Impervious Cover and
Land Use
in the
Chesapeake Bay Watershed

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Disclaimer

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Executive Summary

An understanding of impervious cover is important for watershed managers for several reasons. First, impervious cover is an important indicator of watershed health, and a knowledge of current or future impervious cover in a subwatershed can be used to predict stream quality, and manage future land use to protect stream quality. Second, impervious cover is a critically important variable in most hydrologic and water quality models used to analyze urban watersheds, regardless of whether they are simple or complex.

Despite its importance, watershed managers have had to rely on imprecise and uncertain estimates of the relationships between urban land uses and impervious cover. To fill this gap, the Center for Watershed Protction analyzed 210 polygons of homogeneous land use from the GIS systems of four Chesapeake Bay communities. The study was designed to obtain more precise estimates of the mean impervious cover associated with 12 common urban land use categories.

The four communities sampled as part of this study were Baltimore County (MD), Howard County (MD), James City County (VA), and Lancaster County, (PA). The development patterns in these counties tend to be suburban in nature, and most of the polygons sampled had been constructed since 1970. Consequently, the impervious cover estimates reported here primarily apply to recent suburban development, and may not be transferable to either highly urban areas or developments that predate World War II. In addition, the majority of land use polygons analyzed in this study used conventional development design, as opposed to more innovative techniques that incorporate better site design techniques such as cluster development that minimize impervious cover. Consequently, if widespread implementation of better site design techniques is anticipated within a locale, it will be necessary to adjust these numbers downward. Lastly, large freeways and limited access arterials were not included in sample polygons. If these are present or planned within a given watershed, their contribution to impervious cover must be calculated separately.

Given these limits, the impervious cover estimates within each land use category exhibited relatively little variation, as indicated by the small standard errors associated with the group means. Statistical analysis demonstrated that the land use/impervious cover estimates were very similar within the same zoning category among the four counties sampled. A statistically significant difference between an individual county and its cohorts was detected in only five out of 48 comparisons. The differences that occurred were typically found for low density residential zoning categories in counties that had unusually generous open space requirements.

The impervious cover estimates for individual suburban land use categories in the Chesapeake Bay are provided in the summary table on the following page.

The institutional and open urban land categories exhibited greater variability in impervious cover than other land use categories. The primary reason being the wide range of development types that occur within these loosely defined categories. More specific estimates for impervious cover were derived for schools, churches, and municipal operations in the institutional category. Similarly, significant differences were detected in the most common components of open urban land: cemeteries, parks, and golf courses.

Since the individual components of impervious cover were directly measured in this study, it was possible to determine what percentage of the urban landscape was devoted to building footprints (i.e., people habitat), as compared to streets, driveways and parking lots (i.e., car habitat). Car habitat exceeded the building footprint in every urban land use category, ranging from 55% to 75% of the total impervious surface area for a site. This finding suggests that better site design techniques that reduce the amount of car habitat have the most potential to reduce the mean impervious cover associated with that land use category.

A simple four-step procedure was developed to use these new impervious cover relationships to produce reliable estimates of future impervious cover within a watershed. First, large areas of known unbuildable land must be subtracted from the watershed area. These include large tracts of land in floodplains, wetland areas, stream valleys and major conservation areas. Second, the future land use distribution for the built and buildable portions of the watershed are multiplied by the impervious cover factors to yield a provisional estimate of future impervious cover. Next, the contribution of impervious cover from any existing or planned freeways and limited access arterial roads must be calculated based on their length and width. In the last

Land Use Category	Sample Number (N)	Mean Impervious Cover (SE)	Car Habitat* (%)	Notes
Agriculture	8	**1.9** ± 0.3	56	
Open Urban Land	11	**8.6** ± 1.64	65	High variability, range = 2.4 to 21.5
2 Acre Lot Residential	12	**10.6** ± 0.65	75	Counties variable, range = 8.7 to 12.7
1 Acre Lot Residential	23	**14.3** ± 0.53	65	
½ Acre Lot Residential	20	**21.2** ± 0.78	60	
1/4 Acre Lot Residential	23	**27.8** ± 0.60	56	
1/8 Acre Lot Residential	10	**32.6** ± 1.6	56	
Townhome Residential	20	**40.9** ± 1.39	55	
Multifamily Residential	18	**44.4** ± 2.0	61	Apartments/condos
Institutional	30	**34.4** ± 3.45	67	High variability, range = 8.4 to 82.0
Light Industrial	20	**53.4** ± 2.8	67	No heavy industry
Commercial	23	**72.2** ± 2.0	72	No regional malls

*percent of total impervious surface allocated to streets, driveways, and parking lots

step, the percentage of imperviousness is calculated. This standard method for estimating existing and future impervious cover should be useful for both watershed planners and watershed researchers.

While this project achieved its primary objectives, further impervious cover research would be helpful for both planners and engineers. Three key issues merit further investigation. First, does the age of development influence the basic land use/impervious cover relationship (e.g., pre World War II, vs. 1960s vs. 1990s)? Second, how much would impervious cover estimates be reduced in a community if it employs better site design techniques, such as open space or cluster residential subdivisions? Too few of these kinds of developments were available within our study design to address this important management question. Third, are there consistent patterns in the types of pervious areas found within an urban land use category such as forest, meadow, turf, landscaping, lawns, and exposed soil? Differences in pervious areas are difficult to distinguish within digital orthophotos, so this would require greater ground truthing as the capability of some GIS data are limited to this point.

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1.0 Introduction

Recent research has revealed a strong relationship between impervious cover and various indicators of stream quality (MCDEP, 2000; CWP, 1998; Maxted and Shaver, 1996; Schueler, 1994; Booth and Reinelt, 1993, Arnold and Gibbons, 1996). The Center for Watershed Protection (hereafter, the Center) used this relationship to develop the "Impervious Cover Model," which is illustrated in Figure 1.1. The Impervious Cover Model is based on more than 40 scientific studies and identifies thresholds of impervious cover that correspond to general stream health. In many regions of the country, as little as 10% watershed impervious cover has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases (Schueler, 1994). The Impervious Cover Model is a planning tool that enables an initial screening of the condition of a watershed (based on impervious cover) and provides a classification system with management options to address the protection and mitigation needs of a watershed.

Studies that link impervious cover to stream condition typically show that impacts to a stream fall into four general categories: hydrologic impacts, geomorphic impacts, water quality impacts, and biological impacts. More specifically, when porous land is converted to impervious cover, a greater fraction of annual rainfall is converted to surface runoff, and a smaller volume recharges the groundwater. This increased surface runoff volume causes higher peak flows that erode stream channels, and lower baseflow, resulting in habitat degradation. In addition, surface runoff carries a suite of pollutants that degrade water quality. Research also suggests a link between impervious cover and the diversity, richness and abundance of aquatic life. A complete literature review of this relationship between impervious cover and stream quality can be found in Appendix A, which summarizes 43 studies including recent research that generally confirm the Impervious Cover Model by documenting the impacts of stormwater on streams and receiving waters.

More and more local communities are beginning to use impervious cover as an indicator tool in their local planning, zoning, and watershed analysis efforts as a result of the compelling scientific evidence. Impervious cover is also a critical input variable in many water quality and quantity simulation models, such as the Storm Water Management Model (SWMM), the Hydrologic Simulation Program Fortran (HSPF) model, and the Source Loading and Management Model (SLAMM), as well as engineering models such as the Simple Method, TR-55, and TR-20 (Huber *et al*., 1988; Al-Abed *et al*., 1995; Pitt and Vorhees, 1989; Schueler, 1987; USDA, 1986 and 1982).

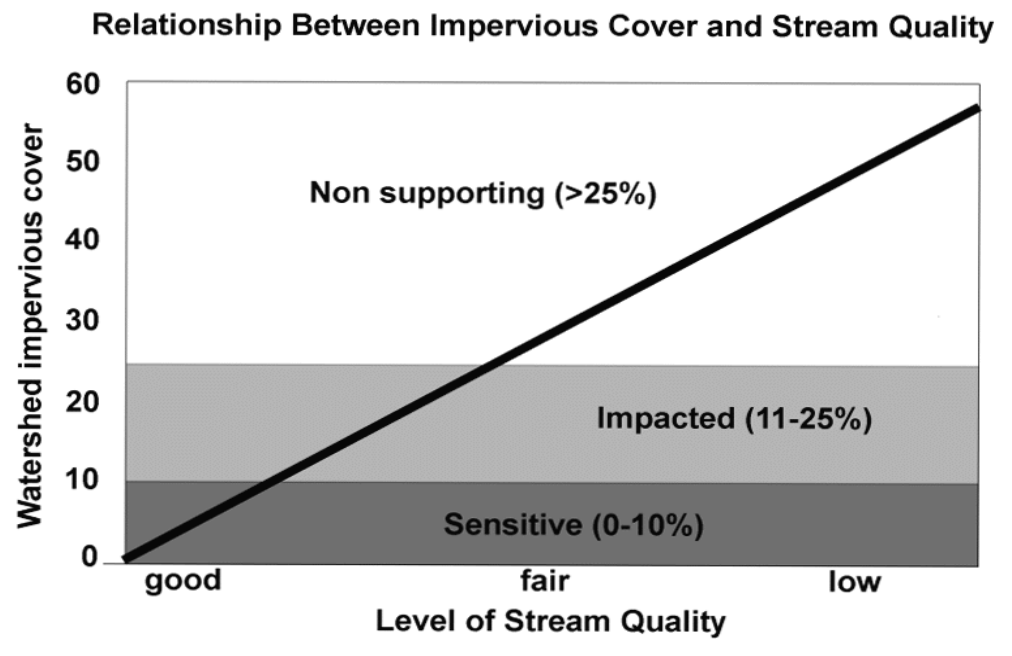

Figure 1.1 - The Impervious Cover Model (CWP, 1998)

To date, most of the research on impervious cover has focused on defining levels at which impacts to the stream become evident. Less effort has been expended on researching methods to accurately measure existing impervious cover or project future impervious cover in an urbanizing landscape. In addition, many of the land use/impervious cover relationships developed by researchers in the past are becoming outdated and may not be transferable to all regions of the country or all development patterns. These relationships are particularly important when it comes to estimating future impervious cover.

With the advent of Geographic Information Systems (GIS), the utility of impervious cover as an indicator is even more valuable due to the relative ease and accuracy with which it can be calculated and tracked. Using this advanced technology, there are opportunities to update and improve land use/impervious cover relationships that provide a greater level of accuracy to the watershed assessment and planning process.

The Center, under a grant provided by the United States Environmental Protection Agency Chesapeake Bay Program, conducted a two-part study with the primary objective of developing more accurate and current land use/impervious cover relationships. Part 1 of the study involved a summary, based on existing research, of the relationship between impervious cover and stream quality. In addition, techniques used by others to estimate impervious cover were reviewed and summarized. Part 2 of the study involved analyzing existing Chesapeake Bay Watershed GIS land use data to derive accurate estimates of impervious cover in relation to various land use categories (e.g., single family residential, commercial, industrial, etc).

This report presents the findings and results of the study. Section 2 describes the two most common techniques for measuring impervious cover and presents case studies of applications of the various techniques. Section 3 details the ArcView GIS analysis that was conducted to generate land use/impervious cover relationships for the Chesapeake Bay, and section 4 presents the results of the GIS analysis.

2.0 Measuring Impervious Cover

Section 1 identified impervious cover as an important indicator of stream quality based on the relationship between the impervious cover in a watershed and various hydrologic, biologic, chemical, and geomorphologic measures of stream health. Therefore, the accurate measurement of impervious cover is essential to using this indicator as a watershed planning and management tool. While there are several methods to arrive at current and future impervious cover, some are more accurate than others. This section describes the most commonly used methods of impervious cover measurement. The four generally accepted techniques include:

- **Direct Measurement:** Actually measures impervious cover "on the ground", including rooftops, roads, and other paved surfaces
- **Land Use:** Estimates impervious cover based on land use (e.g., low density residential, commercial)
- **Road Density:** Estimates impervious cover from road density (length of road per unit area)
- **Population:** Estimates impervious cover from population data

The four techniques become progressively less accurate and generally less expensive. Deciding which technique or combination of techniques may be best for a subwatershed depends largely on the resources and data available for the measurement. Although it is important to accurately measure and forecast impervious cover, it is equally important to measure it within the available budget. Table 2.1 can help watershed managers evaluate each technique based on four characteristics:

- **Effort/ Resources:** How much time and money does this technique require?
- **Accuracy:** How accurate is this measurement?
- **Utility for Future Forecasting:** Can I use this technique to forecast future impervious cover?
- **Utility to Address Better Site Design:** Can this technique reflect the use of site design techniques that reduce impervious cover?

Table 2.1 - Choosing a Method to Estimate Impervious Cover

Technique	Effort/ Resources	Accuracy	Utility for Future Forecasting	Utility to Address Better Site Design	When to Use
Direct Measure	❍	●	❍	❍	• GIS system in place • Large budget • On a limited basis as a foundation for other techniques • Very accurate measure is needed
Land Use	◗	◗	●	●	• Moderate budget • Moderate accuracy is needed
Road Density	●	?	❍	❍	• Back of the envelope estimation • Needs to be calibrated with another method
Population	●[1]	❍[2]	●	❍	• As a quick method to estimate impervious cover increase to the watershed (i.e., not at the subwatershed level) • In combination with another method to predict future impervious cover

● Best (most accurate; least effort; can be used to forecast future impervious cover; can address better site design techniques)
◗ Moderate
❍ Worst
? Unknown

[1] Assumes that population forecasts have been completed

[2] More accurate for larger areas

Source: CWP. 1998

By far the most accurate method of measuring impervious cover is the direct measurement method; however, it is also the most expensive method. Therefore, if accurate impervious cover/land use coefficients are available from direct measure studies, the land use method may be the best choice for measuring impervious cover in terms of cost, accuracy, and time. The road density and population methods are not very accurate when used alone and are often combined with other methods. A more complete discussion of using road density and population to estimate impervious cover can be found in Appendix B. The direct measurement and land use methods are described in further detail below.

2.1 Technique 1: Direct Measurement

In the direct measurement technique, the area of all rooftops, streets, sidewalks and other impermeable surfaces is measured in a subwatershed. The source of these data can be on-site surveying, land use maps, modeling from remote sensing satellite imagery, and aerial photography. Aerial photos are the most common source, often in the form of digital orthophotos, because they are relatively easy to obtain, less expensive than satellite imagery, and can be very accurate.

Direct measurement is the most accurate as well as the most time consuming and expensive method to measure impervious cover. This method has limited value for estimating future impervious cover, except as a baseline for assessing techniques that minimize impervious cover in new development, such as better site design[1]. Realistically, this technique cannot be used throughout the watershed without a GIS system, and full-time staff to convert or digitize the impervious cover data. Typically, managers would need to convert digital aerial photography into a GIS data layer that identifies impervious surfaces (Figure 2.1). Once this data layer is in place, the GIS can calculate the impervious area, using a simple routine.

Several decisions must be made about what surfaces to include as impervious cover as well as whether they are 100% impervious. A distinction may or may not be made between impervious areas that are hydraulically connected to a drainage system such as most driveways and streets, and those impervious areas that have been disconnected from the system, such as rooftops that drain to pervious lawn areas. If only impervious surfaces that are directly connected to the drainage system are measured, this is referred to as the Effective Impervious Area (EIA) (Sutherland, 1995). Another issue is whether to take into account compacted soils such as athletic fields or lawns, which may effectively act as impervious surfaces by producing increased amounts of runoff due to compaction by construction equipment or years of heavy use. This may be difficult to measure, but can be accounted for by assigning different imperviousness values to these land uses based on studies of the infiltration capacity of compacted soils. Finally, stormwater treatment practices such as ponds, wetlands and bioretention areas may actually reduce the impacts of impervious cover by reducing and treating runoff and intercepting it from the drainage collection system. This may be taken into account during impervious cover measurement, particularly if the resulting numbers will be used for hydrological analysis.

Although this is called direct measurement, some assumptions are needed to yield precise answers. For example, MNCPPC (1995) made assumptions to account for the additional area of sidewalks and driveways because of limitations in GIS data. Sidewalks appeared only as lines in a GIS system, so all sidewalks had to be multiplied by a standard width to obtain an area. Similarly, driveways did not appear in the GIS system, so the average driveway area was added to each single family detached house. In addition, it is common to make some assumption regarding the imperviousness of non-paved areas, although this particular set of assumptions may not be appropriate everywhere. Similar assumptions may be needed to capture smaller impervious areas that do not show up on GIS systems or aerial photography, such as sheds, pools and decks.

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[1] Better site design is a fundamentally different approach to residential and commercial development that seeks to accomplish three goals: (1) reduce the amount of impervious cover, (2) increase natural lands set aside for conservation, and (3) use pervious areas for more effective stormwater treatment (CWP, 2000).

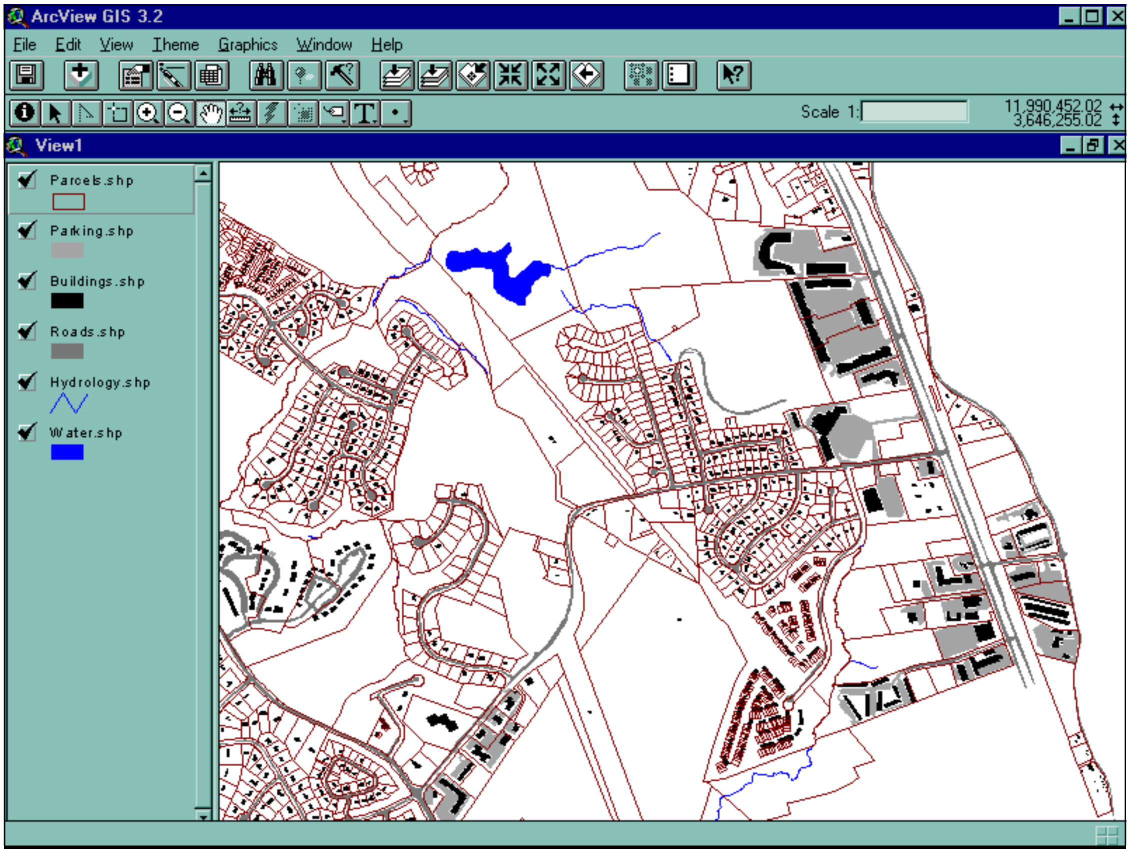

Figure 2.1 - ArcView GIS Impervious Cover Layers for Direct Measurement Technique

Case Study 1: Direct Measure In Montgomery County, MD
(Source: MNCPPC, 1995)

Under an initiative known as the "Countywide Stream Protection Strategy," Montgomery County, Maryland used a GIS system to calculate the impervious area of every subwatershed within the county. Topographic maps were used to delineate subwatersheds, then GIS layers of impervious cover such as parking lots, roads, building footprints and sidewalks were digitized from aerial photos. These data, combined with biological assessments, were used to classify each subwatershed into a management category that determines current and future management decisions. The future impervious area calculation was determined using standardized land use/ impervious cover relationships. One important note is that this project was done on a county-wide basis, and continuous updating of the GIS system will be necessary. The assumptions made during the impervious cover estimation process include:

- Each single-family detached lot has a 30 ft. x 15 ft. driveway
- Sidewalks have an average width of four feet
- Forest is 1% impervious
- Non-paved, non-forest land is 3% impervious

Case Study 2: Direct Measure in Connecticut
(Source: Prisloe et al., 2000)

An impervious cover study was conducted to derive land use-landcover (LULC) and impervious cover relationships for potential application in estimating impervious cover throughout the northeastern United States. Data used included GIS layers from 4 municipalities in Connecticut including buildings, roads, driveways, sidewalks, parking lots, pools, tennis courts, and patios originally digitized from aerial photos. Satellite-derived LULC data was classified into 1 of 28 LULC categories and overlaid with the impervious surface GIS data. Summary statistics were derived of the total area of each LULC category and the total area of impervious cover within each LULC category. A second set of impervious cover coefficients was calculated based on parcel size and zoning, which is useful for conducting zoning-based build-out analyses that predict future impervious cover. Some assumptions made by this study include:

- There was no distinction between impervious cover and effective impervious area
- There was no distinction based on method of delivery to stormwater conveyance system
- Non-paved impervious surfaces were not included in the study

The results of this study are preliminary and once revised, are intended to improve the application of a GIS-based model to estimate nonpoint source pollution impacts on stream quality. It is important to note that the coefficients derived for each land use in this study do not include any impervious cover found within the road right of way. Further research is needed to determine how to account for the contribution of roads to the total impervious area.

Case Study 3: Direct Measure in the Chesapeake Bay Watershed (Source: CGIS, 2000)

This study, which is not yet completed, uses remote sensing, digital image processing and GIS to educate local land use decision makers about the link between land use and water quality. Satellite-derived impervious cover data for the Chesapeake Bay and Maryland Coastal Bays Watersheds will be clipped to watershed and county boundaries. The V-I-S model, which assigns values for vegetation, impervious surfaces, and soil to the satellite image, will be used for the digital image processing. The study also measures impervious cover in several jurisdictions using local planimetric data and GIS to derive impervious surface coefficients for these jurisdictions for various land use zoning and lot sizes. The latter analysis will serve as a calibration of the satellite data analysis used for estimating impervious cover. The resulting land use-impervious cover coefficients and guidance on how to use them to predict future build-out conditions will be provided on the CGIS website at http://www.towson.edu/cgis.

Case Study 4: Direct Measure in Grand Traverse County, MI (Source: Harrison and Dunlap, 1998)

This study involved calculating impervious cover for the Mitchell, Acme, and Yuba Creek watersheds in Grand Traverse County, Michigan. Areas not directly connected to the drainage system were subtracted from the percent impervious calculations. Aerial photos were used to digitize GIS layers of impervious cover including buildings, roads, driveways, and parking lots. Percent impervious area was calculated for each subwatershed as well as for the whole watershed. The results showed that all three watersheds had impervious cover percentages below the threshold of 10-20%. This data will be applied at the planning level to help manage the impacts of future development.

2.2 Technique 2: Land Use

Often, a product of the direct measure technique is land use/impervious cover coefficients. The land use technique uses these coefficients along with land use classification and zoning data (e.g., single family residential, commercial) to estimate impervious cover. To determine the total impervious cover in a watershed or subwatershed, the area of each land use is measured and multiplied by an associated impervious coefficient. Table 2.2 presents some examples of impervious cover coefficients that have been derived over time for specific land uses.

Land use techniques are the most cost-effective way to estimate impervious cover, although not as accurate as direct measurement. Perhaps more importantly, land use techniques are the primary method used to forecast future impervious cover.

Traditionally, impervious area is linked to land use using standardized values. However, there can be significant variability among different sources of values (see Table 2.2) for a given land use, which can limit applicability and cause confusion as to which numbers to use when estimating impervious cover. More specifically, there are several problems with the current collection of impervious cover/land use data: the wide range of values for a given land use among different sources, the wide range of methods used to derive the coefficients, differences in the types of regions in which the studies were conducted, and study-specific limitations to applying the data (i.e., some coefficients include only effective impervious area, some do not include roads, others were not derived using the direct measure method). This problem is addressed in Section 3, which describes the derivation of more precise impervious cover/land use coefficients using the direct measurement method for the Chesapeake Bay watershed and Section 4, which presents the resulting coefficients.

As mentioned above, the land use technique can also be used to forecast future impervious area, based on zoning (Table 2.3). The methodology is the same as estimating current impervious cover. However, for this analysis, impervious area-land use relationships are combined with land use areas from zoning maps or future land use maps, rather than current land use maps. One criticism of this technique is that zoning represents the "hopes and dreams" of a community and that the economy of a region may never support the zoned land use (Schueler, 1996a). In addition, zoning designations can change over time. In some cases, it may be desirable and more realistic to use an alternative estimation of build-out, such as 70% or 80% of "full build-out" to calculate near term and mid-term impervious cover.

Table 2.2 Impervious Cover (%) for Various Land Uses

	Source						
Density (du/ac)	**Northern Virginia (NVPDC, 1980)**	**(USDA, 1986)**	**Puget Sound, WA (Aqua Terra, 1994)**	**Rouge River, MI (Kluitenberg, 1994)**	**Olympia, WA (COPWD, 1995)**	**Holliston, MA (CRWA, 1999)**	**Connecticut (Prisloe, 2000)**
-	1	-	-	2	-	1	-
-	1	-	-	2	-	1	-
-	-	-	-	11	-	7-23	-
-	-	-	-	100	-	-	-
<0.5	2-6	-	10	19	-	12	7-10
0.5	9	12	10	19	-	12	7-10
1	12	20	10	19	-	12	7-10
2	18	25	-	19	-	14	14-21
3	20	30	40	19	40	14	14-21
4	25	38	40	19	40	14	14-21
>4	35	-	40	38	40	19	28
Townhouse	40	65	60	51	48	47	39
Apartment	50	65	60	51	48	47	39
High Rise	60-75	-	-	-	-	-	-
-	60-80	72	90	76	86	60	53
-	90-95	85	90	56	86	45	54

Note: NVPDC data measure effective impervious area (i.e., rooftops are not included in residential data), and Prisloe data does not include area from state and local roads

Source: Adapted from CWP, 1998

Table 2.3 - Example Land Use Impervious Calculation

Land Use Category	Current Land Use			Future Land Use Based on Zoning		
	Area (acres)	% Impervious	Impervious Area (acres)	Area (acres)	% Impervious	Impervious Area (area)
Forest	95	0.5	0.5	15	0.5	0.1
Agriculture	128	1	1.3	40	1	0.4
Low Density Residential	123	9	11.1	153	9	13.8
Medium Density Residential	205	21	43.1	268	21	56.3
Commercial	49	78	38.2	124	78	96.7
Totals	600		94.2			167.3
		Current % Impervious	16%		**Future % Impervious**	28%

Table 2.3 above illustrates how land use data can be used to estimate future impervious cover. The actual calculation is:

$$A_{LU} * IC = A_{IC}$$

where A_{LU} = area of land use in acres,
IC = impervious cover coefficient
A_{IC} = impervious area in acres

The percent impervious cover for an entire watershed or other area can be estimated using land use data and the following calculation:

$$(TA_{IC} / TA) * 100 = IC\%$$

where
TA_{IC} = the total area of impervious cover in acres,
TA = the total area of land or the water shed in acres
IC% = the impervious cover percent for the entire area

Another complicating factor of estimating future imperviousness relates to changes in the way development occurs. For example, if a community plan emphasizes better site design techniques as a watershed protection tool, it may be advisable to revise impervious cover fractions downward for each land use to account for the impervious cover reduced through better site design. Indeed, a benefit of the land use technique is that it has the flexibility to incorporate the effect of better site design. Case Study 7 provides an example of how this was done in Olympia, Washington.

2.3 Summary of Techniques

Research has revealed that imperviousness is a powerful and important indicator of stream quality and that significant degradation occurs at relatively low levels of development. This strong relationship between imperviousness and stream quality presents an opportunity for urban watershed managers to use impervious cover to classify and manage their watersheds. Because impervious cover can be readily and quickly identified and measured and also controlled, the reduction of impervious area is an effective technique for improving stream quality at the site level as well as the watershed scale. While direct measurement is the most accurate technique of impervious cover measurement, it may be too expensive and time-consuming to realistically have widespread application. The next most accurate method is the land use technique; however, the impervious cover/land use coefficients needed for this method currently come from a variety of sources with a wide range of values, methodologies, and other limitations. Taking these factors into account, the land use method is advocated as the best method for estimating impervious cover provided that accurate and standardized land use/impervious cover coefficients are developed for widespread application to predict current and future imperviousness.

Case Study 5: Land Use Estimation and Direct Measure in Holliston, MA
(Source: Roberts, 1999)

Two methods were used to estimate the impervious cover of Holliston, Massachusetts: first, literature-derived land use-impervious cover coefficients and current Holliston land use data were used to estimate impervious coverage, and second, impervious cover was directly measured using polygons of homogeneous land use and GIS to digitize the impervious cover within each land use polygon. The second method generated Holliston-specific coefficients as well as a means to test the applicability of the literature-derived coefficients. The results of the analysis indicated that the estimated impervious cover was significantly higher than the directly measured impervious cover for industrial, commercial, transportation, multifamily, and high density residential land uses. This suggests that the literature-derived values were developed in older highly urbanized areas, and that watershed-specific subsampling is an important and valuable QA/QC measure when applying the land use technique.

Case Study 6: Land Use Estimation in the Rouge River
(Source: Kluitenberg, 1994)

In the Rouge River Basin near Detroit, MI land use/ impervious area relationships were used to estimate impervious cover. Instead of using standard values, aerial photography was “sampled.” Using 1:2400 scale photographs, 300 sample locations were analyzed to determine the percent impervious area for several land uses. These land use-impervious cover relationships were then combined with land use data to characterize the impervious area in the subwatersheds of the Rouge River Basin.

Case Study 7: Land Use Estimation in Olympia, Washington
(Source: COPWD, 1995)

The City of Olympia and the Washington State Department of Ecology conducted an analysis of impervious area in three Olympia drainage basins. The purpose of the study was to determine the impact of innovative development on the impervious cover of future development. To determine the impervious area associated with the different land use categories, eleven sample developments were analyzed to represent residential, multifamily and commercial development. Actual development site plans were used to complete the analysis. The same eleven developments were then used to determine the effect of various site design principles. For example, based on an analysis of conventional commercial developments, approximately 53% of the land area was in parking. The City found that reducing commercial parking by 5% yielded a 2.7% reduction in impervious area for commercial land uses.

3.0 Chesapeake Bay Watershed GIS Analysis

Section 2 identified two primary methods for measuring impervious cover: direct measurement and estimation based on land use. Direct measurement is the most accurate although also the most expensive method. Realistically, a GIS is needed to compute impervious cover using the direct measurement method. A GIS is fast and accurate, but also requires trained staff to convert the impervious layer data, which can be expensive and time-consuming. However, if accurate land use/ impervious cover coefficients can be derived using the direct measurement method, these numbers will provide the basis for a simple, accurate, and efficient method for estimating impervious cover based on land use alone. Estimating impervious cover based on land use does not require as much time or resources as the direct measure method, and can be used by planners and others who do not have access to a GIS. Up to this point, a major limitation to using the land use method has been the lack of accurate land use/impervious cover coefficients that apply to different areas, types, and ages of development.

Part 2 of this two-part study analyzed (using the direct measurement technique) existing Chesapeake Bay Watershed GIS land use data to derive accurate estimates of impervious cover in relation to various land use categories. The results of the analysis provide direct measurement of impervious cover for the four jurisdictions selected for the study, which is a useful tool for managing future land use to protect stream quality. Also provided are current land use/impervious cover coefficients that can be used by suburban communities within the Chesapeake Bay watershed to predict current and future watershed imperviousness. Lastly, the region-specific land use/impervious cover coefficients will be useful in the development and refinement of water quality and pollutant loading models.

3.1 Study Area

The Chesapeake Bay is the largest estuary in the Unites States, spanning some 200 miles from Havre de Grace, MD to Norfolk, VA, with over 100,000 streams and rivers draining to it. The bay was formed about 5000 to 6000 years ago when the lower portion of the Susquehanna Valley was flooded from glacial meltwater. Continuing sea level rise and shoreline erosion carved out the current shape of the bay. The bay holds on average 15 trillion gallons of water and has an average depth of only 21 feet. It is one of the most productive estuaries in the world, and is home to over 3600 species of plants and animals.

The Chesapeake Bay watershed encompasses 66,388 square miles in six states and the District of Columbia. The year 2000 estimated population of the Chesapeake Bay watershed is 15.5 million, and is projected to reach 17.7 million by 2020 (CBP, 2000). Estimated land use in the watershed is 60% forest, 27% agriculture, 7% water, 3% developed, 2% wetland, and 1% barren (CBP, 2000). Three major geomorphic regions comprise the watershed, including the Atlantic Coastal Plain, the Piedmont Plateau, and the Appalachian Province. The differing geology of these three regions causes waters flowing to the bay to have a different geochemical makeup; some are rich in calcium and magnesium, while others are high in iron. This in turn affects the quality and productivity of the Chesapeake Bay.

3.2 Study Sites

The Center chose to use the direct measure method and to use aerial photos as a data source for the impervious cover layers because they were deemed most appropriate for the scale under study (the county scale). The Center obtained aerial photos in the form of digital orthophotographs as well as the GIS data digitized from these photos from each of the jurisdictions selected for the analysis. A total of four jurisdictions were selected within the Chesapeake Bay watershed for analysis. The criteria for selection included:

- Jurisdictions with existing GIS systems with sufficient coverage to assess impervious cover
- Jurisdictions that are representative of the entire watershed
- Jurisdictions encompassing urban, suburban and rural areas
- Jurisdictions encompassing different land uses, ages and styles of development
- Jurisdictions which are willing to participate and provide GIS data
- At least one jurisdiction from MD, PA, and VA
- Preference for jurisdictions that the Center is familiar with in terms of planning and zoning rules, buffer and stormwater management requirements, and development standards

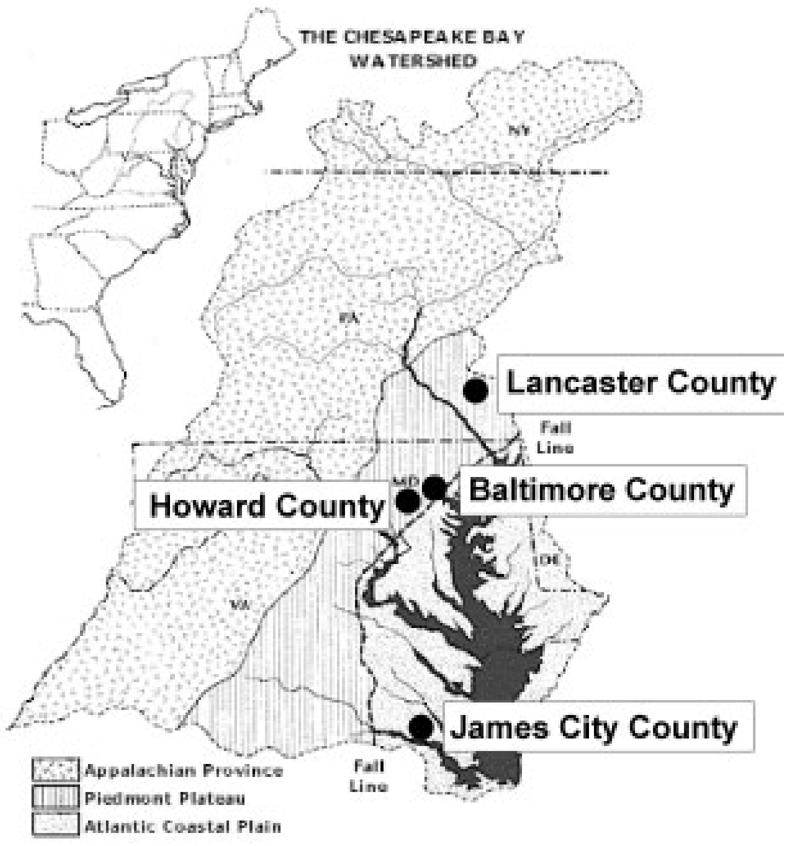

Figure 3.1 - Location of Study Sites Within the Chesapeake Bay Watershed and Its Geologic Regions (CBP, 2000)

The demographics of the four chosen jurisdictions as well as the different types of data in their GIS are described in detail on the following pages.

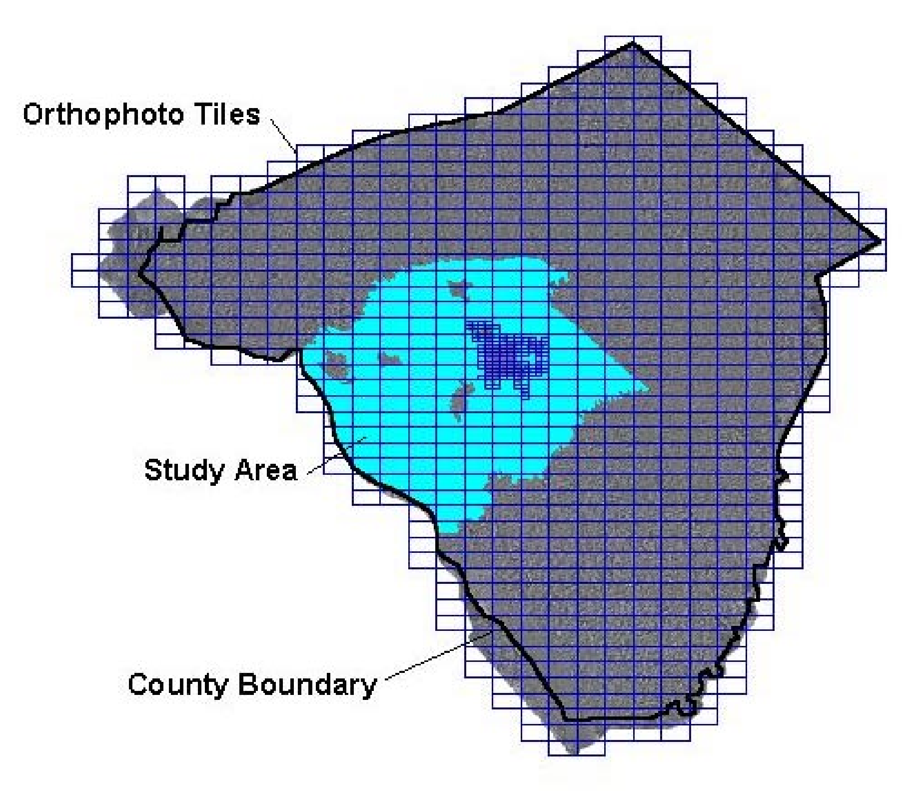

Figure 3.2 - Lancaster County, PA Study Area

3.2.1 Lancaster County, PA

Lancaster County, PA is located in southeastern Pennsylvania and has an estimated current population of 466,000 and a population density of 492.6 persons per square mile (Census Bureau, 2000; Lancaster County, PA, 2000). The median 1995 income in the county was $41,445, and the number of building permits issued in 1999 was 2,273 (Census Bureau, 2000). Lancaster County covers an area of approximately 946 square miles, and includes the city of Lancaster as well as some of the most productive farmland in the country. In fact, 60% of the county is in agricultural use (Lancaster County, 2000). Lancaster County is located within the Piedmont region of the watershed and is governed by the township and borough system. As a result, it is possible that there is more variety in the development types within Lancaster County (i.e., greater variability in standard road widths, lot setbacks, open space requirements, etc.) than in Maryland and Virginia. The data obtained from Lancaster County are described below and summarized in Figure 3.2.

<u>Digital Orthophotos</u>

Scale: 1:24,000
Year: 1993
Tile Structure: covers 5,000’ x 9,000’ on the ground, all county tiles combined into one file using MrSID extension in ArcView
Coverage: all of Lancaster County

<u>GIS Data (ArcView Shapefile format)</u>

Coordinate System: State Plane, Pennsylvania
Units: feet
Scale: 1” = 250’
Datum: NAD83
Themes: parcels, hydrology, roads, buildings, drives, parking lots
Coverage: East Hempfield, West Hempfield, Lancaster, Manheim, Manor, Conestoga, East Lampeter, West Lampeter, and Pequea townships

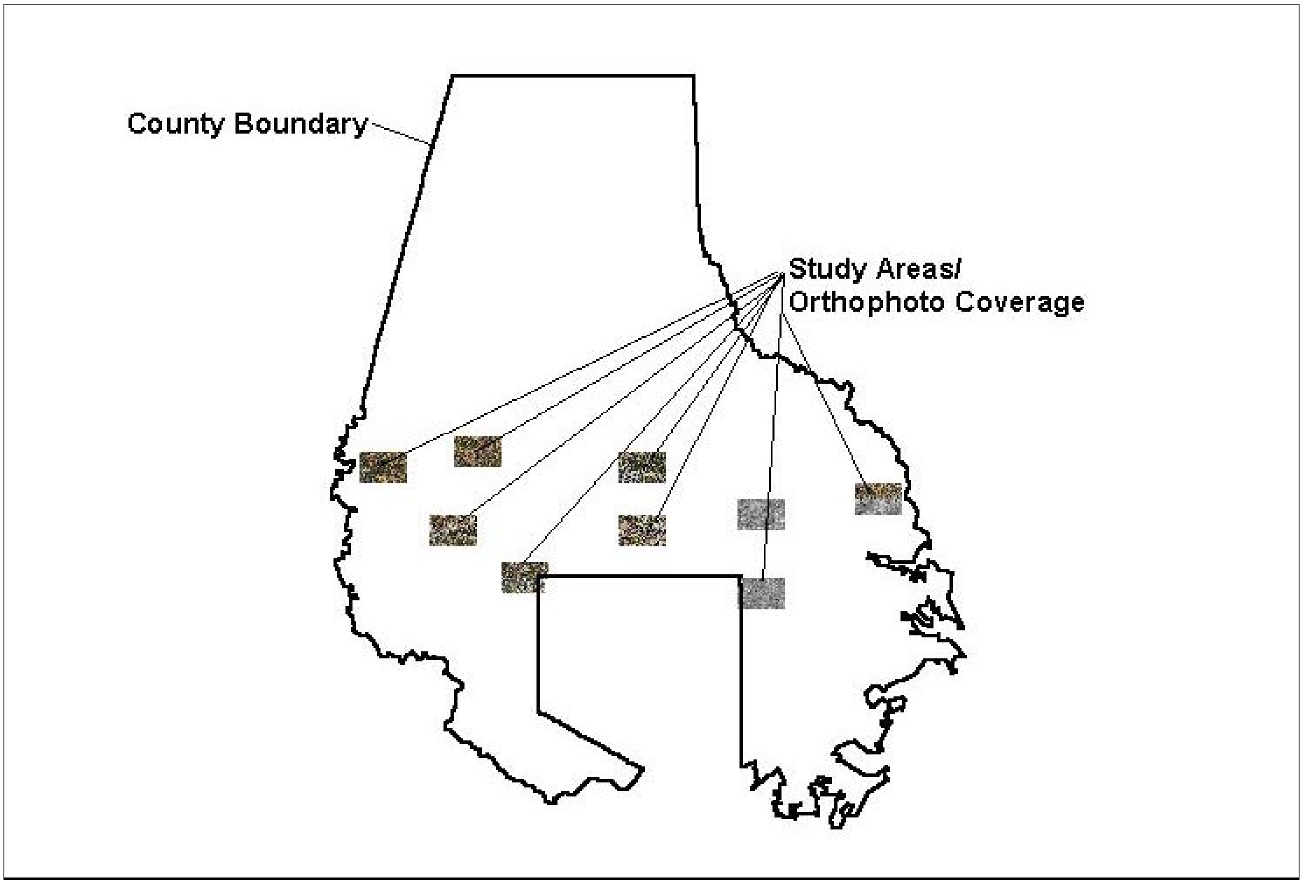

Figure 3.3 - Baltimore County, MD Study Area

3.2.2 Baltimore County, MD

Baltimore County, Maryland is located on the fall line between the Piedmont and the Coastal Plain. It encompasses about 599 square miles and contains the highly urban area outside of Baltimore City. The estimated 1999 population was 723,914, and the population density is 1,209.3 persons per square mile (Census Bureau, 2000). The median 1995 income in the county was $42,021 and the number of building permits in 1999 was 3,752 (Census Bureau, 2000). In Maryland, the county is the local governing unit, therefore development patterns across the county may be more uniform than in Pennsylvania (which is governed at the borough/township level). The data obtained from Baltimore County are described below and summarized in Figure 3.3.

Digital Orthophotos
Scale: 1:2400
Year: 2000
Tile Structure: covers 4,000’ x 6,000’ on the ground
Coverage: selected sets of tiles along urban growth corridors as shown in Figure 3.3

GIS Data (ArcView Shapefile format)
Coordinate System: State Plane 1983, Maryland
Units: feet
Scale: 1” = 200’
Datum: NAD83/91
Themes: hydrology, roads, buildings, parking lots
Coverage: selected sets of tiles along urban growth corridors as shown in Figure 3.3

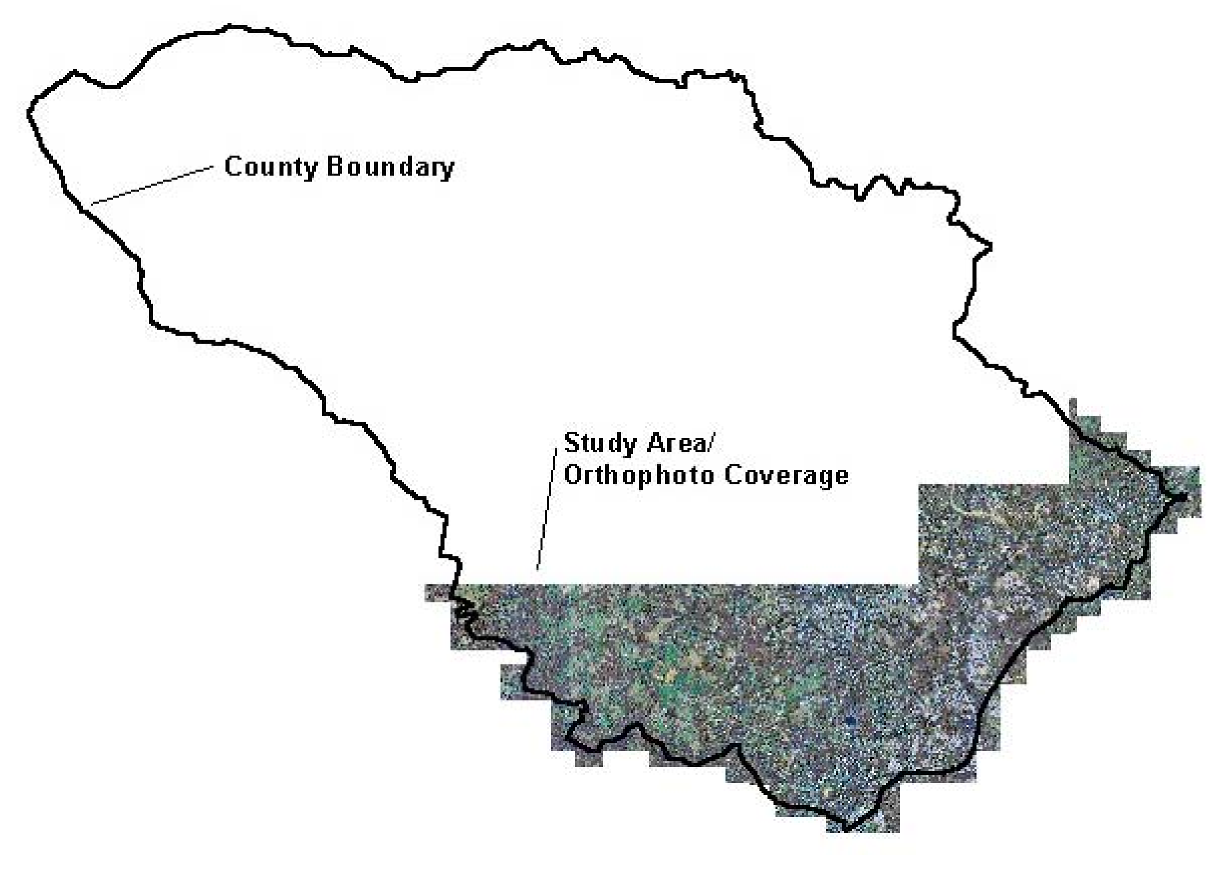

Figure 3.4 – Howard County, MD Study Area

3.2.3 Howard County, MD

Howard County, Maryland is located just southwest of Baltimore County and is found primarily within the Piedmont region, with some fall line influence. The land area is approximately 252 square miles, and includes farmland as well as urbanized areas such as Columbia. The estimated 1999 population was 243,112, and the population density was 964 persons per square mile (Census Bureau, 2000). The median income in 1995 was $64,939 and the number of building permits issued was 2,295 (Census Bureau, 2000). The data obtained from Howard County are described below and summarized in Figure 3.4.

Digital Orthophotos
Scale: 1:24000
Year: 1997
Coverage: southeastern 1/3 of Howard County

GIS Data (ArcView Shapefile format)
Coordinate System: State Plane 1983, Maryland
Units: feet
Scale: 1:7200
Projection: Lambert Conformal Conic
Themes: hydrology, roads, buildings, parking lots, sidewalks, driveways
Year: 1997
Coverage: southeastern 1/3 of Howard County

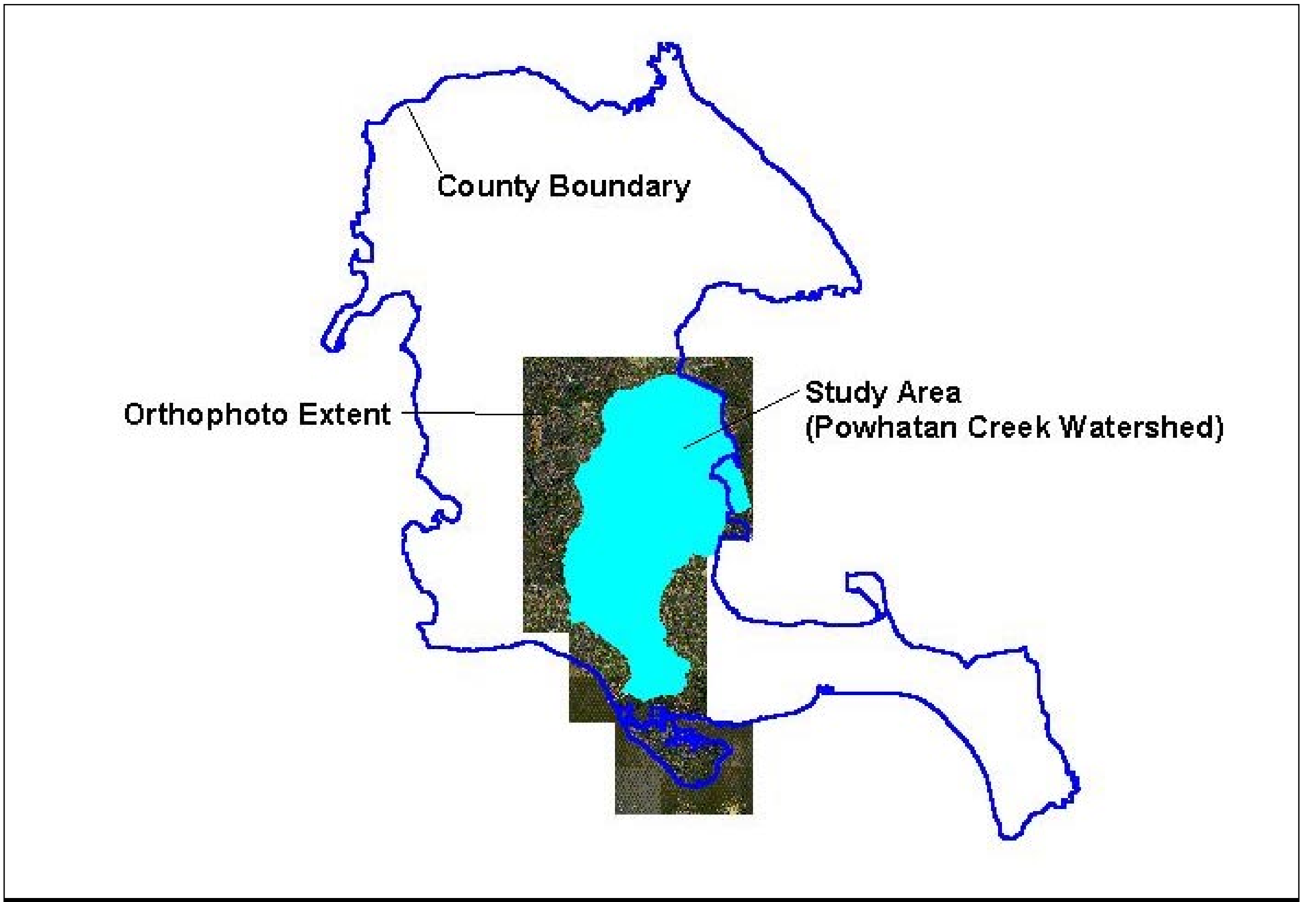

Figure 3.5 - James City County, VA Study Area

3.2.4 James City County

James City County is located west and north of Williamsburg, VA, and includes some developed areas, large portions of forested land, agriculture, and a large number of wetlands. The land area is approximately 144 square miles (the smallest of the four jurisdictions), and the current population is 48,023, with a population density of 333.5 persons per square mile (James City County, 2000). The median income is $47,117, and the number of building permits issued in 1999 was 965 (James City County, 2000; Census Bureau, 2000). James City County government is divided into five districts, which are ruled by a board of supervisors. James City County is located entirely within the Atlantic Coastal Plain, is the least urbanized of the four counties used in this study, and includes the area of 1st settlement within the Chesapeake Bay Watershed, Jamestown Island. The data obtained from James City County are described below and summarized in Figure 3.5.

Digital Orthophotos
Year: 1996 or 1998
Coverage: Powhatan Creek Watershed area

GIS Data (ArcView Shapefile format)
Coordinate System: State Plane 1983, Virginia, South
Units: feet
Datum: NAD83
Themes: parcels, hydrology, roads, buildings
Coverage: all of James City County
Year: parcels are current, all others are 1996 or 1998

3.3 Sampling Protocol and Impervious Cover Measurement

This study was primarily intended to determine the impervious cover level of various land uses at both the development level and the zoning area level. A specific sampling protocol was needed to address this and other questions. The following major steps comprised the protocol:

Step 1: Select the targeted land use categories and number of sampling units
Step 2: Delineate land use polygons
Step 3: Measure Impervious Cover

Step 1: Select the Targeted Land Use Categories and Number of Sampling Units

Table 3.1 lists the selected land use categories and number of sampling units chosen and describes each land use category.

Table 3.1 Selected Land Use Categories and Sampling Target

Land Use	Description	# Sample Units
Agriculture	Cropland and pasture lands	10
Open Urban Land	Developed park land and recreation areas, golf courses, and cemeteries	10
Residential		
2 Acre Lots	Ranges from 1.70 2.30 acres	10
1 Acre Lots	Ranges from 0.75 1.25 acres	20
‰Acre Lots	Ranges from 0.40 0.60 acres	20
…Acre Lots	Ranges from 0.20 0.30 acres	20
1/8 Acre Lots	Ranges from 0.10 0.16 acres, includes duplexes	10
Townhomes	5-10 units/acre, attached single family units that include a lot area	20
Multifamily	10-20 units/acre, residential condominiums and apartments with no lot area associated with the units	10
Light Industrial	Developed areas associated with light manufacturing, distributing, and storage of products	20
Commercial	Areas primarily used for the sale of products and services including strip malls and central business districts, does not include regional malls	20
Institutional		
Churches	Churches and other places of worship	10
Schools	Public and private elementary, middle, and high schools	10
Municipal	Hospitals, government offices and facilities, police and fire stations	10
Total		**200**

These categories were chosen based on typical zoning categories within the Chesapeake Bay Region, as well as the variety of land uses within the study areas. In addition, there was a direct attempt to target and derive impervious cover coefficients for land uses that had little or no previous research associated with it (e.g., open urban land, institutional).

The number of polygons sampled for each land use were chosen based on the frequency and variability of land uses or zoning categories. For example, over 120 samples polygons were needed to characterize the range of housing densities within residential zoning. Given the limited resources available for the study, sample targets were kept to 10 or 20 for each individual land use. Rigorous statistical analysis was conducted to demonstrate that the sample size would still yield information, particularly across certain land use types. Standard statistics, such as the standard error, of the results were used as a measure of the reliability of the results. Based on this study design, between two and five polygons were sampled for each land use within each jurisdiction.

<u>Step 2: Delineate the Land Use Polygons</u>
The criteria used when selecting land use polygons in the GIS are listed below.

For single family residential polygons:

- For residential land uses, the parcel boundary information was used to first classify parcels based on acreage (shown in the description in Table 3.1). Development patterns that most closely matched the land use category (e.g., ¼ acre lots) were selected for sampling. Because most subdivisions do not have uniform lot sizes, subdivisions were selected if the majority of lots or average lot size met the general criteria for the land use category.

- Because of difficulty in finding subdivisions that met the above criteria for polygon delineation, no minimum area was set for the polygon size for residential areas. Instead, it was decided that each residential polygon must include a minimum of 5 lots.

- Polygons were drawn by following the lot lines of contiguous parcels and excluding areas of “unbuildable” land located in the interior of the polygon. Stream valleys that did not originate within the subdivision were excluded from the land use polygons, as were other “unbuildable” lands such as floodplains, wetlands, and conservation areas. The basis behind this rule is that not all development sites include these types of characteristics. When predicting future impervious cover, a planner could estimate the areas based on existing mapping and based on local codes and ordinances that determine “unbuildable” acreage. This acreage could then be removed from the total acreage of the planning area.

For other land use polygons:

- Stormwater ponds and open water were not considered to be impervious cover because they are generally small in area and are not always associated with a single land use. While water surfaces do act as impervious surfaces in a hydrologic sense, they do not generally have similar consequences on stream quality, watershed health, or pollutant loading as more conventional impervious cover such as roads, parking lots, and rooftops.

- Minimum lot sizes were set for agriculture (50 acres), commercial (one acre), industrial (five acres), and multifamily (five acres).

Once a development area was selected, the criteria used to delineate the polygons were generally as follows:

- Parcel lines were used as guides for drawing the polygon boundaries.
- “Unbuildable” land such as floodplains, steep slopes, and conservation areas were not included in the polygons.
- Subdivision lots that were not built out were not included in the polygons.
- Large forested areas located outside parcel boundaries were not included in the polygons.
- Local and arterial roads were included in the polygons if the parcels bordering each side of the road had the same land use.
- If a local or arterial road bordering a parcel had a different land use bordering the other side of the road, only half the road was included in the polygon.
- Interstate and state highways were not included in the polygons.
- Parcel data such as a business or owner name was used to verify land use.
- Orthophotos were also used to verify land use.

Step 3: Measure Impervious Cover

The methods used to calculate impervious cover are listed below. More detail is provided in Appendix C on the specific steps used in ArcView to perform the analysis. The general impervious cover calculation steps are as follows:

1. Set up a project in ArcView that includes each impervious cover theme, digital orthophotos, and parcel data
2. Create a new theme for each land use and digitize polygons based on criteria
3. Check the polygons against the orthophotos
4. Calculate the acreage of each polygon in its corresponding data table
5. Intersect each land use polygon with each impervious cover theme (e.g., commercial roads, commercial parking lots, commercial buildings)
6. Calculate the area of each impervious cover type for each land use polygon
7. Export the data tables to Excel and sum impervious cover within each polygon and divide by polygon area to get percent impervious cover

Although the methods used provide an accurate direct measure of impervious cover, there were some assumptions made due to lack of data. Specifically, residential driveways and sidewalks were estimated using the orthophotos for Lancaster County, Baltimore County, and James City County. Using the orthophotos as a guide, a parking lot layer was created for James City County and a parking lot layer and roads layer were created for Howard County. Additionally, an impervious cover theme was digitized for each jurisdiction that represented any impervious surface not included in the other layers, such as tennis courts, garages, and other paved areas. The major assumptions made for the analysis are listed and described below.

For single family residential:

Sidewalk Estimation

Orthophotos were used to measure the length of sidewalks in each polygon, which was then multiplied by 4 feet (assumed sidewalk width). The resulting numbers were added to the data table for calculation of total impervious cover.

Driveway Estimation

Orthophotos were used to determine an average driveway size for each polygon, which was then multiplied by the number of homes within the polygon. The resulting numbers were added to data table for calculation of total impervious cover.

For other land uses:

Parking Lots

James City County was the only jurisdiction without a parking lot layer. Therefore, a parking lot layer was created for the chosen land use polygons, and this layer was included in the processing and calculation of total impervious cover.

Other Impervious Surfaces

Orthophotos were used to digitize an impervious cover layer that included tennis courts, garages, and other impervious surfaces not included in the buildings, parking lots, roads, driveways, or sidewalks layers. This layer was included in the processing and calculation of total impervious cover.

4.0 Results and Discussion

Table 4.1 shows the sample number, mean, and standard error for each land use category. The impervious cover estimates within each land use category showed relatively little variation, as indicated by the small standard errors. Table 4.2 summarizes the results by land use and location. A complete table of all results by land use polygon can be found in Appendix D. Statistical analysis demonstrated that the land use/impervious cover estimates were very similar within the same zoning category among the four counties sampled. A statistically significant difference between an individual county and its cohorts was detected in only five out of 48 comparisons. The differences that occurred were typically found for low density residential zoning categories in counties that had unusually generous open space requirements. Overall, it appears that the impervious cover/ land use relationships can be generalized beyond the individual counties in which they were derived, and that they are broadly transferable to other Chesapeake Bay communities with similar development patterns.

Table 4.1 - Impervious Cover Results by Land Use Category

Land Use Category	Sample Number (N)	Mean Impervious Cover (SE)	Car Habitat* (%)	Notes
Agriculture	8	**1.9** – 0.3	56	
Open Urban Land	11	**8.6** – 1.64	65	High variability, range = 2.4 to 21.5
2 Acre Lot Residential	12	**10.6** – 0.65	75	Counties variable, range = 8.7 to 12.7
1 Acre Lot Residential	23	**14.3** – 0.53	65	
‰Acre Lot Residential	20	**21.2** – 0.78	60	
…Acre Lot Residential	23	**27.8** – 0.60	56	
1/8 Acre Lot Residential	10	**32.6** – 1.6	56	
Townhome Residential	20	**40.9** – 1.39	55	
Multifamily Residential	18	**44.4** – 2.0	61	Apartments/condos
Institutional	30	**34.4** – 3.45	67	High variability, range = 8.4 to 82.0
Light Industrial	20	**53.4** – 2.8	67	No heavy industry
Commercial	23	**72.2** – 2.0	72	No regional malls

* percent of total impervious surface allocated to streets, driveways, and parking lots

Table 4.2 Impervious Cover Study Results by Location

Land Use	Lancaster County, PA	Baltimore County, MD	Howard County, MD	James City County, VA	Chesapeake Bay Average
Agriculture	1.8%	N/A	1.5%	2.3%	1.9%
Open Urban Land	4.2%	9.8%	10.9%	10.3%	8.6%
2 Acre Lot Residential	10.4%	8.7%*	N/A	12.7%*	10.6%
1 Acre Lot Residential	13.3%	14.9%	13.2%	15.7%	14.3%
‰Acre Lot Residential	24.6%*	17.7%	19.5%	19.2%	21.2%
…Acre Lot Residential	28.9%	29.8%	25.4%	25.0%*	27.8%
1/8 Acre Lot Residential	33.0%	N/A	37.2%	30.2%	32.6%
Townhome Residential	38.5%	43.3%	40.9%	39.3%	40.9%
Multifamily Residential	42.1%	48.5%	48.7%	40.2%	44.4%
Institutional	40.5%	33.3%	34.9%	27.6%	34.4%
Light Industrial	47.8%	55.4%	53.6%	60.7%	53.4%
Commercial	72.1%	79.2%	78.3%	65.6%*	72.2%

N/A: Land use not sampled
*numbers differ significantly from the mean

Since the individual components of impervious cover were directly measured in this study, it was possible to determine what percentage of the urban landscape was devoted to building footprints (i.e., people habitat), as compared to streets, driveways, and parking lots (i.e., car habitat). Car habitat exceeded the building footprint in every urban land use category, ranging from 55% to 75% of the total impervious surface area for a site. This finding suggests that better site design techniques that reduce the amount of car habitat have the most potential to reduce mean impervious cover associated with that land use category.

The impervious cover results for each land use can be further broken out into subcategories of impervious cover type. Several patterns were apparent as shown by the pie charts in Figures 4.1 through 4.7. For single family residential categories, driveways consistently made up about 4% of the polygon area, while roads and buildings comprised an equal percentage that progressively increased with development density. Sidewalks in residential areas composed from <1% to 2% of the polygon area, and this number also increased with development density. For commercial and industrial land uses, roads made up 6-7% of the polygon area and buildings made up 18-20% of the polygon area. However, parking lot area was significantly higher in the commercial areas, comprising 45% of the total area as compared with 29% in industrial areas.

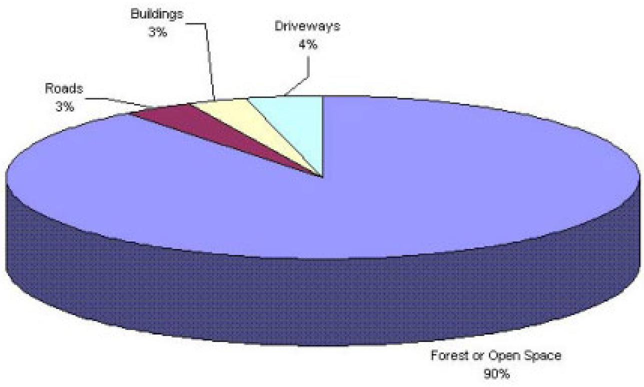

Figure 4.1 – Components of 2 Acre Lot Residential

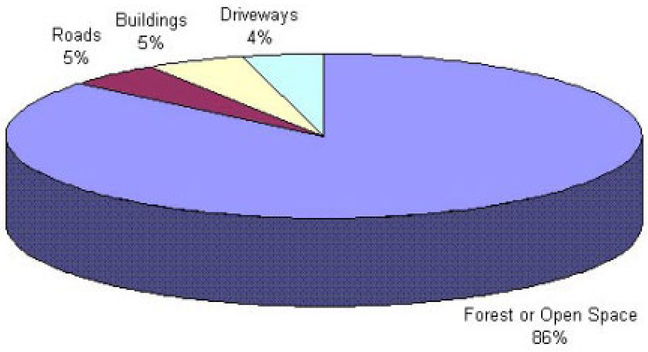

Figure 4.2 – Components of 1 Acre Lot Residential

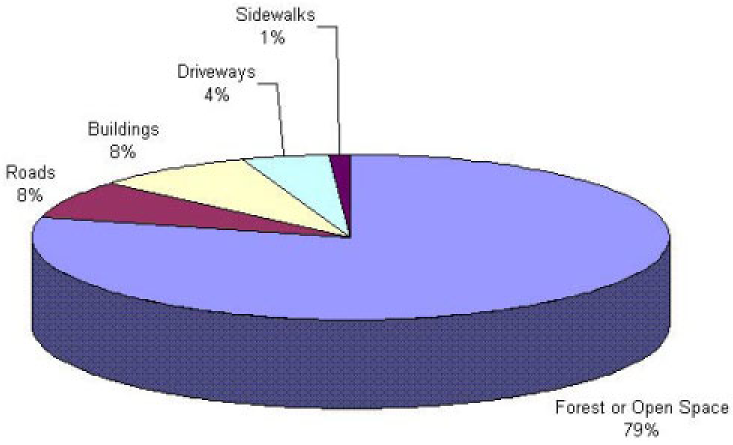

Figure 4.3 – Components of ½ Acre Lot Residential

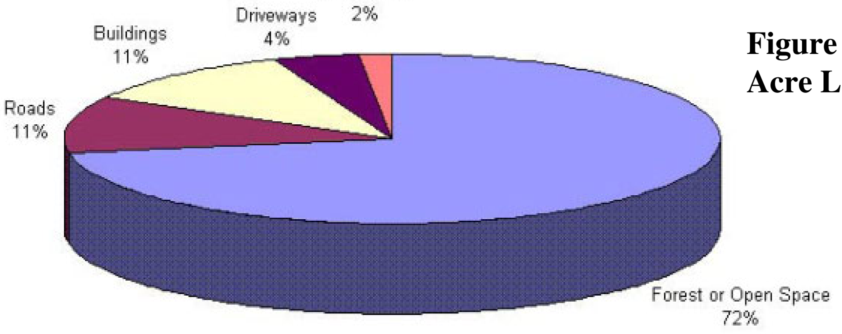

Figure 4.4 – Components of ¼ Acre Lot Residential

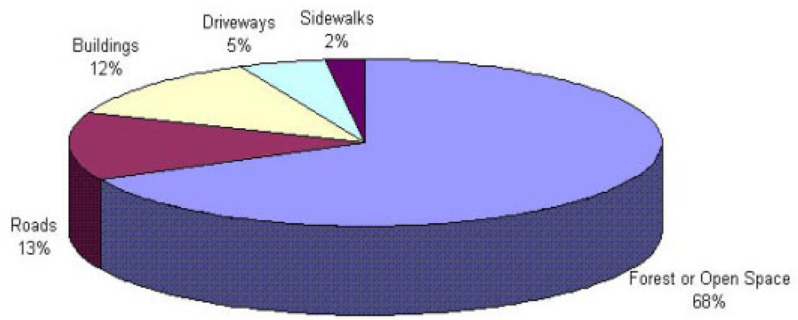

Figure 4.5 – Components of 1/8 Acre Lot Residential

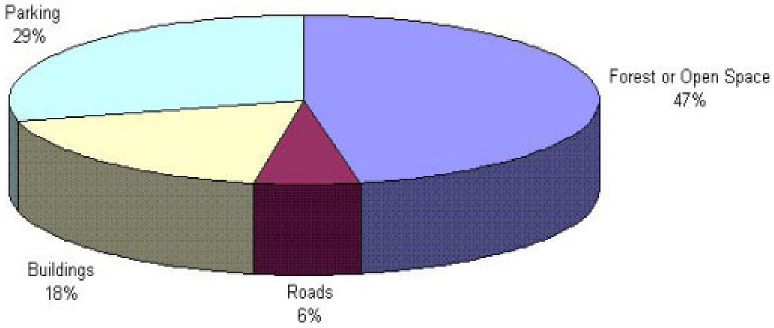

Figure 4.6 – Components of Light Industrial

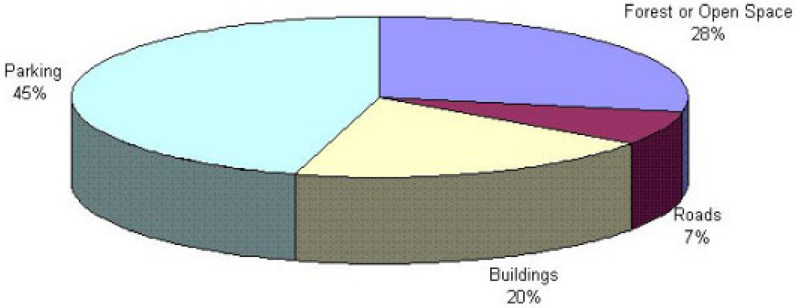

Figure 4.7 – Components of Commercial

The institutional and open urban land categories exhibited greater variety in impervious cover than other land use categories. The primary reason is the wide range of development types that occur within these loosely defined categories. More specific estimates for impervious cover were derived for schools, churches, and municipal operations in the institutional categories. Similarly, significant differences were detected in the most common components of open urban land: cemeteries, parks, and golf courses. This data is shown in Table 4.3. The major component of impervious cover in open urban areas was the other impervious category, which consisted primarily of tennis courts. Churches in James City County had the lowest imperviousness due to the generous open space requirements in the county, and the institutional land uses as a whole tended to have higher imperviousness in more urbanized areas.

Table 4.3 Impervious Cover Results for Institutional and Open Urban Land Categories

Land Use Category	Sample Number (N)	Mean Impervious Cover (SE)
Churches	8	**39.9** – 7.8
Schools	13	**30.3** – 4.8
Municipal	9	**35.4** – 6.3
Golf Courses	4	**5.0** – 1.7
Cemeteries	3	**8.3** – 3.5
Parks	4	**12.5** – 0.7

4.1 How to Use the Data

The results from this study can be used to predict the future impervious cover of each of the four jurisdictions used, as well as the current and future impervious cover for regions within the Chesapeake Bay watershed with similar development patterns. Because all four jurisdictions are primarily suburban, these numbers would not apply in highly urbanized areas. Using current or future land use data and these derived land use/ impervious cover coefficients, current or future impervious cover can be predicted using the land use method. The land use method of predicting impervious cover can be an effective water resource planning and protection tool, and is a good alternative for local communities and watershed organizations that may not have access or funds available to conduct a detailed GIS analysis of impervious cover measurement.

In addition to accurate impervious cover coefficients, an accurate natural resource inventory is needed for a good estimate of imperviousness. “Unbuildable” land such as wetlands, floodplains, stream buffers, steep slopes, restricted soils, and conservation areas must be identified and subtracted from the total land use area. The amount and types of “unbuildable” land will depend on both the natural topography and local land use regulations such as open space requirements, and forest conservation requirements. Information regarding “unbuildable” land can usually be acquired from the local planning department.

In the study design, major highways and limited access arterial roads were excluded from the land use polygons. Therefore, if these are present or planned within a given watershed, their contribution to impervious cover must be calculated separately. The area of these roads must be calculated based on their length and width, and then added to the total impervious cover before calculating the percent imperviousness.

The following steps illustrate how to use the land use/ impervious cover coefficients to estimate impervious cover, using the example of estimating the future imperviousness of a watershed.

Step 1. Subtract areas of unbuildable land from the acreage of each land use within the watershed

$$\mathbf{A_{LU} - A_{UL} = A_{BL}}$$

where A_{LU} = area of land use in acres
A_{UL} = area of unbuildable land in acres
A_{BL} = area of buildable land in acres

Step 2. Multiply the area of buildable land for each land use by the corresponding impervious cover coefficient derived from this study

$$\mathbf{A_{BL} * IC = A_{IC}}$$

where A_{BL} = area of buildable land in acres
IC = impervious cover coefficient
A_{IC} = impervious area in acres

Step 3. Calculate the area of highways and arterial roads, and add this number to the sum of the impervious areas for all land uses in the watershed

$$\mathbf{SUM(A_{IC}) + A_H = TA_{IC}}$$

where A_{IC} – impervious area in acres
A_H = area of major highways in acres
TA_{IC} = total area of impervious cover in acres

Step 4. Divide the total impervious area by the total area of the watershed to get an impervious cover fraction, and multiply by 100 to get a percent

$$\mathbf{(TA_{IC} / TA) * 100 = IC\%}$$

where TA_{IC} = total area of impervious cover in acres
TA = total area of the watershed in acres
IC% = the impervious cover percent for the watershed

Table 4.4 below illustrates the above steps using the impervious cover coefficients derived in this study. The results from this study are comparable to those of earlier studies, as can be seen in Table 4.5.

4.2 Summary and Conclusions

An understanding of impervious cover is important for watershed managers for several reasons. First, impervious cover is an important indicator of watershed health, and a knowledge of current or future impervious cover in a subwatershed can be used to predict stream quality, and manage future land use to protect stream quality. Second, impervious cover is a critically important variable in most hydrologic and water quality models used to analyze urban watersheds, regardless of whether they are simple or complex.

Despite its importance, watershed managers have had to rely on imprecise and uncertain estimates of the relationships between urban land uses and impervious cover. To fill this gap, the Center analyzed 210 polygons of homogeneous land use from the GIS systems of four Chesapeake Bay communities. The study was designed to obtain more precise estimates of the mean impervious cover associated with 12 common urban land use categories.

The development patterns in the four communities sampled tend to be suburban in nature, and most of the polygons sampled had been constructed since 1970. Consequently, the impervious cover estimates reported

Table 4.4 Estimating Future Impervious Cover

Land Use	Acres	Acres Unbuildable Land	Acres Buildable Land	Impervious Cover Coefficient	Acres Impervious Area
Agriculture	128	12	116	.019	2.2
Low Density Residential*	123	10	113	.124	14.0
Medium Density Residential*	160	9	151	.245	37.0
Multifamily Residential	45	2	43	.444	19.1
Light Industrial	95	8	87	.534	46.5
Commercial	49	1	48	.722	34.7
Totals	600				153.5

Total acres impervious area (153.5) + area of major highways (34) = 187.5 acres
Total impervious area of watershed (187.5 acres) / watershed area (600 acres) = .31
.31 * 100 = 31% watershed imperviousness

*Low Density Residential includes 1 acre and 2 acre lots, and Medium Density Residential includes ‰ acre and …acre lots for this example

Table 4.5 Comparison of Chesapeake Bay Study to Impervious Cover (%) for Various Land Uses

Land Use	Density (du/ac)	Source							
		Northern Virginia (NVPDC, 1980)	(USDA, 1986)	Puget Sound, WA (Aqua Terra, 1994)	Rouge River, MI (Kluitenberg, 1994)	Olympia WA (COPWD, 1995)	Holliston, MA (CRWA, 1999)	Connecticut (Prisloe, 2000)	Chesapeake Bay (CWP, 2000)
Forest	-	1	-	-	2	-	1	-	-
Agriculture	-	1	-	-	2	-	1	-	2
Urban Open Land	-	-	-	-	11	-	7-23	-	9
Water/ Wetlands	-	-	-	-	100	-	-	-	-
Low Density Residential	<0.5	2-6	-	10	19	-	12	7-10	-
	0.5	9	12	10	19	-	12	7-10	11
	1	12	20	10	19	-	12	7-10	14
Medium Density Residential	2	18	25	-	19	-	14	14-21	21
	3	20	30	40	19	40	14	14-21	-
	4	25	38	40	19	40	14	14-21	28
High Density Residential	>4	35	-	40	38	40	19	28	33
Multifamily	Townhouse	40	65	60	51	48	47	39	41
	Apartment	50	65	60	51	48	47	39	44
	High Rise	60-75	-	-	-	-	-	-	-
Industrial	-	60-80	72	90	76	86	60	53	53
Commercial	-	90-95	85	90	56	86	45	54	72

Note: NVPDC data measure effective impervious area (i.e., rooftops are not included in residential data), and Prisloe data does not include area from state and local roads

n CWP, 1998

here primarily apply to recent suburban development, and may not be transferable to either highly urban areas or developments that predate World War II. In addition, the majority of land use polygons analyzed in this study used conventional development design, as opposed to more innovative techniques that incorporate better site design techniques such as cluster development that minimize impervious cover. Consequently, if widespread implementation of better site design techniques is anticipated within a locale, it will be necessary to adjust these numbers downward. Lastly, large freeways and limited access arterials were not included in sample polygons. If these are present or planned within a given watershed, their contribution to impervious cover must be calculated separately.

Given these limits, the impervious cover estimates within each land use category exhibited relatively little variation, as indicated by the small standard errors associated with the group means. Statistical analysis demonstrated that the land use/impervious cover estimates were very similar within the same zoning category among the four counties sampled. A statistically significant difference between an individual county and its cohorts was detected in only five out of 48 comparisons. The differences that occurred were typically found for low density residential zoning categories in counties that had unusually generous open space requirements.

The institutional and open urban land categories exhibited greater variability in impervious cover than other land use categories. The primary reason being the wide range of development types that occur within these loosely defined categories. More specific estimates for impervious cover were derived for schools, churches, and municipal operations in the institutional category. Similarly, significant differences were detected in the most common components of open urban land: cemeteries, parks, and golf courses.

Since the individual components of impervious cover were directly measured in this study, it was possible to determine what percentage of the urban landscape was devoted to building footprints (i.e., people habitat), as compared to streets, driveways and parking lots (i.e., car habitat). Car habitat exceeded the building footprint in every urban land use category, ranging from 55% to 75% of the total impervious surface area for a site. This finding suggests that better site design techniques that reduce the amount of car habitat have the most potential to reduce the mean impervious cover associated with that land use category.

A simple four-step procedure was developed to use these new impervious cover relationships to produce reliable estimates of future impervious cover within a watershed. First, large areas of known "unbuildable" land must be subtracted from the watershed area. These include large tracts of land in floodplains, wetland areas, stream valleys and major conservation areas. Second, the future land use distribution for the built and "buildable" portions of the watershed are multiplied by the impervious cover factors to yield a provisional estimate of future impervious cover. In the next step, the contribution of impervious cover from any existing or planned freeways and limited access arterial roads must be calculated based on their length and width. Finally, the percentage of imperviousness is calculated. The use of this standard method for estimating existing and future impervious cover should be useful for both watershed planners and watershed researchers.

While this project achieved its primary objectives, further impervious cover research would be helpful for both planners and engineers. Three key issues merit further investigation. First, does the age of development influence the basic land use/impervious cover relationship (e.g., pre World War II, vs. 1960s vs. 1990s)? Second, how much would the impervious cover estimates be reduced in a community if it employs better site design techniques, such as open space or cluster residential subdivisions? Too few of these kinds of developments were available within our study design to address this important management question. Third, are there consistent patterns in the types of pervious areas found within an urban land use category such as forest, meadow, turf, landscaping, lawns, and exposed soil? Differences in pervious areas are difficult to distinguish within digital orthophotos, so this would require greater ground truthing as the capability of some GIS data are limited to this point.

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Appendix A

Literature Review of the Impervious Cover/Stream Quality Relationship

Impacts of Urbanization

The conversion of farmland, forests, wetlands, and meadows to rooftops, roads, and lawns creates a layer of impervious surface and compacted pervious surface in the urban landscape.

This process of urbanization has a profound influence on the hydrology, morphology, water quality, and ecology of surface waters (Horner, *et al.*, 1996). Because of this relationship between impervious cover and stream quality, the amount of impervious cover in a watershed can be used as an indicator to predict the impacts on aquatic systems. This appendix reviews 43 studies that characterize the impervious cover/stream quality relationship.

Impervious cover directly influences urban streams by dramatically increasing surface runoff during storm events. Depending on the degree of impervious cover, the annual volume of stormwater runoff can increase by two to 16 times its predevelopment rate, with proportional reductions in groundwater recharge (Schueler, 1994). In natural settings, very little annual rainfall is converted to runoff and about half is infiltrated into the underlying soils and the water table. This water is filtered by the soils, supplies deep water aquifers, and helps support adjacent surface waters with clean water during dry periods. In urbanized areas, less and less annual rainfall is infiltrated and more and more volume is converted to runoff. Not only is this runoff volume greater, it also occurs more frequently and at higher magnitudes. As a result, less water is available to streams and waterways during dry periods and more flow occurs during storms.

Many of the pollutants associated with stormwater runoff can be directly toxic to organisms (e.g., pesticides, metals, hydrocarbons) or can cause conditions in the receiving waters that are detrimental to aquatic organisms and even humans (e.g., eutrophication, pathogens). An increase in runoff volume affects the total amount of pollutants transported and delivered to receiving waters. In addition, the increased runoff volume influences geomorphic changes, which govern sediment transport and the integrity of instream habitat.

Physical Impacts of Urbanization

The driving force behind most of the physical changes in a watershed is the change in hydrology. This change in hydrology is represented in Figure A.1, which shows the pre and post-development hydrograph. The change in the basic hydrologic cycle causes a series of other impacts. Perhaps the most visible and striking impact is the process of channel erosion. At low levels of imperviousness, the stream has a stable channel, large woody debris (LWD), and a complex habitat structure. As urbanization increases, the stream becomes increasingly unstable, increases its cross-sectional area to accommodate increased flows, and loses habitat structure.

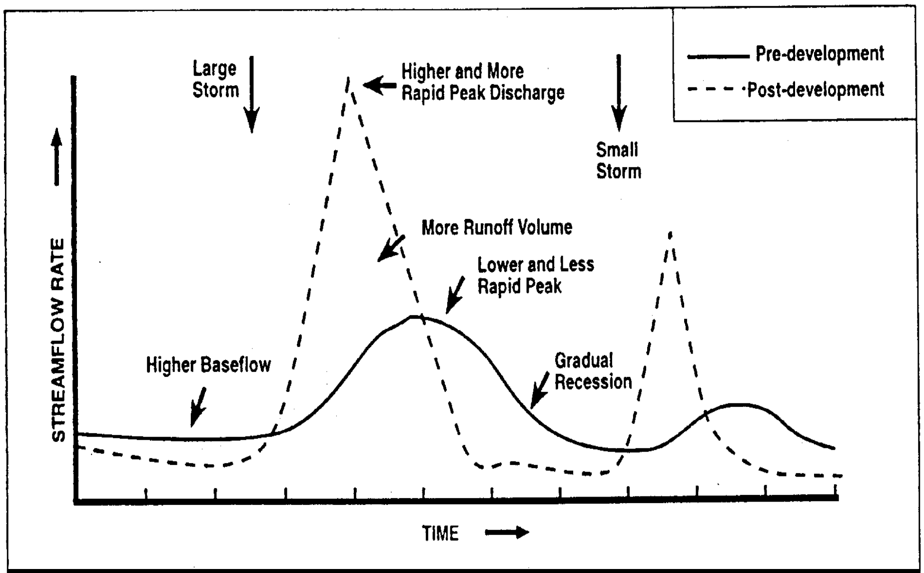


Figure A.1 - Altered Hydrograph in Response to Urbanization (Schueler, 1987)

Figure A.2 shows the increase in channel cross-sectional area (the enlargement ratio which is the ratio of pre-disturbance cross-sectional area to post-disturbance cross-sectional area), which results from different levels of impervious cover. This process of channel response to increases in impervious surfaces accelerates sediment transport and destroys habitat. Urbanization frequently leads to the "improvement of channels," such as piping, straightening or lining with concrete or rock to quickly transport water away from developed areas. These conveyance efficiencies are often associated with fish blockages resulting from culverts and other man-made barriers. Finally, impervious surfaces absorb heat and often increase stream temperatures during runoff events. These physical changes are commonly accompanied by decreasing water quality and decreasing biodiversity. Table A.1 highlights many of the physical impacts of urbanization and some of the scientific basis for these conclusions.

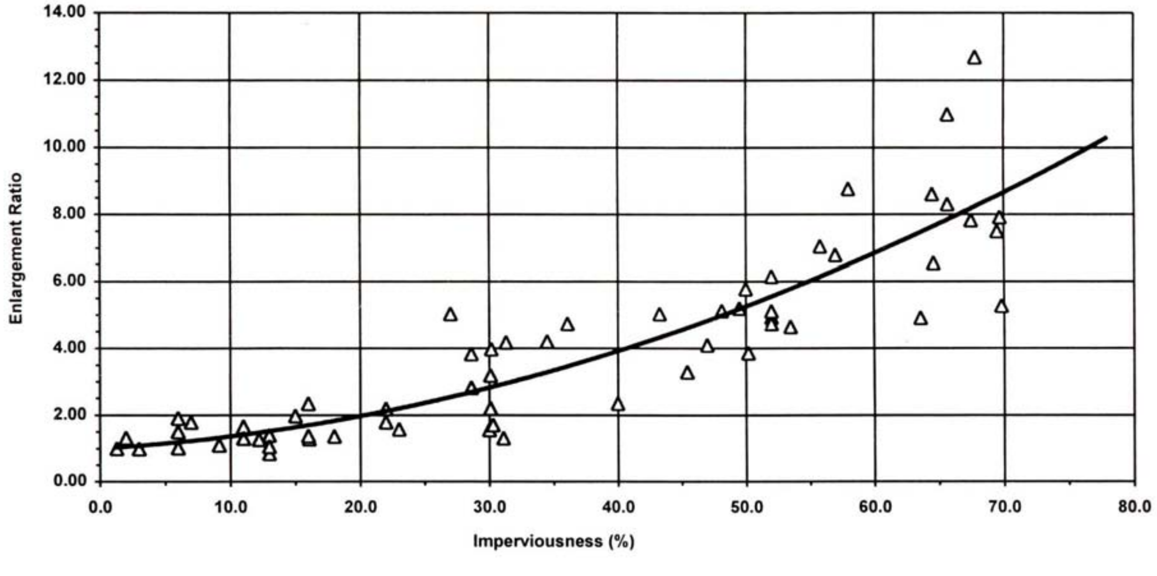


Figure A.2 - Channel Enlargement as a Function of Imperviousness (MacRae and DeAndrea, 1999; Claytor and Brown, 2000)

Table A.1 Physical Impacts of Urbanization

Physical Impacts	Key Finding	Reference	Year
Hydrology			
Increased Runoff Volume	Parking lot produces 15 times more runoff than a meadow	Schueler	1987
Increased Flood Peaks	50% imperviousness of a watershed can result in a doubling of the 100-year event	Sauer *et al.*	1983
Increased Bankfull Discharge	Bankfull discharge increased two to five times after urbanization	Hollis	1975
	Bankfull frequency increased two to seven times after urbanization	Leopold	1994
Decreased Baseflow	Two Long Island streams went dry as a result of urbanization	Simmons and Reynolds	1982
Geomorphology			
Increased Transport of Sediment	Bank erosion accounted for over 66% of the sediment transport in a CA study	Trimble	1997
	Bank erosion accounted for up to 75% of the sediment transport in Austin, TX study	Dartinguenave *et al.*	1997
	Bank erosion in agricultural regions only accounts for 5 to 20% of sediment load	Wallling and Woodward	1995
Channels Increase in Size	Enlargement ratios ranged from 0.7 to 3.8 in urban watersheds in PA	Hammer	1972
	Enlargement ratios in two urban TX streams ranged from 1.7 to 2.4	Allen and Narramore	1985
	Ultimate channel enlargement correlated with ultimate impervious cover	MacRae and DeAndrea	1999
Habitat Characteristics			
Embeddedness	Interstitial spaces between substrate fill with increasing watershed imperviousness	Horner *et al.*	1996
Large Woody Debris	Important for habitat diversity and anadramous fish	Spence	1996
	Decreased LWD with increases in imperviousness	Booth *et al.*	1996
Changes in Stream Features	Altered pool/riffle sequence with urbanization	Richey	1982
	Loss of habitat diversity	Scott *et al.*	1986
Thermal Impacts			
Temperature	Increase in stream temperatures five to twelve degrees Fahrenheit with urbanization (check figures)	Galli	1991
Direct Channel Impacts			
Reduction in 1st Order Streams	Replacement by storm drains and pipes increases erosion rate downstream	Dunne and Leopold	1978
Channelization and Hardening of Stream Channels	Increased instream velocities often leading to increased erosion rates downstream	Sauer *et al.*	1983
Fish Blockages	Fish blockages caused by bridges and culverts	MWCOG	1992

Impacts of Urbanization on the Biological Community

The physical and chemical impacts associated with urbanization diminish the quantity of the aquatic biota and the quality of their habitat. The fundamental change in hydrology, as well as the quality of storm runoff in urban streams causes both a decrease in biological diversity and a shift from more pollutant sensitive to less sensitive aquatic organisms. Figure A.3 illustrates the impacts that urbanization can exert on the aquatic community by showing the inverse relationship between the abundance and diversity of macroinvertebrates (represented by the sensitive species index) and imperviousness.

Although impervious cover is often used as the unifying factor to examine the impacts of urbanization, how the level of imperviousness is calculated is not always the same. Impervious cover, housing density, population density, and percent urban land use have been used to examine the relationship between urbanization and the quality of urban receiving waters. Section 2 discusses in more detail many of these methodologies for estimating impervious cover.

Regardless of the method for calculating the impervious cover in a watershed, the negative relationship between increases in imperviousness and aquatic community abundance and diversity does not change. The actual level at which a particular species begins to decline is dependent on a number of variables, including sensitivity to water quality changes, the type of land use within the watershed, the presence of riparian cover and other watershed effects. Some researchers have found impacts at impervious cover levels as low as 5% (May *et.al.*, 1997). Other research has suggested that the presence of certain stressors such as sewage treatment plants (Yoder and Miltner, 2000) or construction sites (Reice, 2000) may further lower the level of impervious cover where biological impacts become evident.

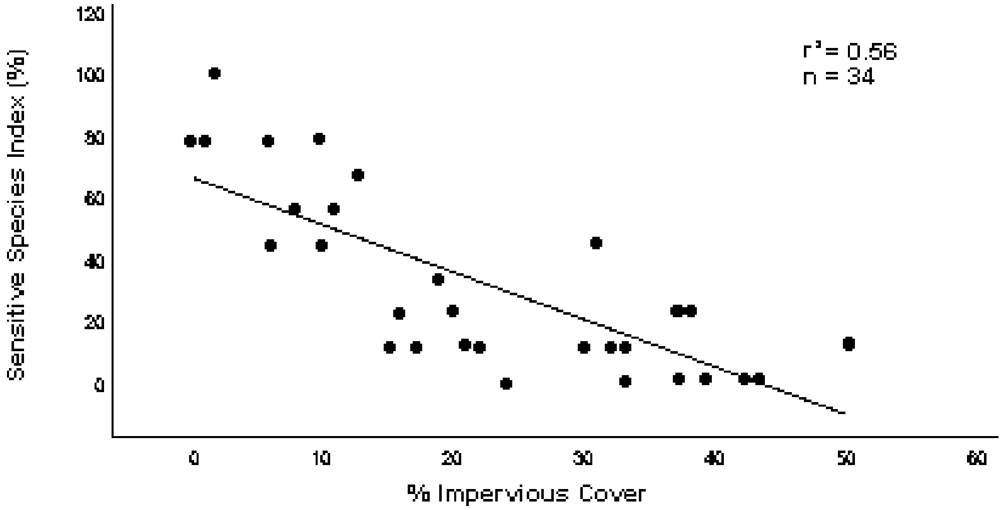


Figure A.3 - Macroinvertebrate Abundance and Diversity as a Function of Impervious Cover for Delaware Piedmont Streams (Maxted and Shaver, 1996)

Some of the more recent research that has been conducted investigating the relationship between impervious cover and stream and watershed health involves the following studies:

- Booth, D. 2000—Booth provides a review of the scientific framework for basing management decisions on the impact of urbanization on aquatic systems and the use of impervious cover as an indicator. The ability of forest cover to minimize impacts on stream stability at low levels of impervious cover is documented. Also expressed, is the concept that impervious cover, as a single land use parameter, may not be an appropriate indicator of stream health in rural watersheds with impervious cover measurements of less than 10%.

- Boward *et al.*, 1999—In The Mountains to the Sea: the State of Maryland's Freshwater Streams, the Maryland Department of Natural Resources (MDDNR) provides information on the status of the biological community in the state's streams. The relationship between land use and impervious cover is examined for fish, macroinvertebrates, amphibians and other sensitive species. Above a 15% impervious cover threshold, streams were found to have a poor or fair biological condition. Sensitive species, such as the native brook trout, were shown to disappear beyond two percent impervious cover. Other relationships between land use and stream water quality are covered in the document as well.

- Horner *et al.*, 1999—This study, using watersheds in Maryland, Texas, Colorado and Washington state, evaluated the ability of structural and nonstructural management practices to mitigate and ameliorate the impacts of impervious surfaces on biological communities. It found that nonstructural techniques such as riparian buffers and upland forest retention were more effective at ameliorating the impacts of impervious surfaces than structural management practices. They did, however, conclude that the ability of these nonstructural techniques to mitigate biological impacts was limited to low levels of impervious cover and that at higher levels of impervious cover biological impacts were difficult to prevent.

- MacRae and DeAndrea, 1999—This research developed a methodology for placing a stream in its proper historical context in terms of channel enlargement. The MacRae and DeAndrea method utilizes historical and current data on stream cross-sections and land use. Historic cross-sections are obtained from many sources including prior geomorphological research, engineering surveys or floodplain modeling. Current and historic impervious cover estimates are derived from low altitude aerial photographs taken at different intervals through the urbanization process. Using a basic hydraulic model, these data are used to characterize the pre-development and current cross-sections, and predict the ultimate cross-sections. An ultimate enlargement curve for 60 channel reaches of alluvial streams in Texas, Maryland and Vermont is presented in Figure A.2.

In addition to the recent studies outlined above, over the last 20 years several studies have assessed the effects of urbanization on aquatic community structure and diversity. Table A.2 presents some of the key findings of this body of research. A number of the studies have examined the link between urbanization and the impact on aquatic organisms and habitat. For example, habitat structure such as large woody debris (LWD) has been shown to decrease with increasing imperviousness (Figure A.4). Other research has documented evidence that nonstructural and structural management practices mitigate some of the impacts of urban runoff (Figure A.5); however, most of the data suggests that at around the 10% impervious cover level, species appear to begin a steady decline in both abundance and diversity.

Table A.2 Recent Research Examining the Relationship of Urbanization to Aquatic Habitat and Organisms

Year	Watershed Indicator	Key Finding	Reference	Location
2000	Aquatic insects & fish	For watersheds smaller than 100 mi^2 a significant drop in IBI scores occurred at around 15% imperviousness.	Yoder and Miltner	Ohio
2000	Aquatic insects and fish	A study of first and second order stream conditions in urbanized watersheds found that for streams rated as being in excellent or good condition watersheds had either high levels of riparian buffers (>67%) or moderate buffers (>33%) in combination with moderate storm water management (at least 33% of imperviousness treated).	ERM	Maryland
1999	Amphibians	Several sensitive species were not found at impervious levels greater than 3%. Only a few intolerant species were found at impervious levels greater than 25%.	Boward, *et al.*	Maryland
1999	Fish	Brook trout were not found in watersheds with greater than 2% imperviousness.	Boward, *et al.*	Maryland
1997	Aquatic insects	Significant declines in various indicators of wetland aquatic macroinvertebrate community health were observed as impervious cover increased to 8-9%.	Hicks & Larson	Connecticut
1997	Fish	There is a strong correlation between population density and fish community assessments such that as population density increased, community assessment scores went from the better-good range to fair-poor.	Dreher	Illinois
1997	Fish	Amount of urban land use upstream of sample sites had a strong negative relationship with biotic integrity, and there appeared to be a threshold between 10-20% urban land use where IBI scores declined dramatically. Watersheds above 20% urban land invariably had scores less than 30 (poor to very poor).	Wang, *et al.*	Wisconsin
1996	Aquatic habitat	There is a decrease in the quantity of large woody debris (LWD) found in urban streams at around 10% impervious cover.	Booth, *et al.*	Washington
1997	Fish, habitat	As watershed population density increased, there was a negative impact on urban fish and habitat. Urban stream IBI scores were inversely related to watershed population density, and once density exceeded four persons per acre, urban streams were consistently rated as very poor.	DeVivo, *et al.*	Atlanta

Table A.2 Recent Research Examining the Relationship of Urbanization to Aquatic Habitat and Organisms

Year	Watershed Indicator	Key Finding	Reference	Location
1996	Aquatic insects	Biological health of the macroinvertebrate community declined as imperviousness increased. It appears that stormwater treatment practices (STPs) are capable of mitigating some of these impacts within the 12-23% I range. Above this range, declines in biological condition continue at a similar rate to sites without STPs. Evidence suggests that if high levels of riparian forest or wetlands >30m are saved, a doubling in total impervious area could occur while still maintaining high B-IBI and fish ratio scores.	Horner, *et.al.*	Puget Sound Washington
1996	Aquatic insects & stream habitat	No significant difference in biological and physical metrics for 8 STP sites versus 33 sites without STPs (with varying impervious area). STP s did not attenuate the impacts of urbanization once the watershed reached 20% impervious cover, and did not prevent a shift in the macroinvertebrate community from pollutant sensitive species to pollutant tolerant organisms.	Maxted and Shaver	Delaware
1996	Aquatic insects and fish	Unable to show improvements in biological community at 8 sites downstream of STPs as compared to reference conditions.	Jones, *et al.*	Northern Virginia
1996	Insects, fish, habitat water quality, riparian zone	Steepest decline of biological functioning after 6% imperviousness. There was a steady decline, with approx 50% of initial biotic integrity at 45% impervious area.	Horner, *et al.*	Puget Sound Washington
1994	Fish, Aquatic insects	A study of five urban streams found that as land use shifted from rural to urban, fish and macroinvertebrate diversity decreased.	Masterson and Bannerman	Wisconsin
1993	Aquatic insects	As watershed development levels increased, the macroinvertebrate community diversity decreased.	Richards, *et al.*	Minnesota
1993	Fish	Shift from less tolerant coho salmon to more tolerant cutthroat trout population between 10-15% imperviousness at 9 sites.	Luchetti & Fuersteburg	Seattle
1993	Wetland plants, amphibians	Mean annual water fluctuation inversely correlated to plant & amphibian density in urban wetlands. Declines noted beyond 10% impervious area.	Taylor	Seattle
1992	Aquatic insects and fish	There was significant decline in the diversity of aquatic insects and fish at 10% impervious cover.	MWCOG	Washington, DC

Table A.2 Recent Research Examining the Relationship of Urbanization to Aquatic Habitat and Organisms

Year	Watershed Indicator	Key Finding	Reference	Location
1991	Fish	As watershed development increased to about 10%, fish communities simplified to more habitat and trophic generalists and fish abundance and species richness declined. IBI scores for the urbanized stream fell from the good to fair category.	Weaver	Virginia
1991	Fish habitat and channel stability	Channel stability and fish habitat quality declined rapidly after 10% impervious area.	Booth	Seattle
1990	Fish spawning	Resident and anadromous fish eggs & larvae declined in 16 streams with > 10% impervious area.	Limburg & Schmidt	New York
1989	Aquatic insects and fish	A comparison of three stream types found urban streams had lowest diversity and richness. Urban streams had substantially lower EPT scores (22% vs 5% as the number of all taxa, 65% vs 10% as a percent abundance) and IBI scores in the poor range.	Crawford & Lenat	North Carolina
1988	Aquatic insects	Biotic integrity decreases with increasing urbanization in study involving 209 sites, with a sharp decline at 10% impervious. Riparian condition helps mitigate effects.	Steedman	Ontario
1987	Aquatic insects	Urban streams had sharply lower insect diversity with human population above 4/acre. (About 10% impervious)	Jones & Clark	Northern Virginia
1997	Insects, fish, habitat, water quality, riparian zone	Physical and biological stream indicators declined most rapidly during the initial phase of the urbanization process as the percentage of total impervious area exceeded the 5-10% range.	May, *et al.*	Washington
1991	Aquatic insects & fish	All 40 urban sites sampled had fair to very poor index of biotic integrity (IBI) scores, compared to undeveloped reference sites.	Yoder	Ohio

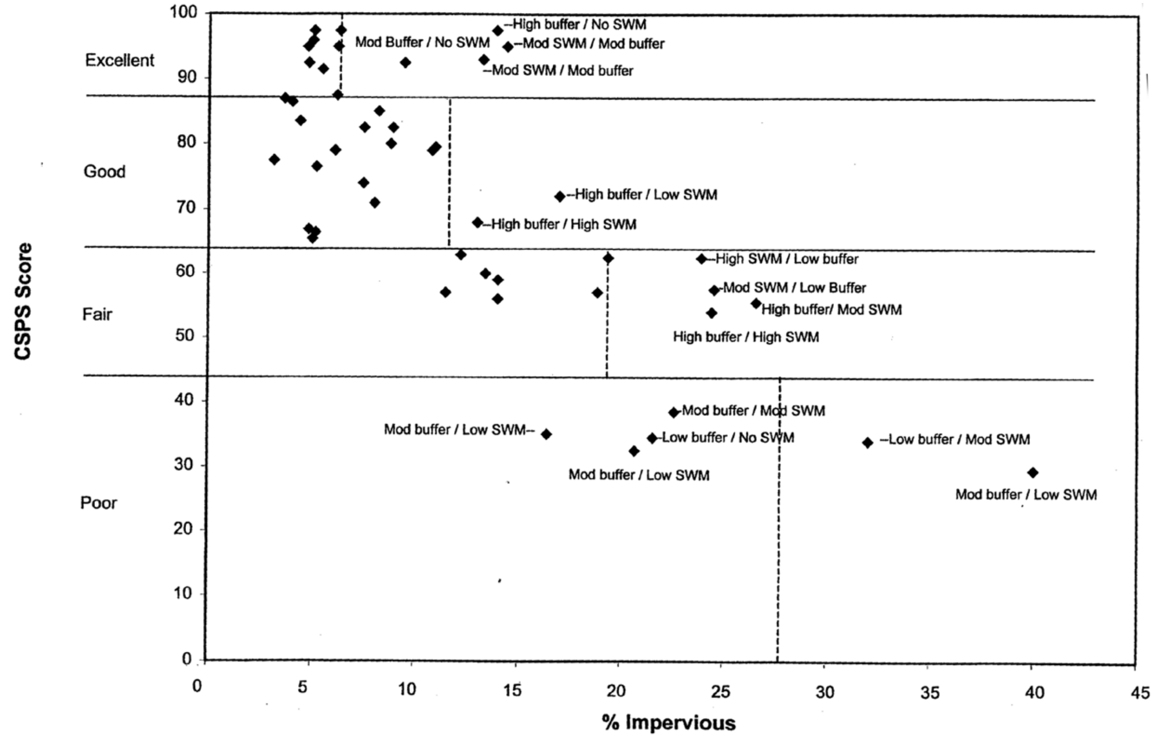


Figure A.4 - Macroinvertebrate and Fish Abundance and Diversity (i.e., CSPS Score) as a Function of Impervious Cover
(additional correlation with forest buffer and stormwater management indicated by notations where: High buffer = >66% of buffer forested; Mod buffer = 33-65% buffer forested; Low buffer = <33% of buffer forested; High SWM = >66% of impervious managed; Mod SWM = 33-65% of impervious managed; Low SWM = <33% of impervious managed) (ERM, 2000)

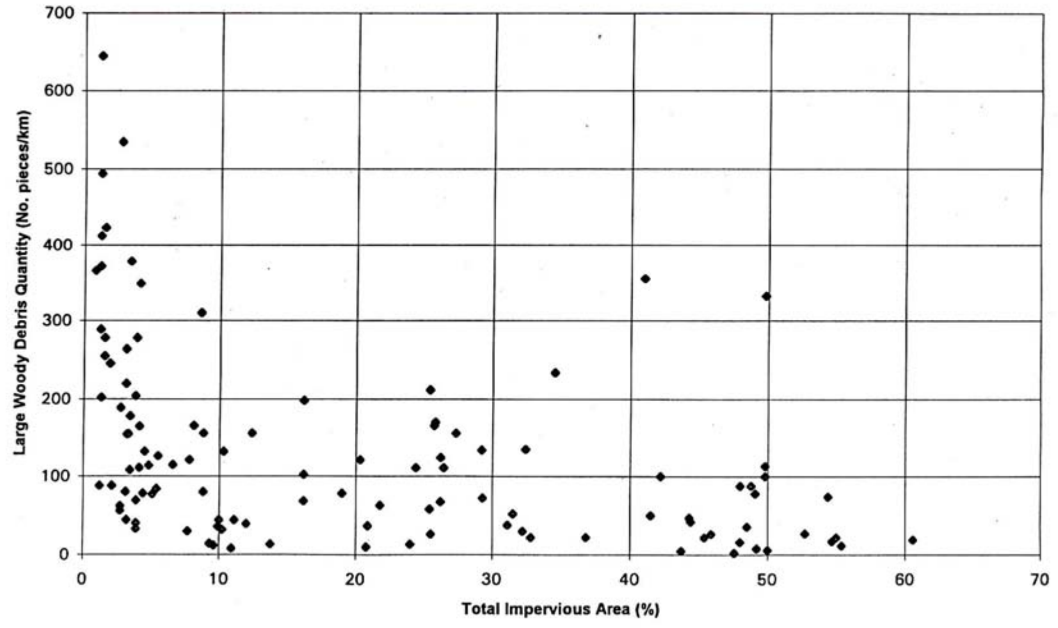


Figure A.5 - Large Woody Debris as a Function of Imperviousness (Horner *et al.*, 1996)

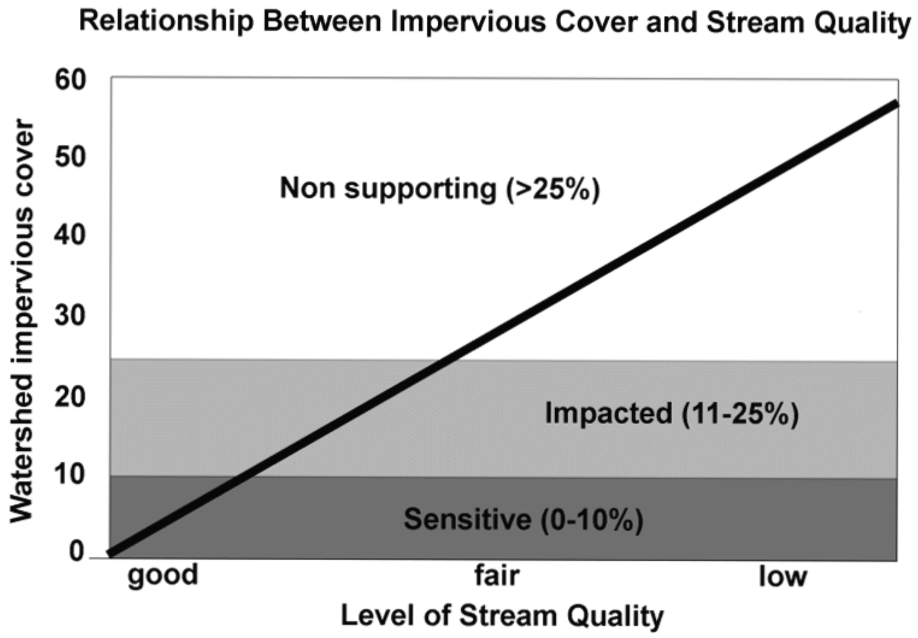


Figure A.6 – The Impervious Cover Model (Source: CWP, 1998)

Summary of Impervious Cover/Stream Quality Relationship

The studies reviewed in this section generally confirm the Impervious Cover Model shown in Figure A.6, which classifies streams according to the amount of impervious cover in the watershed.

It is important to keep in mind that there are several limitations to using the Impervious Cover Model. The model generally should only be applied to 1st to 3rd order streams because most of the research supporting it has been conducted at the watershed or subwatershed scale. Additionally, most of the supporting research was done in Mid-Atlantic or Puget Sound areas and a variety of different methods were used to measure stream quality as well as impervious cover. The Impervious Cover Model is intended to predict potential rather than actual stream quality, so an individual stream may depart from the model for various reasons. Lastly, further research is needed regarding the influence of stormwater treatment practices, pervious areas, and riparian forest cover, as well as the threshold between impacted and non-supporting streams. Despite these limitations, the Impervious Cover Model is still one of the best tools for evaluating and managing a watershed or subwatershed as well as reducing the cumulative impacts of development.

Appendix B

Other Methods for Estimating Impervious Cover

Estimating Impervious Cover

Section 2 described the two most common methods of estimating impervious cover: direct measurement and land use. Direst measurement is the most accurate and expensive method, while land use is a more economical and reasonably accurate approach. Other methods of estimating land use are less common, and are most often used in combination with either direct measurement or land use. These methods include: estimation using road density and estimation using population, and are described in detail below.

Road Density

Road density (road length per unit area) can be used as an indirect measure of impervious cover. This method is easy to use, and requires little data (only a street map). Unfortunately, little data are available to relate road density to imperviousness. One study, however, developed a linear relationship between road density and impervious area for the Puget Sound Region in Washington (Figure B.1) (May *et al.*, 1997). Although the correlation is strong, it may not necessarily apply in other regions of the country. Road density has limited value for predicting future impervious cover or incorporating better site design techniques, as roads other than major arterials are rarely planned well into the future. Currently, the best use for the road density technique is as an interim calculation, before a more thorough analysis can be completed. Also, since road density has a strong correlation with impervious cover in one study, it shows promise as an effective "first cut" method in the future, so long as more data points are collected nationwide.

Population

Population-based impervious cover methods calculate impervious cover based on the relationship between impervious cover and population. Although population techniques can estimate current impervious cover, they are most useful to project future impervious cover from a known current value. In general, these techniques are best used in combination with land use or direct measure methods.

Study results indicate that population/impervious cover correlation varies depending on the region (Figure B.2). A New Jersey study represents the most comprehensive data to date (including data from 527 municipalities). As the data from a Washington, D.C. study indi-

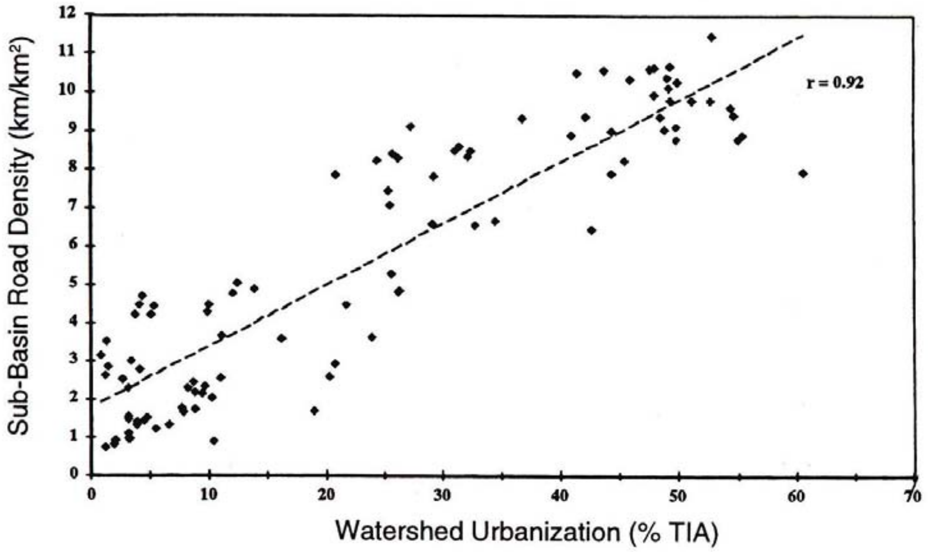


Figure B.1 - Impervious Cover % as a Function of Road Density (Source: May, *et al.*, 1997)

cates, the results can be quite variable. This is at least partially because some land uses have high impervious area values and low population densities (e.g., commercial areas). As an alternative to using these regressions, the calculation can be based on a certain amount of impervious cover per person. Thus, impervious cover would increase at the same rate as population.

Reliable population forecasts are integral to using this impervious cover estimation technique successfully. Two sources of data for population predictions are transportation departments for metropolitan regions and water/sewer utilities. Predictions are based on a regional analysis of economic growth, and then broken down to smaller areas based on available land and zoning (Mofritz, 1997). However, it is important to note that the accuracy of population forecasting is not very high at a small scale, particularly for long-term predictions.

Population methods are most effective in combination with direct measurement or land use methods. Since direct measurement or land use methods can determine current impervious cover, these measurements can then be multiplied by a rate of growth factor based on population growth in each subwatershed, or over the entire watershed. One good example of this application is Schueler (1996b), who combined current land use, zoning, and population forecasts to forecast future imperviousness in each of the sub-basins draining to the Occoquan Basin in Northern Virginia.

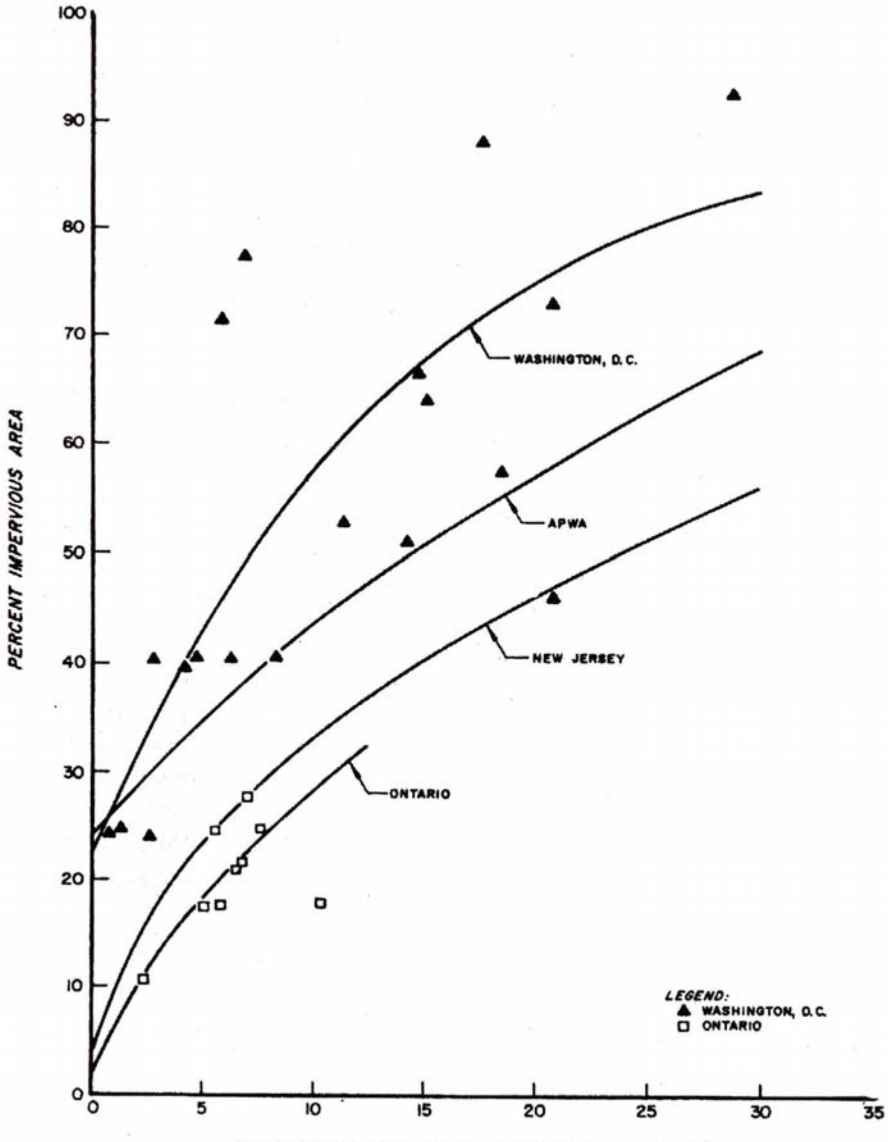


Figure B.2 - Impervious Cover % as a Function of Population Density (USEPA, 1979)

Appendix C

Methodology for Computing Impervious Cover Using ESRI's ArcView

This appendix outlines the methods used to determine the impervious cover values for this study. The results of the analysis are included in Table D.1 in Appendix D. The approach used to measure impervious cover involves three basic steps that were completed after selecting the land use categories, determining the number of samples per category, and deciding which areas of each jurisdiction would be sampled. These three steps are as follows:

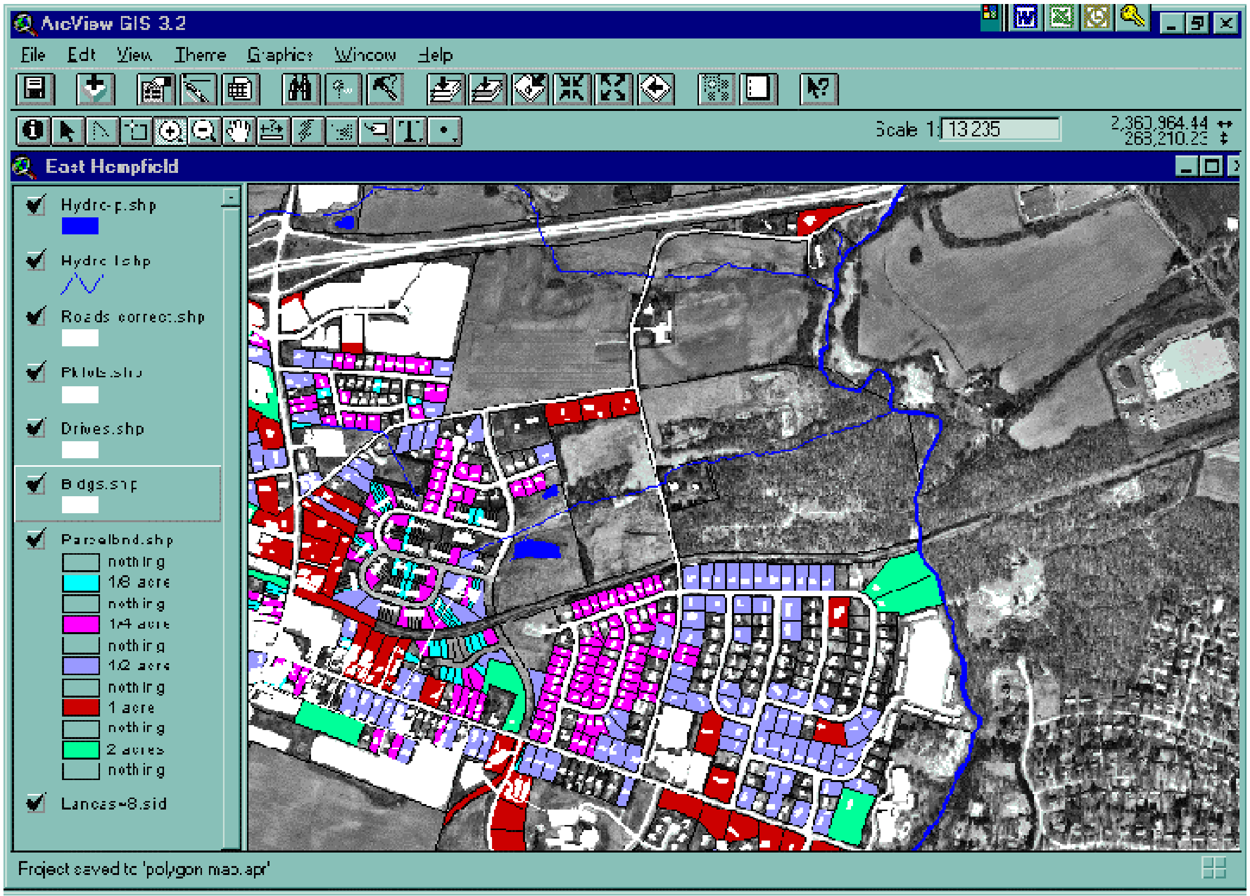
Step 1: Create Land Use Polygons
Step 2: Intersect Impervious Cover Themes with Land Use Polygons
Step 3: Calculate Impervious Cover

Step 1: Create Land Use Polygons

In order to develop land use-impervious cover coefficients, it was necessary to identify areas of homogenous land use for which impervious cover percentages could be calculated. These land use polygons were created using ArcView. The methods for creating land use polygons are described below.

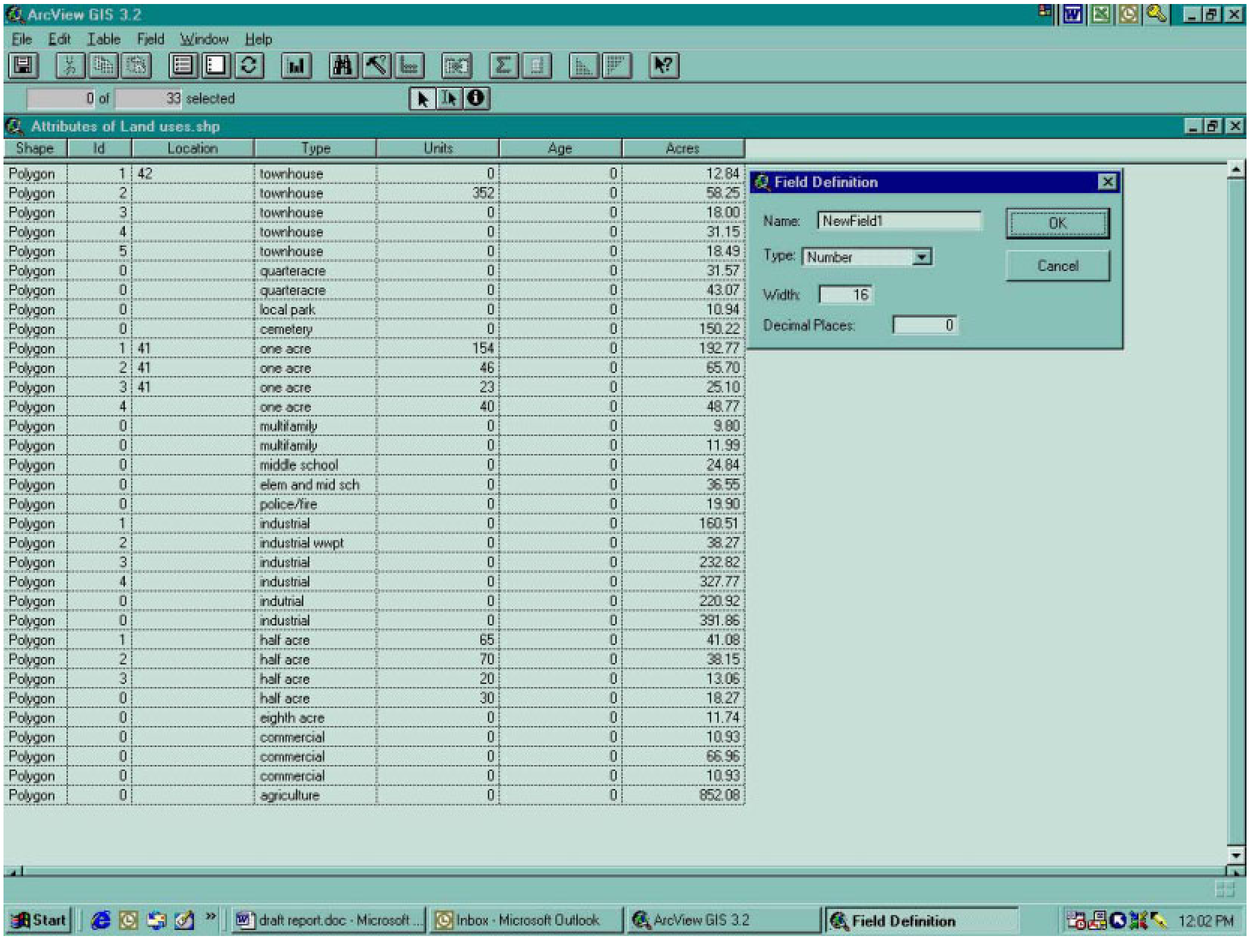
1A). Open **ArcView**, and create a new project with a new view

1B). Use **View> Add Theme** to add orthophotos, hydrology, impervious cover layers, and parcel data to the view (see Figure C.1)



Project saved to 'polygon map.apr'

Figure C.1 – Setting Up the Impervious Cover Project in ArcView



0 of 33 selected

Shape	Id	Location	Type	Units	Age	Acres
Polygon	1	42	townhouse	0	0	12.84
Polygon	2		townhouse	352	0	58.25
Polygon	3		townhouse	0	0	18.00
Polygon	4		townhouse	0	0	31.15
Polygon	5		townhouse	0	0	18.49
Polygon	0		quarteracre	0	0	31.57
Polygon	0		quarteracre	0	0	43.07
Polygon	0		local park	0	0	10.94
Polygon	0		cemetery	0	0	150.22
Polygon	1	41	one acre	154	0	192.77
Polygon	2	41	one acre	46	0	65.70
Polygon	3	41	one acre	23	0	25.10
Polygon	4		one acre	40	0	48.77
Polygon	0		multifamily	0	0	9.80
Polygon	0		multifamily	0	0	11.99
Polygon	0		middle school	0	0	24.84
Polygon	0		elem and mid sch	0	0	36.55
Polygon	0		police/fire	0	0	19.90
Polygon	1		industrial	0	0	160.51
Polygon	2		industrial wwpt	0	0	38.27
Polygon	3		industrial	0	0	232.82
Polygon	4		industrial	0	0	327.77
Polygon	0		indutrial	0	0	220.92
Polygon	0		industrial	0	0	391.86
Polygon	1		half acre	65	0	41.08
Polygon	2		half acre	70	0	38.15
Polygon	3		half acre	20	0	13.06
Polygon	0		half acre	30	0	18.27
Polygon	0		eighth acre	0	0	11.74
Polygon	0		commercial	0	0	10.93
Polygon	0		commercial	0	0	66.96
Polygon	0		commercial	0	0	10.93
Polygon	0		agriculture	0	0	852.08

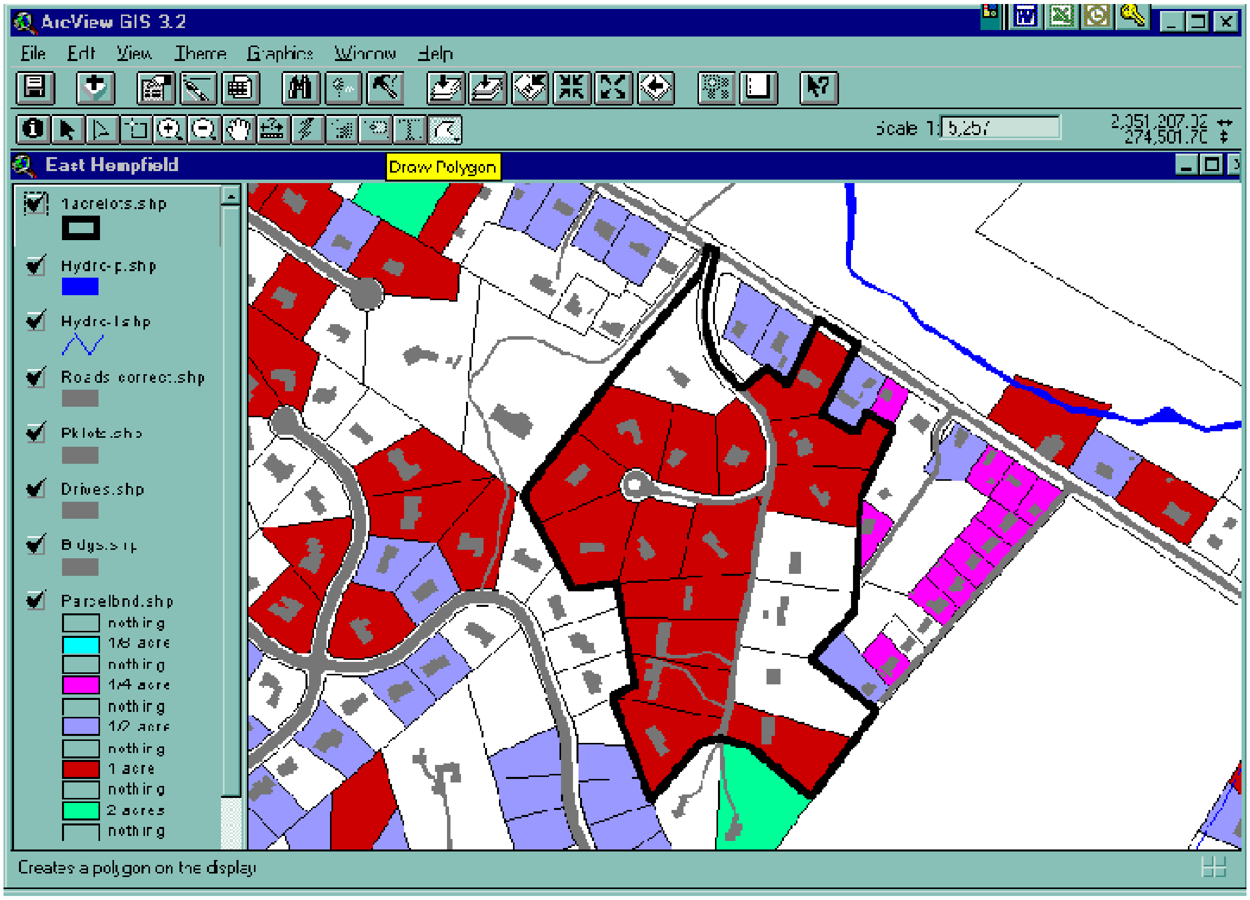
Name: NewField1
Type: Number
Width: 16
Decimal Places: 0

Figure C.2 – Adding a New Field in a Theme's Attribute Table

1C). Using **View>New Theme** create a new polygon theme for each of the land use categories
To simplify the process, you may combine several land uses into one theme but be sure to create a field in the attribute table that describes the land use (see next step).

1D). To edit an attribute table, open the theme table, and go to **Table>Start Editing**, then use **Edit> Add Field** to add a field to your table. Choose a name for the field and specify string or number and the width and decimal places. Once you create a new field, select the text edit tool to type data in each record (see Figure C.2).

1E). To add polygons to the land use themes, the theme must be in edit mode. You will know the theme is in edit mode if there is a dashed line around the box in the legend. Otherwise, select **Theme> Start Editing** from the view menu. Use the polygon tool to draw the polygons (look in the drop-down menu of graphics buttons on the far right part of the menu). Polygons may be edited later on using the vertex tool.



Creates a polygon on the display

Figure C.3 - Creating Land Use Polygon Themes in ArcView

1F). Use the following criteria to draw polygons for each land use:

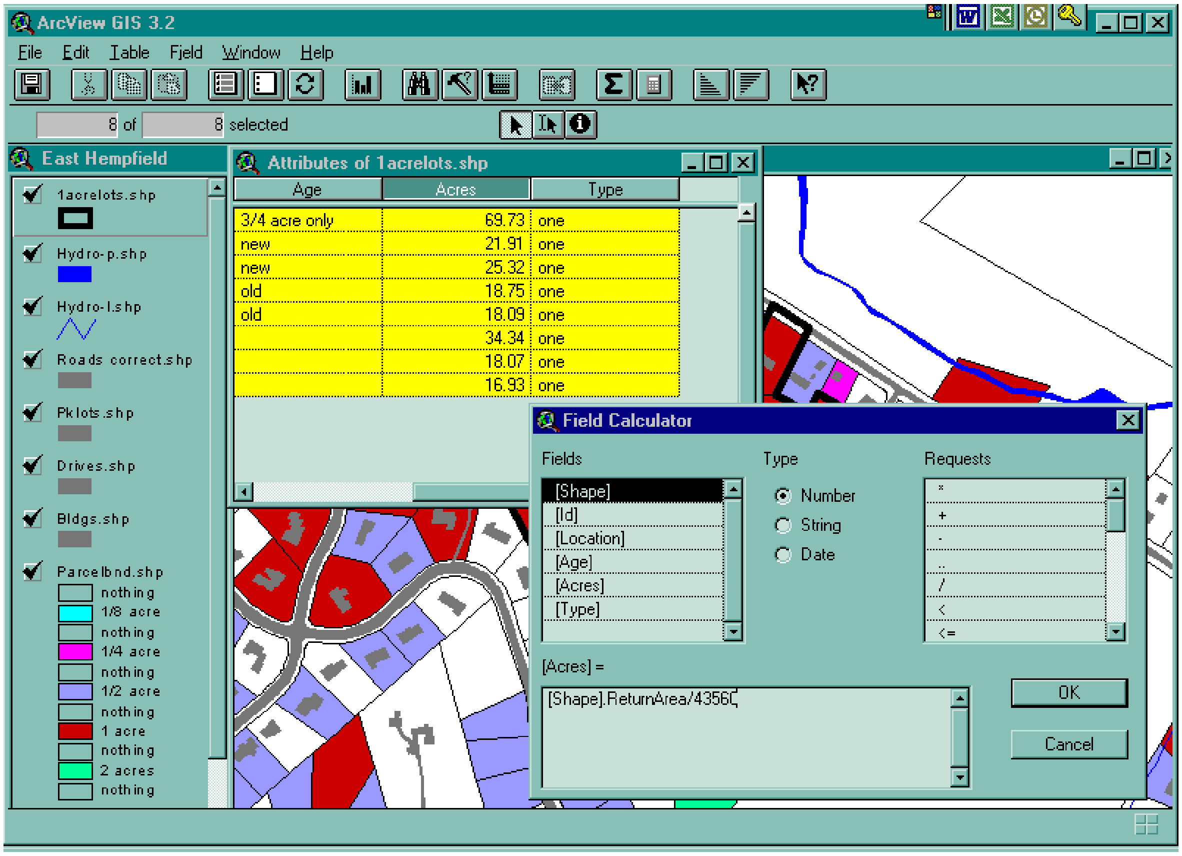
- Use parcel lines as guides for the polygon boundaries
- Do not include unbuildable areas in the polygon area (floodplains, steep slopes, restricted soils, conservation areas, etc)
- Do not include lots that are not yet built on
- Do not include large forested areas outside parcel boundaries
- Local and arterial roads should be included if a parcel is adjacent to it, but only include half the road if the land on the other side of the road is of a different land use
- Interstate and state highways should be excluded from polygons
- If unsure of land use check with the parcel data for business or owner name
- Check with orthophotos to make sure land use polygon is correct

1G). It is helpful to know the acreage of the parcels in order to identify residential land use categories. A simple way to display this is to edit the table of the parcel theme by adding a new field called **Acres**. Then select all records, use the calculate button and type **Acres = Shape.ReturnArea/43560** (assuming the current area is in square feet). Then save the edits and classify the parcels in the legend according to the following boundaries:

- 1/8 acre = 0.10 – 0.16
- ¼ acre = 0.20 – 0.30
- ½ acre = 0.40 – 0.60
- 1 acre = 0.75 – 1.25
- 2 acres = 1.70 – 2.30

1H). Save the legend to apply it later if needed. This allows you to display different parcel sizes with different colors as a guide when drawing land use polygons such as one-acre residential developments (see Figure C.3)

1I). Calculate the acreage of each land use polygon by creating a new field in the attribute table, using the calculate button, and typing Acres = **Shape.Return Area/43560** (see Figure C.4)



Age	Acres	Type
3/4 acre only	69.73	one
new	21.91	one
new	25.32	one
old	18.75	one
old	18.09	one
	34.34	one
	18.07	one
	16.93	one

Fields: [Shape], [Id], [Location], [Age], [Acres], [Type]

Type: ● Number ○ String ○ Date

Requests: *, +, -, .., /, <, <=

[Acres] =

[Shape].ReturnArea/43560

Figure C.4 - Calculating Polygon Areas in the Attribute Table in ArcView

Step 2: Intersecting Impervious Cover Themes With Land Use Polygons

2A). Use the **Geoprocessing Wizard** to intersect each land use polygon theme with each impervious cover theme to create a new theme (e.g., new themes: commercial roads, commercial parking lots, commercial buildings). The impervious cover layer will be the input theme and the land use polygon will be the overlay theme (see Figure C.5).

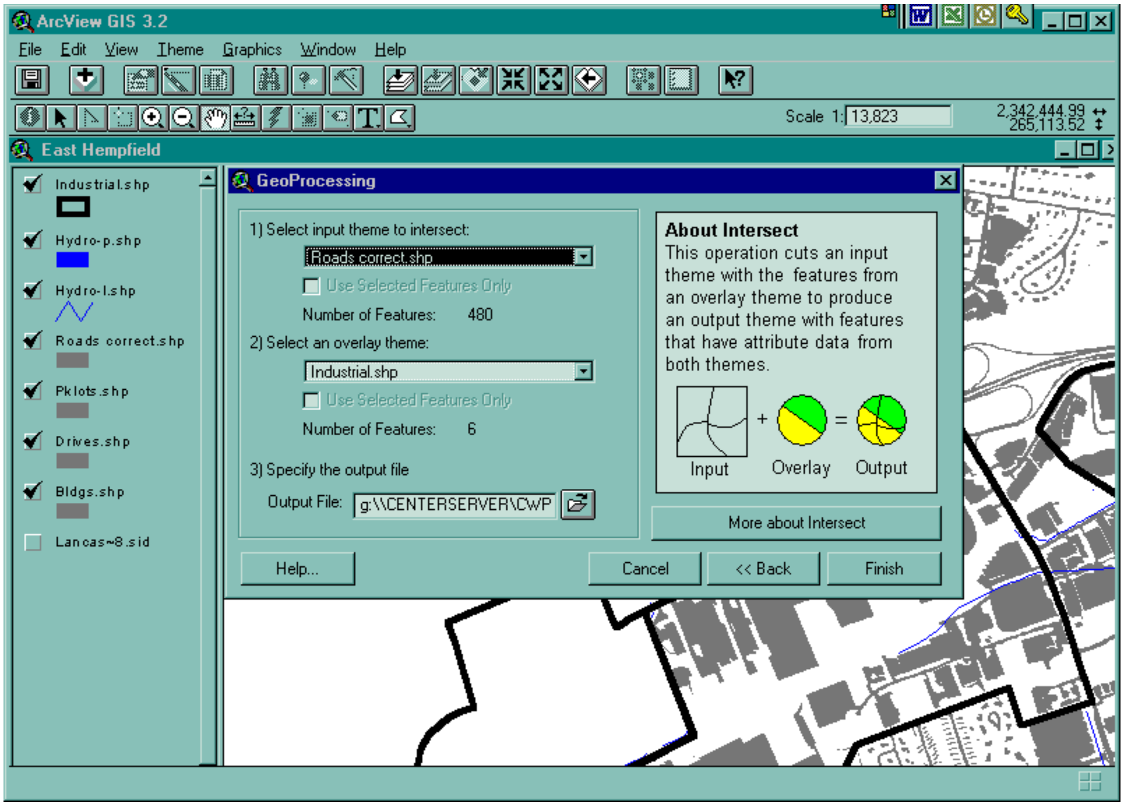
2B). Recalculate the areas of all newly created themes in the attribute table. Because **Intersect** will combine the attributes of both the input and overlay themes, you may also want to delete some unnecessary fields at this time; however, be sure to retain the **Acres** field in order to distinguish data from different polygons.

Step 3: Calculating Impervious Cover

3A). With the attribute table open, use **File>Export** to export the attribute table of each newly created theme to a delimited text file.

3B). Open the text file in **Excel** and sort each worksheet based on the **Acres** field to keep each polygon's data separate. If you combined several land uses into one theme you will first need to sort by land use.

3C). Add the area of road cover, building cover, driveway cover, sidewalk cover and parking lot cover for each land use polygon (if these layers exist). Add these totals to get a total impervious area per polygon. Divide by the polygon area to get the percent impervious cover (see Figure C.6)



1) Select input theme to intersect: Roads correct.shp

☐ Use Selected Features Only

Number of Features: 480

2) Select an overlay theme: Industrial.shp

☐ Use Selected Features Only

Number of Features: 6

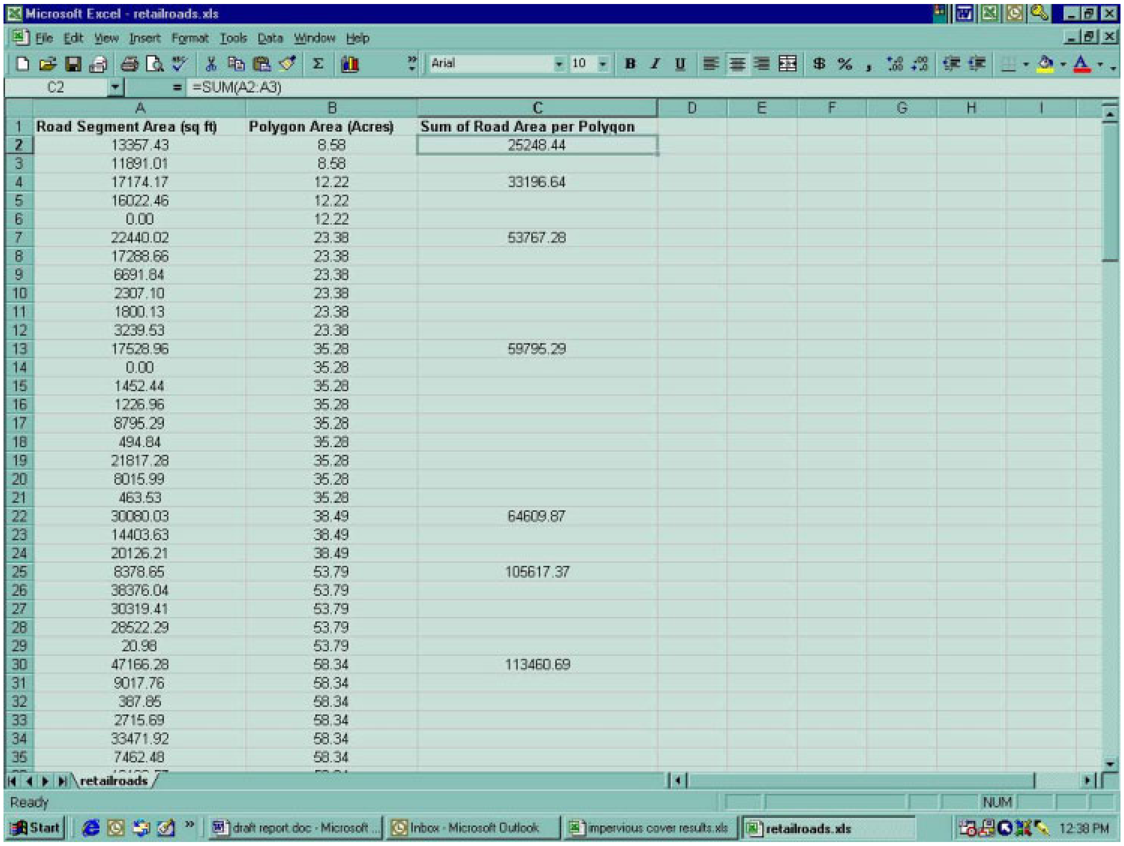
3) Specify the output file

Output File: g:\\CENTERSERVER\CWP

About Intersect

This operation cuts an input theme with the features from an overlay theme to produce an output theme with features that have attribute data from both themes.

Figure C.5 - Using the GeoProcessing Wizard to Intersect Impervious Cover Themes with Land Use Polygons



C2 =SUM(A2:A3)

	A	B	C
1	Road Segment Area (sq ft)	Polygon Area (Acres)	Sum of Road Area per Polygon
2	13357.43	8.58	25248.44
3	11891.01	8.58	
4	17174.17	12.22	33196.64
5	16022.46	12.22	
6	0.00	12.22	
7	22440.02	23.38	53767.28
8	17288.66	23.38	
9	6691.84	23.38	
10	2307.10	23.38	
11	1800.13	23.38	
12	3239.53	23.38	
13	17528.96	35.28	59795.29
14	0.00	35.28	
15	1452.44	35.28	
16	1226.96	35.28	
17	8795.29	35.28	
18	494.84	35.28	
19	21817.28	35.28	
20	8015.99	35.28	
21	463.53	35.28	
22	30080.03	38.49	64609.87
23	14403.63	38.49	
24	20126.21	38.49	
25	8378.65	53.79	105617.37
26	38376.04	53.79	
27	30319.41	53.79	
28	28522.29	53.79	
29	20.98	53.79	
30	47166.28	58.34	113460.69
31	9017.76	58.34	
32	387.85	58.34	
33	2715.69	58.34	
34	33471.92	58.34	
35	7462.48	58.34	

Figure C.6 - Data Table of Lancaster County Commercial Roads Sorted and Totaled by Polygon Acreage

3D). Where estimation was necessary due to lack of data, the orthophotos were used to calculate sidewalk and driveway areas. These methods are described below.

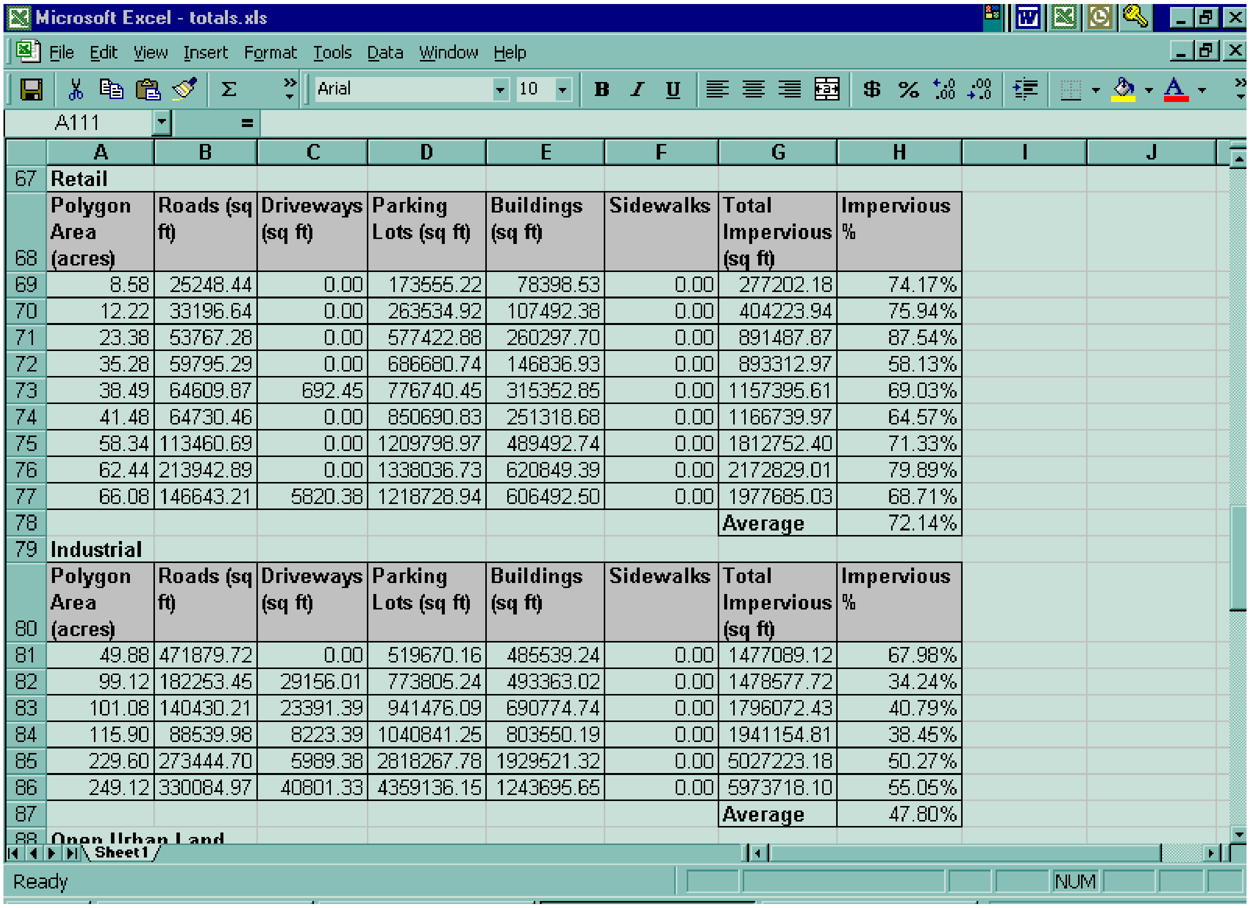
Sidewalk Estimation
Use the orthophotos and the measure tool in **ArcView** to measure the length of sidewalk in each polygon and multiply by 4 feet (assumed sidewalk width). Add these numbers to data table for calculation of impervious cover.

Driveway Estimation
Use orthophotos and the measure tool in **ArcView** to get an average driveway size for each polygon and multiply by the number of homes within the polygon. Add these numbers to data table for calculation of impervious cover.

3E). Where data was lacking, new themes were created for impervious cover layers. These methods are described below.

Parking Lots
James City County was the only jurisdiction without a parking lot layer. Therefore, we digitized a parking lot layer for the chosen land use polygons and included them in the processing and calculation of total impervious cover.

Other Impervious Surfaces
Use orthophotos to digitize an impervious cover layer that includes tennis courts, garages, and other impervious surfaces that not included in the other impervious layers. Add these numbers to data table for calculation of total impervious cover.



	A	B	C	D	E	F	G	H
67	**Retail**							
68	**Polygon Area (acres)**	**Roads (sq ft)**	**Driveways (sq ft)**	**Parking Lots (sq ft)**	**Buildings (sq ft)**	**Sidewalks**	**Total Impervious (sq ft)**	**Impervious %**
69	8.58	25248.44	0.00	173555.22	78398.53	0.00	277202.18	74.17%
70	12.22	33196.64	0.00	263534.92	107492.38	0.00	404223.94	75.94%
71	23.38	53767.28	0.00	577422.88	260297.70	0.00	891487.87	87.54%
72	35.28	59795.29	0.00	686680.74	146836.93	0.00	893312.97	58.13%
73	38.49	64609.87	692.45	776740.45	315352.85	0.00	1157395.61	69.03%
74	41.48	64730.46	0.00	850690.83	251318.68	0.00	1166739.97	64.57%
75	58.34	113460.69	0.00	1209798.97	489492.74	0.00	1812752.40	71.33%
76	62.44	213942.89	0.00	1338036.73	620849.39	0.00	2172829.01	79.89%
77	66.08	146643.21	5820.38	1218728.94	606492.50	0.00	1977685.03	68.71%
78							**Average**	72.14%
79	**Industrial**							
80	**Polygon Area (acres)**	**Roads (sq ft)**	**Driveways (sq ft)**	**Parking Lots (sq ft)**	**Buildings (sq ft)**	**Sidewalks**	**Total Impervious (sq ft)**	**Impervious %**
81	49.88	471879.72	0.00	519670.16	485539.24	0.00	1477089.12	67.98%
82	99.12	182253.45	29156.01	773805.24	493363.02	0.00	1478577.72	34.24%
83	101.08	140430.21	23391.39	941476.09	690774.74	0.00	1796072.43	40.79%
84	115.90	88539.98	8223.39	1040841.25	803550.19	0.00	1941154.81	38.45%
85	229.60	273444.70	5989.38	2818267.78	1929521.32	0.00	5027223.18	50.27%
86	249.12	330084.97	40801.33	4359136.15	1243695.65	0.00	5973718.10	55.05%
87							**Average**	47.80%
88	**Open Urban Land**							

Figure C.7 - Data Table for Commercial and Industrial Land Use Polygons

Appendix D

Impervious Cover Database

Appendix D -Impervious Cover Data Table

Table D.1 - Chesapeake Bay Watershed Impervious Cover Results by Land Use Polygon

County	Landuse	Type	Polygon Area (acres)	Roads (sq ft)	Driveways (sq ft)	Parking (sq ft)	Buildings (sq ft)	Sidewalks (sq ft)	Other Impervious (sq ft)	Total Impervious (sq ft)	Impervious %	# Units	Age of Development	Impervious Cover/Housing Unit	Gross Density (units/acre)	Average House Size	Impervious Cover/Building sq ft	Parking/Building sq ft	% Forest or Open Space	% Roads	% Buildings	% Parking	% Driveways	% Sidewalks	% Other Impervious
Lancaster	Agriculture		265.69	1062.76	132050.60	0.00	88639.34	0.00	0.00	221752.69	1.92%						2.50		98.08%	0.01%	0.77%	0.00%	1.14%	0.00%	0.00%
Lancaster	Agriculture		271.86	134575.90	75349.92	57.93	55495.45	0.00	0.00	265479.21	2.24%						4.78		97.76%	1.14%	0.47%	0.00%	0.64%	0.00%	0.00%
Lancaster	Agriculture		304.27	43136.29	35873.10	0.00	56031.96	0.00	0.00	135041.35	1.02%						2.41		98.98%	0.33%	0.42%	0.00%	0.27%	0.00%	0.00%
Lancaster	Agriculture		373.27	140220.23	62387.11	0.00	109877.30	0.00	0.00	312484.64	1.92%						2.84		98.08%	0.86%	0.68%	0.00%	0.38%	0.00%	0.00%
Lancaster	Agriculture		389.35	176625.12	65524.40	0.00	108385.41	0.00	0.00	350534.92	2.07%						3.23		97.93%	1.04%	0.64%	0.00%	0.39%	0.00%	0.00%
Howard	Agriculture		852.08	191397.42	23214.88	2824.93	181328.6	0.00	167542.20	566308.03	1.53%						3.12		98.47%	0.52%	0.49%	0.01%	0.06%	0.00%	0.45%
James City	Agriculture		217.14	77154.17	0.00	0.00	5645.24	0.00	22290.00	105089.42	1.11%						18.62		98.89%	0.82%	0.06%	0.00%	0.00%	0.00%	0.24%
James City	Agriculture		94.58	21624.53	0.00	0.00	48933.49	0.00	74960.00	145518.01	3.53%						2.97		96.47%	0.52%	1.19%	0.00%	0.00%	0.00%	1.82%
	Agriculture	**AVERAGE**	**346.03**	**98224.55**	**49300.00**	**360.36**	**81792.10**	**0.00**	**33099.03**	**262776.03**	**0.02**						**5.06**		**0.98**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**
Lancaster	Open Urban	golf course	100.01	53948.46	0.00	36689.07	22011.48	43564.00	0.00	156213.01	3.59%						7.10	1.67	96.41%	1.24%	0.51%	0.84%	0.00%	1.00%	0.00%
Lancaster	Open Urban	golf course	128.07	43199.31	9543.27	94309.05	31615.29	55787.00	0.00	234453.93	4.20%						7.42	2.98	95.80%	0.77%	0.57%	1.69%	0.17%	1.00%	0.00%
Lancaster	Open Urban	park	8.26	4498.48	0.00	2024.35	0.00	0.00	11105.00	17627.83	4.90%								95.10%	1.25%	0.00%	0.56%	0.00%	0.00%	3.09%
Baltimore	Open Urban	cemetery	74.14	279250.15	0.00	0.00	14332.55	0.00	17814.00	311396.70	9.64%						21.73		90.36%	8.65%	0.44%	0.00%	0.00%	0.00%	0.55%
Baltimore	Open Urban	golf course	156.89	243585.07	8815.23	117663.77	87596.35	29448.00	188868.60	675977.02	9.89%						7.72	1.34	90.11%	3.56%	1.28%	1.72%	0.13%	0.43%	2.76%
Baltimore	Open Urban	local park	4.92	8615.20	0.00	0.00	809.80	3365.00	8119.00	20909.00	9.76%						25.82		90.24%	4.02%	0.38%	0.00%	0.00%	1.57%	3.79%
Howard	Open Urban	cemetery	150.22	104927.98	246473.05	116315.57	28415.26	31967.00	0.00	528098.86	8.07%						18.59		91.93%	1.60%	0.43%	1.78%	3.77%	0.49%	0.00%
Howard	Open Urban	local park	10.94	2281.22	0.00	19899.1	2252.18	3968.28	37262.87	65663.65	13.78%						29.16		86.22%	0.48%	0.47%	4.18%	0.00%	0.83%	7.82%
James City	Open Urban	golf course	183.93	122315.65	0.00	0.00	11156.04	56280.00	0.00	189751.69	2.37%						17.01		97.63%	1.53%	0.14%	0.00%	0.00%	0.70%	0.00%
James City	Open Urban	cemetery	40.05	43959.09	0.00	0.00	0.00	1093.00	79598.75	124650.84	7.15%								92.85%	2.52%	0.00%	0.00%	0.00%	0.06%	4.56%
James City	Open Urban	county park	20.17	42780.25	0.00	49601.20	0.00	8504.00	88055.82	188941.27	21.50%								78.50%	4.87%	0.00%	5.65%	0.00%	0.97%	10.02%
	Open Urban	**AVERAGE**	**79.78**	**86305.53**	**24075.60**	**39682.01**	**18017.18**	**21270.57**	**39165.82**	**228516.71**	**0.09**						**16.82**	**2.00**	**0.91**	**0.03**	**0.00**	**0.01**	**0.00**	**0.01**	**0.03**
Lancaster	2 Acre Lots		10.49	11002.33	6816.15	0.00	18136.25	0.00	0.00	35954.73	7.87%	5	new	7190.95	0.48	3627.25	1.98		92.13%	2.41%	3.97%	0.00%	1.49%	0.00%	0.00%
Lancaster	2 Acre Lots		13.28	24902.04	22184.44	0.00	22402.82	0.00	0.00	69489.31	12.01%	7	new	9927.04	0.53	3200.40	3.10		87.99%	4.30%	3.87%	0.00%	3.83%	0.00%	0.00%
Lancaster	2 Acre Lots		20.54	28609.68	23014.84	0.00	27538.20	0.00	0.00	79162.73	8.85%	8	new	9895.34	0.39	3442.28	2.87		91.15%	3.20%	3.08%	0.00%	2.57%	0.00%	0.00%
Lancaster	2 Acre Lots		56.93	124968.01	82770.89	0.00	108252.19	0.00	0.00	315991.09	12.74%	24	new	13166.30	0.42	4510.51	2.92		87.26%	5.04%	4.37%	0.00%	3.34%	0.00%	0.00%
Baltimore	2 Acre Lots		42.70	42498.13	34840.22	0.00	55457.92	0.00	8352.00	141148.26	7.59%	23	new	6136.88	0.54	2411.21	2.55		92.41%	2.28%	2.98%	0.00%	1.87%	0.00%	0.45%
Baltimore	2 Acre Lots		48.64	89770.89	46133.82	0.00	41716.15	0.00	10000.00	187620.87	8.86%	12	new	15635.07	0.25	3476.35	4.50		91.14%	4.24%	1.97%	0.00%	2.18%	0.00%	0.47%
Baltimore	2 Acre Lots		10.29	14332.12	7410.00	0.00	16353.37	0.00	2365.00	40460.49	9.03%	5		8092.10	0.49	3270.67	2.47		90.97%	3.20%	3.65%	0.00%	1.65%	0.00%	0.53%
Baltimore	2 Acre Lots		152.87	225919.01	142528.90	0.00	224117.37	0.00	17280.00	609845.28	9.16%	79	new	7719.56	0.52	2836.93	2.72		90.84%	3.39%	3.37%	0.00%	2.14%	0.00%	0.26%
James City	2 Acre Lots		25.85	42166.56	73191.69	0.00	31474.74	0.00	0.00	146832.99	13.04%	12		12236.08	0.46	2622.89	4.67		86.96%	3.74%	2.80%	0.00%	6.50%	0.00%	0.00%
James City	2 Acre Lots		26.97	51727.03	76362.86	0.00	36868.12	0.00	0.00	164958.01	14.04%	14		11782.71	0.52	2633.44	4.47		85.96%	4.40%	3.14%	0.00%	6.50%	0.00%	0.00%
James City	2 Acre Lots		43.88	54024.25	124241.83	0.00	60068.62	0.00	0.00	238334.70	12.47%	23		10362.38	0.52	2611.68	3.97		87.53%	2.83%	3.14%	0.00%	6.50%	0.00%	0.00%
James City	2 Acre Lots		28.27	18749.10	80043.68	0.00	37553.70	0.00	0.00	136346.48	11.07%	12		11362.21	0.42	3129.48	3.63		88.93%	1.52%	3.05%	0.00%	6.50%	0.00%	0.00%
	2 Acre Lots	**AVERAGE**	**40.06**	**60722.43**	**59961.61**	**0.00**	**56661.62**	**0.00**	**3166.42**	**180512.08**	**0.11**	**18.67**		**10292.22**	**0.46**	**3147.76**	**3.32**		**0.89**	**0.03**	**0.03**	**0.00**	**0.04**	**0.00**	**0.00**
Lancaster	1 Acre Lots		16.93	33443.98	20735.16	0.00	41708.24	0.00	0.00	95887.39	13.00%	13	new	7375.95	0.77	3208.33	2.30		87.00%	4.53%	5.66%	0.00%	2.81%	0.00%	0.00%
Lancaster	1 Acre Lots		18.07	40859.91	16779.87	0.00	52402.07	0.00	0.00	110041.85	13.98%	17	new 1979	6473.05	0.94	3082.47	2.10		86.02%	5.19%	6.66%	0.00%	2.13%	0.00%	0.00%
Lancaster	1 Acre Lots		18.09	22814.10	19125.00	125.85	27838.07	5412.00	0.00	75315.03	9.56%	17	old	4430.30	0.94	1637.53	2.71		90.44%	2.90%	3.53%	0.02%	2.43%	0.69%	0.00%
Lancaster	1 Acre Lots		18.75	23727.96	28900.00	0.00	37423.40	0.00	0.00	90051.37	11.03%	17	old	5297.14	0.91	2201.38	2.41		88.97%	2.91%	4.58%	0.00%	3.54%	0.00%	0.00%
Lancaster	1 Acre Lots		21.91	39491.25	31045.85	0.00	44503.67	0.00	0.00	115040.77	12.05%	19	new	6054.78	0.87	2342.30	2.58		87.95%	4.14%	4.66%	0.00%	3.25%	0.00%	0.00%
Lancaster	1 Acre Lots		25.32	69137.90	32305.69	0.00	54367.81	16204.00	0.00	172015.40	15.60%	22	new	7818.88	0.87	2471.26	3.16		84.40%	6.27%	4.93%	0.00%	2.93%	1.47%	0.00%
Lancaster	1 Acre Lots		34.34	63990.10	57800.00	0.00	93910.25	0.00	0.00	215700.35	14.42%	34	old	6344.13	0.99	2762.07	2.30		85.58%	4.28%	6.28%	0.00%	3.86%	0.00%	0.00%
Lancaster	1 Acre Lots	3/4 acre only	69.73	242584.23	115500.00	0.00	138022.03	23120.00	0.00	519226.26	17.09%	77	new	6743.20	1.10	1792.49	3.76		82.91%	7.99%	4.54%	0.00%	3.80%	0.76%	0.00%
Baltimore	1 Acre Lots		21.11	46029.90	25306.19	0.00	29105.46	0.00	7155.00	107596.56	11.70%	15		7173.10	0.71	1940.36	3.70		88.30%	5.01%	3.17%	0.00%	2.75%	0.00%	0.78%
Baltimore	1 Acre Lots		32.30	64709.03	63188.71	0.00	96206.30	0.00	0.00	224104.05	15.93%	32		7003.25	0.99	3006.45	2.33		84.07%	4.60%	6.84%	0.00%	4.49%	0.00%	0.00%
Baltimore	1 Acre Lots		39.53	71090.12	65736.96	0.00	78268.35	0.00	12276.00	227371.42	13.20%	29	new	7840.39	0.73	2698.91	2.91		86.80%	4.13%	4.55%	0.00%	3.82%	0.00%	0.71%
Baltimore	1 Acre Lots		42.28	93327.07	46695.90	0.00	79900.28	0.00	6956.00	226879.25	12.32%	33	new	6875.13	0.78	2421.22	2.84		87.68%	5.07%	4.34%	0.00%	2.54%	0.00%	0.38%
Baltimore	1 Acre Lots		84.44	252388.58	209021.23	0.00	313634.62	0.00	11090.00	786134.44	21.37%	119	new	6606.17	1.41	2635.59	2.51		78.63%	6.86%	8.53%	0.00%	5.68%	0.00%	0.30%
Howard	1 Acre Lots		25.10	62861.00	48413.04	0.00	44950.25	0.00	0.00	156224.29	14.29%	23		6792.36	0.92		3.48		85.71%	5.75%	4.11%	0.00%	4.43%	0.00%	0.00%
Howard	1 Acre Lots		48.77	95183.00	61406.67	0.00	101595.90	0.00	15844.96	274030.53	12.90%	40		6850.76	0.82		2.70		87.10%	4.48%	4.78%	0.00%	2.89%	0.00%	0.75%
Howard	1 Acre Lots		63.04	103816.00	85114.71	0.00	114469.20	0.00	8694.00	312093.91	11.37%	46		6784.65	0.73		2.73		88.63%	3.78%	4.17%	0.00%	3.10%	0.00%	0.32%
Howard	1 Acre Lots		192.77	499454.00	272109.24	0.00	375144.40	3261.68	39936.00	1189905.32	14.17%	154		7726.66	0.80		3.17		85.83%	5.95%	4.47%	0.00%	3.24%	0.04%	0.48%
James City	1 Acre Lots		29.73	53043.9457	90000	0.00	64016.525	0.00	0.00	207060.47	15.99%	30	new	6902.02	1.01	2133.88	3.23		84.01%	4.10%	4.94%	0.00%	6.95%	0.00%	0.00%
James City	1 Acre Lots		91.76	152825.507	273000	0.00	238788.774	0.00	0.00	664614.28	16.63%	91		7303.45	0.99	2624.05	2.78		83.37%	3.82%	5.97%	0.00%	6.83%	0.00%	0.00%
James City	1 Acre Lots		39.71	63581.0177	111000	0.00	85819.0874	0.00	0.00	260400.11	15.05%	37		7037.84	0.93	2319.43	3.03		84.95%	3.68%	4.96%	0.00%	6.42%	0.00%	0.00%
James City	1 Acre Lots		46.43	96193.2751	117000	0.00	90813.7804	0.00	0.00	304007.06	15.03%	39		7795.05	0.84	2328.56	3.35		84.97%	4.76%	4.49%	0.00%	5.78%	0.00%	0.00%
James City	1 Acre Lots		20.53	42499.3837	39100	0.00	48143.8685	0.00	0.00	129743.25	14.51%	17		7631.96	0.83	2831.99	2.69		85.49%	4.75%	5.38%	0.00%	4.37%	0.00%	0.00%
James City	1 Acre Lots		63.03	130672.956	181300	0.00	145863.157	0.00	0.00	457836.11	16.68%	49	new	9343.59	0.78	2976.80	3.14		83.32%	4.76%	5.31%	0.00%	6.60%	0.00%	0.00%
	1 Acre Lots	**AVERAGE**	**46.25**	**102770.62**	**87416.71**	**5.47**	**104212.85**	**2086.86**	**4432.69**	**300925.19**	**0.14**	**42.17**		**6965.38**	**0.90**	**2495.53**	**2.87**		**0.86**	**0.05**	**0.05**	**0.00**	**0.04**	**0.00**	**0.00**
Lancaster	1/2 Acre Lots		21.18	102442.35	34850.00	59.59	90332.18	23476.00	0.00	251160.12	27.22%	41	new	6125.86	1.94	2203.22	2.78		72.78%	11.10%	9.79%	0.01%	3.78%	2.54%	0.00%
Lancaster	1/2 Acre Lots		24.66	81881.89	42840.00	0.00	114348.14	26556.00	0.00	265626.03	24.73%	36	new	7378.50	1.46	3176.34	2.32		75.27%	7.62%	10.65%	0.00%	3.99%	2.47%	0.00%
Lancaster	1/2 Acre Lots		26.31	96910.88	50830.00	0.00	105626.07	36416.00	0.00	289782.95	25.29%	46	new	6299.63	1.75	2296.22	2.74		74.71%	8.46%	9.22%	0.00%	4.44%	3.18%	0.00%
Lancaster	1/2 Acre Lots		26.54	110301.14	36550.00	0.00	86103.76	22208.00	0.00	255162.90	22.07%	43	old	5934.02	1.62	2002.41	2.96		77.93%	9.54%	7.45%	0.00%	3.16%	1.92%	0.00%
Lancaster	1/2 Acre Lots		33.17	159977.95	56043.62	0.00	131621.62	36808.00	0.00	384451.19	26.61%	57	new	6744.76	1.72	2309.15	2.92		73.39%	11.07%	9.11%	0.00%	3.88%	2.55%	0.00%
Lancaster	1/2 Acre Lots		41.44	148456.30	60350.00	0.00	166112.98	39184.00	0.00	414103.28	22.94%	71	new	5832.44	1.71	2339.62	2.49		77.06%	8.22%	9.20%	0.00%	3.34%	2.17%	0.00%
Lancaster	1/2 Acre Lots		47.09	202924.18	93800.00	0.00	192164.54	32456.00	0.00	521344.72	25.42%	67	new	7781.26	1.42	2868.13	2.71		74.58%	9.89%	9.37%	0.00%	4.57%	1.58%	0.00%
Lancaster	1/2 Acre Lots		71.97	293079.84	104400.38	0.00	252668.04	62880.00	0.00	713028.26	22.74%	117	new	6094.26	1.63	2159.56	2.82		77.26%	9.35%	8.06%	0.00%	3.33%	2.01%	0.00%
Baltimore	1/2 Acre Lots		25.23	34742.88	40971.16	38.80	77986.35	0.00	2552.00	156291.19	14.22%	42		3721.22	1.66	1856.82	2.00		85.78%	3.16%	7.10%	0.00%	3.73%	0.00%	0.23%
Baltimore	1/2 Acre Lots		2.71	4150.92	7602.00	0.00	10250.09	0.00	0.00	22003.00	18.64%	5	new	4400.60	1.85	2050.02	2.15		81.36%	3.52%	8.68%	0.00%	6.44%	0.00%	0.00%
Baltimore	1/2 Acre Lots		25.17	82945.76	29315.00	0.00	94034.85	0.00	15312.00	221607.61	20.21%	41		5405.06	1.63	2293.53	2.36		79.79%	7.57%	8.58%	0.00%	2.67%	0.00%	1.40%
Howard	1/2 Acre Lots		13.06	33026.00	25258.42	0.00	33327.83	5984.36	0.00	97596.61	17.16%	20		4879.83	1.53		2.93		82.84%	5.81%	5.86%	0.00%	4.44%	1.05%	0.00%
Howard	1/2 Acre Lots		18.27	77286.00	29005.86	0.00	56244.88	0.00	2579.38	165116.12	20.75%	30		5503.87	1.64		2.94		79.25%	9.71%	7.07%	0.00%	3.64%	0.00%	0.32%
Howard	1/2 Acre Lots		38.15	104027.00	66249.89	0.00	132190.50	0.00	16445.00	318912.39	19.19%	70		4555.89	1.83		2.41		80.81%	6.26%	7.95%	0.00%	3.99%	0.00%	0.99%
Howard	1/2 Acre Lots		41.08	117225.00	102656.39	0.00	124135.40	22590.28	5262.97	371870.04	20.78%	65		5721.08	1.58		3.00		79.22%	6.55%	6.94%	0.00%	5.74%	1.26%	0.29%
James City	1/2 Acre Lots		20.64	60923.2721	40700	0.00	59172.5802	8800	0.00	169595.85	18.86%	37	new	4583.67	1.79	1599.26	2.87		81.14%	6.78%	6.58%	0.00%	4.53%	0.98%	0.00%
James City	1/2 Acre Lots		49.87	133974.834	140800	0.00	108076.35	0	0.00	382851.18	17.62%	88	new	4350.58	1.76	1228.14	3.54		82.38%	6.17%	4.98%	0.00%	6.48%	0.00%	0.00%
James City	1/2 Acre Lots		29.75	69778.6851	81600	0.00	111163.751	6560	0.00	269102.44	20.77%	48	new	5606.30	1.61	2315.91	2.42		79.23%	5.38%	8.58%	0.00%	6.30%	0.51%	0.00%
James City	1/2 Acre Lots		74.21	239674.973	123000	0.00	196906.153	0	0.00	559581.13	17.31%	123	new	4549.44	1.66	1600.86	2.84		82.69%	7.41%	6.09%	0.00%	3.81%	0.00%	0.00%
James City	1/2 Acre Lots		53.52	166186.534	140800	0.00	165237.806	22000	0.00	494224.34	21.20%	88	new	5616.19	1.64	1877.70	2.99		78.80%	7.13%	7.09%	0.00%	6.04%	0.94%	0.00%
	1/2 Acre Lots	**AVERAGE**	**34.20**	**115995.82**	**65381.14**	**4.92**	**115385.19**	**17295.93**	**2107.57**	**316170.57**	**0.21**	**56.75**		**5554.22**	**1.67**	**2136.06**	**2.71**		**0.79**	**0.08**	**0.08**	**0.00**	**0.04**	**0.01**	**0.00**
Lancaster	1/4 Acre Lots		19.89	105154.20	35685.00	0.00	77379.74	26584.00	0.00	244802.94	28.25%	61	old	4013.16	3.07	1268.52	3.16		71.75%	12.14%	8.93%	0.00%	4.12%	3.07%	0.00%
Lancaster	1/4 Acre Lots		25.25	100433.01	54600.00	0.00	142959.67	0.00	0.00	297992.68	27.09%	84	old	3547.53	3.33	1701.90	2.08		72.91%	9.13%	13.00%	0.00%	4.96%	0.00%	0.00%
Lancaster	1/4 Acre Lots		26.33	156205.80	44100.00	0.00	108661.17	29980.00	0.00	338946.96	29.55%	84	new	4035.08	3.19	1293.59	3.12		70.45%	13.62%	9.47%	0.00%	3.85%	2.61%	0.00%
Lancaster	1/4 Acre Lots		26.79	127236.62	44720.00	0.00	135726.26	0.00	0.00	307682.88	26.37%	80	old	3846.04	2.99	1696.58	2.27		73.63%	10.90%	11.63%	0.00%	3.83%	0.00%	0.00%
Lancaster	1/4 Acre Lots		38.72	208187.40	66690.00	0.00	200168.41	0.00	0.00	475045.82	28.17%	114	new	4167.07	2.94	1755.86	2.37		71.83%	12.34%	11.87%	0.00%	3.95%	0.00%	0.00%
Lancaster	1/4 Acre Lots		45.91	277803.80	58240.00	0.00	234626.46	55664.00	0.00	626334.26	31.32%	112	new 1988	5592.27	2.44	2094.88	2.67		68.68%	13.89%	11.73%	0.00%	2.91%	2.78%	0.00%
Lancaster	1/4 Acre Lots		45.92	210677.01	87100.00	0.00	196276.05	1548.00	0.00	495601.07	24.78%	134	old	3698.52	2.92	1464.75	2.53		75.22%	10.53%	9.81%	0.00%	4.35%	0.08%	0.00%

Appendix D -Impervious Cover Data Table

Table D.1 - Chesapeake Bay Watershed Impervious Cover Results by Land Use Polygon

County	Landuse	Type	Polygon Area (acres)	Roads (sq ft)	Driveways (sq ft)	Parking (sq ft)	Buildings (sq ft)	Sidewalks (sq ft)	Other Impervious (sq ft)	Total Impervious (sq ft)	Impervious %	# Units	Age of Development	Impervious Cover/Housing Unit	Gross Density (units/acre)	Average House Size	Impervious Cover/Building sq ft	Parking/Building sq ft	% Forest or Open Space	% Roads	% Buildings	% Parking	% Driveways	% Sidewalks	% Other Impervious
Lancaster	1/4 Acre Lots		62.64	379936.86	107120.00	8010.46	371459.99	0.00	0.00	866527.32	31.76%	206	new1988	4206.44	3.29	1803.20	2.33	0.02	68.24%	13.92%	13.61%	0.29%	3.93%	0.00%	0.00%
Lancaster	1/4 Acre Lots		71.09	422345.08	96750.00	0.00	344389.34	147600.00	0.00	1011084.42	32.65%	215	old	4702.72	3.02	1601.81	2.94		67.35%	13.64%	11.12%	0.00%	3.12%	4.77%	0.00%
Baltimore	1/4 Acre Lots		25.37	94600.11	42900.00	0.00	169385.36	28012.00	8160.00	343057.46	31.04%	110	old	3118.70	4.34	1539.87	2.03		68.96%	8.56%	15.33%	0.00%	3.88%	2.53%	0.74%
Baltimore	1/4 Acre Lots		33.39	151025.13	59150.00	0.00	153863.07	35796.00	3500.00	403334.21	27.73%	91	new	4432.24	2.73	1690.80	2.62		72.27%	10.38%	10.58%	0.00%	4.07%	2.46%	0.24%
Baltimore	1/4 Acre Lots		57.23	257890.15	135116.25	0.00	285838.12	64232.00	10500.00	753576.52	30.23%	171	new	4406.88	2.99	1671.57	2.64		69.77%	10.34%	11.47%	0.00%	5.42%	2.58%	0.42%
Baltimore	1/4 Acre Lots		140.25	737949.19	308880.00	0.00	688608.72	169768.00	15840.00	1921045.92	31.44%	432	new	4446.87	3.08	1594.00	2.79		68.56%	12.08%	11.27%	0.00%	5.06%	2.78%	0.26%
Baltimore	1/4 Acre Lots		143.49	739367.73	279500.00	0.00	661101.78	147880.00	7800.00	1835649.51	29.37%	430	new	4268.95	3.00	1537.45	2.78		70.63%	11.83%	10.58%	0.00%	4.47%	2.37%	0.12%
Baltimore	1/4 Acre Lots		157.22	783075.70	232389.04	0.00	849228.94	94364.00	9828.00	1968885.68	28.75%	393	new	5009.89	2.50	2160.89	2.32		71.25%	11.43%	12.40%	0.00%	3.39%	1.38%	0.14%
Howard	1/4 Acre Lots		31.57	127735.00	69173.78	0.00	136824.90	12353.48	3771.08	349858.24	25.44%	95		3682.72	3.01		2.56		74.56%	9.29%	9.95%	0.00%	5.03%	0.90%	0.27%
Howard	1/4 Acre Lots		43.07	180831.00	77931.95	0.00	192319.20	25793.68	0.00	476875.83	25.42%	110		4335.23	2.55		2.48		74.58%	9.64%	10.25%	0.00%	4.15%	1.37%	0.00%
James City	1/4 Acre Lots		28.86	102761.99	65450.00	0.00	115119.08	22240.00	0.00	305571.07	24.31%	77	new	3968.46	2.67	1495.05	2.65		75.69%	8.17%	9.16%	0.00%	5.21%	1.77%	0.00%
James City	1/4 Acre Lots		17.94	85891.76	28000.00	0.00	97999.92	0.00	0.00	211891.68	27.11%	56	new	3783.78	3.12	1750.00	2.16		72.89%	10.99%	12.54%	0.00%	3.58%	0.00%	0.00%
James City	1/4 Acre Lots		24.65	101191.70	57600.00	0.00	100544.87	21470.00	0.00	280806.58	26.15%	64		4387.60	2.60	1571.01	2.79		73.85%	9.42%	9.36%	0.00%	5.36%	2.00%	0.00%
James City	1/4 Acre Lots		15.15	60835.33	38000.00	0.00	59657.39	11900.00	0.00	170392.72	25.82%	38	new	4484.02	2.51	1569.93	2.86		74.18%	9.22%	9.04%	0.00%	5.76%	1.80%	0.00%
James City	1/4 Acre Lots		34.19	126084.67	80960.00	0.00	176170.90	0.00	0.00	383215.57	25.73%	92		4165.39	2.69	1914.90	2.18		74.27%	8.47%	11.83%	0.00%	5.44%	0.00%	0.00%
James City	1/4 Acre Lots		53.70	178734.74	115000.00	0.00	163587.07	26820.00	0.00	484141.80	20.70%	100	new	4841.42	1.86	1635.87	2.96		79.30%	7.64%	6.99%	0.00%	4.92%	1.15%	0.00%
	1/4 Acre Lots	**AVERAGE**	**50.81**	**248519.74**	**95002.44**	**348.28**	**246169.41**	**40087.18**	**2582.57**	**632709.61**	**0.28**	**145.61**		**4223.52**	**2.91**	**1657.73**	**2.58**	**0.02**	**0.72**	**0.11**	**0.11**	**0.00**	**0.04**	**0.02**	**0.00**
Lancaster	1/8 Acre Lots		2.53	24287.90	5460.00	0.00	8579.98	5096.00	0.00	43423.88	39.40%	12	new	3618.66	4.74	715.00	5.06		60.60%	22.04%	7.79%	0.00%	4.95%	4.62%	0.00%
Lancaster	1/8 Acre Lots		7.21	42905.13	14220.13	0.00	53062.46	0.00	0.00	110187.73	35.08%	36	old	3060.77	4.99	1473.96	2.08		64.92%	13.66%	16.90%	0.00%	4.53%	0.00%	0.00%
Lancaster	1/8 Acre Lots		12.74	73041.64	15925.00	0.00	79764.82	16160.00	0.00	184891.47	33.32%	35	new	5282.61	2.75	2278.99	2.32		66.68%	13.16%	14.37%	0.00%	2.87%	2.91%	0.00%
Lancaster	1/8 Acre Lots		15.14	86977.08	39000.00	0.00	75246.45	19288.00	0.00	220511.53	33.44%	100	new	2205.12	6.61	752.46	2.93		66.56%	13.19%	11.41%	0.00%	5.91%	2.92%	0.00%
Lancaster	1/8 Acre Lots		16.72	103883.90	39468.00	0.00	56497.76	22080.00	0.00	221929.66	30.47%	92	new	2412.28	5.50	614.11	3.93		69.53%	14.26%	7.76%	0.00%	5.42%	3.03%	0.00%
Lancaster	1/8 Acre Lots		53.57	273646.36	94651.82	0.00	188580.23	50960.00	0.00	607838.41	26.05%	234	new1989	2597.60	4.37	805.90	3.22		73.95%	11.73%	8.08%	0.00%	4.06%	2.18%	0.00%
Howard	1/8 Acre Lots		11.74	54727.00	24194.89	0.00	105938.50	5280.56	0.00	190140.95	37.18%	71		2678.04	6.05	1492.09	1.79		62.82%	10.70%	20.72%	0.00%	4.73%	1.03%	0.00%
James City	1/8 Acre Lots		7.08	37023.46	16500.00	0.00	50283.83	11620.00	0.00	115427.29	37.43%	33	new	3497.80	4.66	1523.75	2.30		62.57%	12.00%	16.30%	0.00%	5.35%	3.77%	0.00%
James City	1/8 Acre Lots		14.37	58759.82	30100.00	0.00	68143.69	11710.00	0.00	168713.51	26.95%	43	new	3923.57	2.99	1584.74	2.48		73.05%	9.39%	10.89%	0.00%	4.81%	1.87%	0.00%
James City	1/8 Acre Lots		7.32	44278.73	15000.00	0.00	24252.78	0.00	0.00	83531.51	26.20%	25		3341.26	3.42	970.11	3.44		73.80%	13.89%	7.61%	0.00%	4.70%	0.00%	0.00%
	1/8 Acre Lots	**AVERAGE**	**14.84**	**79953.10**	**29451.98**	**0.00**	**71035.05**	**14219.46**	**0.00**	**194659.59**	**0.33**	**68.10**		**3261.77**	**4.61**	**1221.11**	**2.95**		**0.67**	**0.13**	**0.12**	**0.00**	**0.05**	**0.02**	**0.00**
Lancaster	Townhomes		10.37	53416.28	24960.00	0.00	96961.82	7920.00	0.00	183258.10	40.57%	64	new	2863.41	6.17	1515.03	1.89		59.43%	11.83%	21.47%	0.00%	5.53%	1.75%	0.00%
Lancaster	Townhomes		14.56	61962.00	32760.00	0.00	74372.18	12624.00	0.00	181718.18	28.65%	63	new1989	2884.42	4.33	1180.51	2.44		71.35%	9.77%	11.73%	0.00%	5.17%	1.99%	0.00%
Lancaster	Townhomes		22.60	151147.33	69300.00	8532.58	209049.80	18404.00	0.00	456433.70	46.36%	154	new	2963.86	6.81	1357.47	2.18	0.04	53.64%	15.35%	21.24%	0.87%	7.04%	1.87%	0.00%
Lancaster	Townhomes		32.54	182950.08	97760.00	0.00	201637.13	32664.00	0.00	515011.21	36.33%	188	new	2739.42	5.78	1072.54	2.55		63.67%	12.91%	14.23%	0.00%	6.90%	2.30%	0.00%
Lancaster	Townhomes		33.71	187386.76	108150.00	0.00	263773.55	32560.00	0.00	591870.31	40.31%	206	new	2873.16	6.11	1280.45	2.24		59.69%	12.76%	17.96%	0.00%	7.37%	2.22%	0.00%
Baltimore	Townhomes		14.18	171534.07	0.00	0.00	102586.38	11952.00	3997.00	290069.45	46.96%		new				2.83		53.04%	27.77%	16.61%	0.00%	0.00%	1.93%	0.65%
Baltimore	Townhomes	duplexes	33.30	207643.05	116480.00	0.00	201638.96	40192.00	5440.00	571394.01	39.39%		old				2.83		60.61%	14.31%	13.90%	0.00%	8.03%	2.77%	0.38%
Baltimore	Townhomes		5.46	3655.00	0.00	37296.00	40936.00	13584.00	0.00	95471.00	40.14%						2.33	0.91	59.86%	1.54%	17.21%	15.68%	0.00%	5.71%	0.00%
Baltimore	Townhomes		6.36	70079.27	0.00	0.00	45501.91	15436.00	0.00	131017.18	47.29%						2.88		52.71%	25.30%	16.42%	0.00%	0.00%	5.57%	0.00%
Baltimore	Townhomes		6.39	65773.29	0.00	0.00	56059.20	16120.00	2871.00	140823.49	50.59%						2.51		49.41%	23.63%	20.14%	0.00%	0.00%	5.79%	1.03%
Baltimore	Townhomes		13.25	131228.64	0.00	0.00	88329.25	19388.00	0.00	238945.89	41.40%						2.71		58.60%	22.74%	15.30%	0.00%	0.00%	3.36%	0.00%
Baltimore	Townhomes		50.92	414676.22	0.00	0.00	362984.70	45552.00	0.00	823212.92	37.11%						2.27		62.89%	18.70%	16.36%	0.00%	0.00%	2.05%	0.00%
Howard	Townhomes		12.84	21463.14	0.00	114729.32	105469.10	25408.80	0.00	267070.36	47.75%						2.53		52.25%	3.84%	18.86%	20.51%	0.00%	4.54%	0.00%
Howard	Townhomes		18.00	18416.83	21870.29	172089.52	129255.20	29458.20	0.00	371090.04	47.33%						2.87		52.67%	2.35%	16.48%	21.95%	2.79%	3.76%	0.00%
Howard	Townhomes		18.49	53762.05	0.00	178487.88	104503.30	24857.36	17078.96	378689.55	47.02%						3.62		52.98%	6.67%	12.97%	22.16%	0.00%	3.09%	2.12%
Howard	Townhomes		31.15	11674.78	0.00	250085.02	143518.10	28217.08	0.00	433494.98	31.95%						3.02		68.05%	0.86%	10.58%	18.43%	0.00%	2.08%	0.00%
Howard	Townhomes		58.25	143252.06	0.00	338533.09	223808.10	65732.52	0.00	771325.77	30.40%	352					3.45		69.60%	5.65%	8.82%	13.34%	0.00%	2.59%	0.00%
James City	Townhomes		5.68	17589.61	0.00	38606	33158.95	0	0	89354.56	36.11%		new				2.69	1.16	63.89%	7.11%	13.40%	15.60%	0.00%	0.00%	0.00%
James City	Townhomes		17.67	158760.68	0.00	0	146192.92	0	6324.82	311278.42	40.44%		new				2.13		59.56%	20.63%	18.99%	0.00%	0.00%	0.00%	0.82%
James City	Townhomes		7.42	25969.41	0.00	0.00	82767.18	4800.00	19800.00	133336.59	41.25%						1.61		58.75%	8.03%	25.61%	0.00%	0.00%	1.49%	6.13%
	Townhomes	**AVERAGE**	**20.66**	**107617.03**	**23564.01**	**56917.97**	**135625.19**	**22243.50**	**2775.59**	**348743.29**	**0.41**	**171.17**		**2864.85**	**5.84**	**1281.20**	**2.58**	**0.71**	**0.59**	**0.13**	**0.16**	**0.06**	**0.02**	**0.03**	**0.01**
Lancaster	Multifamily		17.51	18289.05	0.00	141423.72	115638.47	8344.00	0.00	283695.23	37.19%		new				2.45	1.22	62.81%	2.40%	15.16%	18.54%	0.00%	1.09%	0.00%
Lancaster	Multifamily		24.98	106896.50	0.00	162503.27	157286.53	6884.00	8038.24	441608.54	40.58%		new				2.81	1.03	59.42%	9.82%	14.45%	14.93%	0.00%	0.63%	0.74%
Lancaster	Multifamily		41.48	124574.17	2044.67	280564.33	270709.52	26800.00	13957.42	718650.11	39.77%		new				2.65	1.04	60.23%	6.89%	14.98%	15.53%	0.11%	1.48%	0.77%
Lancaster	Multifamily		45.93	239209.68	0.00	384883.35	357519.53	28872.00	36710.36	1047194.93	52.34%		new				2.93	1.08	47.66%	11.96%	17.87%	19.24%	0.00%	1.44%	1.83%
Lancaster	Multifamily		64.12	196684.53	0.00	500518.47	379797.38	27072.00	28491.62	1132563.99	40.55%		new				2.98	1.32	59.45%	7.04%	13.60%	17.92%	0.00%	0.97%	1.02%
Baltimore	Multifamily		8.76	105401.41	0.00	0.00	76916.70	12560.00	8477.10	203355.21	53.29%						2.64		46.71%	27.62%	20.16%	0.00%	0.00%	3.29%	2.22%
Baltimore	Multifamily		14.56	95607.71	0.00	84245.46	99949.14	15872.00	5148.00	300822.31	47.43%						3.01	0.84	52.57%	15.07%	15.76%	13.28%	0.00%	2.50%	0.81%
Baltimore	Multifamily		17.17	209135.78	0.00	17717.17	137478.35	14744.00	9458.00	388533.29	51.95%						2.83	0.13	48.05%	27.96%	18.38%	2.37%	0.00%	1.97%	1.26%
Baltimore	Multifamily		22.45	298512.64	0.00	0.00	273306.28	18584.00	7411.00	597813.92	61.13%						2.19		38.87%	30.53%	27.95%	0.00%	0.00%	1.90%	0.76%
Baltimore	Multifamily		36.50	271617.10	0.00	106997.55	238702.56	48236.00	8987.00	674540.21	42.43%						2.83	0.45	57.57%	17.08%	15.01%	6.73%	0.00%	3.03%	0.57%
Baltimore	Multifamily		51.03	506722.08	0.00	0.00	245315.03	10556.00	8238.00	770831.11	34.68%						3.14		65.32%	22.80%	11.04%	0.00%	0.00%	0.47%	0.37%
Howard	Multifamily		9.80	29878.03	0.00	97375.17	79739.70	13988.60	0.00	220981.50	51.77%						2.77		48.23%	7.00%	18.68%	22.81%	0.00%	3.28%	0.00%
Howard	Multifamily		11.99	16318.32	0.00	127820.00	75838.95	15351.96	3255.50	238584.73	45.68%						3.15		54.32%	3.12%	14.52%	24.47%	0.00%	2.94%	0.62%
James City	Multifamily		16.11	7468.03676	0.00	144717	109393.224	0	8867.92	270446.18	38.54%		new				2.47	1.32	61.46%	1.06%	15.59%	20.62%	0.00%	0.00%	1.26%
James City	Multifamily		11.34	6802.41889	0.00	136819	50399.9664	0	5304.95	199326.34	40.35%		new				3.95	2.71	59.65%	1.38%	10.20%	27.70%	0.00%	0.00%	1.07%
James City	Multifamily		46.82	352982.242	0.00	3648	157145.264	13884	28700.6	556360.11	27.28%		new				3.54	0.02	72.72%	17.31%	7.71%	0.18%	0.00%	0.68%	1.41%
James City	Multifamily		11.95	139274.877	0.00	0	59966.2675	0	9303.23	208544.37	40.06%		new				3.48		59.94%	26.76%	11.52%	0.00%	0.00%	0.00%	1.79%
James City	Multifamily		6.96	0	0.00	92234	70392.1663	0	4049.57	166675.74	54.98%		new				2.37	1.31	45.02%	0.00%	23.22%	30.42%	0.00%	0.00%	1.34%
	Multifamily	**AVERAGE**	**25.53**	**151409.70**	**113.59**	**126748.14**	**164194.17**	**14541.59**	**10799.92**	**467807.10**	**0.44**						**2.90**	**1.04**	**0.56**	**0.13**	**0.16**	**0.13**	**0.00**	**0.01**	**0.01**
Lancaster	Institutional	school	6.16	18098.36	0.00	97625.64	96952.68	7308.00	0.00	219984.68	81.98%						2.27	1.01	18.02%	6.74%	36.13%	36.38%	0.00%	2.72%	0.00%
Lancaster	Institutional	school	7.66	8672.23	0.00	84467.34	32442.75	2004.00	8178.00	135764.32	40.69%						4.18	2.60	59.31%	2.60%	9.72%	25.31%	0.00%	0.60%	2.45%
Lancaster	Institutional	school	66.69	116801.04	0.00	304583.52	292345.45	5888.00	183751.00	903369.01	31.10%						3.09	1.04	68.90%	4.02%	10.06%	10.48%	0.00%	0.20%	6.33%
Lancaster	Institutional	school	35.82	26333.30	0.00	221677.46	116984.37	0.00	47034.00	412029.13	26.41%						3.52	1.89	73.59%	1.69%	7.50%	14.21%	0.00%	0.00%	3.01%
Lancaster	Institutional	church	4.14	7631.58	0.00	28695.50	9497.60	0.00	0.00	45824.68	25.41%						4.82	3.02	74.59%	4.23%	5.27%	15.91%	0.00%	0.00%	0.00%
Lancaster	Institutional	church	6.24	25533.03	0.00	89977.51	38673.62	0.00	0.00	154184.16	56.72%						3.99	2.33	43.28%	9.39%	14.23%	33.10%	0.00%	0.00%	0.00%
Lancaster	Institutional	church	9.54	44064.81	0.00	168283.64	31417.80	0.00	0.00	243766.25	58.66%						7.76	5.36	41.34%	10.60%	7.56%	40.50%	0.00%	0.00%	0.00%
Lancaster	Institutional	municipal	34.14	17938.13	413840.62	0.00	102603.76	0.00	127372.00	661754.51	44.50%						6.45		55.50%	1.21%	6.90%	0.00%	27.83%	0.00%	8.56%
Lancaster	Institutional	nursing home	53.60	119715.48	50527.53	50452.49	127591.03	6328.00	0.00	354614.54	15.19%						2.78	0.40	84.81%	5.13%	5.46%	2.16%	2.16%	0.27%	0.00%
Lancaster	Institutional	sewer authority	0.18	704.26	0.00	0.00	256.08	0.00	0.00	960.34	12.25%						3.75		87.75%	8.98%	3.27%	0.00%	0.00%	0.00%	0.00%
Lancaster	Institutional	town hall	0.59	5255.69	0.00	2447.38	4525.83	1264.00	0.00	13492.90	52.50%						2.98	0.54	47.50%	20.45%	17.61%	9.52%	0.00%	4.92%	0.00%
Baltimore	Institutional	church	1.19	6660.08	0.00	16128.79	12558.60	2785.00	0.00	38132.48	73.56%						3.04	1.28	26.44%	12.85%	24.23%	31.11%	0.00%	5.37%	0.00%
Baltimore	Institutional	church/school	6.16	20525.56	0.00	66738.17	35553.83	5008.00	0.00	127825.56	47.64%						3.60	1.88	52.36%	7.65%	13.25%	24.87%	0.00%	1.87%	0.00%
Baltimore	Institutional	elementary school	18.87	23611.89	0.00	0.00	61680.30	14592.00	11273.00	111157.19	13.52%						1.80		86.48%	2.87%	7.50%	0.00%	0.00%	1.78%	1.37%
Baltimore	Institutional	middle school	22.33	18526.47	0.00	72405.37	75165.00	13616.00	14030.00	193742.85	19.92%						2.58	0.96	80.08%	1.90%	7.73%	7.44%	0.00%	1.40%	1.44%
Baltimore	Institutional	private high school	47.22	129392.42	0.92	77470.43	111766.71	5896.00	126578.00	451104.49	21.93%						4.04	0.69	78.07%	6.29%	5.43%	3.77%	0.00%	0.29%	6.15%
Baltimore	Institutional	special ed school	17.98	24706.85	0.00	47717.97	42740.56	12056.00	22286.00	149507.38	19.09%						3.50	1.12	80.91%	3.15%	5.46%	6.09%	0.00%	1.54%	2.85%
Baltimore	Institutional	ymca	9.82	73738.44	0.00	11950.04	38304.94	0.00	36767.00	160760.42	37.58%						4.20	0.31	62.42%	17.24%	8.95%	2.79%	0.00%	0.00%	8.60%

Appendix D -Impervious Cover Data Table

Table D.1 - Chesapeake Bay Watershed Impervious Cover Results by Land Use Polygon

County	Landuse	Type	Polygon Area (acres)	Roads (sq ft)	Driveways (sq ft)	Parking (sq ft)	Buildings (sq ft)	Sidewalks (sq ft)	Other Impervious (sq ft)	Total Impervious (sq ft)	Impervious %	# Units	Age of Development	Impervious Cover/Housing Unit	Gross Density (units/acre)	Average House Size	Impervious Cover/Building sq ft	Parking/Building sq ft	% Forest or Open Space	% Roads	% Buildings	% Parking	% Driveways	% Sidewalks	% Other Impervious
Howard	Institutional	school	36.55	15673.50	0.00	131883.59	178316.70	11573.72	34003.96	371451.47	23.33%						2.08		76.67%	0.98%	11.20%	8.28%	0.00%	0.73%	2.14%
Howard	Institutional	school	24.84	1102.83	0.00	99280.27	143014.20	15720.04	32230.62	291347.96	26.93%						2.04		73.07%	0.10%	13.22%	9.18%	0.00%	1.45%	2.98%
Howard	Institutional	police/fire	19.25	57876.59	1186.19	315645.27	81192.79	0.00	0.00	455900.84	54.37%						5.62		45.63%	6.90%	9.68%	37.64%	0.14%	0.00%	0.00%
James City	Institutional	baptist church	3.13	3079.11	0.00	24329.38	5690.37	0.00	0.00	33098.86	24.28%						5.82	4.28	75.72%	2.26%	4.17%	17.84%	0.00%	0.00%	0.00%
James City	Institutional	7th day adventist church	10.09	8423.25	0.00	38983.25	6977.75	0.00	0.00	54384.25	12.37%						7.79	5.59	87.63%	1.92%	1.59%	8.87%	0.00%	0.00%	0.00%
James City	Institutional	community chapel	15.56	7760.84	0.00	108584.00	19191.10	3020.00	0.00	138555.94	20.44%						7.22	5.66	79.56%	1.15%	2.83%	16.02%	0.00%	0.45%	0.00%
James City	Institutional	elementary school	24.24	11432.03	0.00	134307.25	57809.44	3984.00	18221.00	225753.72	21.38%						3.91	2.32	78.62%	1.08%	5.47%	12.72%	0.00%	0.38%	1.73%
James City	Institutional	high school	49.43	13639.51	0.00	482482.54	201985.75	9140.00	114722.00	821969.81	38.17%						4.07	2.39	61.83%	0.63%	9.38%	22.41%	0.00%	0.42%	5.33%
James City	Institutional	high school	78.97	27371.15	0.00	723177.85	161672.70	11780.00	77864.94	1001866.64	29.12%						6.20	4.47	70.88%	0.80%	4.70%	21.02%	0.00%	0.34%	2.26%
James City	Institutional	fire house	1.64	2874.27	0.00	0.00	13247.36	0.00	24288.58	40410.21	56.57%						3.05		43.43%	4.02%	18.54%	0.00%	0.00%	0.00%	34.00%
James City	Institutional	police station	2.88	7245.38	0.00	0.00	9715.93	0.00	29705.86	46667.17	37.20%						4.80		62.80%	5.78%	7.74%	0.00%	0.00%	0.00%	23.68%
James City	Institutional	state hospital	463.93	578389.91	0.00	380401.24	630348.76	30380.00	72262.63	1691782.54	8.37%						2.68	0.60	91.63%	2.86%	3.12%	1.88%	0.00%	0.15%	0.36%
	Institutional	**AVERAGE**	**35.96**	**47425.93**	**15518.51**	**125989.86**	**91340.79**	**5411.43**	**32685.62**	**318372.14**	**0.34**						**4.12**	**2.26**	**0.66**	**0.05**	**0.10**	**0.14**	**0.01**	**0.01**	**0.04**
Lancaster	Industrial		49.88	471879.72	0.00	519670.16	485539.24	0.00	0.00	1477089.12	67.98%						3.04	1.07	32.02%	21.72%	22.35%	23.92%	0.00%	0.00%	0.00%
Lancaster	Industrial		99.12	182253.45	29156.01	773805.24	493363.02	0.00	0.00	1478577.72	34.24%						3.00	1.57	65.76%	4.22%	11.43%	17.92%	0.68%	0.00%	0.00%
Lancaster	Industrial		101.08	140430.21	23391.39	941476.09	690774.74	0.00	0.00	1796072.43	40.79%						2.60	1.36	59.21%	3.19%	15.69%	21.38%	0.53%	0.00%	0.00%
Lancaster	Industrial		115.90	88539.98	8223.39	1040841.25	803550.19	0.00	0.00	1941154.81	38.45%						2.42	1.30	61.55%	1.75%	15.92%	20.62%	0.16%	0.00%	0.00%
Lancaster	Industrial		229.60	273444.70	5989.38	2818267.78	1929521.32	0.00	0.00	5027223.18	50.27%						2.61	1.46	49.73%	2.73%	19.29%	28.18%	0.06%	0.00%	0.00%
Lancaster	Industrial		249.12	330084.97	40801.33	4359136.15	1243695.65	0.00	0.00	5973718.10	55.05%						4.80	3.50	44.95%	3.04%	11.46%	40.17%	0.38%	0.00%	0.00%
Baltimore	Industrial		6.60	19233.65	0.00	93491.84	59758.40	0.00	4285.00	176768.89	61.49%						2.96	1.56	38.51%	6.69%	20.79%	32.52%	0.00%	0.00%	1.49%
Baltimore	Industrial		18.44	62854.30	0.00	198596.21	240537.90	0.00	11257.00	513245.41	63.90%						2.13	0.83	36.10%	7.83%	29.95%	24.72%	0.00%	0.00%	1.40%
Baltimore	Industrial		24.93	60399.58	0.00	277821.49	123826.49	0.00	4639.00	466686.57	42.97%						3.77	2.24	57.03%	5.56%	11.40%	25.58%	0.00%	0.00%	0.43%
Baltimore	Industrial		25.90	99950.98	0.00	489010.21	237737.73	0.00	4972.00	831670.91	73.72%						3.50	2.06	26.28%	8.86%	21.07%	43.34%	0.00%	0.00%	0.44%
Baltimore	Industrial		38.76	147329.38	4931.01	206424.58	229018.64	0.00	920.00	588623.61	34.86%						2.57	0.90	65.14%	8.73%	13.56%	12.23%	0.29%	0.00%	0.05%
Howard	Industrial		160.51	561744.89	0.00	1390379.32	1682842.00	1010.12	0.00	3635976.33	52.00%						2.16		48.00%	8.03%	24.07%	19.89%	0.00%	0.01%	0.00%
Howard	Industrial		232.82	424146.19	0.00	2974502.21	1803780.00	37321.48	0.00	5239749.88	51.67%						2.90		48.33%	4.18%	17.79%	29.33%	0.00%	0.37%	0.00%
Howard	Industrial		327.77	704941.23	0.00	3596298.14	4524778.00	30519.40	0.00	8856536.77	62.03%						1.96		37.97%	4.94%	31.69%	25.19%	0.00%	0.21%	0.00%
Howard	Industrial		391.86	1093615.91	798.40	6036168.36	3584339.00	5700.40	0.00	10720622.07	62.81%						2.99		37.19%	6.41%	21.00%	35.36%	0.00%	0.03%	0.00%
Howard	Industrial	wwtp	38.27	771.71	0.00	332914.36	203840.30	2057.84	0.00	539584.21	32.37%						2.65		67.63%	0.05%	12.23%	19.97%	0.00%	0.12%	0.00%
Howard	Industrial		220.92	575667.20	1463.67	3075442.87	2154397.00	33732.04	0.00	5840702.78	60.69%						2.71		39.31%	5.98%	22.39%	31.96%	0.02%	0.35%	0.00%
James City	Industrial		17.77	33206.9606	0.00	368671	90226.0707	0.00	17357.00	509461.03	65.82%						5.65	4.09	34.18%	4.29%	11.66%	47.63%	0.00%	0.00%	2.24%
James City	Industrial		26.41	36398.1125	0.00	438454	136064.147	0.00	0.00	610916.26	53.10%						4.49	3.22	46.90%	3.16%	11.83%	38.11%	0.00%	0.00%	0.00%
James City	Industrial		12.01	28837.0747	0.00	202809	98847.8246	0.00	0.00	330493.90	63.17%						3.34	2.05	36.83%	5.51%	18.89%	38.77%	0.00%	0.00%	0.00%
	Industrial	**AVERAGE**	**119.38**	**266786.51**	**5737.73**	**1506709.01**	**1040821.88**	**5517.06**	**2171.50**	**2827743.70**	**0.53**						**3.11**	**1.94**	**0.47**	**0.06**	**0.18**	**0.29**	**0.00**	**0.00**	**0.00**
Lancaster	Commercial		8.58	25248.44	0.00	173555.22	78398.53	0.00	0.00	277202.18	74.17%		new				3.54	2.21	25.83%	6.76%	20.98%	46.44%	0.00%	0.00%	0.00%
Lancaster	Commercial		12.22	33196.64	0.00	263534.92	107492.38	0.00	0.00	404223.94	75.94%		new				3.76	2.45	24.06%	6.24%	20.19%	49.51%	0.00%	0.00%	0.00%
Lancaster	Commercial		23.38	53767.28	0.00	577422.88	260297.70	0.00	0.00	891487.87	87.54%		new				3.42	2.22	12.46%	5.28%	25.56%	56.70%	0.00%	0.00%	0.00%
Lancaster	Commercial		35.28	59795.29	0.00	686680.74	146836.93	0.00	0.00	893312.97	58.13%						6.08	4.68	41.87%	3.89%	9.55%	44.68%	0.00%	0.00%	0.00%
Lancaster	Commercial		38.49	64609.87	692.45	776740.45	315352.85	0.00	0.00	1157395.61	69.03%		new				3.67	2.46	30.97%	3.85%	18.81%	46.33%	0.04%	0.00%	0.00%
Lancaster	Commercial		41.48	64730.46	0.00	850690.83	251318.68	0.00	0.00	1166739.97	64.57%						4.64	3.38	35.43%	3.58%	13.91%	47.08%	0.00%	0.00%	0.00%
Lancaster	Commercial		58.34	113460.69	0.00	1209798.97	489492.74	0.00	0.00	1812752.40	71.33%		new				3.70	2.47	28.67%	4.46%	19.26%	47.61%	0.00%	0.00%	0.00%
Lancaster	Commercial		62.44	213942.89	0.00	1338036.73	620849.39	0.00	0.00	2172829.01	79.89%		new				3.50	2.16	20.11%	7.87%	22.83%	49.19%	0.00%	0.00%	0.00%
Lancaster	Commercial		66.08	146643.21	5820.38	1218728.94	606492.50	0.00	0.00	1977685.03	68.71%		new				3.26	2.01	31.29%	5.09%	21.07%	42.34%	0.20%	0.00%	0.00%
Baltimore	Commercial		4.86	45088.24	0.00	65802.18	32856.49	4684.00	0.00	148430.91	70.11%						4.52	2.00	29.89%	21.30%	15.52%	31.08%	0.00%	2.21%	0.00%
Baltimore	Commercial		9.03	11010.89	0.00	178364.50	148424.14	4684.00	799.00	343282.53	87.27%						2.31	1.20	12.73%	2.80%	37.73%	45.35%	0.00%	1.19%	0.20%
Baltimore	Commercial		13.79	63804.75	0.00	333191.40	110758.88	8020.00	6729.00	522504.03	86.98%						4.72	3.01	13.02%	10.62%	18.44%	55.47%	0.00%	1.34%	1.12%
Baltimore	Commercial		14.81	60608.21	0.00	221164.20	122416.45	14012.00	34238.00	452438.87	70.13%						3.70	1.81	29.87%	9.39%	18.98%	34.28%	0.00%	2.17%	5.31%
Baltimore	Commercial		15.07	21091.73	0.00	363879.59	146048.47	2308.00	0.00	533327.79	81.24%						3.65	2.49	18.76%	3.21%	22.25%	55.43%	0.00%	0.35%	0.00%
Howard	Commercial		10.93	49360.50	0.00	236049.09	116706.90	0.00	0.00	402116.49	84.46%						3.45		15.54%	10.37%	24.51%	49.58%	0.00%	0.00%	0.00%
Howard	Commercial		66.96	91265.93	0.00	1517402.95	457034.10	20596.60	17427.63	2103727.21	72.13%						4.60		27.87%	3.13%	15.67%	52.02%	0.00%	0.71%	0.60%
James City	Commercial		39.89	69116.9939	0.00	809890	348379.929	0.00	0.00	1227386.92	70.64%						3.52	2.32	29.36%	3.98%	20.05%	46.61%	0.00%	0.00%	0.00%
James City	Commercial		4.64	5185.26692	0.00	81183	35330.7332	0.00	0.00	121699.00	60.21%						3.44	2.30	39.79%	2.57%	17.48%	40.17%	0.00%	0.00%	0.00%
James City	Commercial		14.26	47738.6687	0.00	254978	90450.2105	0.00	0.00	393166.88	63.30%						4.35	2.82	36.70%	7.69%	14.56%	41.05%	0.00%	0.00%	0.00%
James City	Commercial		10	16288.9127	0.00	223433	76204.7665	0.00	0.00	315926.68	72.53%						4.15	2.93	27.47%	3.74%	17.49%	51.29%	0.00%	0.00%	0.00%
James City	Commercial		1.55	9188.51054	0.00	27787	7790.67047	0.00	0.00	44766.18	66.30%						5.75	3.57	33.70%	13.61%	11.54%	41.15%	0.00%	0.00%	0.00%
James City	Commercial		4.76	4199.08652	0.00	61759	38327.3628	0.00	0.00	104285.45	50.30%						2.72	1.61	49.70%	2.03%	18.48%	29.79%	0.00%	0.00%	0.00%
James City	Commercial		4.16	22921.8615	0.00	66452	48218.091	0.00	0.00	137591.95	75.93%						2.85	1.38	24.07%	12.65%	26.61%	36.67%	0.00%	0.00%	0.00%
	Commercial	**AVERAGE**	**24.39**	**56185.41**	**283.17**	**501588.07**	**202412.13**	**2361.07**	**2573.64**	**765403.47**	**0.72**						**3.88**	**2.45**	**0.28**	**0.07**	**0.20**	**0.45**	**0.00**	**0.00**	**0.00**