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IMPERVIOUS SURFACES IN URBAN WATERSHEDS

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ABSTRACT
Urbanization causes profound changes in the hydrology of the area, specifically the timing of the runoff, the water use, runoff volume and flow rates, channel complexity, and especially pollution in receiving waters. Water quality problems increase with increasing imperviousness of the watershed. Impervious areas cause increased runoff and contaminated discharges from these areas and also contribute to receiving water contamination. Although much interest has been expressed concerning impervious areas in urban areas, actual data for the patterns of use of these surfaces is generally lacking. In this study, 125 neighborhoods were surveyed to determine the critical development characteristics representing 16 major land use areas located in the Little Shades Creek Watershed, near Birmingham, AL. The details of the impervious surfaces in these areas are described in this paper. Future project activities will include detailed stormwater modeling of each of these areas, so that the expected variations of important stormwater attributes can be quantified. A parallel study is investigating six drainage areas that have been extensively monitored as part of the Jefferson County, AL, stormwater permit program. The surfaces making up the drainage areas are described in detail and that information is being used to re-verify the WinSLAMM stormwater model for these local conditions. The final local version of the model will be used to measure the variation of the stormwater from the Little Shades Creek land use areas.

KEYWORDS
Impervious surface, stormwater pollutant sources

INTRODUCTION
Increases in urban population, and associated urban sprawl alters drainage basins and rivers. When watershed areas are urbanized, much of the vegetation and top soil is replaced by impervious surfaces (roads, parking lots, and roof tops) and much of the remaining soils are compacted. Population increases therefore cause increases in impervious areas which means less water will soak into the ground and more water will go directly to urban streams during the rains, along with faster rises in runoff. In addition to the high flows caused by urbanization, the increased runoff also contains increased contaminants.

Impervious cover has become an increasing used indicator in measuring the impact of land development on drainage systems and aquatic life (Schueler, 1994). Impervious cover is one of the variables that can be quantified for different types of land development, although there are many different types of impervious surfaces and how they are connected to the drainage system.

OBJECTIVE

The objective of this research is to measure the variations in runoff quantity and quality associated with variations in site characteristics, especially impervious cover. In order to determine how land development variability affects the quantity and quality of runoff, different land surfaces (roofs, streets, landscaped areas, parking lots, etc.) for different land uses (residential, commercial, industrial, institutional, etc) were measured. The field data will be used with WinSLAMM (Source Loading and Management Model for Windows, Pitt and Voorhees 1995; 2002) to model the runoff quantity and quality for each neighborhood investigated. Statistical analyses will be conducted at several levels to establish the quantitative and qualitative runoff sensitivity associated with variations of site characteristics.

In this study, 125 neighborhoods were surveyed to determine the actual development characteristics representing 16 major land use areas (Table 2) located in the Little Shades Creek Watershed, near Birmingham, AL. This information was collected over a period of several years as part of a volunteer effort using the Jefferson County "Earth Team" of the local USDA office during the mid 1990s. Initially, this data was used along with source area and outfall monitoring data to calibrate WinSLAMM. The current project is intended to measure the variability in stormwater characteristics associated with the variability of the development characteristics for each land use category. Currently, additional data from the NSQD (National Stormwater Quality Database) MS4 (municipal separate storm sewer system) database for Jefferson County, Alabama, is being used to conduct a re-validation of the model for current local conditions.

METHODOLOGY

The first step in this research was to collect the field data. An "Area Description" field sheet was used to record the important characteristics of the study areas during field surveys (Figure 1). In addition, aerial photographs were used to measure the actual coverage of each type of surface in each neighborhood studied. The following briefly explains the important elements of this sheet. Field training of the people responsible for collecting the information was carried out to assure data consistency.

- Location: The block number range and the street name were noted. A subarea name could also be used to describe the drainage area. Descriptions were made for homogeneous block segments in the study area. Specific blocks to be surveyed were randomly selected and located on the aerial photographs before the survey began. Each site had at least two photographs taken: one was a general scene and the other was a close-up (showing about 25 by 40 centimeters of pavement). Additional photographs were usually taken to record unusual conditions. These photographs are very important to confirm the descriptions recorded on the sheets and to verify the consistency of information for the many areas. The photographs are also very important when additional site information is needed, but not recorded on the sheets.

• Land-use: The land-use type that best describes the block was circled. If more than one land-use was present, the estimated distribution was shown. The approximate income level for residential areas was also circled. The specific types of industrial activities (warehouses, metal plating, bottling, electronics, gas station, etc.) for industrial and commercial areas were also written in. Also, the approximate age of development was circled.

• Roof drainage: The discharge location of the roof drains was noted. The approximate distribution was also noted if more than one discharge location was evident. The “underground” location may be to storm sewers, sanitary sewers, or dry wells. Some areas have the roof drains apparently directed underground but are actually discharged to the roadside gutter or drainage ditch. If they lead to the gutter, then the “to gutter” category was circled. Additionally, if the flow path length is less than about five feet over pervious ground, it is functionally directly connected to impervious areas, requiring circling the “to impervious” category. The roof types and building heights were also indicated (again, the approximate distributions were noted if more than one type was present). It was necessary to take an inventory of all visible roof drains in the study block by keeping tallies of each type of drain connection. The distribution of the percentage per connection type was put on the sheet. If other categories of characteristics varied in the study block (paved or unpaved driveway categories is another common variation), then these were also tallied for each category. The roof types were also indicated.

• Sediment sources: Sediment sources near the drainage (street, drainage way or gutter), such as construction sites, unpaved driveways, unpaved parking areas or storage lots, or eroding vacant land, were described and photographed.

• Street and Pavement: Traffic and parking characteristics were noted. Pavement condition and texture are quite different: condition implies the state of repair, specifically relating to cracks and holes in the pavement, while texture implies roughness. A rough street may be in excellent condition: many new street overlays result in very rough streets. Some very worn streets may also be quite smooth, but with many cracks. A close-up photograph of the street surface is needed to make final determinations of street texture. An overview photograph of the street was also taken to make the final determination of the street condition. The gutter/street interface condition is an indication of how well the street pavement and the gutter material join. Many new street overlay jobs are sloppy, resulting in a several centimeter ridge along the gutter/street interface. If the interface is in poor condition or uneven, an extra close-up photograph is taken showing the interface. The perception of the quantity of litter was also circled. Another photograph was taken of heavily littered areas.

After the test area descriptions were filled out for each neighborhood surveyed, the corresponding aerial photographs were examined and the individual elements (roofs, parking areas, street areas, sidewalks, landscaping, etc) were measured, and the data were then summarized in an Excel spreadsheet (Table 2). This information was used to build the WinSlamm files to describe each land use area. This information had to be manually measured from the photographs, as automated mapping software resulted in many errors and could not distinguish the necessary surface components. Mapping software may be used to total the main surface categories, but accuracy must be verified.

Figure 1. LITTLE SHADES CREEK CORRIDOR TEST AREA DESCRIPTIONS

Location: Site number:
Date: Time:
Photo numbers:
Land-use and industrial activity:
Residential: low medium high density single family
multiple family
trailer parks
high rise apartments
Income level: low medium high
Age of development: <1960 1960-1980 >1980
Institutional: school hospital other (type):
Commercial: strip shopping center downtown hotel offices
Industrial: light medium heavy (manufacturing) describe:
Open space: undeveloped park golf cemetery
Other: freeway utility ROW railroad ROW other:
Maintenance of building: excellent moderate poor
Heights of buildings: 1 2 3 4+ stories
Roof drains: % underground % gutter % impervious % pervious
Roof types: flat composition shingle wood shingle other:
Sediment source nearby? No Yes (describe):
Treated wood near street? No telephone poles fence other:
Landscaping near road:
Quantity: none some much
Type: deciduous evergreen lawn
Maintenance: excessive adequate poor
Leafs on street: none some much
Topography:
Street slope: flat (<2%) medium (2-5%) steep (>5%)
Land slope: flat (<2%) medium (2-5%) steep (>5%)
Traffic speed: <25mph 25-40mph >40mph
Traffic density: light moderate heavy
Parking density: none light moderate heavy
Width of street: number of parking lanes:
number of driving lanes:
Condition of street: good fair poor
Texture of street: smooth intermediate rough
Pavement material: asphalt concrete unpaved
Driveways: paved unpaved
Condition: good fair poor
Texture: smooth intermediate rough
Gutter material: grass swale lined ditch concrete asphalt
Condition: good fair poor
Street/gutter interface: smooth fair uneven
Litter loadings near street: clean fair dirty
Parking/storage areas (describe):
Condition of pavement: good fair poor
Texture of pavement: smooth intermediate rough unpaved
Other paved areas (such as alleys and playgrounds), describe:
Condition: good fair poor
Texture: smooth intermediate rough
Notes:

LAND USE DESCRIPTION

<u>Little Shades Creek Watershed Land Use Characteristics</u>

The Little Shades Creek Watershed has an area of almost eight square miles and was about 70% developed at the time of these surveys. It lies under the jurisdiction of several municipal governments (Hoover, Vestavia Hills, and Cahaba Heights) as well as having some unincorporated land directly under the jurisdiction of the county government (Jefferson County), which made land development highly variable and uncoordinated. Many land development categories are represented in the watershed, even though the residential area, mostly with single family residential units, is predominant. Table 1 shows the areas of the local planning agency land use categories in the watershed.

Table 1. Local Planning Agency Land Use Categories in the Little Shades Creek Watershed

Land Use	Total Acres
Single family residential	3,611
Town home	122
Multi-family residential	87
Schools and churches	109
Recreation	112
Public lands	5
Cemeteries	3
Open space	26
Office parks	62
Commercial areas	82
Industrial areas	9
Utility	2
Vacant land	989
Total	**5,218**

Sixteen land uses categories in the watershed were surveyed by investigating about 10 neighborhoods in each area. The predominant land use in the watershed was residential land, and was therefore subdivided according to density and age. All surveyed residential areas (high density, medium density, low density, apartments, and multi-family complexes) had pitched roofs that drained mainly to pervious surfaces with the only exception being multi-family areas. The soil is represented by sandy loam and silt loam soils, in about equal amounts. The land is mostly flat or with medium slopes. Some landscaping was present near the roads and was mostly lawns and evergreen shrubs. Streets and driveways had asphalt as the most common pavement material and had intermediate texture. The predominant drainage system was composed of concrete curbs and gutters in good or fair condition, with a small percentage of grass swale drainages in high and medium density residential areas.

Commercial land use areas were represented in the watershed by office parks and shopping centers with flat roofs draining mostly to impervious areas. Lawns and evergreen shrubs in excellent condition were found near the roads. The paved parking lots represented the largest connected impervious source areas. Runoff from the roofs drains directly to parking areas and then to the drainage systems that were mostly curbs and gutters in good condition. The streets, driveways, and parking area were paved with asphalt having intermediate or smooth texture.

Schools and churches comprised the institutional land use category of the watershed. The school roofs were flat and drained slightly more to impervious surfaces than to pervious areas. However, school playgrounds were mostly unpaved. Churches had pitched roofs that drained to impervious areas. Landscaped areas had an even distribution of deciduous and evergreen shrubs, and lawns were near the streets. Streets and parking lots were paved with asphalt and had intermediate textures. The drainage systems had both grass swales and curbs and gutters, all in fair condition.

Businesses in the industrial land use category included a lumber manufacturing facility, several equipment storage and office complexes, a public mini-storage facility, a construction supply center, a door manufacturer, and an automobile junkyard. All buildings were directly connected to the stormwater collection system. All facilities were closely bounded by other developments, roads, steep banks, and for one site by Little Shade Creek. The industrial sites were relatively small, covering no more than a few acres and they were all dominated by parking and storage areas, and roofs.

The open space land use included parks, cemeteries, a golf course, vacant land, and areas under construction. The few roofs that were found in the vacant land use and golf course areas drained to pervious areas. The parking lots were paved and directly connected to the drainage system. The stormwater drainage system was a combination of curbs and gutters and grass swales.

The drainage system in the freeway land use was comprised of grass swales in the medians and along the shoulders. The pavement was asphalt, with a smooth texture.

Jefferson County Stormwater Permit Monitoring Sites

The sites that will be used to re-validate the WinSLAMM model are in Jefferson County, AL, and are being monitored for the counties MS4 (municipal separate storm sewer system) stormwater permit program. This data is incorporated in the National Stormwater Quality Database (NSQD) database (Pitt, *et al*. 2004). About 10 events have been sampled at each of these six areas. Manual sampling was used, with composite samples collected during the first three hours of the rains. Each of the six sampling sites is described in the following paragraphs, while the measured areas of the different surfaces are shown in Table 4:

ALJC001 (Light Industrial) - Drainage area is 341 acres. The sampling location is in a drainage ditch running parallel to the railroad tracks near the 10th Avenue viaduct and 35th Street, Birmingham, AL. The drainage ditch is a western tributary of the Cotton Mill Branch Creek within the Village Creek watershed. This area drains approximately 62% industrial property, 12% commercial land use (shopping centers), a small percentage of high density residential (8.5%) and open space (6.4%). About 11% of this watershed is represented by freeways.

ALJC002 (Heavy Industrial) - Drainage area is 721 acres. The sampling location is in a creek that discharges into Village Creek off Third Street West in the vicinity of the East Thomas

Railroad yards located along Finley Boulevard, Birmingham, AL. Approximately 75% of the drainage area is industrial land uses, while 14.5% is high density residential, and a small percentage (2.5%) is represented by commercial land use and open space (6.7%).

ALJC004 (Downtown Commercial) - Drainage area is 1,048 acres. These sampling locations are at two culvert outfalls on 5th Avenue N and 7th Street in the downtown Birmingham area. Outfall 004N drains an old commercial area and a dense portion of downtown office buildings in the City of Birmingham, along with residential and institutional areas. The flows from the south and north culverts are being sampled and analyzed separately. The aerial photograph measurements for this large area are not completed yet and are therefore not represented on Table 4.

ALJC009 (High Density Residential) - Drainage area is 102 acres. The sampling location is at a 60 inch pipe downstream from a paved channel along Woodland Drive in the Edgewood community of Homewood, AL. The majority of the drainage area is comprised of residential lots 1/4 of an acre, or less in size. A small portion of the land use within the basin is institutional (6.7%) and commercial (4.1%) which includes an elementary school, a small church, and a small strip commercial area consisting of small shops, restaurants, and a grocery store. This was found to be typical for many dense residential neighborhoods where small isolated institutional and commercial land uses are not large enough to be assigned separate land use categories.

ALJC010 (Low Density Residential) - Drainage area is 133 acres. The sampling location is in a paved channel along Ponderosa Circle in the Tanglewood subdivision of Vestavia Hills, AL. The drainage area is almost entirely residential lots greater than 1/3 of an acre (82.5%), except for a small portion of undeveloped land (17.5%) on a steep slope that is wooded with heavy cover. This sampling point is on a designated blue line on the USGS quad map; however, this was not a perennially flowing stream.

ALJC012 (**Commercial Mall) -** Drainage area is 228 acres. The sampling location is at a large culvert running under Highway 31 just south of where Highway 31 intersects Highway 150, in Hoover, AL. A majority of the drainage basin is composed of strip commercial shopping centers and a fragment of the Riverchase Galleria shopping mall, except for some apartments which make up 25% of the drainage area along with some undeveloped woodland which is 5% of the drainage area.

DISCUSSION

Urban pollutant loads in aquatic systems are directly related to watershed imperviousness. It is generally found that stream degradation occurs at low levels of imperviousness (about 10 to 15%), where sensitive stream elements are lost from the system. There is a second threshold at around 25 to 30% impervious cover, where most indicators of stream quality change to a poor condition (Schueler, 1994)

This data shows that the Little Shades Creek watershed in Birmingham, Alabama, has a watershed impervious cover of about 35%, of which about 25% is directly connected to the drainage system and 10% drains to pervious areas (Table 3). As expected, the land use with the least impervious cover is open space (parks, cemeteries, golf course), and the land uses with the largest impervious covers are commercial areas, followed by industrial areas (Figure 2 and 3).

WinSLAMM will be used to investigate the relationship between watershed and runoff characteristics for each of the 125 neighborhoods investigated. A preliminary evaluation is shown on Figures 4 and 5 which illustrate the relationships between the directly connected impervious area percentages and the calculated volumetric runoff coefficients (Rv) for each land use category (using the average land use characteristics), based on 43 years of local rain data. As expected, there is a strong relationship between these parameters for both sandy and clayey soil conditions. The fitted exponential equations are:

Sandy soils: $y = 0.062e^{0.031x}$ ($R^2 = 0.83$)
Clayey soils: $y = 0.15e^{0.017x}$ ($R^2 = 0.72$)

Where y is the volumetric runoff coefficients (Rv) and x is the directly connected impervious areas (%) for the areas. It is interesting to note that the Rv is relatively constant until the 10 to 15% directly connected impervious cover values are reached (at Rv values of about 0.07 for sandy soil areas and 0.16 for clayey soil areas), the point where receiving water degradation typically is observed to start. The 25 to 30% directly connected impervious levels (where significant degradation is observed), is associated with Rv values of about 0.14 for sandy soil areas and 0.25 for clayey soil areas, and is where the curves start to greatly increase in slope.

The Storm Water Management Authority of Jefferson County is currently conducting biological and habitat surveys in Little Shades Creek in this study area at five locations. These mid summer and early spring surveys will be used to verify the assumed relationship between impervious areas and biological conditions for this watershed. WinSLAMM is also being modified to track the amounts of directly connected and partially connected impervious areas in modeled areas, along with predicting equivalent directly connected impervious amounts for different stormwater control scenarios. The model currently calculates outfall flow rates at closely spaced intervals for both wet and dry weather conditions. The model is being modified to present this information in flow-duration probability curves to also assist stormwater managers in predicting receiving water responses to alternative stormwater management programs.

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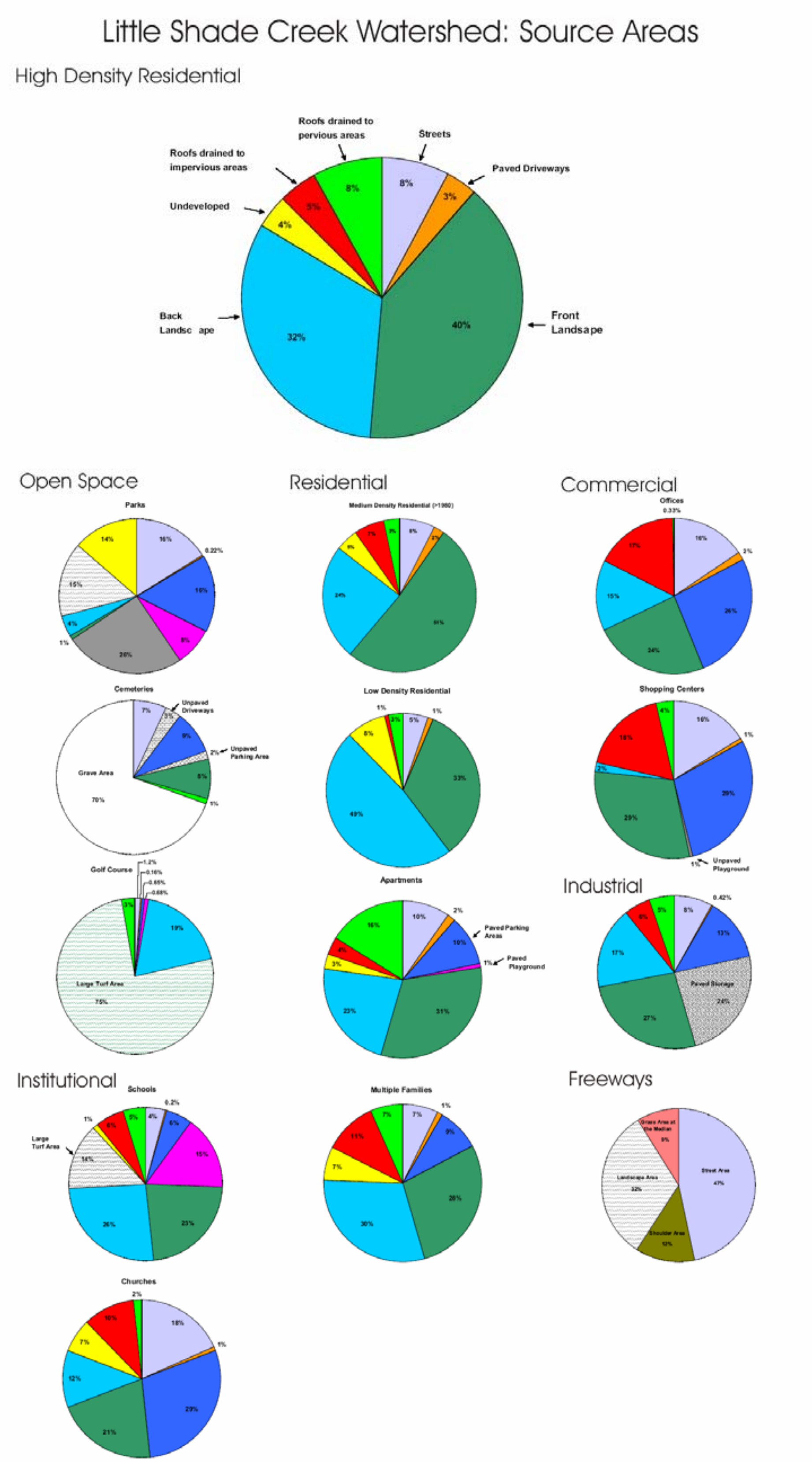
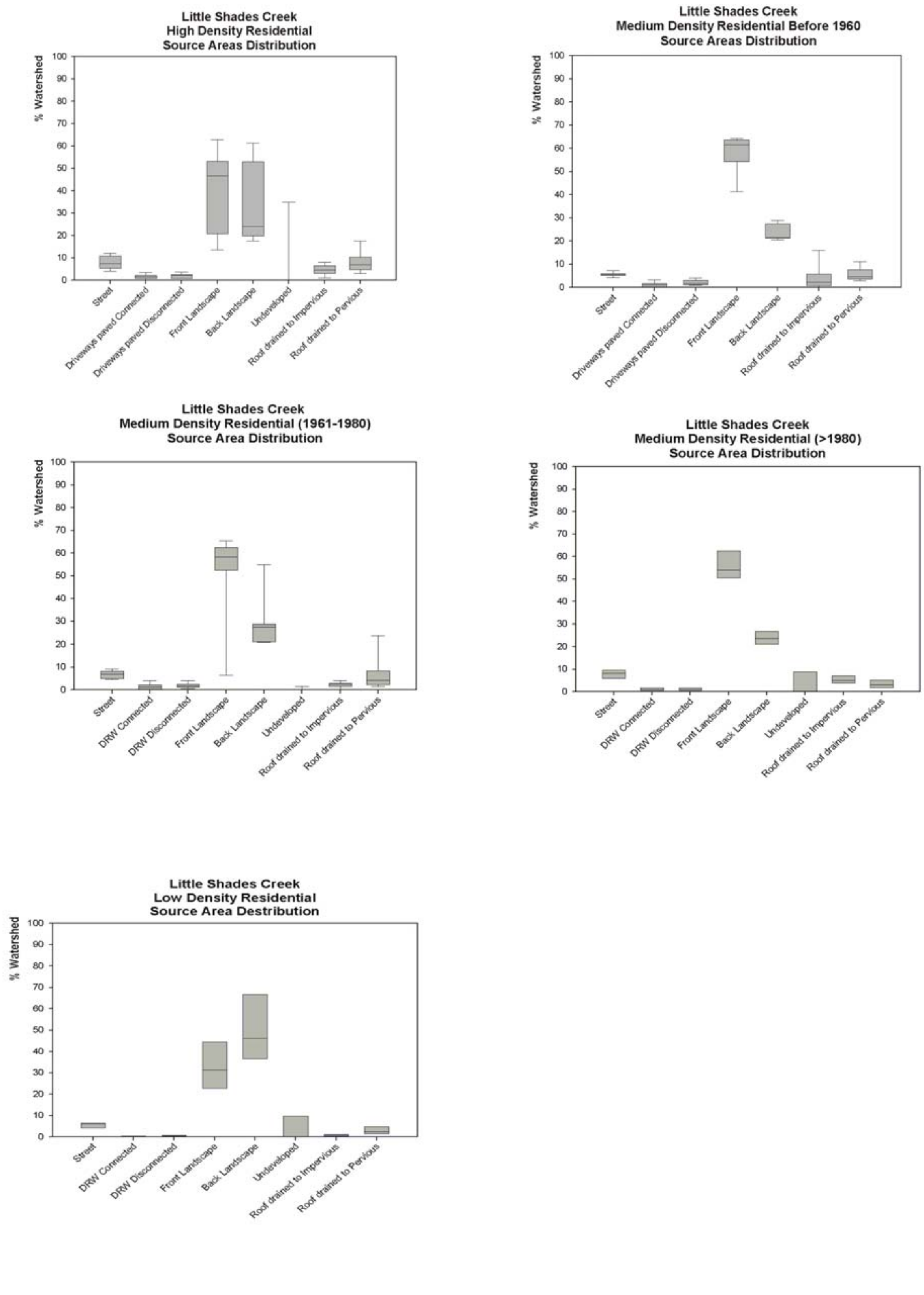
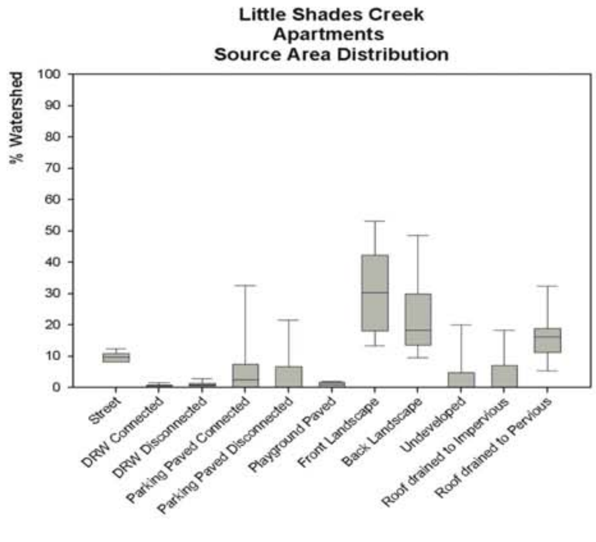
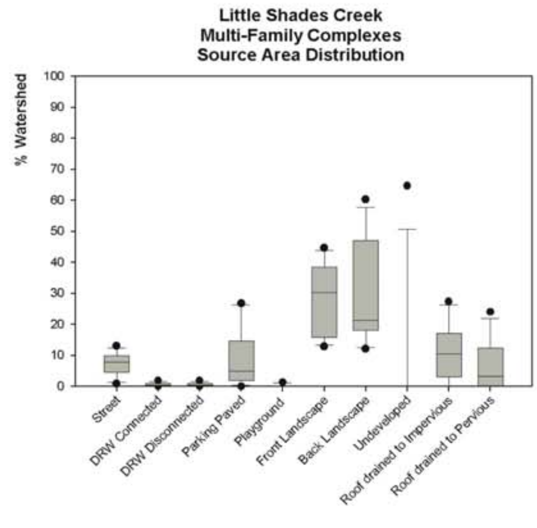


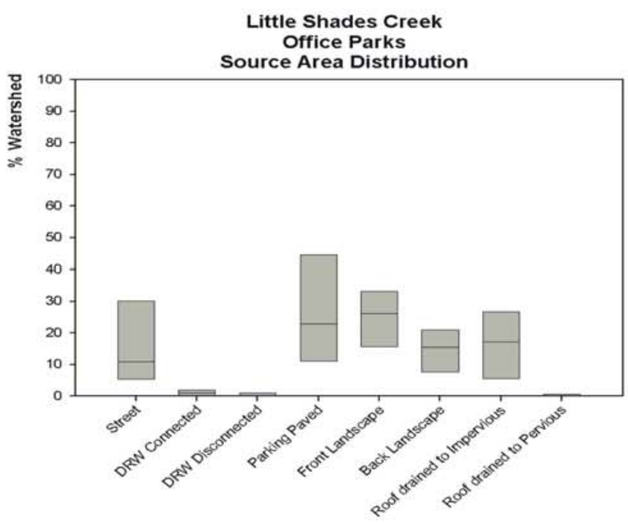
Figure 2: Little Shades Creek Watershed: Source Area Distribution using Pie Charts

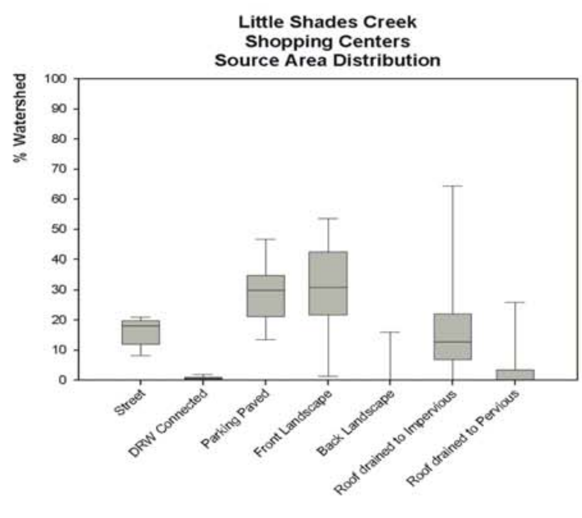
Figure 3: Little Shades Creek Watershed: Source Area Distribution using Box Plots

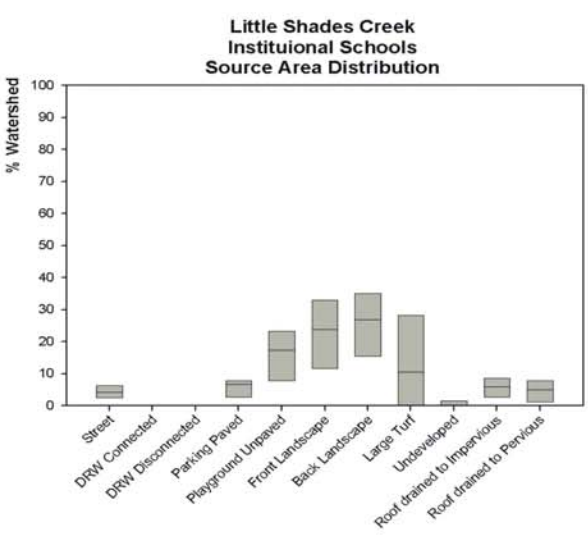


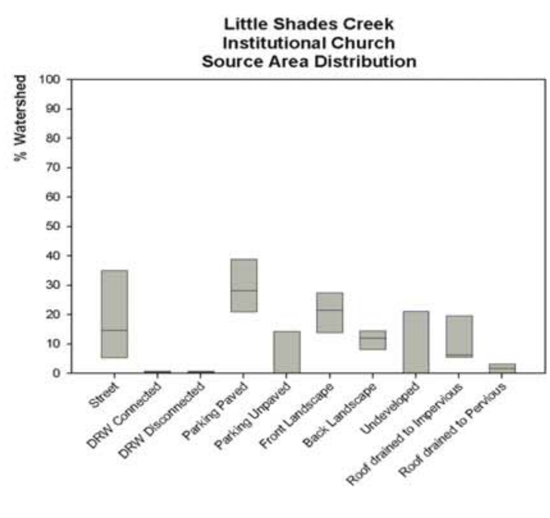

Little Shades Creek
Apartments
Source Area Distribution
% Watershed
Street
DRW Connected
DRW Disconnected
Parking Paved Connected
Parking Paved Disconnected
Playground Paved
Front Landscape
Back Landscape
Undeveloped
Roof drained to Impervious
Roof drained to Pervious

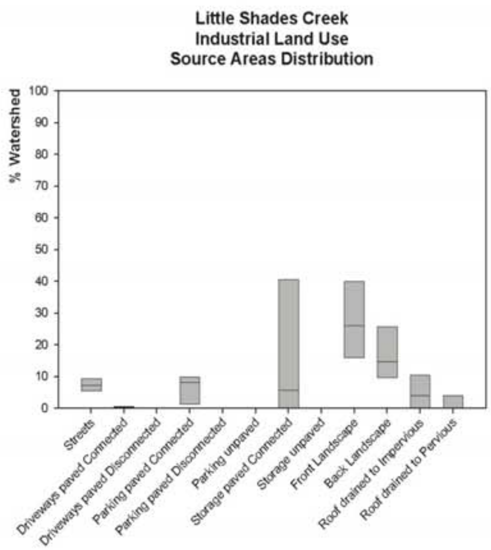

Little Shades Creek
Multi-Family Complexes
Source Area Distribution
% Watershed
Street
DRW Connected
DRW Disconnected
Parking Paved
Playground
Front Landscape
Back Landscape
Undeveloped
Roof drained to Impervious
Roof drained to Pervious

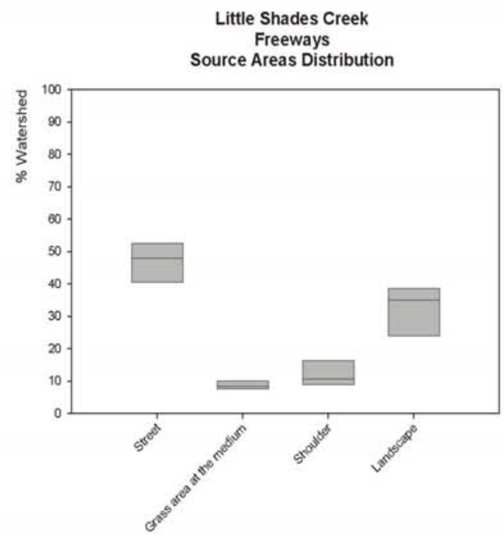

Little Shades Creek
Office Parks
Source Area Distribution
% Watershed
Street
DRW Connected
DRW Disconnected
Parking Paved
Front Landscape
Back Landscape
Roof drained to Impervious
Roof drained to Pervious

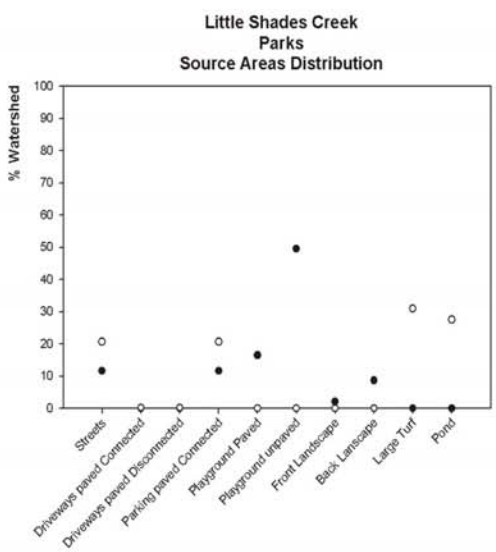

Little Shades Creek
Shopping Centers
Source Area Distribution
% Watershed
Street
DRW Connected
Parking Paved
Front Landscape
Back Landscape
Roof drained to Impervious
Roof drained to Pervious

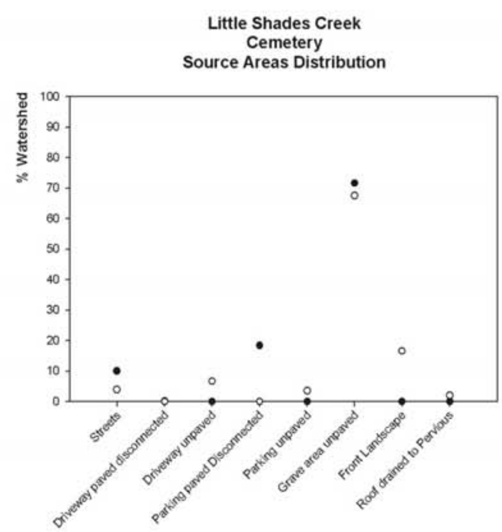

Little Shades Creek
Instituional Schools
Source Area Distribution
% Watershed
Street
DRW Connected
DRW Disconnected
Parking Paved
Playground Unpaved
Front Landscape
Back Landscape
Large Turf
Undeveloped
Roof drained to Impervious
Roof drained to Pervious

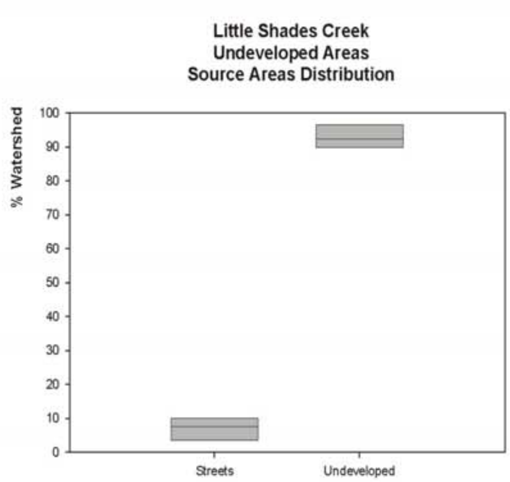

Little Shades Creek
Institutional Church
Source Area Distribution
% Watershed
Street
DRW Connected
DRW Disconnected
Parking Paved
Parking Unpaved
Front Landscape
Back Landscape
Undeveloped
Roof drained to Impervious
Roof drained to Pervious


Little Shades Creek
Industrial Land Use
Source Areas Distribution
% Watershed
Streets
Driveways paved Connected
Driveways paved Disconnected
Parking paved Connected
Parking paved Disconnected
Parking unpaved
Storage paved Connected
Storage unpaved
Front Landscape
Back Landscape
Roof drained to Impervious
Roof drained to Pervious


Little Shades Creek
Freeways
Source Areas Distribution
% Watershed
Street
Grass area at the medium
Shoulder
Landscape


Little Shades Creek
Parks
Source Areas Distribution
% Watershed
Streets
Driveways paved Connected
Driveways paved Disconnected
Parking paved Connected
Playground Paved
Playground unpaved
Front Landscape
Back Lanscape
Large Turf
Pond


Little Shades Creek
Cemetery
Source Areas Distribution
% Watershed
Streets
Driveway paved disconnected
Driveway unpaved
Parking paved Disconnected
Parking unpaved
Grave area unpaved
Front Landscape
Roof drained to Pervious


Little Shades Creek
Undeveloped Areas
Source Areas Distribution
% Watershed
Streets
Undeveloped

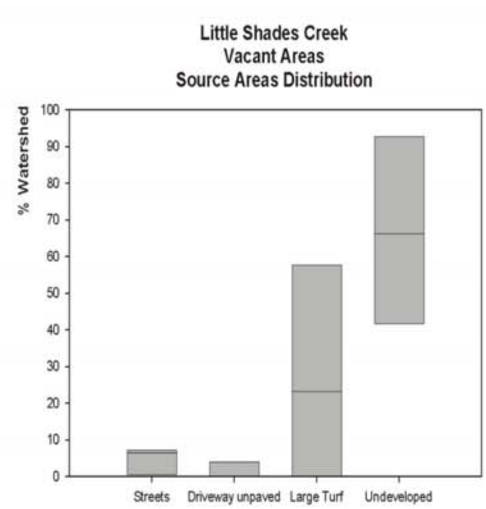

Little Shades Creek
Vacant Areas
Source Areas Distribution
% Watershed
Streets
Driveway unpaved
Large Turf
Undeveloped

Table 2. Little Shade Creek Watershed, near Birmingham, AL: Average Source Areas by Land Use

Land Use	Curb Miles/ 100 ac	Street Area (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Driveways Unpaved (%)	Parking Paved Connected (%)	Parking Paved Disconnected (%)	Parking Unpaved (%)	Playground Paved Disconnected (%)	Playground Unpaved (%)
High Dens. Residential	6.9	7.8	1.6	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Med. Dens. Residential (<1960)	5.0	5.6	1.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Med. Dens. Residential (1961-80)	5.8	6.7	1.3	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Med. Dens. Residential (>1980)	6.5	7.5	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0
Low Dens. Residential	4.6	5.3	0.23	0.80	0.0	0.0	0.0	0.0	0.0	0.0
Apartments	8.2	9.8	0.52	1.0	0.0	6.6	3.9	0.0	0.84	0.0
Multi Family	6.3	7.3	0.60	0.60	0.0	8.7	0.0	0.0	0.16	0.0
Offices	13	16	1.1	0.62	0.0	25	1.9	0.0	0.0	0.0
Shopping Centers	14	16	0.74	0.0	0.0	29	0.0	0.61	0.0	0.0
Schools	3.6	4.2	0.10	0.10	0.0	5.7	0.0	0.0	0.0	15
Churches	16	18	0.38	0.38	0.0	25	0.0	4.8	0.0	0.0
Industrial	7.1	8.0	0.32	0.10	0.0	8.9	2.5	1.8	0.0	0.0
Parks	14	16	0.11	0.11	0.0	16	0.0	0.0	8.3	25
Cemeteries	0.0	6.9	0.0	0.07	3.3	0.0	9.2	1.8	0.0	0.0
Golf Courses	1.0	1.2	0.08	0.08	0.0	0.65	0.0	0.0	0.68	0.0
Vacant	4.1	4.8	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0

Table 2. Little Shade Creek Watershed, near Birmingham, AL: Average Source Areas by Land Use – continuation

Land Use	Storage Paved Connected (%)	Storage Unpaved (%)	Front Landscape (%)	Back Landscape (%)	Large Turf (%)	Undeveloped (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Walkway (%)	Grave Area (%)	Total (%)
High Dens. Residential	0.0	0.0	40	32	0.0	3.9	4.6	8.1	0.0	0.0	100
Med. Dens. Residential (<1960)	0.0	0.0	58	23	0.0	0.0	4.0	5.5	0.0	0.0	100
Med. Dens. Residential (1961-80)	0.0	0.0	53	28	0.0	0.17	2.2	6.6	0.0	0.0	100
Med. Dens. Residential (>1980)	0.0	0.0	51	24	0.0	4.8	6.6	3.2	0.0	0.0	100
Low Dens. Residential	0.0	0.0	33	48	0.0	8.4	0.87	2.9	0.0	0.0	100
Apartments	0.0	0.0	32	23	0.0	3.3	3.6	16	0.0	0.0	100
Multi Family	0.0	0.0	28	30	0.0	6.9	11	6.7	0.1	0.0	100
Offices	0.0	0.0	24	15	0.0	0.0	17	0.33	0.0	0.0	100
Shopping Centers	0.0	0.0	30	1.8	0.0	0.0	18	3.6	0.0	0.0	100
Schools	0.0	0.0	23	26	14	1.0	6.1	4.8	0.0	0.0	100
Churches	0.0	0.0	21	12	0.0	7.0	10	1.7	0.0	0.0	100
Industrial	16	8.1	27	17	0.0	0.0	5.5	5.4	0.0	0.0	100
Parks	0.0	0.0	1.0	4.3	15	14	0.0	0.0	0.0	0.0	100
Cemeteries	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.98	0.0	70	100
Golf Courses	0.0	0.0	19	0.0	76	0.0	0.0	2.8	0.0	0.0	100
Vacant	0.0	0.0	0.0	0.0	27	67	0.	0.0	0.0	0.0	100

Table 3. Little Shade Creek, Birmingham, AL: Average of Source Area Drainage Connections by Land Use

Land Use	Pervious Areas (%)	Directly Connected Impervious Areas (%)	Disconnected Impervious Areas (%) (draining to pervious areas)	Volumetric Runoff Coefficient (Rv) if Sandy Soils	Volumetric Runoff Coefficient (Rv) if Clayey Soils
High Dens. Residential	76	13	11	0.09	0.17
Med. Dens. Residential (<1960)	82	9.1	9.2	0.06	0.14
Med. Dens. Residential (1961-1980)	81	8.8	10	0.07	0.15
Med. Dens. Residential (>1980)	82	14	4.3	0.09	0.17
Low Dens. Residential (drained by swales)	90	4.9	5.2	0.05	0.17
Apartments	58	16	26	0.09	0.17
Multi Family	65	27	7.4	0.13	0.14
Offices	39	57	4.6	0.41	0.43
Shopping Centers	33	64	3.6	0.43	0.47
Schools	79	16	4.9	0.12	0.17
Churches	44	54	2.1	n/a	n/a
Strip Commercial	7.9	88	4.3	0.60	0.61
Industrial	54	36	11	0.46	0.49
Parks	59	32	8.4	0.29	0.34
Cemeteries (drained by swales)	83	0.0	17	0.08	0.16
Golf Courses (drained by swales)	95	1.9	3.5	0.04	0.15
Freeways (drained by swales)	41	0.0	59	0.08	0.26
Vacant (drained by swales)	95	0.0	4.8	0.06	0.17

Figure 4. Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (Rv) for each land use category for sandy soil

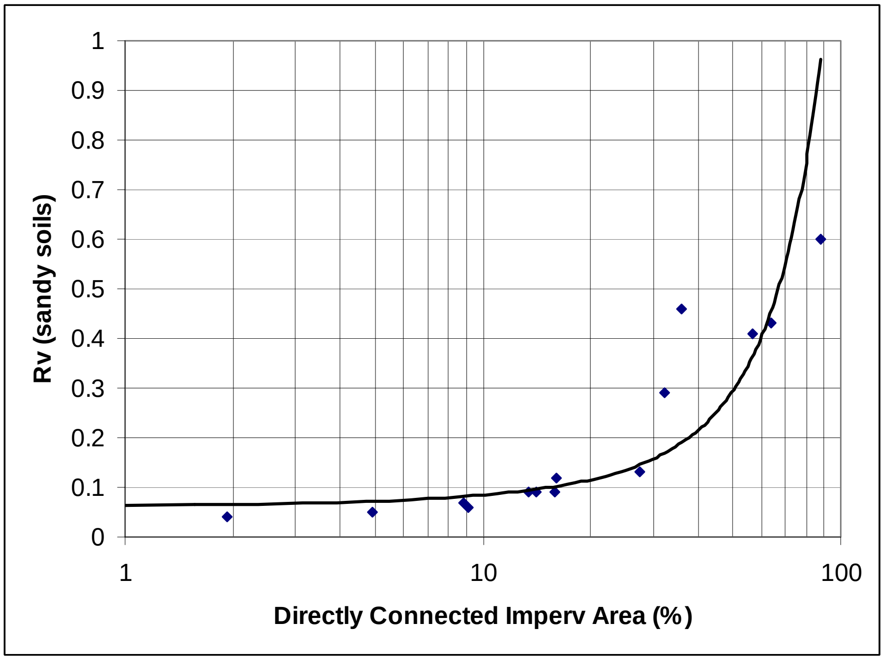


Figure 5. Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (Rv) for each land use category for clayey soil

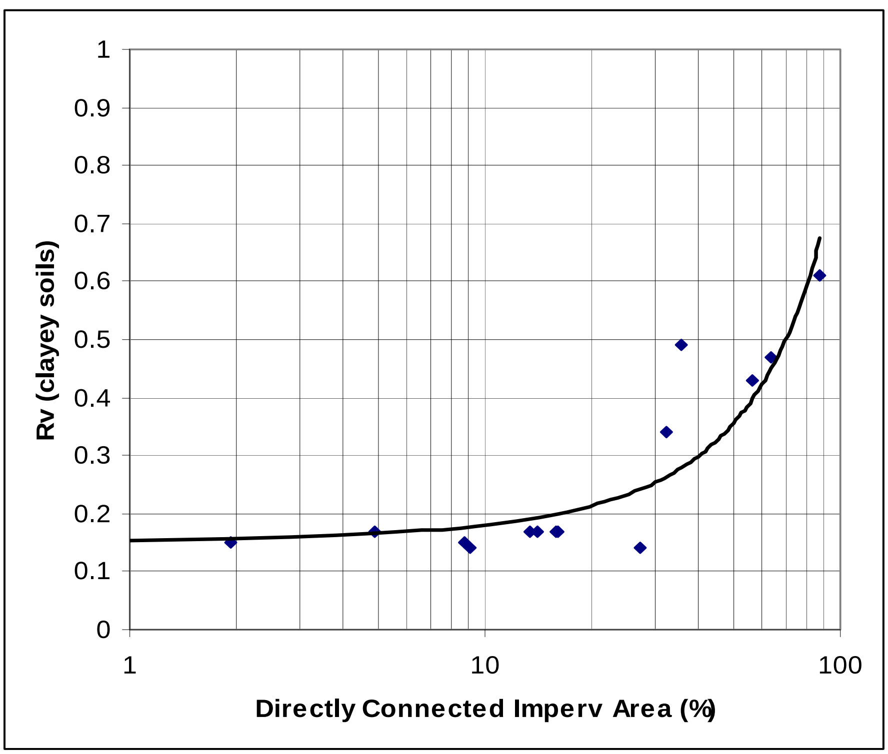


Table 4: Jefferson County Alabama, MS4 watersheds: Average Source Areas by Land Use

ALJC001 Watershed

LAND USE ALJC001	Curb Miles/ 100 ac	Street (%)	Street Unpaved (%)	Parking paved (%)	Parking Unpaved (%)	Storage paved (%)	Front Landscape (%)	Back Landscape (%)	Large Turf (%)	Un-developed (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)
COMMERCIAL	6.8	23	0.0	37	0.97	1.3	3.6	2.9	0.0	16	15	0.0
R. HIGH DENS.	7.8	21	0.0	0.0	0.0	0.0	26	30	0.0	0.0	0.0	23
INDUSTRIAL	7.0	24	1.6	45	3.9	0.0	0.0	0.0	0.0	5.3	19	1.3
UNDEVELOPED	2.4	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93	0.0	0.0
OPEN SPACE	11	21	0.0	0.0	0.0	0.0	0.0	0.0	79	0.0	0.0	0.0
FREEWAY	0.0	55	0.0	0.0	0.0	0.0	0.0	0.0	45	0.0	0.0	0.0

ALJC 002 Watershed

LAND USE ALJC002	Curb Miles /100 ac	Street Gutter (%)	Curb Miles /100 ac	Street Grass Swales (%)	Street Unpaved (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Parking Paved Connected (%)	Parking Unpaved (%)	Storage paved (%)	Storage unpaved (%)
INDUSTRIAL	3.8	12	1.1	1.8	3.2	0.0	0.0	22	16	8.0	4.9
COMMERCIAL	12	25	0.0	0.0	0.0	0.0	0.0	47	0.0	1.6	0.0
R. HIGH DENS.	12	24	0.0	0.0	0.0	1.8	1.8	0.23	0.0	0.0	0.0
INSTITUTIONAL	9.6	30	0.0	0.0	0.0	0.0	0.0	19	0.0	0.0	0.0
OPEN	0.0	0.0	7.6	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAND USE ALJC002	Playground unpaved (%)	Front Landscape (%)	Back Landscape (%)	Large Turf (%)	Un-developed (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Tracks (%)	Pond (%)	Other Pervious (%)	TOTAL (%)
INDUSTRIAL	0.0	0.0	0.0	3.6	4.6	15	3.6	3.8	0.47	1.3	100
COMMERCIAL	0.0	0.0	0.0	1.7	8.2	16	0.00	0.0	0.0	0.0	100
R. HIGH DENS.	0.21	17	29	5.9	6.8	3.8	9.9	0.0	0.0	0.0	100
INSTITUTIONAL	18	21	0.0	3.5	0.0	9.3	0.0	0.0	0.0	0.0	100
OPEN	0.0	0.0	0.0	30	0.0	0.0	0.0	0.0	0.0	52	100

ALJC009 Watershed

LAND USE ALJC009	Curb Miles/ 100 ac	Street (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Parking Paved (%)	Play-ground Paved (%)	Play-ground Unpaved (%)	Front Land-scape (%)	Back Land-scape (%)	Roof drained to Imperv-ious (%)	Roof drained to Pervious (%)
COMMERCIAL	7.7	31	0.0	0.0	38	0.0	0.0	0.0	0.0	31	0.0
R. HIGH DENS.	10	20	1.6	1.6	0.0	0.0	0.0	25	34	6.9	11
INSTITUTIONAL	8.0	14	7.0	7.0	17	12	8.3	3.0	8.1	23	0.0

ALJC010 Watershed

LAND USE ALJC010	Curb Miles/ 100 ac	Street Gutter (%)	Curb Miles /100 ac	Street Grass Swales (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Front Landscape (%)	Back Landscape (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Other Pervious (%)	TOTAL (%)
RESID. MEDIUM DENS.	8.5	20	2.6	3.3	2.6	2.6	32	24	7.8	7.0	0.0	100
UNDEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100

ALJC012 Watershed

LAND USE ALJC012	Curb Miles/ 100 ac	Street Gutter (%)	Parking paved (%)	Storage paved (%)	Large Turf (%)	Undeveloped (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Other Pervious (%)	TOTAL (%)
APARTMENTS	5.3	12	15	0.0	0.0	0.0	14	0.0	60	100
COMMERCIAL	4.7	16	36	5.7	28	0.0	14	0.0	0.0	100