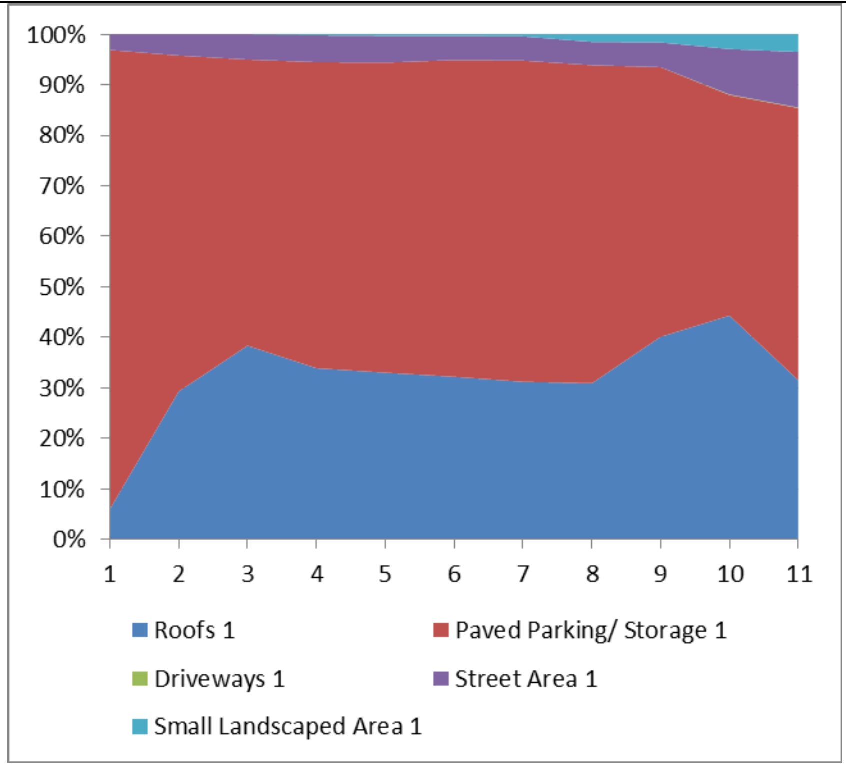


Medium Density Residential Area (1960 - 1980) TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

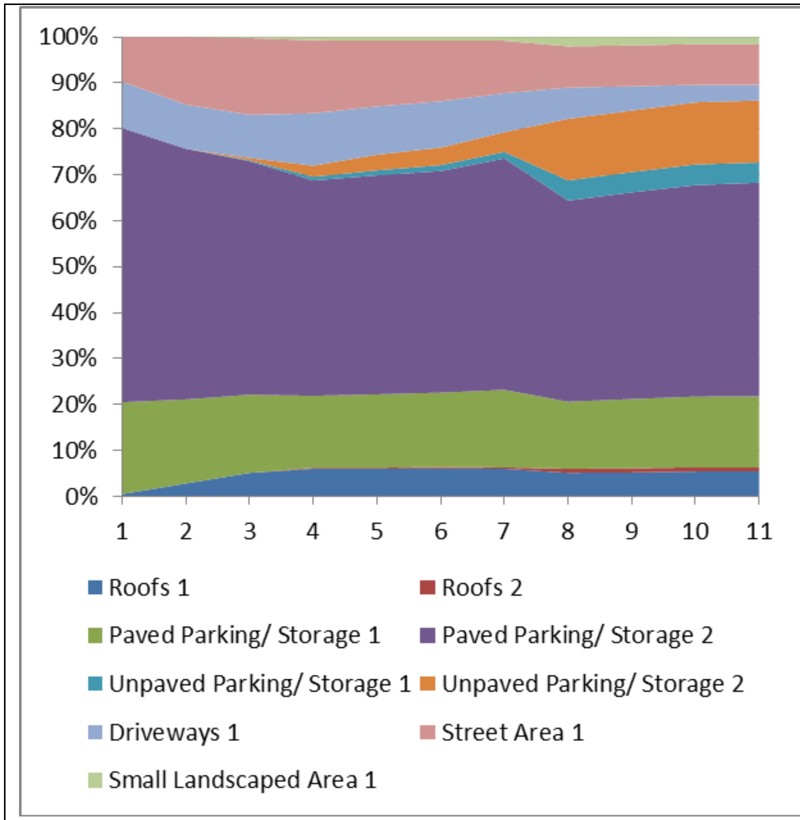
Chemical Oxygen Demand Mass Contributions



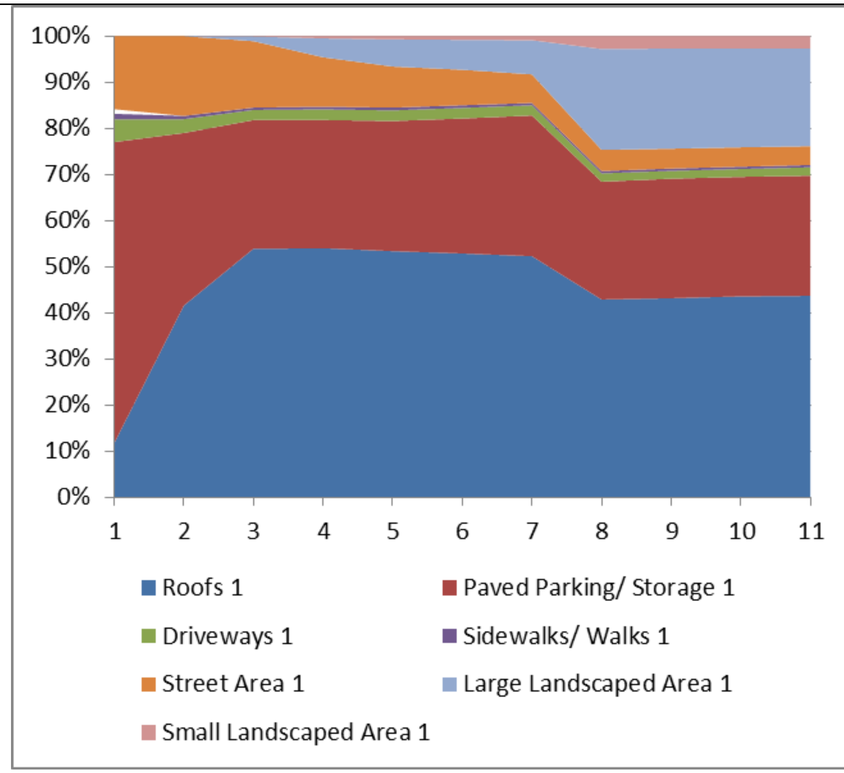
Commercial – Strip Mall Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



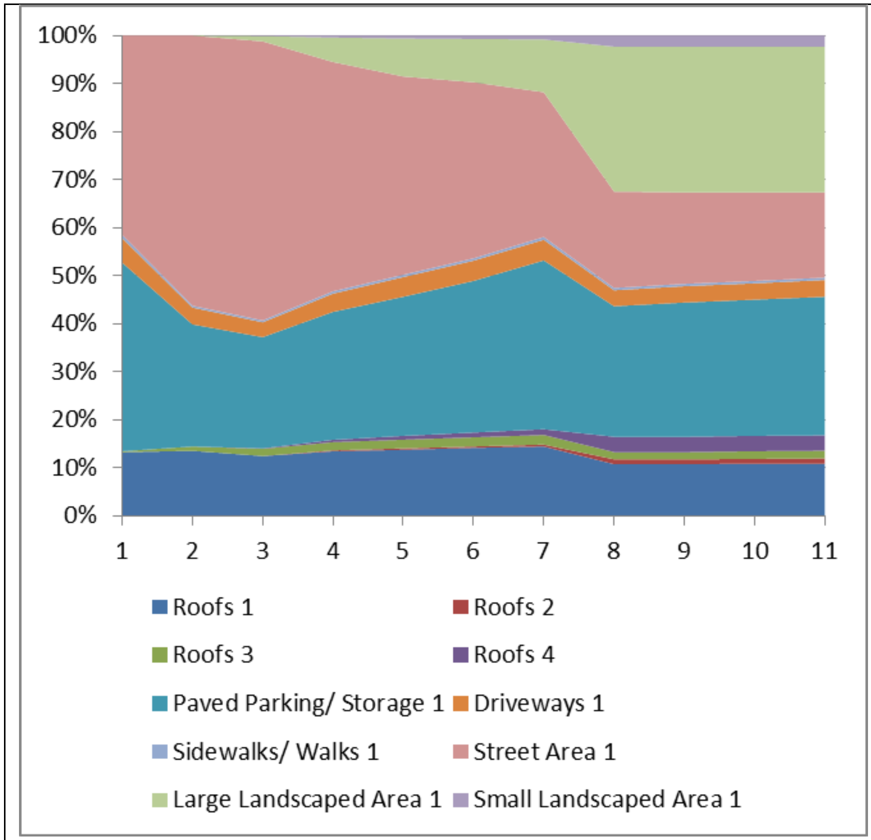
Commercial – Shopping Center Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



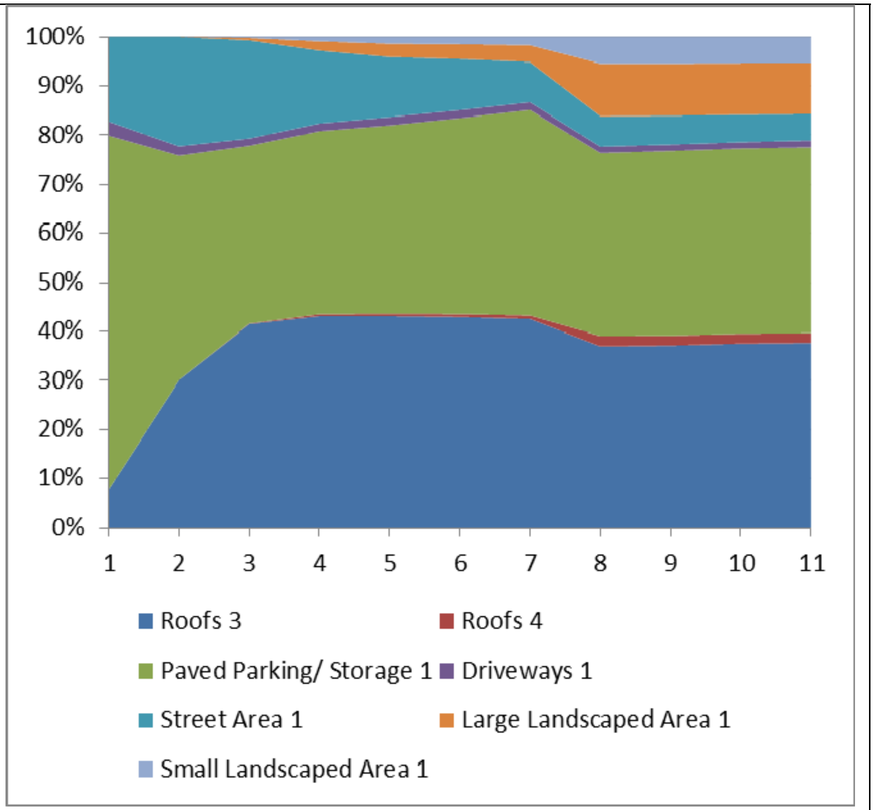
Light Industrial Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



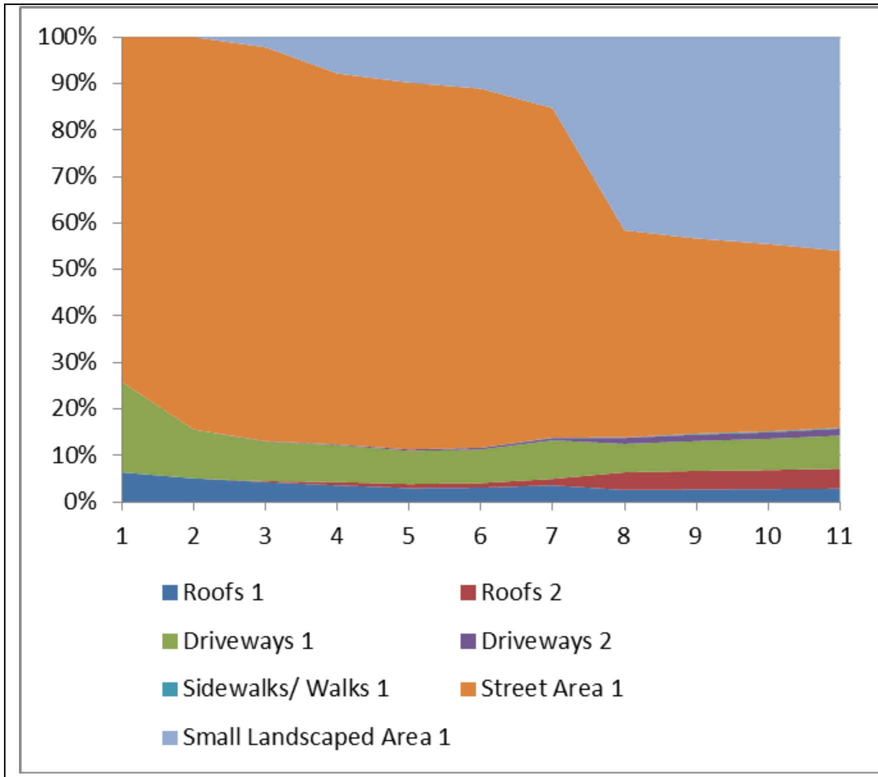
Institutional - School Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



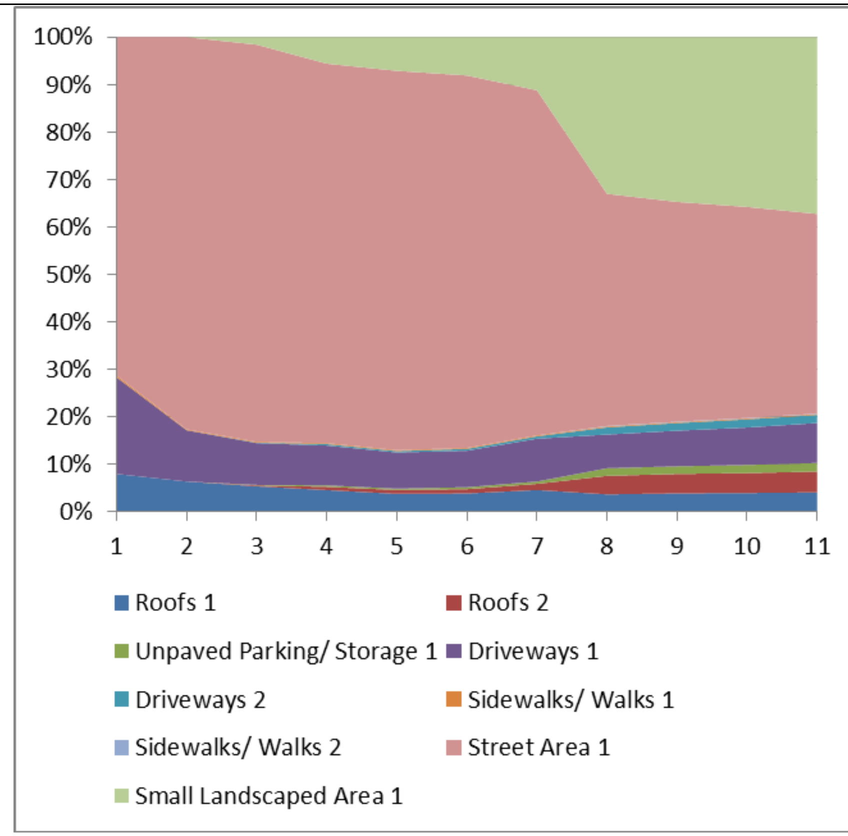
Institutional – Church Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



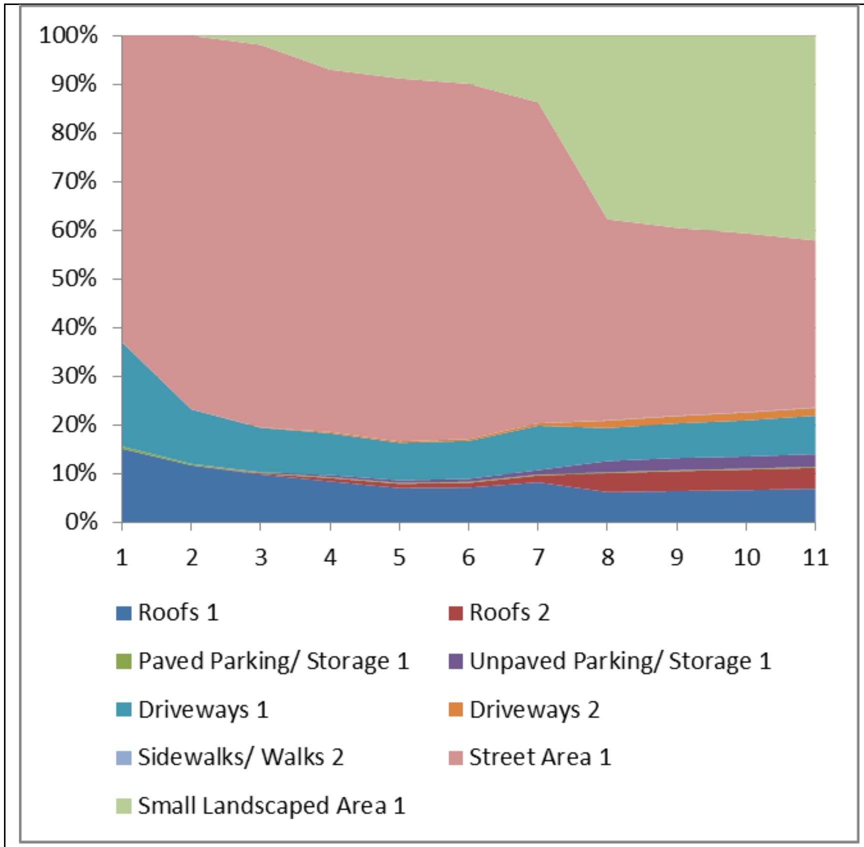
Institutional - Hospital Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”
”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

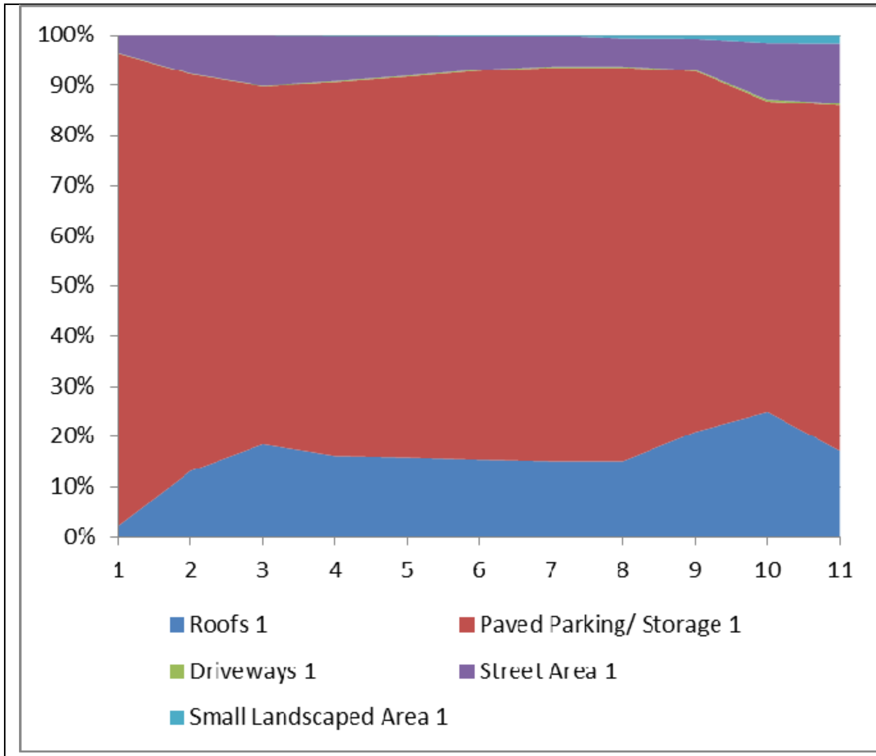


Medium Density Residential Area (<1960) COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

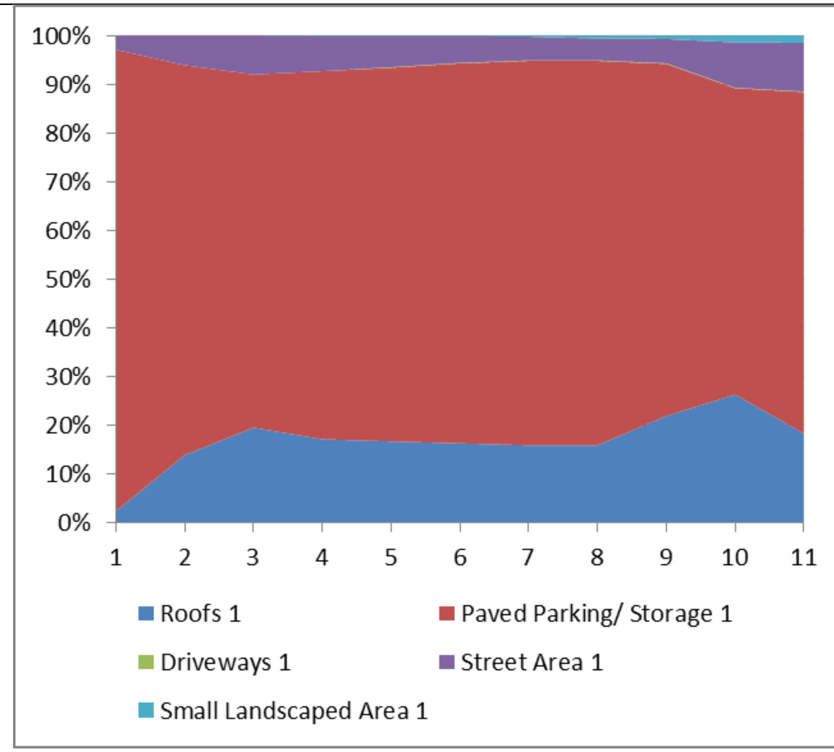


Medium Density Residential Area (1960 - 1980) COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

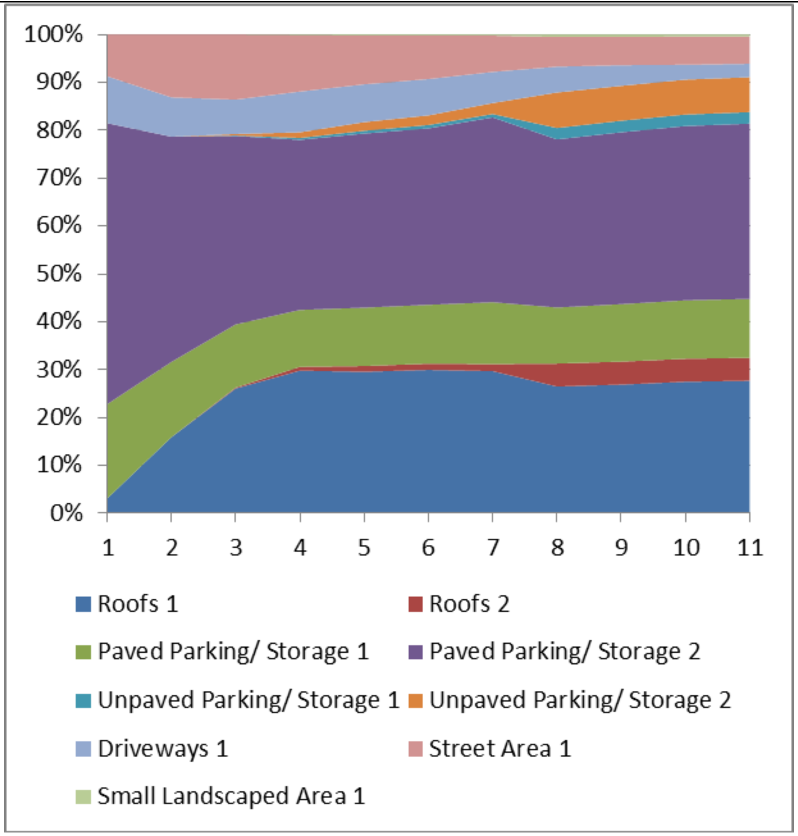
Total Copper Mass Contributions



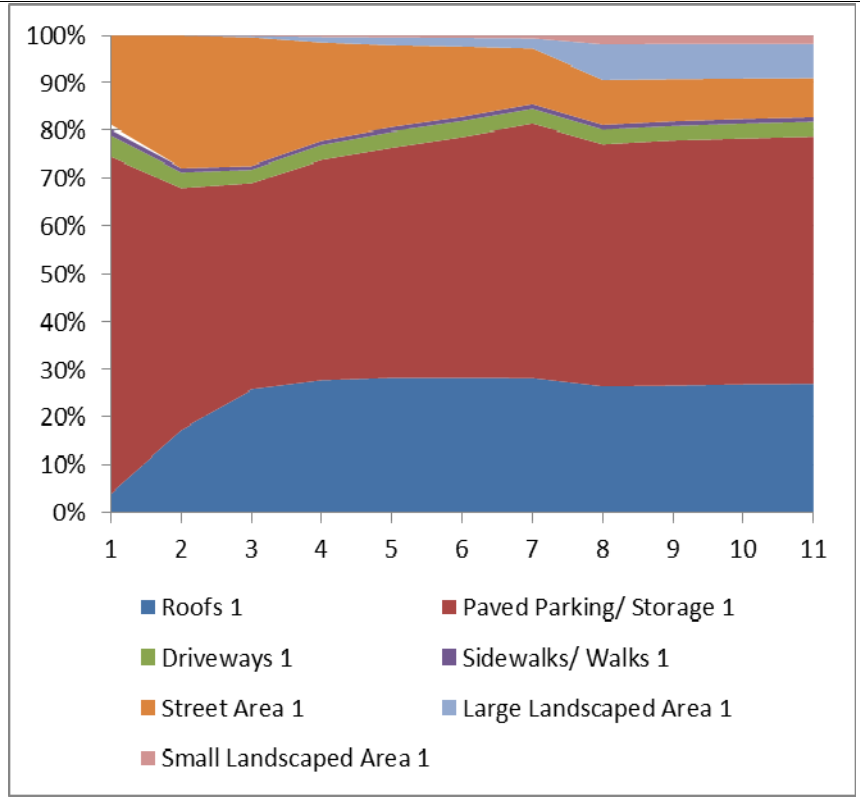
Commercial – Strip Mall Area Cu Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



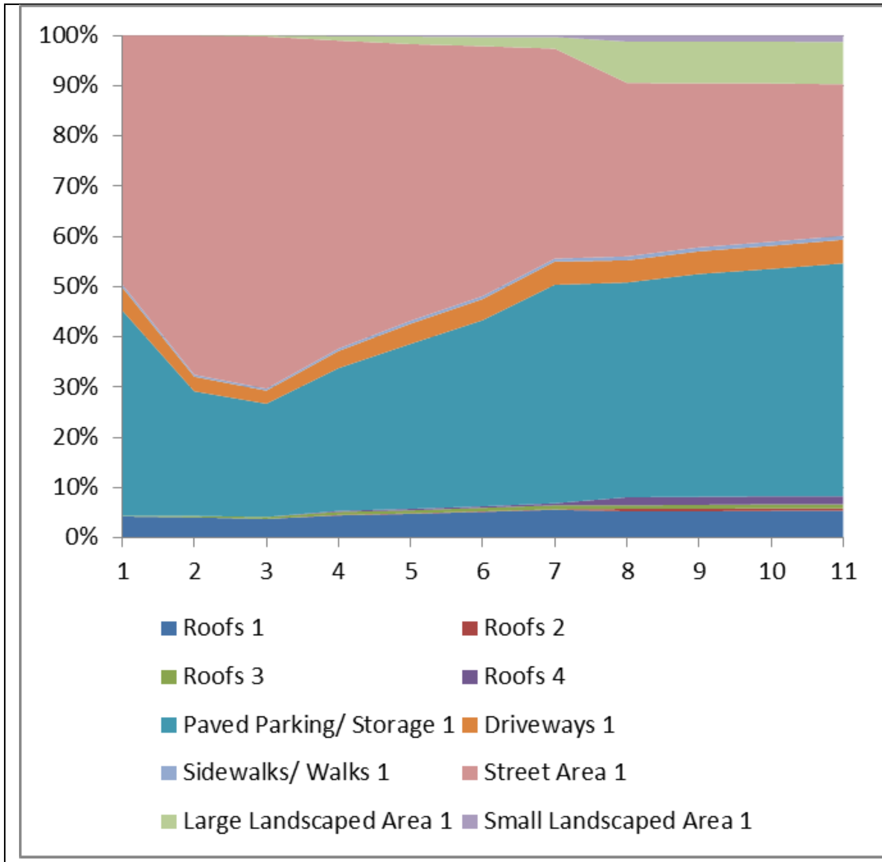
Commercial – Shopping Center Area Cu Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



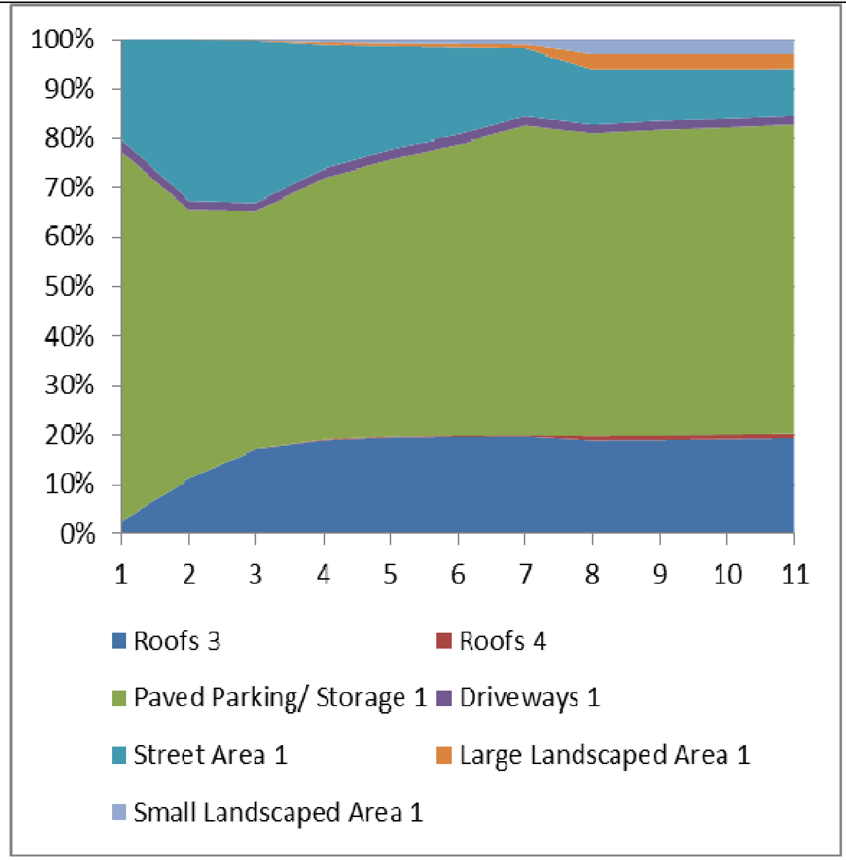
Light Industrial Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



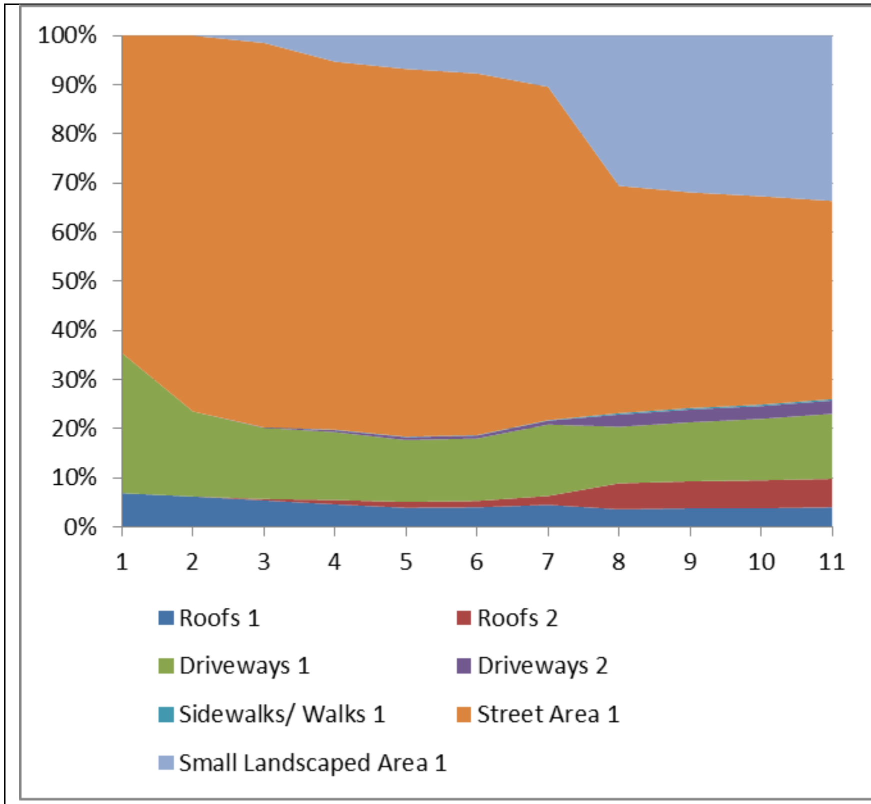
Institutional - School Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



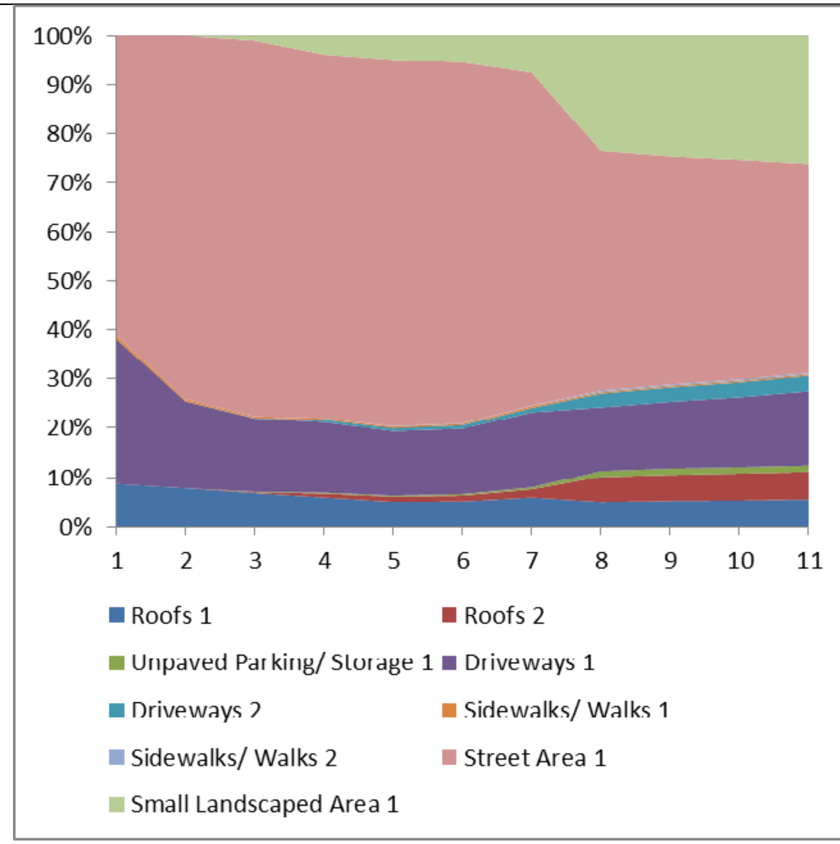
Institutional – Church Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



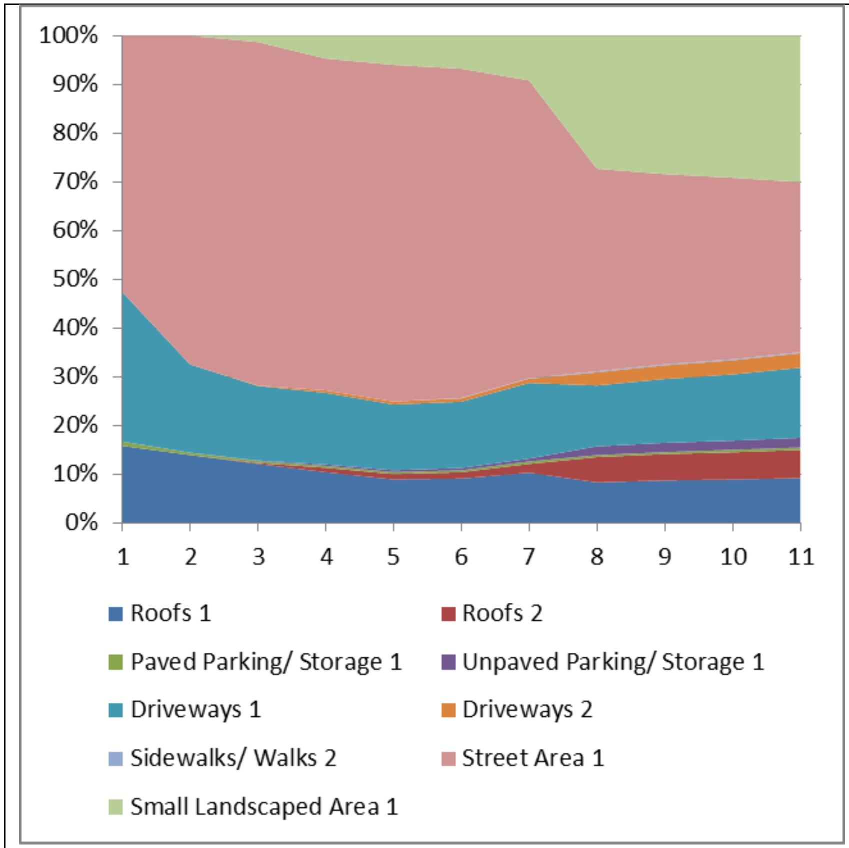
Institutional - Hospital Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

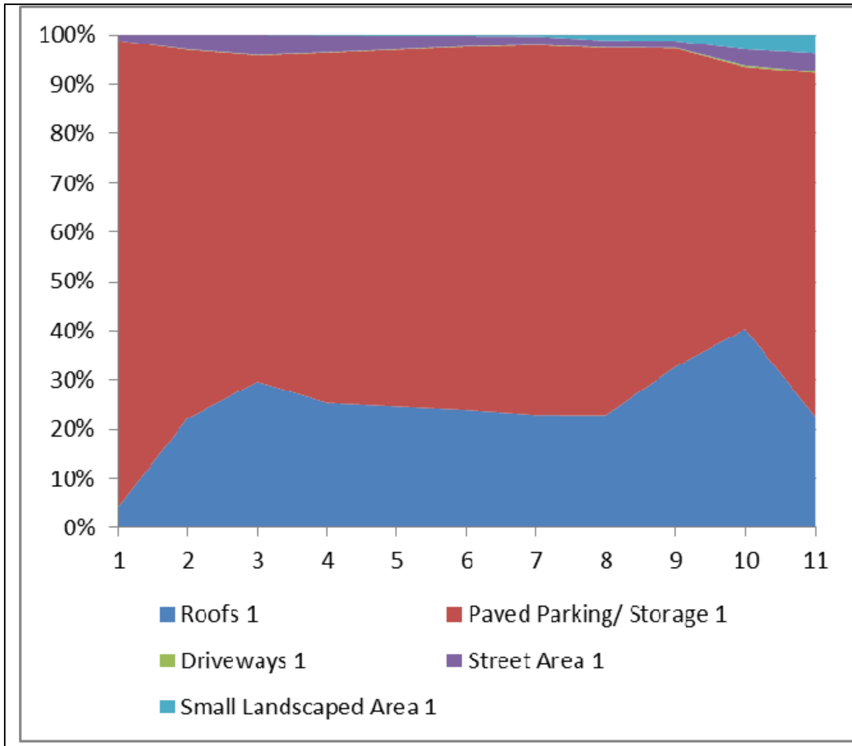


Medium Density Residential Area (<1960) Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

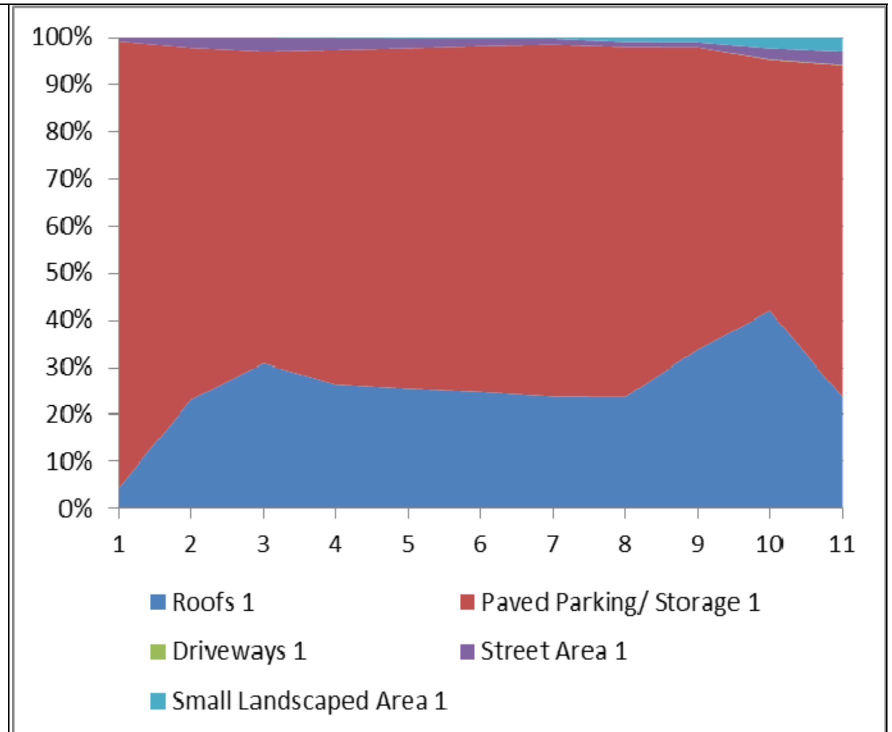


Medium Density Residential Area (1960 - 1980) Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

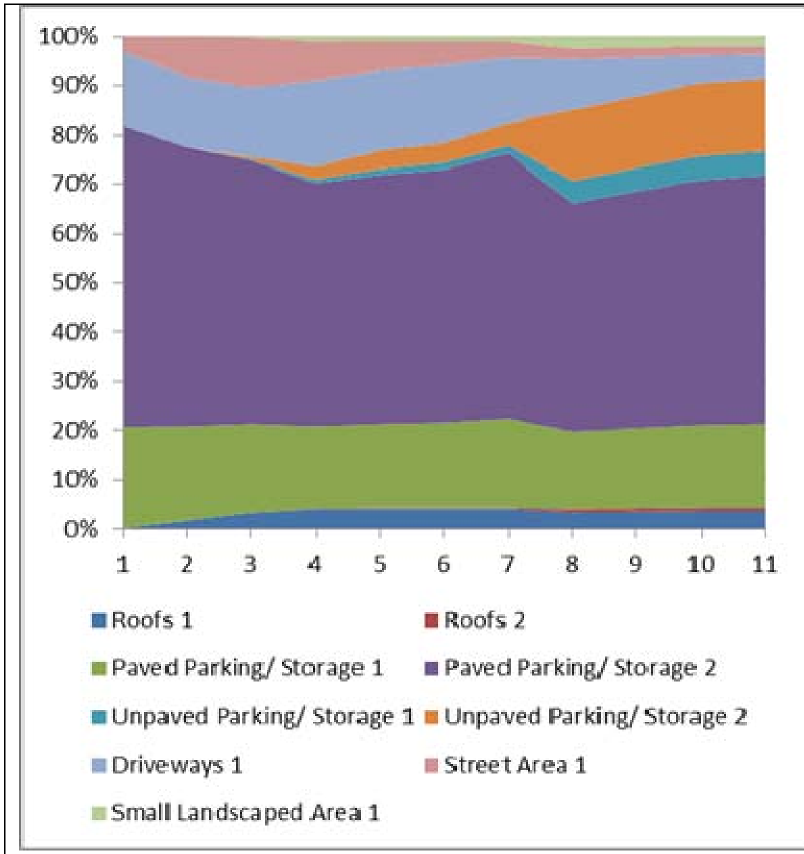
Total Lead Mass Contributions



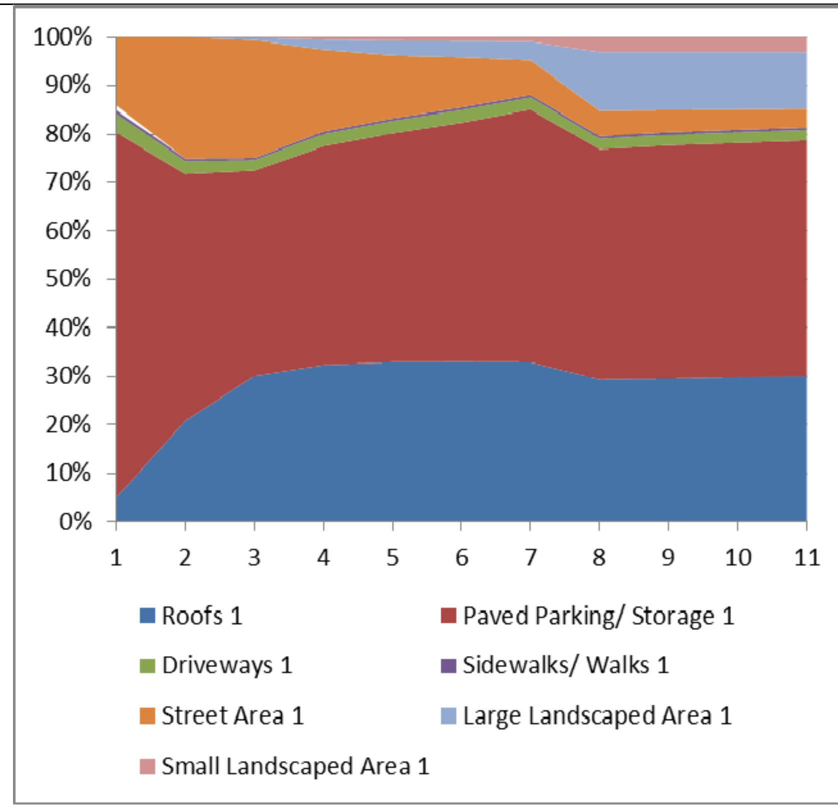
Commercial – Strip Mall Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



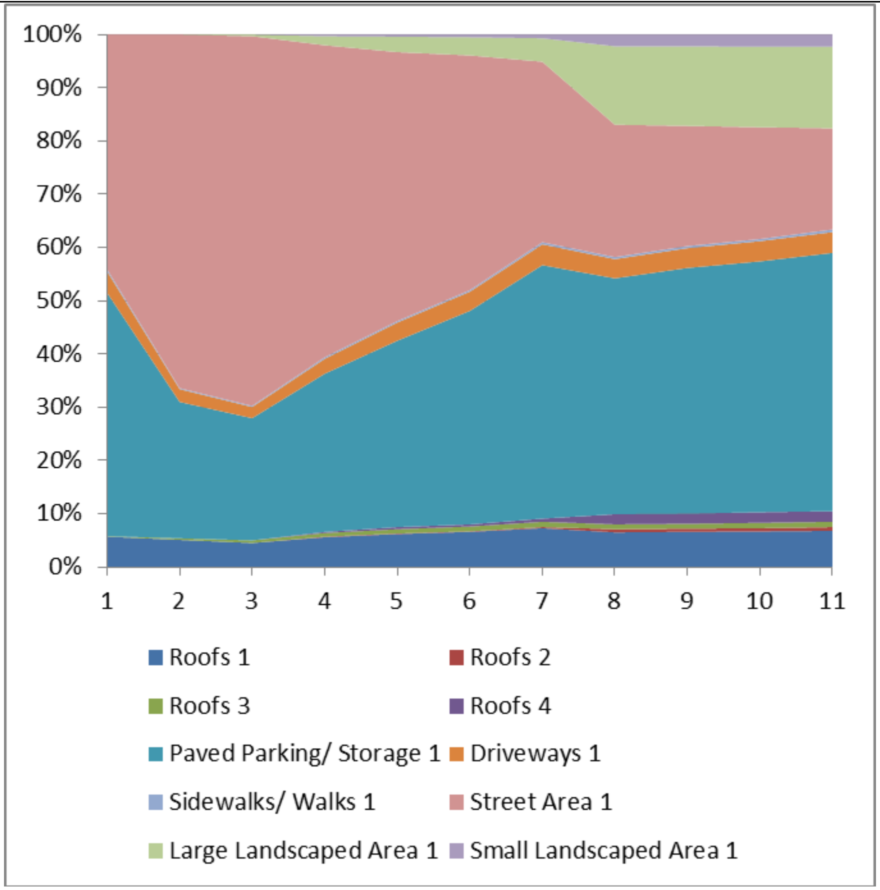
Commercial – Shopping Center Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



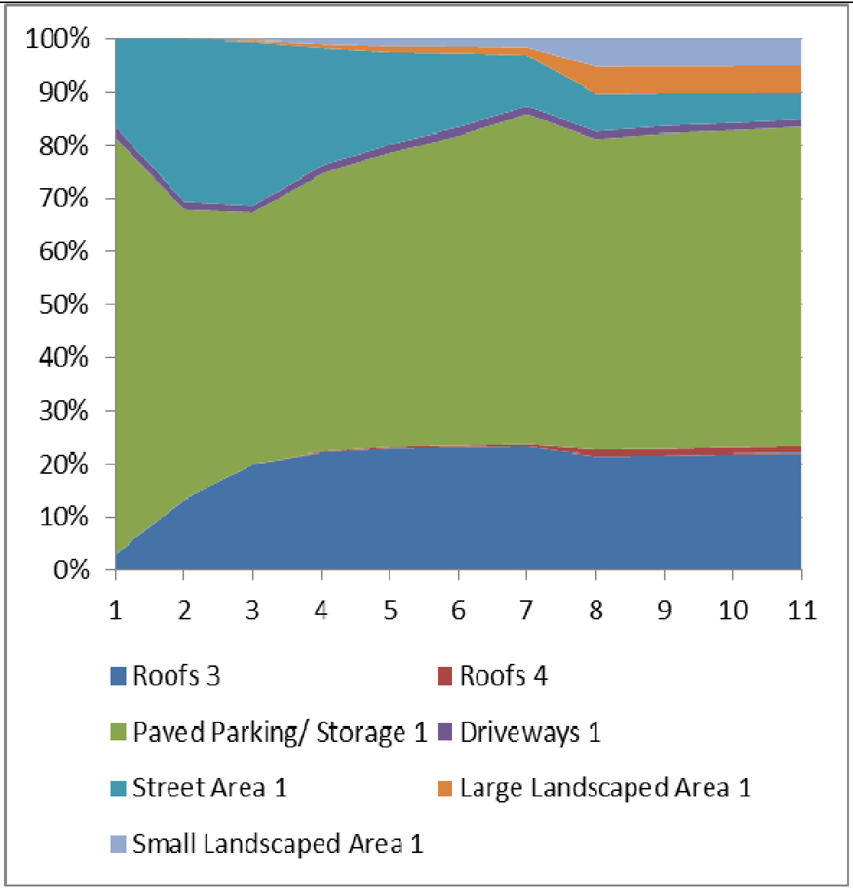
Light Industrial Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



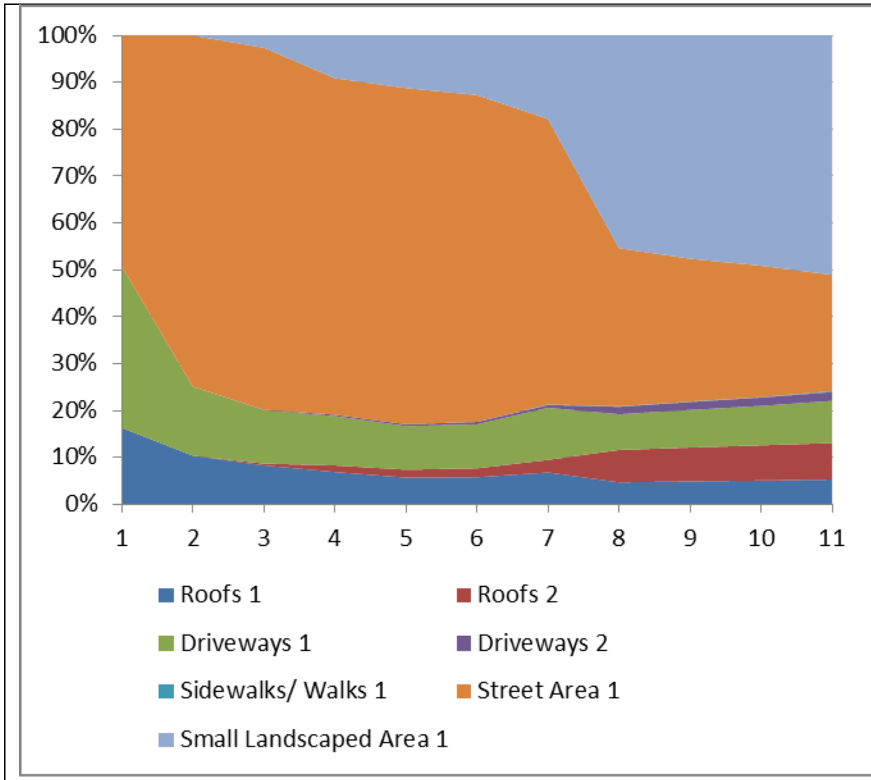
Institutional - School Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



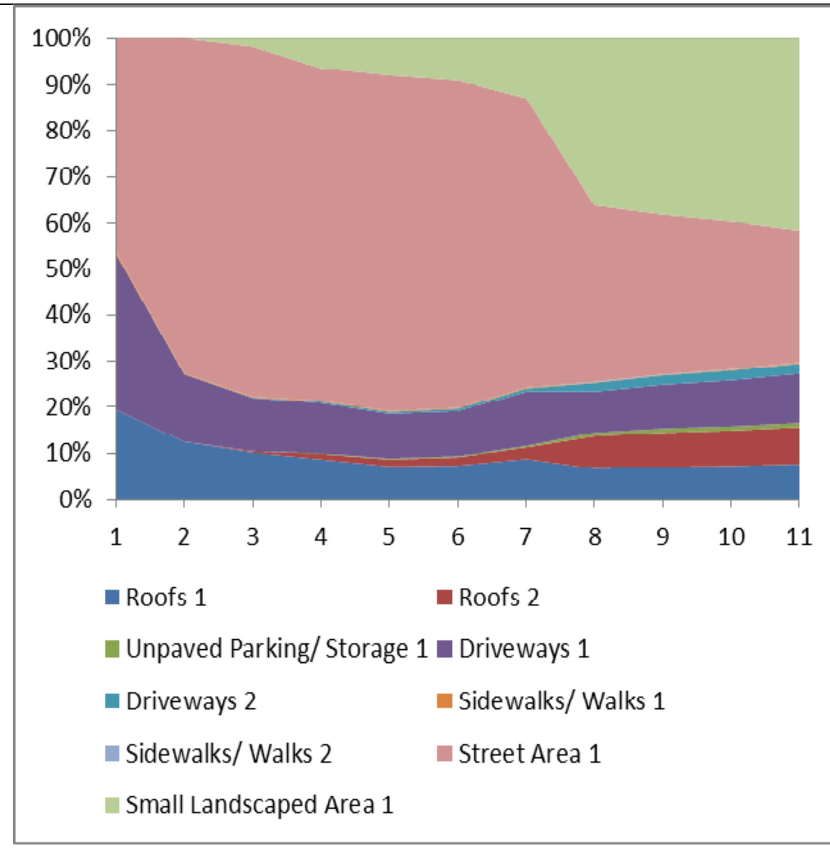
Institutional – Church Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



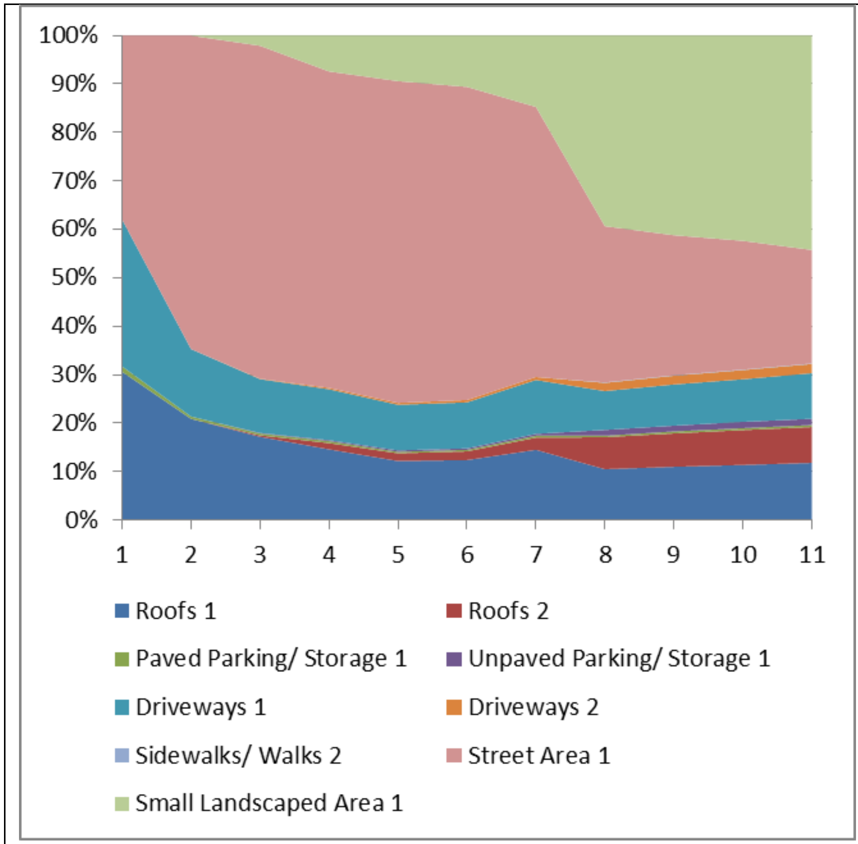
Institutional - Hospital Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

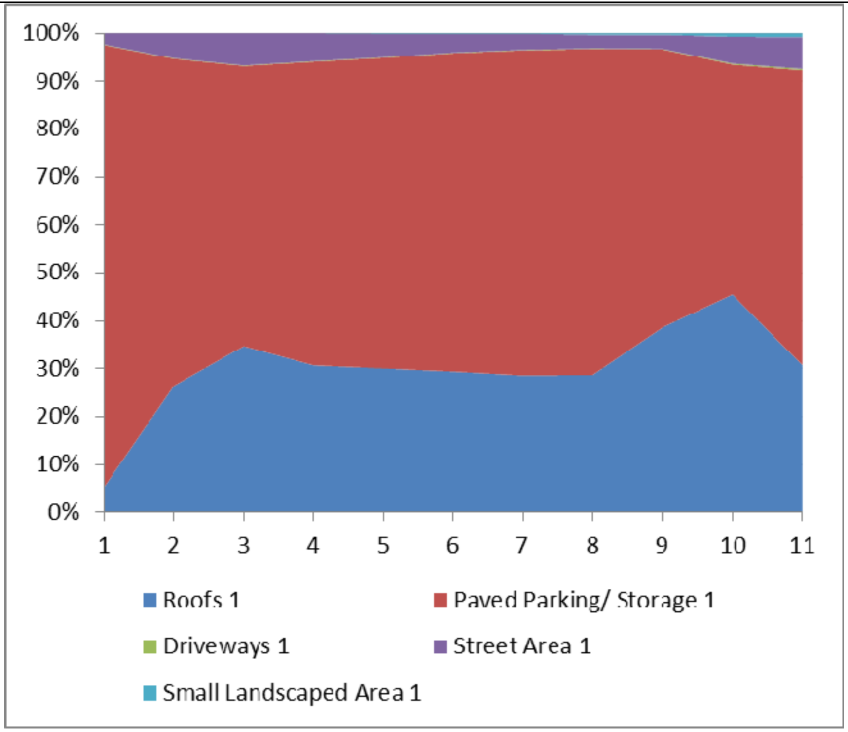


Medium Density Residential Area (<1960) Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

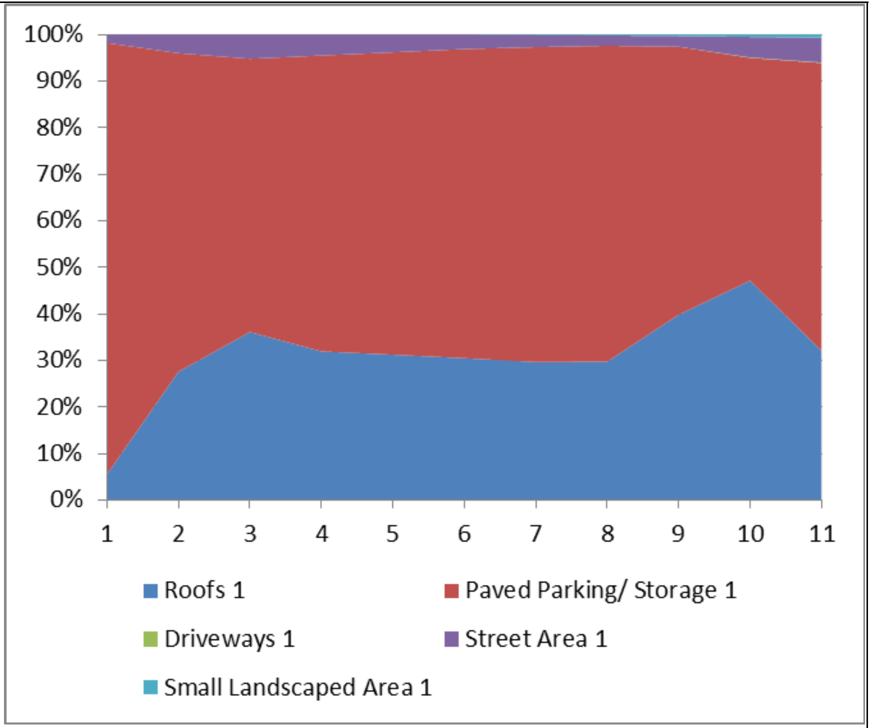


Medium Density Residential Area (1960 - 1980) Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

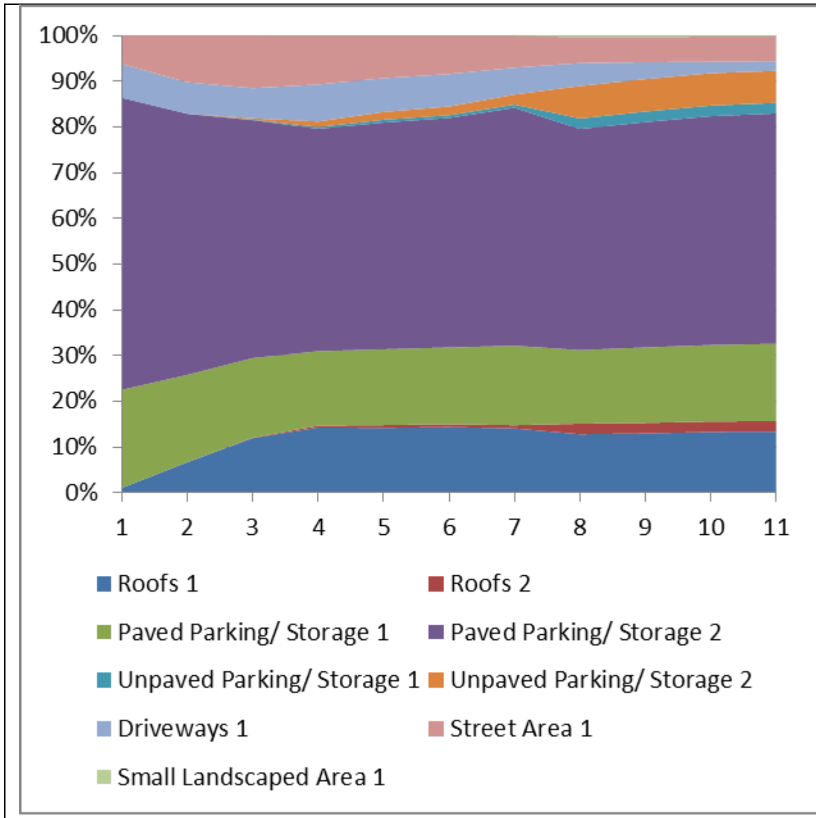
Total Zinc Mass Contributions



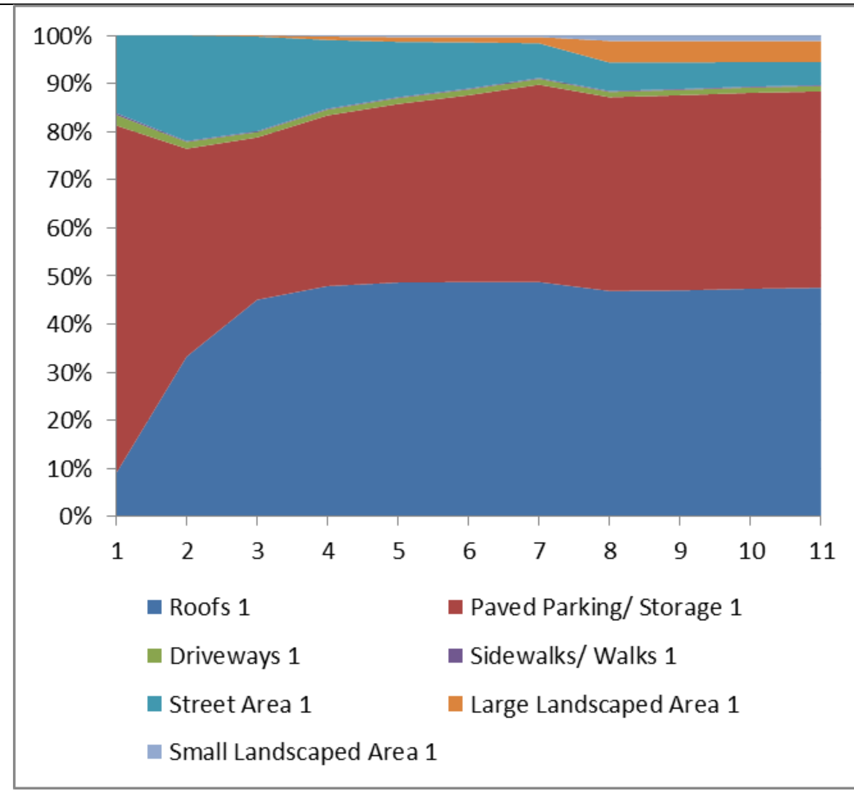
Commercial – Strip Mall Area Zn Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



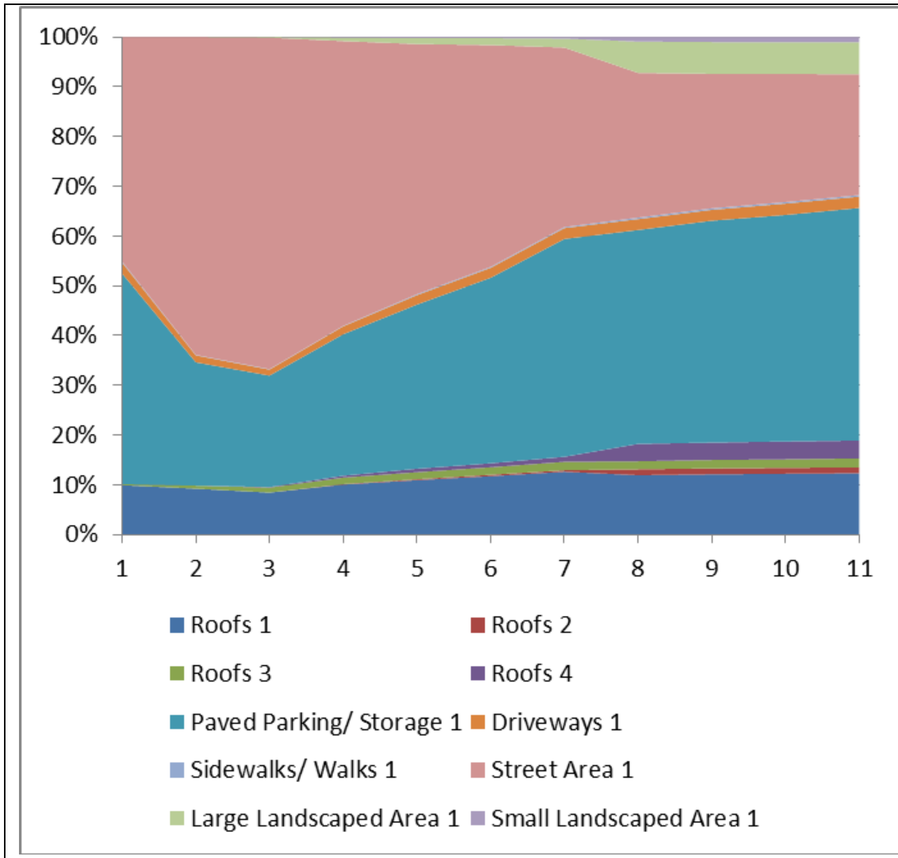
Commercial – Shopping Center Area Zn Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



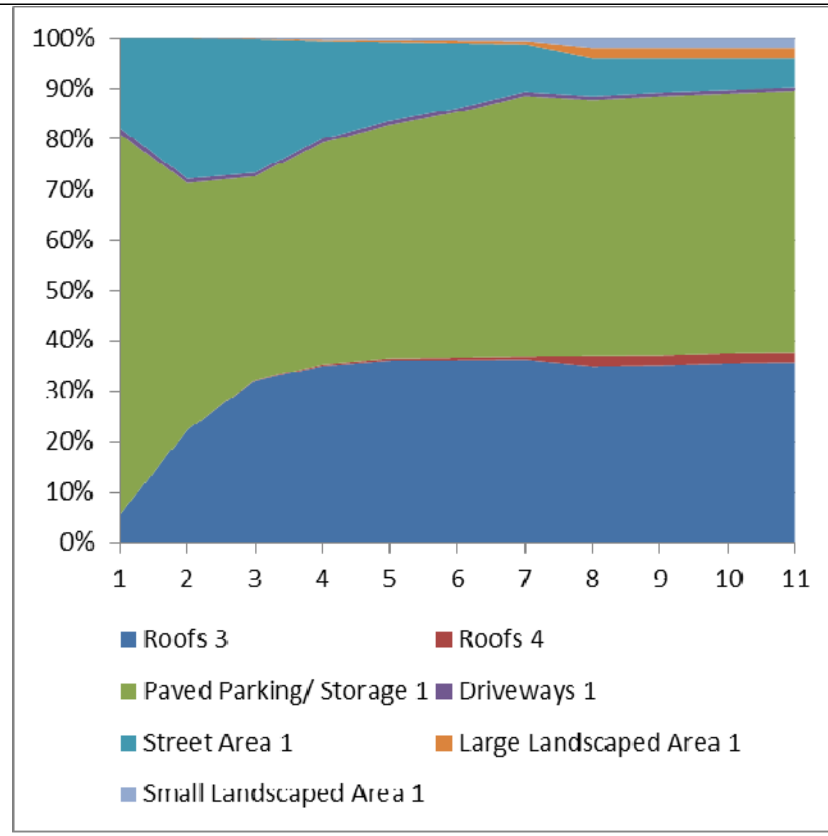
Light Industrial Area Zn Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



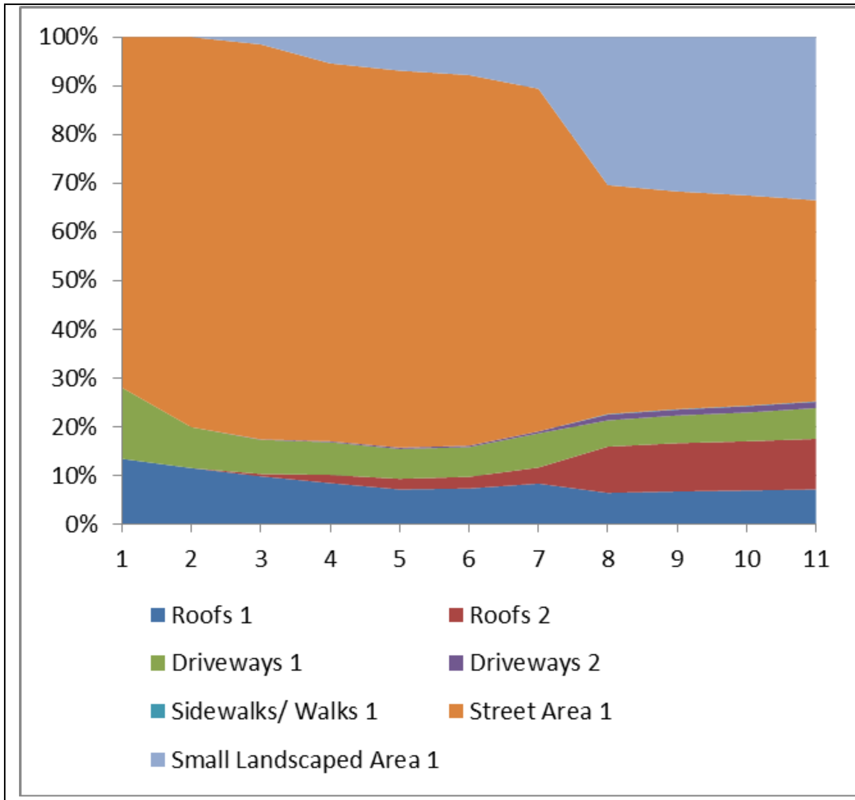
Institutional - School Area Zn Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



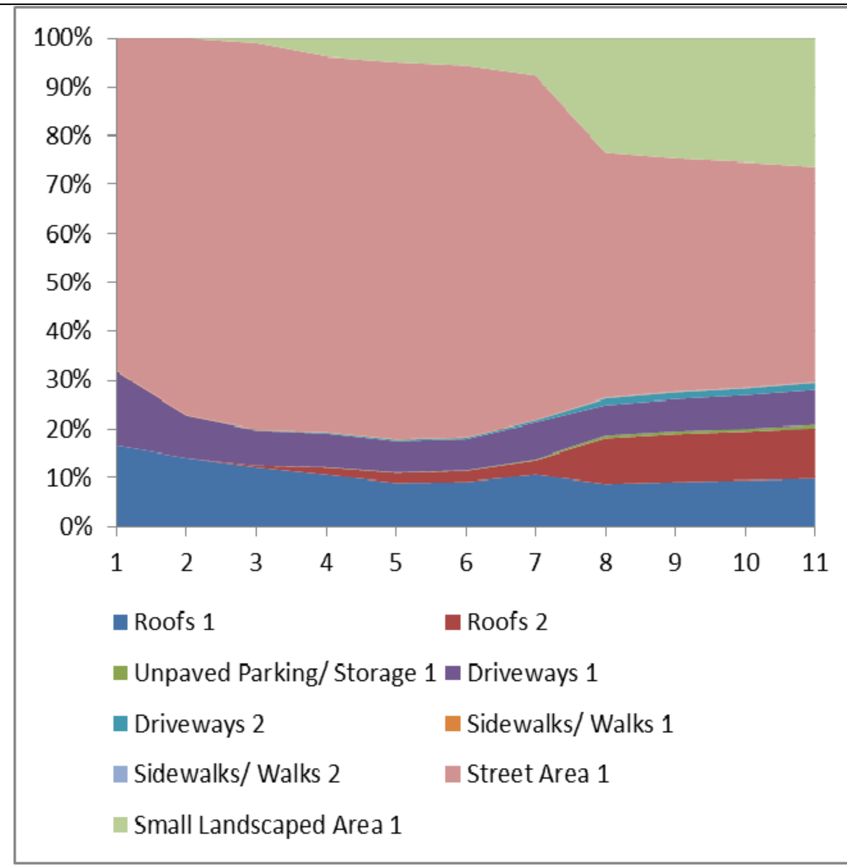
Institutional – Church Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



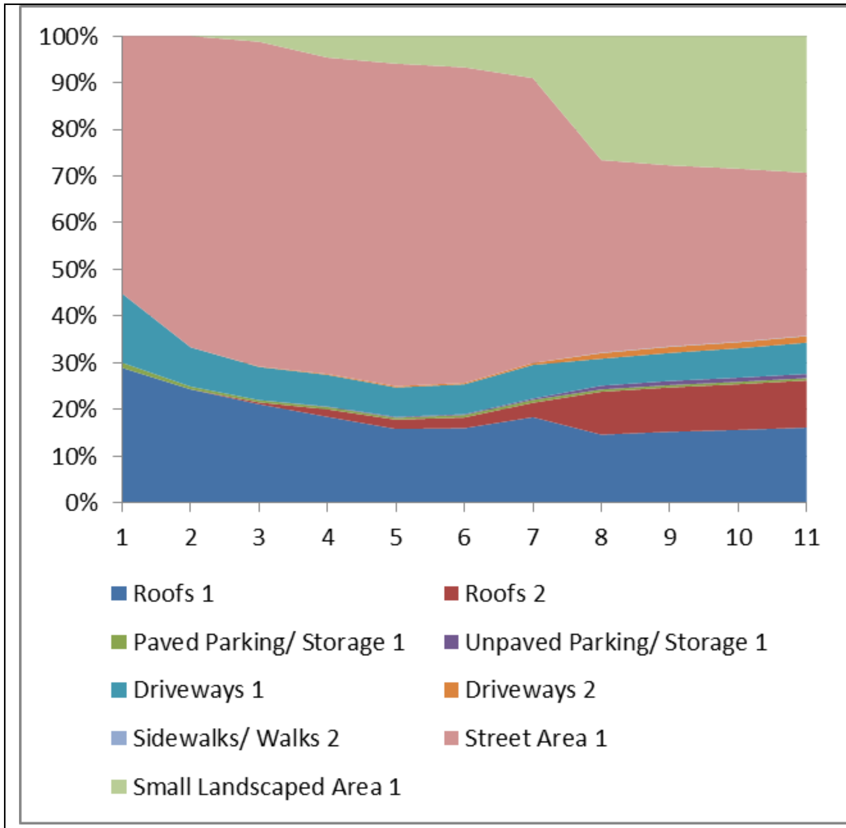
Institutional - Hospital Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

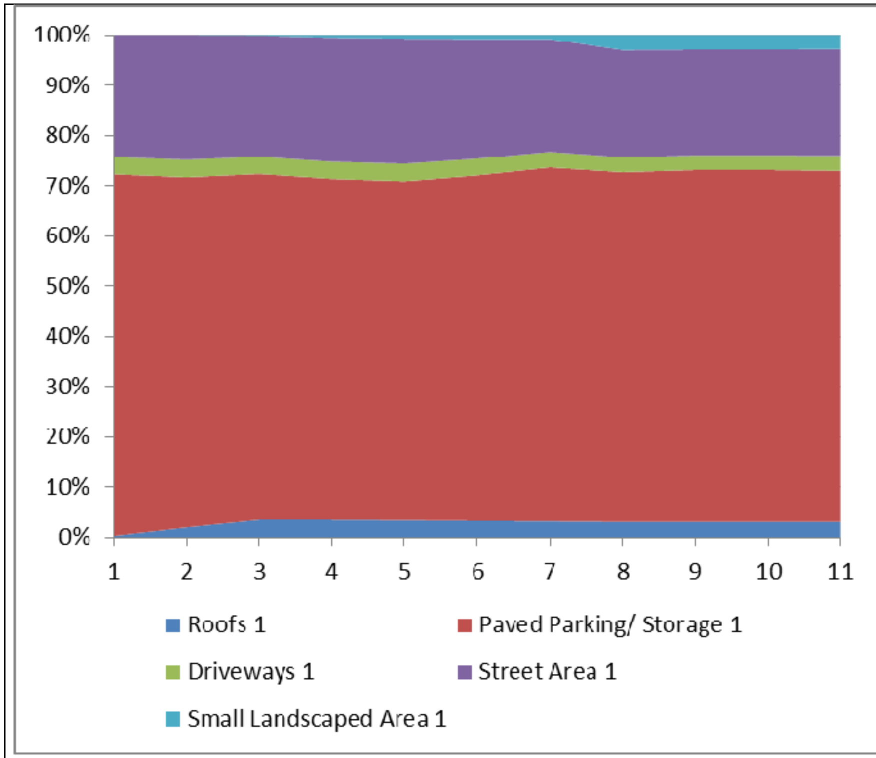


Medium Density Residential Area (<1960) Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

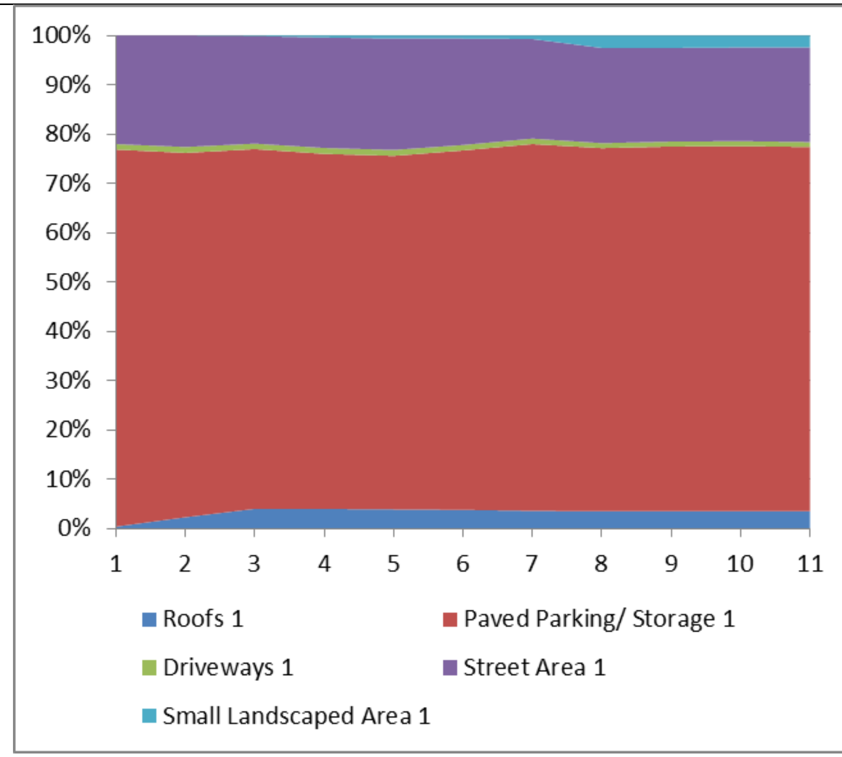


Medium Density Residential Area (1960 - 1980) Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

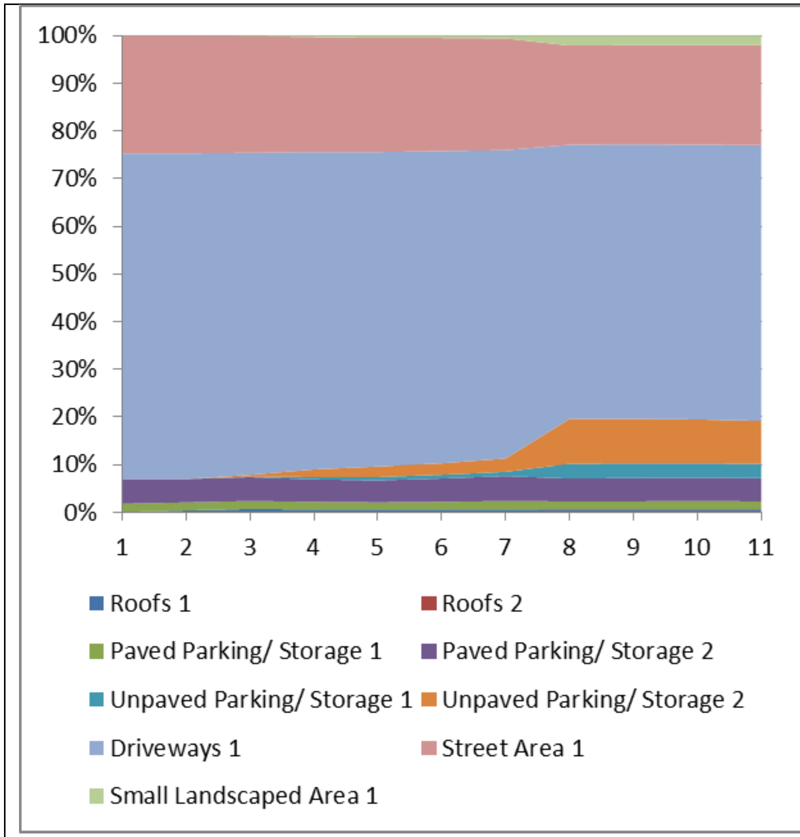
Fecal Coliform Bacteria Contributions



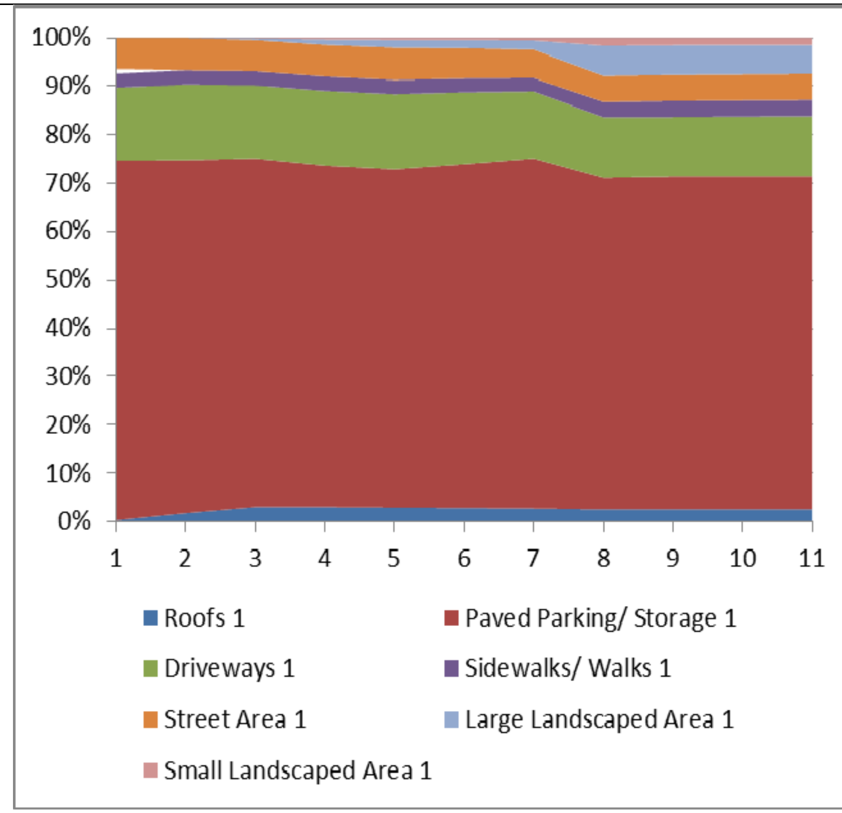
Commercial – Strip Mall Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



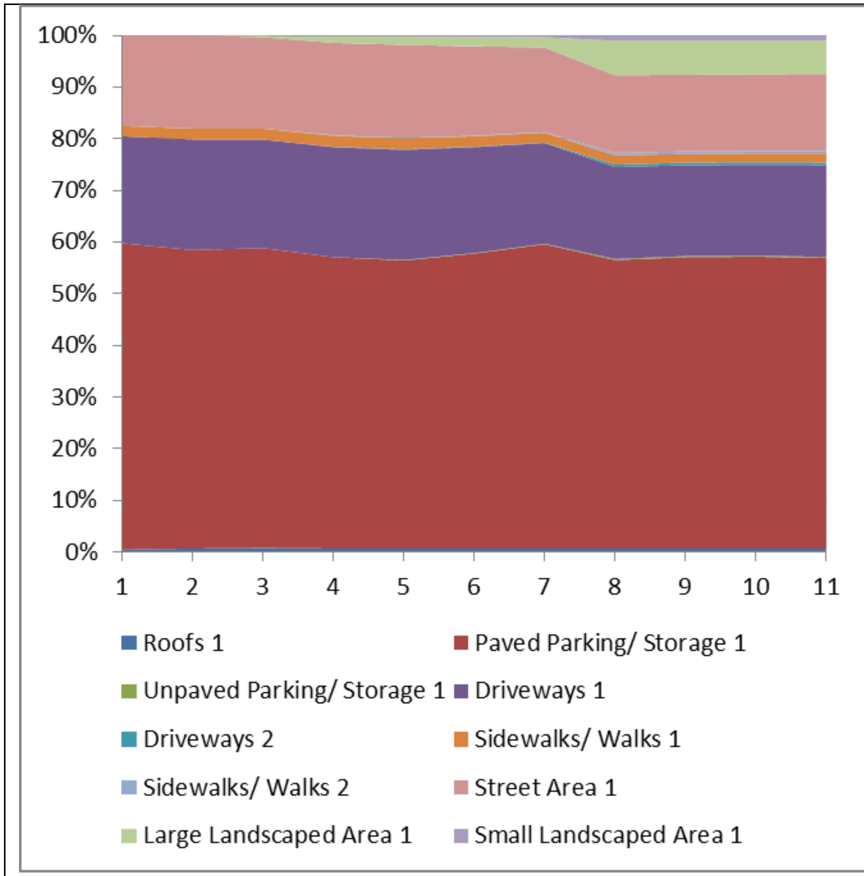
Commercial – Shopping Center Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



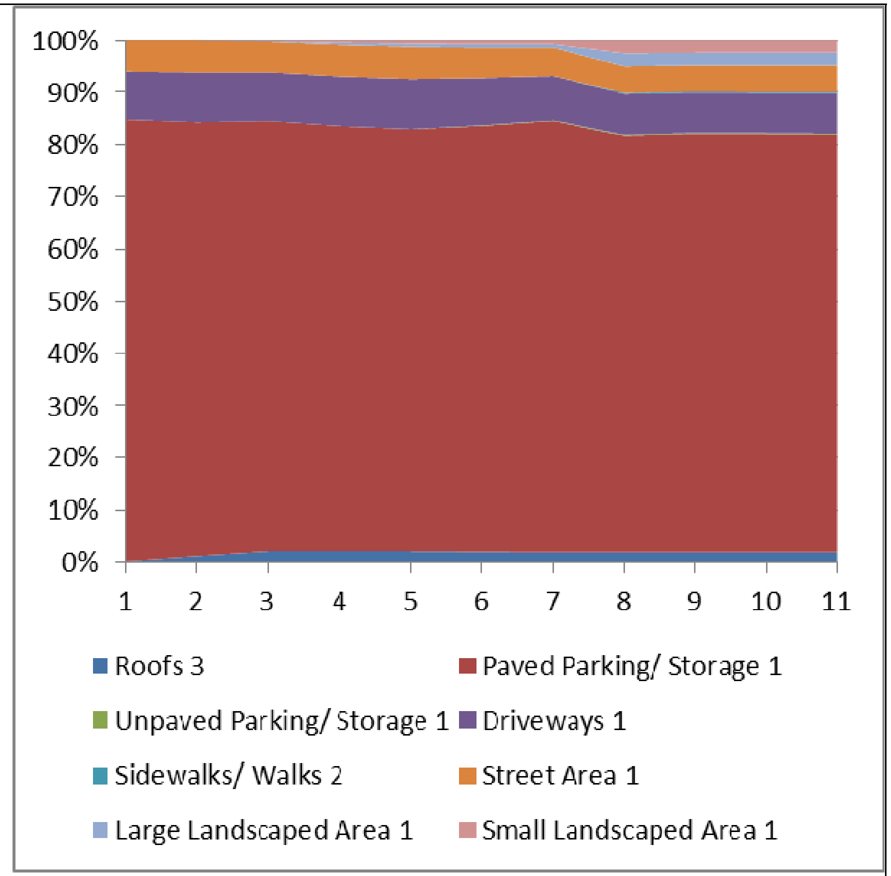
Light Industrial Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



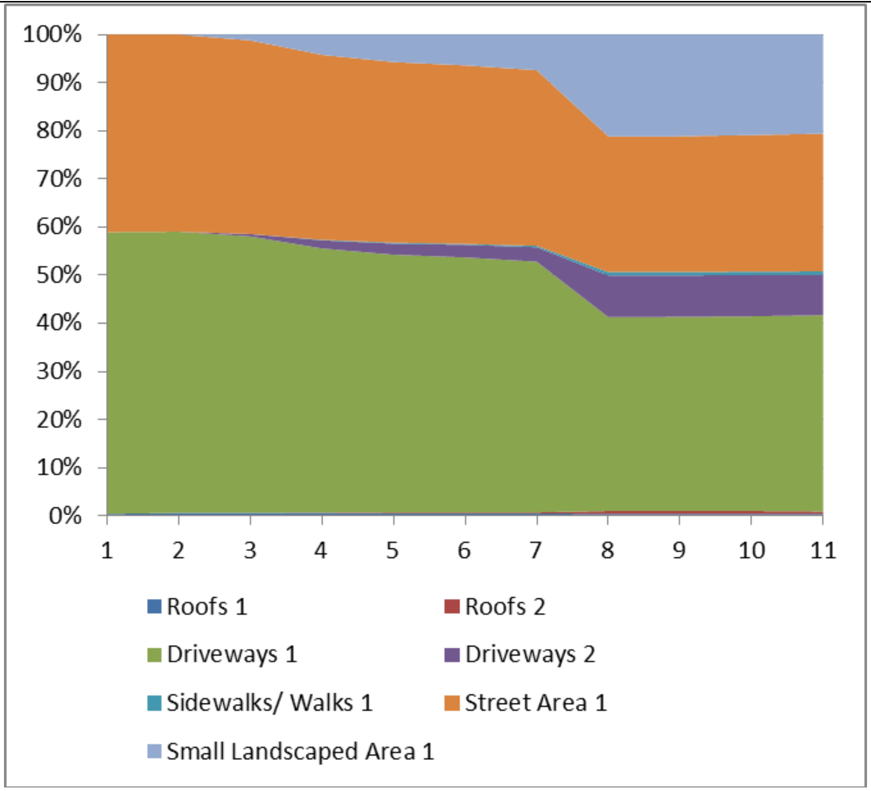
Institutional - School Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



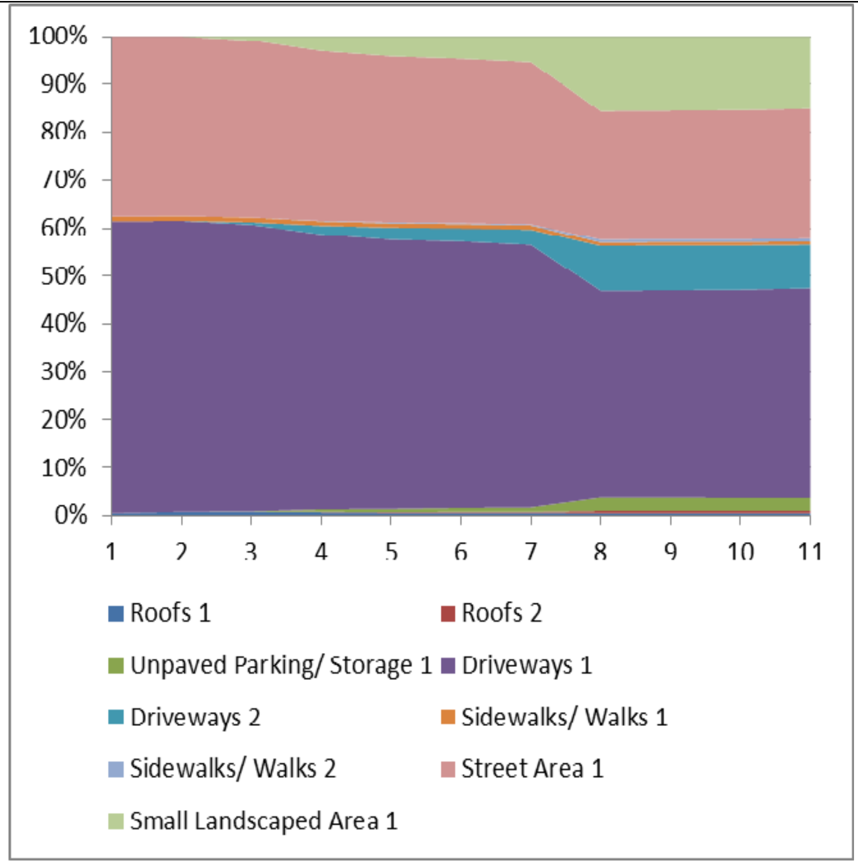
Institutional – Church Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



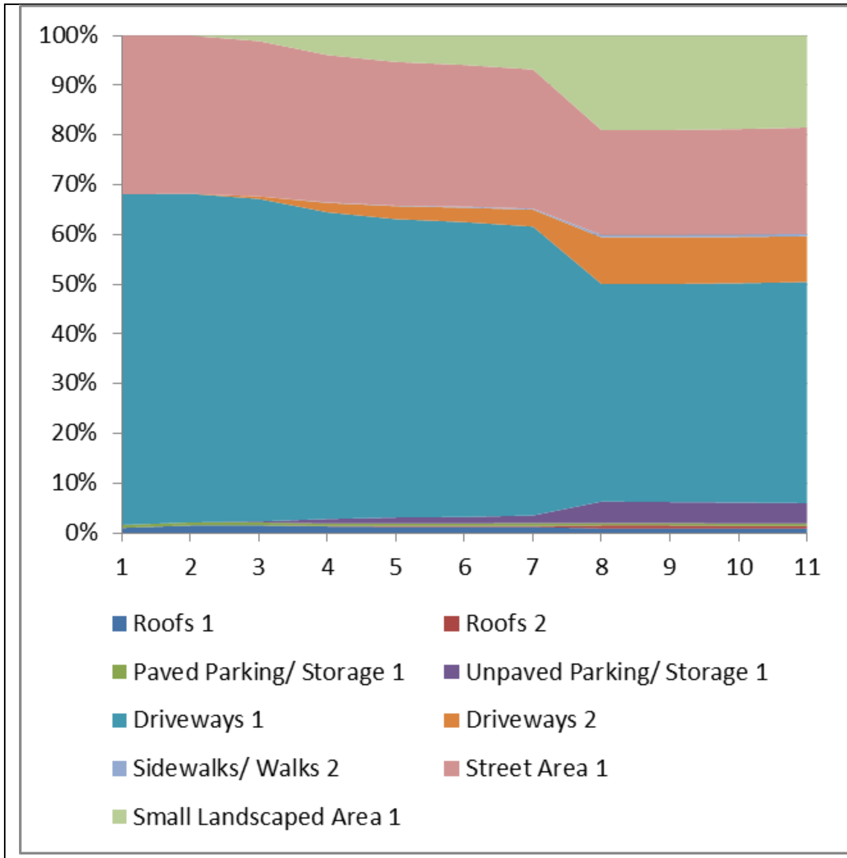
Institutional - Hospital Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



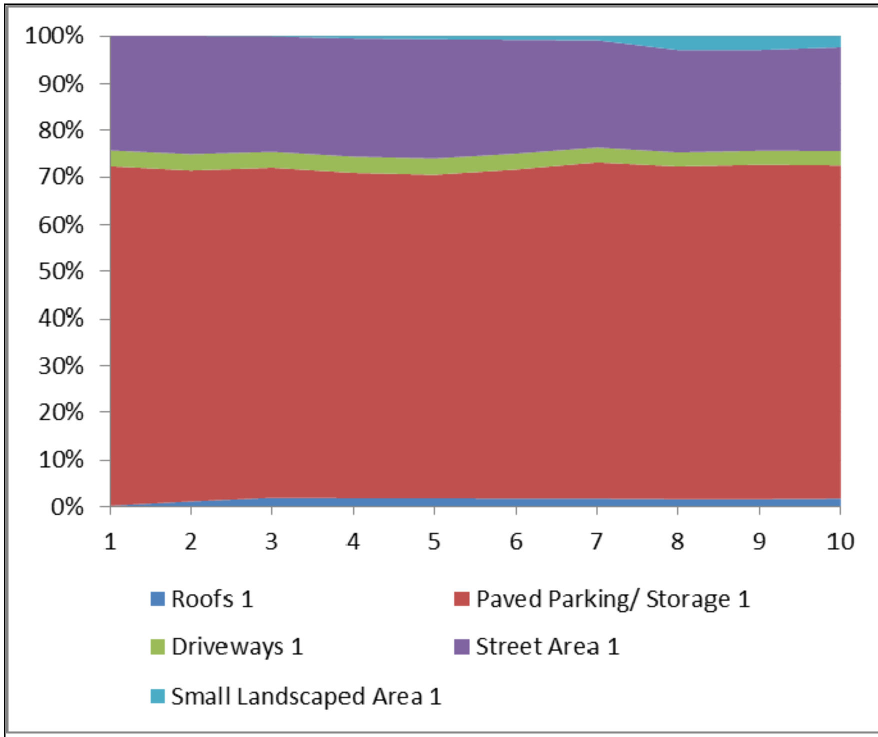
Medium Density Residential Area (<1960) Fecal Coliform Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



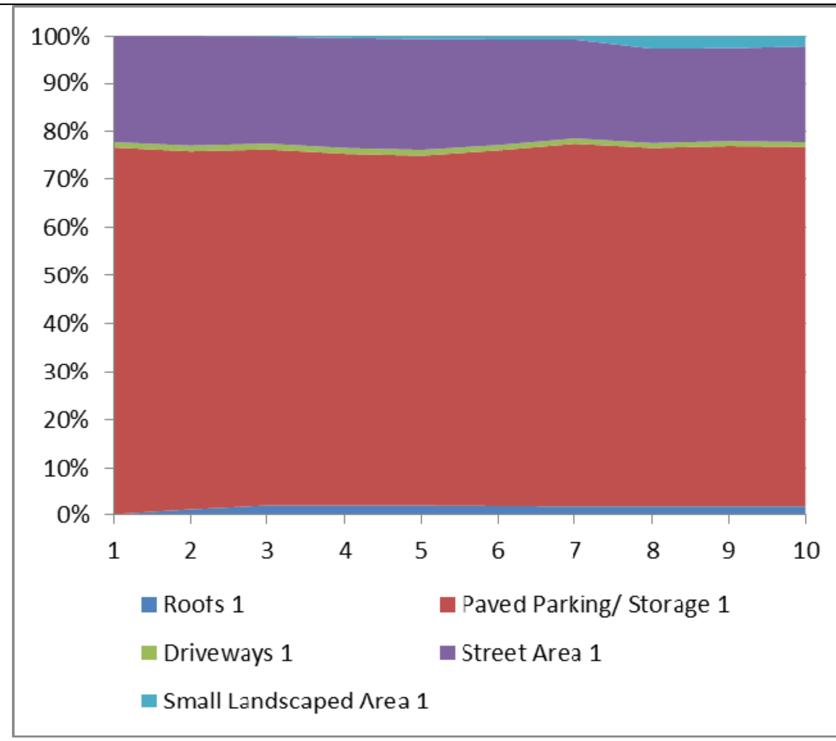
Medium Density Residential Area (1960 - 1980) Fecal Coliform Contributions

Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

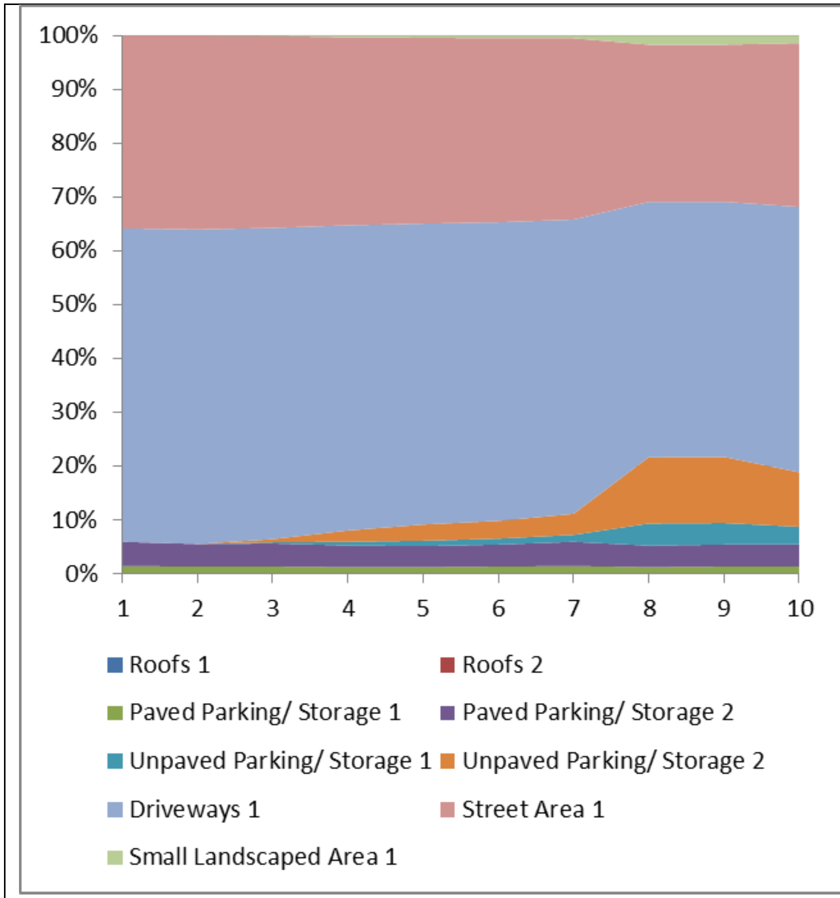
E. Coli Bacteria Contributions



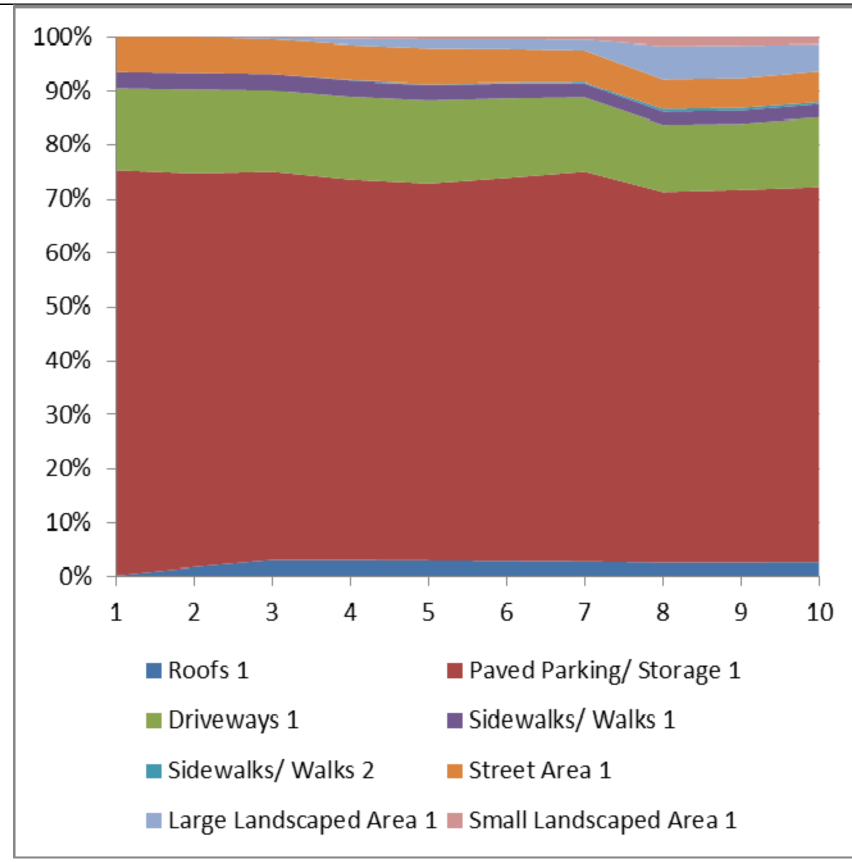
Commercial – Strip Mall Area E. Coli Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



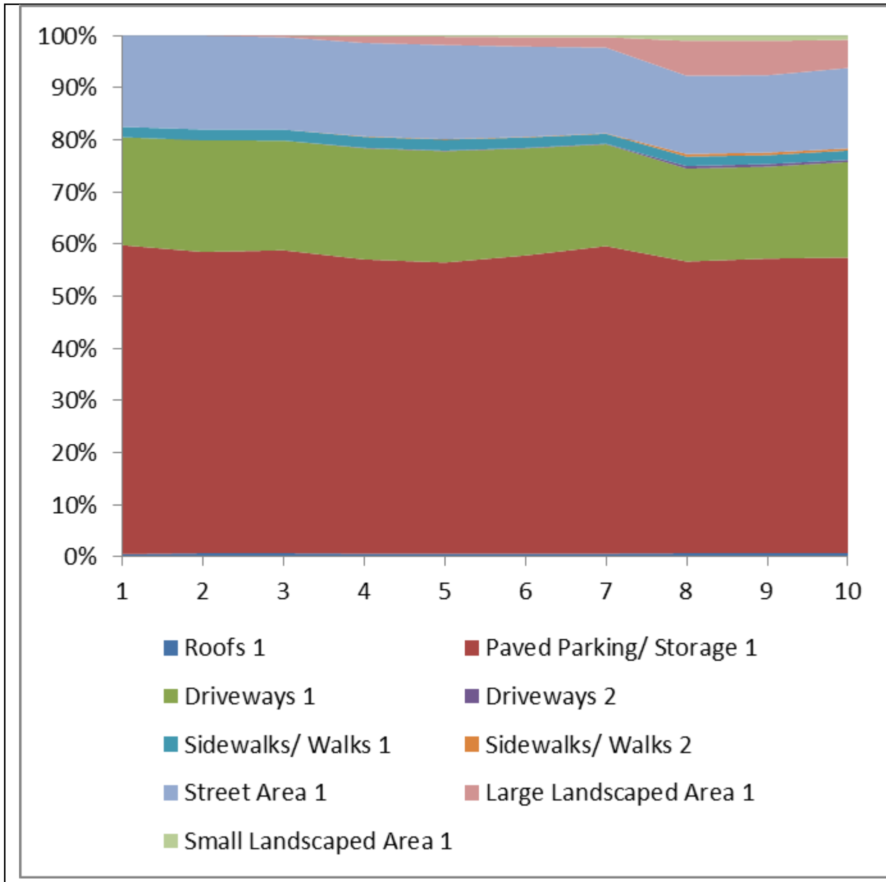
Commercial – Shopping Center Area E. Coli Contributions
Rains: 1: 0.05"; 2: 0.1"; 3: 0.25"; 4: 0.5"; 5: 0.75"; 6: 1"; 7: 1.5"; 8: 2"; 9: 2.5"; 10:3"; 11: 4"



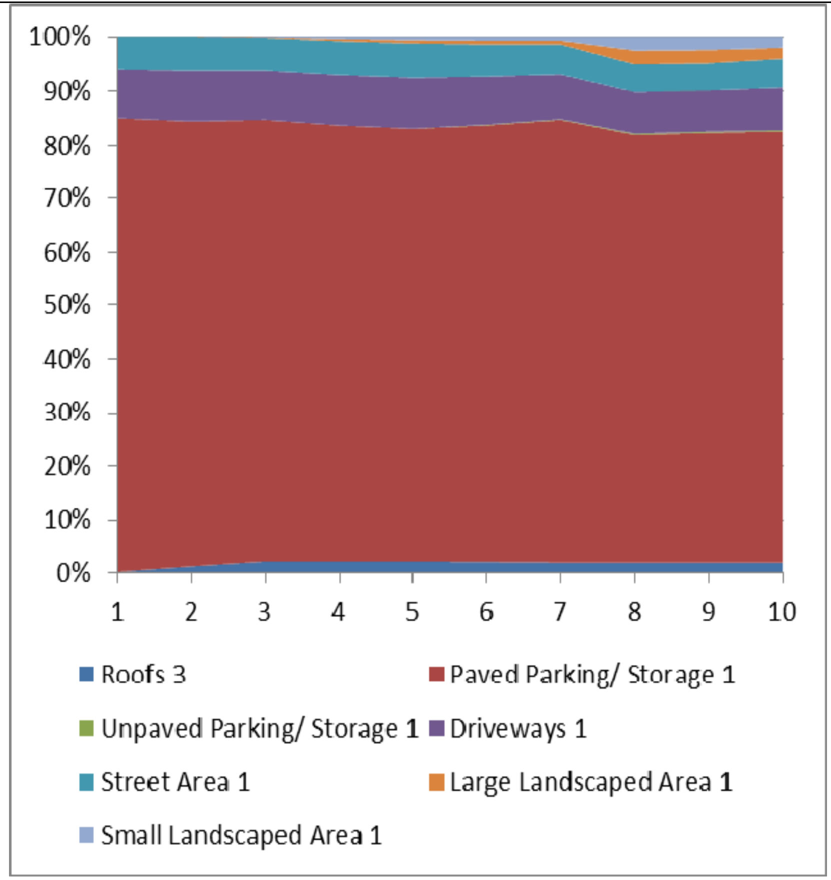
Light Industrial Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



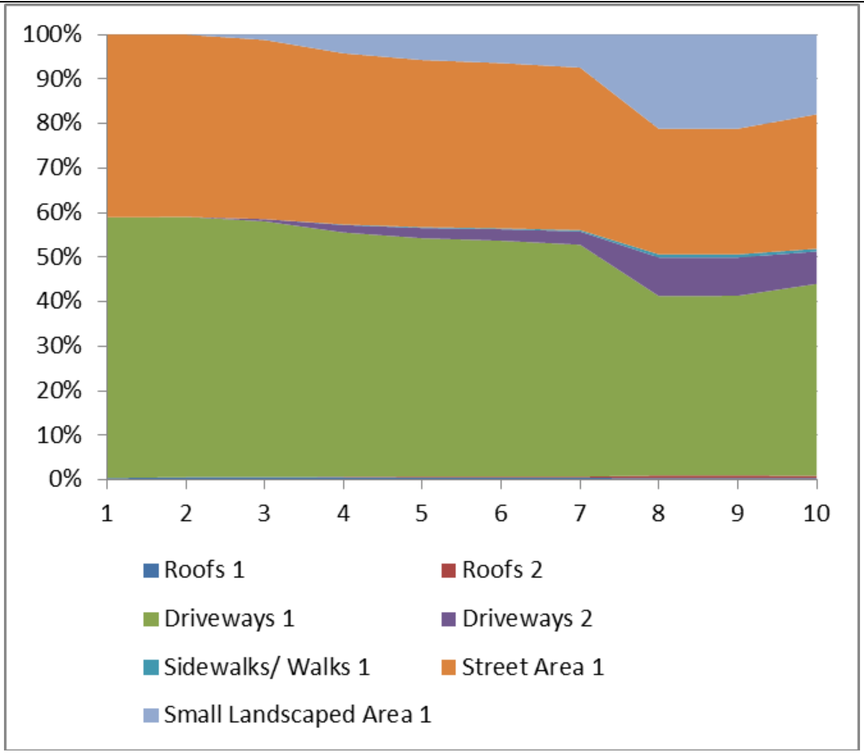
Institutional - School Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



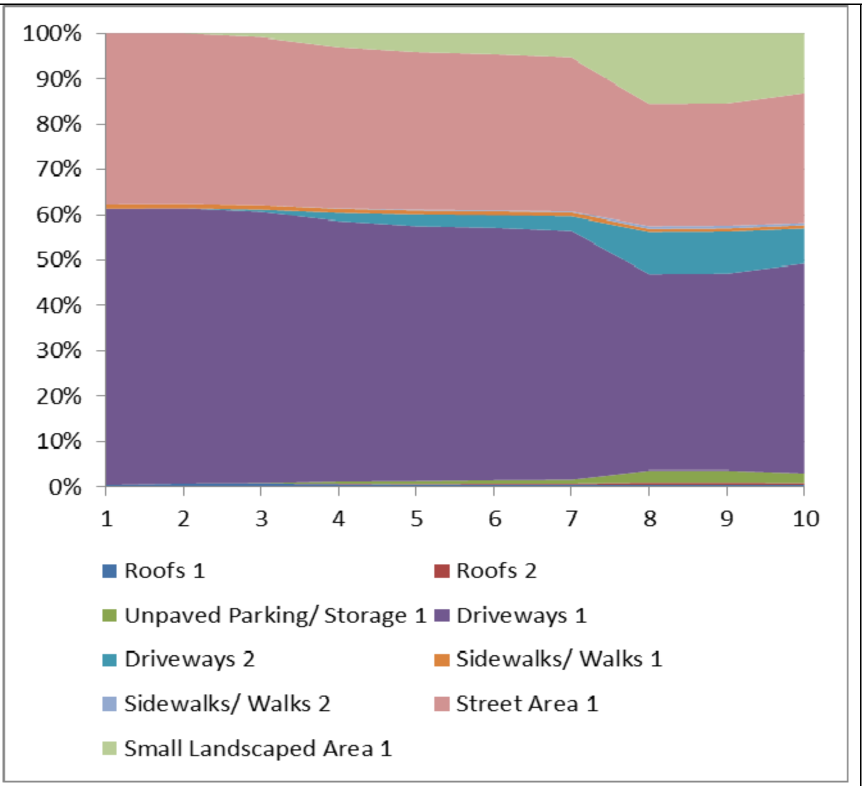
Institutional – Church Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



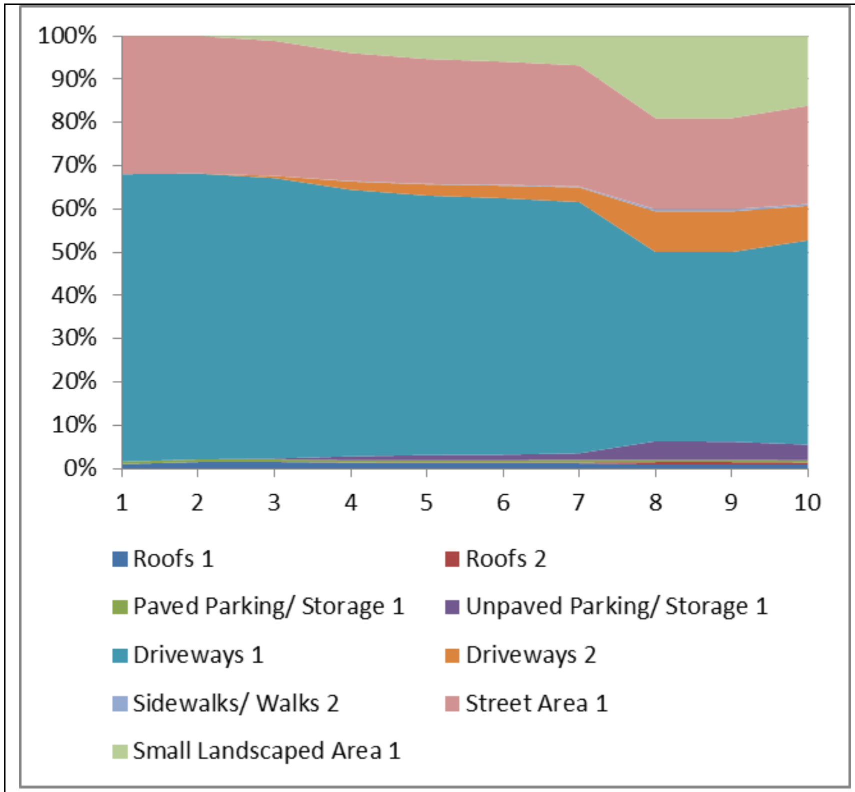
Institutional - Hospital Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Medium Density Residential Area (<1960) E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Medium Density Residential Area (1960 - 1980) E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”