Technical Memorandum

Date: August 31, 2011

To: Sarah Taylor-Rogers, Harry R. Hughes Center for Agro-Ecology, Inc.

From: Karen Cappiella and Lisa Fraley-McNeal, Center for Watershed Protection, Inc.

Subject: Forests on the Fringe: Innovative Approaches to Increase Forest Cover in Maryland's Developing Watersheds

1.0 Introduction

Approximately 43% of Maryland is covered by forest, much of which is located near exurban areas. Maryland's population has been rapidly expanding at an average rate of 1% each year, with projected estimates of an additional one million people by 2030 (Maryland Department of Planning, 2006; Maryland Department of Planning, 2002). While the growth rate has been fairly steady, the corresponding consumption of land associated with development has been disproportionately high. In fact, the average lot size in the Chesapeake Bay region has increased by 60% over the past 30 years (CBP, no date). The expected population growth and land conversion threatens these "forests on the fringe."

While the Maryland Forest Conservation Act affords some protection from forest loss during development, it does not typically apply to the low-density residential development most commonly seen in exurban areas. The result is the rapid conversion of agricultural and forested land to a sprawling landscape of low-density housing interspersed with a few trees and small forest fragments. Climbing land values in Maryland's exurban areas provides little economic incentive to prevent forest and agricultural landowners from selling their land for development.

Frederick County, Maryland contains a mix of urban, suburban and rural land and is under heavy development pressure due to its close proximity to Washington, DC and Baltimore, MD. The County is a good example of forests on the fringe since it contains many exurban watersheds and has experienced an increase in urban growth of 76% from 1982 to 1997 (USDA Natural Resources Conservation Service, 1997). The estimated forest loss in the County for a similar time period (1986-1999) was 10,000 acres (2.3% of the total county area) (USDA Forest Service, 2005). At the end of that time period, the County had only 30% forest cover remaining (USDA Forest Service, 2005). To prevent the fragmentation and loss of remaining forests, immediate action is needed, such as an approach that evaluates and manages forest cover at the watershed scale.

Scientists and researchers agree that forests provide many watershed benefits and services. Forests capture and store rainwater, reducing the amount of rainfall that becomes stormwater runoff. Trees remove pollutants from the air, soil and water, and reduce air temperatures. They also prevent erosion by stabilizing the soil, and provide habitat for wildlife and opportunities for recreation. Watersheds with a high percentage of forest cover generally have good stream quality, clean drinking water, less stormwater runoff, and greater aquatic diversity. Goetz et al. (2003) found that watersheds with 45% or more forest cover consistently had stream health ratings of Excellent or Good, while watersheds with 37% forest cover or less had stream health ratings of Fair or Poor. Booth (2000) found that watersheds with at least 65% forest cover usually had a healthy aquatic insect community. In addition to the amount of forest cover, the size, location and condition of remaining forest tracts in a watershed is also important from an ecological standpoint.

The Center for Watershed Protection (CWP) recently completed a project funded by the Harry R. Hughes Center for Agro-Ecology, Inc. to apply a planning approach to increase forest cover in a pilot watershed in Frederick County. The approach included estimating current and future forest cover, identifying priority tracts for conservation and reforestation, and making initial policy and technical recommendations for the County and other stakeholders to achieve a forest cover goal in the pilot watershed. The pilot watershed selected for this project is the Linganore Creek watershed, which has been identified as a priority watershed by the County.

The objectives of the study were to:

- Estimate potential forest loss in the pilot watershed under full build-out.
- Develop forest cover coefficients for use by the County and planners in the state to estimate future forest cover.
- Identify priority forest conservation and reforestation sites in the pilot watershed.
- Formulate a numeric forest cover goal for the pilot watershed, and make specific recommendations for meeting the goal.
- Work closely with County staff to ensure recommendations are integrated with the goals and Action Plan for the Linganore Creek TMDL and explore opportunities for linking forest cover goals with TMDL implementation (e.g., include forest cover goal as part of watershed overlay zone, fund reforestation projects through water utility fees).
- Present results to the County Board of Commissioners to educate them about the project and encourage them to make forest conservation and reforestation a priority in Linganore Creek and the County as a whole.
- Develop educational materials about the importance of forests, their link to drinking water quality, the pilot project in Linganore Creek, and work with local partners to incorporate into their education programs.
- Hold a half day workshop to present results of study to County staff and provide training on how to use the forest cover coefficients in other watersheds, methods for prioritizing and evaluating forest conservation and reforestation sites, and discuss how to get to implementation.
- Disseminate project results to watershed and county residents as well as other Maryland communities.

This technical memo presents the objectives, methods, and results of this project, and discusses the implications of the results for the Linganore Creek Watershed, Frederick County and their transferability to similar communities in Maryland and beyond.

2.0 Study Area

The Linganore Creek Watershed is located in the Piedmont Region of Maryland, primarily in Frederick County, with a small portion extending into Carroll County. Linganore Creek is a major tributary of the Monocacy River, a National Scenic River that is part of the Potomac River Basin and eventually drains to the Chesapeake Bay. It has been utilized as a drinking water source for the City of Frederick and Frederick County since the construction of the Linganore Creek Water Treatment Plant (WTP) in 1932. The Lake Linganore Dam was constructed in 1972 by Lake Linganore Association, Inc. as a recreational lake for the Lake Linganore residential developments and to augment the flow in Linganore Creek. It has been classified by the Maryland Department of the Environment (MDE) as Class IVP, Recreational Trout Waters and Public Water Supply. The watershed boundary used for this analysis is the source water protection area for Lake Linganore, not including the Carroll County portion of the watershed, with a drainage area of 83.8 mi^2 and approximately 209 miles of streams (Figure 1). We were unable to obtain data for the Carroll County portion and chose to use the source water area boundary so that any resulting recommendations could be easily aligned with the Lake Linganore source water protection plan.

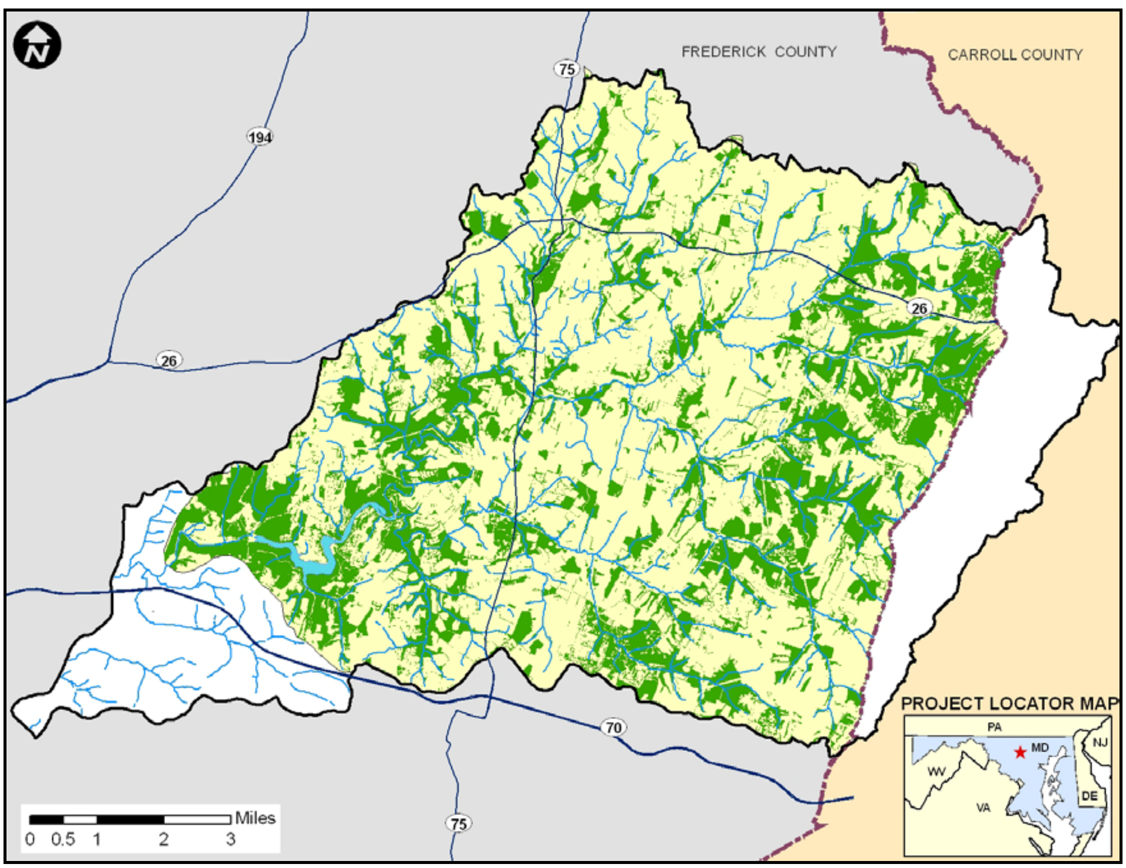

Figure 1. 2005 Forest cover (green) within the Frederick County portion of the Lake Linganore source water area boundary (beige). Approximately 90% of the Linganore source area is located within Frederick County, with the remaining 10% located in Carroll County. White areas are the portions of the Linganore Creek Watershed that are located outside of the source water area boundary or in the Carroll County portion of the watershed and were not analyzed in this study.

Table 1. 2007 Land Use/Land Cover Distribution in the Linganore Creek Watershed (Source: MDP, nd)	
Type of Land Use / Land Cover	**Percent of Watershed in 2007**
Urban/Suburban/Open Urban	15.2
Agricultural	55.7
Forest	28.2
Wetlands	0.04
Open Water	0.43
Barren/Transitional	0.52

The dominant land use within the watershed is agriculture, especially in the northern and eastern portions. However, much of the land in the southern part of the watershed, along the I-70 corridor, is classified as low-, medium-, or high-density residential. Frederick County began to experience significant urban development in the 1970's and residential subdivisions proliferated throughout the county, including the Lake Linganore planned unit development (PUD). In the 1980s and 1990s, these residential areas saw increased development. Major centers of development within the watershed include the incorporated municipalities of New Market and Mount Airy, the unincorporated communities of New London and Libertytown, and several communities surrounding Lake Linganore. Table 1 summarizes the land use distribution in the watershed.

While the pre-settlement vegetation in Frederick County was primarily forest, most significant forest stands were cleared for farming and charcoal production by the early 20th century. During the 1930s to 1960s, abandonment of previously farmed steep slopes and wet areas allowed for natural regeneration of stands of deciduous trees, which represent most of the forest cover seen today. The Linganore Creek Watershed has approximately 30% forest cover based on the County's 2005 planimetric data and information on the amount of forest cleared between 2005 and 2009 (M. Wilkins, Frederick County Principal Planner, unpublished data). In 2005, Maryland's Department of Natural Resources mapped two large green infrastructure (GI) 'hubs' in the watershed, as well as several small GI hubs (contiguous interior forest) and forested corridors that are important for wildlife passage because of their ability to connect the larger hubs. A good deal of the remaining forest is fragmented and located in areas having topographic constraints for farming or development, such as steep slopes and stream corridors. It is generally considered to be low-medium to high-medium quality forests in terms of ecological health and diversity.

Sediment accumulation in Lake Linganore has been accelerated due to increased sediment and phosphorus loads from land use/land cover changes in the watershed and the presence of highly erodible soils and steep slopes. Frequent nuisance seasonal algal blooms which interfere with water supply and recreational uses are attributable to excessive nutrient inputs entering the lake. Due to the excess sediment and phosphorus, the lake is included on the state list of impaired water bodies by the State of Maryland. As a result of being on this list, the state has set regulatory limits of phosphorus and sediment to the lake; these limits are known as Total Maximum Daily Loads, or TMDLs. The Lake Linganore TMDL was approved in May 2003 to reduce long-term sediment and phosphorus loadings to acceptable levels.

According to the TMDL study, 86.2% of the non-point phosphorus load and 89.2% of the non-point sediment load to the lake is attributed to agricultural land (MDE, 2002). Developed lands generate 13.2% of the non-point phosphorus load and 8.4% of the non-point sediment load, while the remaining load is from forest land. Although agricultural land contributes the largest phosphorus load, it is unlikely that agricultural land in the watershed will increase in the future; yet agriculture will likely remain the dominant watershed land use. Therefore, reduction efforts will be concentrated on installation of Best

Management Practices (BMPs) on existing agricultural lands. Of concern is that under existing local regulations, forest land and other features important for water quality in the watershed are not protected (i.e., using conservation easements or conservation zoning) and are subject to development and other land use changes.

Further, there is additional concern with the contribution of future development planned for the watershed to water quality problems. The County's New Market Region Plan describes the planned growth for the towns of New Market and Mount Airy and for the residential areas surrounding Lake Linganore. Three of the County's Community Growth Areas (CGAs) where residential, commercial, and employment uses will be concentrated, are located here (Linganore, Holly Hills, and Spring Ridge). Together, these CGAs have 3,982 new dwelling units in the pipeline with potential for an addition 953 units (Frederick County Division of Planning, 2009). Because all new development in the County with planned water service will be hooked up to the Potomac water system, this future growth should not put additional strain on Lake Linganore as a drinking water source from a supply standpoint. However, the impact of additional development on erodible soils may further reduce the forest cover in the watershed and increase erosion and phosphorus loadings to Linganore Creek and Lake Linganore.

The management of forests in Frederick County is guided by the 1991 Maryland Forest Conservation Act (FCA). Md. Code Ann. [Nat. Res.] §5 1601–1613 (1991). The FCA requires local governments to develop forest conservation programs, which must include an ordinance that establishes standards for fulfilling forest conservation, reforestation, and afforestation requirements for certain land use categories and regulated activities. *Id*. § 5 1603–1612. In Frederick County, the local ordinance established under the FCA is the Forest Resource Ordinance (FRO), which was adopted in 1992. In 2007, significant and unique changes were made to the FRO that resulted in conservation requirements that are more stringent than what is mandated by the state law; however, these requirements were recently lowered to once again correspond with the state FCA. Under the FRO, development, forest clearing, and earth disturbing activities must meet FRO requirements as follows:

- Reforestation or Conservation: replaces forest that is removed as part of the development process and conserves remaining forest, with numeric thresholds specific for different land use types.
- Afforestation: requires developers to plant trees to meet a numeric threshold of forest cover for sites that do not have much remaining forest to conserve.

Developers may choose to meet FRO requirements by purchasing forest banking credits or by paying a per-square-foot fee of required forest mitigation into a fee-in-lieu fund. The County has collected approximately $1.5 million in fees, and in 2010, the Board of County Commissioners authorized the use of a portion of these funds to purchase forest conservation easements along certain stream segments in the Linganore Creek watershed.

The County also has a forest banking program, which accepts voluntary FRO easements. Each acre placed into easement is a "credit" that can be sold to others who need to meet their FRO requirements. Finally, there are several state conservation programs available for landowners who wish to place conservation easements on their land; however, there is generally limited participation in these programs since they are voluntary especially for forest land owners.

3.0 Methods

Deriving Forest Cover Coefficients for Frederick County

This portion of the project was designed to answer the question: what is the typical post-development forest cover on various land uses in Frederick County, Maryland? In order to address this question, CWP conducted an analysis using ESRI ArcGIS© software to develop forest cover coefficients specific to Frederick County. Forest cover coefficients (FCCs) represent the proportion of a particular area of land use that is covered by forest. They are used to predict future forest cover under different land use scenarios. The protocol for deriving forest cover coefficients (FCCs) for Frederick County included the following major steps:

Step 1: Select the targeted land use categories
Step 2: Delineate the sample land use polygons
Step 3: Measure forest cover

The data used to derive the forest cover coefficients is included in Table 2 below.

Table 2. Data used to Derive the Forest Cover Coefficients

Data	Year	Source	Description
Land Use / Land Cover	1973	MD Dept. of Planning	Level 2 USGS classification of land use / land cover developed using high altitude aerial photography and state highway administration county maps. (scale: 1" = 1 mile; minimum mapping unit: 10 acres)
	2002	MD Dept. of Planning	Level 2 USGS classification of land use / land cover developed using high altitude aerial photography and satellite imagery. Urban land use categories were further refined using parcel data from MD Property View. (scale: 1" = 1 mile; minimum mapping unit: 10 acres)
Planimetrics	2005	Frederick County	Planimetric data delineated from 6 inch ground resolution true color orthophotography that includes forest cover delineated by edge of tree mass following outline along the outer edge of the tree trunks.
Parcels	2008	Frederick County	Parcel boundaries within Frederick County.
Tax Points	2008	Frederick County	Tax points from Maryland Property View for Frederick County that includes ownership information.
Subdivisions	2008	Frederick County	Subdivision boundaries within Frederick County
Aerial Photos	1988	Frederick County	Black and white historic aerial photo for Frederick County
	1993	MD DNR	Color orthophoto produced from color infrared aerial photographs by Photo Science Inc. (scale: 1:12,000)
	2000	Frederick County	Color orthophoto (scale= 1:2,400; resolution = 1 ft)
	2005	Frederick County	Color orthophoto (resolution = 3 ft)
	2007	USDA NRCS	National Agricultural Imagery Program (NAIP) color orthophoto (scale: 1:40,000)

Step 1: Select the Targeted Land Use Categories

We hypothesized that the amount of forest cover present on a given land use parcel will vary by the land use type and intensity, as well by as the amount of pre-development forest cover. We developed an initial list of eight land use categories to sample, based on ones for which impervious cover coefficients were developed by Cappiella and Brown (2001) (Table 3). The goal of aligning land use categories with this study was twofold: first, the categories are general enough to be readily transferable to other jurisdictions, and second, it would facilitate future land cover estimates that focus on impervious cover and forest cover using consistent land use categories and methods.

Table 3. Land Use Categories Sampled in Frederick County to Develop Forest Cover Coefficients

Land Use Category	**Description**	**Corresponding Land Use Category from Frederick County's Comprehensive Plan**	**Comprehensive Plan Land Use Description**
Open Urban Land (OPEN)	Golf courses, parks, recreation areas (except areas associated with schools or other institutions), game preserves	Public Parkland/Open Space (PO)	Local, state or federal public parkland; publicly-owned open space
Institutional (INST)	Schools, churches, government offices and facilities	Institutional (I)	Public and government uses, such as schools, libraries, public safety facilities, and water/sewer facilities
Industrial (IND)	Manufacturing and industrial facilities, including associated warehouses, storage yards, and research laboratories; business, professional and corporate office parks	Limited Industrial (LI), Office/Research (ORI), General Industrial (GI)	LI – warehousing, wholesaling, limited manufacturing, corporate office, research/development ORI – businesses, professional and corporate offices, research and development GI – heavy industrial and manufacturing
Commercial (COM)	Retail, small office and business uses	General Commercial (GC), Village Center (VC)	GC – general retail, small-scale office, business/personal uses, and highway services; VC – mixture of low-intensity commercial and residential uses

Table 3. Land Use Categories Sampled in Frederick County to Develop Forest Cover Coefficients			
Land Use Category	**Description**	**Corresponding Land Use Category from Frederick County's Comprehensive Plan**	**Comprehensive Plan Land Use Description**
Very Low Density Residential (VLDR)	Single family residential development with a density of less than 1 DU/acre	Rural Residential (RurR)	Major residential subdivisions on well/septic with 1 DU/acre
Low Density Residential (LDR)	Single family residential development with a density of 1-4 DU/acre	Low Density Residential (LDR)	Single family residential with public water/sewer and a density of 3-6 DU/acre
Medium Density Residential (MDR)	Single family and attached residential development with a density of 5-10 DU/acre	Medium Density Residential (MDR)	Single family and attached residential with public water/sewer and a density of 6-10 DU/acre
High Density Residential (HDR)	Residential development with density > 10 DU/acre, generally multi-family development	High Density Residential (HDR)	Multifamily residential with density > 10 DU/acre

In order to identify potential sample land use polygons for Step 2, GIS was used to locate areas of the county that were representative of the land use categories and pre-development forest cover. The owner information and year developed for each parcel were obtained by joining the parcel layer with the tax map points. The parcels were then overlain with 1973 land use/land cover data from Maryland Department of Planning (MDP) to select parcels that were undeveloped (i.e., forest or agricultural land) as of 1973. In addition, only parcels developed before 2005 were included, which is when forest cover was delineated in the County's planimetric data. The 2002 land use/land cover data from MDP was also used to help identify parcels developed during this time period. For residential land uses, the subdivision layer from Frederick County was used as opposed to individual parcels and overlain with the 1973 and 2002 MDP data. This preliminary analysis of the parcel data to help identify potential sample polygons was limited by the following:

- The tax map layer was a point shapefile that was joined to the parcel layer based on the spatial location of the tax map points within the parcel polygons. However, some tax map points were not located within the correct parcels and therefore those parcels had limited owner information and were missing the year built.
- The minimum mapping unit (MMU) for the 1973 and 2002 MDP land use / land cover data was 10 acres. Land uses smaller than the MMU could not be identified from the MDP data.

In addition to land use type and pre-development forest cover, we were also interested in testing the hypothesis that parcels built after enactment of the Maryland Forest Conservation Act in 1991 would have significantly greater forest area than parcels built prior to this date. A number of factors limited the ability to fully test this hypothesis, including:

- A number of subdivisions evaluated were built over a long time period, some prior to the FCA and some post-FCA, making it difficult to classify those land use polygons as either/or.

- There was not enough information to determine whether parcels built after the FCA were subject to the requirements or were "grandfathered in," as is often the case when developments are approved prior to adoption of regulations but are actually constructed after the regulations take effect.
- There were few sample points for the post-1991 time period.

The result of Step 1 was a GIS layer of parcels/subdivisions that could potentially be included as part of sample polygon delineation in Step 2.

Step 2: Delineate the Sample Land Use Polygons

This step involved three major tasks: determining the number of sample polygons needed, delineating the boundaries of the sample land use polygons, and classifying each polygon into one of the selected land use categories. The result of this step was a new GIS layer of land use polygons that contained the following information within the data table: land use type, pre-development land use (agriculture, forest, or mixed forest and agriculture), whether the parcel was built before or after enactment of the FCA, and a more detailed description of the land use for INST, OPEN, and HDR categories (e.g., golf course, park, school, apartments, etc). Pre-development land use was considered forest if >90% of the sample polygon was covered by forest, agriculture if >90% of the sample polygon was agriculture, and mixed for all other combinations of forest/agriculture. The following methods were used to delineate land use polygons:

- For residential land uses (with the exception of VLDR), polygons were drawn following the lot lines of contiguous parcels that correspond to that specific type of residential land use category (e.g., ¼ acre lots) and generally follow subdivision boundaries. Residential parcels were lumped in this way, as opposed to using individual parcels, which is consistent with the land use development and approval process, where the conservation of forest cover and other open space is determined at the subdivision scale, rather than individual parcels. Lots that were not yet built were not included as part of the subdivision. In some instances, common land was split between two sample polygons (i.e., MDR and HDR polygons adjacent to one another that shared a park). Figure 2 shows an example of a residential polygon delineation.
- Parcel boundaries and landowner information were used as guides when delineating OPEN, INST, COM and IND land. Each individual parcel constituted a single land use polygon, except in cases where a single business was comprised of multiple parcels (e.g., a university).
- The owner/business name listed in the tax map data and aerial photos from 1988, 1993, 2005, and 2007 were also used to help verify the pre-development and existing land use and forest cover for each sample polygon.
- Interstate/state highways were not included in the polygons. Interior roads (e.g., subdivision roads) were included within the land use 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.
- After delineating each polygon, a sample number and land use type was assigned to it.

Figure 2. Example of a residential sample polygon delineation for Frederick County. Parcels are shown as yellow lines, forest cover in green, and the sample polygon delineation in black.

In order to determine the sample size required to produce statistically valid forest cover coefficients, a random selection of the parcels/subdivisions identified in Step 1 was used to delineate a targeted minimum of 10 sample polygons for each land use category stratified by pre-development land use (i.e., 10 sample polygons each for LDR/forest, LDR/ag, and LDR/mixed). The goal was to use a statistical analysis to predict the required sample size based on the results of the initial 10 sample polygons delineated for each land use category and pre-development type. To achieve this, data in the attribute table for the preliminary selection of parcels/subdivisions identified in Step 1 was exported to Microsoft Excel, and was then grouped according to existing and pre-development land use (e.g., previously forested LDR, previously agricultural LDR, and previously mixed LDR). Parcels were identified according to their tax account identification numbers and subdivisions were identified by subdivision identification codes assigned by the County. For each parcel and subdivision, a random number generator in Excel was used to assign a random numeric value. The parcels and subdivisions were then sorted based on the assigned numeric value from low to high. To delineate sample land use polygons for OPEN, INST, IND, and COM, the parcels were found using GIS based on the order of the random number generated and visually evaluated to determine whether they were good candidates for sample polygons. To delineate sample land use polygons for VLDR, LDR, MDR, and HDR, the subdivisions were found using GIS based on the order of the random number generated and visually evaluated. Sample polygon delineation was done according to the procedure outlined above.

We were unable to identify a minimum of 10 sample polygons for most combinations of land use categories and pre-development land use due to data limitations and/or because few of those specific land uses exist within the County. In addition, statistical analysis showed that the data did not follow a normal distribution and therefore, it was not possible to accurately predict the sample size needed to provide a significant result. As an alternative, all possible sample polygons that were developed between 1973 and 2005 were delineated, which provided the maximum sample size that could be achieved.

Table 4 lists the land use categories targeted for the analysis by pre-development land use and shows the number of corresponding sample polygons delineated.

Table 4.Distribution of Samples by Land Use Category and Pre-Development Land Use				
Land Use Category	**Number of Samples by Pre-Development Land Use**			**Total Number of Samples**
	Forest	**Agriculture**	**Mixed Forest and Agriculture**	
Open Urban Land (OPEN)	**Total: 4** *1 pre FCA* *3 unknown date*	**Total: 8** *4 pre FCA* *1 post FCA* *3 unknown date*	**Total: 2** *2 pre FCA*	**14**
Institutional (INST)	**Total: 0**	**Total: 13** *10 pre FCA* *3 post FCA*	**Total: 4** *4 pre FCA*	**17**
Industrial (IND)	**Total: 2** *2 pre FCA*	**Total: 12** *7 pre FCA* *5 post FCA*	**Total: 2** *1 pre FCA* *1 post FCA*	**16**
Commercial (COM)	**Total: 10** *10 pre FCA*	**Total: 14** *12 pre FCA* *2 post FCA*	**Total: 5** *3 pre FCA* *2 post FCA*	**29**
Very Low Density Residential (VLDR)	**Total: 25** *20 pre FCA* *5 post FCA*	**Total: 12** *11 pre FCA* *1 post FCA*	**Total: 32** *28 pre FCA* *4 post FCA*	**69**
Low Density Residential (LDR)	**Total: 4** *2 pre FCA* *2 post FCA*	**Total: 9** *8 pre FCA* *1 post FCA*	**Total: 9** *8 pre FCA* *1 post FCA*	**22**
Medium Density Residential (MDR)	**Total: 3** *2 post FCA* *1 unknown date*	**Total: 8** *6 pre FCA* *2 post FCA*	**Total: 10** *6 pre FCA* *4 post FCA*	**21**
High Density Residential (HDR)	**Total: 6** *5 pre FCA* *1 post FCA*	**Total: 14** *10 pre FCA* *4 post FCA*	**Total: 12** *6 pre FCA* *6 post FCA*	**32**

<u>Step 3: Measure Forest Cover</u>
Both pre- and post-development forest cover were measured for each sample land use polygon. GIS was used to calculate the area of each of the polygons. Next, pre-development forest cover was calculated by intersecting the polygons with forest cover in the 1973 MDP land use / land cover data. Post-development forest cover was calculated by intersecting the polygons with the 2005 forest cover from the County's planimetric data. Data in the attribute table of the sample land use polygon shapefile was then exported to Excel so that the percentage of pre- and post-development forest cover for each sample polygon could be summed by dividing the forest cover in each polygon by the total polygon area. Limitations of the forest cover data include:

- The 1973 MDP data has a 10 acre minimum mapping unit. Therefore, the pre-development forest cover is typically over or underestimated (i.e. forest tracts less than 10 acres are not mapped).
- Many areas reforested to meet the requirements of the Forest Conservation Act are not reflected in the 2005 forest cover data because they had not yet matured enough for mapping methods to classify these areas as forest.

The percentage of 2005 forest cover by land use type is shown in the box and whisker plot in Figure 3 below. The bottom and top of the gray boxes show the 1st and 3rd quartiles of the data, respectively. The solid horizontal line within each box is the median and the whiskers show the minimum and maximum of the data. Land use category abbreviations correspond to the descriptions in Table 2. The number of sample land use polygons is represented by “n” below each land use category.

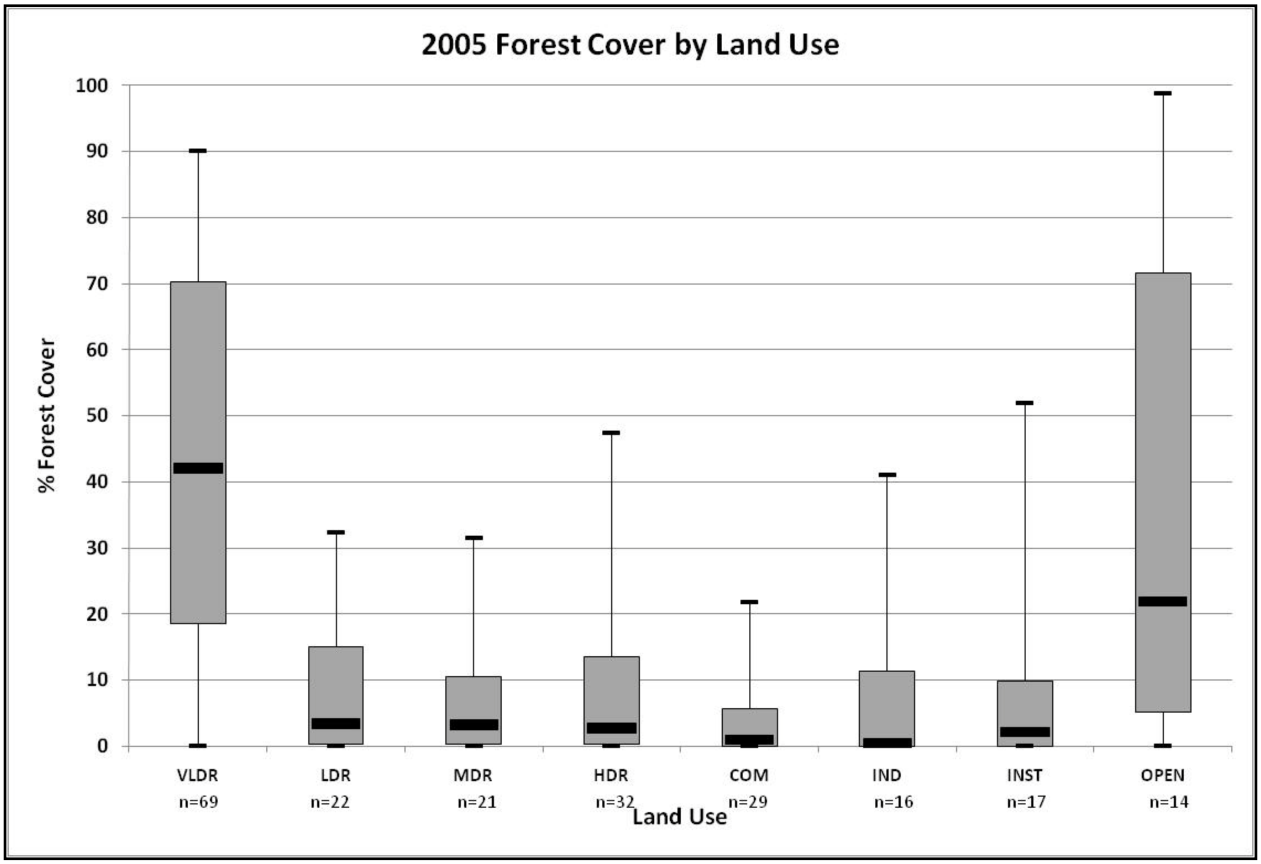

Figure 3. Box and whisker plot showing the percentage of 2005 forest cover across land use categories in Frederick County.

As can be seen from Figure 3, VLDR and OPEN are the most variable land use categories. A statistical analysis was conducted to determine any relationships that exist between and within the individual land use categories, as well as the data before and after the FCA. All analyses were conducted using XL Stat for Microsoft Excel. A summary of the analysis is provided below and the detailed statistical test results can be found in Appendix A.

Test for Normality

Data for each land use category was first tested for normality to determine whether parametric or nonparametric statistical tests should be used. Normality was determined from a combination of histograms, as well as the Shapiro-Wilk and Jarque-Bera tests for normality. The results indicate that the data is not normally distributed and tends to be skewed towards lower percentages of impervious cover for most land use categories. Therefore, non-parametric statistical tests were needed to examine the relationship between and within land use categories.

Comparison between Land Use Categories

The Kruskal-Wallis test was used to compare LDR, MDR, HDR, COM, IND, and INST and found no statistical difference when comparing the data across land use categories. The test was also used to determine if there was a difference between forest cover at churches and forest cover at schools included in the INST land use category. Again, no significant statistical difference was found.

Comparison before and after the Forest Conservation Act

The Mann-Whitney U Test was used to compare the data in each land use category before and after implementation of the FCA. The results showed no significant difference in the data. Prior to 2007, the FRO followed the same requirements as the FCA, which allowed a certain amount of forest clearing above conservation thresholds set for various land uses.

Relationship of Pre- and Post-Development Forest Cover

The pre-development and post-development forest cover data was plotted for each land use category to determine if the amount of forest cover present before development is influential in the amount that remains after development. Table 5 shows the results of the linear regression analysis and the plots of this data can be found in Appendix A. Pre-development forest cover was calculated from the 1973 MDP land use / land cover data and post-development forest cover was calculated from the 2005 forest cover layer. A linear regression was fitted to each plot. VLDR and OPEN land use categories showed a high correlation between pre- and post-development forest cover. LDR, IND, and INST regressions were found to be statistically significant at the 95% confidence level, but showed low correlation according to the R-squared values. We found no significant relationship for the remaining land use categories.

Table 5. Linear Regressions Comparing the Percentage of Forest Cover Before and After Development

Land Use Category	Linear Regression	R^2	Significance F
VLDR	Y = 0.0071X + 0.0397	0.86	0.00
LDR	Y = 0.0014X + 0.0043	0.24	0.02
MDR	Y = 0.0008X + 0.0048	0.09	0.20
HDR	Y = 0.0008X + 0.0066	0.06	0.17
COM	Y = 0.0003X + 0.0024	0.08	0.14
IND	Y = 0.0003X + 0.0024	0.62	0.00
INST	Y = 0.0062X + 0.0033	0.46	0.00
OPEN	Y = 0.0087X + 0.0142	0.98	0.00

Notes: Y, coefficient for post-development forest cover; X, % pre-development forest cover. Significance F is the probability that the equation does not explain the variation in Y. If the significance F is less than 0.1, the correlation is significant.

The analysis showed that the sample polygons for the OPEN land use category represented two distinct types of land use (i.e., active vs. passive recreation) so these were analyzed further to determine if splitting these data into two separate categories would reduce the variability. Results of a Kruskall Wallace test showed that active versus passive recreation sites were two distinct populations (p-value = 0.002). Active recreation sites included golf courses and recreation areas, and passive recreation sites included parks and game preserves. Box and whisker plots of the results are shown in Figure 4 compared to the initial results from analyzing all OPEN sites together.

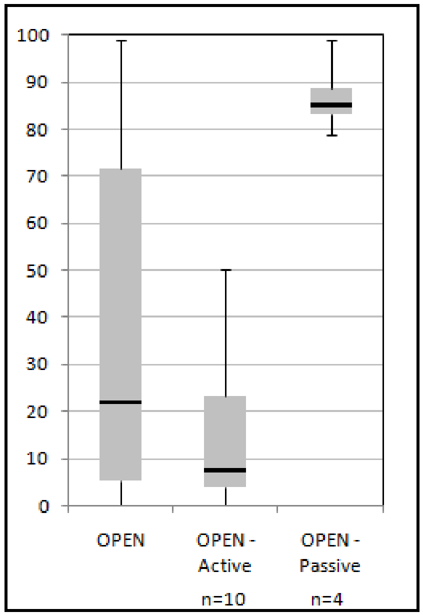

Figure 4. Box and whisker plot showing the percentage of 2005 forest cover in OPEN, OPEN-active and OPEN-passive recreational land use in Frederick County

Estimating Current Forest Cover for the Linganore Creek Watershed

GIS was used to clip Frederick County's 2005 forest layer to the watershed boundary and estimate the acreage and percent existing forest cover. The forest layer was extracted from the County's 2005 planimetric layer, which was delineated from 6 inch ground resolution true color orthophotography. To estimate the current (2010) forest cover, the acres of forest cleared from 2005-2009 were subtracted from the 2005 forest cover. The acres cleared were obtained from the County, which tracks forest acres cleared, conserved, regenerated and planted for each development site subject to the FRO. The following assumptions were made for this step:

- Any tree planting that occurred during this period had a negligible effect on total forest cover because new plantings typically take 5 – 10 years to become established and 15 years until they show up on mapping.
- Any land that was forested in 2005 and was not developed is still forested.

Estimating Future Forest Cover for the Linganore Creek Watershed

The Leafout Analysis (Cappiella et al., 2005) is a GIS analysis that estimates future forest cover in a watershed, and can also be used to evaluate the effect of different watershed protection scenarios on future land cover. The method has several assumptions:

1. Full build-out of the watershed will occur based on allowable zoning (e.g., no rezoning)
2. Current forest cover on developed land will remain the same with the future build-out, unless specific changes are identified in a watershed protection scenario (e.g., reforestation)

3. All buildable land will be developed, and the resulting forest cover will be determined by forest cover coefficients

The Leafout Analysis involves the following five steps:

1. Identify buildable land
2. Calculate the area of each land use category that is buildable
3. Multiply the buildable land in each land use category by the corresponding forest cover coefficients
4. Calculate total forest cover on developed and protected land
5. Sum future forest cover on buildable, developed and protected land

The specifics of each step as applied to the Linganore Creek Watershed are described below.

<u>Step 1: Identify buildable land</u>
Frederick County provided a layer of developed, undeveloped, and underdeveloped land within the watershed (Figure 5). Undeveloped lands were defined as parcels in the process of being developed or those that are not developed to their full potential. For this analysis, both undeveloped and underdeveloped parcels were identified as “buildable” land. Lands that are permanently protected from development by easement or other measures were subtracted from the undeveloped land. Protected lands that include stream buffers, steep slopes, etc. were not subtracted out because these lands were not subtracted from the sampling polygons when determining the forest cover coefficients. Open water was also subtracted from the undeveloped land. The result of this step was a new GIS layer of ‘buildable’ lands (Figure 7).

Based on discussions with County planning staff, the buildable portions of the watershed are limited to those within the designated Community Growth Areas (CGAs) (Figure 6) because land outside the CGAs is predominantly agricultural and has limited development potential. In Maryland, county governments designate planned CGAs. Maryland’s Smart Growth Act of 1997 includes a mechanism called Priority Funding Areas to guide where state funding should be targeted. Generally, PFAs are located within CGAs and provide incentives for governments to limit most of their growth to these areas. Rezoning outside of the CGAs is a possibility, but was not possible to predict as part of this study. Therefore, the Leafout Analysis used the assumption that no rezoning would occur outside of the CGAs (the April 2010 version of the CGA boundaries was used for this analysis, although it has since been revised).

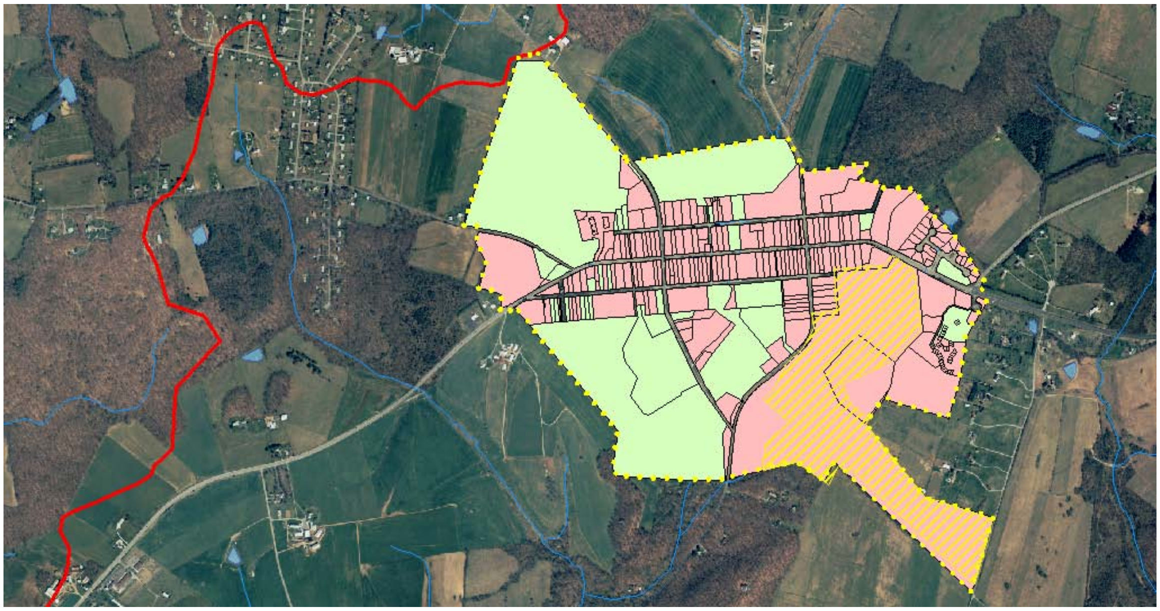

Figure 5. Developed (pink) and undeveloped (green) lands within a CGA. Permanently protected lands are identified in the yellow hatching.

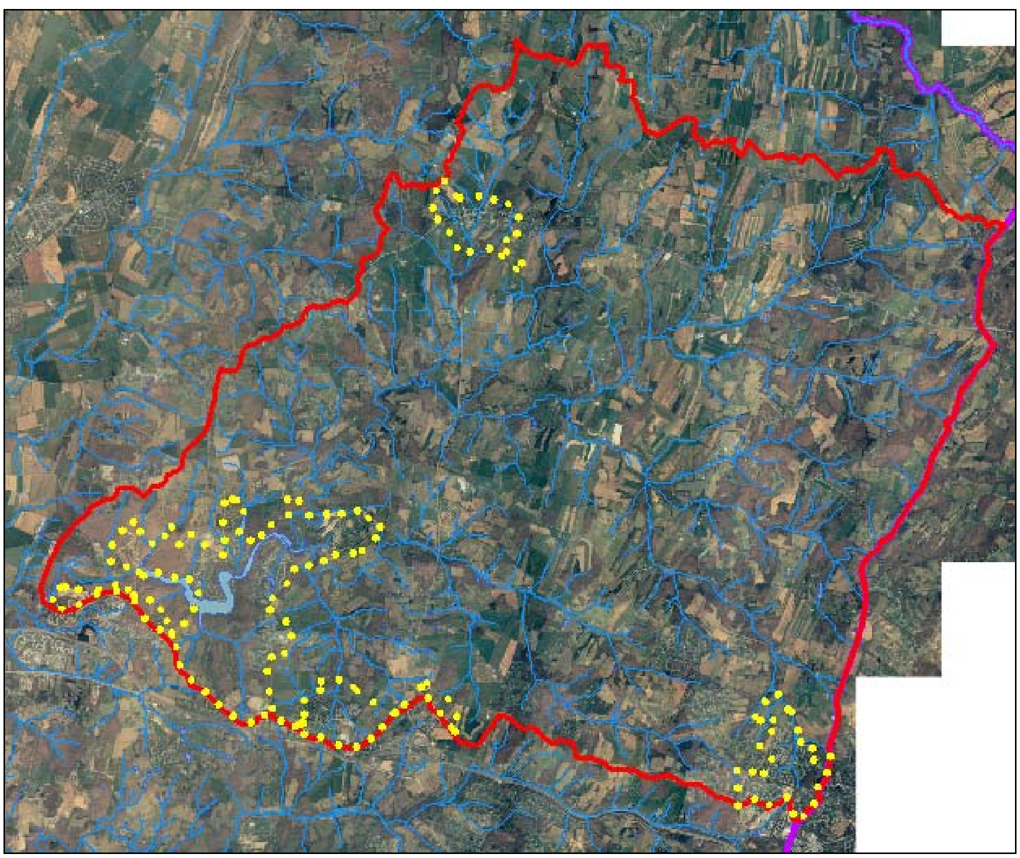

Figure 6. Community growth areas within the Linganore Creek watershed.

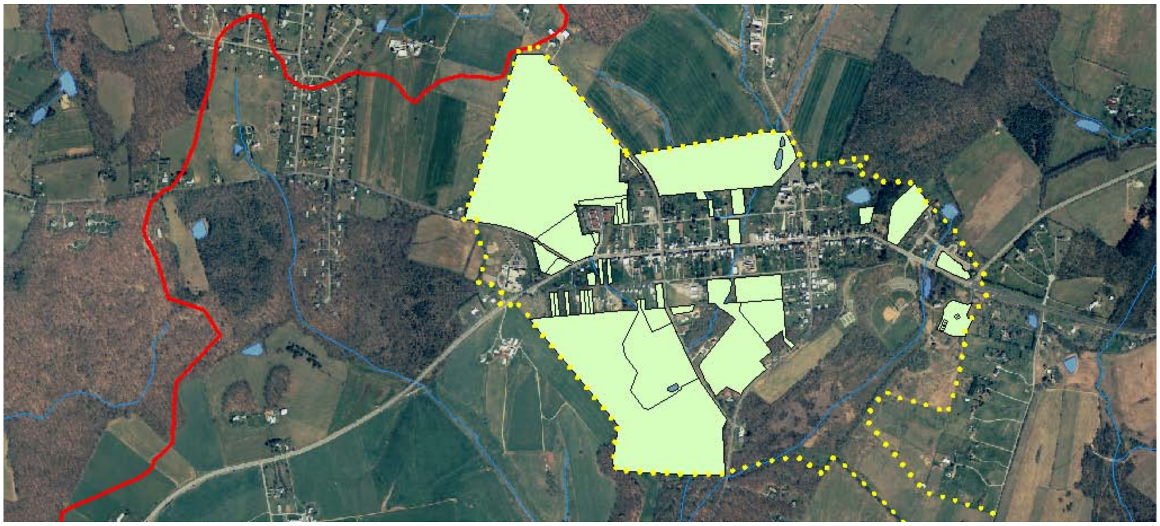

Figure 7. Buildable land within a CGA resulting from Step 1 of the Leafout Analysis.

<u>Step 2: Calculate the area of each land use category that is</u> *buildable*
This step requires intersecting the comprehensive plan designation GIS layer with the buildable land layer resulting from Step 1. The result was a new GIS layer of buildable land classified according to comprehensive plan designation (Figure 8). Table 6 shows the area of buildable land by land use category.

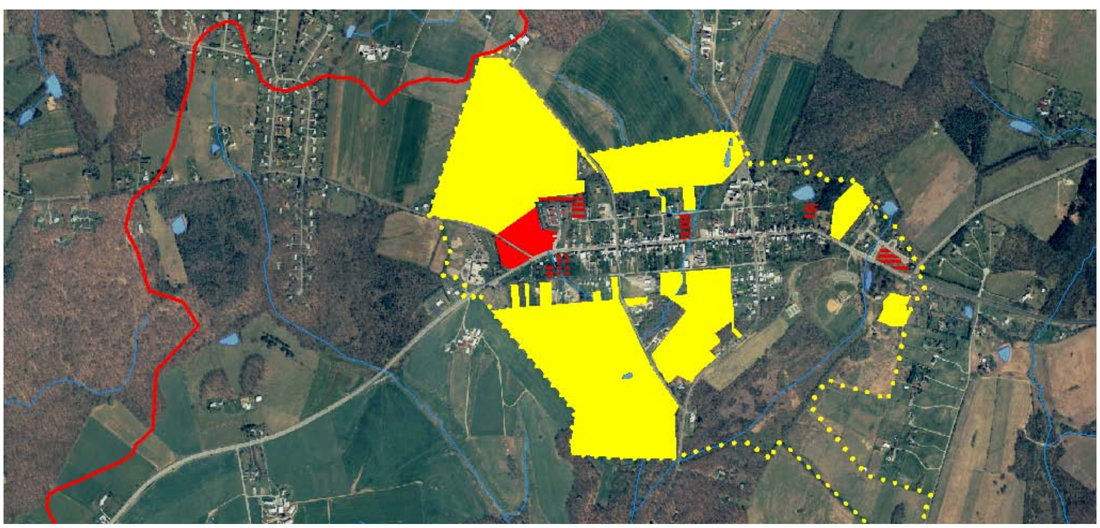

Figure 8. Buildable land intersected with the comprehensive plan designations for a CGA (solid yellow is low density residential, solid red is general commercial, and striped red is village center).

<u>Step 3: Multiply the buildable land in each land use category by the corresponding forest cover coefficients</u>
The buildable area for each comprehensive plan designation was multiplied by the corresponding forest cover coefficients for Frederick County, which were determined as described in Section 4 of this report. This resulted in an estimate of future forest cover for buildable land in the watershed. Table 6 illustrates this calculation.

Table 6. Area of Buildable Land and Future Forest Cover by Land Use Category			
Future Land Use Category	**Buildable Area (acres)**	**Forest Cover Coefficient**	**Future Forest Cover on Buildable Land (acres)**
Commercial (COM)	14.23	0.01	0.14
Low Density Residential (LDR)	1,180.57	0.034	40.14
Medium Density Residential (MDR)	14.32	0.033	0.47
Open Urban Land (OPEN)	111.67	0.50	56.30
Right-of-Way[1]	5.65	N/A	0.00
Agriculture[2]	32.52	N/A	8.50
Total	**1,358.96**		**105.55**

[1] We did not calculate FCCs for right-of-ways because interior roads were included within the sample polygons of the individual land use categories. However, the GIS layer of developed, undeveloped and underdeveloped land provided by the County included roads as separate polygons for other land uses. To account for this discrepancy, it was assumed that parcels with a future land use designation of right-of-way would be entirely cleared when developed, as impervious cover studies consistently find that they consist of 95% impervious cover and most medians and rights-of-way are mowed to maintain sight lines and setbacks. It was also assumed that any reforestation within the right-of-way would be minimal considering that less than 6 acres has this future land use designation, so an FCC of zero was used for the Leafout Analysis.

[2] We did not calculate FCCs for agriculture. For the Leafout Analysis, it was assumed that forest cover on parcels with a future land use designation of Agriculture (all of which are currently zoned for agricultural use) would not change from the current forest cover.

Step 4: Calculate total forest cover on developed and protected land

The total amount of forest cover present on the developed and protected portion of the watershed was quantified. This required intersecting the 2005 forest cover layer with the developed and protected land layers (Figure 9). It was assumed that the future forest cover on these lands will be equal to the current forest cover.

Figure 9. Developed and protected land (pink) within a CGA overlaid with 2005 forest cover (green).

Step 5: Sum future forest cover on buildable and developed land

This step involved summing future forest cover on buildable, developed, and protected land (derived during the previous steps) to yield future forest cover in the watershed (Table 7). A spreadsheet was used for this purpose.

Table 7. Future Forest Cover in the Linganore Creek Watershed

Land Use Category	**Future Forest Cover on Developed and Protected Land (acres) (from Step 4)**	**Future Forest Cover on Buildable Land (acres) (from Step 3)**	**Total Future Forest Cover (acres)**
Very Low Density Residential (VLDR)	868.98	0	868.98
Low Density Residential (LDR)	441.18	40.14	481.32
Medium Density Residential (MDR)	0	0.47	0.47
Commercial (COM)	53.6	0.14	53.74
Industrial (IND)	0.53	0	0.53
Institutional (INST)	28.12	0	28.12
Open Urban Land (OPEN)	51.51	56.30	107.81
Agriculture	9,134.37	8.50	9142.87
Right-of-Way	150.51	0	150.51
Natural Resources Conservation	2,914.84	0	2,914.84
Rural Community	27.73	0	27.73
Total	13,671.37	105.55	13,776.92

*Forest cover coefficients were not developed for these land use categories in the County's Comprehensive Plan.

4.0 Results

Recommended Forest Cover Coefficients for Frederick County

Based on the statistical analyses described in Section 2.0, use of the linear regression relating pre- and post-development forest cover data is recommended for the VLDR and OPEN land use categories. The linear regression is recommend for OPEN instead of the median values for OPEN-active and OPEN-passive due to the low sample size for these sub-categories and because of the expected difficulty in assigning a designation of "active recreation" versus "passive recreation" to buildable lands zoned for recreation use. Communities having knowledge of the intended uses for their future OPEN lands may wish to use the FCCs for OPEN-active and OPEN-passive. The median of each land use category is recommended for LDR, MDR, HDR, COM, IND, and INST. The median is recommended as opposed to the mean because the mean tends to be affected by outliers, which are present in all of the land use categories. The median is a better measure of central tendencies and discounts the importance of numbers outside the data range. Table 8 below presents the recommended forest cover coefficients.

Table 8. Recommended Forest Cover Coefficients for Frederick County

Land Use Category	Land Use Category Description	Forest Cover Coefficient[1]	Measure of Variance[2,3]
Very Low Density Residential (VLDR)	Single family residential development with a density of less than 1 dwelling unit/acre	Y = 0.0071X + 0.0397	0.110
Low Density Residential (LDR)	Single family residential development with a density of 1-4 dwelling units/acre	0.034	0.147
Medium Density Residential (MDR)	Single family and attached residential development with a density of 5-10 dwelling units/acre	0.033	0.103
High Density Residential (HDR)	Residential development with density > 10 dwelling units/acre, generally multi-family development	0.028	0.132
Commercial (COM)	Retail, small office and business uses	0.010	0.057
Industrial (IND)	Manufacturing and industrial facilities, including associated warehouses, storage yards, and research laboratories; business, professional and corporate office parks	0.005	0.113
Institutional (INST)	Schools, churches, government offices and facilities	0.022	0.098
Open Urban Land (OPEN)[4]	Includes active recreational uses (golf courses and recreation areas except areas associated with schools or other institution) and passive recreational uses such as parks and game preserves	Y = 0.0087X + 0.0142 (OPEN) OR 0.074 (OPEN-active) 0.850 (OPEN-passive)	0.065 (OPEN linear regression) 0.193 (OPEN-active) 0.055 (OPEN-passive)

[1] Y = **coefficient** for post-development forest cover; X = **percent** pre-development forest cover

[2] Interquartile Range is used as a measure of variance for the LDR, MDR, HDR, COM, IND, INST, OPEN-active, and OPEN-passive land use categories, where FCCs represent the median of the sample data. It is a measure of statistical dispersion and is defined as the difference between the third and first quartiles.

[3] Variance for the VLDR and the linear regression version of OPEN land use categories is the standard error of the linear regressions that are used to calculate the FCCs.

[4] The OPEN-active and OPEN-passive coefficients should be used when the use (golf courses, parks, playgrounds, etc.) of future open urban land is known. Otherwise, the linear regression relating pre- and post-development forest cover data for open urban land is recommended.

Current and Future Forest Cover in the Linganore Creek Watershed

The results of the Leafout Analysis show that the current (2010) forest cover in the Linganore Creek Watershed is 30.0%. With future buildout of the watershed, 634.8 acres of forest will be cleared, decreasing watershed forest cover to 28.7%. This represents only a 4.4% loss across the watershed, but a 40.8% loss within the CGAs. Table 9 provides a summary of the Leafout results.

Table 9. Summary of current and future forest cover for the Linganore Creek watershed

	Acres	%
2010 Forest Cover	14,411.71	30.0[1]
Future Forest Cover	13,776.96	28.7 (potential error of -0.1%/+0.3%)[2]
Total Area	48,088.87 acres	
Loss in Forest Cover	4.4%	

[1] This estimate of 2010 forest cover (30.0%) varies from the 2007 estimate (28.2%) presented in Table 1 because the Leafout was conducted before the 2007 land use / land cover data from MDP was available.
[2] Potential error was calculated by using the 1st quartile of the sample data for the low-end estimate of error and the 3rd quartile for the high-end estimate of error. The exception was for open urban land where the FCC was calculated by a linear regression, which used standard error as opposed to the quartiles to estimate error.

The greatest loss in forest cover (more than 98% of the total loss) is attributed to the development of LDR land use. Within each land use category, the greatest loss of existing forest occurred in the rights-of-way, LDR and COM land uses (> 80%), while moderate (>40%) loss occurred on MDR land and a loss of 10% or less occurring on OPEN and agricultural land (Figure 10).

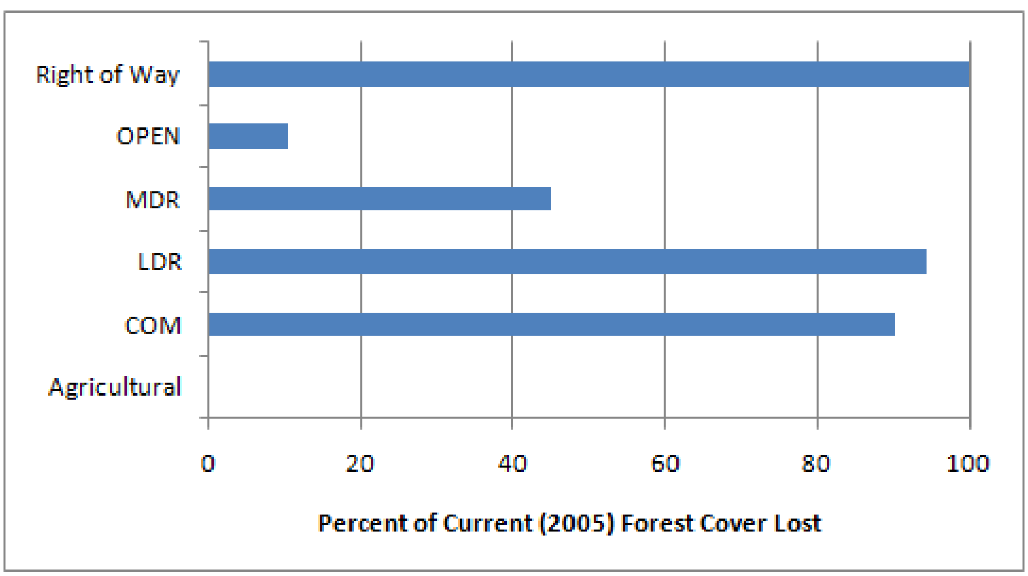

Figure 10. Percentage of forest loss within land use categories with future buildout of the watershed.

5.0 Discussion

We observed a number of data limitations in the Frederick County study. For example, the 1973 forest cover derived from MDP data are mapped at a lower spatial resolution (i.e., a 4-ha [10-acre] minimum mapping unit) than the 2005 forest cover derived from the planimetric data; therefore, the pre-development forest cover is typically over- or underestimated (e.g., forest tracts less than 4 ha [10 acres] are not mapped). Further, many areas reforested as part of the FCA are not reflected in the 2005 forest cover data because they had not yet matured enough for mapping methods to classify these areas as forest. New plantings typically take an estimated 5–10 years to become established and 15 years until they are identifiable using moderate-resolution remote-sensing imagery. However, the ability to identify and map individual tree canopy is also dependent on the spatial resolution of the remote-sensing imagery (e.g., 30-m Landsat compared to digital aerial imagery at a resolution of less than 0.3 m).

An additional option for improving the FCC methodology in Frederick County is to delineate a larger number of sample polygons that were built after establishment of the FCA (once more recent land use land cover data becomes available) to determine impacts attributed to the forest conservation regulations. The analysis conducted as part of this study found no significant relationship between the calculated forest cover and whether the sample polygon was developed before or after establishment of the FCA. However, the sample sizes were limited and in many instances it was difficult to determine the specific date a development occurred. Another analysis that could be added is incorporation of the age of the development when delineating the sample polygons to determine how age affects the FCCs. One would expect that older developments should have greater percentages of forest cover because trees in such developments have been growing for a longer duration.

The results of this study show that the median post-development forest cover for all Frederick County land use categories except VLDR and OPEN is less than 5%, regardless of pre-existing land use. This suggests that forest loss during development is substantial within the County, despite the existence of state-wide and local forest conservation regulations. Some possible explanations for the very low forest cover values include:

- Developers may plant trees or allow for natural regeneration on-site as part of compliance with the FCA. As mentioned previously, it is unlikely that these areas would have matured enough to be classified as forest in the 2005 forest cover layer used in this analysis. Therefore, the actual post-development forest cover is likely to be higher than what was calculated in this study, although to what extent is uncertain because the County's FRO database is not spatially linked. A detailed analysis of the data collected under the FCA to determine how much on-site planting and natural regeneration occurred on the parcels selected for the analysis would be informative to help answer this question.
- Other options to comply with the FCA if on-site conservation or reforestation is not practical include purchase of banking credits, reforestation of off-site sensitive lands, conservation of off-site forest, and payment into a fee-in-lieu fund, all of which would protect or increase forest elsewhere in the County. Therefore, the FCC analysis would not have captured this "transfer" of forests from on-site to off-site. Additional analysis of the FRO data would be useful to further evaluate forest loss in the County.
- A large proportion of the data was from sites that were developed prior to adoption of the FCA, which may have skewed the data towards greater forest loss. However, there were too few sample polygons available for sites developed after adoption of the FCA to develop robust FCCs

for just this time period. Statistical tests found no significant difference in the data before and after implementation of the FCA for the full dataset. However, a preliminary analysis of only the post-FCA sites shows that the median post-development forest cover values are similar to or higher than the FCCs calculated using the entire dataset, depending on land use type (Figure 11). A linear regression of the post-FCA data comparing pre-development forest cover to post-development forest cover showed that the pre-existing land use is important in predicting post-development forest cover for VLDR and LDR land uses. Again, the sample size is too small to draw any meaningful conclusions and additional analysis is warranted that also examines parcel-specific data collected under the FCA.

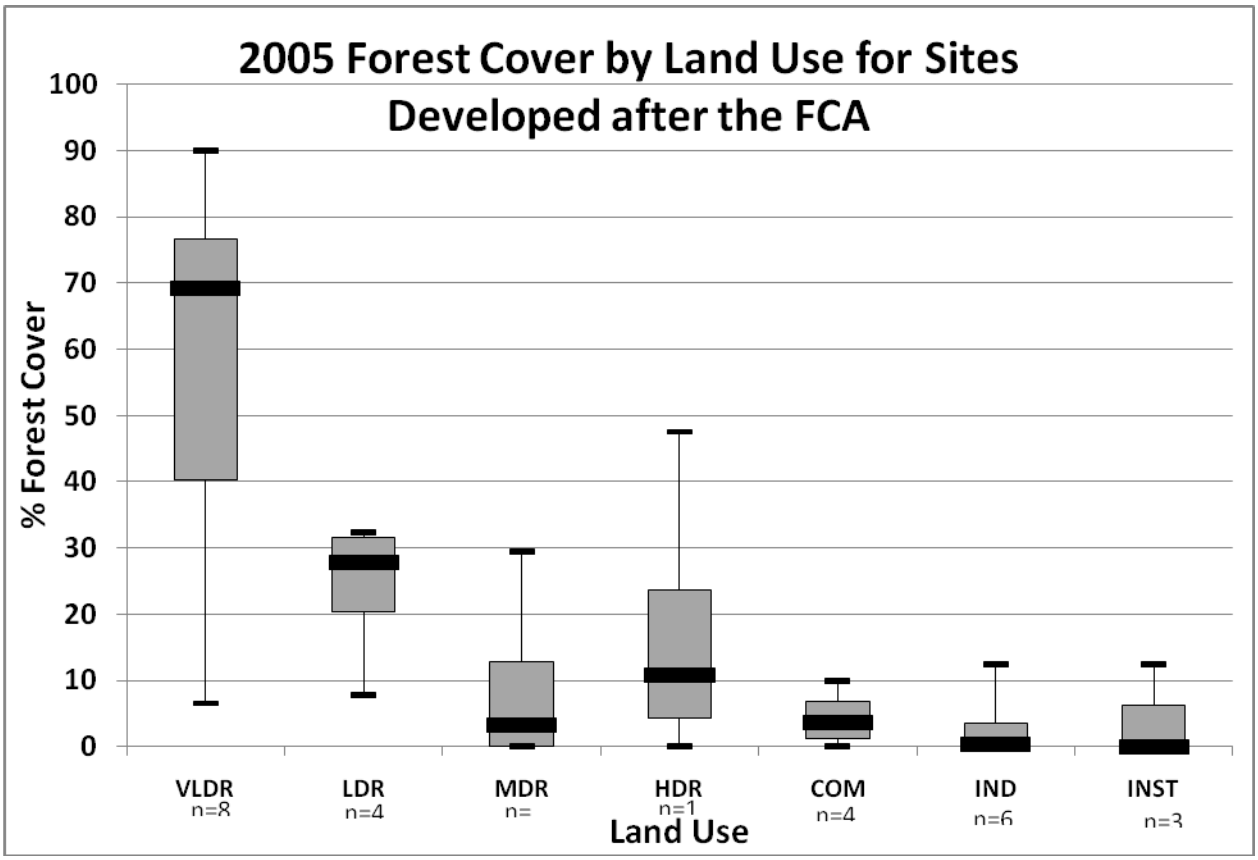

Figure 11. Median post-development forest cover on Frederick County sites developed after implementation of the Forest Conservation Act, by land use

One of the assumptions of the Leafout Analysis was that land outside of the CGAs would not be rezoned. However, rezoning is a real possibility, especially considering the population increase projected for the County. Hanlon et al (2010) found that PFAs are not a one hundred percent effective strategy and that some of the areas experiencing the greatest market pressure for development are outside the PFAs. Therefore, future forest loss in the watershed may actually be greater than predicted. In addition, even with the concentration of growth caused by the CGAs, development within the watershed continues to place added stress on the drinking water supply reservoir in terms of water quality.

The resulting FCCs can be applied in Maryland communities with similar patterns of development as Frederick County (i.e., watersheds with a mix of urban, suburban, and rural land), but may have limited application outside of the state because of variations in forest management regulations. Also, as noted above, the FCCs likely underestimate post-development forest cover because they do not include trees that were recently planted as part of FCA mitigation and were calculated using data from sites built prior to FCA implementation. While there are uncertainties regarding these values, they represent our only current knowledge of post-development forest cover by land use and provide a baseline that can be built upon with future studies and/or better tracking and analysis of the extensive data collected by Maryland communities to comply with the FCA. When applying the methodology presented in this study to derive FCCs and conduct the Leafout Analysis in communities outside of Maryland, the methods should be adjusted based on available data and local conditions.

6.0 Recommended Forest Cover Goals and Priority Actions

More than 25 communities across the Chesapeake Bay Watershed have set urban tree canopy (UTC) goals as part of a broader strategy to improve water quality in the Bay by reducing sedimentation and nutrient loads. Increasing UTC is recommended in part to protect and improve water quality but also to provide benefits, such as air quality improvement, cooling and shade, energy savings, noise reduction and beautification, to residents of urban areas. Communities vary greatly in their UTC goal-setting processes, and many opt to adopt American Forests' recommendation for 40% tree canopy in urban areas east of the Mississippi.

The following factors were initially evaluated to develop recommended forest cover goals and strategies for the Linganore Creek Watershed:

- Consideration of the current (~30%) and future (~29%) forest cover as a starting point to help determine what is realistic given the planned development in the watershed.
- Use of GIS data generated through the Leafout Analysis to determine what is possible to achieve in terms of conservation and reforestation (e.g., available sites for conservation, types of land available for reforestation).
- Review of studies on the relation between watershed forest cover and water quality or stream condition (summarized in Box 1).

This data was used to evaluate the feasibility of setting a watershed-wide forest cover goal and several options were discussed with the County. It was determined that increasing watershed forest cover to approach literature values representing good watershed health would not be feasible without significantly changing the current agricultural character of the region. We also determined that the original intent of tying the forest cover goal and recommendations to the Linganore TMDL was not practical since, during the course of the project, the Chesapeake Bay TMDL was developed, requiring the County to shift their priorities to this important mandate that will likely require enormous resources but is associated with much uncertainty regarding its effect on the local TMDLs. Another major challenge is that the "credit" given to tree planting and forest conservation activities in the context of the Bay TMDL as well as by MDE for MS4 permit activities is currently under discussion and is not likely to provide a sufficient motivator for pursing an extensive tree planting effort in this watershed. Based on these factors and discussion with the County, a set of forest cover goals and recommendations was developed that achieve the following objectives:

- Preserve the agricultural character of the community
- Reduce the adverse impacts of urban and suburban development on water quality
- Provide access to green space and UTC benefits within the designated community growth areas
- Conserve or increase forest cover in locations that are identified as important for water quality, habitat or other benefit

Box 1. Studies linking Watershed Forest Cover to Water Quality and Stream Condition

Booth (2000) found that at least 65% watershed forest cover is needed for the presence of a healthy aquatic insect community in a Puget Sound, Washington study.

In a Montgomery County, Maryland study, Goetz et al. (2003) found that for streams to have a health rating of Excellent, at least 65% of the length of the stream network in the watershed must be forested (within 100 feet of the stream).

A survey of 27 water suppliers conducted in 2002 by the Trust for Public Land and the American Water Works Association (Ernst, 2004), found that operating treatment plant costs decreased as forest cover in the source area watershed increased. Specifically, for every 10 percent increase in forest cover, treatment and chemical costs decreased approximately 20 percent, up to about 60 percent forest cover. Not enough data were obtained on drinking water watersheds with more than 60 percent forest cover; however, the study authors suggest that treatment costs level off when forest cover is greater than 70 percent. About 50-55 percent of the variation in treatment costs was explained by the amount of forest cover in the watershed. The other 50 percent was attributed to the varying treatment practices used, the size of the treatment facility, and the characteristics of development and agricultural land in the watershed, including use of best management practices (BMPs).

A follow-up study was conducted by the Trust for Public Land (Freeman et al., 2008) and summarized raw water quality data, forest cover data, and drinking water treatment cost data for 60 water treatment plants across the country. This study found that there were significant relationships among percent land cover, source water quality, and drinking water treatment costs. Decreased forest cover was significantly related to decreased water quality, while low water quality was related to higher treatment cost. The variability associated with the potential treatment costs given a change in watershed land cover precluded the development of a statistical model to predict treatment costs with certainty.

The *location* of forest cover in a watershed is also an important indicator of stream condition. Riparian forest cover appears to be an important factor in maintaining stream geomorphology and various indexes of biotic integrity. Studies suggest that stream indicator values increase when riparian forest cover is retained over at least 50 to 75% of the length of the upstream network (Moore and Palmer 2005; Goetz et al. 2003; Wang et al. 2003).

The final recommended goals include:

- Green Infrastructure Plan in place to target watershed-wide conservation and reforestation based on water quality/habitat goals
- Forest buffers along 75% of the stream network by 2040
- 40% forest cover in the Community Growth Areas by 2040

Recommended strategies to achieve these goals are described below.

Goal: Green Infrastructure Plan in place to target watershed-wide conservation and reforestation based on water quality/habitat goals

Description:
Frederick County is currently working with Maryland Department of Natural Resources and EPA on a Green Infrastructure (GI) analysis for the entire County. The goal of this analysis is to map GI resources (e.g., forests, wetlands, streams, grasslands, critical habitats) and identify sites that are important for providing functions such as habitat and water quality improvement. The results will be integrated into a GI plan that can be used to inform conservation and reforestation efforts along with other factors such as vulnerability and land ownership.

The original project objective of identifying priority conservation and reforestation sites in the Linganore Creek watershed will be achieved through the GI analysis, which uses extensive data and analysis as well as a method that will be applied consistently across the County. Rather than duplicating this exercise, the Center instead spent some time providing input into the various data layers and weighting and scoring factors used in the GI analysis. The GIS layer of buildable lands developed as part of the Leafout Analysis was provided to the County for use as an "overlay" to the GI mapping to help make determinations about priority based on vulnerability.

Once the County's GI plan is complete, it is recommended that it be used to identify priority forest tracts for conservation, either inside or outside the CGAs, as well as identify priority sites for reforestation across the Linganore Creek Watershed. The intent of this goal is that forest cover in the watershed will be targeted to those sites providing the most benefits as opposed to a more extensive reforestation effort to achieve a numeric target that would conflict with the currently agricultural nature of the watershed.

Target:
No specific numeric target

Strategies:

- Identify priority forest conservation and reforestation sites in the watershed
- Seek funding to purchase or place easements on priority conservation sites
- Reforest priority sites to connect existing forest parcels, close gaps, and/or maximize water quality or habitat functions
- Conduct targeted outreach to landowners of priority sites to encourage participation in conservation and reforestation programs such as the forest banking program and Neighborhood Green
- Refer to the GI Plan in the FRO review process to identify potential sites for off-site mitigation

Goal: Forest buffers along 75% of the stream network by 2040

Description:
Streambank erosion has been identified as a significant source of sediment in the Linganore Creek watershed. Based on this and on studies that link increased riparian forest coverage to improved stream conditions, a riparian forest cover goal of 75% was set for the watershed. This means that the goal is for 75% of the entire stream network to have a forest buffer of 100 feet on both sides of the stream. The 100-foot width was chosen because it is a commonly recommended buffer width that provides stream shade and water quality and some habitat benefits. It is also the minimum required buffer width in the Linganore Stream Buffer Ordinance. A review of the Stream Corridor Assessment data from the Monocacy Watershed shows that the Linganore Creek Watershed stream network is already 62% buffered. To achieve 75% coverage, 142,287 linear feet of stream with inadequate buffers would need to be reforested to a width of 100 feet.

In 2007, The County adopted the Linganore Source Water Protection Plan, which recommends that 75% of the FRO fee-in-lieu funds be spent in the watershed. As a result, the Linganore Watershed Forest Easement Purchase Program was developed which uses the fee-in-lieu funds to purchase conservation easements in accordance with State and County regulations. The County Board of Commissioners recently approved the allocation of up to $1,126,000 to this program, which will allow for reforestation of 113.6 acres of riparian land in the watershed. During the process of identifying sites for this program, County staff surveyed 190 riparian landowners and received positive responses from 24 of them, although only 4 of these properties can be reforested with the current funds. These numbers show that there is significant interest from riparian landowners in the watershed in participating in such a program.

Target:
327 acres

Strategies:
- Use results of GI analysis and the USGS's ongoing study to identify significant sources of sediment and phosphorus to Lake Linganore study to target priority riparian lands for reforestation
- Continue to apply funds dedicated from the FRO fee in lieu to target buffer reforestation in Linganore
- Conduct targeted outreach to farmers to encourage participation in the Forest Banking Program

40% forest cover in the Community Growth Areas by 2040

Description:
In the Community Growth Areas (CGAs), the current (2005) forest cover is 35.6% and with future buildout this will be reduced to 21.1%, according to the Leafout Analysis results. However, the FCCs calculated in this study for use in the Leafout Analysis likely underestimate post-development forest cover because the data includes sites developed prior to FCA requirements and does not capture new forests planted on-site or elsewhere in the County as part of FCA mitigation. Replacing the FCCs with the median forest cover of only the sites developed after FCA adoption (LDR= 0.244, MDR= 0.033, COM= 0.036) would reduce forest loss by 248 acres and increase the future forest cover in the CGAs to 26.2%.

It is unknown whether these values are truly reflective of on-site post-development forest cover in Frederick County, but it is suggested that these thresholds be used as a guide while simultaneously improving tracking of parcel-level forest loss under the FCA and utilizing the FRO review process to achieve the maximum practical on-site conservation as remaining buildable lands in the watershed are developed.

Considering forest loss with future buildout, the acreage that would need to be reforested to increase CGA forest cover to 40% is 640 acres. The most likely candidates for reforestation within the CGAs are public lands. Frederick County Public Schools (FCPS) system has set an urban tree canopy (UTC) goal of 20% for all schools. The County has also been discussing setting a UTC goal for the County parks and a portion of the FRO fee-in-lieu funds have been set aside for tree planting at County parks. The UTC analysis conducted as part of the FCPS goal-setting showed that, on average, schools have 38% of their property potentially available for planting. There are 130 acres of Institutional zoned land in within the Linganore Creek Watershed CGAs, most of which is school property but also includes parks, and other public lands. Using the 38% estimate, 50 acres of public land could be reforested toward the 40% forest cover goal for the CGAs.

One of the reasons for setting a forest cover goal for the CGAs is to bring the benefits of trees to the places where people can actually enjoy them. To this end, trees planted along streets can be enjoyed by all and provide a shady place to walk, traffic calming and beautification. While no data was available on the current extent of street trees within the CGAs, the total length of the road network is 77 miles. A conservative estimate that one quarter of the road length could be planted with street trees amounts to planting 5,082 trees at 20-foot spacing. This roughly equates to reforesting 50 acres of land (at a density of 100 trees per acre) towards the 40% forest cover goal for the CGAs. This estimate provides a rough approximation of the street tree planting potential; however, the actual spacing and placement will depend on the tree species and actual site conditions.

By far, the bulk of available planting space within the CGAs is found on private lands, primarily single family residential land. For example, there are 1,934 acres of developed low density residential land and 11 acres of developed commercial land in the Linganore Creek Watershed CGAs. Additionally, a review of the FCCs for Frederick County and impervious cover coefficients calculated for the County under a separate project shows that LDR land use has the highest planting potential at 76% (i.e., portion of the parcel that is not impervious or forest).The remaining reforestation required to achieve the 40% forest cover goal for the CGAs will likely have to occur on private land and is estimated at 540 acres. Reforestation of riparian buffers is not counted towards the CGA forest cover goal because it is not known at this time specifically where the reforestation will occur (inside versus outside the CGAs) but it is likely that some portion can be counted towards the goal.

Targets:

- Maximize forest conservation on buildable land
- Reforest 50 acres of public lands, including schools and parks
- Plant 5,082 street trees
- Encourage reforestation of 540 acres of private lands in the CGA

Strategies:

- Using the GI Plan, carefully consider the environmental value of a forested property before a higher zoning is given to a property
- Utilize the FRO review process to assure that "every reasonable effort" has been made to conserve on-site in order to achieve the maximum practical on-site conservation as remaining buildable lands in the watershed are developed.
- Modify the FRO tracking so that forest loss, conservation and planting activities can be tracked at the small watershed scale to better facilitate identification of mitigation sites within the same watershed (e.g. by adding database fields or linking with GIS). This will require additional resources be allocated to the planning division and should comply with state FCA reporting requirements.
- Analyze the FRO data to calculate post-development on-site forest cover and use these results to determine if state or local level changes are warranted, such as increasing the conservation threshold for higher density development and increasing the penalty for clearing above the breakeven point. These results can also inform revisions to the FCCs which can be used to estimate future forest cover in other County watersheds.
- Coordinate with existing Frederick County Public Schools UTC program and planned UTC goal setting for the Parks Department.
- Conduct a street tree inventory for all CGAs to identify potential planting sites and establish a baseline for the street tree planting goal.
- Utilize the GI Plan (specifically the priority reforestation sites) during the development process to assist municipal staff and developers with identifying potential FRO mitigation sites that are located within the Linganore Creek CGAs.
- Expand the Neighborhood Green program to provide trees and planting assistance to homeowners in exchange for maintenance of trees – and target owners with "excess" lawn (modeled after Baltimore County's Rural Residential Stewardship Program)
- Establish an outreach program to encourage tree planting that uses the forest cover goal and best methods in social marketing (e.g., use surveys and focus groups to determine what motivates the target audience) to help determine best methods to institute behavior change.

The total number of acres to be reforested to achieve the riparian goal and the CGA goal is 967 acres. It is assumed that street tree plantings and half the required plantings on private land will occur at a rate of 100 trees/acre (e.g., large stock), and all other plantings at a rate of 200 trees/acre. Based on these assumptions, a total of 161,359 trees must be planted to achieve the goals, or 5,564 trees/year over a 29-year period. This estimate does not account for additional forest loss due to natural tree mortality.

Frederick County Watershed Management Division has long been committed to forest conservation and restoration as an important component of reducing nonpoint source pollution under their NPDES MS4 permit. The goals and strategies in this report were developed in conjunction with County staff with the intent that they can be incorporated as part of the MS4 program and/or Phase II WIP. However the recently proposed "credits" for tree planting and reforestation proposed by MDE are still draft and possibly provide a disincentive for the use of trees as a water quality practice over structural practices, leaving few resources available to focus on a major tree planting effort. Until these issues are resolved, the County cannot formally "adopt" these recommended goals. It is our hope that they come to fruition and the Center is continuing work with Frederick County as part of the Chesapeake Bay Circuit Rider program to evaluate pollution reductions that can be achieved under various WIP scenarios. A presentation to the Board of Commissioners will be given by County staff at a future date once their Watershed Implementation Plan is developed so that a clear and cohesive message can be relayed regarding if and how the recommended forestry efforts fit into the Bay TMDL.

7.0 Dissemination and Outreach

Several project objectives were related to dissemination of the project results, training and outreach. First, the Center presented the study results to the County. We also updated the existing training materials for the Leafout Analysis (which include a slideshow and spreadsheet) to reflect the study findings and provided these to the County. In lieu of providing a half day training on conducting the Leafout Analysis in other watersheds, or conducting field assessments of potential forest conservation sites, the County indicated that it would be more useful for the Center to provide assistance with figuring out how the forest cover goals and strategies can be tied into the Bay TMDL goals to provide an impetus for action.

The Center conducted a multi-media outreach campaign focused on the Linganore Creek watershed to 1) increase tree planting within the watershed and 2) track the effectiveness of the various outreach mechanisms in encouraging landowners to plant trees. This shift in focus (the original objective was to develop general educational materials about the importance of forest to water quality) allowed us to realize some immediate improvement towards the forest cover goal, although it had not yet been set when the campaign was begun. The outreach campaign included:

1. A series of ads and articles published in the Frederick News Post and ads in local newsletters and church bulletins. The basic message of the ad is to plant a tree for clean drinking water and encourages folks to visit the Marylanders Plant Trees website to download a coupon for $25 off the purchase of a native tree from participating nurseries.
2. Radio ad(s) on local station Key 103. The basic ad was run during traffic and weather announcements for one week and focused primarily on promoting tree planting and the $25 coupon. A longer ad providing more info on why you should plant trees for clean drinking water was run during the prime listening time that same week.
3. A short (1 minute) video podcast was developed with a similar message as the print and radio ads. The podcast was widely broadcast through various Frederick County partners as well as social media sites such as Facebook.

The Maryland Department of Natural Resources (DNR)'s Marylanders Plant Trees program tracks participants who redeem coupons at local nurseries and will provide this data to the Center so that the number of trees planted in Spring 2011 in the Linganore Creek Watershed can be tallied. The coupons also require the user to note where they heard about the program. The Center will use this information to determine if one of the media types was more effective in encouraging watershed residents to plant trees. The data analysis will be completed in Fall 2011. The outreach materials were provided to the County and DNR for use in future outreach efforts and will also be disseminated for more general use on the Center website.

Additional dissemination of project results included:

- Presentation of the methodology used to develop the FCCs at the American Water Resources Association Spring 2010 Specialty Conference – "Geographic Information Systems and Water

Resources VI." The presentation was titled, "The Leafout Analysis as a Tool in Urban Watershed Forestry" and included a manuscript published in the conference proceedings.

- An article to be published in the Fall 2011 issue of the *Watershed Science Bulletin*, a peer-reviewed journal of the Center's membership program, the Association of Watershed and Stormwater Professionals. This article is titled, "Estimating Forest Loss with Urbanization: An Important Step toward Using Trees and Forests to Protect and Restore Watersheds."
- Presentation of the methodology and results at the 2009 and 2011 Forestry tracks of the Chesapeake Watershed Forum. The 2011 forum is scheduled to be held in October.
- Publication of an article summarizing project results in the Fall 2011 issue of Runoff Rundown, the Center's quarterly e-newsletter sent to more than 16,000 watershed professionals nationwide.
- Posting the summary article, outreach materials and Leafout Analysis training materials on www.cwp.org and www.forestsforwatersheds.org .

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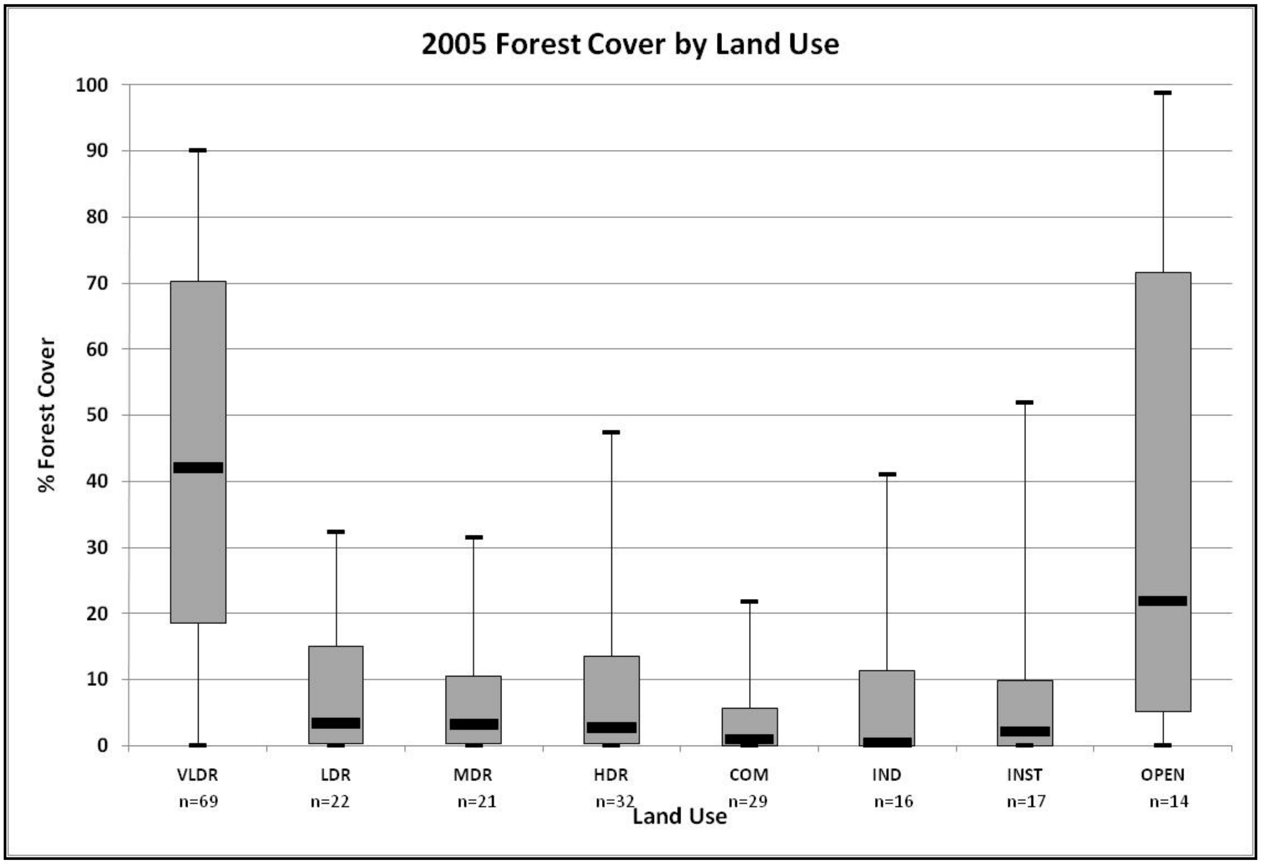
APPENDIX A: FOREST COVER COEFFICIENT STATISTICAL ANALYSIS



Note that numbers in the table below are provided as percentages

Statistic*	VLDR	LDR	MDR	HDR	COM	IND	INST	OPEN
min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q1	18.6	0.3	0.3	0.4	0.0	0.0	0.0	5.3
median	42.1	3.4	3.3	2.8	1.0	0.5	2.2	21.9
q3	70.4	15.0	10.6	13.6	5.7	11.3	9.8	71.6
max	90.2	32.4	31.5	47.5	21.8	41.2	52.0	98.8
mean	42.4	9.1	7.6	9.4	3.8	6.5	7.4	35.4
StDev	27.8	11.0	10.4	12.8	5.8	10.8	12.6	36.5
MAD	25.4	3.4	3.2	2.8	1.0	0.5	2.2	18.6
n	69	22	21	32	29	16	17	14

**min = minimum*
q1 = first quartile
q3 = third quartile
max = maximum
StDev = standard deviation
MAD = median absolute deviation
N = number of samples

Tests of Normality

Tests of Normality			
Land Use Category	**Shapiro-Wilk Test p-value**	**Jarque-Bera Test p-value**	**Normal Distribution**
VLDR	0.002	0.100	No
LDR	0.001	0.153	Maybe
MDR	<0.0001	0.042	Maybe
HDR	<0.0001	<0.0001	No
COM	<0.0001	0.000	No
IND	<0.0001	<0.0001	No
INST	<0.0001	<0.0001	No
OPEN	0.010	0.390	No

*p-value <0.05 indicates that the sample does not follow a normal distribution

*distribution determined from a combination of the results from the normality tests, as well the histogram.

Tests of Normality for INST		
Land Use Category	**Shapiro-Wilk Test p-value**	**Jarque-Bera Test p-value**
INST	<0.0001	<0.0001
Churches	0.001	0.484
Schools	0.000	0.017

Comparison between Land Use Categories

Used the Kruskal-Wallis test, which is equivalent to the Mann-Whitney U test, but allows the comparison of more than 2 samples.

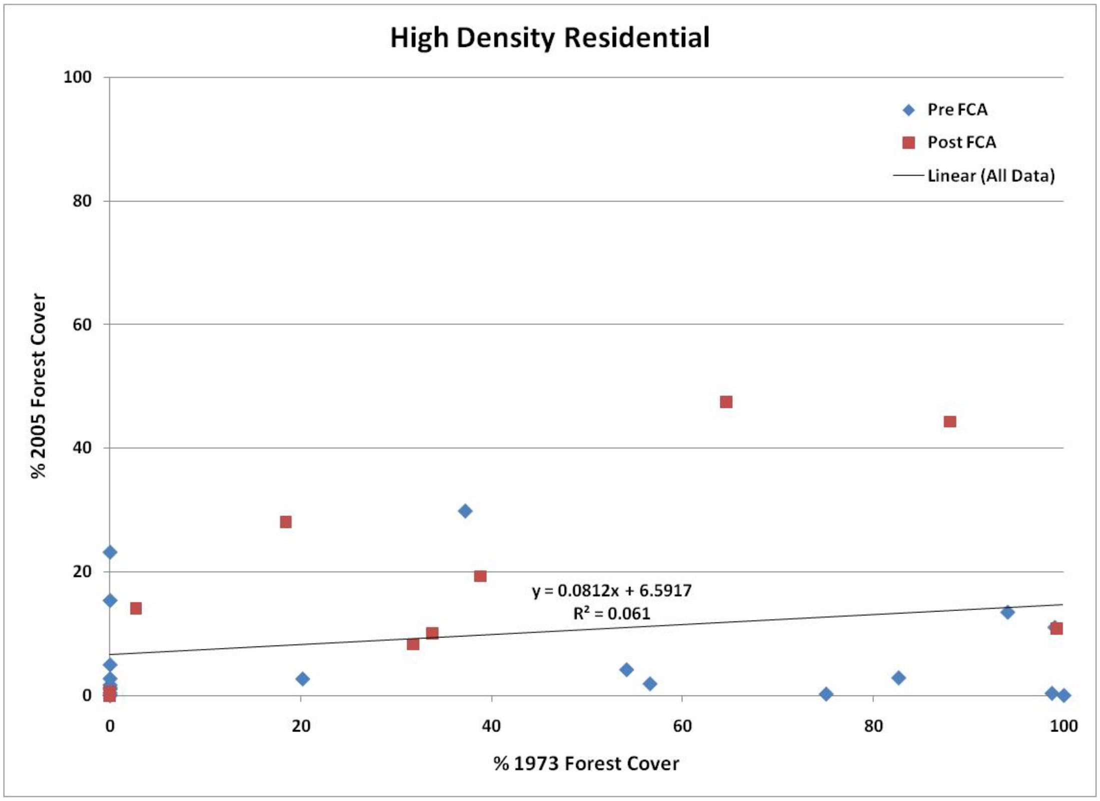
Kruskal-Wallis Test to Compare Land Use Categories		
Land Use Categories	**p-value**	**Conclusion**
LDR, MDR, HDR	0.984	The samples come from the same population
COM, IND, INST	0.564	The samples come from the same population
INST, Churches, Schools	0.523	The samples come from the same population
LDR, MDR, HDR, COM, IND, INST	0.252	The samples come from the same population

Comparison between Pre/Post Forest Conservation Act

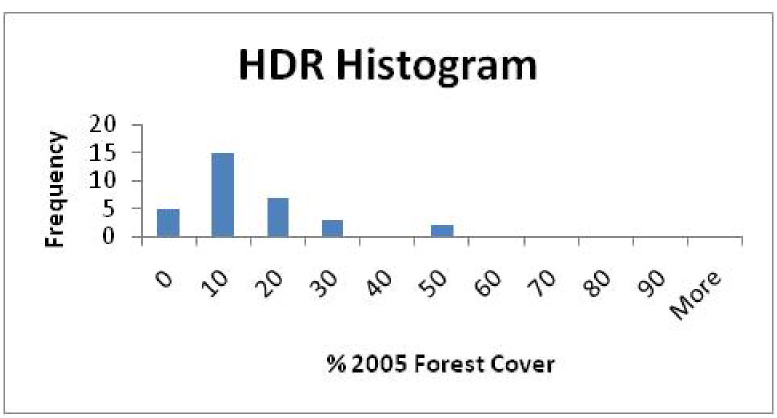
Used the Mann-Whitney U Test to compare the data pre- and post-implementation of the Forest Conservation Act.

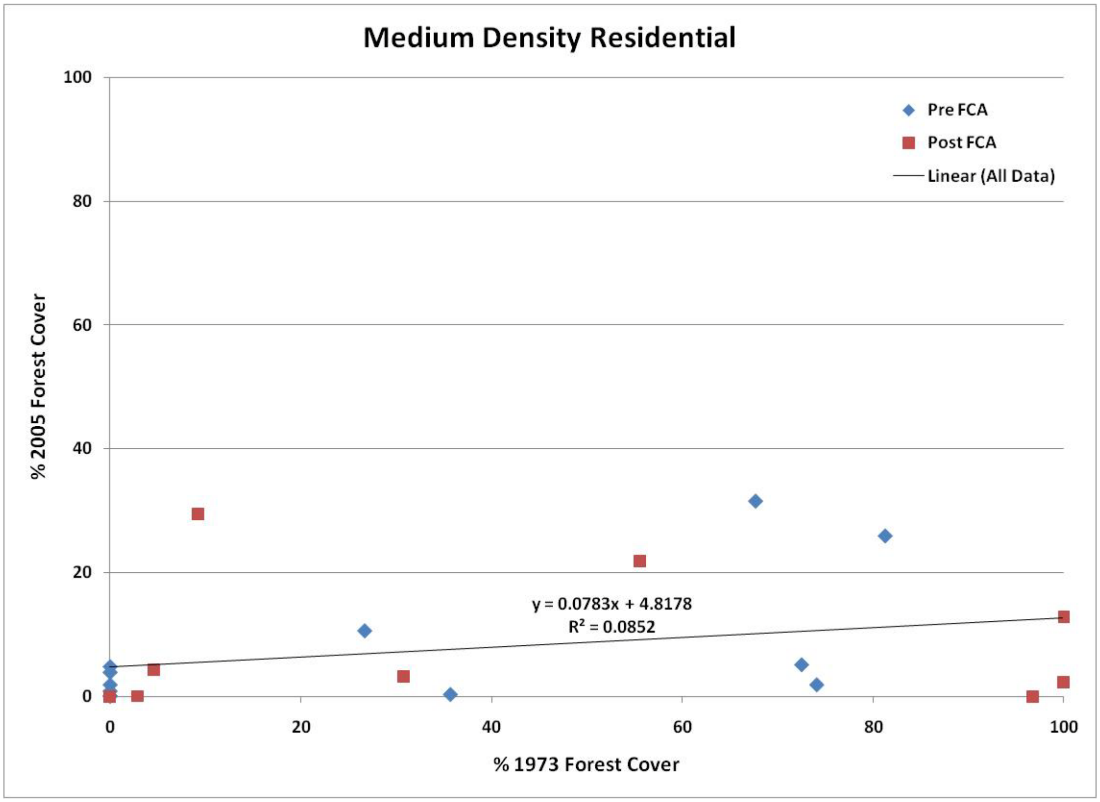
Mann-Whitney Test to Compare Pre/Post FCA Data			
Land Use Category	**# Sample Points**	**p-value**	**Conclusion**
VLDR	60 Pre 10 Post	0.574	Pre/Post VLDR data are not significantly different
LDR	18 Pre 4 Post	0.015	Pre/Post LDR data are significantly different
MDR	12 Pre 9 Post	0.858	Pre/Post MDR data are not significantly different
HDR	21 Pre 11 Post	0.080	Pre/Post HDR data are not significantly different
COM	25 Pre 4 Post	0.529	Pre/Post COM data are not significantly different
IND	10 Pre 6 Post	0.545	Pre/Post IND data are not significantly different
INST	14 Pre 3 Post	0.483	Pre/Post INST data are not significantly different
OPEN	12 Pre 2 Post	0.784	Pre/Post OPEN data are not significantly different

Comparison of Pre- and Post-Development Forest Cover and Histograms



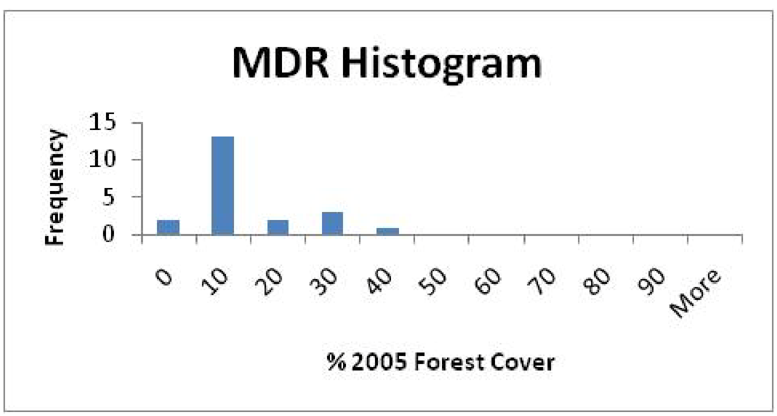
n = 32



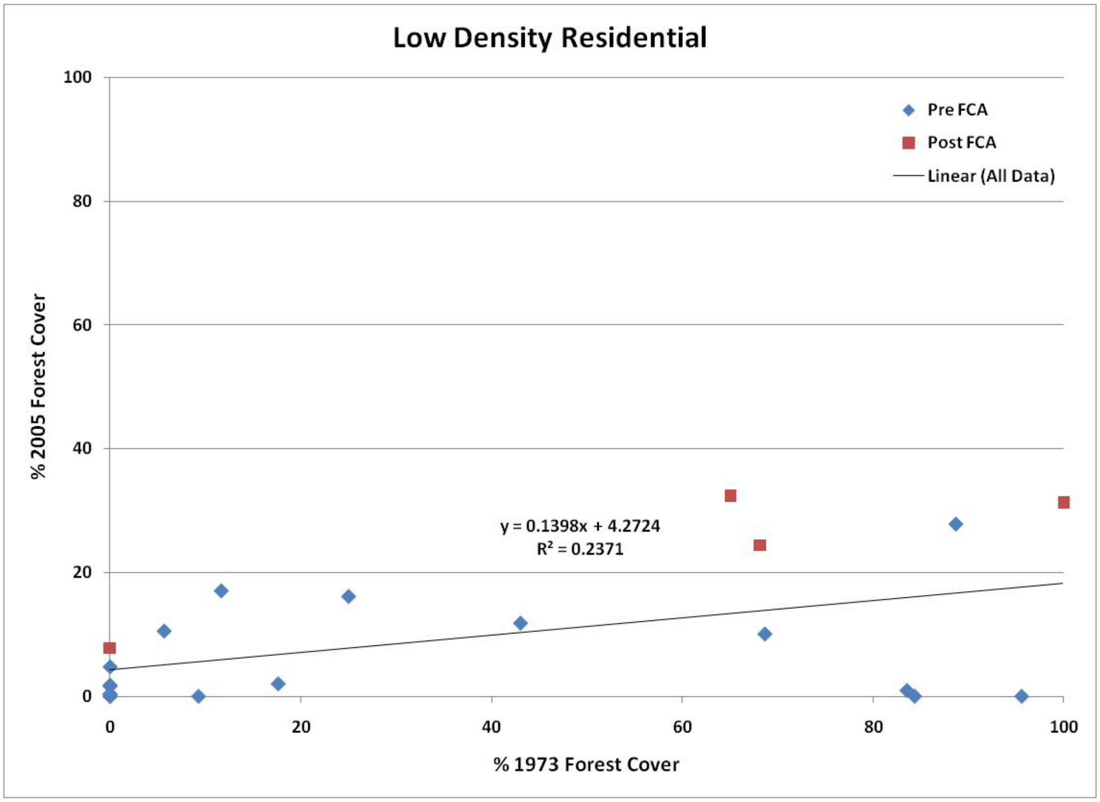


Medium Density Residential
100
80
60
40
20
0
% 2005 Forest Cover
0
20
40
60
80
100
% 1973 Forest Cover
Pre FCA
Post FCA
Linear (All Data)
y = 0.0783x + 4.8178
R² = 0.0852

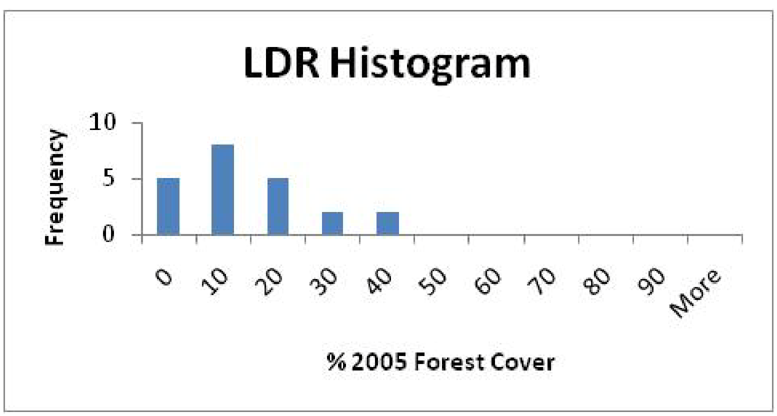
n = 21

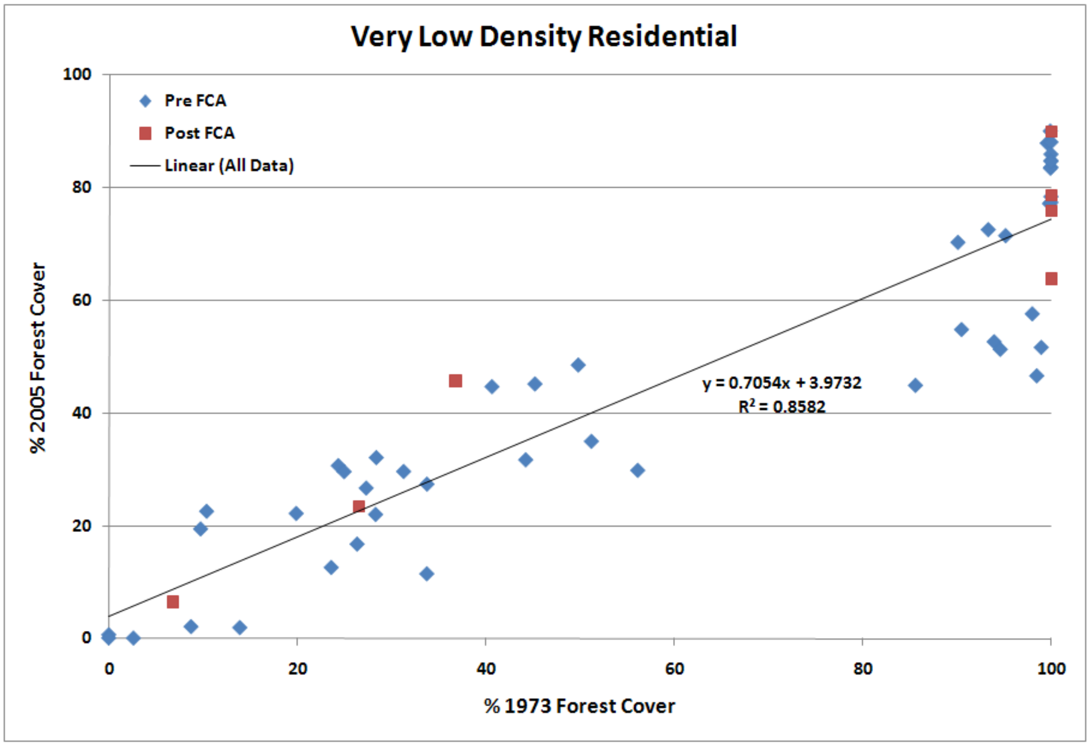


MDR Histogram
15
10
5
0
Frequency
0
10
20
30
40
50
60
70
80
90
More
% 2005 Forest Cover


Low Density Residential
100
80
60
40
20
0
% 2005 Forest Cover
0
20
40
60
80
100
% 1973 Forest Cover
Pre FCA
Post FCA
Linear (All Data)
y = 0.1398x + 4.2724
R² = 0.2371

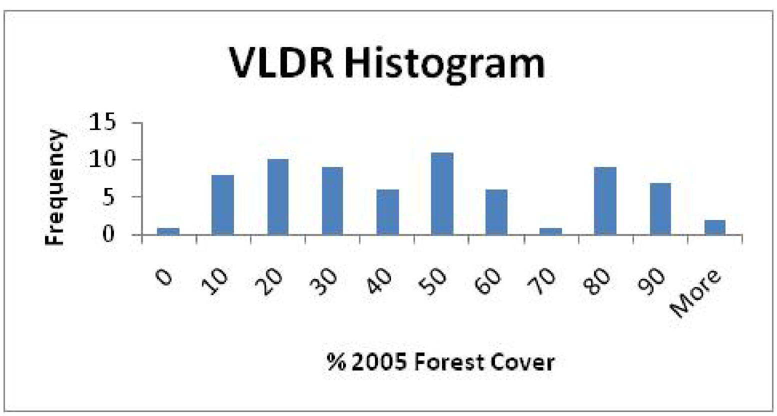
n = 22

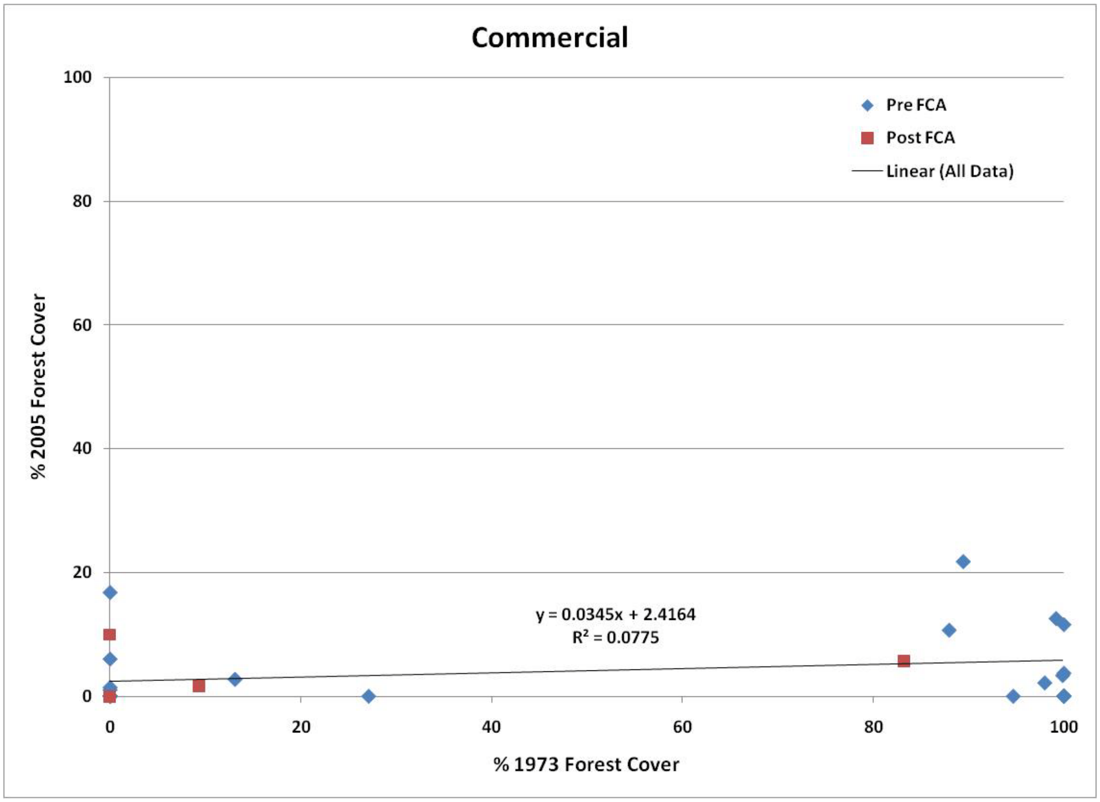

LDR Histogram
10
5
0
Frequency
0
10
20
30
40
50
60
70
80
90
More
% 2005 Forest Cover



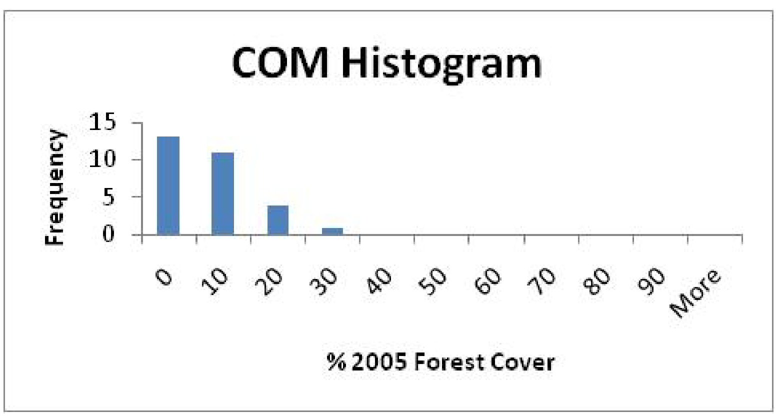
n = 53

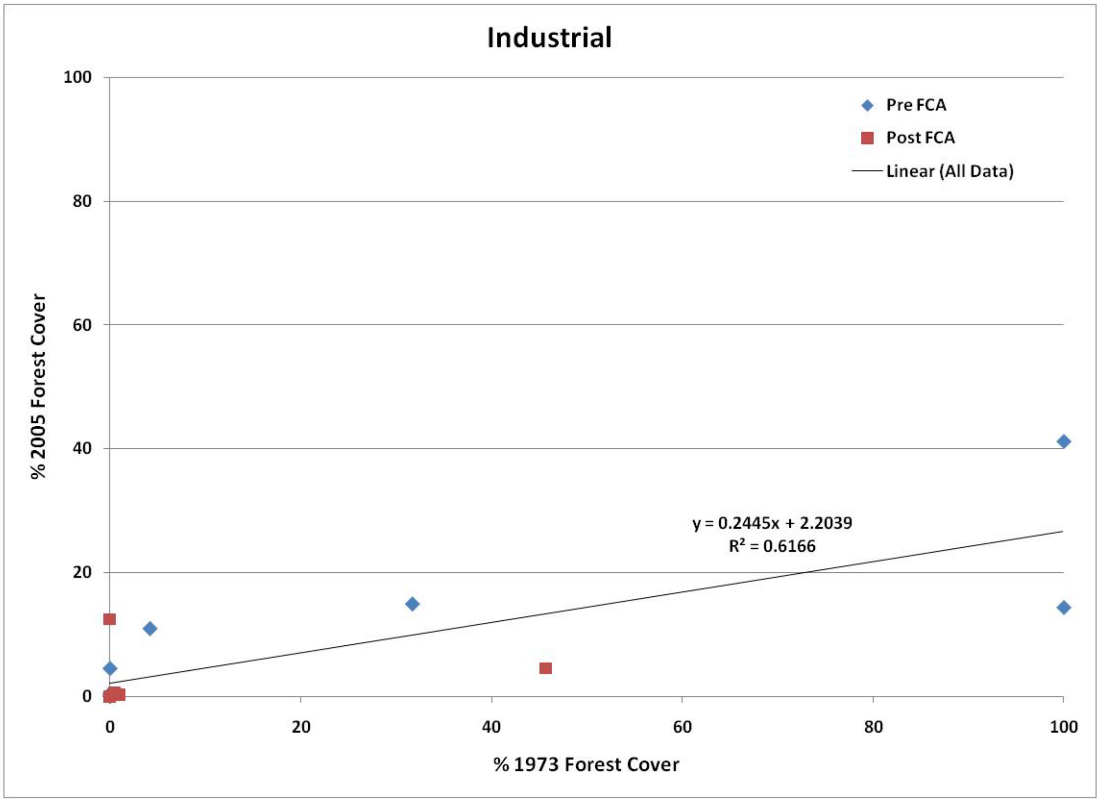
Several land use polygon samples were eliminated from the data shown on this chart, which accounts for the difference in sample size between this chart and the box and whisker chart shown on the first page of this appendix. A total of 16 outliers were removed, which showed a marked increase in the amount of forest cover between 1973 and 2005. This increase was due to the quality of the 1973 MDP land use data, which often underestimated the amount of pre-development forest cover on a sample land use polygon.



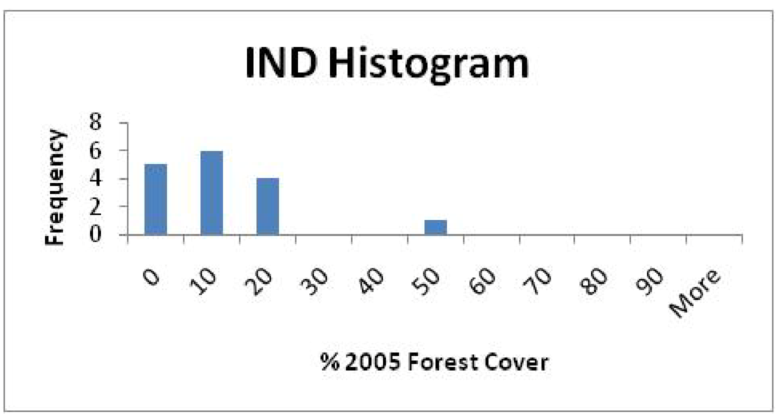

Commercial
100
80
60
40
20
0
% 2005 Forest Cover
Pre FCA
Post FCA
Linear (All Data)
y = 0.0345x + 2.4164
R² = 0.0775
0
20
40
60
80
100
% 1973 Forest Cover

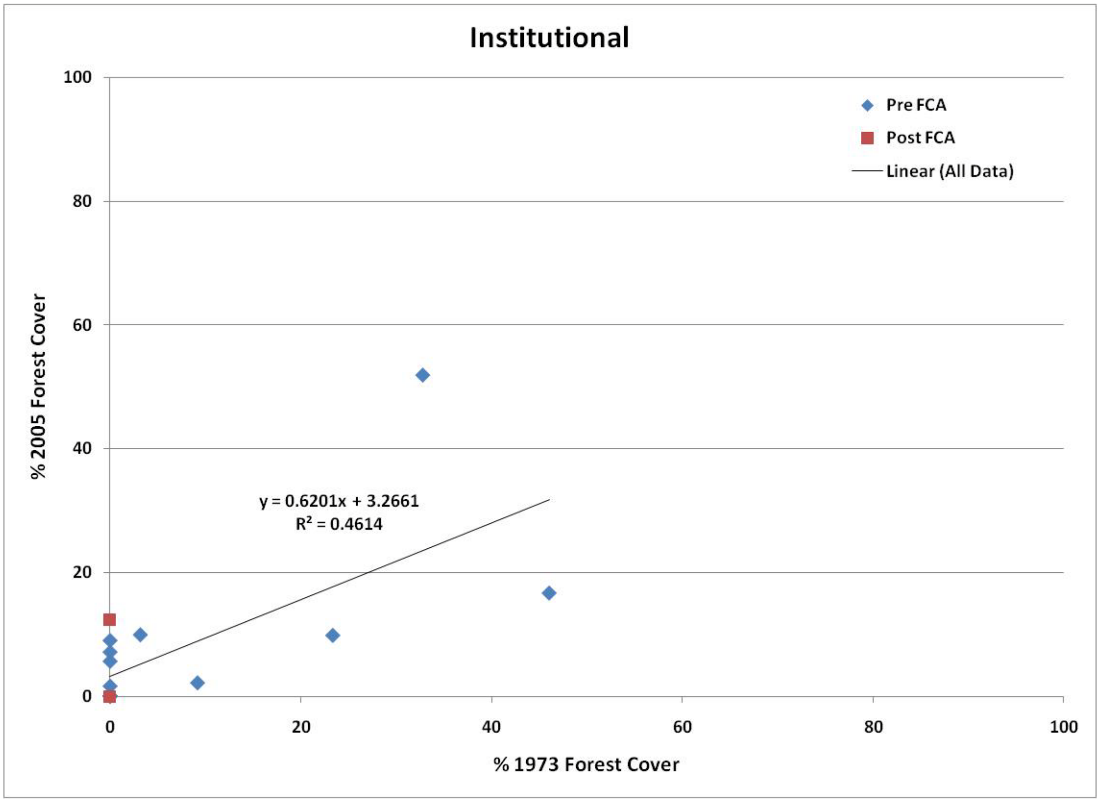
n = 29


COM Histogram
Frequency
15
10
5
0
0
10
20
30
40
50
60
70
80
90
More
% 2005 Forest Cover

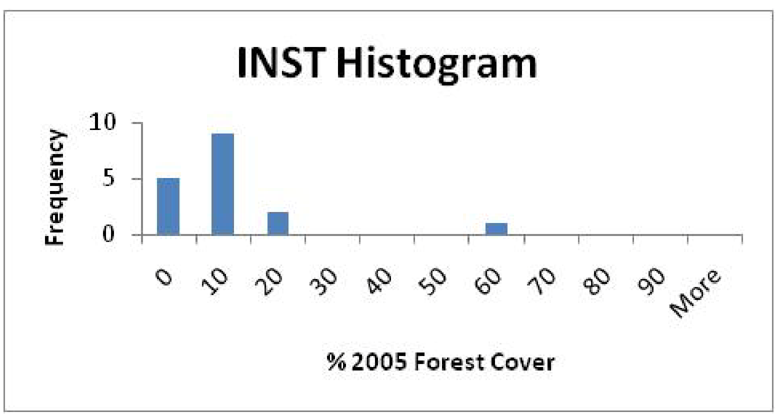

Industrial
100
80
60
40
20
0
% 2005 Forest Cover
Pre FCA
Post FCA
Linear (All Data)
y = 0.2445x + 2.2039
R² = 0.6166
0
20
40
60
80
100
% 1973 Forest Cover

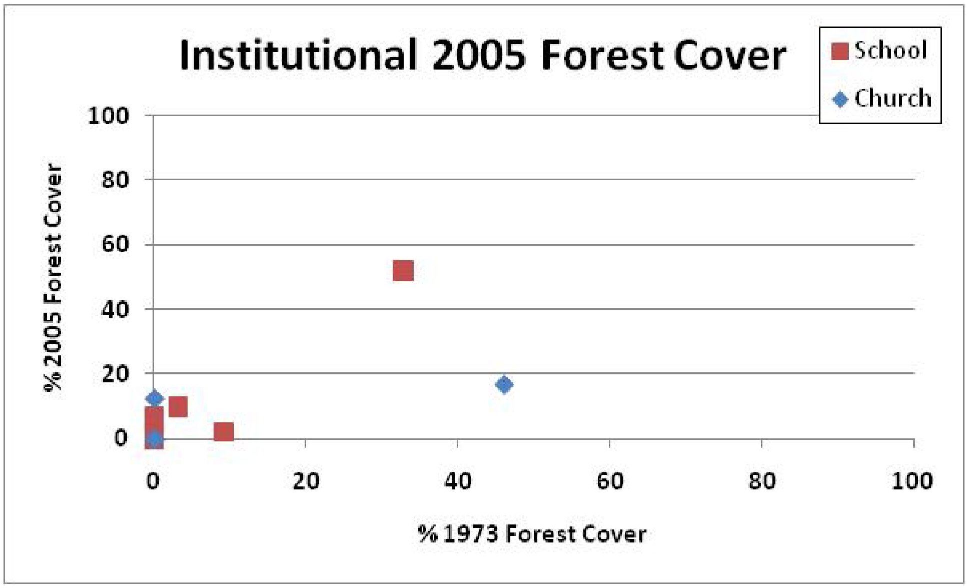
n = 16

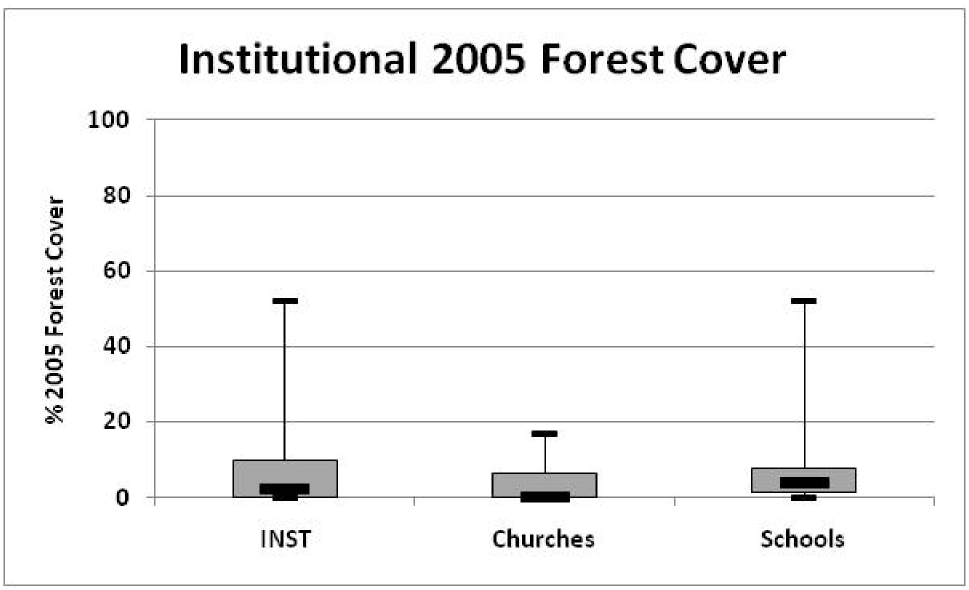

IND Histogram
Frequency
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
More
% 2005 Forest Cover

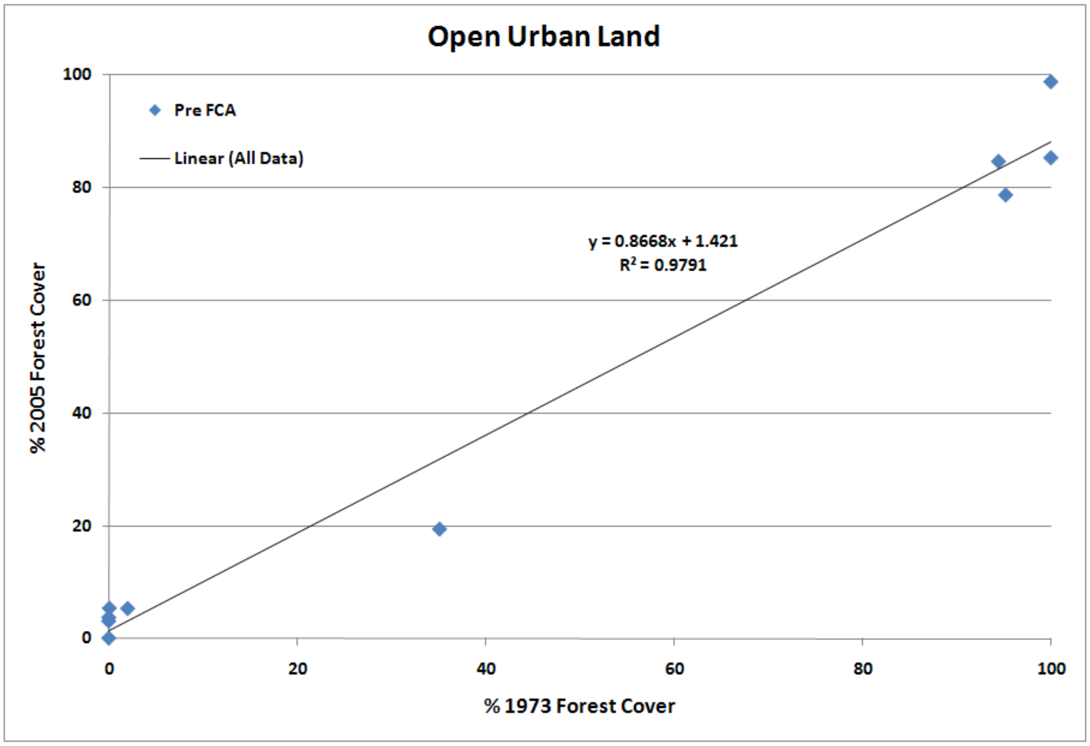

Institutional
100
80
60
40
20
0
% 2005 Forest Cover
Pre FCA
Post FCA
Linear (All Data)
y = 0.6201x + 3.2661
R² = 0.4614
0
20
40
60
80
100
% 1973 Forest Cover

n = 17


INST Histogram
10
5
0
Frequency
0
10
20
30
40
50
60
70
80
90
More
% 2005 Forest Cover


Institutional 2005 Forest Cover
School
Church
% 2005 Forest Cover
% 1973 Forest Cover
100
80
60
40
20
0
0
20
40
60
80
100


Institutional 2005 Forest Cover
% 2005 Forest Cover
100
80
60
40
20
0
INST
Churches
Schools



n = 10

Several land use polygon samples were eliminated from the data shown on this chart, which accounts for the difference in sample size between this chart and the box and whisker chart shown on the first page of this appendix. A total of four outliers were removed, which showed a marked increase in the amount of forest cover between 1973 and 2005. This increase was due to the quality of the 1973 MDP land use data, which often underestimated the amount of pre-development forest cover on a sample land use polygon.