The Economic Value of Protected Open Space

in Southeastern Pennsylvania

Produced for

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Technical Appendices

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The Economic Value of Protected Open Space

in Southeastern Pennsylvania

Technical Appendix A

The Effect of Protected Open Space on Property Values

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Methodology

The model estimating the capitalization of open space is a hedonic regression that used all arms-length transactions of land in the five-county Philadelphia metropolitan area from 2005-2009. The data was obtained from two separate sources. For the city, deeded title transfers from the City's Department of Records were merged with tax roll data from the BRT, based upon common parcel ID numbers. For the suburbs, sales data were provided from Prudential Fox Roach, based upon the universe of all broker-transacted home sales. For both datasets, each record includes detailed information on the sale date, sale price, buyer, seller, address, lot size, building size and other assorted physical characteristics.

The data was carefully screened and cleaned to remove non-arms-length sales such as transactions between family members, transactions where the buyer or seller was a state or federal government agency or bank, as well as blanket sales, nominal sales or sheriff sales. In addition, observations with missing or implausible characteristics were also dropped. From the original dataset of nearly 250,000 transactions, just over 230,000 met the criteria of being arms-length transactions with complete and accurate data, and were used in the estimation of the regression model.

Each transaction was geo-coded (assigned a unique latitude and longitude) based upon its address, and hence assigned a spatial location. The data was read into ArcView GIS along with a shapefile of protected open space in the Delaware Valley, which was provided by DVRPC. For each transaction, the distance to the nearest parcel of open space was computed by spatially joining the transactions file to the protected open space file. In addition to computing the distance for each transaction, the characteristics of the nearest open space parcel were also assigned to each transaction.

The following set of variables were then computed, and added to the basic hedonic model as the open space variables of interest:

- Distance to nearest open space (mi.)
- Acreage of nearest open space
- Dummy variable (0,1) if home is <= ¼ mile from open space

In addition, the following interaction and control variables were computed:

- Transaction year*
- Dummy variable (0,1) if home is <= ¼ mile from open space
- Planning area type: Core City, Developed Community, Growing Suburb, Rural Area

The regression used to estimate the model has natural log of house price as the dependent variable. By using the natural log of price, rather than price itself, as the dependent variable, the coefficients have the interpretation of being the percent change, rather than dollar change, in the price of a home as a result of a change in the independent variables. This makes the valuation less sensitive to price inflation (or deflation) over time, which certainly occurred during the 2005-2009 period.

The model is estimated by regressing the dependent variable on a vector of control variables, plus the open space variables of interest. The control variables include house size, lot size, age of dwelling, distance from CBD, density, county, year and quarter of sale, among others. There are more than thirty control variables. The resulting R-squared of the model ranges from 64% to 71%, which indicates that variation in the model's variables explain 64-71% of the variation in house values in the Philadelphia region (100% indicates a perfect regression). This is a reasonably high R-squared for a hedonic house value regression because there are many unobserved characteristics of the dwelling that are not recorded in the data.

The effect of open space on house values is obtained from the estimated coefficients on the open space variables in the regression. They give the % change in house values, given a unit change in the value of the open space variable. For example, the estimated coefficient on distance-to-open space indicates what the average % change in house prices for each additional mile further from open space, controlling for other housing characteristics. Lastly, the t-values of each coefficient are obtained, which indicate the strength of the statistical association between house values and the independent variables. A value greater than 1.96 or less than -1.96 indicates a “statistically significant” (i.e. strong and non-random) relationship.

To obtain the aggregate effect of open space, these regression results were applied to the entire housing stock of the region. Total housing units and median house value by Census Block Group were obtained from GeoLytics, which is updated from the U.S. Census. Where the number of vacant units in each block group was large, only occupied housing units were counted. For each block group, the distance from the centroid to the nearest open space parcel was computed with the assistance of ArcView GIS. The regression results were then applied to each parcel’s distance from open space to compute the percent increase in home values attributable to proximity to open space. This percentage was then multiplied times the median house value to obtain the median dollar value of a home’s proximity to open space. This was then multiplied times the number of homes in each block group to obtain the total value of proximity to open space. Lastly, the average county-level property tax rate was applied to the total value to obtain the total additional tax revenue generated by this additional value. These results are further aggregated to be reported at the county and planning area levels.

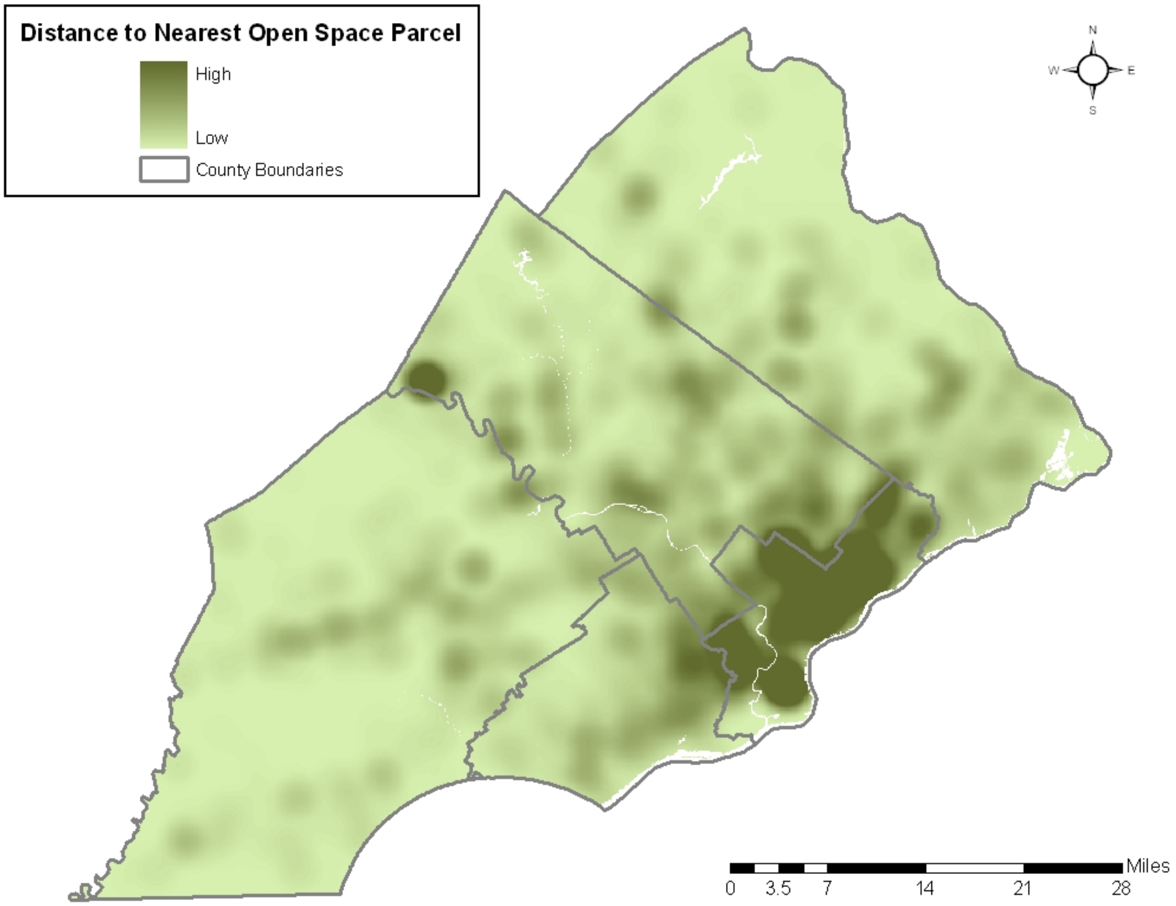
Results I: City homes are actually more proximate to protected open space than suburban/rural homes.

The below map shows the five counties of southeastern Pennsylvania, color-coded by the density of proximity to protected open space. Average distance-to-open-space was computed for every grid point in the region using the home sales data, and the results are displayed in the map. Darker shades of green denote relatively short distances to the nearest open space parcel, while lighter shades of green denote relatively further distances to open space.

As the map indicates, city homes have a relatively shorter distance to open space than suburban or rural homes. The reason for this has to do with the greater density of both housing and open space in Philadelphia than outside Philadelphia. There are more protected spaces in the city than out, and there are more homes located near these spaces in the city than out.

While this may seem to be a somewhat counterintuitive result, it should be interpreted with care. First, it does not mean that there is a greater quantity of open space in the city than outside of it; merely that that there are more parcels. Non-urban areas may have fewer open space parcels, but they are on average larger than the open space parcels in urban locations. Secondly, protected open space should not be conflated with all open (i.e. undeveloped) space. While the non-urban areas may have fewer protected parcels, they certainly have more overall open space. Indeed, by mere virtue of the lower density of development, individual dwellings outside of the city have larger yards, and hence more green space, than urban dwellings. However, it is worth noting that proximity to protected open space is higher in the city than outside of it.

Figure A.1



Results II: The value of proximity to open space is positive and significant.

The following tables give the first set of regression results, showing the value of proximity to protected open space.[i] The regressions are estimated separately for city homes versus suburban homes to examine for the possibility that the value of proximity to open space may be different for city versus suburban households.

Figure A.2

Philadelphia County Regression
N=100,457, R-sq=0.64

Variable	Label	Est. Coeff.	S.E.	t Value	Pr > |t|
Intercept		6.65084	0.1563	42.55	<.0001
qtr_mi_5	dummy=1 if <=1/4 mile from open space >=5 acres	0.06922	0.00963	7.19	<.0001
dist_ospace_5	distance to open space (mi.) >=5 acres	-0.29739	0.0577	-5.15	<.0001
ospace_acres	acreage of nearest open space	0.00002143	1.01E-05	2.12	0.0339

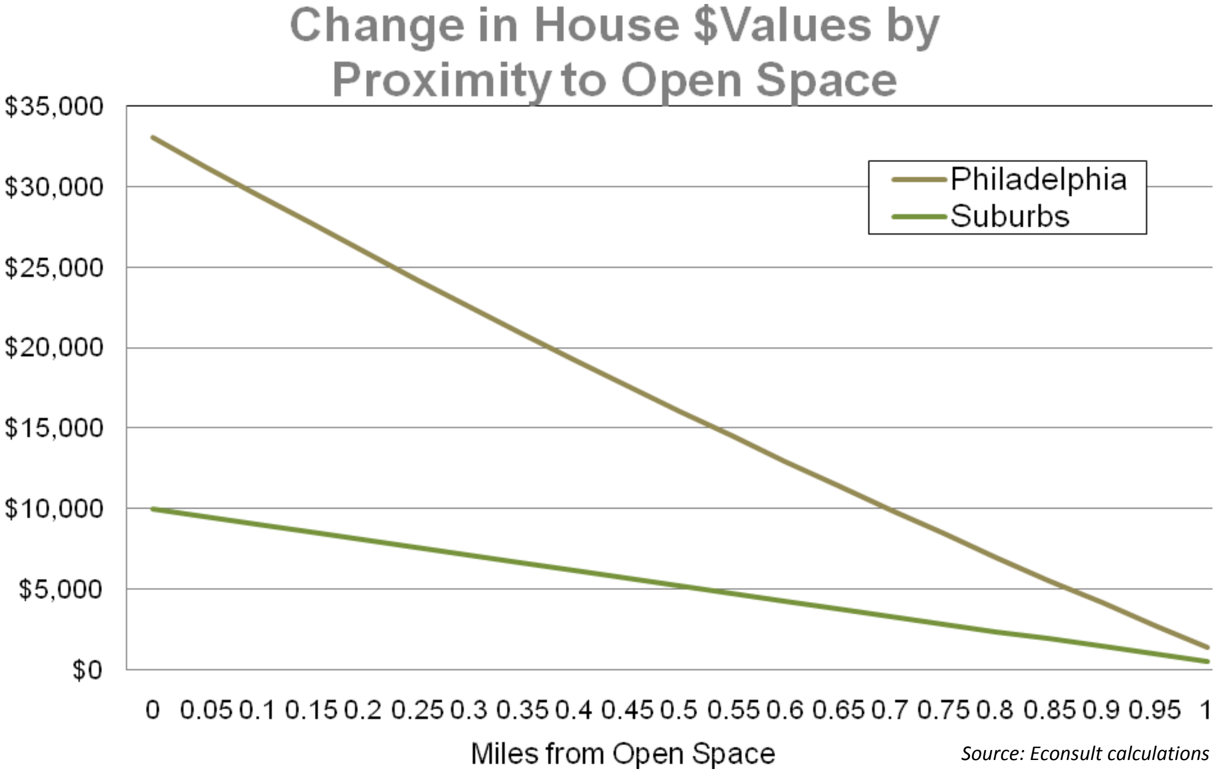
Source: Econsult calculations

The estimated coefficients show how the value of open space is capitalized into house values, while the t-values indicate the statistical "strength" of this relationship. Being within a quarter mile of protected open space is associated with an approximately 7% increase in home values in the city and a 5.5% increase in home values in the suburbs, respectively. As proximity to open space declines, so too do house values. At a distance of one mile from open space, home values decline nearly 30% in the city and 3.6% in the suburbs, respectively. The size of the nearest parcel of protected open space also matters. Each additional acre of open space is associated with an increase in home values of .002% in both the city and suburbs. Lastly, all of these relationships meet the threshold of statistical significance. Each of these will now be explored in further detail.

Results III: Open space is more valuable to city residents

To convert the value of open space from percentages to dollars, the coefficients from the regression were applied to the 2009 median house value in the city and suburbs, respectively. The following chart shows the approximate dollar change in house values as a function of distance to protected open space.

Figure A.3



Source: Econsult calculations

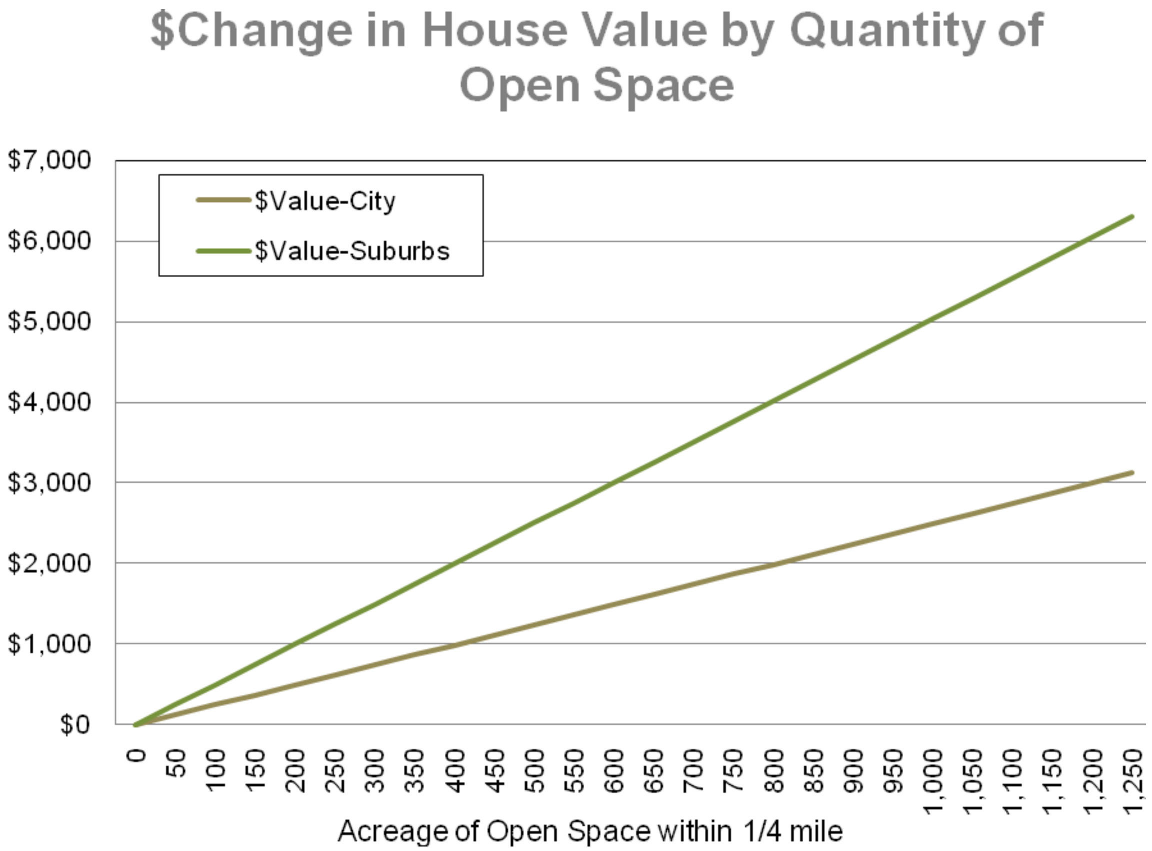
For a city home that is immediately adjacent to open space, there is an average increase in its value of $35,000, relative to comparable homes that are not near (>1 mile) open space. This declines to $15,000 within ½ mile of proximity, and attenuates to zero at one mile. For suburban homes, the value of immediate adjacency is $10,000, declining to $5,000 within ½ mile and attenuating to zero at a distance of one mile. Since these results control for other characteristics and location of dwellings, they indicate that proximity to open space is indeed associated with higher house values. Moreover, the results indicate that the value of proximity is higher for city homes.

A likely reason for the higher value to city homeowners is that, where an amenity is relatively scarce, it has a greater value. Since dense urban environments have less open space in general, the value of proximity to it is higher than in more rural areas where open space exists in greater abundance. This is further supported by the fact that house values in Philadelphia are, on average, less than those in the suburbs. So, the fact that open space not only has a higher percent value but also a higher dollar value in the city is consistent with the notion that its relative scarcity is what is driving this result.

Results IV: Proximity to open space is more valuable than quantity of open space

To examine how house values might change in response to the quantity of open space nearby, we apply the regression coefficients on size to the median house value in the city and suburbs, and then vary the total quantity of open space. The results are shown in the following table, which show the dollar increase in house values as the total acreage of open space increases.

Figure A.4

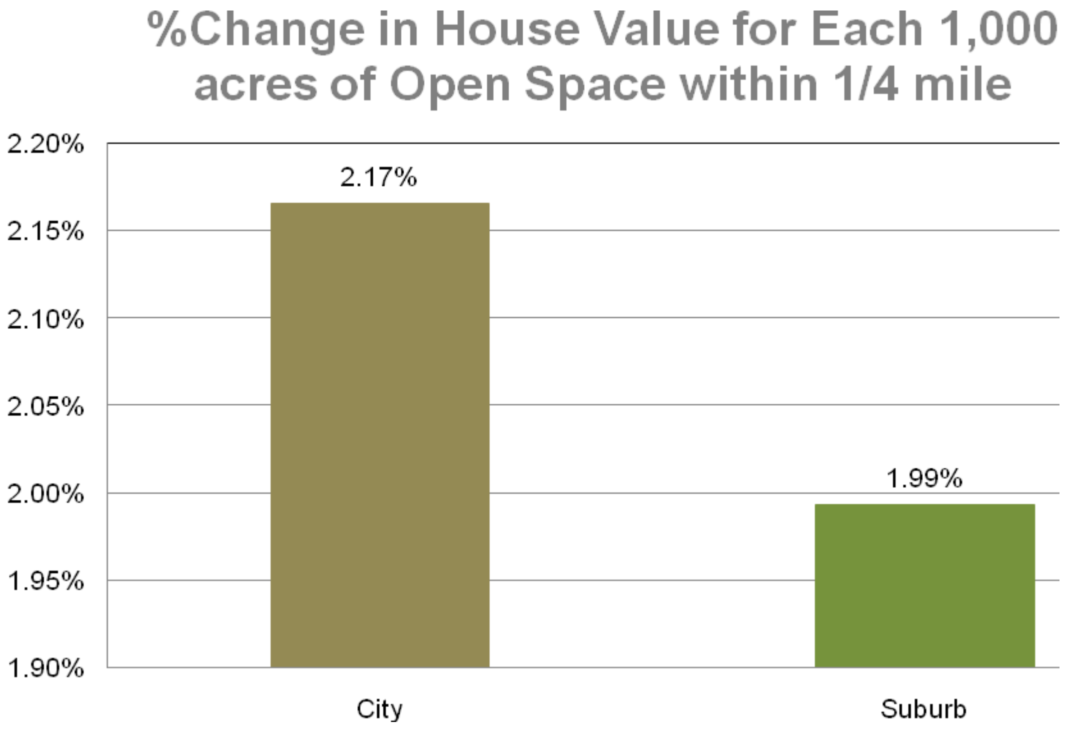


Source: Econsult calculations

The results indicate that it takes very large quantities of protected open space to have a meaningful impact on house values. If the quantity of the nearest parcel of open space is increased from one acre to five hundred acres, the associated increase in house values is only $1,239 in the city and $2,505 in the suburbs. At 1,000 acres, the effect is still relatively small. The incremental increase in house values is only $3,122 in the city and $6,300 in the suburbs.

Since these effects seem relatively small compared to the effects of proximity discussed in the previous section, it may be worth examining if they vary with distance. To do this, we examine what the percent increase would be for just homes within a 1/4 mile of protected open space. The results are shown in the following chart.

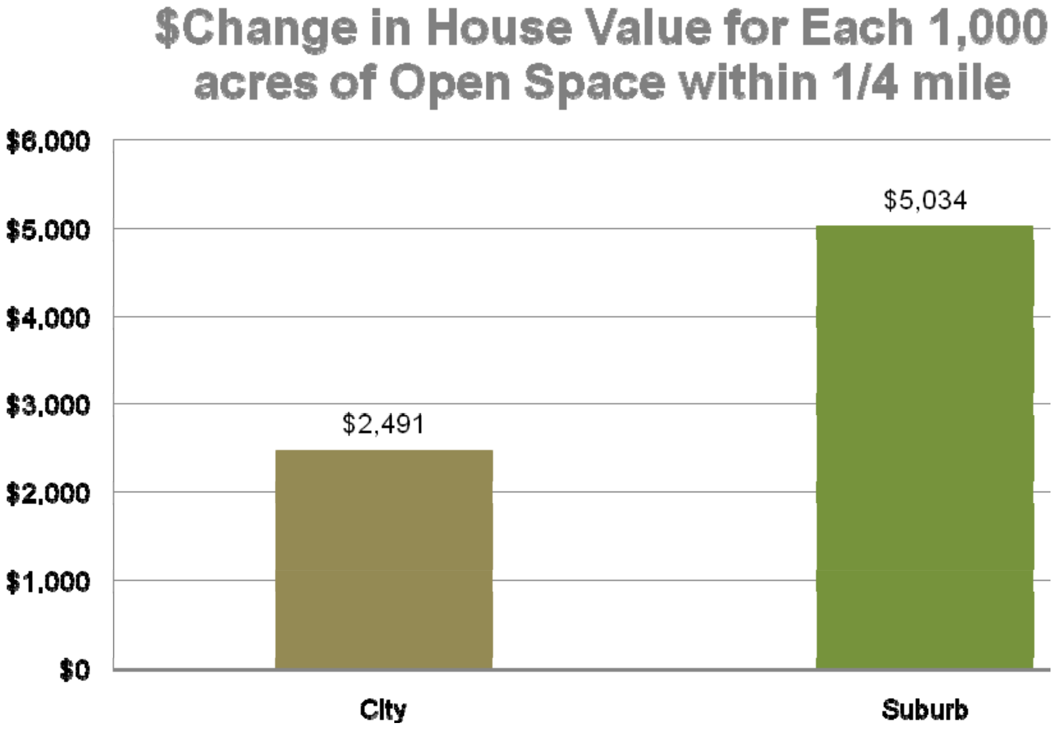
Figure A.5



Source: Econsult calculations

In the city, the associated increase in house values would be 2.17%; while in the suburbs, it is just below 2%. Applying this to the 2009 median house price in both locations converts this to dollars, and is shown in the following chart.

Figure A.6



Source: Econsult calculations

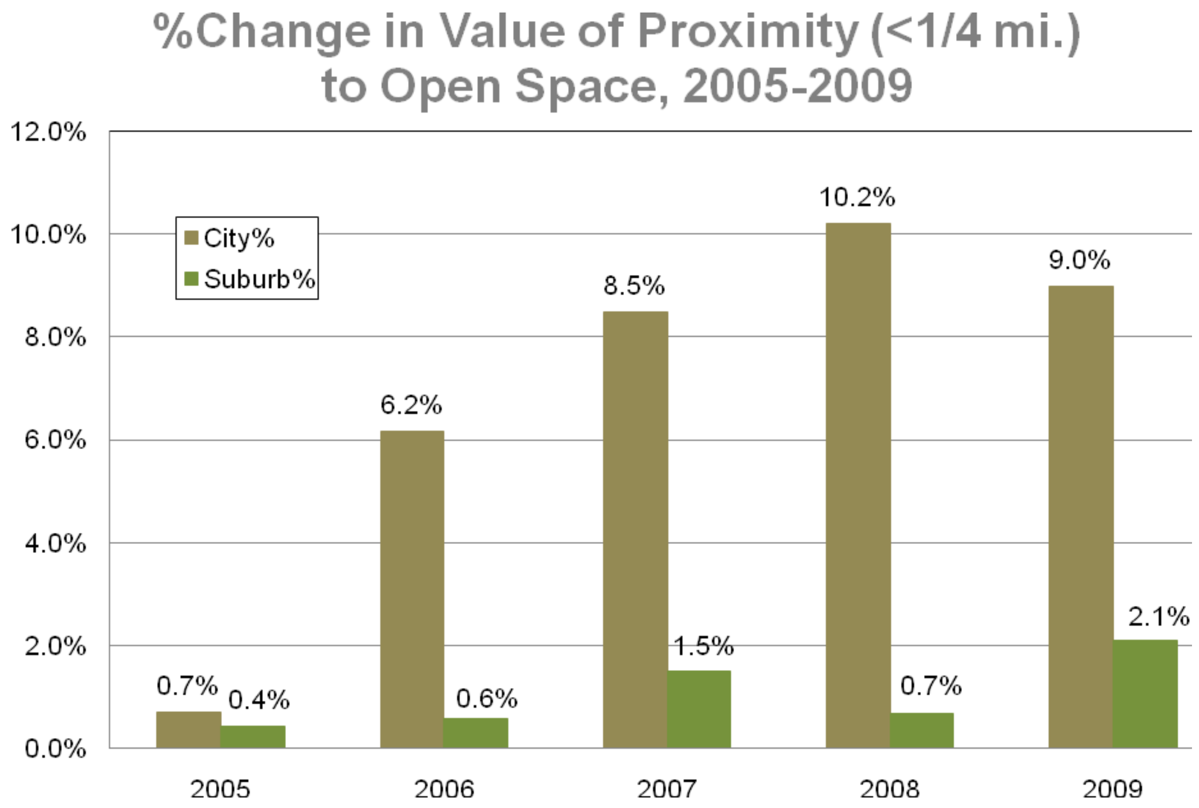
For a city home within a ¼ mile of 1,000 acres, the associated increase in value is $2,491, while in the suburbs it is $5,034. Although the percent increase in the city is larger than in the suburbs, the dollar increase is smaller because house prices in the city are, on average, significantly less than in the suburbs.[ii]

These results may initially seem counterintuitive when compared with the results in the previous section, which showed much larger increases in house values for proximity to open space. However, it should be noted that these effects are *in addition to* the dollar increase in house values associated with proximity, not *in place of*. Since the regression simultaneously estimates the value of proximity and the value of quantity, it jointly measures the effects of each while controlling for the other. So the increases associated with quantity are in addition to the increases associated with proximity. For example, if a suburban home is within ¼ mile of a 1,000 acre parcel of open space, its total increase in value is $7,559 due to proximity (being within a ¼ mile of open space), plus an additional $5,034 due to the size (being near such a large parcel), for a total gain in value of $12,593.

Results V: The value of proximity to preserved open space has been increasing in recent years.

To uncover further detail in the value of open space, the calculations interacted the proximity variables with the variables indicating in which year the homes sold. These results indicate how the relative value that homeowners place on proximity to open space has evolved over time. The results are given in the following chart.

Figure A.7

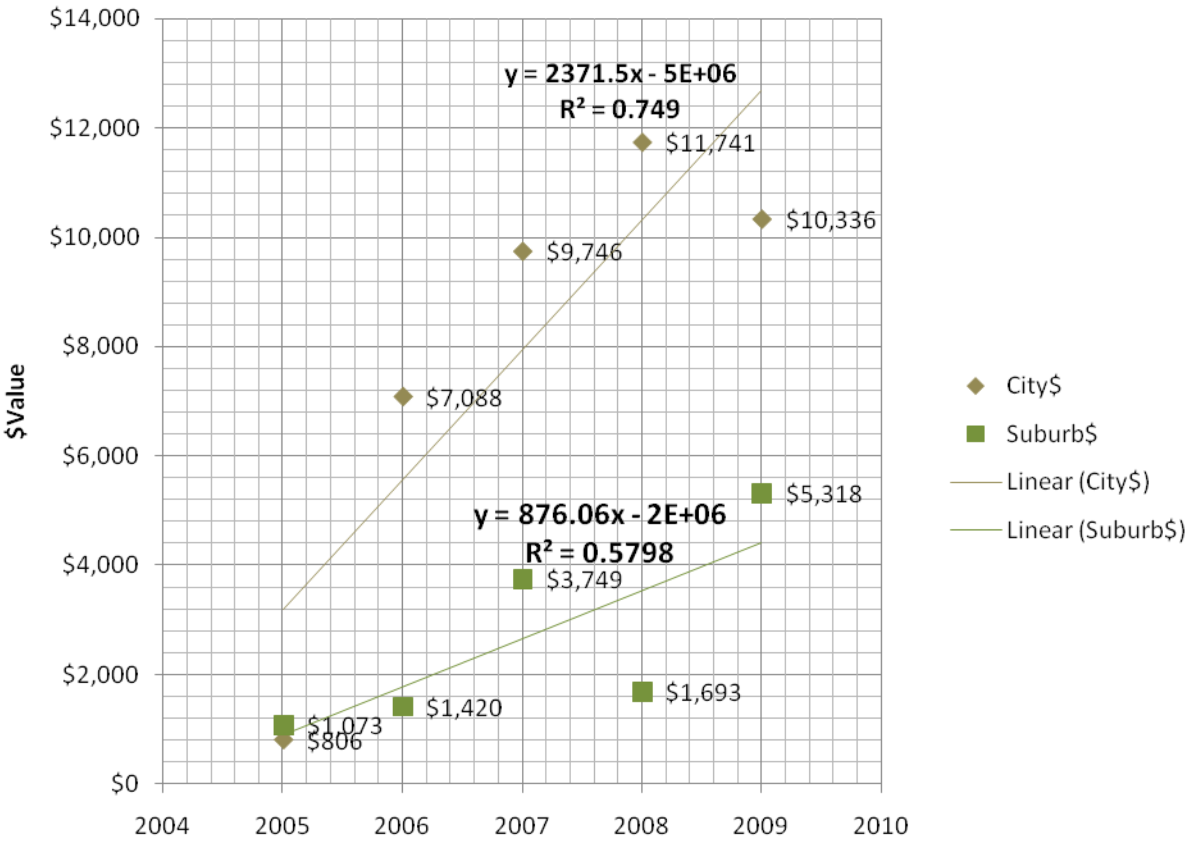


Source: Econsult calculations

The results indicate that the general value of open space has been increasing over time, and this is especially so in the city. In 2005, being within a ¼ mile of preserved open space was associated with a 0.7% and 0.4% increase in house values, in the city and suburbs respectively. By 2009, the same proximity was associated with a 9.0% and 2.1% increase in house values, respectively.[iii] This general upward trend may be due to a number of factors. Among them could be: a greater ecological consciousness and appreciation of environmental amenities (e.g. the "green" lifestyle movement and/or concern for climate change), a renewed interest in urban living among young homeowners that drives up demand in areas where open space exists in relatively scarce amounts, or improved maintenance and investment in the region's open spaces, especially parks.

While the reasons behind the increased values which homeowners have been placing on proximity to open space may vary, it is important to formally identify whether this trend is meaningful or merely spurious. To test this, a regression of the dollar value of open space on a time trend variable was conducted to see if the increase is truly "significant" (meaningfully different from zero) in a statistical sense. The results are shown in the following chart, with the estimated regression lines plotted against the data points in each year.

Figure A.8



Source: Econsult calculations

In the suburbs, the value of proximity (<¼mile) to open space has been rising by an average of $876 per year from 2005 through 2009. In the city, the value has been rising by an average of $2,732 per year. The t-scores for both variables exceed 1.96, which indicates that this increase is statistically meaningful and not illusory. This is further supported by the relatively high R-squareds of both regressions (58% and 75%, respectively), which is especially notable considering that both the number of variables and number of data points are quite small.

Results VI: The value of open space is robust to the type of open space and location, but can vary significantly.

To add further detail to these results, we were asked to examine how capitalization of open space into house values might vary with the qualitative characteristics of open space and the type of communities in which they were located.

To examine the first part, the DVRPC and GSA selected seven representative open space parcels from the portfolio of all open space parcels. They vary in size, location and type of use. They are displayed in the following map, with labels and ¼ mile buffers surrounding them.

Figure A.9

Source: Econsult Corporation

To estimate the value of proximity, we expanded the regression specification to include dummy variables (which take a value of 0 or 1) that denote a home sale within a ¼ mile of each of the seven sites. A separate dummy variable was created for each site. All results were significant at the 5% level. The only exception was Glenolden, which was close to being significant and is likely due to the relative paucity of valid home sales within ¼ mile. The same procedure in which the estimated coefficients were applied to the median house prices in the city and suburbs was done to convert the value of proximity from percentages to dollars. The results are given in the following chart.[iv]

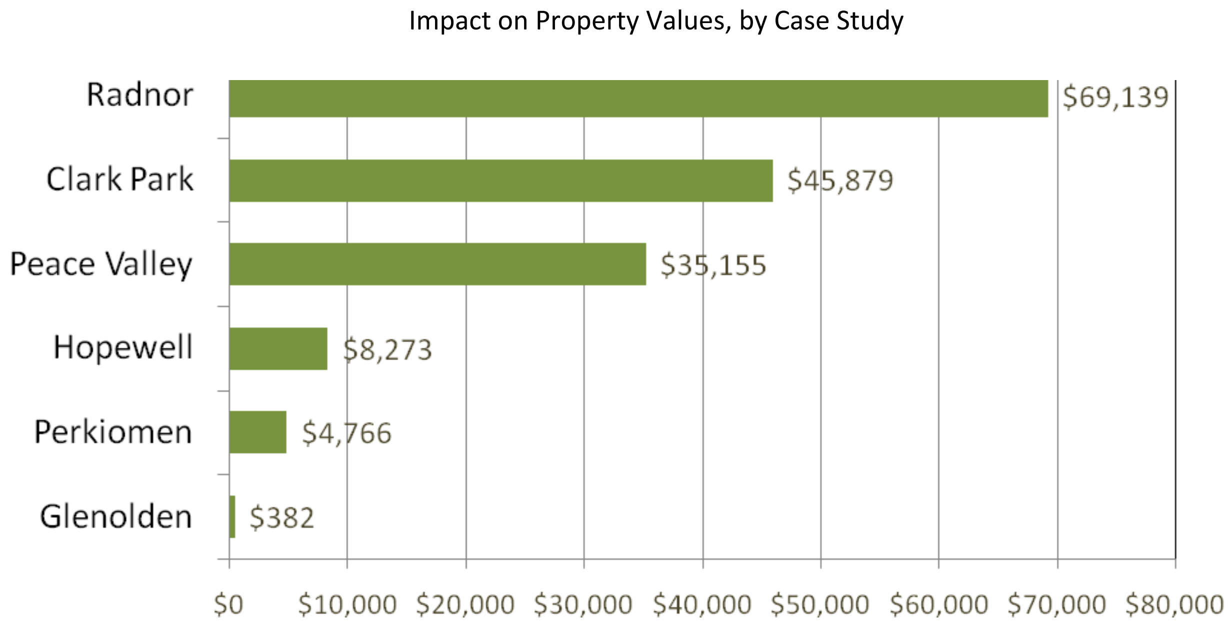

Impact on Property Values, by Case Study

Figure A.10

In all cases except one, the effect of being within a ¼ mile was positive and significant. The largest effect was in Radnor, where being within a ¼ mile of the Radnor Trail was associated with an incremental increase in house value of $69,139.[v] Next was Clark Park (+$45,879), then Peace Valley (+35,155), Hopewell (+$8,273), Perkiomen Trail (+$4,766) and lastly Glenolden (+$382), which is not considered large enough to be significant. The results generally indicate that proximity is usually positively capitalized, albeit with much variation. Because property value impacts associated with agricultural uses vary so greatly with different types of agricultural activities, a property value analysis for the Honey Brook case study would not be representative of and is therefore not included.

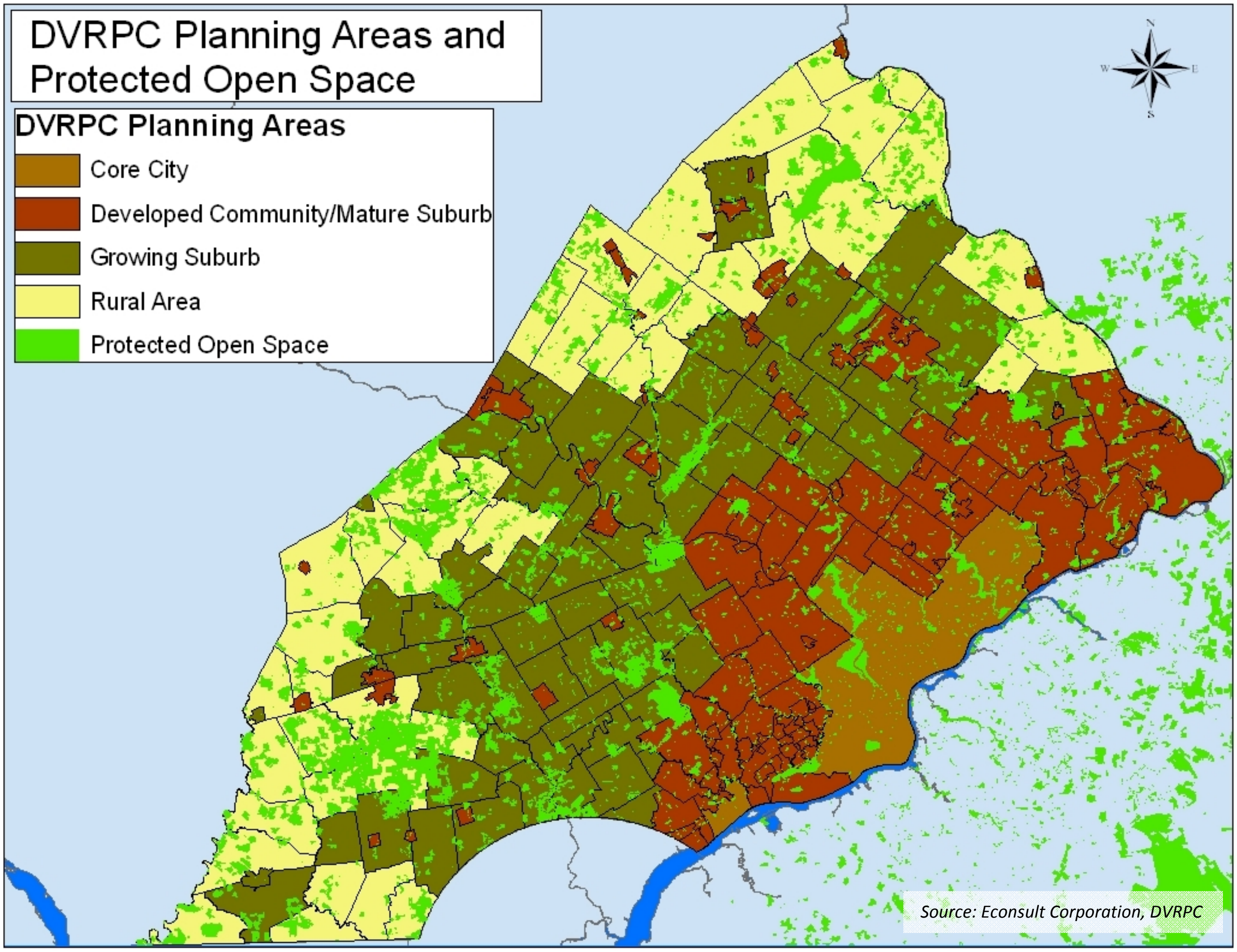
Next, the analysis examined the effects of proximity variation with the type of community in which the open space parcels are located. This analysis makes use of DVRPC data classifying each municipality in the region into four categories:

- "Core City"[vi]
- "Developed Community"
- "Growing Suburb"
- "Rural Area"

Source: Econsult calculations

The following map shows each municipality, color-coded by its classification, along with the open space parcels in the portfolio (in green).

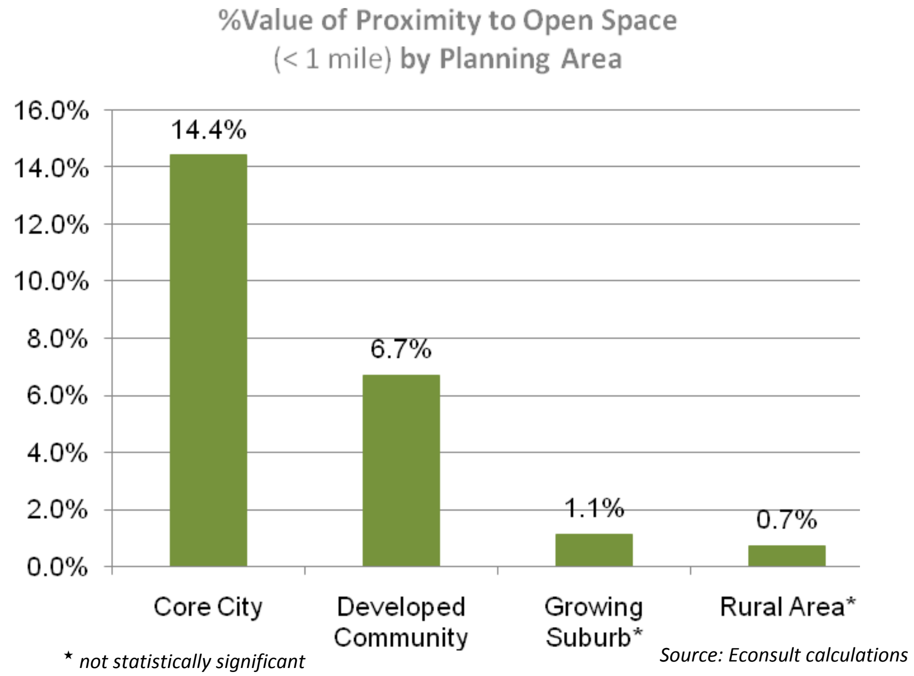
Figure A.11



Source: Econsult Corporation, DVRPC

To estimate the effect that the classification might have on the value of open space, the ¼ mile proximity dummy variables were interacted with dummy variables denoting the type of planning area. The results are shown in the following chart.

Figure A.12



* *not statistically significant*

Source: Econsult calculations

All results were positive, but only the variables for Core City and Developed Community were statistically significant. Proximity to open space (being within one mile) is associated with a 14.4% increase in house values in Core Cities, and a 6.7% increase in house values in Developed Communities. These results are consistent with city-v.-suburb results presented earlier, and provide further support to the notion that open space has a higher value where it is relatively scarce. Moreover, the fact that the results were not statistically significant for Growing Suburbs and Rural Areas does not necessarily mean that open space has no value in those locations. Rather, it may very well be the case that the low density of development and relative abundance of undeveloped land in those communities means that the marginal effect of additional preserved space is negligible. So, where there are large quantities of open space that do not appear to be under imminent threat of development, the value of designating some parcels for preservation is relatively low compared to areas where either the quantity of open space is small and/or the probability of development is large.

Results VII: The economic and fiscal value of open space is meaningful.

To understand what these individual impacts mean for the entire region, these values were aggregated upwards by applying these results to the total housing stock of the region. From the U.S. Census, the total number of occupied housing units was obtained for each county in the most recent year available (2008). This was multiplied by the average house value in each county, which was obtained from the sales data used in the regressions, to obtain a total value of the housing stock. The percent of home sales within one mile of open space in each county was applied to total housing stock in each county to identify what percentage of the housing stock was affected by proximity to open space. The regression results were then applied to the value of the impacted housing stock to impute the percent of this value attributable to open space, which was then multiplied by the aggregate value to obtain the total dollar value of proximity to open space. The respective assessment and property tax formulas in each county were applied to obtain the incremental property tax revenue generated by the value of open space. Lastly, these numbers were divided by the total number of households in each county to identify what these economic and fiscal values mean to the average household. The results are given in the following table.

Table A.1

Total Economic and Fiscal Value of Proximity to Open Space, by Geography

Geography	# Housing Units	Total $Value of Open Space	Total Property Tax $Value of Open Space	Total $Value/ Household	Property Tax $Value/ Household
Bucks County	245,000	$2,474,442,734	$39,789,042	$10,100	$162
Chester County	189,000	$2,090,385,914	$34,177,819	$11,060	$181
Delaware County	222,000	$1,993,566,511	$41,446,245	$8,980	$187
Montgomery County	317,000	$3,263,326,083	$52,311,121	$10,294	$165
Philadelphia County	659,000	$6,433,499,151	$59,831,548	$9,763	$91
5-County Region	**1,632,000**	**$16,255,220,393**	**$227,555,775**	**$9,960**	**$139**

Proximity to open space increases the value of the region's housing stock by an estimated $16.3B, according to these results. The county with the largest single share of this value is Philadelphia, where the presence of open space increases the value of its housing stock by an estimated $6.4B. This is especially notable in light of the fact that Philadelphia has both the smallest share of open space acreage and the lowest house values of the five counties.

The additional property taxes generated by this value are $227.6M annually, with Philadelphia again having the single largest share of any county.[vii] For the typical household, this translates to an additional $9,960 in housing wealth and $139 in annual property taxes.

These analyses were also conducted by Planning Area. The results are given in the following table.

Table A.2

Total Economic and Fiscal Value of Proximity to Open Space, by Planning Area

Planning Area	# Housing Units	Total $Value of Open Space	Total $Tax Value of Open Space	Total $Value/ Household	Tax $Value/ Household
Core City	675,000	$6,486,596,219	$60,935,431	$9,610	$90
Developed Community	613,000	$5,965,114,072	$104,150,593	$9,731	$170
Growing Suburb	279,000	*$3,041,655,746	*$50,127,255	*$10,902	$180
Rural Area	65,000	*$761,854,356	*$12,342,496	*$11,721	$190
All Planning Areas	**1,632,000**	**$16,255,220,393**	**$227,555,775**	**$9,960**	**$139**

** not statistically significant*

Source: Econsult calculations

The aggregate results remain the same, but the apportionment of economic and fiscal values is different from the county-level analysis. Consistent with the results of the previous sections, the greatest values are in the older, built-up areas of Core Cities and Developed Communities, where open space exists in relative scarcity. Together, these two areas account for 77% of the economic value (increased house values) of open space and 73% of the fiscal value (increased tax revenues) of open space in the entire region.

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[i] For the sake of brevity, we show the results of only those variables of interest and omit non-open space variables, such as home size or age. The full set of results is available from the authors upon request.

[ii] $115,000 in Philadelphia and $252,500 in the surrounding counties in 2009, respectively.

[iii] Although the values go down from 2008 to 2009, this may be likely due to the onset of the recession and household's subsequent (in)ability to pay higher dollar amounts for open space, rather than a contraction in demand for open space.

[iv] The full regression results are omitted for brevity, but are available upon request.

[v] The result for Radnor was the only one obtained using a separate regression with Radnor-only home sales. The initial results, which used region-wide home sales, indicated an implausibly large effect (+$180,000) of being near the Radnor trail. As such, we hypothesized that this was really measuring the effect of homes being in an exceptionally wealthy suburb and high-performing school district, rather than being near the trail. Re-estimating the regression using only home sales in Radnor gives the effect of being near the trail, net of any benefits of being in Radnor township.

[vi] Home sale data used in regressions only covers PA.

[vii] Note: this analysis does not explicitly take into account any inaccuracies or errors in assessments. It implicitly assumes that all dwellings—and hence the value of proximity to open space—are uniformly and accurately assessed.

The Economic Value of Protected Open Space

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Technical Appendix B

The Environmental Value of Protected Open Space

Introduction

Public and private decision makers want and need better information about the values of ecosystems in weighing the advantages and disadvantages of human actions that may affect ecosystems, such as the decisions to develop a parcel of open space (Bingham et al., 1995). Ecosystem services represent the benefits that human populations derive, directly or indirectly, from ecosystem functions.[viii] Because ecosystem services are not fully 'captured' in commercial markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions (Costanza et al., 1997).

The ecosystem services provided by the preserved open space vary depending on the type of land cover and the preserved open space located within our study area is composed of diverse mixture of land cover, including: forests, wetlands, pastures, croplands, and riparian buffers. There are substantial differences in ecosystem service values based on the predominate types of land cover on the different types of preserved open space.

The United Nation's Millennium Ecosystem Assessment (MEA) groups ecosystem services into the following main categories (Mates and Reyes, 2004 and Costanza et al., 2006):

Provisioning Services: The products obtained from ecosystems, such as food and water.

Hydrologic Services: Many land cover types (i.e. forests and wetlands) and their underlying soils help ensure that rainwater is stored and released gradually rather than being allowed to immediately flow downstream as runoff. Forests and wetlands also provide a natural protective buffer between anthropogenic activities and water supplies helping to filter out pathogens, excess nutrients, metals and sediments.

Regulating Services:[ix] The benefits obtained from the regulation of ecosystem and abiotic processes.

Disturbance Mitigation: Many natural landscapes help provide a buffering function that protects humans from destructive perturbations. Forest, wetlands, and flood plains help mitigate the effects of floods by trapping and containing storm water.

Biological Control: The dynamic regulation of species populations, including the control of invasive species and unwanted species, such as pest predators, weeds, and disease vectors (i.e. mosquitoes).

Cultural Services:[x] The non-material benefits that people obtain from ecosystems, such as aesthetic experiences.

Supporting Services: Those that are necessary for the production of all other ecosystem services. These services differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time.

Wildlife Habitat/Refugia: Contiguous patches of land cover with sufficient area to hold naturally functioning ecosystems support a diversity of plant and animal life. Intact forests and wetlands function as critical population sources for plant and animal species that humans value for both aesthetic value and functional reasons.

Soil Formation/Retention: Soils provide many of the services mentioned above, including water storage/filtration, waste assimilation, and a medium for plant growth. Natural systems create and enrich soil through weathering and decomposition and retain soil by preventing it from being washed away by precipitation.

> Pollination: Forests provide pollinators essential to the reproduction of plant populations. Pollination is essential for many agricultural crops and substitutes for local pollinators are increasingly expensive.

Policymakers are constantly making decisions on issues involving development and land use. These decisions require a choice between competing uses for the natural environment: preserving the land in its existing state or converting it to developed uses. The benefits and *SOME* costs of development[xi] and the benefits of preservation are well known, while many of the social and ecological costs of development are simply left out of the analysis. This omission makes it hard to know exactly what we are gaining when we preserve a parcel in its undeveloped state or what is lost when we decide not to protect an undeveloped parcel. By estimating the economic value of these ecosystem services not traded in markets, social costs or benefits that otherwise would remain hidden or unappreciated are revealed, providing decision and policy makers with complete information about the costs and benefits of alternative land use scenarios (Costanza et al., 2006).

Methodology

In this analysis we use value transfer[xii] to estimate the ecosystem services discussed above. Value transfer essentially involves the adaptation of existing valuation or information to new policy contexts. Value transfer is typically used as a "second-best" strategy when primary research is not possible or justified because of limited time or budget constraints. While value transfer is the second best strategy, it is much better than the alternative of not accounting for ecosystem services in the analysis and thereby implying that the value of those services is zero. Value transfer has become a very important tool for policy makers since it can be used to reliably estimate the economic values associated with a particular landscape, based on existing research, for considerably less time and expense than a new primary study (Costanza et al., 2006).

Costanza et al. (2006) compiled and summarized over 100 academic studies comprising 210 individual value estimates for the types of ecosystem present in the state of New Jersey.[xiii] Table B.1 includes data on the number of studies reviewed by Costanza et al. as well as the minimum, mean, and maximum willingness to pay values for each activity. Please note that per acre values for the different ecosystem services vary by the type of land cover and Table B.1 is an aggregate of all of the land cover values for a given ecosystem service.

Table B.1

Willingness to Pay Values and Valuation Methods from Costanza (2006)

Ecosystem Service	# of Studies	Min	Mean	Max	Valuation Methods
Water Supply	23	$3	$1,102	$3,839	AC (2), CV (12), HP (1), RC (1), TC (5), VT (2)
Waste Assimilation	3	$44	$309	$838	VT (3)
Disturbance Prevention	5	$6	$768	$3,657	AC (3), VT (2)
Habitat	12	$1	$772	$3,883	CV (11), VT (1)

Source: Costanza et al. (2006)

Since, most of the ecosystem services provided by the preserved open space are natural functions, well-functioning markets for these services do not exist. When there are no explicit markets for the services, more indirect means of assessing values must be utilized. The studies analyzed by Costanza et al. (2006) utilized a variety of non-market techniques (the list of techniques used for each ecosystem service is included in Table B.1). The techniques are defined as follows:

Avoided Cost (AC): Some of the ecosystem services allow society to avoid costs that would have been incurred in the absence of those services. For example, flood control provided by intact riparian buffers helps avoid property damage downstream.

Replacement Cost (RC): Some of the ecosystem could be replaced with man-made systems. For example, the waste assimilation service provided by wetlands could be replaced with chemical or mechanical alternatives (such as wastewater treatment plants). The replacement cost would the estimated costs of replacing the natural waste assimilation service with the chemical or mechanical alternatives.

Travel Cost (TC): Service demand may require travel, the cost of which can reflect the implied value of the service.

Hedonic Pricing (HP): Service demand may be reflected in the prices people will pay for associated goods.

Contingent Valuation (CV): Service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives.

Some of the estimates of the value of various ecosystem services included in Costanaza et al. (2006) were obtained from studies that used Value Transfer (VT) techniques and also Direct Market (DM) valuations.

The type and value of the ecosystem services provided by the preserved open space varies depending on land cover of the preserved open space. Table B.2 lists the different land covers that have been found to provide the various ecosystem services.[xiv] In order to estimate the amount of ecosystem services provided by the preserved open space, the amount of various land cover types on the preserved open space was estimated. Satellite-derived land cover data from 2001 (the most recent year available) obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium[xv] and ArcGIS were used to calculate the acres of the ten different land cover types[xvi] located on the preserved open space. The amount of intact riparian buffers were calculated by creating fifty foot buffers around all of the stream segments that flow through the preserved open space and calculating the amount of the various land cover types in the buffer. For the forest, wetland, and pasture land cover types found in the riparian buffers, the riparian ecosystem service values were used rather the than the ecosystem service value for that land cover type.

Table B.2

Land Covers Associated with Selected Ecosystem Services

Ecosystem Service	Land Cover(s) Associated with the Ecosystem Service
Water Supply	Forests, Freshwater Wetlands, Open Freshwater, Riparian Buffer
Waste Assimilation	Forests, Freshwater Wetlands, Pasture, Riparian Buffer
Disturbance Prevention	Freshwater Wetlands, Riparian Buffers, Urban Green Space
Biological Control	Cropland, Forests, Pasture
Habitat	Cropland, Forests, Freshwater Wetlands
Soil Formation	Forests, Pasture
Pollination	Cropland, Forests, Pasture

Source: Costanza et al. (2006)

Once specific land cover types were identified, ecosystem flow values for the various land cover types were calculated by multiplying areas of each land cover type, in acres, by the minimum, mean, and maximum annualized dollar value per acre for that cover type as reported by Costanza et al. (2006) (See Table B.3.1 for specific values used). The total ecosystem service value of a given type of preserved open space was determined by aggregating up the individual ecosystem service values associated with each land cover type found on the preserved open space. The following formula was used:

$$V(ESV_i) = \sum_{k=1}^{n} A(LC_i) \times V(ES_{ki})$$

Where:

$A(LC_i) =$ Area of land cover(i)

$V(ES_{ki}) =$ Annualized value of Ecosystem Service (k) for each Land Cover (i).

The ecosystem services provided by the preserved open space can be thought of as stream of annual "natural income," and the ecosystems that provide the services that make up the stream of income can be thought of as the total "natural capital" of the preserved open space. The valuation methods used in the report estimate the value of the preserved open space by quantifying the value of the annual flow of "natural income" that the asset (the preserved open space) provides. To fully quantify the value of the "natural capital," the stream of benefits must be converted from the future flows of ecosystem services into a net present value (NPV). This requires some form of discounting. The simplest form of discounting assumes a constant flow of services into the indefinite future and a constant discount rate. Under these assumptions, the NPV is simply the value of the annual flow divided by the discount rate. The net-present value of the natural capital was calculated using a 1%, 3%, 5%, and 8% discount rates.[xvii]

Benefits

The ecosystem service benefits provided by the preserved open space are as follows:

Water Supply

The preserved open space provides two types of hydrologic services. The first is water supply. Many land cover types (i.e. forests and wetlands) and their underlying soils help ensure that rainwater is stored and released gradually rather than being allowed to immediately flow downstream as runoff. Using the minimum, mean, and maximum values from Costanza et al. (2006), it was found that that the water supply services provided by the preserved open space range from $1.0 million to 138.6 million, with a likely value of $50.2 million (Tables B.3, B.3a, B.3b, and B.3c). Due to the wide variety of land cover types that comprises the different types of open space, there is a wide variety in the average value per acre of preserved open space. The average values range from between $101 per acre of preserved farmland to $596 per acre for federally owned land; the average value for types of open space is $254 per acre. The water supply benefits will primarily be driven by the amount of forest and wetland land cover that is on the open space; those open space parcels with greater amounts of wetland and forest cover will generate greater amounts of water supply services.

Table B.3

Water Supply Service by Type of Open Space ($M per year)

Type of Open Space	Acres	Value	$/Acre
Federal	4,420	$ 2.6	$596
State	26,715	$9.3	$346
County	28,700	$12.4	$430
Municipal	35,975	$ 10.4	$290
Preserved Farmland	42,035	$4.2	$101
Land Trust/Privately Protected	59,590	$11.3	$190
Total	**197,435**	**$ 50.2**	**$254**

Source: Costanza et al. (2006), Econsult Calculations

Table B.3a

Water Supply Service by Type of Open Space,
Based on the Minimum Values from Costanza et al. (2006) ($M per year)

Min	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$ 0.01	$0.01	$ 0.01	$0.01	**$0.04**
State	$0.13	$0.06	$0.02	$0.02	*	**$0.23**
County	$0.06	$0.04	$0.01	$0.03	$0.06	**$0.20**
Municipal	$0.06	$ 0.04	$0.03	$0.05	*	**$0.18**
Preserved Farmland	$ 0.02	$0.06	*	$0.02	-	**$0.10**
Land Trust/Privately Protected	$0.03	$0.19	$0.02	$0.03	*	**$0.27**
Total	**$0.30**	**$0.40**	**$0.09**	**$0.16**	**$0.07**	**$1.02**

Source: Costanza et al. (2006), Econsult Calculations
** Values less than $50,000*

Table B.3b

Water Supply Service by Type of Open Space,
Based on the Mean Values from Costanza et al. (2006) ($M per year)

Mean	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$0.31	$1.30	$0.43	$0.59	**$2.63**
State	$5.42	$2.55	$0.46	$ 0.80	$0.03	**$ 9.26**
County	$3.72	$2.40	$0.29	$1.78	$4.16	**$12.35**
Municipal	$4.39	$2.27	$1.83	$1.84	$0.09	**$10.42**
Preserved Farmland	$0.99	$2.70	$0.02	$0.53	-	**$4.24**
Land Trust/Privately Protected	$1.84	$ 7.63	$0.89	$0.87	$0.06	**$11.29**
Total	**$16.36**	**$17.86**	**$4.79**	**$6.25**	**$ 4.93**	**$ 50.19**

Source: Costanza et al. (2006), Econsult Calculations

Table B.3c

Water Supply Service by Type of Open Space,
Based on the Maximum Values from Costanza et al. (2006) ($M per year)

Max	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$0.85	$2.85	$0.96	$1.35	**$ 6.01**
State	$12.80	$6.50	$ 1.43	$2.58	$0.13	**$23.44**
County	$9.55	$6.17	$1.00	$4.78	$11.01	**$32.51**
Municipal	$11.56	$7.25	$5.30	$6.40	$0.20	**$30.71**
Preserved Farmland	$2.93	$8.16	$0.08	$1.72	-	**$12.89**
Land Trust/Privately Funded	$4.94	$22.64	$2.61	$2.66	$0.15	**$33.00**
Total	**$41.78**	**$51.57**	**$13.27**	**$19.10**	**$12.84**	**$138.56**

Source: Costanza et al. (2006), Econsult Calculations

Waste Assimilation

The second hydrologic service provided by the preserved open space is waste assimilation. Forests and wetlands also provide a natural protective buffer between anthropogenic activities and water supplies, helping to filter out pathogens, excess nutrients, metals and sediments. Using the minimum, mean, and maximum values from Costanza et al. (2006), it was found that that the waste assimilation services provided by the preserved open space range from $8.6 million to $11.3 million with a likely value of $10.8 million (Tables B.4, B.4a, B.4b. and B.4c). Due to wide variety of land cover that comprises the different types of open space, there is a wide variety in the average value per acre of preserved open space. The average values range from between $36 per acre of preserved farmland to $107 per acre for federally owned land; the average value for types of open space is $55 per acre. The waste assimilation benefits will primarily be driven by the amount of forest, wetland, and riparian buffer cover that is on the open space; those open space parcels with greater amounts of wetland, forest, and riparian buffer cover will generate greater amounts of waste assimilation services.

Table B.4

Waste Assimilation Service by Type of Open Space ($M per year)

Type of Open Space	Acres	Value	$/Acre
Federal	4,420[T]	$0.5	$107
State	26,715[T]	$1.7	$64
County	28,700[T]	$2.2	$78
Municipal	35,975[T]	$2.0	$54
Preserved Farmland	42,035[T]	$1.5	$36
Land Trust/Privately Funded	59,590[T]	$2.9	$49
Total	**197,435**[T]	**$10.8**	**$55**

Source: Costanza et al. (2006), Econsult Calculations

[T] *Figures not in $M*

Table B.4a

Waste Assimilation Service by Type of Open Space,
Based on Minimum Values from Costanza et al. (2006) ($M per year)

Min	**Bucks**	**Chester**	**Delaware**	**Montgomery**	**Philadelphia**	**Total**
Federal	-	$0.06	$0.22	$0.09	$0.10	**$0.47**
State	$0.97	$0.44	$0.10	$0.14	*	**$1.65**
County	$0.61	$0.44	$0.04	$0.32	$0.71	**$2.12**
Municipal	$0.75	$0.35	$0.29	$0.27	$0.02	**$1.68**
Preserved Farmland	$0.16	$0.43	*	$0.08	-	**$0.67**
Land Trust/Privately Funded	$0.34	$1.32	$ 0.15	$0.16	$0.02	**$1.99**
Total	**$2.83**	**$3.04**	**$0.80**	**$1.06**	**$0.85**	**$8.58**

Source: Costanza et al. (2006), Econsult Calculations
** Values less than $10,000*

Table B.4b

Waste Assimilation Service by Type of Open Space,
Based on Mean Values from Costanza et al. (2006) ($M per year)

Mean	**Bucks**	**Chester**	**Delaware**	**Montgomery**	**Philadelphia**	**Total**
Federal	-	$0.06	$0.22	$0.09	$0.10	**$0.47**
State	$ 0.98	$0.47	$0.10	$0.15	$0.01	**$1.71**
County	$0.64	$0.48	$0.05	$0.34	$0.73	**$2.24**
Municipal	$0.83	$0.45	$0.30	$0.34	$0.02	**$1.94**
Preserved Farmland	$0.27	$1.01	$0.01	$0.22	-	**$1.51**
Land Trust/Privately Funded	$0.38	$2.18	$ 0.18	$0.17	$0.02	**$2.93**
Total	**$3.10**	**$4.65**	**$0.86**	**$1.31**	**$0.88**	**$10.80**

Source: Costanza et al. (2006), Econsult Calculations

Table B.4c

Water Assimilation Service by Type of Open Space,
Based on the Maximum Values from Costanza et al. (2006) ($M per year)

Max	**Bucks**	**Chester**	**Delaware**	**Montgomery**	**Philadelphia**	**Total**
Federal	$0.06	$0.22	$0.09	$0.10	$0.47	**$0.94**
State	$0.98	$0.47	$0.10	$0.15	$0.01	**$1.71**
County	$0.64	$0.48	$0.05	$0.34	$0.73	**$2.24**
Municipal	$0.83	$0.45	$0.30	$0.34	$0.02	**$1.94**
Preserved Farmland	$0.27	$1.01	$0.01	$0.22	-	**$1.51**
Land Trust/Privately Funded	$0.38	$2.18	$0.18	$0.17	$0.02	**$2.93**
Total	**$3.16**	**$4.81**	**$0.73**	**$1.32**	**$1.25**	**$11.27**

Source: Costanza et al. (2006), Econsult Calculations

Disturbance (Flood) Mitigation

Many natural landscapes help provide a buffering function that protects humans from destructive perturbations. Forest, wetlands, and flood plains help mitigate the effects of floods by trapping and containing storm water. Using the minimum, mean, and maximum values from Costanza et al. (2006), it was found that that the Disturbance (Flood) Mitigation services provided by the preserved open space range from $21.6 million to $62.3 million with a likely value of $37.4 million (Tables B.5, B.5a, B.5b. and B.5c). Due to wide variety of land cover that comprises the different types of open space, there is a wide variety in the average value per acre of preserved open space. The average values range from between $83 per acre of preserved farmland to $709 per acre for federally owned land; the average value for types of open space is $189 per acre. The disturbance (flood) mitigation benefits will primarily be driven by the amount of forest, wetland, and riparian buffer cover that is on the open space; those open space parcels with greater amounts of wetland, forest, and riparian buffer cover will generate greater amounts of waste assimilation services.

Table B.5

Disturbance (Flood) Mitigation Service by Type of Open Space ($M per year)

Type of Open Space	Acres	Value	$/Acre
Federal	4,420^T	$3.1	$709
State	26,715^T	$6.9	$257
County	28,700^T	$6.7	$233
Municipal	35,975^T	$9.0	$249
Preserved Farmland	42,035^T	$3.5	$83
Land Trust/Privately Funded	59,590^T	$8.2	$137
Total	**197,435^T**	**$37.4**	**$189**

Source: Costanza et al. (2006), Econsult Calculations

^{T} *Figures not in $M*

Table B.5a

Disturbance (Flood) Mitigation Service by Type of Open Space,
Based on the Minimum Values from Costanza et al. (2006) ($M per year)

Min	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$0.13	$0.94	$0.24	$0.42	**$1.73**
State	$2.57	$1.05	*	$ 0.15	$0.01	**$3.78**
County	$1.98	$1.29	$0.07	$0.92	$2.45	**$ 6.71**
Municipal	$2.59	$0.85	$0.93	$0.49	$0.06	**$4.92**
Preserved Farmland	$0.44	$1.28	*	$0.22	-	**$1.94**
Land Trust/ Privately Funded	$0.88	$1.32	$0.15	$0.16	$0.02	**$2.53**
Total	**$8.46**	**$5.92**	**$2.09**	**$2.18**	**$2.96**	**$21.61**

Source: Costanza et al. (2006), Econsult Calculations
**Values less than $10,000*

Table B.5b

Disturbance (Flood) Mitigation Service by Type of Open Space,
Based on the Mean Values from Costanza et al. (2006) ($M per year)

Mean	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$0.24	$1.70	$0.44	$0.76	**$3.11**
State	$4.66	$1.90	$0.01	$0.28	$0.01	**$6.86**
County	$1.98	$1.29	$0.07	$0.92	$2.45	**$6.71**
Municipal	$4.71	$1.56	$1.68	$0.91	$ 0.11	**$8.97**
Preserved Farmland	$0.80	$2.29	*	$0.39	-	**$3.48**
Land Trust/Privately Funded	$1.61	$5.47	$0.70	$0.39	$0.03	**$8.20**
Total	**$13.76**	**$12.75**	**$4.16**	**$3.33**	**$3.36**	**$37.36**

Source: Costanza et al. (2006), Econsult Calculations

**Values less than $10,000*

Table B.5c

Disturbance (Flood) Mitigation Service by Type of Open Space,
Based on the Maximum Values from Costanza et al. (2006) ($M per year)

Max	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$0.35	$2.46	$0.63	$1.10	**$4.54**
State	$6.75	$2.77	$0.02	$0.41	$0.02	**$9.97**
County	$5.21	$3.39	$0.20	$2.42	$6.44	**$17.66**
Municipal	$6.83	$2.28	$2.45	$1.33	$0.15	**$13.04**
Preserved Farmland	$1.17	$3.36	$0.01	$0.58	-	**$5.12**
Land Trust/ Privately Funded	$2.33	$8.02	$1.01	$0.57	$0.04	**$11.97**
Total	**$22.29**	**$20.17**	**$6.15**	**$5.94**	**$7.75**	**$62.31**

Source: Costanza et al. (2006), Econsult Calculations

Wildlife Habitat/Refugia

Contiguous patches of land cover with sufficient area to hold naturally functioning ecosystems support a diversity of plant and animal life. Intact forests and wetlands function as critical population sources for plant and animal species that humans value for both aesthetic value and functional reasons. Using the minimum, mean, and maximum values from Costanza et al. (2006), it was found that that the wildlife habitat/refugia services provided by the preserved open space range from $16.9 million to $278.4 million with a likely value of $102.3 million (Tables B.6, B.6a, B.6b. and B.6c). Using the mean values from Costanza et al. (2006), it was found that the average values range from between $410 per acre of preserved farmland to $717 per acre for state owned land; the average value for all types of open space is $517 per acre.

Table B.6

Wildlife Habitat/Refugia Service by Type of Open Space ($M per year)

Type of Open Space	Acres	Value	$/Acre
Federal	4,420^T	$1.74	$394
State	26,715^T	$0.59	$22
County	28,700^T	$2.27	$79
Municipal	35,975^T	$4.98	$138
Preserved Farmland	42,035^T	$6.07	$144
Land Trust/Privately Funded	59,590^T	$1.23	$21
Total	**197,435**^T	**$16.88**	**$85**

Source: Costanza et al. (2006), Econsult Calculations

^T *Figures not in $M*

Table B.6a

Wildlife Habitat/Refugia Service by Type of Open Space,
Based on the Minimum Values from Costanza et al. (2006) ($M per year)

Min	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	$0.64	$0.35	$0.11	$0.51	$0.13	$1.74
State	$0.00	$0.17	$0.04	$0.37	$0.01	$0.59
County	$0.89	$0.59	$0.23	$0.54	$0.02	$2.27
Municipal	$1.28	$3.26	$0.21	$0.20	$0.03	$4.98
Preserved Farmland	$2.21	$2.93	$0.02	$0.91	$0.00	$6.07
Land Trust/ Privately Funded	$0.50	$0.27	$0.09	$0.31	$0.06	$1.23
Total	**$5.52**	**$7.57**	**$0.70**	**$2.84**	**$0.25**	**$16.88**

Source: Costanza et al. (2006), Econsult Calculations

Table B.6b

Wildlife Habitat/Refugia Service by Type of Open Space,
Based on the Mean Values from Costanza et al. (2006) ($M per year)

Mean	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	-	$0.96	$0.15	$1.46	$0.07	**$2.64**
State	$9.12	$4.78	$2.16	$2.91	$0.18	**$19.15**
County	$4.75	$3.71	$0.81	$3.29	$3.59	**$16.15**
Municipal	$5.26	$4.57	$2.13	$4.44	$0.12	**$16.52**
Preserved Farmland	$5.76	$8.88	$0.11	$2.49	-	**$17.24**
Land Trust/ Privately Funded	$5.47	$20.03	$1.81	$2.77	$0.31	**$30.39**
Total	**$30.36**	**$42.93**	**$7.17**	**$17.36**	**$4.27**	**$102.09**

Source: Costanza et al. (2006), Econsult Calculations

Table B.6c

Wildlife Habitat/Refugia Service by Type of Open Space,
Based on the Maximum Values from Costanza et al. (2006) ($M per year)

Min	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	$14.58	$11.00	$2.46	$9.83	$12.48	$50.35
State	$0.00	$2.27	$0.32	$3.75	$0.20	$6.54
County	$15.37	$12.46	$6.80	$13.92	$0.34	$48.89
Municipal	$14.50	$49.69	$5.74	$9.28	$1.02	$80.23
Preserved Farmland	$11.59	$11.25	$0.32	$5.21	$0.00	$28.37
Land Trust/Privately Funded	$31.17	$15.56	$7.55	$9.34	$0.40	$64.02
Total	**$87.21**	**$102.23**	**$23.19**	**$51.33**	**$14.44**	**$278.40**

Source: Costanza et al. (2006), Econsult Calculations

Total Ecosystem Service Benefits

The approximately 200,000 acres of preserved open space generate $215.3 million dollars in ecosystem service benefits, with a likely range between $54.9 million and $512.9 million (Table B.9). Table B.7 presents the ecosystem services by type and by county calculated using mean values from Costanza et al. (2006). Chester County's preserved open space generates the most ecosystem service benefits ($78.19 million) and Philadelphia the least ($13.44), with the amount of benefits for each county proportional to the amount of preserved open space in that respective county. However, while Chester County observes the greatest total ecosystem service benefits, they have the lowest average benefits per acre at $844 per acre. Delaware County has the greatest average benefits per acre of preserved open space. Table B.8 presents the ecosystem service values by type of preserved open space. As with the benefits by county, there is quite a bit of variation between the types of open space and the value of the benefits which is proportional to the amount of each type of preserved open space. Non-profit owned and eased land provides the greatest amount of ecosystem service benefits ($52.81 million) and federally owned land provides the least amount ($8.88 million). However, on a per acre basis, federally owned land generates the most ecosystem service benefits ($2,009 per acre) and preserved farmland generates the least amount of ecosystem service value per acre ($630 per acre).

Table B.7

Total Ecosystem Services by County,
Based on the Mean Values from Costanza et al. (2006) ($M per year)

Mean	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Water Supply	$16.36	$17.86	$4.79	$6.25	$4.93	**$50.19**
Waste Assimilation	$3.10	$4.65	$0.86	$1.31	$0.88	**$10.80**
Disturbance (Flood) Mitigation	$13.76	$12.75	$4.16	$3.33	$3.36	**$37.36**
Wildlife Habitat/Refugia	$30.36	$42.93	$7.17	$17.36	$4.27	**$102.09**
Total	$63.58	$78.19	$16.98	$28.25	$13.44	$200.44
Acres of Open Space	**50,790**^T^	**92,630** ^T^	**12,740** ^T^	**30,430** ^T^	**10,840** ^T^	**197,430** ^T^
Benefits per Acre	**1,250** ^T^	**844** ^T^	**1,333** ^T^	**928** ^T^	**1,240** ^T^	**1,015** ^T^

Source: Costanza et al. (2006), Econsult Calculations

^T^ *Figures not in $M*

Table B.8

Total Ecosystem Services by Type of Open Space,
Based on the Mean Values from Costanza et al. (2006) ($M)

Mean	County	Federal	Municipal	Land Trust/ Privately Funded	Preserved Farmland	State	Total
Water Supply	$12.35	$2.63	$10.42	$11.29	$4.24	$9.26	**$50.19**
Waste Assimilation	$2.24	$0.47	$1.94	$2.93	$1.51	$1.71	**$10.80**
Disturbance (Flood) Mitigation	$6.71	$3.14	$8.97	$8.20	$3.48	$6.86	**$37.36**
Wildlife Habitat/Refugia	$16.15	$2.64	$16.52	$30.39	$17.24	$19.15	**$102.09**
Total	$37.45	$8.88	$37.85	$52.81	$26.47	$36.98	$200.44
Acres of Open Space	**28,700** ^T^	**4,420** ^T^	**35,975** ^T^	**59,590** ^T^	**42,030** ^T^	**26,715** ^T^	**197,430** ^T^
Benefits per Acre	**1,305**^T^	**2,009**^T^	**1,052**^T^	**886**^T^	**630**^T^	**1,384**^T^	**1,015**^T^

Source: Costanza et al. (2006), Econsult Calculations

^T^ *Figures not in $M*

Table B.9

Total Ecosystem Services,
Based on the Minimum, Mean, and Maximum Values
from Costanza et al. (2006) ($M per year)

	Total
Minimum	$54.9
Mean	$215.3
Maximum	$512.9

Source: Econsult Calculations

Net Present Value of Benefits

As discussed above, the stream of annual ecosystem service benefits can be converted into the total value of the natural capital. Table B.10 converts the minimum, mean, and maximum streams of annual benefits using a range of discount rates. The case of a constant discount rate and constant flow of ecosystem services from the preserved open space is assumed. Since the open space that was analyzed in this report is permanently preserved and under no immediate danger of being developed, the assumption of a constant flow of services may be appropriate. NPV of the annual flow of ecosystem service benefits calculated using the mean values from Costanza et al. (2006) ($215.3 million) yields figures ranging from $21,531 million (using a 1% discount rate) to $2,691 million (using an 8% discount rate). As the discount rate increases, the NPV decreases.

Table B.10

Net Present Value of the Annual Flows
of Ecosystem Services using Various Discount Rates ($M)

Annual	Flow Value	1%	3%	5%	8%
Minimum	$54.9	$5,492	$1,831	$1,098	$686
Mean	$215.3	$21,531	$7,177	$4,306	$2,691
Maximum	$512.9	$51,293	$17,098	$10,259	$6,412

Source: Econsult Calculations

Caveats

The estimates presented above are likely a conservative estimate of the value of the ecosystem services provided by the preserved open space. As illustrated in Table B.2, not all land cover (ecosystems) types have been well studied and there exists some gaps in the valuation literature. More complete coverage would almost certainly increase the values. Additionally, since most estimates are based on an individual's estimate of their willingness to pay, which are limited by their perceptions and knowledge base, increasing their knowledge of the contribution that various ecosystem services make to their welfare would almost certainly increase their willingness to pay values. Furthermore, this analysis uses a static framework that ignores interdependencies and dynamics. More elaborate studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values, as changes in ecosystem service levels ripple through the ecosystem and the economy. If these and other problems could be addressed, the result would most likely be significantly higher values. Unfortunately, it is impossible to know how much higher the values would be (Costanza et al., 2006).

Air Pollution Removal Benefits

Introduction

Poor air quality is a common problem in many urban and suburban areas and can lead to a variety of human health problems, including asthma and other respiratory aliments. Additionally, air pollution can also damage buildings, plants, and disrupt many ecosystem services and can cause reduced visibility and smog. Trees offer the ability to remove significant amounts of air pollution and consequently improve environmental quality and human health. In particular, trees have been found to remove significant amounts of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and particulate matter. Trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant's surface. Trees also remove pollution by intercepting airborne particles (Nowak et al., 2006).

Urban and suburban trees also help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in new biomass each year. Carbon storage by trees is another way that trees can influence climate change. As trees grow, they store more carbon by holding it in their accumulated tissue. As trees die and decay, they release much of the stored carbon back to the atmosphere (Nowak et al., 2007). Carbon storage is an estimate of the total amount of carbon that is currently stored in the above and below ground biomass of the forest, while carbon sequestration is a measure of how much new carbon dioxide is taken up by the forest each year through new growth.

Methodology

The i-Tree Vue model developed by the U.S. Forest service was used to estimate the air pollution removal and carbon sequestration and storage benefits of the preserved open space. The model uses National Land Cover Datasets (NLCD) to estimate the amount of tree canopy (Table B.11) and then uses pollution removal rates to estimate the total amount of pollutant removal. The i-Tree Vue model has the advantage of allowing for the adjustment of the per acre pollution removal values. A range of pollution removal values from the academic literature as well as other similar studies was utilized to estimate the air pollution removal benefits of the preserved open space. Table B.12 presents the pollutant removal values as well as the source of the values. Tables B.13a, B.13b, and B.13c report the total pollutant removal amounts, in tons, calculated using the Low and High values from Nowak et al. (2006) as well as the average of all of the values reported in Table B.12.

Table B.11

Tree Canopy Cover by County and by Type of Open Space (Acres)

Tree Canopy Cover	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Federal	0	623	103	677	154	**1,557**
State	8,364	4,477	1,955	2,206	59	**17,061**
County	3,642	3,229	594	2,332	3,774	**13,571**
Municipal	3,959	3,716	1,861	3,673	115	**13,324**
Preserved Farmland	1,387	3,267	568	709	0	**5,931**
Land Trust/ Privately Funded	2,838	14,065	1,421	2,450	254	**21,028**
Total	**20,190**	**29,377**	**6,502**	**12,047**	**4,356**	**72,472**

Source: Econsult Calculations

Table B.12

Estimated Pollution Removal Rates per Acre of Tree Cover (Pounds per Acre of Tree Canopy)

	From Nowak et al. (2006)			*TPL (2008)*	*USDA (2010)*	*Econsult Calculations*
Pollutant	**Low**	**Expected**	**High**	**Values Used by TPL**	**Default i-Tree Pa Values**	**Average**
O3	8.17	30.83	39.83	34.09	32.45	29.07
PM10	12.66	32.33	50.33	49.20	17.84	32.47
NO2	7.67	15.50	20.50	17.96	9.19	14.16
SO2	3.67	6.83	11.33	18.00	9.40	9.85
CO	1.67	1.67	1.67	3.08	1.03	1.82

Table B.13a

Estimated Pollution Removal Amounts (tons),
Based on the "Low" Values from Table B.12

Pollutant	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
O3	82	120	27	49	18	**296**
PM10	128	186	41	76	28	**459**
NO2	77	113	25	46	17	**278**
SO2	37	54	12	22	8	**133**
CO	17	24	5	10	4	**60**

Source: Econsult Calculations

Table B.13b

Estimated Pollution Removal Amounts (tons),
Based on the "Average" Values from Table B.12

Pollutant	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
O3	293	427	95	175	63	**1,053**
PM10	328	477	106	196	71	**1,177**
NO2	143	208	46	85	31	**513**
SO2	99	145	32	59	21	**357**
CO	18	27	6	11	4	**66**

Source: Econsult Calculations

Table B.13c

Estimated Pollution Removal Amounts (tons),
Based on the "High" Values from Table B.12

Pollutant	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
O3	402	585	129	240	87	1,443
PM10	508	739	164	303	110	1,824
NO2	207	301	67	123	45	743
SO2	114	166	37	68	25	411
CO	17	24	5	10	4	60

Source: Econsult Calculations

Pollution removal values were estimated using national median externality values. The values were based on the median monetized dollar per ton externality values used in energy-decision-making from various studies. These values in dollars per metric ton are: NO_2 = \$6752 t^{-1}, PM_{10} = \$4508 t^{-1}, SO_2 = \$1653 t^{-1}, and CO = \$959 t^{-1}. The externality values for O_3 were set to equal the value for NO_2. Externality values can be considered the estimated costs of pollution to society that are not accounted for in the market price of the goods or services that produced the pollution (Nowak et al., 2006; Murray et al., 1994). The total pollutant removal values for each pollutant will vary across types of open space depending on the amount of tree canopy cover on the open space; increased tree cover leads to greater total removal and greater pollutant removal values (Nowak et al., 2006).

Table B.14 includes the low, average, and high carbon storage and sequestration rates used in this analysis. Tables B.15a, B.15b, and B.15c report the total carbon storage and sequestration amounts, in tons, calculated using the minimum, mean, and maximum values from Table B.14. The value of the carbon storage and sequestration was estimated using the default value used in the i-Tree Vue model of \$21 per ton.

Table B.14

Estimated Carbon Storage and Sequestration Rates
(Pounds per Acre of Tree Canopy)

	Nowak et al. (2007)	*Econsult Calculations*	*USDA (2010)*
Pollutant	**Low**	**Average**	**High**
Carbon Sequestration	2433.95	2555.24	2676.53
Carbon Storage	80123.80	80656.05	81188.30

Table B.15a

Estimated Carbon Storage and Sequestration Amounts (tons),
Based on the "Low" Values from Table B.14

Pollutant	**Bucks**	**Chester**	**Delaware**	**Montgomery**	**Philadelphia**	**Total**
Carbon Sequestration	24,569	35,751	7,912	14,661	5,302	**88,196**
Carbon Storage	808,802	1,176,906	260,462	482,642	174,526	**2,903,338**

Source: Econsult Calculations

Table B.15b

Estimated Carbon Storage and Sequestration Amounts (tons),
Based on the "Average" Values from Table B.14

Pollutant	**Bucks**	**Chester**	**Delaware**	**Montgomery**	**Philadelphia**	**Total**
Carbon Sequestration	25,794	37,533	8,306	15,392	5,566	**92,591**
Carbon Storage	814,174	1,184,724	262,193	485,848	175,685	**2,922,624**

Source: Econsult Calculations

Table B.15c

Estimated Carbon Storage and Sequestration Amounts (tons),
Based on the "High" Values from Table B.14

Pollutant	**Bucks**	**Chester**	**Delaware**	**Montgomery**	**Philadelphia**	**Total**
Carbon Sequestration	27,018	39,314	8,701	16,123	5,830	**96,986**
Carbon Storage	819,547	1,192,542	263,923	489,054	176,844	**2,941,911**

Source: Econsult Calculations

Benefits

Using the minimum, mean, and maximum pollutant removal amounts, it was found that the air pollutant removal benefits can range from $5.64 million to $22.53 million, with a likely value of $15.00 million for the 5-County Study area (Table B.16). Tables B.16a, B.16b, and B.16c present the results by pollutant for each County using the minimum, mean, and maximum values, respectively.

Table B.16

Estimated Total Pollution Removal Benefits ($M per year)

Pollutant	Minimum	Mean	Maximum
O3	$1.81	$6.45	$8.84
PM10	$1.88	$4.81	$8.22
NO2	$1.70	$3.14	$3.35
SO2	$0.20	$0.54	$1.85
CO	$0.05	$0.06	$0.27
Total	$5.64	$15.00	$22.53

Source: Econsult Calculations

Table B.16a

Estimated Pollution Removal Benefits (thousands $),
Based on the "Low" Values from Table B.12

Pollutant	$ / ton	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
O3	$6,752	$505.0	$734.9	$162.6	$301.4	$109.0	$1,812.9
PM10	$4,508	$523.0	$761.0	$168.4	$312.1	$112.9	$1,877.3
NO2	$6,752	$474.1	$689.9	$152.7	$282.9	$102.3	$1,701.9
SO2	$1,653	$55.5	$80.8	$17.9	$33.1	$12.0	$199.3
CO	$959	$14.6	$21.3	$4.7	$8.7	$3.2	$52.5
Total		$1,572.3	$2,287.9	$506.3	$938.2	$339.3	$5,644.0

Source: Econsult Calculations

Table B.16b

Estimated Pollution Removal Benefits (thousands $),
Based on the "Average" Values from Table B.12

Pollutant	$ / ton	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
O3	$6,752	$1,798.1	$2,616.5	$579.1	$1,073.0	$388.0	$6,454.7
PM10	$4,508	$1,340.9	$1,951.1	$431.8	$800.1	$289.3	$4,813.2
NO2	$6,752	$875.9	$1,274.6	$282.1	$522.7	$189.0	$3,144.3
SO2	$1,653	$149.1	$216.9	$48.0	$89.0	$32.2	$535.1
CO	$959	$16.0	$23.3	$5.2	$9.5	$3.5	$57.4
Total		$4,180.0	$6,082.4	$1,346.1	$2,494.4	$902.0	$15,004.8

Source: Econsult Calculations

Table B.16c

Estimated Pollution Removal Benefits (thousands $),
Based on the "High" Values from Table B.12

Pollutant	$ / ton	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
O3	$6,752	$2,463.3	$3,584.4	$793.3	$1,469.9	$531.5	$8,842.5
PM10	$4,508	$2,078.2	$3,024.0	$669.2	$1,240.1	$448.4	$7,459.9
NO2	$6,752	$1,267.7	$1,844.7	$408.3	$756.5	$273.6	$4,550.7
SO2	$1,653	$171.6	$249.7	$55.3	$102.4	$37.0	$615.9
CO	$959	$14.6	$21.3	$4.7	$8.7	$3.2	$52.5
Total		$5,995.4	$8,724.1	$1,930.7	$3,577.7	$1,293.7	$21,521.6

Source: Econsult Calculations

Using the minimum, mean, and maximum carbon storage and sequestration rates, it was found that the carbon sequestration benefits can range from $1.85 million to $2.04 million, with a likely value of $1.94 million for the 5-County Study Area and the carbon storage benefits can range from $60.97 million to $61.78 million, with a likely value of $61.38 million (Table B.17). The Tables B.17a, B.17b, and B.17c, present the results for each County using the minimum, mean, and maximum values, respectively.

Table B.17

Estimated Carbon Storage and Sequestration Benefits

	Low	Average	High
Carbon Sequestration	1.85	1.94	2.04
Carbon Storage	60.97	61.38	61.78

Source: Econsult Calculations

Table B.17a

Estimated Carbon Storage and Sequestration Benefits,
Based on the "Low" Values from Table B.14

	$ / ton	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Carbon Sequestration	**$21**	$0.52	$0.75	$0.17	$0.31	$0.11	**$1.85**
Carbon Storage	**$21**	$16.98	$24.72	$5.47	$10.14	$3.67	**$60.97**

Source: Econsult Calculations

Table B.17b

Estimated Carbon Storage and Sequestration Benefits,
Based on the "Average" Values from Table B.14

	$ / ton	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Carbon Sequestration	**$21**	$0.54	$0.79	$0.17	$0.32	$0.12	**$1.94**
Carbon Storage	**$21**	$17.10	$24.88	$5.51	$10.20	$3.69	**$61.38**

Source: Econsult Calculations

Table B.17c

Estimated Carbon Storage and Sequestration Benefits,
Based on the "High" Values from Table B.14

Pollutant	$ / ton	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Carbon Sequestration	**$21**	$0.57	$0.83	$0.18	$0.34	$0.12	**$2.04**
Carbon Storage	**$21**	$17.21	$25.04	$5.54	$10.27	$3.71	**$61.78**

Source: Econsult Calculations

Please note that NLCD provides tree cover estimates with a 30-meter pixel resolution for the contiguous United States. The national database provides important information on our national tree resources, but has limitations; particularly at the local scale. Tree cover estimates from the NLCD cover maps are believed to underestimate tree cover by an average of about 10%(Greenfield et al., in press). Thus, the tree cover and consequently the ecosystem service estimates at the local level are likely conservative, but the exact degree of underestimation in specific areas is not currently known (US Forest Service, 2010).

Watershed Case Studies – Stormwater Analysis

Modeling Land Cover Effects in Marsh Creek Watershed

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Yang Yang and Ted Endreny, State University of New York, College of Environmental Science and Forestry

This report details results of changes in stream flow due to the effects of development in the Marsh Creek watershed (22.2 km^2, Figure B.1) using the i-Tree / UFORE Hydro model (Wang et al., 2008).

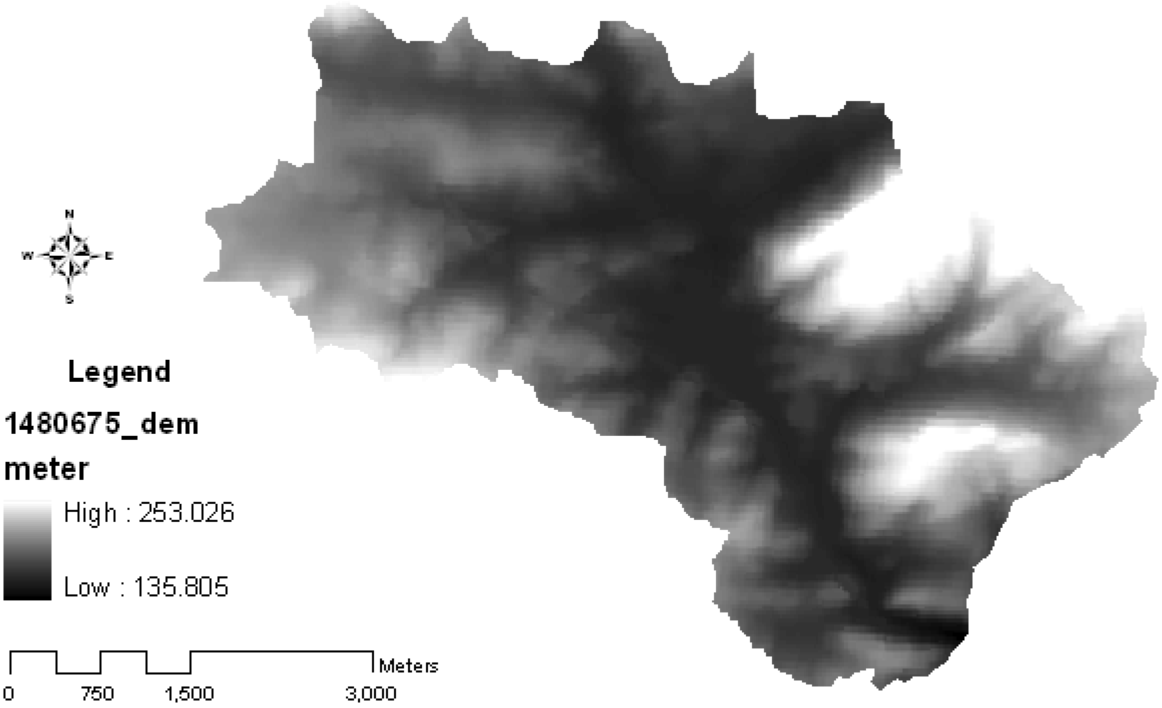

Figure B.1 DEM of Marsh Creek Watershed near Glenmoore, Philadelphia, PA (USGS 01480675)

Data and Model Calibration

The precipitation and weather data for this analysis were collected from a local weather station near the Philadelphia International Airport (WBAN: 724080 13739). Tree and impervious cover parameters were derived for protected and unprotected areas of the watershed from photo-interpretation of Google Earth imagery (image data 2010) using 1,000 randomly located points (Table B.18). Protected and unprotected areas were delimited based on boundary files provided by Econsult Corporation. Protected areas have higher tree cover and lower impervious cover (i.e., roads, buildings, concrete, etc.).

Table B.18 Cover estimates for watershed.

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	1.2	56.2	42.4	0.2
Unprotected Area	8.3	48.9	45.0	0.0

Whole Watershed	5.3	51.5	43.9	0.1

The model was calibrated using hourly stream flow data collected at the Marsh Creek near Glenmoore, Philadelphia, PA (USGS 01480675) gauging station (04/15/2007 – 10/31/2007). Model results were calibrated against measured stream flow to yield the best fit between model and measured stream flow results. Calibration coefficients (0-1 with 1.0 = perfect fit) were calculated for peak flow, base flow, and balance flow (peak and base) (Table B.19). Calibrations can often be off, particularly for peak flows, due to mismatching of steam flow and weather data as the weather stations are often outside of the watershed area. For example, it may be raining at the weather station and not in the watershed or vice versa. Tree canopy leaf area index (LAI) was estimated at 5.0 based on various field studies and the amount of percent of impervious cover connected to the stream was estimated at 40 percent.

Table B.19 Calibration coefficients for model estimates and gauging station data.

	Calibration Coefficients		
Watershed	Peak Flow	Base Flow	Balanced Flow
Marsh Creek	0.58	0.50	0.71

Model Scenarios

The model scenario employed in this analysis is the conversion of protected land characteristics to unprotected land characteristics (Table B.20). That is, it depicts what would happen if the protected areas developed like unprotected areas with additional impervious cover replacing tree cover in protected areas. In this case impervious cover in the watershed would increase from 5.3% to 8.3%, tree cover drop from 51.5% to 48.0% overall.

Table B.20 Cover change for watershed.

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	8.3	47.9	42.4	0.2
Unprotected Area	8.3	48.9	45.0	0.0
Whole Watershed	8.3	48.0	43.9	0.1

In addition, effects of changes in tree and impervious cover in this watershed were explored. After calibration, the model was run a number of times under various conditions to see how the stream flow would respond given varying tree and impervious cover in the watershed. For tree cover simulations, impervious cover was held constant at the original value with tree cover varying between 0 and 100%. Increasing tree cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally impervious covered land. At 100% tree cover, all impervious land is cover by trees. This assumption is unreasonable as all buildings, road and parking lots would be cover by trees, but the results illustrate the potential impact. Reductions in tree cover were assumed to be filled with grass and shrub cover.

For impervious cover simulations, tree cover was held constant at the original value with impervious cover varying between 0 and 100%. Increasing impervious cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally under tree canopies. The assumption of 100% impervious cover is unreasonable, but the results illustrate the potential impact. In addition, as impervious increased from the current conditions, so did the percent of the impervious cover connected to the stream such that at 100% impervious cover, all (100%) impervious cover is connected to the stream. Reductions in impervious cover were assumed to be filled with grass and shrub cover.

Water Quality Effects – Event Mean Concentration to Calculate Pollution Load

The term event mean concentration (EMC) is a statistical parameter used to represent the flow-proportional average concentration of a given parameter during a storm event. It is defined as the total constituent mass divided by the total runoff volume, although EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. Mathematically (Sansalone and Buchberger, 1997; Charbeneau and Barretti, 1998):

$$EMC = \overline{C} = \frac{M}{V} = \frac{\int C(t)\,Q(t)dt}{\int Q(t)dt} \approx \frac{\sum C(t)\,Q(t)\Delta t}{\sum Q(t)\Delta t} \qquad (1)$$

where $C(t)$ and $Q(t)$ are the time-variable concentration and flow measured during the runoff event, and *M* and *V* are pollutant mass and runoff volume as defined in Equation 1. It is clear that the EMC results from a flow-weighted average, not simply a time average of the concentration. EMC data is used for estimating pollutant loading into watersheds. EMCs are reported as a mass of pollutant per unit volume of water (usually mg/L).

The pollution Load (L) calculation from the EMC method is

$$L = EMC * Q = EMC * d_r * A \qquad (2)$$

Where EMC is event mean concentration (mg/l, mg/m^3, …), Q is runoff of a time period associated with EMC (l/h, m^3 /day…), d_r is runoff depth of unit area (mm/h, m/h, m/day…), A is the land area (m^2, …) which is catchment area in i-Tree / UFORE-Hydro.

Thus, when the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. As is evident from Figure B.2, the instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterisation replaces the actual time variation of *C* versus *t* in a storm with a pulse of constant concentration having equal mass and duration as the actual event. This process ensures that mass loadings from storms will be correctly represented. EMCs represent the concentration of a specific pollutant contained in stormwater runoff coming from a particular land use type or from the whole watershed. Under most circumstances, the EMC provides the most useful means for quantifying the level of pollution resulting from a runoff event (USEPA, 2002).

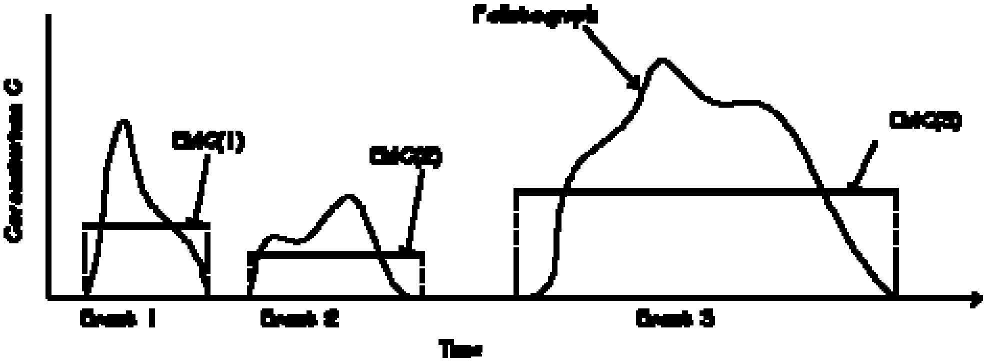

Figure B.2 Interstorm variation of pollutographs and EMCs

Since collecting the data necessary for calculating site-specific EMCs can be cost-prohibitive, researchers or regulators will often use values that are already available in the literature. If site-specific numbers are not available, regional or national averages can be used, although the accuracy of using these numbers is questionable. Due to the specific climatological and physiographic characteristics of individual watersheds, agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Beaulac and Reckhow 1982).

To understand and control urban runoff pollution, The U.S. Congress included the establishment of the Nationwide Urban Runoff Program (NURP) in the 1977 Amendments of the Clean Water Act (PL 95-217). The U.S. Environmental Protection Agency developed the NURP to expand the state knowledge of urban runoff pollution by applying research projects and instituting data collection in selected urban areas throughout the country.

In 1983, the U.S. Environmental Protection Agency (U.S. EPA, 1983) published the results of the NURP, which nationally characterizes urban runoff for 10 standard water quality pollutants, based on data from 2,300 station-storms at 81 urban sites in 28 metropolitan areas.

Two important conclusions from NURP investigations:

- The variance of the EMCs when data from sites are grouped by land use type or geographic region is so great that difference in measures of central tendency among groups statistically are not significant;
- Statistically, the entire sample of EMCs, and the medians of all EMCs among sites, are lognormally distributed.

Thus the numbers in Table B.21 do not distinguish between different urban land use types.

Subsequently, the USGS created another urban stormwater runoff base (Driver et al. 1985), based on data measured through mid-1980s for over 1,100 stations at 97 urban sites located in 21 metropolitan areas. Additionally, many major cities in the United States collected urban runoff quality data as part of the application requirements for stormwater discharge permits under the National Pollutant Discharge Elimination System (NPDES). The NPDES data are from over 30 cities and more than 800 station-storms for over 150 paramaters (Smullen et al, 1999).

The data from the three sources (NURP, USGS and NPDES) were used to compute new estimates of EMC population means and medians for the 10 pollutants with many more degrees of freedom than were available to the NURP investigators (Smullen et al, 1999). A “pooled” mean was calculated representing the mean of the total population of sample data. The NURP and pooled mean EMCs for the 10 constitutes are listed in Table B.21 (Smullen et al, 1999). NURP or pooled mean EMCs were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors.

Table B.21 National Pooled EMCs and NURP EMCs

Constitute	Data Source	EMCs (mg/l)		No. of Events
		Mean	Median	
Total Suspended Solids: TSS	Pooled	78.4	54.5	3047
	NURP	17.4	113	2000
Biochemical Oxygen Demand: BOD_5	Pooled	14.1	11.5	1035
	NURP	10.4	8.39	474
Chemical Oxygen Demand: COD	Pooled	52.8	44.7	2639
	NURP	66.1	55	1538
Total phosphorus: TP	Pooled	0.315	0.259	3094

	NURP	0.337	0.266	1902
Soluble phosphorus: Soluble P	Pooled	0.129	0.103	1091
	NURP	0.1	0.078	767
Total Kjeldhal nitrogen: TKN	Pooled	1.73	1.47	2693
	NURP	1.67	1.41	1601
Nitrite and Nitrate: NO_2 and NO_3	Pooled	0.658	0.533	2016
	NURP	0.837	0.666	1234
Copper: Cu	Pooled	13.5	11.1	1657
	NURP	66.6	54.8	849
Lead: Pb	Pooled	67.5	50.7	2713
	NURP	175	131	1579
Zinc: Zn	Pooled	162	129	2234
	NURP	176	140	1281

Note;

(1) Polled data sources include: NURP, USGS, NPDES
(2) No BOD_5 data available in the USGS dataset - polled includes NURP+NPDES
(3) NO TSP data available in NPDES dataset - polled includes NURP+USGS

For UFORE-Hydro, the pooled median and mean EMC value for each pollutant (Table B.21) were applied to the runoff regenerated from pervious and impervious surface flow, not the base flow values, to estimate effects on pollutant load across the entire modeling time frame. All rain events are treated equally using the EMC value, which mean some events may be over-estimated and others underestimated. In addition, local management actions (e.g., street sweeping) can affect these values. However, across the entire season, if the EMC value is representative of the watershed, the estimate of cumulative effects on water quality should be relatively accurate. Accuracy of pollution estimates will be increased by using locally derived coefficients. It is not known how well the national EMC values represent local conditions.

Results

The overall effect of converting all protected land to unprotected land characteristics is projected to lead to a 3.0% increase in total flow (122,000 cubic meters) for the model period of 04/15/2007 – 10/31/2007 (Table 5). Base flow is projected to decrease by 0.2%, while impervious flow (runoff from impervious areas) is projected to increase by 57.5% and pervious flow (runoff from pervious areas) is projected to increase by 1.3%.

Table B.22 Flow Result of original land cover and developed land cover.

	Flow (cubic meters)			
Watershed	Total Flow	Base Flow	Impervious Flow	Pervious Flow
Original	4,034,492	3,540,427	221,102	272,960
After Development	4,156,638	3,532,014	348,134	276,494
Change[1]	122,146	-8,413	127,032	3,534
Percentage Change	3.0%	-0.2%	57.5%	1.3%

[1] After development - original

Tree Cover Effects: Loss of current tree cover in the Marsh Creek watershed (Figure B.1) would increase total flow during the simulation period by an average of 4.7% (190,000 m^3). Increasing canopy cover from 51.5% to 60% would reduce overall flow by another 0.7% (30,000 m^3) during this 5.5 month period (Figure B.3). Increasing tree cover reduces base flow, as well as flow regenerated from both pervious and impervious areas (Figure B.4).

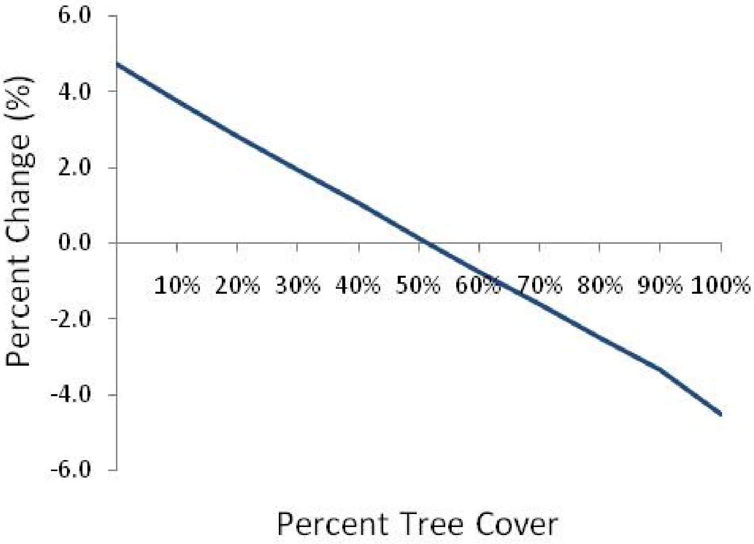

Figure B.3 Percent change in total flow with changes in percent tree cover.

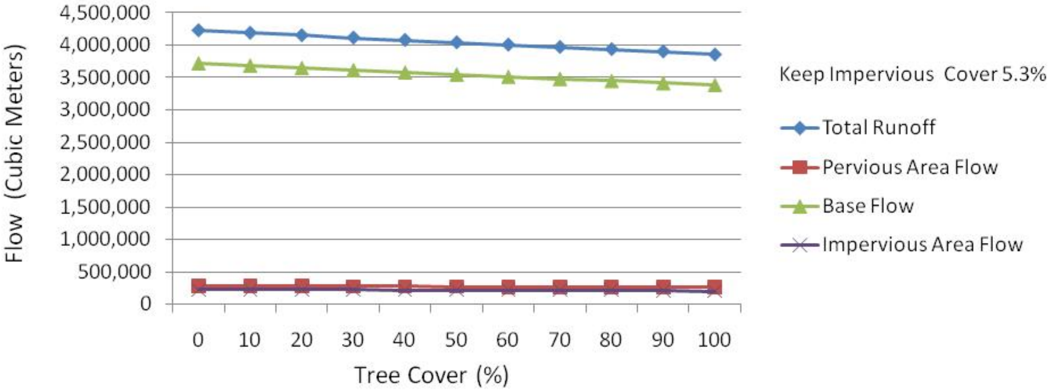

Figure B.4 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent tree cover in the Marsh Creek watershed.

Impervious Cover Effects: Removal of current impervious cover would reduce total flow during the simulation period by an average of 5.7% (231,000 m^3). Increasing impervious cover from 5.3% to 10% of the watershed would increase total flow another 7.4% (300,000 m^3) during this 5.5 month period (Figure B.5). Increasing impervious cover reduces base flow and pervious runoff while significantly increasing flow from impervious surfaces (Figure B.6).

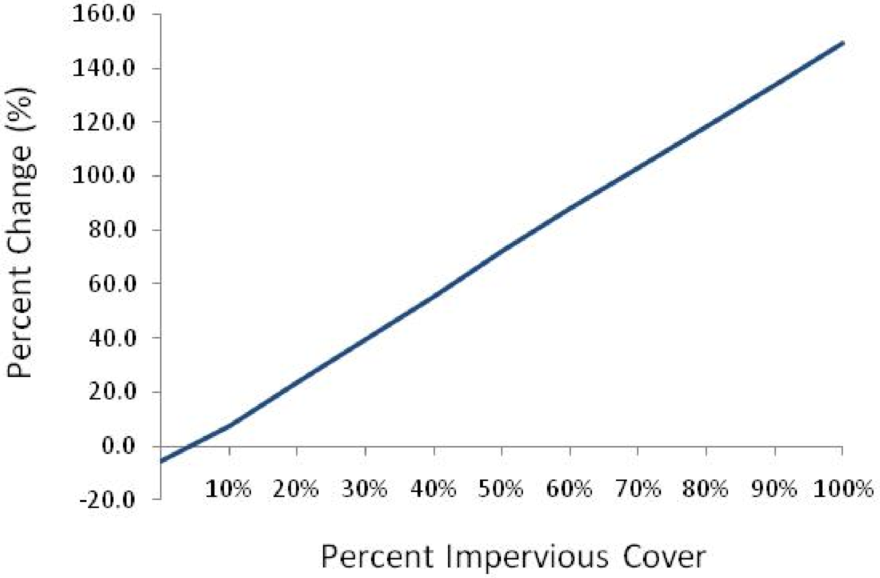

Figure B.5 Percent change in total flow with changes in percent impervious cover.

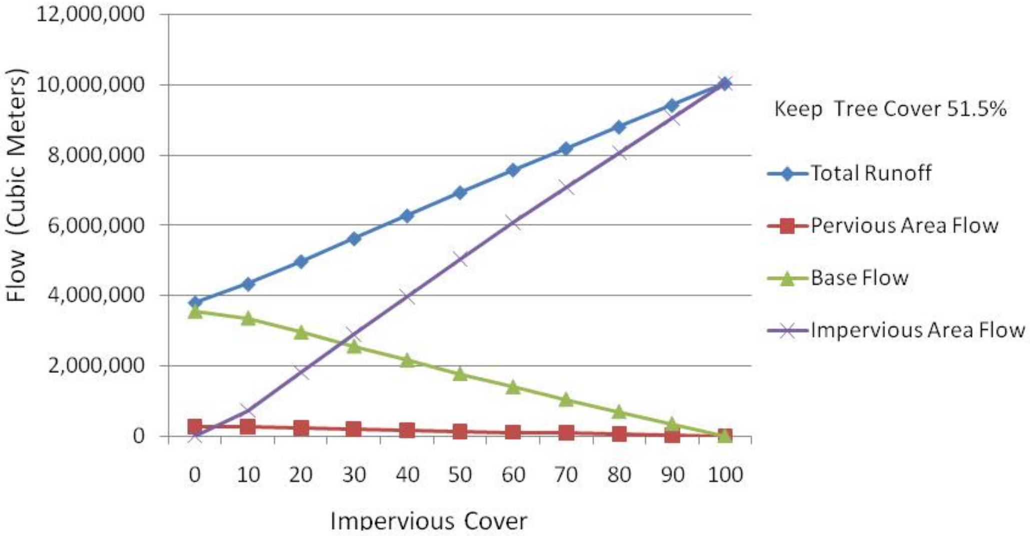

Figure B.6 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent impervious cover in the Marsh Creek watershed.

Increasing tree cover will reduce stream flow, but the dominant cover type influencing stream flow is impervious surfaces. Under current cover conditions, increasing impervious cover had an 11 times greater impact on flow relative to tree cover. Increasing impervious cover by 1% averaged a 1.0% increase in stream flow, while increasing tree cover by 1% averaged only a 0.09% decrease in stream flow. The interactions between changing both tree and impervious cover are illustrated for both total flow during the simulation period (Figure B.7) and for changes in percent flow (Figure B.8).

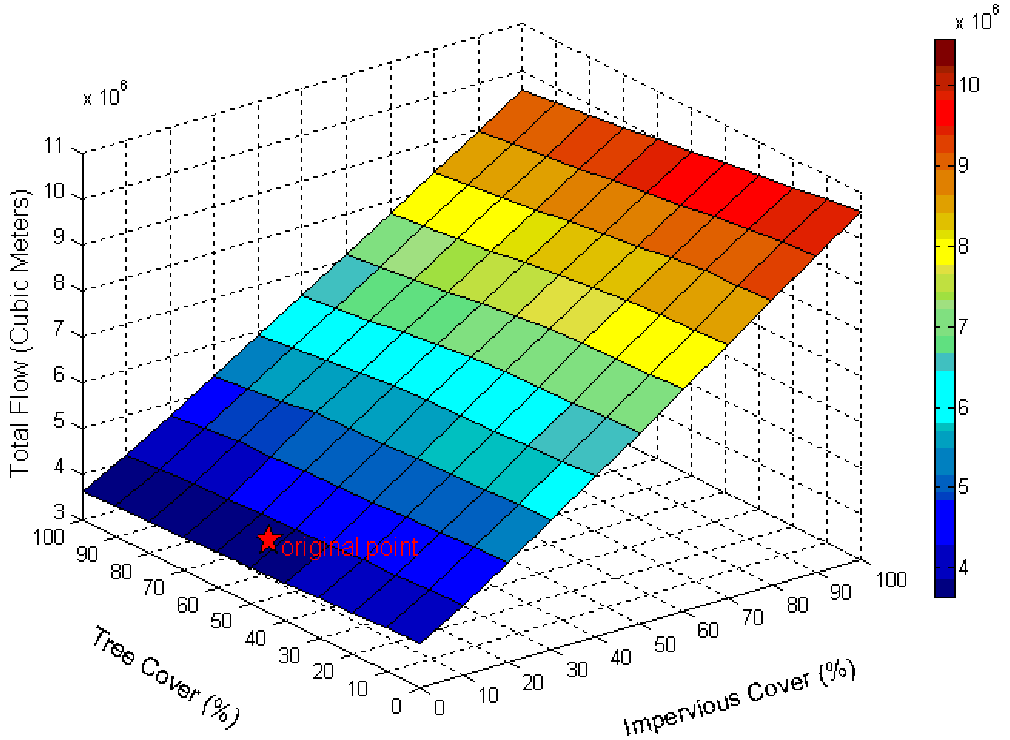

Figure B.7 Changes in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

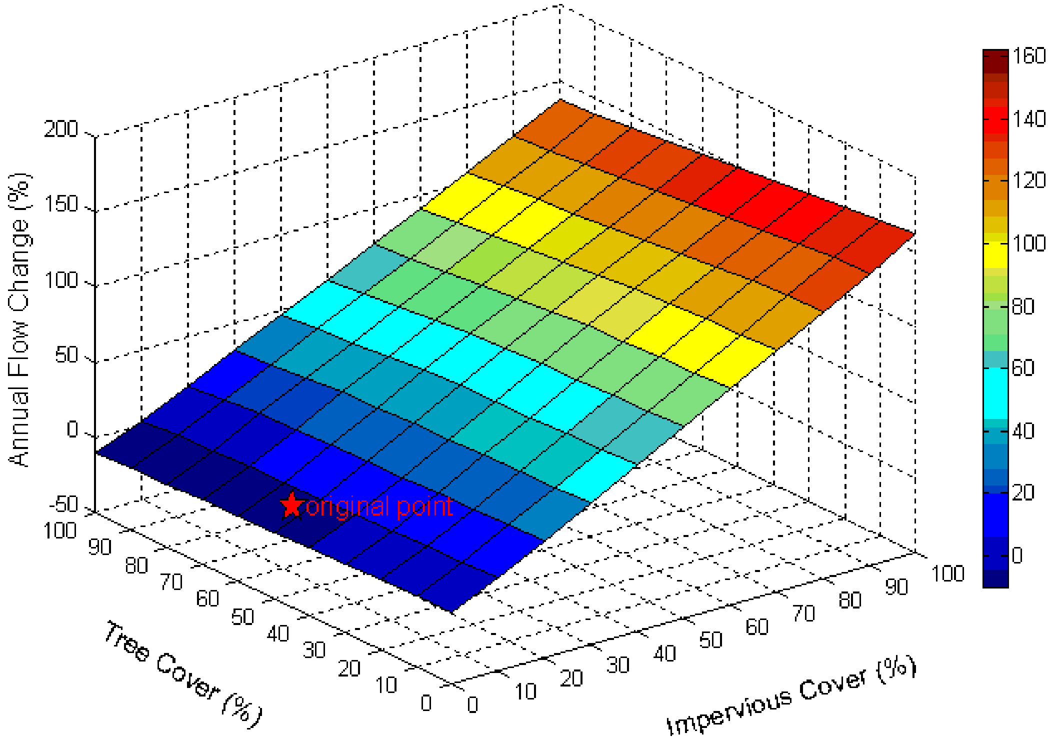

Figure B.8 Percent change in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

During the simulation period the total rainfall recorded was 499.6 mm. Since that amount is assumed to have fallen over the entire 22.2 sq. km watershed, a total of 11.1 million cubic meters of rain fell on the watershed during the simulation time. The total modeled flow in Marsh Creek watershed throughout the simulation time for the base case scenario (no landscape change) was 4.0 million cubic meters. The total flow is made up of surface runoff and baseflow (water that travels underground to the stream). Base flow was estimated to generate 87.8% of total flow. Runoff from pervious and impervious areas contributed 6.8% and 5.5% of total flow generated respectively. Areas of tree canopies intercepted about 9.5% of the total rainfall, but as only 51.5% of watershed in under tree cover, interception of total precipitation in the watershed by trees was only 4.9% (543,000 cubic meters). Areas of short vegetation, including shrubs, intercepted about 3.4% of the total rainfall, but as only 44% of watershed in under short vegetation, interception of total precipitation in the watershed by short vegetation was only 1.5% (164,000 cubic meters). About 57% of total precipitation is estimated to re-enter the atmosphere through evaporation or evapotranspiration.

Based on these changes in flow rates and national EMC values, the current tree cover is estimated to reduce total suspended solids during the simulation period by around 0.8 to 1.1 metric tons. Other chemical constituents are also reduced (Table B.23).

Table B.23 Estimated reduction in chemical constituents in Marsh Creek watershed due to existing tree cover during simulation period based on median and mean pooled event mean concentration values (Table 4).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	-0.8	-1.1
Biochemical Oxygen Demand	-0.2	-0.2
Chemical Oxygen Demand	-0.6	-0.8
Total phosphorus	-0.00	-0.00
Soluble phosphorus	-0.00	-0.00
Total Kjeldhal nitrogen	-0.0	-0.0
Nitrite and Nitrate	-0.0	-0.0
Copper	-0.2	-0.2

Changing protected land cover to unprotected land cover characteristics by increasing impervious cover at the expense of existing tree cover increased total suspended solids during the simulation period by around 7.1 to 10.2 metric tons. Other chemical constituents are also increased (Table B.24).

Table B.24 Estimated change in chemical constituents in Marsh Creek watershed due to changing protected land to unprotected land conditions (increasing impervious cover at the expense of tree cover) during simulation period based on median and mean pooled event mean concentration values (Table 4).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	7.1	10.2
Biochemical Oxygen Demand	1.5	1.8
Chemical Oxygen Demand	5.8	6.9
Total phosphorus	0.03	0.04
Soluble phosphorus	0.01	0.02
Total Kjeldhal nitrogen	0.2	0.2
Nitrite and Nitrate	0.1	0.1
Copper	1.4	1.8

Modeling Land Cover Effects in Neshaminy Creek Watershed

David Nowak, USDA Forest Service, Northern Research Station
Yang Yang and Ted Endreny, State University of New York, College of Environmental Science and Forestry

This report details results of changes in stream flow due to the effects of development in the Neshaminy Creek watershed (236.3 km^2, Figure B.11) using the i-Tree / UFORE Hydro model (Wang et al., 2008).

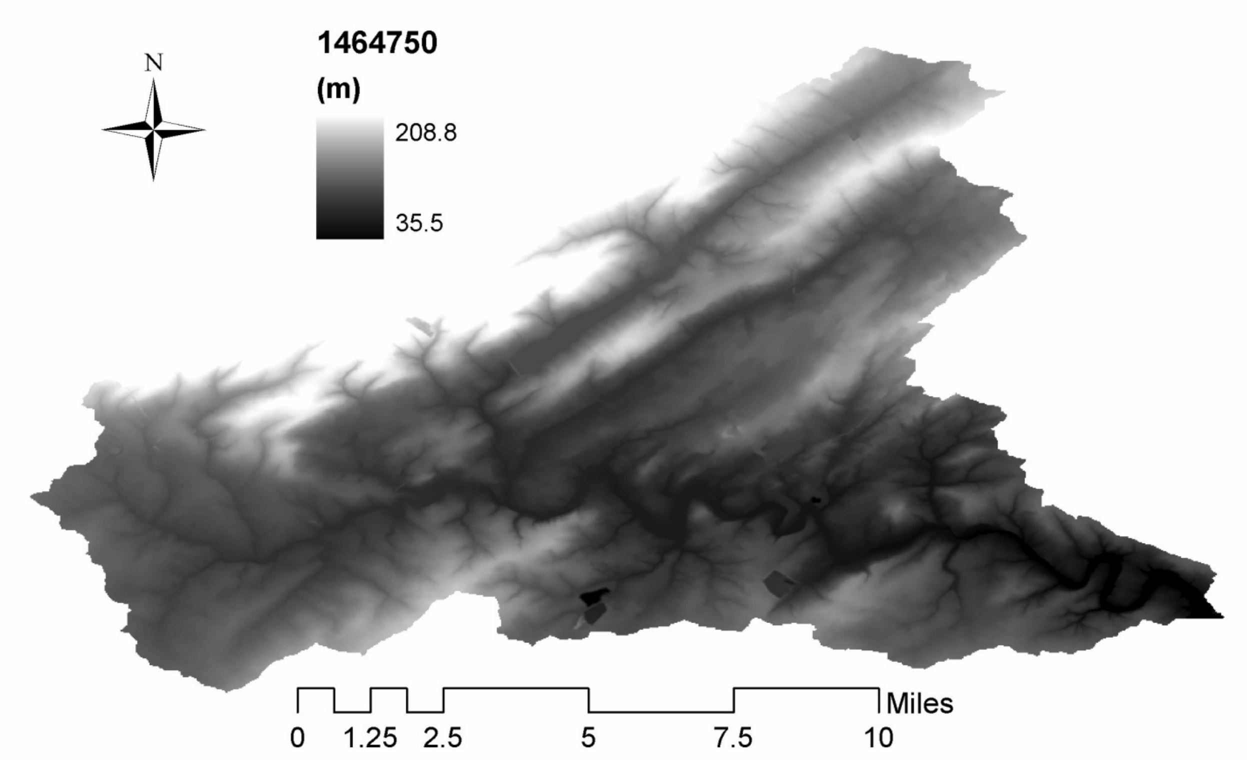

Figure B.11 DEM of Watershed Neshaminy Creek near Rushland, PA (USGS 01464750)

Data and Model Calibration

The precipitation and weather data for this analysis were collected from a local weather station at Willow Grove (WBAN: 724086 14793). Tree and impervious cover parameters were derived for protected and unprotected areas of the watershed from photo-interpretation of Google Earth imagery (image data 2010) using 1,000 randomly located points (Table B.25). Protected and unprotected areas were delimited based on boundary files provided by Econsult Corporation. Protected areas have higher tree cover and lower impervious cover (i.e., roads, buildings, concrete, etc.).

Table B.25 Cover estimates for watershed

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	14.0	51.0	36.0	0.0
Unprotected Area	25.6	33.3	43.1	1.9
Whole Watershed	24.1	35.5	42.3	1.6

The model was calibrated using hourly stream flow data collected at the Neshaminy Creek near Rushland, PA (USGS 01464750) gauging station (04/15/2009 – 10/31/2009). Model results were calibrated against measured stream flow to yield the best fit between model and measured stream flow results. Calibration coefficients (0-1 with 1.0 = perfect fit) were calculated for peak flow, base flow, and balance flow (peak and base) (Table B.26). Calibrations can often be off, particularly for peak flows, due to mismatching of steam flow and weather data as the weather stations are often outside of the watershed area. For example, it may be raining at the weather station and not in the watershed or vice versa. Tree canopy leaf area index (LAI) was estimated at 5.0 based on various field studies and the amount of percent of impervious cover connected to the stream was estimated at 95 percent.

Table B.26 Calibration coefficients for model estimates and gauging station data.

	Calibration Coefficients		
Watershed	Peak Flow	Base Flow	Balanced Flow
Neshaminy Creek	0.39	0.33	0.42

Model Scenarios

The model scenario employed in this analysis is the conversion of protected land characteristics to unprotected land characteristics (Table B.27). That is, it depicts what would happen if the protected areas developed like unprotected areas with additional impervious cover replacing tree cover in protected areas. In this case impervious cover in the watershed would increase from 24.1% to 25.5%, tree cover drop from 35.5% to 34.0% overall.

Table B.27 Cover change for watershed

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	25.6	39.4	36.0	0.0
Unprotected Area	25.6	33.3	43.1	1.9
Whole Watershed	25.5	34.0	42.2	1.6

In addition, effects of changes in tree and impervious cover in this watershed were explored. After calibration, the model was run a number of times under various conditions to see how the stream flow would respond given varying tree and impervious cover in the watershed. For tree cover simulations, impervious cover was held constant at the original value with tree cover varying between 0 and 100%. Increasing tree cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally impervious covered land. At 100% tree cover, all impervious land is covered by trees. This assumption is unreasonable as all buildings, road and parking lots would be cover by trees, but the results illustrate the potential impact. Reductions in tree cover were assumed to be filled with grass and shrub cover.

For impervious cover simulations, tree cover was held constant at the original value with impervious cover varying between 0 and 100%. Increasing impervious cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally under tree canopies. The assumption of 100% impervious cover is unreasonable, but the results illustrate the potential impact. In addition, as impervious increased from the current conditions, so did the percent of the impervious cover connected to the stream such that at 100% impervious cover, all (100%) impervious cover is connected to the stream. Reductions in impervious cover were assumed to be filled with grass and shrub cover.

Water Quality Effects – Event Mean Concentration to Calculate Pollution Load

The term event mean concentration (EMC) is a statistical parameter used to represent the flow-proportional average concentration of a given parameter during a storm event. It is defined as the total constituent mass divided by the total runoff volume, although EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. Mathematically (Sansalone and Buchberger, 1997; Charbeneau and Barretti, 1998):

$$EMC = \overline{C} = \frac{M}{V} = \frac{\int C(t)\,Q(t)dt}{\int Q(t)dt} \approx \frac{\sum C(t)\,Q(t)\Delta t}{\sum Q(t)\Delta t} \qquad (1)$$

where $C(t)$ and $Q(t)$ are the time-variable concentration and flow measured during the runoff event, and *M* and *V* are pollutant mass and runoff volume as defined in Equation 1. It is clear that the EMC results from a flow-weighted average, not simply a time average of the concentration. EMC data is used for estimating pollutant loading into watersheds. EMCs are reported as a mass of pollutant per unit volume of water (usually mg/L).

The pollution Load (L) calculation from the EMC method is

$$L = EMC * Q = EMC * d_r * A \qquad (2)$$

Where EMC is event mean concentration (mg/l, mg/m^3, …), Q is runoff of a time period associated with EMC (l/h, m^3 /day…), d_r is runoff depth of unit area (mm/h, m/h, m/day…), A is the land area (m^2, …) which is catchment area in i-Tree / UFORE-Hydro.

Thus, when the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. As is evident from Figure B.12, the instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterisation replaces the actual time variation of *C* versus *t* in a storm with a pulse of constant concentration having equal mass and duration as the actual event. This process ensures that mass loadings from storms will be correctly represented. EMCs represent the concentration of a specific pollutant contained in stormwater runoff coming from a particular land use type or from the whole watershed. Under most circumstances, the EMC provides the most useful means for quantifying the level of pollution resulting from a runoff event (USEPA, 2002).

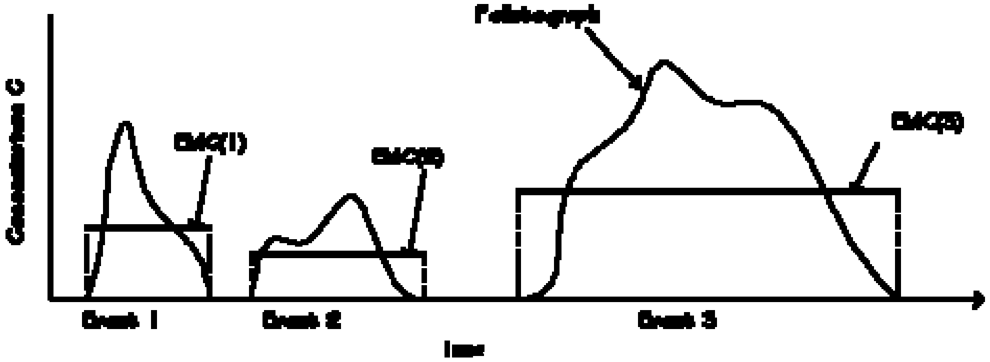

Figure B.12 Interstorm variation of pollutographs and EMCs

Since collecting the data necessary for calculating site-specific EMCs can be cost-prohibitive, researchers or regulators will often use values that are already available in the literature. If site-specific numbers are not available, regional or national averages can be used, although the accuracy of using these numbers is questionable. Due to the specific climatological and physiographic characteristics of individual watersheds, agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Beaulac and Reckhow 1982).

To understand and control urban runoff pollution, The U.S. Congress included the establishment of the Nationwide Urban Runoff Program (NURP) in the 1977 Amendments of the Clean Water Act (PL 95-217). The U.S. Environmental Protection Agency developed the NURP to expand the state knowledge of urban runoff pollution by applying research projects and instituting data collection in selected urban areas throughout the country.

In 1983, the U.S. Environmental Protection Agency (U.S. EPA, 1983) published the results of the NURP, which nationally characterizes urban runoff for 10 standard water quality pollutants, based on data from 2,300 station-storms at 81 urban sites in 28 metropolitan areas.

Two important conclusions from NURP investigations:

- The variance of the EMCs when data from sites are grouped by land use type or geographic region is so great that difference in measures of central tendency among groups statistically are not significant;
- Statistically, the entire sample of EMCs, and the medians of all EMCs among sites, are lognormally distributed.

Thus the numbers in Table B.28 do not distinguish between different urban land use types.

Subsequently, the USGS created another urban stormwater runoff base (Driver et al. 1985), based on data measured through mid-1980s for over 1,100 stations at 97 urban sites located in 21 metropolitan areas. Additionally, many major cities in the United States collected urban runoff quality data as part of the application requirements for stormwater discharge permits under the National Pollutant Discharge Elimination System (NPDES). The NPDES data are from over 30 cities and more than 800 station-storms for over 150 paramaters (Smullen et al, 1999).

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Table B.28 National Pooled EMCs and NURP EMCs

Constitute	Data Source	EMCs (mg/l)		No. of Events
		Mean	Median	
Total Suspended Solids: TSS	Pooled	78.4	54.5	3047
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Note;

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Results

The overall effect of converting all protected land to unprotected land characteristics is projected to lead to a 4.2% increase in total flow (3.3 million cubic meters) for the model period of 04/15/2009 – 10/31/2009 (Table B.29). Base flow is projected to decrease by 1.7%, while impervious flow (runoff from impervious areas) is projected to increase by 5.4% and pervious flow (runoff from pervious areas) is projected to decrease by 1.5%.

Table B.29 Flow Result of original land cover and developed land cover.

	Flow (cubic meters)			
Watershed	Total Flow	Base Flow	Impervious Flow	Pervious Flow
Original	77,346,446	132,391	63,852,956	13,361,000
After Development	80,604,783	130,120	67,311,231	13,163,307
Change[1]	3,258,337	-2,271	3,458,275	-197,693
Percentage Change	4.2%	-1.7%	5.4%	-1.5%

[1] After development - original

Tree Cover Effects: Loss of current tree cover in the Neshaminy Creek watershed (Figure B.11) would increase total flow during the simulation period by an average of 1.0% (767,000 m^3). Increasing canopy cover from 35.5% to 40% would reduce overall flow by another 0.1% (93,000 m^3) during this 5.5 month period (Figure B.13). Increasing tree cover reduces base flow, as well as flow regenerated from both pervious and impervious areas (Figure B.14).

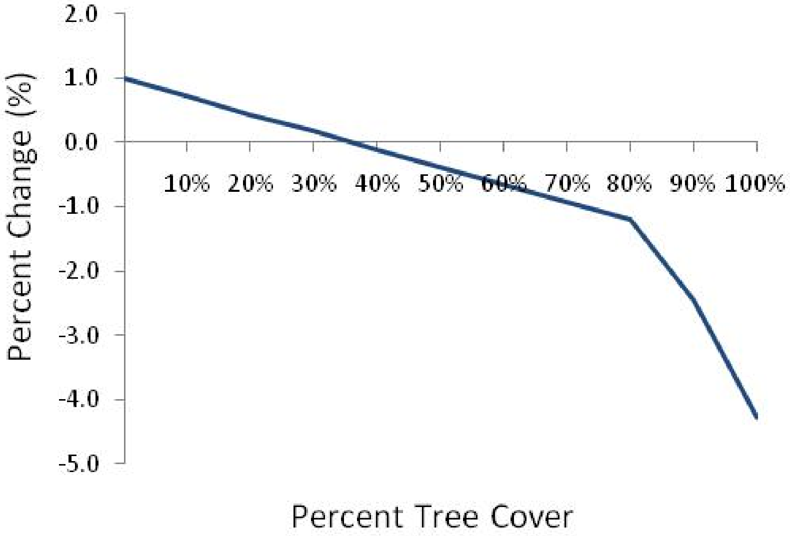


Figure B.13 Percent change in total flow with changes in percent tree cover.

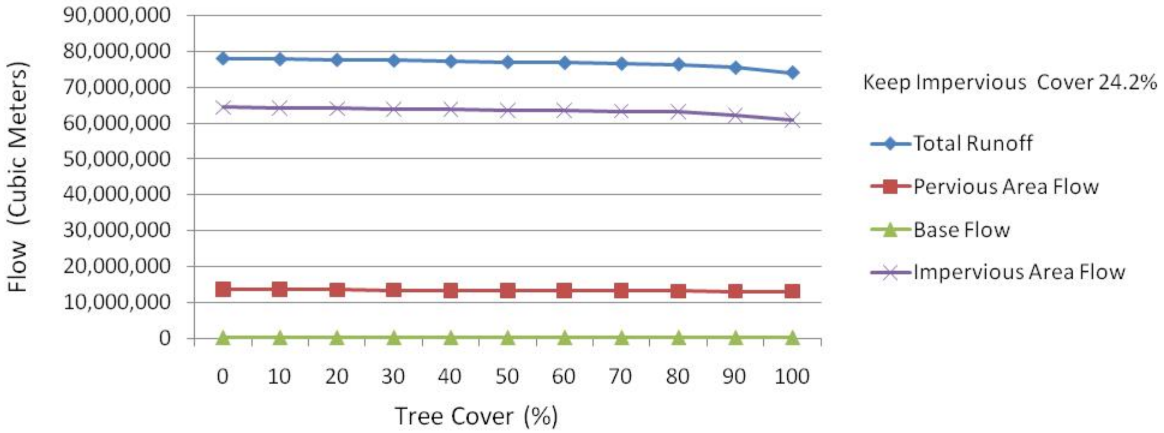


Figure B.14 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent tree cover in the Neshaminy Creek watershed.

<u>Impervious Cover Effects</u>: Removal of current impervious cover would reduce total flow during the simulation period by an average of 77.4% (59.9 million m^3). Increasing impervious cover from 24.2% to 30% of the watershed would increase total flow another 19.8% (15.3 million m^3) during this 5.5 month period (Figure B.15). Increasing impervious cover reduces base flow and pervious runoff while significantly increasing flow from impervious surfaces (Figure B.16).

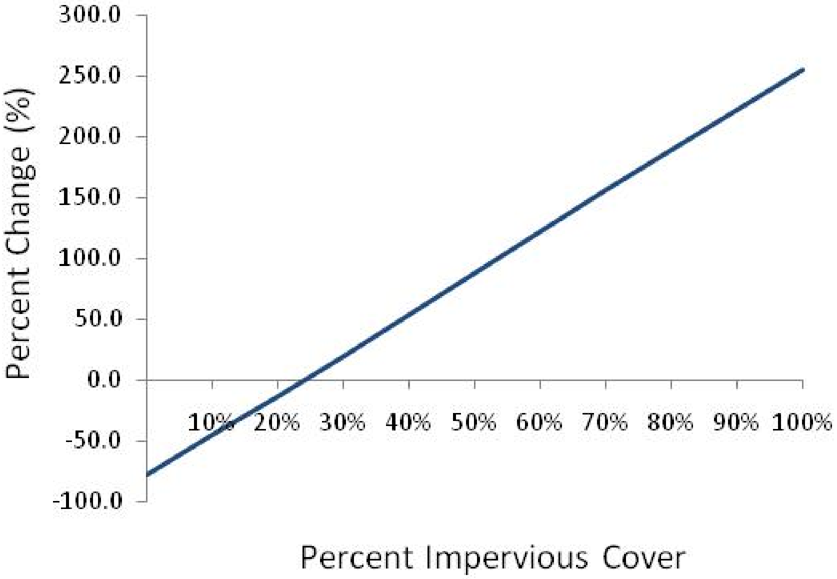


Figure B.15 Percent change in total flow with changes in percent impervious cover.

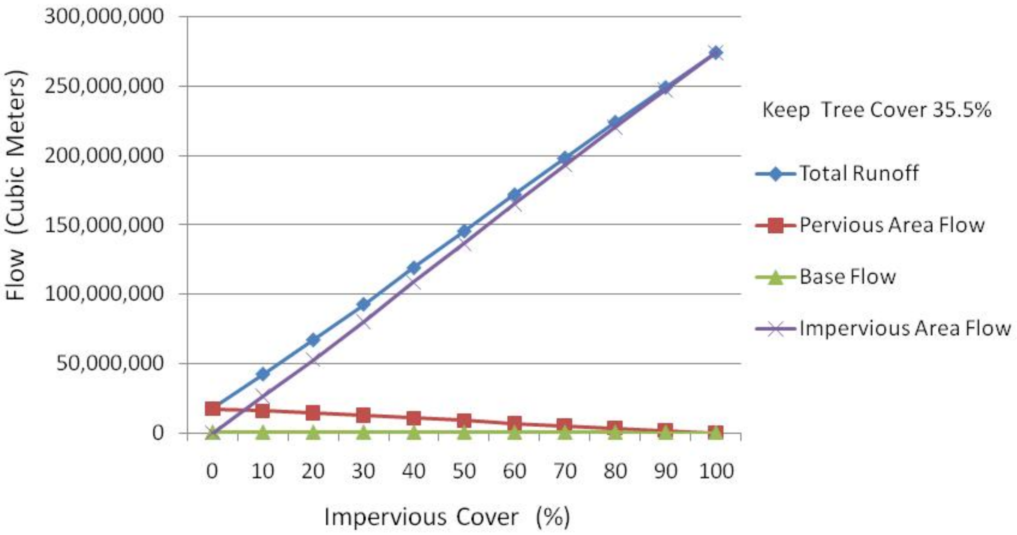


Figure B.16 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent impervious cover in the Neshaminy Creek watershed.

Increasing tree cover will reduce stream flow, but the dominant cover type influencing stream flow is impervious surfaces. Under current cover conditions, increasing impervious cover had a 67 times greater impact on flow relative to tree cover. Increasing impervious cover by 1% averaged a 3.6% increase in stream flow, while increasing tree cover by 1% averaged only a 0.05% decrease in stream flow. The interactions between changing both tree and impervious cover are illustrated for both total flow during the simulation period (Figure B.17) and for changes in percent flow (Figure B.18).

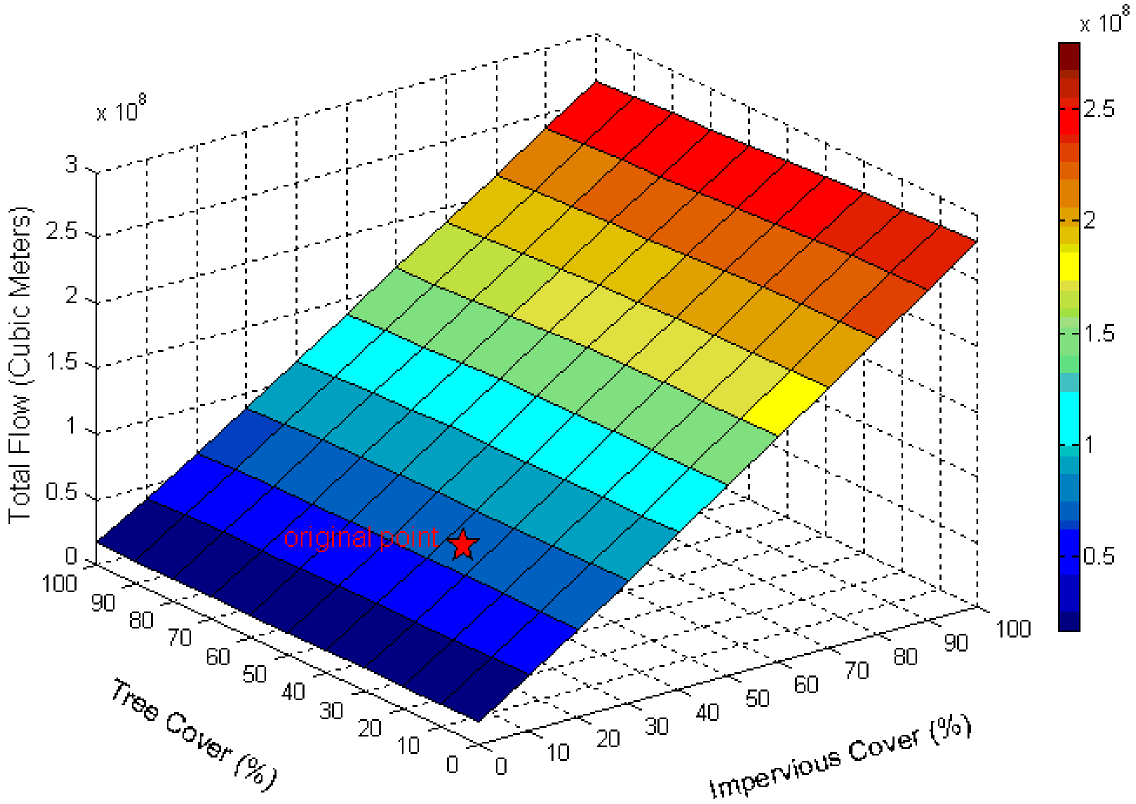


Figure B.17 Changes in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

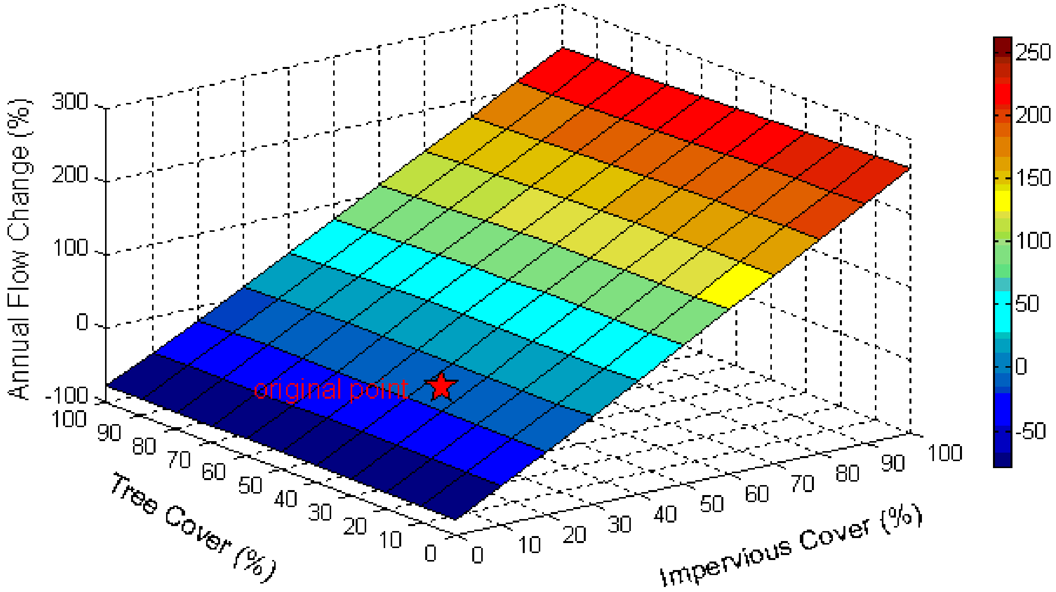


Figure B.18 Percent change in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

During the simulation period the total rainfall recorded was 1,413.3 mm. Since that amount is assumed to have fallen over the entire 236.3 sq. km watershed, a total of 334 million cubic meters of rain fell on the watershed during the simulation time. The total modeled flow in Neshaminy Creek watershed throughout the simulation time for the base case scenario (no landscape change) was 77.3 million cubic meters. The total flow is made up of surface runoff and baseflow (water that travels underground to the stream). Runoff from impervious and pervious areas is the biggest contributor to stream flow with 82.6% and 17.3% of total flow generated from impervious and pervious runoff respectively. Base flow was estimated to generate 0.2% of total flow. Areas of tree canopies intercepted about 5.7% of the total rainfall, but as only 35.5% of watershed in under tree cover, interception of total precipitation in the watershed by trees was only 2.0% (6.8 million cubic meters). Areas of short vegetation, including shrubs, intercepted about 2.2% of the total rainfall, but as only 42% of watershed in under short vegetation, interception of total precipitation in the watershed by short vegetation was only 1.1% (3.1 million cubic meters). About 74% of total precipitation is estimated to re-enter the atmosphere through evaporation or evapotranspiration.

Based on these changes in flow rates and national EMC values, the current tree cover is estimated to reduce total suspended solids during the simulation period by around 42 and 60 metric tons. Other chemical constituents are also reduced (Table B.30).

Table B.30 Estimated reduction in chemical constituents in Neshaminy Creek watershed due to existing tree cover during simulation period based on median and mean pooled event mean concentration values (Table B.28).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	-41.8	-60.2
Biochemical Oxygen Demand	-8.8	-10.8
Chemical Oxygen Demand	-34.3	-40.5
Total phosphorus	-0.20	-0.24
Soluble phosphorus	-0.08	-0.10
Total Kjeldhal nitrogen	-1.1	-1.3
Nitrite and Nitrate	-0.4	-0.5
Copper	-8.5	-10.4

Changing protected land cover to unprotected land cover characteristics by increasing impervious cover at the expense of existing tree cover increased total suspended solids during the simulation period by around 177 and 256 metric tons. Other chemical constituents are also increased (Table B.31).

Table B.31 Estimated change in chemical constituents in Neshaminy Creek watershed due to changing protected land to unprotected land conditions (increasing impervious cover at the expense of tree cover) during simulation period based on median and mean pooled event mean concentration values (Table B.28).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	177.7	255.6
Biochemical Oxygen Demand	37.5	46.0
Chemical Oxygen Demand	145.7	172.2
Total phosphorus	0.84	1.03
Soluble phosphorus	0.34	0.42
Total Kjeldhal nitrogen	4.8	5.6
Nitrite and Nitrate	1.7	2.1
Copper	36.2	44.0

Modeling Land Cover Effects in Ridley Creek Watershed

David Nowak, USDA Forest Service, Northern Research Station
Yang Yang and Ted Endreny, State University of New York, College of Environmental Science and Forestry

This report details results of changes in stream flow due to the effects of development in the Ridley Creek watershed (78.5 km^2, Figure B.21) using the i-Tree / UFORE Hydro model (Wang et al., 2008).

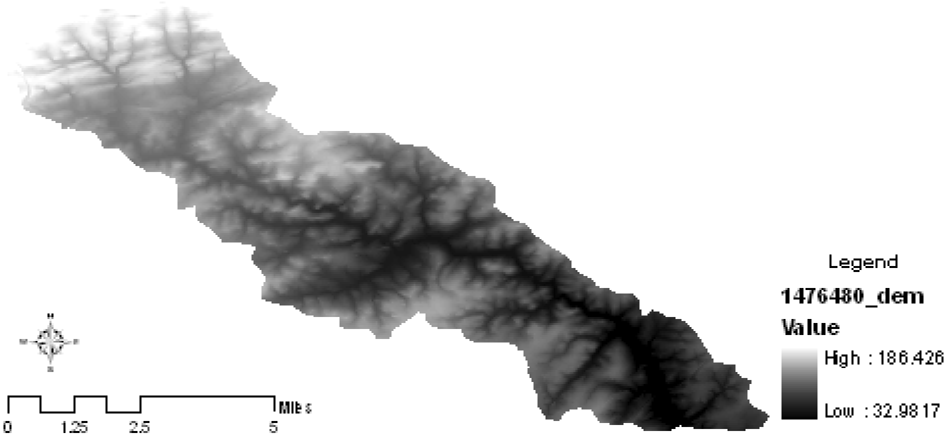


Figure B.21 DEM of Watershed Ridley Creek at Media (USGS 01476480)

Data and Model Calibration

The precipitation and weather data for this analysis were collected from a local weather station at the Philadelphia International Airport (WBAN: 724080 13739). Tree and impervious cover parameters were derived for protected and unprotected areas of the watershed from photo-interpretation of Google Earth imagery (image data 2010) using 1,000 randomly located points (Table B.32). Protected and unprotected areas were delimited based on boundary files provided by Econsult Corporation. Protected areas have higher tree cover and lower impervious cover (i.e., roads, buildings, concrete, etc.).

Table B.32 Cover estimates for watershed.

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	3.9	62.3	33.5	0.6
Unprotected Area	17.5	49.5	33.0	2
Whole Watershed	13.1	53.6	33.2	1.6

The model was calibrated using hourly stream flow data collected at the Ridley Creek at Media, PA (USGS: USGS 01476480) gauging station (04/15/2007 – 10/31/2007). Model results were calibrated against measured stream flow to yield the best fit between model and measured stream flow results (Appendix B.3). Calibration coefficients (0-1 with 1.0 = perfect fit) were calculated for peak flow, base flow, and balance flow (peak and base) (Table B.33). Calibrations can often be off, particularly for peak flows, due to mismatching of steam flow and weather data as the weather stations are often outside of the watershed area. For example, it may be raining at the weather station and not in the watershed or vice versa. Tree canopy leaf area index (LAI) was estimated at 5.0 based on various field studies and the amount of percent of impervious cover connected to the stream was estimated at 65 percent.

Table B.33 Calibration coefficients for model estimates and gauging station data.

	Calibration Coefficients		
Watershed	Peak Flow	Base Flow	Balanced Flow
Ridley Creek at Media	0.71	0.29	0.33

Model Scenarios

The model scenario employed in this analysis is the conversion of protected land characteristics to unprotected land characteristics (Table B.34). That is, it depicts what would happen if the entire watershed had the characteristics of the unprotected areas in the watershed. In this case impervious cover in the watershed would increase from 13.1% to 17.5%, tree cover drop from 53.6% to 49.1% overall.

Table B.34 Cover change for watershed

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	17.5	48.7	33.5	0.6
Unprotected Area	17.5	47.5	33.0	2.0
Whole Watershed	17.5	49.1	33.2	1.6

In addition, effects of changes in tree and impervious cover in this watershed were explored. After calibration, the model was run a number of times under various conditions to see how the stream flow would respond given varying tree and impervious cover in the watershed. For tree cover simulations, impervious cover was held constant at the original value with tree cover varying between 0 and 100%. Increasing tree cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally impervious covered land. At 100% tree cover, all impervious land is cover by trees. This assumption is unreasonable as all buildings, road and parking lots would be cover by trees, but the results illustrate the potential impact. Reductions in tree cover were assumed to be filled with grass and shrub cover.

For impervious cover simulations, tree cover was held constant at the original value with impervious cover varying between 0 and 100%. Increasing impervious cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally under tree canopies. The assumption of 100% impervious cover is unreasonable, but the results illustrate the potential impact. In addition, as impervious increased from the current conditions, so did the percent of the impervious cover connected to the stream such that at 100% impervious cover, all (100%) impervious cover is connected to the stream. Reductions in impervious cover were assumed to be filled with grass and shrub cover.

Water Quality Effects – Event Mean Concentration to Calculate Pollution Load

The term event mean concentration (EMC) is a statistical parameter used to represent the flow-proportional average concentration of a given parameter during a storm event. It is defined as the total constituent mass divided by the total runoff volume, although EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. Mathematically (Sansalone and Buchberger, 1997; Charbeneau and Barretti, 1998):

$$EMC = \overline{C} = \frac{M}{V} = \frac{\int C(t)\, Q(t) dt}{\int Q(t) dt} \approx \frac{\sum C(t)\, Q(t) \Delta t}{\sum Q(t) \Delta t} \qquad (1)$$

where $C(t)$ and $Q(t)$ are the time-variable concentration and flow measured during the runoff event, and *M* and *V* are pollutant mass and runoff volume as defined in Equation 1. It is clear that the EMC results from a flow-weighted average, not simply a time average of the concentration. EMC data is used for estimating pollutant loading into watersheds. EMCs are reported as a mass of pollutant per unit volume of water (usually mg/L).

The pollution Load (L) calculation from the EMC method is

$$L = EMC * Q = EMC * d_r * A \qquad (2)$$

Where EMC is event mean concentration (mg/l, mg/m^3, …), Q is runoff of a time period associated with EMC (l/h, m^3 /day…), d_r is runoff depth of unit area (mm/h, m/h, m/day…), A is the land area (m^2, …) which is catchment area in i-Tree / UFORE-Hydro.

Thus, when the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. As is evident from Figure B.22, the instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterisation replaces the actual time variation of *C* versus *t* in a storm with a pulse of constant concentration having equal mass and duration as the actual event. This process ensures that mass loadings from storms will be correctly represented. EMCs represent the concentration of a specific pollutant contained in stormwater runoff coming from a particular land use type or from the whole watershed. Under most circumstances, the EMC provides the most useful means for quantifying the level of pollution resulting from a runoff event (USEPA, 2002).

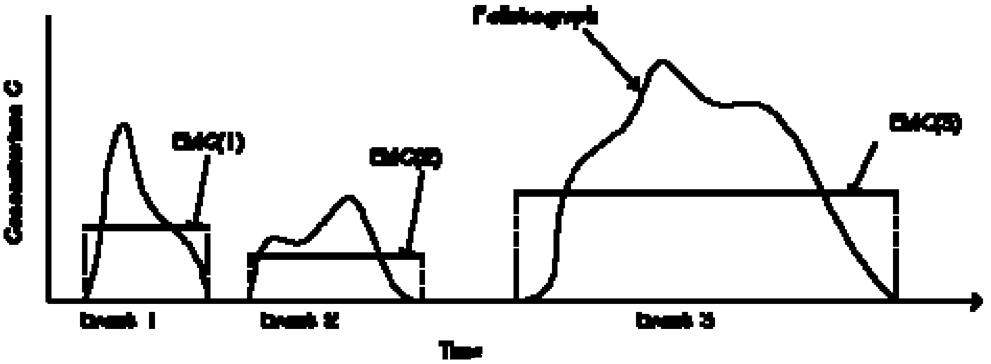


Figure B.22 Interstorm variation of pollutographs and EMCs

Since collecting the data necessary for calculating site-specific EMCs can be cost-prohibitive, researchers or regulators will often use values that are already available in the literature. If site-specific numbers are not available, regional or national averages can be used, although the accuracy of using these numbers is questionable. Due to the specific climatological and physiographic characteristics of individual watersheds, agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Beaulac and Reckhow 1982).

To understand and control urban runoff pollution, The U.S. Congress included the establishment of the Nationwide Urban Runoff Program (NURP) in the 1977 Amendments of the Clean Water Act (PL 95-217). The U.S. Environmental Protection Agency developed the NURP to expand the state knowledge of urban runoff pollution by applying research projects and instituting data collection in selected urban areas throughout the country.

In 1983, the U.S. Environmental Protection Agency (U.S. EPA, 1983) published the results of the NURP, which nationally characterizes urban runoff for 10 standard water quality pollutants, based on data from 2,300 station-storms at 81 urban sites in 28 metropolitan areas.

Two important conclusions from NURP investigations:

- The variance of the EMCs when data from sites are grouped by land use type or geographic region is so great that difference in measures of central tendency among groups statistically are not significant;
- Statistically, the entire sample of EMCs, and the medians of all EMCs among sites, are lognormally distributed.

Thus the numbers in Table B.35 do not distinguish between different urban land use types.

Subsequently, the USGS created another urban stormwater runoff base (Driver et al. 1985), based on data measured through mid-1980s for over 1,100 stations at 97 urban sites located in 21 metropolitan areas. Additionally, many major cities in the United States collected urban runoff quality data as part of the application requirements for stormwater discharge permits under the National Pollutant Discharge Elimination System (NPDES). The NPDES data are from over 30 cities and more than 800 station-storms for over 150 paramaters (Smullen et al, 1999).

The data from the three sources (NURP, USGS and NPDES) were used to compute new estimates of EMC population means and medians for the 10 pollutants with many more degrees of freedom than were available to the NURP investigators (Smullen et al, 1999). A “pooled” mean was calculated representing the mean of the total population of sample data. The NURP and pooled mean EMCs for the 10 constitutes are listed in Table B.35 (Smullen et al, 1999). NURP or pooled mean EMCs were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors.

Table B.35 National Pooled EMCs and NURP EMCs.

Constitute		Data Source	EMCs (mg/l)		No. of Events
			Mean	Median	
Total Suspended Solids:	TSS	Pooled NURP	78.4 17.4	54.5 113	3047 2000
Biochemical Oxygen Demand:	BOD_5	Pooled NURP	14.1 10.4	11.5 8.39	1035 474
Chemical Oxygen Demand:	COD	Pooled NURP	52.8 66.1	44.7 55	2639 1538
Total phosphorus:	TP	Pooled NURP	0.315 0.337	0.259 0.266	3094 1902
Soluble phosphorus:	Soluble P	Pooled NURP	0.129 0.1	0.103 0.078	1091 767
Total Kjeldhal nitrogen:	TKN	Pooled NURP	1.73 1.67	1.47 1.41	2693 1601
Nitrite and Nitrate:	NO_2 and NO_3	Pooled NURP	0.658 0.837	0.533 0.666	2016 1234
Copper:	Cu	Pooled NURP	13.5 66.6	11.1 54.8	1657 849
Lead:	Pb	Pooled NURP	67.5 175	50.7 131	2713 1579
Zinc:	Zn	Pooled NURP	162 176	129 140	2234 1281

Note;

(1) Polled data sources include: NURP, USGS, NPDES
(2) No BOD_5 data available in the USGS dataset - polled includes NURP+NPDES
(3) NO TSP data available in NPDES dataset - polled includes NURP+USGS

For UFORE-Hydro, the pooled median and mean EMC value for each pollutant (Table B.35) were applied to the runoff regenerated from pervious and impervious surface flow, not the base flow values, to estimate effects on pollutant load across the entire modeling time frame. All rain events are treated equally using the EMC value, which mean some events may be over-estimated and others underestimated. In addition, local management actions (e.g., street sweeping) can affect these values. However, across the entire season, if the EMC value is representative of the watershed, the estimate of cumulative effects on water quality should be relatively accurate. Accuracy of pollution estimates will be increased by using locally derived coefficients. It is not known how well the national EMC values represent local conditions.

Results

The overall effect of converting all protected land to unprotected land characteristics is projected to lead to a 5.3% increase in total flow (802,000 cubic meters) for the model period of 04/15/2007 – 10/31/2007 (Table B.36). Base flow is projected to decrease by 2.9%, while impervious flow (runoff from impervious areas) is projected to increase by 34.4% and pervious flow (runoff from pervious areas) is projected to decrease by 2.4%.

Table B.36 Flow Result of original land cover and developed land cover.

	Flow (cubic meters)			
Watershed	Total Flow	Base Flow	Impervious Flow	Pervious Flow
Original	15,019,172	789,279	3,184,275	11,045,625
After Development	15,821,132	766,453	4,278,472	10,776,239
Change[1]	801,960	-22,826	1,094,197	-269,386
Percentage Change	5.3%	-2.9%	34.4%	-2.4%

[1] After development - original

Tree Cover Effects: Loss of current tree cover in the Ridley Creek watershed (Figure B.21) would increase total flow during the simulation period by an average of 4.3% (639,000 m^3). Increasing canopy cover from 54% to 60% would reduce overall flow by another 0.6% (86,000 m^3) during this 5.5 month period (Figure B.23). Increasing tree cover reduces base flow, as well as flow regenerated from both pervious and impervious areas (Figure B.24).

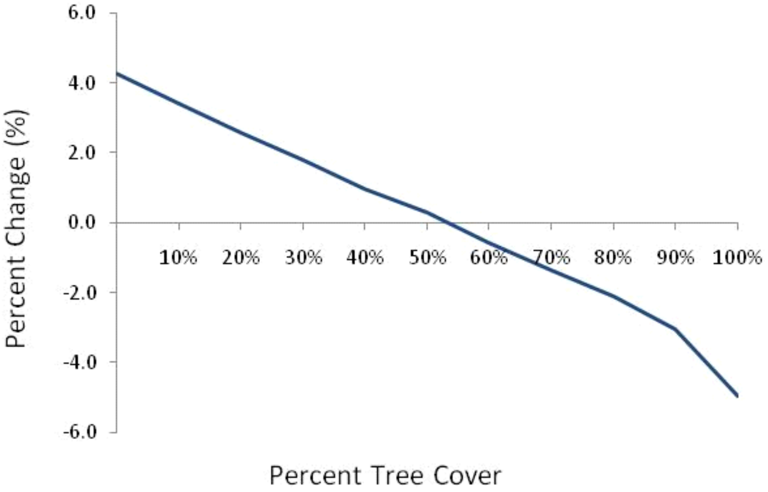


Figure B.23 Percent change in total flow with changes in percent tree cover.

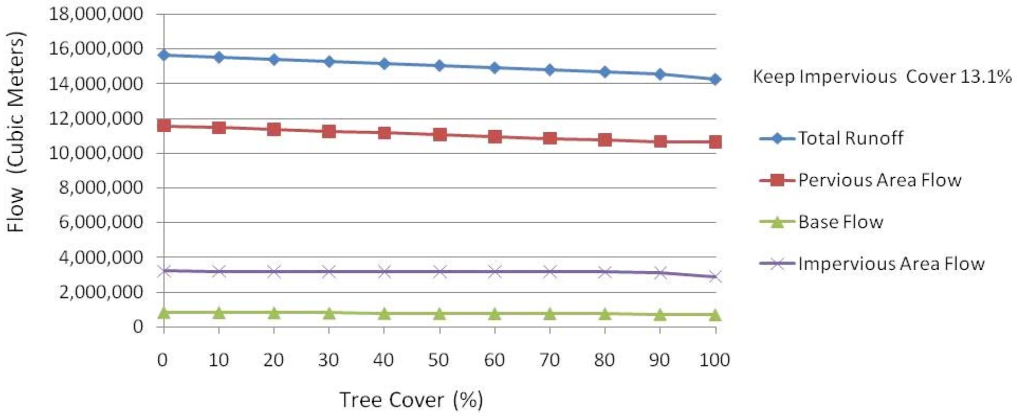


Figure B.24 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent tree cover in the Ridley Creek watershed.

Increasing tree cover will reduce stream flow, but the dominant cover type influencing stream flow is impervious surfaces. Under current cover conditions, increasing impervious cover had a 12.1 times greater impact on flow relative to tree cover. Increasing impervious cover by 1% averaged a 1.1% increase in stream flow, while increasing tree cover by 1% averaged only a 0.09% decrease in stream flow. The interactions between changing both tree and impervious cover are illustrated for both total flow during the simulation period (Figure B.27) and for changes in percent flow (Figure B.28).

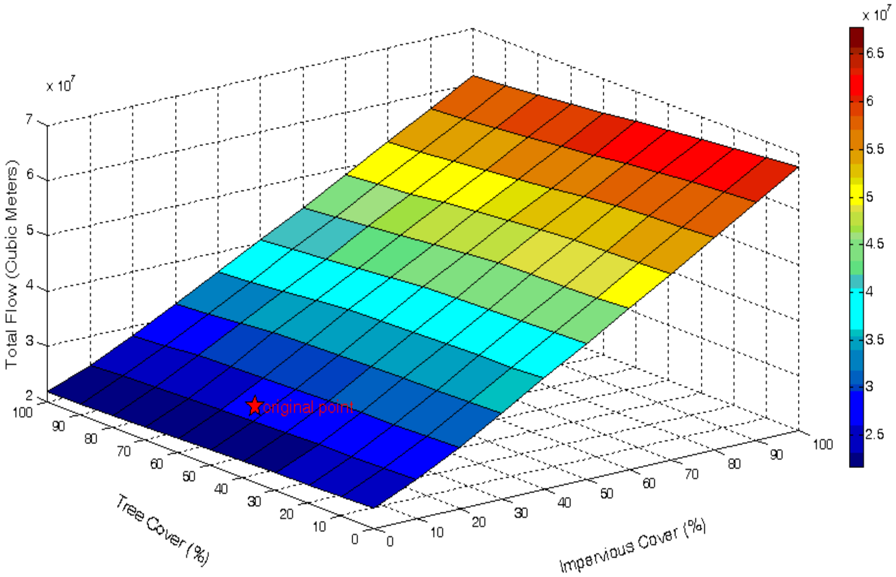


Figure B.27 Changes in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

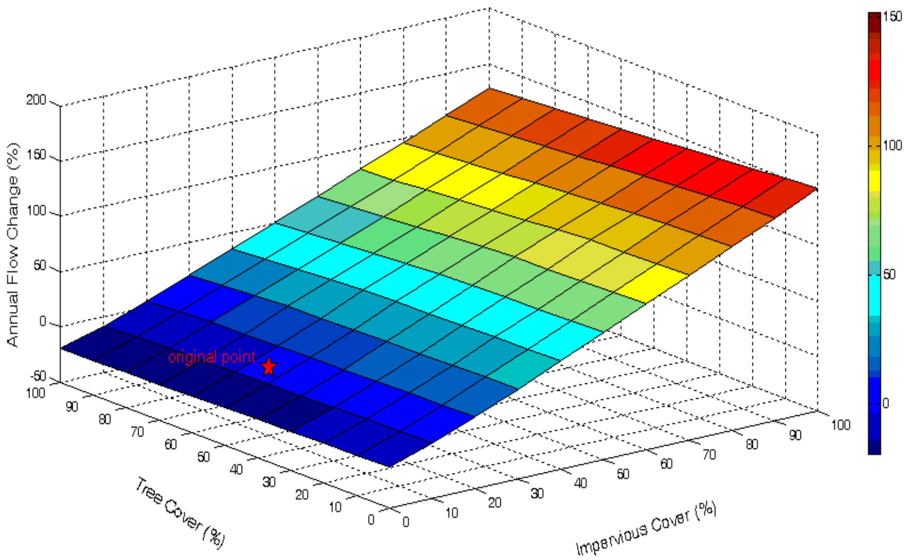


Figure B.28 Percent change in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

During the simulation period the total rainfall recorded was 499.6 mm. Since that amount is assumed to have fallen over the entire 78.5 sq. km watershed, a total of 39.2 million cubic meters of rain fell on the watershed during the simulation time. The total modeled flow in Ridley Creek watershed throughout the simulation time for the base case scenario (no landscape change) was 15.0 million cubic meters. The total flow is made up of surface runoff and baseflow (water that travels underground to the stream). Runoff from pervious and impervious areas is the biggest contributor to stream flow with 73.5% and 21.2% of total flow generated from pervious and impervious runoff respectively. Base flow was estimated to generate 5.3% of total flow. Areas of tree canopies intercepted about 9.5% of the total rainfall, but as only 53.6% of watershed in under tree cover, interception of total precipitation in the watershed by trees was only 5.1% (2.0 million cubic meters). Areas of short vegetation, including shrubs, intercepted about 3.4% of the total rainfall, but as only 33% of watershed in under short vegetation, interception of total precipitation in the watershed by short vegetation was only 1.1% (435,000 cubic meters). About 55% of total precipitation is estimated to re-enter the atmosphere through evaporation or evapotranspiration.

Based on these changes in flow rates and national EMC values, the current tree cover is estimated to reduce total suspended solids during the simulation period by around 31 to 45 metric tons. Other chemical constituents are also reduced (Table B.37).

Table B.37 Estimated reduction in chemical constituents in Ridley Creek watershed due to existing tree cover during simulation period based on median and mean pooled event mean concentration values (Table B.35).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	-31.0	-44.6
Biochemical Oxygen Demand	-6.5	-8.0
Chemical Oxygen Demand	-25.4	-30.0
Total phosphorus	-0.15	-0.18
Soluble phosphorus	-0.06	-0.07
Total Kjeldhal nitrogen	-0.8	-1.0
Nitrite and Nitrate	-0.3	-0.4
Copper	-6.3	-7.7

Changing protected land cover to unprotected land cover characteristics by increasing impervious cover at the expense of existing tree cover increased total suspended solids during the simulation period by around 45 to 65 metric tons. Other chemical constituents are also increased (Table B.38).

Table B.38 Estimated change in chemical constituents in Ridley Creek watershed due to changing protected land to unprotected land conditions (increasing impervious cover at the expense of tree cover) during simulation period based on median and mean pooled event mean concentration values (Table B.35).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	45.0	64.7
Biochemical Oxygen Demand	9.5	11.6
Chemical Oxygen Demand	36.9	43.6
Total phosphorus	0.21	0.26
Soluble phosphorus	0.08	0.11
Total Kjeldhal nitrogen	1.2	1.4
Nitrite and Nitrate	0.4	0.5
Copper	9.2	11.1

Modeling Land Cover Effects in Wissahickon Creek Watershed

David Nowak, USDA Forest Service, Northern Research Station
Yang Yang and Ted Endreny, State University of New York, College of Environmental Science and Forestry

This report details results of changes in stream flow due to the effects of development in the Wissahickon Creek watershed (165.3 km^2, Figure B.31) using the i-Tree / UFORE Hydro model (Wang et al., 2008).

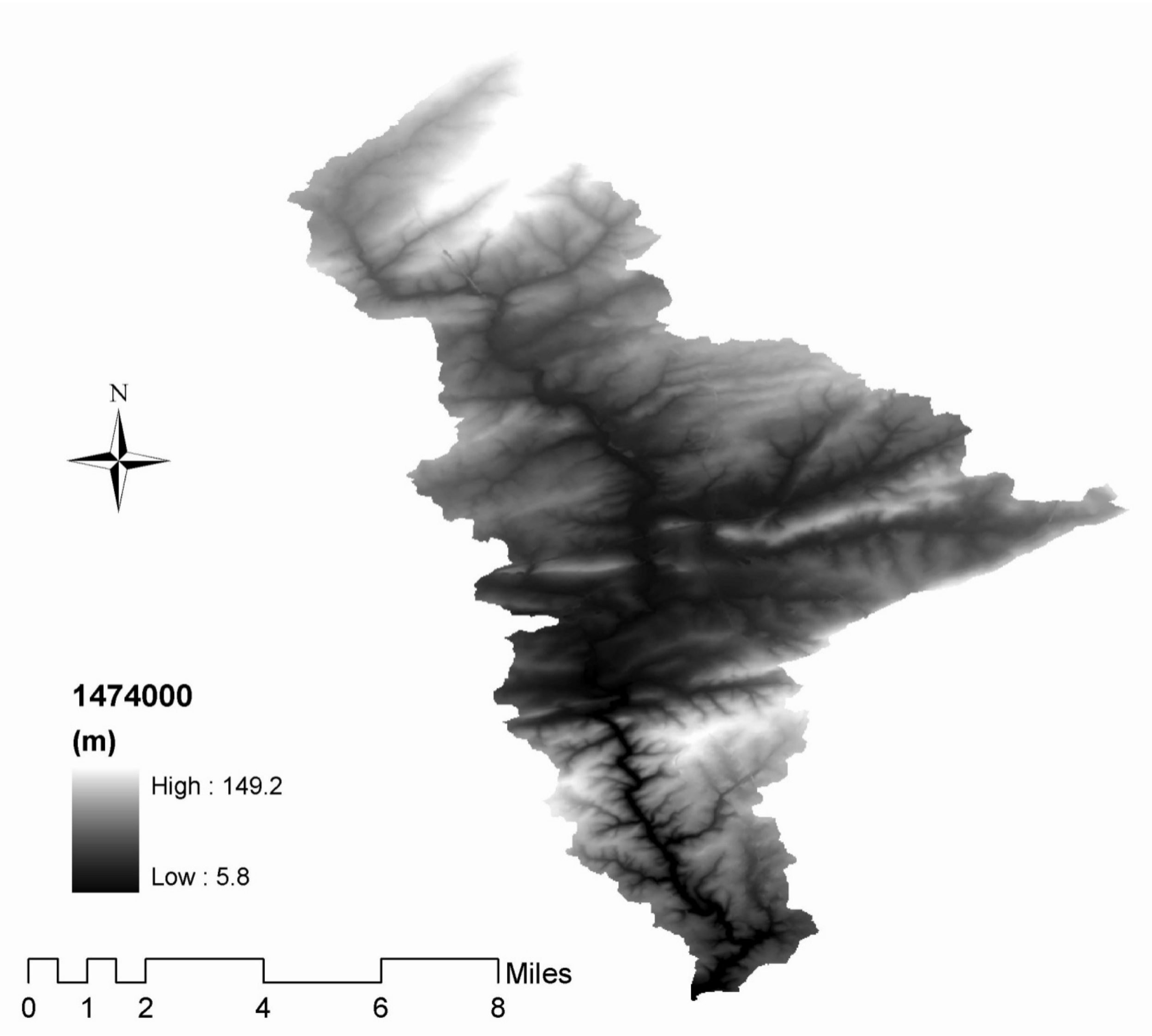


Figure B.31 DEM of Wissahickon Creek Watershed at Mouth, Philadelphia, PA (USGS 01474000)

Data and Model Calibration

The precipitation and weather data for this analysis were collected from a local weather station at Willow Grove (WBAN: 724086 14793). Tree and impervious cover parameters were derived for protected and unprotected areas of the watershed from photo-interpretation of Google Earth imagery (image data 2010) using 1,000 randomly located points (Table B.39). Protected and unprotected areas were delimited based on boundary files provided by Econsult Corporation. Protected areas have higher tree cover and lower impervious cover (i.e., roads, buildings, concrete, etc.).

Table B.39 Cover estimates for watershed.

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	8.4	64.6	29.2	0.8
Unprotected Area	35.2	37.5	36.1	0.5
Whole Watershed	31.8	41.1	35.2	0.6

The model was calibrated using hourly stream flow data collected at the Wissahickon Creek at Mouth, Philadelphia, PA (USGS 01474000) gauging station (04/15/2007 – 10/31/2007). Model results were calibrated against measured stream flow to yield the best fit between model and measured stream flow results. Calibration coefficients (0-1 with 1.0 = perfect fit) were calculated for peak flow, base flow, and balance flow (peak and base) (Table B.40). Calibrations can often be off, particularly for peak flows, due to mismatching of steam flow and weather data as the weather stations are often outside of the watershed area. For example, it may be raining at the weather station and not in the watershed or vice versa. Tree canopy leaf area index (LAI) was estimated at 5.0 based on various field studies and the amount of percent of impervious cover connected to the stream was estimated at 95 percent.

Table B.40 Calibration coefficients for model estimates and gauging station data.

	Calibration Coefficients		
Watershed	Peak Flow	Base Flow	Balanced Flow
Wissahickon Creek	0.66	0.43	0.61

Model Scenarios

The model scenario employed in this analysis is the conversion of protected land characteristics to unprotected land characteristics (Table B.41). That is, what would happen if the protected areas developed like unprotected areas with additional impervious cover replacing tree cover in protected areas. In this case impervious cover in the watershed would increase from 31.8% to 35.2%, tree cover drop from 41.1% to 37.6% overall.

Table B.41 Cover change for watershed.

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Protected Area	35.2	37.8	29.2	0.8
Unprotected Area	35.2	37.5	36.1	0.5
Whole Watershed	35.2	37.6	35.2	0.6

In addition, effects of changes in tree and impervious cover in this watershed were explored. After calibration, the model was run a number of times under various conditions to see how the stream flow would respond given varying tree and impervious cover in the watershed. For tree cover simulations, impervious cover was held constant at the original value with tree cover varying between 0 and 100%. Increasing tree cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally impervious covered land. At 100% tree cover, all impervious land is cover by trees. This assumption is unreasonable as all buildings, road and parking lots would be cover by trees, but the results illustrate the potential impact. Reductions in tree cover were assumed to be filled with grass and shrub cover.

For impervious cover simulations, tree cover was held constant at the original value with impervious cover varying between 0 and 100%. Increasing impervious cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally under tree canopies. The assumption of 100% impervious cover is unreasonable, but the results illustrate the potential impact. In addition, as impervious increased from the current conditions, so did the percent of the impervious cover connected to the stream such that at 100% impervious cover, all (100%) impervious cover is connected to the stream. Reductions in impervious cover were assumed to be filled with grass and shrub cover.

Water Quality Effects – Event Mean Concentration to Calculate Pollution Load

The term event mean concentration (EMC) is a statistical parameter used to represent the flow-proportional average concentration of a given parameter during a storm event. It is defined as the total constituent mass divided by the total runoff volume, although EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. Mathematically (Sansalone and Buchberger, 1997; Charbeneau and Barretti, 1998):

$$EMC = \overline{C} = \frac{M}{V} = \frac{\int C(t)\,Q(t)dt}{\int Q(t)dt} \approx \frac{\sum C(t)\,Q(t)\Delta t}{\sum Q(t)\Delta t} \qquad (1)$$

where $C(t)$ and $Q(t)$ are the time-variable concentration and flow measured during the runoff event, and *M* and *V* are pollutant mass and runoff volume as defined in Equation 1. It is clear that the EMC results from a flow-weighted average, not simply a time average of the concentration. EMC data is used for estimating pollutant loading into watersheds. EMCs are reported as a mass of pollutant per unit volume of water (usually mg/L).

The pollution Load (L) calculation from the EMC method is

$$L = EMC * Q = EMC * d_r * A \qquad (2)$$

Where EMC is event mean concentration (mg/l, mg/m^3, …), Q is runoff of a time period associated with EMC (l/h, m^3 /day…), d_r is runoff depth of unit area (mm/h, m/h, m/day…), A is the land area (m^2, …) which is catchment area in i-Tree / UFORE-Hydro.

Thus, when the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. As is evident from Figure B.32, the instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterisation replaces the actual time variation of *C* versus *t* in a storm with a pulse of constant concentration having equal mass and duration as the actual event. This process ensures that mass loadings from storms will be correctly represented. EMCs represent the concentration of a specific pollutant contained in stormwater runoff coming from a particular land use type or from the whole watershed. Under most circumstances, the EMC provides the most useful means for quantifying the level of pollution resulting from a runoff event (USEPA, 2002).

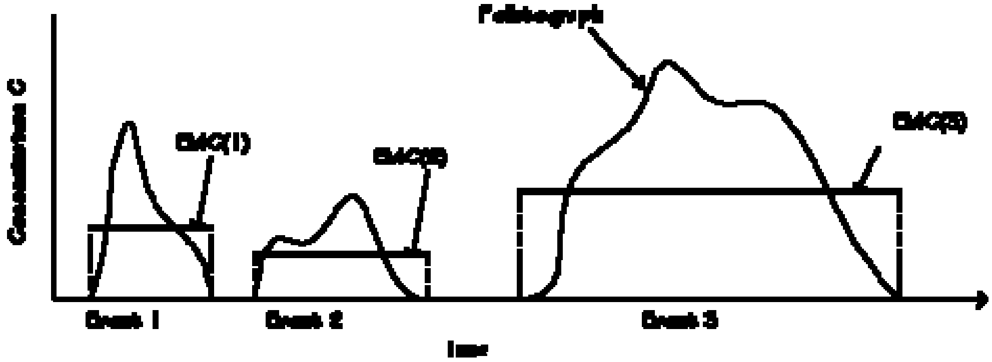


Figure B.32 Interstorm variation of pollutographs and EMCs

Since collecting the data necessary for calculating site-specific EMCs can be cost-prohibitive, researchers or regulators will often use values that are already available in the literature. If site-specific numbers are not available, regional or national averages can be used, although the accuracy of using these numbers is questionable. Due to the specific climatological and physiographic characteristics of individual watersheds, agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Beaulac and Reckhow 1982).

To understand and control urban runoff pollution, The U.S. Congress included the establishment of the Nationwide Urban Runoff Program (NURP) in the 1977 Amendments of the Clean Water Act (PL 95-217). The U.S. Environmental Protection Agency developed the NURP to expand the state knowledge of urban runoff pollution by applying research projects and instituting data collection in selected urban areas throughout the country.

In 1983, the U.S. Environmental Protection Agency (U.S. EPA, 1983) published the results of the NURP, which nationally characterizes urban runoff for 10 standard water quality pollutants, based on data from 2,300 station-storms at 81 urban sites in 28 metropolitan areas.

Two important conclusions from NURP investigations:

- The variance of the EMCs when data from sites are grouped by land use type or geographic region is so great that difference in measures of central tendency among groups statistically are not significant;
- Statistically, the entire sample of EMCs, and the medians of all EMCs among sites, are lognormally distributed.

Thus the numbers in Table B.42 do not distinguish between different urban land use types.

Subsequently, the USGS created another urban stormwater runoff base (Driver et al. 1985), based on data measured through mid-1980s for over 1,100 stations at 97 urban sites located in 21 metropolitan areas. Additionally, many major cities in the United States collected urban runoff quality data as part of the application requirements for stormwater discharge permits under the National Pollutant Discharge Elimination System (NPDES). The NPDES data are from over 30 cities and more than 800 station-storms for over 150 paramaters (Smullen et al, 1999).

The data from the three sources (NURP, USGS and NPDES) were used to compute new estimates of EMC population means and medians for the 10 pollutants with many more degrees of freedom than were available to the NURP investigators (Smullen et al, 1999). A “pooled” mean was calculated representing the mean of the total population of sample data. The NURP and pooled mean EMCs for the 10 constitutes are listed in Table B.42 (Smullen et al, 1999).

NURP or pooled mean EMCs were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors.

Table B.42 National Pooled EMCs and NURP EMCs.

Constitute	Data Source	EMCs (mg/l)		No. of Events
		Mean	Median	
Total Suspended Solids: TSS	Pooled	78.4	54.5	3047
	NURP	17.4	113	2000
Biochemical Oxygen Demand: BOD$_5$	Pooled	14.1	11.5	1035
	NURP	10.4	8.39	474
Chemical Oxygen Demand: COD	Pooled	52.8	44.7	2639
	NURP	66.1	55	1538
Total phosphorus: TP	Pooled	0.315	0.259	3094
	NURP	0.337	0.266	1902
Soluble phosphorus: Soluble P	Pooled	0.129	0.103	1091
	NURP	0.1	0.078	767
Total Kjeldhal nitrogen: TKN	Pooled	1.73	1.47	2693
	NURP	1.67	1.41	1601
Nitrite and Nitrate: NO$_2$ and NO$_3$	Pooled	0.658	0.533	2016
	NURP	0.837	0.666	1234
Copper: Cu	Pooled	13.5	11.1	1657
	NURP	66.6	54.8	849
Lead: Pb	Pooled	67.5	50.7	2713
	NURP	175	131	1579
Zinc: Zn	Pooled	162	129	2234
	NURP	176	140	1281

Note;

(7) Polled data sources include: NURP, USGS, NPDES
(8) No BOD$_5$ data available in the USGS dataset - polled includes NURP+NPDES
(9) NO TSP data available in NPDES dataset - polled includes NURP+USGS

For UFORE-Hydro, the pooled median and mean EMC value for each pollutant (Table B.42) were applied to the runoff regenerated from pervious and impervious surface flow, not the base flow values, to estimate effects on pollutant load across the entire modeling time frame. All rain events are treated equally using the EMC value, which mean some events may be over-estimated and others underestimated. In addition, local management actions (e.g., street sweeping) can affect these values. However, across the entire season, if the EMC value is representative of the watershed, the estimate of cumulative effects on water quality should be relatively accurate. Accuracy of pollution estimates will be increased by using locally derived coefficients. It is not known how well the national EMC values represent local conditions.

Results

The overall effect of converting all protected land to unprotected land characteristics is projected to lead to a 2.7% increase in total flow (1.3 million cubic meters) for the model period of 04/15/2007 – 10/31/2007 (Table B.43). Base flow is projected to decrease by 5.1%, while impervious flow (runoff from impervious areas) is projected to increase by 11.4% and pervious flow (runoff from pervious areas) is projected to decrease by 4.4%.

Table B.43 Flow Result of original land cover and developed land cover.

	Flow (cubic meters)			
Watershed	Total Flow	Base Flow	Impervious Flow	Pervious Flow
Original	46,737,408	14,049,369	21,628,182	11,059,757
After Development	48,002,430	13,329,839	24,099,719	10,572,804
Change[1]	1,265,022	-719,530	2,471,537	-486,953
Percentage Change	2.7%	-5.1%	11.4%	-4.4%

[1] After development - original

Tree Cover Effects: Loss of current tree cover in the Wissahickon Creek watershed (Figure B.31) would increase total flow during the simulation period by an average of 2.7% (1.2 million m^3). Increasing canopy cover from 41.1% to 50% would reduce overall flow by another 0.5% (255,000 m^3) during this 5.5 month period (Figure B.33). Increasing tree cover reduces base flow, as well as flow regenerated from both pervious and impervious areas (Figure B.34).

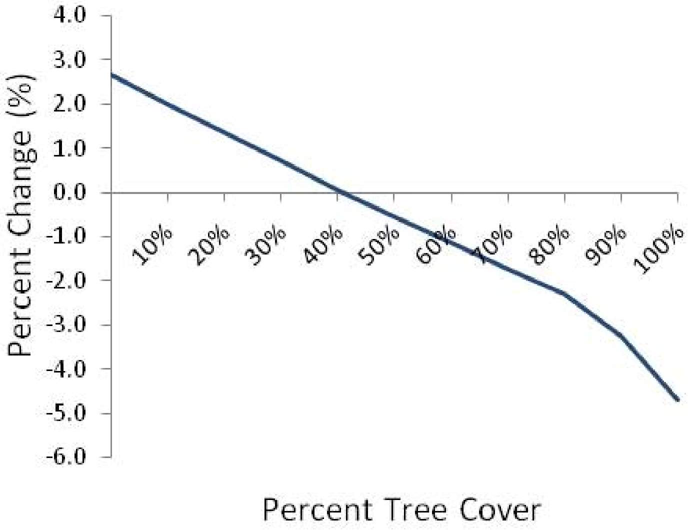


Figure B.33 Percent change in total flow with changes in percent tree cover.

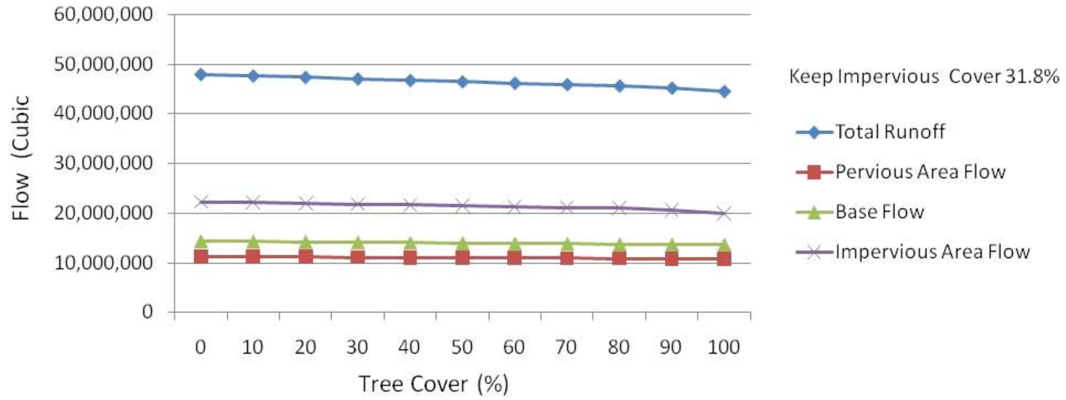


Figure B.34 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent tree cover in the Wissahickon Creek watershed.

<u>Impervious Cover Effects</u>: Removal of current impervious cover would reduce total flow during the simulation period by an average of 22.0% (10.3 million m^3). Increasing impervious cover from 31.8% to 40% of the watershed would increase total flow another 6.3% (2.9 million m^3) during this 5.5 month period (Figure B.35). Increasing impervious cover reduces base flow and pervious runoff while significantly increasing flow from impervious surfaces (Figure B.36).

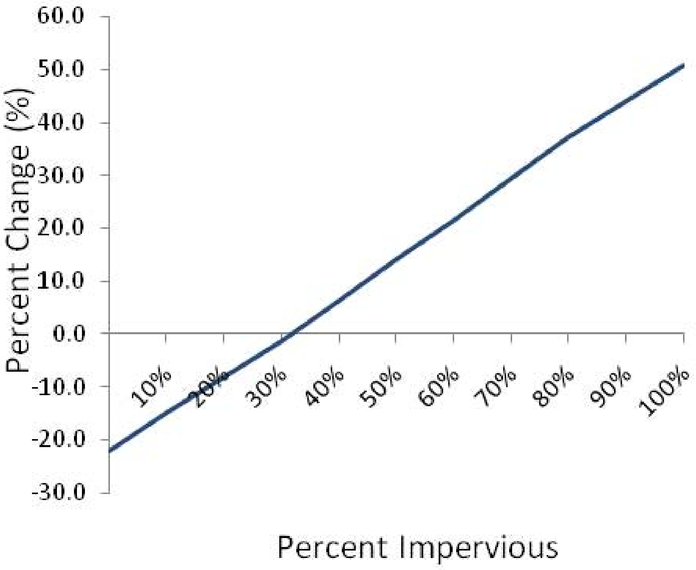


Figure B.35 Percent change in total flow with changes in percent impervious cover.

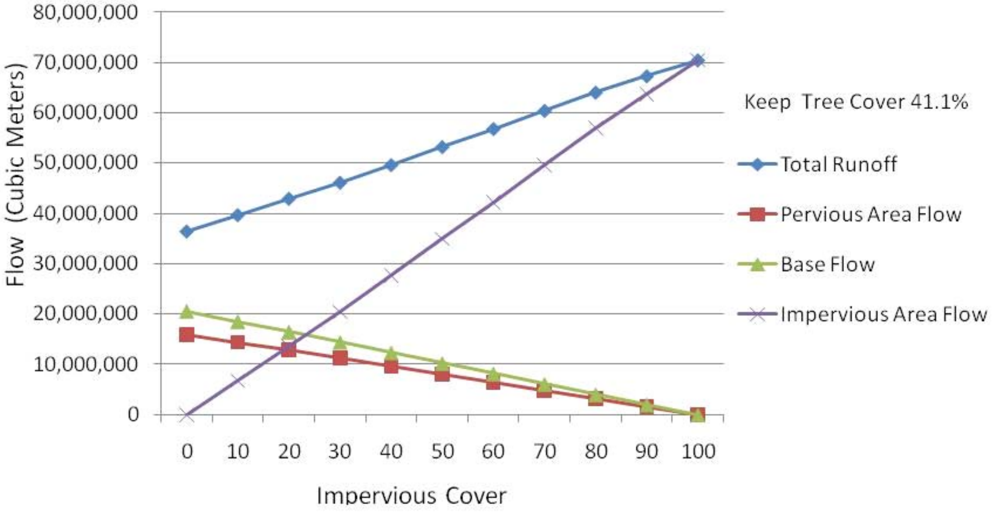


Figure B.36 Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent impervious cover in the Wissahickon Creek watershed.

Increasing tree cover will reduce stream flow, but the dominant cover type influencing stream flow is impervious surfaces. Under current cover conditions, increasing impervious cover had a 9.2 times greater impact on flow relative to tree cover. Increasing impervious cover by 1% averaged a 0.7% increase in stream flow, while increasing tree cover by 1% averaged only a 0.07% decrease in stream flow. The interactions between changing both tree and impervious cover are illustrated for both total flow during the simulation period (Figure B.37) and for changes in percent flow (Figure B.38).

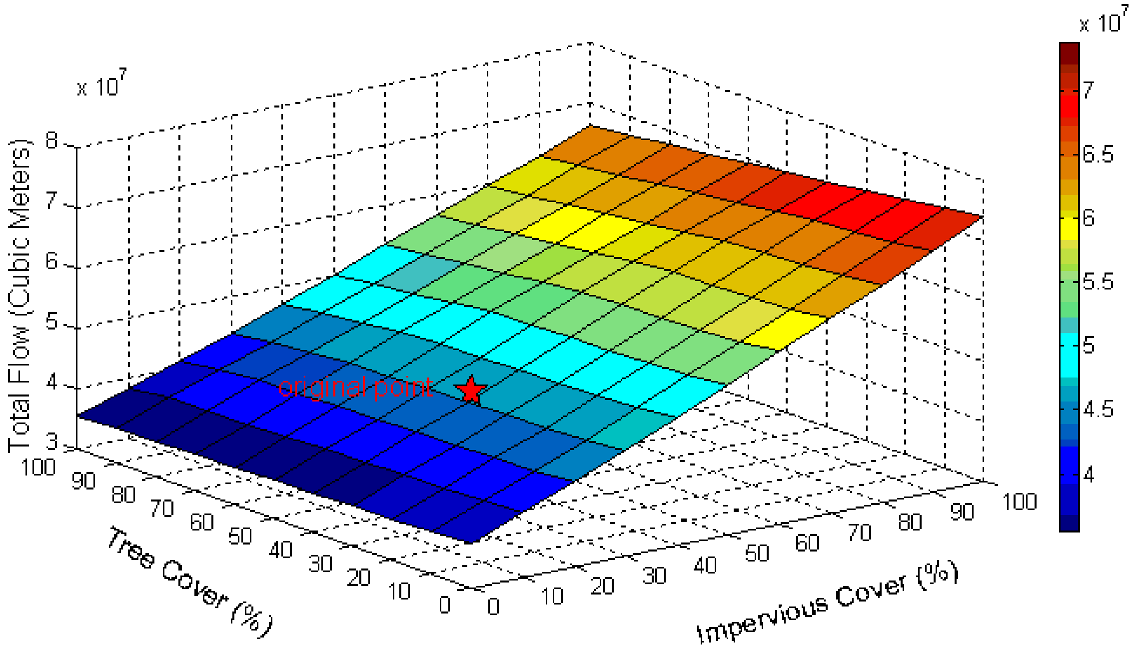


Figure B.37 Changes in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

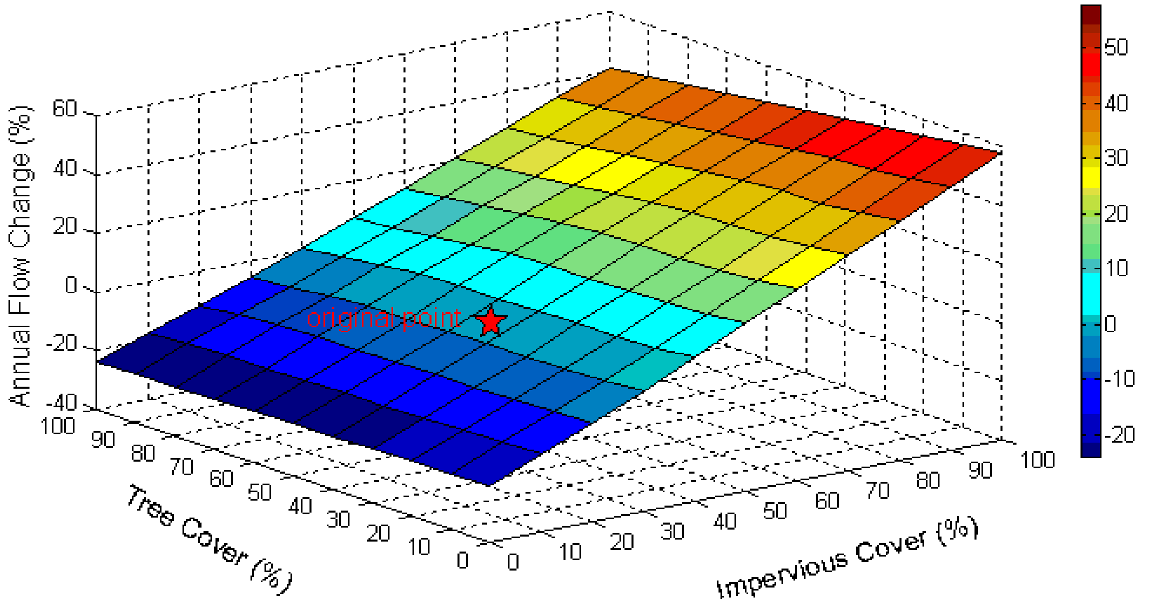


Figure B.38 Percent change in total flow during simulation period based on changes in percent impervious and percent tree cover. Red star indicates current conditions.

During the simulation period the total rainfall recorded was 468.6 mm. Since that amount is assumed to have fallen over the entire 165.3 sq. km watershed, a total of 77.5 million cubic meters of rain fell on the watershed during the simulation time. The total modeled flow in Wissahickon Creek watershed throughout the simulation time for the base case scenario (no landscape change) was 46.7 million cubic meters. The total flow is made up of surface runoff and baseflow (water that travels underground to the stream). Runoff from impervious areas is the biggest contributor to stream flow with 46.3% of total flow generated from impervious runoff. Base flow was estimated to generate 30.1% of total flow, while pervious flow generated about 23.7% of total flow. Areas of tree canopies intercepted about 10.5% of the total rainfall, but as only 41.1% of watershed in under tree cover, interception of total precipitation in the watershed by trees was only 4.3% (3.4 million cubic meters). Areas of short vegetation, including shrubs, intercepted about 3.5% of the total rainfall, but as only 35% of watershed in under short vegetation, interception of total precipitation in the watershed by short vegetation was only 1.2% (963,000 cubic meters). About 66% of total precipitation is estimated to re-enter the atmosphere through evaporation or evapotranspiration.

Based on these changes in flow rates and national EMC values, the current tree cover is estimated to reduce total suspended solids during the simulation period by around 47 to 68 metric tons. Other chemical constituents are also reduced (Table B.44).

Table B.44 Estimated reduction in chemical constituents in Wissahickon Creek watershed due to existing tree cover during simulation period based on median and mean pooled event mean concentration values (Table B.42).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	-47.4	-68.2
Biochemical Oxygen Demand	-10.0	-12.3
Chemical Oxygen Demand	-38.9	-45.9
Total phosphorus	-0.23	-0.27
Soluble phosphorus	-0.09	-0.11
Total Kjeldhal nitrogen	-1.3	-1.5
Nitrite and Nitrate	-0.5	-0.6
Copper	-9.7	-11.7

Changing protected land cover to unprotected land cover characteristics by increasing impervious cover at the expense of existing tree cover increased total suspended solids during the simulation period by around 108 to 156 metric tons. Other chemical constituents are also increased (Table B.45).

Table B.45 Estimated change in chemical constituents in Wissahickon Creek watershed due to changing protected land to unprotected land conditions (increasing impervious cover at the expense of tree cover) during simulation period based on median and mean pooled event mean concentration values (Table B.42).

	Change (t)	
Constituent	Median	Mean
Total Suspended Solids	108.2	155.6
Biochemical Oxygen Demand	22.8	28.0
Chemical Oxygen Demand	88.7	104.8
Total phosphorus	0.51	0.63
Soluble phosphorus	0.20	0.26
Total Kjeldhal nitrogen	2.9	3.4
Nitrite and Nitrate	1.1	1.3
Copper	22.0	26.8

Economic Analysis of the Effect of Protected Open Space on Runoff Volumes

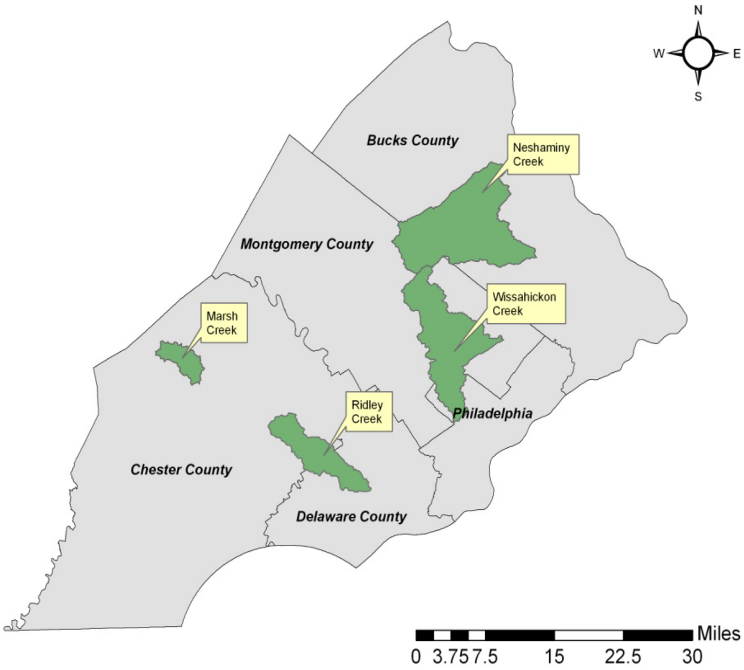
Pennsylvania is one of the most flood prone states in the country. Pennsylvania, including South Eastern PA, has experienced several serious and sometimes devastating floods during the past century, often as a result of tropical storms and hurricanes, and heavy rainfall on an existing snow pack.[1]

Preserved open space in a watershed helps to reduce the chances of flooding by reducing the amount of rainfall that actually reaches the stream as runoff. When rain falls on forests and meadow areas, over half of the annual precipitation returns to the atmosphere through evaporation and transpiration. The vegetation itself also intercepts and slows the rainfall, reducing its erosive energy, reducing overland flow of runoff, and allowing infiltration to occur. The root systems of plants also provide pathways for downward water movement into the soil to help recharge groundwater.[2] In order to quantify the total amount of runoff reduction generated by the preserved open space, the consultant team, asked the US Forest Service to model the amount of runoff reductions generated in four watersheds located in the study area (Neshamniny, Wisssahickon, Marsh Creek and Ridley Creek watersheds) (See Table B.46 and Figure B.39).

Table B.46

Watershed	Size (Sq km)	Percent in Preserved Open Space	Percent Developed	Percent Impervious	County
Neshaminy	236.3	12.58%	45.29%	24.10%	Bucks
Wissahickon	165.3	13.04%	60.36%	31.80%	Philadelphia/Montgomery
Marsh Creek	22.2	44.00%	17.00%	5.30%	Chester
Ridley Creek	78.5	45.75%	45.75%	13.10%	Delaware/Chester

Figure B.39 Location of Analyzed Watersheds



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[1] PA DEP (2006). Pennsylvania Stormwater Management Best Management Practices Manual. Pennsylvania Department of Environmental Protection. December 30, 2006.

[2] PA DEP (2006). Pennsylvania Stormwater Management Best Management Practices Manual. Pennsylvania Department of Environmental Protection. December 30, 2006

The US Forest Service utilized the i-Tree hydro model to estimate the amount of annual runoff generated in each watershed under current conditions. They then ran model assuming that preserved open space was developed at the same intensity as the developed areas surrounding the preserved open space. For example, if the developed portions of the watershed were covered by 30 percent impervious surface, the Forest Service assumed that the open space, when developed, would also be covered by 30 percent impervious surface cover. The difference between the two scenarios is the amount of additional runoff that would be generated if the preserved open space were to be developed. Table B.47 presents the annual increase in runoff that would occur if the preserved open space were to be developed. This could also be thought of as the amount of runoff reduced by the preserved open space annually.

Table B.47 Decrease in Runoff Volume Due to Preserved Open Space
(million ft^3 per year)

Watershed	Current Runoff	Projected Runoff	Difference	Percent Increase
Neshaminy	2,731.5	2,846.5	115.1	4.20%
Wissahickon	1,650.5	1,695.2	44.7	2.70%
Marsh Creek	142.5	146.8	4.3	3.00%
Ridley Creek	530.4	558.7	28.3	5.30%

The reduction in runoff volume generated by the preserved open space remaining preserved also reduces public expenditures on storm water infrastructure. The reduction can be quantified in dollar terms by estimating the amount of stormwater management infrastructure that would need to be installed to effectively manage the additional runoff that would be generated if the preserved open space were to be developed.

It is important to note that stormwater infrastructure would not be required to manage the entire increase in runoff detailed in Table B.47 above. But rather, infrastructure would only be required to manage the amount of rainfall generated by a storm with a recurrence interval of 2 years, or 3.3 inches[3].

Established methods were used to calculate the amount of runoff generated by a storm with a two-year recurrence interval in each watershed under the current conditions and also the amount that would be generated if all the preserved open space were to be converted into developed uses. The analysis assumes that the infrastructure currently installed in each watershed can effectively manage the current runoff generated and that there is no excess capacity in the system, so that all of the runoff generated by the new development would have to be managed through investments in new infrastructure. Table B.48 presents an estimate of the amount of runoff currently generated by a storm with a two-year recurrence interval, the amount that would be generated if the preserved open space were to be developed, the amount of runoff due to development of the preserved open space, as well as the total capital costs of the infrastructure required to manage the additional stormwater. Detailed methodology can be found below.

Table B.48 Estimate of Required Stormwater Infrastructure

Watershed	Current Conditions (ft3)	Projected Conditions (ft3)	Increased Runoff (ft3)	Total Capital Costs
Neshaminy	186,691,000	195,504,000	8,813,000	$ 22,032,500
Wissahickon	164,506,000	179,479,000	14,973,000	$ 37,432,500
Marsh Creek	6,420,000	8,195,000	1,775,000	$ 4,437,500
Ridley Creek	39,015,000	48,217,000	9,202,000	$ 23,005,000

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[3] PA DEP (2006). Pennsylvania Stormwater Management Best Management Practices Manual. Pennsylvania Department of Environmental Protection. December 30, 2006

Table B.48 estimates the total capital costs required to manage the additional stormwater, assuming that runoff is managed using conventional methods, such as detention basins. These costs represent a one-time investment by the local municipality and could be thought of costs avoided by the municipality by having the permanently preserved open space. In addition to the one-time annual cost to the municipality of installing the infrastructure, the infrastructure would also generate annual maintenance costs. Table B.49 presents the total annualized capital costs that are avoided by not having to manage the runoff that would be generated if the preserved open space were to be developed.

Table B.49 Total Annualized Avoided Costs (2010 dollars)

Watershed	Total Capital Costs	Annualized Capital Costs	Annual Maintenance Costs	Total Annual Costs
Neshaminy	$22,034,000	$ 1,806,000	$661,000	$2,467,000
Wissahickon	$37,432,000	$ 3,068,000	$1,123,000	$4,191,000
Marsh Creek	$4,436,000	$ 364,000	$133,000	$497,000
Ridley Creek	$23,005,000	$ 1,885,000	$690,000	$2,575,000

<u>*Methodology*</u>

The cost of stormwater management is typically based on the water quality volume (WQV) for which the stormwater management infrastructure was designed to store and treat (Weiss, et al., 2005). The WQV for a particular precipitation amount can be calculated as follows:

$$WQV = \left(\frac{43560}{12}\right) * P * R_V * A$$

Where: P = Precipitation depth of the design storm (inches)
R_V = Ratio of runoff to rainfall in the watershed
A = watershed area (acres) and the constants are conversion factors.

This analysis used a relatively simple rainfall to runoff ratio was used. The ratio was calculated as follow:

$$R_V = 0.05 + 0.009 * (I)$$

where I is the percent of the watershed that is impervious.

For each watershed, the WQV and the appropriate R_V was calculated using current impervious surface cover percentages. This provided an estimate of the current amount of runoff volume that needs to be controlled in the watershed under existing conditions. The analysis also assumes that this runoff volume is currently managed using existing infrastructure. The WQV was then calculated under the assumption that the preserved open space was developed at an intensity similar to the surrounding area. This increased the amount of impervious surface cover in the watershed and also the value for R_V used in the above equation. This is the amount of runoff that would result if the preserved open space were to be developed.

Next, the WQV calculated under existing conditions was subtracted from the new WQV calculated assuming that the open space was developed. This difference is amount of runoff volume that results from the conversion of preserved open space to developed uses. This is also the amount of infrastructure that would need to be installed to manage the amount of new runoff generated. The construction costs of the new infrastructure were calculated by assuming a capital cost of $2.50 per cubic foot of WQV. Annual maintenance costs were assumed to be equal to 5 percent of the construction costs (Weiss et al., 2005). These costs can be thought of as avoided costs. In other words, they are stormwater management costs that are avoided by having the preserved open space remain in that condition.

Pollution Reduction

The problems of converting preserved areas to developed areas are not limited solely to increase runoff and flooding. Stormwater runoff carries significant quantities of pollutants washed from the impervious and altered land surfaces. The mix of potential pollutants ranges from sediment to varying quantities of nutrients, organic chemicals, petroleum hydrocarbons, and other constituents that cause water quality degradation. Table B.50 presents the increase amount of various pollutants that would reach the stream if the permanently preserved open space were developed.

Table B.50 Pollution Reduction Estimates (tons per year)

Watershed	Total Suspended Solids	Total Phosphorus	Total Nitrogen	BOD & COD	Heavy Metals
Neshaminy	177.7	0.84	6.5	183.2	36.2
Wissahickon	108.2	0.51	4.0	111.5	22.0
Marsh Creek	7.1	0.03	0.3	5.3	1.4
Ridley Creek	45.0	0.21	1.6	46.4	9.2

Endnotes for Technical Appendix B: The Environmental Value of Protected Open Space

[viii] Ecosystem functions refer variously to the habitat, biological, or system properties or processes of ecosystems. Please note that ecosystem services and ecosystem functions do not necessarily show a one-to-one correspondence. In some cases, a single ecosystem service is the product of two or more ecosystem functions; whereas, in other cases, a single ecosystem function contributes to two or more ecosystem services. There is also a great deal of interdependence between many ecosystem functions and services (Costanza et al., 1997).

[ix] Also typically included under regulating services is climate/gas regulation. Climate/gas regulation is not included in this section, because in the next section we utilize the i-Tree model developed by the US Forest Service to estimate the air pollution and carbon storage/sequestration benefits of the preserved open space.

[x] The ecosystem services that fall under the MEA's Cultural Services category include aesthetic/recreational and cultural/ spiritual. There is a great deal of overlap between these ecosystem services and the recreation/health cost benefits and property value impacts that are estimated in other sections of this report and, as such, to avoid double counting, these services were not included in our estimate of the value of ecosystem services.

[xi] These costs include increased demand for municipal services; public infrastructure; costs for school expansion; increased traffic congestion; stress on water supplies; and others.

[xii] Value transfer is essentially the same as the benefit transfer method used in the recreation and health cost sections. The term value transfer was used in this context rather than benefit transfer to reflect the fact that the analysis of ecosystem services is not restricted to economic benefits, but can also be extended to the value functions themselves.

[xiii] Due to similarity between the climate, land cover, and ecosystems of New Jersey and our study area, the studies compiled by Costanza et al. (2006) were used for their study of ecosystem values in New Jersey. The similarities should allow the values used by Costanza et al. (2006) to easily "transfer" to this study area.

[xiv] Please note that just because a land cover is not listed in Table B.2 does not mean that the land cover does not supply that specific ecosystem service. Rather, it means that there has not been a valuation study undertaken to value that specific ecosystem service on that specific land cover.

[xv] The MRLC is a consortium of nine federal agencies (USGS, EPA, USFS, NOAA, NASA, BLM, NPS, NRCS, and USFWS) that jointly funded the collection of satellite land cover data.

[xvi] While the MRLC contains more than ten land cover classes, the number of classes was condensed for the purposes of our study. The ten different land cover types include: water, open-space development, low-intensity development, medium-intensity development, high-intensity development, barren, forests, pasture, cropland, wetlands.

[xvii] The major source of uncertainty in NPV analysis is in the choice of the discount rate, and there is a great deal of debate over which is the correct discount rate to use. To help quantify this uncertainty, the NPV of the annual stream of ecosystem services was calculated using a discount rate of 1%, 3%, 5%, and 8%. However, beyond the choice of what is the appropriate discount rate, there is also debate over how one should discount. The simplest form of discounting assumes a constant discount rate (the discount rate used is same for all time periods). The constant discount rate assumes "exponential" discounting, but others have proposed "decreasing," "logistic," "intergenerational," and other forms of discounting. To keep the analysis simple, we only consider the case of a constant discount rate and we further assume a constant flow of ecosystem service from the preserved open space.

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SUPPLEMENT B.1

Model Calibration Graphs
Marsh Creek Watershed Analysis

Model calibration procedures adjust several model parameters (mostly related to soils) to find the best fit between the observed flow and the model flow on an hourly basis. However, there are often mismatches between the precipitation data, which often collected outside of the watershed, and the actual precipitation that occurs in the watershed. Even if the precipitation measurements are within the watershed, local variations in precipitation intensity can lead to differing amounts of precipitation than observed at the measurement station. These differences in precipitation can lead to poorer fits between the observed and predicted estimates of flow as the precipitation is a main driver of the stream flow. As can often be observed in the graph below (Figure B.9), the observed and simulated results will diverge, which is often an artifact of the precipitation data. For example, observed flow will rise sharply, but predicted flow does not, which is an indication of rain in the watershed but not at the precipitation measurement station. Conversely, the simulated flow may rise but the observed flow does not, which is an indication of rain at the precipitation station, but not in the watershed. Figure B.9 illustrates the hourly differences between the observed and predicted flow after model calibration.

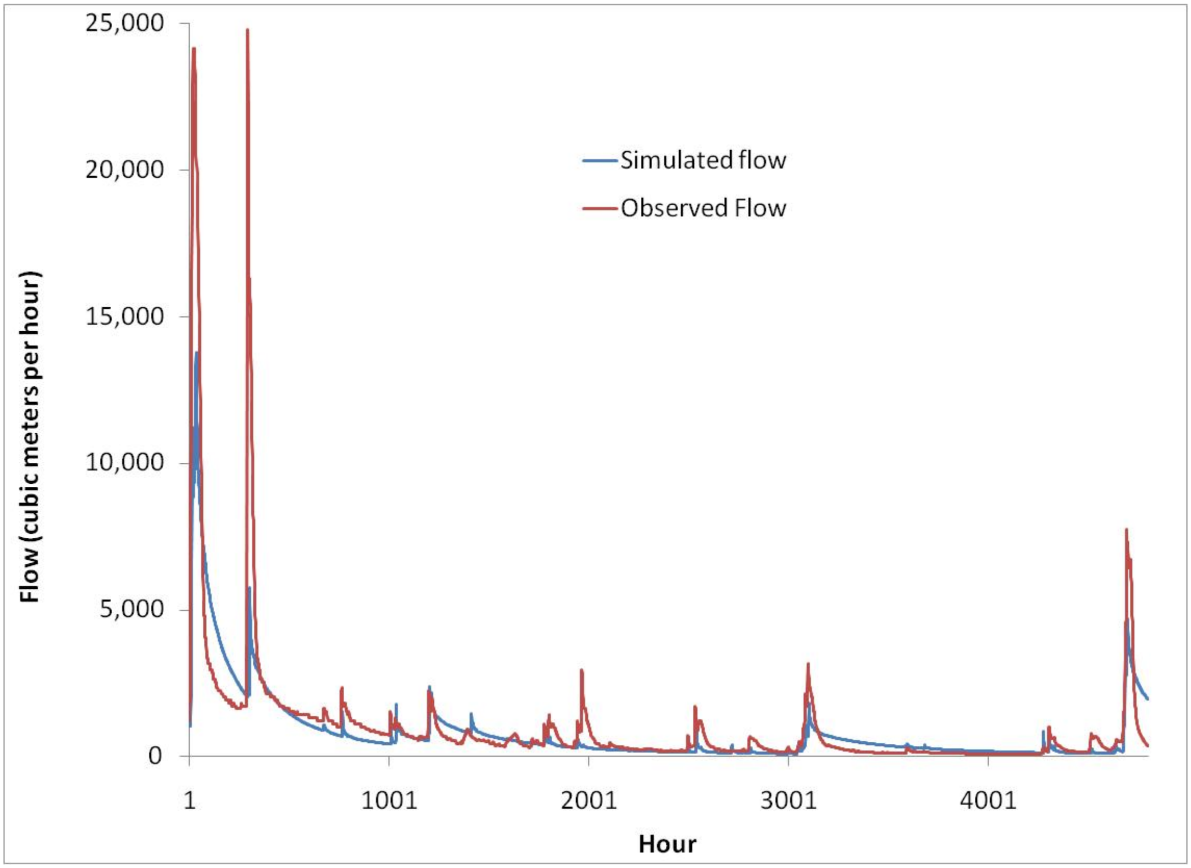

Figure B.9 Comparison of simulated model flow vs. observed flow in Marsh Creek watershed.

As the model simulations are comparisons between the base simulation flows and another simulated flow where surface cover is changed (e.g., increase or decrease in tree cover), both model runs are using the same simulation parameters. What this means is that the effects of changes in cover types are comparable, but may not exactly match the flow of the stream. That is the estimates of the changes in flow are reasonable (e.g., the relative amount of increase or decrease in flow is sound as both are using the same model parameters and precipitation data), but the absolute estimate of flow may be off. Thus the model results can be used to assess the relative differences in flow due to changes in cover parameters, but are likely off in predicting the actual effects on stream flow due to precipitation and calibration imperfections. The model can be used to compare the changes in flow (e.g., increased tree cover leads to an x% change in stream flow), but will likely not exactly match the flow observed in the stream. The model is more diagnostic of cover change effects than predictive of actual stream flow due to imperfections of models and input data used in the model.

Overall the model tends to underestimate observed peak flows, particularly flows over about 9,000 cubic meters per hour in Marsh Creek (Figure B.10), which only occurred during two storm events during the simulation period (Figure B.9).

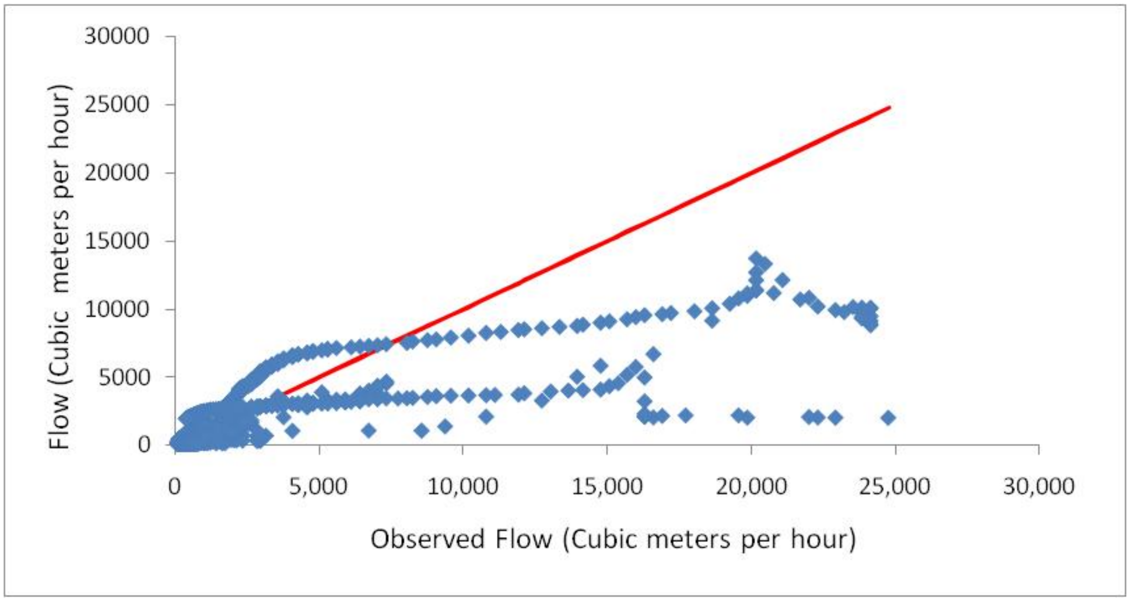

Figure B.10 Comparison observed vs. simulated flow.

SUPPLEMENT B.2

Model Calibration Graphs
Neshaminy Creek Watershed Analysis

Model calibration procedures adjust several model parameters (mostly related to soils) to find the best fit between the observed flow and the model flow on an hourly basis. However, there are often mismatches between the precipitation data, which often collected outside of the watershed, and the actual precipitation that occurs in the watershed. Even if the precipitation measurements are within the watershed, local variations in precipitation intensity can lead to differing amounts of precipitation than observed at the measurement station. These differences in precipitation can lead to poorer fits between the observed and predicted estimates of flow as the precipitation is a main driver of the stream flow. As can often be observed in the graph below (Figure B.19), the observed and simulated results will diverge, which is often an artifact of the precipitation data. For example, observed flow will rise sharply, but predicted flow does not, which is an indication of rain in the watershed but not at the precipitation measurement station. Conversely, the simulated flow may rise but the observed flow does not, which is an indication of rain at the precipitation station, but not in the watershed. Figure B.19 illustrates the hourly differences between the observed and predicted flow after model calibration.

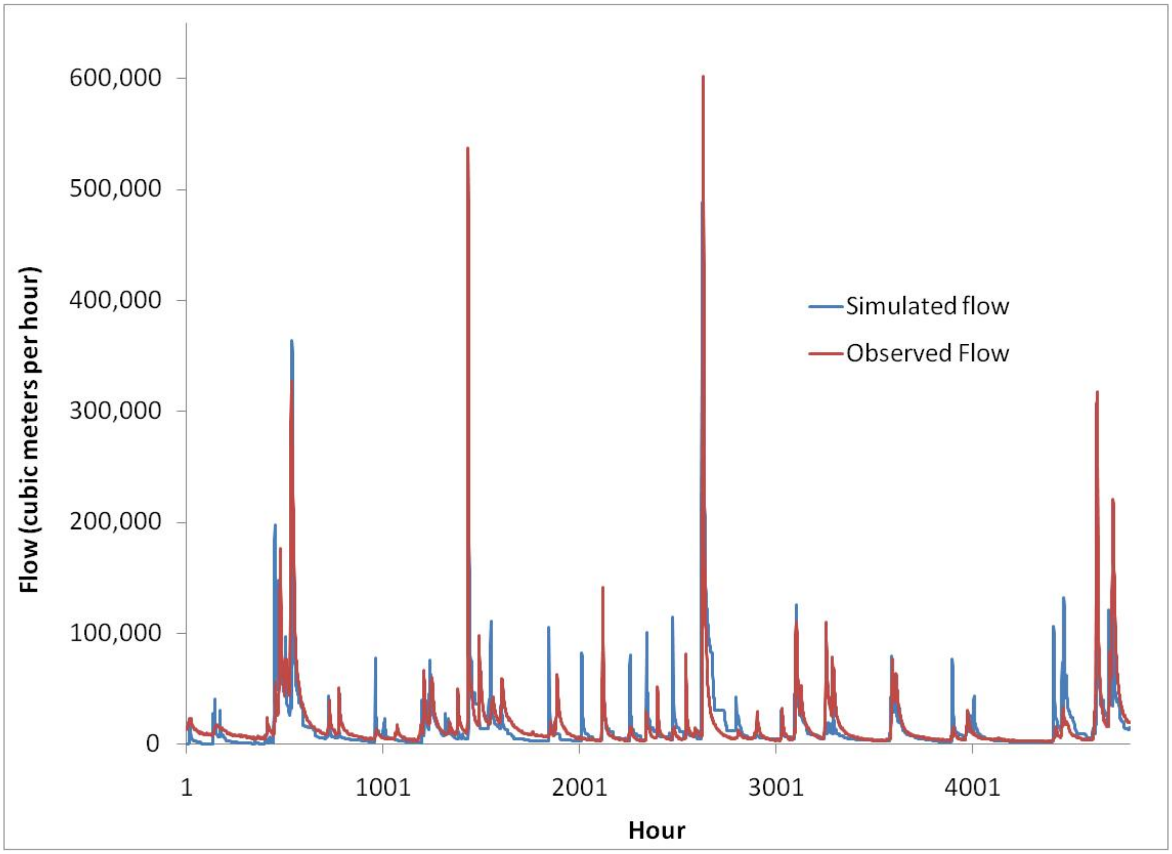

Figure B.19 Comparison of simulated model flow vs. observed flow in Neshaminy Creek watershed.

As the model simulations are comparisons between the base simulation flows and another simulated flow where surface cover is changed (e.g., increase or decrease in tree cover), both model runs are using the same simulation parameters. What this means is that the effects of changes in cover types are comparable, but may not exactly match the flow of the stream. That is the estimates of the changes in flow are reasonable (e.g., the relative amount of increase or decrease in flow is sound as both are using the same model parameters and precipitation data), but the absolute estimate of flow may be off. Thus the model results can be used to assess the relative differences in flow due to changes in cover parameters, but are likely off in predicting the actual effects on stream flow due to precipitation and calibration imperfections. The model can be used to compare the changes in flow (e.g., increased tree cover leads to an x% change in stream flow), but will likely not exactly match the flow observed in the stream. The model is more diagnostic of cover change effects than predictive of actual stream flow due to imperfections of models and input data used in the model.

Overall the model tends to underestimate observed peak flows, particularly flows over about 500,000 cubic meters per hour in Neshaminy Creek (Figure B.20), which only occurred during two storm events during the simulation period (Figure B.19).

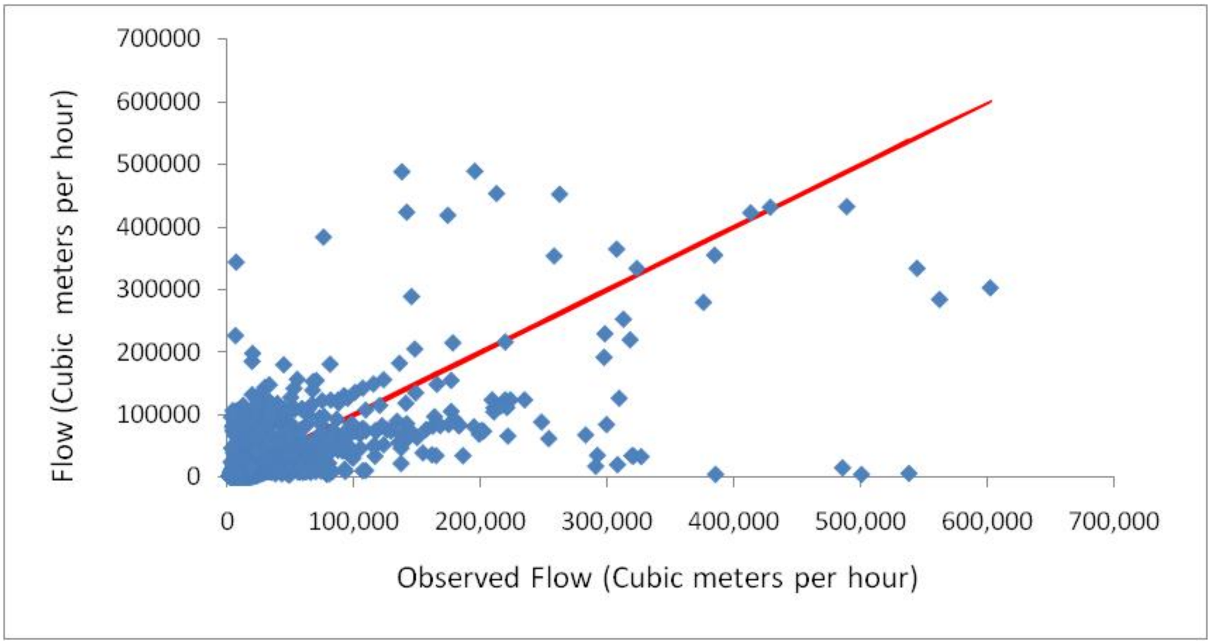

Figure B.20 Comparison observed vs. simulated flow.

SUPPLEMENT B.3

Model Calibration Graphs
Ridley Creek Watershed Analysis

Model calibration procedures adjust several model parameters (mostly related to soils) to find the best fit between the observed flow and the model flow on an hourly basis. However, there are often mismatches between the precipitation data, which are often collected outside of the watershed, and the actual precipitation that occurs in the watershed. Even if the precipitation measurements are within the watershed, local variations in precipitation intensity can lead to differing amounts of precipitation than observed at the measurement station. These differences in precipitation can lead to poorer fits between the observed and predicted estimates of flow as the precipitation is a main driver of the stream flow. As can often be observed in the graph below (Figure B.29), the observed and simulated results will diverge, which is often an artifact of the precipitation data. For example, observed flow will rise sharply, but predicted flow does not, which is an indication of rain in the watershed but not at the precipitation measurement station. Conversely, the simulated flow may rise but the observed flow does not, which is an indication of rain at the precipitation station, but not in the watershed. Figure B.29 illustrates the hourly differences between the observed and predicted flow after model calibration.

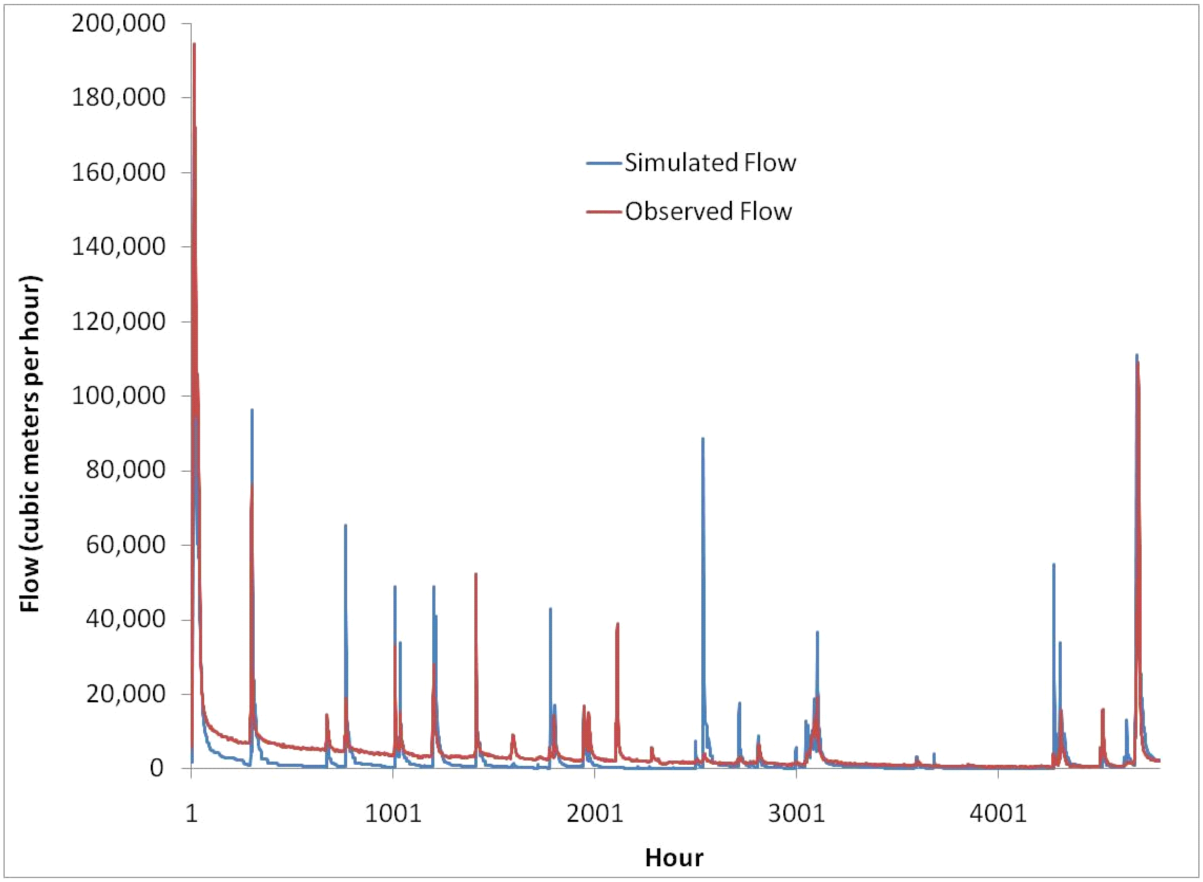

Figure B.29. Comparison of simulated model flow vs. observed flow in Ridley Creek watershed.

As the model simulations are comparisons between the base simulation flows and another simulated flow where surface cover is changed (e.g., increase or decrease in tree cover), both model runs are using the same simulation parameters. What this means is that the effects of changes in cover types are comparable, but may not exactly match the flow of the stream. That is the estimates of the changes in flow are reasonable (e.g., the relative amount of increase or decrease in flow is sound as both are using the same model parameters and precipitation data), but the absolute estimate of flow may be off. Thus the model results can be used to assess the relative differences in flow due to changes in cover parameters, but are likely off in predicting the actual effects on stream flow due to precipitation and calibration imperfections. The model can be used to compare the changes in flow (e.g., increased tree cover leads to an x% change in stream flow), but will likely not exactly match the flow observed in the stream. The model is more diagnostic of cover change effects than predictive of actual stream flow due to imperfections of models and input data used in the model.

Overall the model tends to underestimate observed peak flows, particularly flows over about 160,000 cubic meters per hour in Ridley Creek, which did not occur too often during the simulation period (Figure B.30).

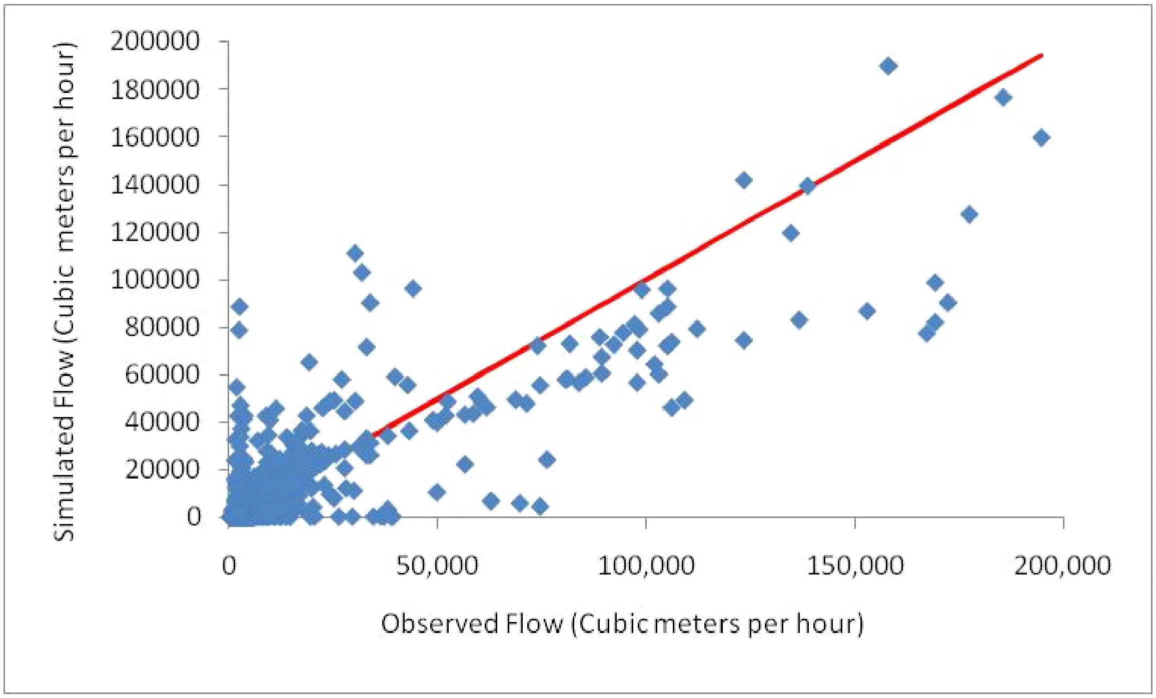

Figure B.30 Comparison observed vs. simulated flow.

SUPPLEMENT B.4

Model Calibration Graphs

Wissahickon Creek Watershed Analysis

Model calibration procedures adjust several model parameters (mostly related to soils) to find the best fit between the observed flow and the model flow on an hourly basis. However, there are often mismatches between the precipitation data, which often collected outside of the watershed, and the actual precipitation that occurs in the watershed. Even if the precipitation measurements are within the watershed, local variations in precipitation intensity can lead to differing amounts of precipitation than observed at the measurement station. These differences in precipitation can lead to poorer fits between the observed and predicted estimates of flow as the precipitation is a main driver of the stream flow. As can often be observed in the graph below (Figure B.39), the observed and simulated results will diverge, which is often an artifact of the precipitation data. For example, observed flow will rise sharply, but predicted flow does not, which is an indication of rain in the watershed but not at the precipitation measurement station. Conversely, the simulated flow may rise but the observed flow does not, which is an indication of rain at the precipitation station, but not in the watershed. Figure B.39 illustrates the hourly differences between the observed and predicted flow after model calibration.

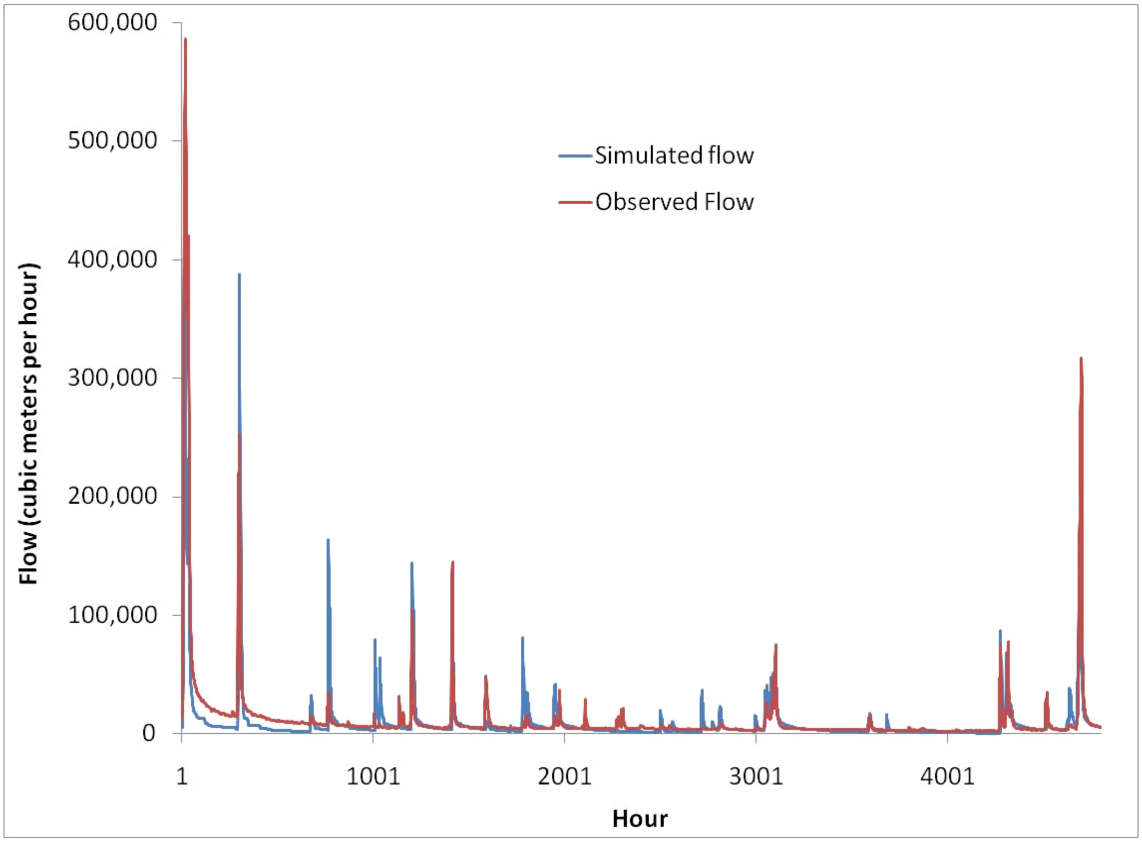

Figure B.39 Comparison of simulated model flow vs. observed flow in Wissahickon Creek watershed.

As the model simulations are comparisons between the base simulation flows and another simulated flow where surface cover is changed (e.g., increase or decrease in tree cover), both model runs are using the same simulation parameters. What this means is that the effects of changes in cover types are comparable, but may not exactly match the flow of the stream. That is the estimates of the changes in flow are reasonable (e.g., the relative amount of increase or decrease in flow is sound as both are using the same model parameters and precipitation data), but the absolute estimate of flow may be off. Thus the model results can be used to assess the relative differences in flow due to changes in cover parameters, but are likely off in predicting the actual effects on stream flow due to precipitation and calibration imperfections. The model can be used to compare the changes in flow (e.g., increased tree cover leads to an x% change in stream flow), but will likely not exactly match the flow observed in the stream. The model is more diagnostic of cover change effects than predictive of actual stream flow due to imperfections of models and input data used in the model.

Overall the model tends to underestimate observed peak flows, particularly flows over about 500,000 cubic meters per hour in Wissahickon Creek (Figure B.40), which only occurred during one storm event during the simulation period (Figure B.39).

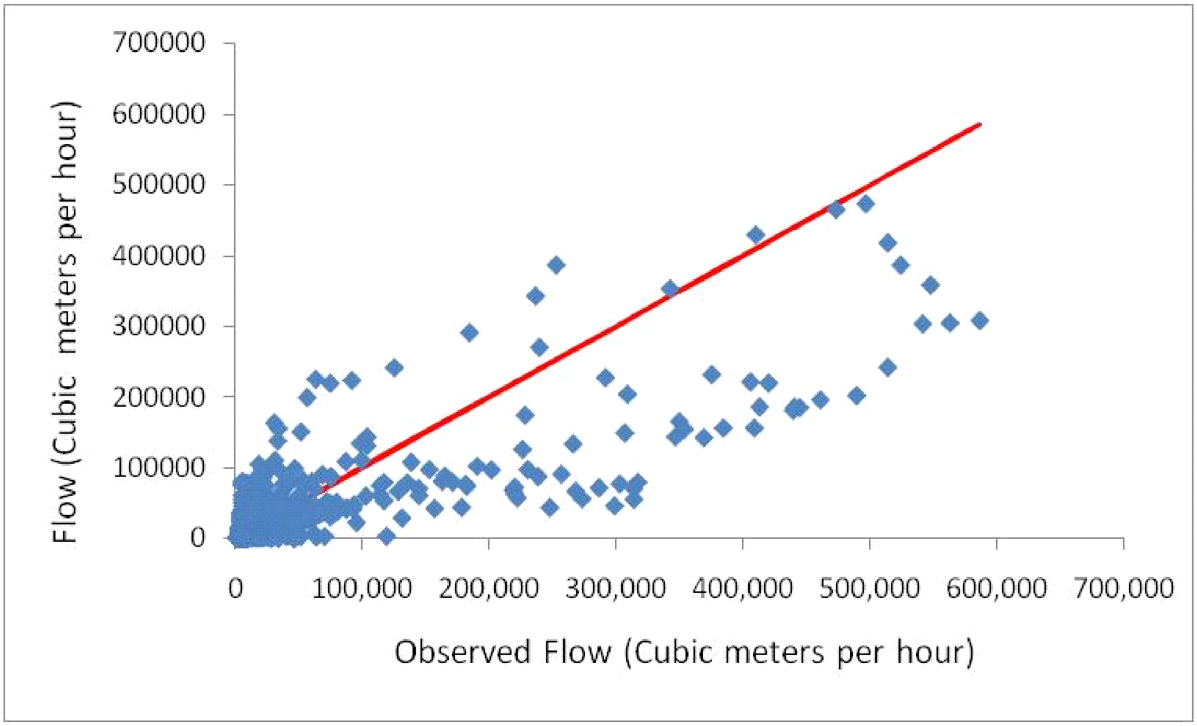

Figure B.40 Comparison observed vs. simulated flow.

The Economic Value of Protected Open Space

in Southeastern Pennsylvania

Technical Appendix C

The Recreational Value of Protected Open Space

Recreation Benefits

Introduction

Parks and preserved open space provide a range of benefits to society, one of which is a variety of recreational opportunities. The proximity to nature and opportunities for outdoor recreation are generally seen as important aspects of the quality of people's living environments; with decreasing amounts of leisure time amid busy schedules, the park or trail or recreation area closest to a person's home may be their most important recreational outlet. The diversity in preserved open space resources in the study area provides a range of opportunities for outdoor recreational pursuits. From the data contained in the State Comprehensive Outdoor Recreation Plan (SCORP) survey as well as usage data collected from the State Parks located in the study area, it appears that the preserved open space is widely used for a variety of activities.

The method of benefit transfer was used to value the recreational benefits of the preserved open space. While it would be preferable to value the recreational benefits of the preserved open space using site-specific data, that is often not feasible due to time and budget constraints. Benefit transfer essentially involves the adaptation and use of economic information derived from a specific site or set of sites under certain resource and policy conditions to a site with similar resources and conditions. Benefit transfer is typically used as a "second-best" strategy when primary research is not possible or justified because of limited time or budget constraints. While benefit transfer is the second best strategy, it is much better than the alternative of not accounting for recreational benefits in the analysis and thereby implying that the recreational value of the preserved open space is zero (Rosenberger and Loomis, 2001).

The recreational benefits of the preserved open space were estimated using the "unit-day-value" approach, which is the industry standard approach for valuing recreation benefits. Loomis (2005) compiled and summarized a number of empirical studies of various recreational uses. Table C.2 includes data on the number of studies reviewed by Loomis as well as the minimum, mean, and maximum willingness to pay values for each activity. All of the benefits reported by Loomis (2005) are average consumer surplus per-person per-day of activity. In the case where Loomis (2005) only reported the results of a single study, the estimates of the values included in Table C.2 are the average consumer surplus for the average individual in the study. In the case where Loomis (2005) relied on multiple studies, the estimate is the average of the study samples' average consumer surplus from all included studies. Consumer surplus is the value of a recreational activity beyond what must be paid to enjoy it.[xviii] Consumer surplus is also referred to as the net willingness to pay, or the willingness to pay in excess of the cost of the good or activity (Rosenberger and Loomis, 2001).

The benefit estimates reported in the literature can vary according to many factors such as differences in the recreation site and user population characteristics, extent of the market, temporal and spatial differences, and methodologically induced differences. To help control for these differences, only studies that were identified by Loomis (2005) as applying to study sites in the Northeastern part of the country were used. To further help control for these differences, the recreational benefits were estimated using the minimum, mean, and maximum values reported by Loomis (2005). The benefit estimates provided by Loomis (2005) will be treated as a constant per-unit value applicable to all possible levels of resource use with no accounting made for congestion. In other words, the same willingness to pay value is applied to the first instance of the activity as is applied to the last instance.

The studies included in Loomis (2005) used a variety of methods to estimate the economic value of outdoor recreation, the two most popular being the travel cost method (TCM) and the contingent valuation method (CVM).[xix] The travel cost method is the most frequently used revealed preference technique.[xx] The TCM uses the variable costs of participating in a recreational activity (travel, lodging, entrance fees, equipment rentals, travel time) as a proxy for the price of that recreation in deriving a demand function for that recreational activity. The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the "price" of access to the site. Thus, people's willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs. This is analogous to estimating an individual's willingness to pay for a marketed good based on the quantity demanded at different prices. The CVM is the stated preference[xxi] technique most frequently used to estimate recreational benefits. The contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific recreational activities. In some cases, people are asked for the amount of compensation they would be willing to accept to give up participating in specific recreational activities. It is called "contingent" valuation, because people are asked to state their willingness to pay, *contingent* on a specific hypothetical scenario and description of the recreational opportunity (Rosenberger and Loomis, 2001).

Rosenberger and Loomis (2001) have found that while revealed preference approaches typically result in slightly larger benefit estimates than stated preference techniques, the two approaches yield measures that are highly correlated. Furthermore, most studies that have compared the two techniques have found the two measures not to be statistically different, providing evidence that the two techniques exhibit convergent validity.

Methodology

To estimate the willingness to pay for the direct-use recreational experience on county, state, and federally owned open space parcels, it was assumed that individuals would participate in the same type of activities in the same proportion on each type of permanently preserved open space. To estimate the average willingness to pay for the recreational opportunities afforded by county, state, and federally owned open space, the usage statistics for the state parks located in the study area for 2007, 2008, and 2009 was obtained. The usage data included the total number of visitors to the park as well as the number of visitors taking part in a variety of activities, from hiking to cross-country skiing. Table C.1 provides the average number of individuals participating in each activity at each state park, while Tables C.1a, C.1b, and C.1c include the data for each state park for 2007, 2008, and 2009 respectively.

[xviii] For example, if a person is willing to pay up to $15 for something, but the market price is $10, then the consumer surplus for that item is $5.

[xix] These methods are generally referred to as "non-market" methods, because not all of the resources important to the quality or quantity of the recreation experience are traded in markets. When markets or market prices are not available, economic techniques must be utilized to directly or indirectly estimate the market prices. The two main categories of non-market techniques are revealed preference and stated preference.

[xx] Revealed preference techniques are indirect methods for estimating consumer surplus and rely on the weak complementary between recreation participation and market-purchased goods necessary for participation.

[xxi] Stated preference techniques are direct methods used to estimate consumer surplus via hypothetical markets constructed by the researcher. It is through these hypothetical markets that individuals express their willingness to pay for various recreational opportunities.

Table C.1

2007-2009 Average Annual State Park Usage

Park	County	Total Visitors	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail Use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping
Delaware Canal	Bucks	526,615	57,846	15,028	0	1,821	9,823	9,343	274,504	62,405	457	1,385	0	14,881	0
Evansburg	Montgomery	654,645	22,493	240,694	0	0	29,840	1,475	22,999	12,149	25,385	37	30,895	25,465	523
Fort Washington	Montgomery	541,756	138,975	0	0	0	9,799	2,827	146,955	24,180	0	4,570	39,015	66,189	2,451
Marsh Creek	Chester	836,882	160,494	3,073	39,541	294,706	226,923	12	175,341	87,270	8,636	4,901	989	0	0
Neshaminy	Bucks	704,508	137,305	30,269	72,790	45,753	26,095	0	214,171	48,870	0	0	63,153	0	0
Nockamixon	Bucks	871,205	100,085	0	37,557	143,101	152,301	3,648	256,354	99,590	110,385	10,729	0	0	6,974
Ralph Stover	Bucks	195,874	28,244	7,070	0	2,354	6,094	229	104,742	21,788	0	946	9,308	2,585	0
Ridely Creek	Delaware	909,404	136,168	11,753	0	0	17,416	830	467,345	61,752	3,504	1,719	49,645	0	1,587
Tyler	Bucks	1,116,233	162,127	111,803	0	3,586	11,409	1,691	836,618	111,621	0	107,537	106,183	22,335	0
White Clay Creek	Chester	68,380	1,942	661	0	0	3,808	2,096	25,472	7,296	1,697	0	0	1,277	0
Total		6,315,503	**945,679**	**420,351**	**149,888**	**491,320**	**493,507**	**22,150**	**2,524,501**	**536,921**	**150,065**	**131,822**	**299,189**	**132,731**	**11,535**

Source: DCNR Bureau of State Parks

Table C.1a

2007 State Park Usage

Park	County	Total Visitors	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping
Delaware Canal	Bucks	495,474	27,604	13,042	0	1,755	10,825	15,528	72,203	35,863	74	1,425	0	1,876	0
Neshaminy	Bucks	681,799	138,113	48,656	68,615	53,376	24,438	0	190,343	46,635	0	0	65,487	0	0
Nockamixon	Bucks	855,956	212,364	0	35,911	260,942	193,272	2,421	241,793	122,998	67,106	32,186	0	0	0
Ralph Stover	Bucks	193,582	21,230	9,910	0	3,385	5,854	348	58,667	29,920	0	2,393	22,102	0	0
Tyler	Bucks	1,022,200	114,730	104,210	0	3,815	9,463	649	766,845	104,010	0	90,470	86,760	20,616	0
Marsh Creek	Chester	829,591	156,500	3,854	39,721	284,694	219,179	35	164,037	82,994	6,848	2,674	0	0	0
White Clay Creek	Chester	61,380	2,006	709	0	0	3,370	1,925	22,682	6,881	1,401	0	0	1,410	0
Ridley Creek	Delaware	910,119	139,976	11,833	0	0	14,247	848	463,862	62,040	4,071	3,339	72,018	0	1,361
Evansburg	Montgomery	623,300	22,220	239,767	0	0	22,695	585	22,137	9,793	24,290	0	20,715	23,585	89
Fort Washington	Montgomery	498,021	189,686	0	0	0	10,395	4,457	133,386	10,656	0	4,670	33,250	57,064	2,371
Total		**6,171,422**	**1,024,429**	**431,981**	**144,247**	**607,967**	**513,738**	**26,796**	**2,135,955**	**511,790**	**103,790**	**137,157**	**300,332**	**104,551**	**3,821**

Source: DCNR Bureau of State Parks

Table C.1b

2008 State Park Usage

Park	County	Total Visitors	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping
Delaware Canal	Bucks	521,080	26,205	22,151	0	2,005	9,788	12,500	217,036	36,231	374	734	0	1,926	0
Neshaminy	Bucks	695,323	131,858	36,350	74,331	40,259	25,827	0	230,158	47,464	0	0	61,293	0	0
Nockamixon	Bucks	891,205	44,557	0	37,784	85,244	133,667	4,588	267,349	89,138	130,063	0	0	0	9,242
Ralph Stover	Bucks	200,077	15,919	5,484	0	3,676	5,262	338	105,073	14,179	0	95	5,821	0	0
Tyler	Bucks	1,100,900	139,960	108,230	0	4,296	11,200	1,056	824,475	109,668	0	109,980	109,980	22,058	0
Marsh Creek	Chester	840,403	168,474	2,662	39,696	306,695	232,328	0	180,634	90,991	8,596	5,622	2,502	0	0
White Clay Creek	Chester	68,040	1,961	632	0	0	3,978	2,172	25,165	6,910	1,692	0	0	1,256	0
Ridley Creek	Delaware	889,718	129,185	11,525	0	0	21,928	844	462,869	60,719	3,262	419	76,367	0	1,875
Evansburg	Montgomery	661,143	23,235	241,825	0	0	31,400	899	23,160	11,420	25,195	0	33,674	25,154	330
Fort Washington	Montgomery	532,541	22,120	0	0	0	10,765	3,540	141,427	48,140	0	1,250	43,493	78,805	1,832
Total		**6,070,430**	**703,474**	**428,859**	**151,811**	**442,175**	**486,143**	**25,937**	**2,477,346**	**514,860**	**169,182**	**118,100**	**333,130**	**129,199**	**13,279**

Source: DCNR Bureau of State Parks

Table C.1c

2009 State Park Usage

Park	County	Total Visitors	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping
Delaware Canal	Bucks	563,290	119,730	9,891	0	1,702	8,855	0	534,274	115,121	922	1,995	0	40,841	0
Neshaminy	Bucks	736,403	141,943	5,800	75,425	43,623	28,021	0	222,011	52,512	0	0	62,678	0	0
Nockamixon	Bucks	866,454	43,333	0	38,976	83,116	129,963	3,935	259,919	86,633	133,986	0	0	0	11,680
Ralph Stover	Bucks	193,964	47,582	5,817	0	0	7,166	0	150,486	21,265	0	350	0	7,754	0
Tyler	Bucks	1,225,600	231,690	122,970	0	2,648	13,564	3,367	918,535	121,185	0	122,160	121,810	24,330	0
Marsh Creek	Chester	840,652	156,508	2,703	38,176	292,729	229,262	0	181,351	87,824	10,465	6,406	465	0	0
White Clay Creek	Chester	75,720	1,860	642	0	0	4,075	2,192	28,570	8,097	1,999	0	0	1,165	0
Ridley Creek	Delaware	928,375	139,344	11,901	0	0	16,073	799	475,304	62,497	3,180	1,400	551	0	1,525
Evansburg	Montgomery	679,493	22,025	240,490	0	0	35,425	2,941	23,700	15,235	26,670	110	38,297	27,655	1,150
Fort Washington	Montgomery	594,706	205,118	0	0	0	8,237	483	166,051	13,743	0	7,789	40,303	62,699	3,149
Total		**6,704,657**	**1,109,133**	**400,214**	**152,577**	**423,818**	**480,641**	**13,717**	**2,960,201**	**584,112**	**177,222**	**140,210**	**264,104**	**164,444**	**17,504**

Source: DCNR Bureau of State Parks

State park usage was then valued using the unit day method consisting of data compiled by the U.S. Department of Agriculture's Forest Service. The unit day value approach uses data on park visits by specific activity and then assigns each activity a dollar value. Loomis (2005) compiled and summarized a number of empirical studies of various recreational uses. Table C.2 includes data on the number of studies reviewed by Loomis (2005) as well as the minimum, mean, and maximum willingness to pay values for each activity. Please note that only studies that included data from the Northeast United States were included in Table C.2 as well as these calculations.

Table C.2

Willingness to Pay Values

Activity	# of Studies	Mean	Min	Max
Picnicking	**2**	$56.45	$8.94	$103.96
Other	**5**	$16.87	$1.97	$46.69
Free Pool	**7**	$22.21	$2.20	$50.10
Boating	**9**	$59.00	$11.93	$111.80
Fishing	**69**	$32.60	$2.08	$253.13
Environmental Education	**1**	$6.01	$6.01	$6.01
Trail Use	**3**	$75.18	$49.80	$91.10
Bike Riding	**1**	$40.93	$40.93	$40.93
Hunting	**87**	$47.45	$4.16	$250.90
Winter Sports	**3**	$34.60	$29.70	$39.49
Summer Sports	**5**	$16.87	$1.97	$ 46.69
Wildlife Viewing	**68**	$31.30	$2.40	$96.30
Camping	**10**	$33.11	$6.73	$66.44

Source: Loomis (2005)

Using the mean willingness to pay values reported in Loomis (2005), the total willingness to pay for the recreation experience obtained from the State Parks was estimated by using the average number of people who participated in each activity between 2007 and 2009 and the unit day values reported by Loomis (2005). Tables C.3, C.4, C.5 present the total willingness to pay by activity for each state park using the mean, minimum, and maximum values reported by Loomis (2005).[xxii] The average willingness to pay value for the average state park visitor was calculated by dividing the total aggregate willingness to pay for all activities (calculated using the mean values from Loomis (2005) by the total state park visitors. Using the mean values reported by Loomis (2005), it was found that total willingness to pay for the recreational opportunities afforded by the state parks located in the study area was approximately $359.0 million and dividing by the average number of total visitors (from Table C.1), 6,315,000, results in an average willingness to pay of $56.79 per visit. Using the minimum total value (from table C.4), approximately $170.0 million, results in an average willingness to pay of $26.89 per visit and using the maximum value (from Table C.5), approximately $628.0 million, results in an average willingness to pay of $99.40 per visit.

[xxii] The values included in Loomis (2005) are defined as the visitor's net willingness to pay or their consumer surplus. The values summarized are from original or primary contingent valuation method (CVM) or travel cost method (TCM) studies. All values reported by Loomis (2005) are in 2004$. The studies used from Loomis (2005) in this research were only those studies that presented data specific to Northeastern United States.

Table C.3

Total Willingness to Pay Values, Based on the Mean Values from Loomis (2005) ($M per year)

Mean	County	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail Use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping	Total
Delaware Canal	Bucks	$3.27	$0.25	-	$0.11	$0.32	$0.06	$20.64	$2.55	$0.02	$0.05	-	$0.47	-	**$27.73**
Neshaminy	Bucks	$7.75	$1.71	$4.11	$2.58	$1.47	-	$12.09	$2.76	-	-	$3.56	$0.00	-	**$36.04**
Nockamixon	Bucks	$5.65	-	$2.12	$8.08	$8.60	$0.21	$14.47	$5.62	$6.23	$0.61	-	$0.00	$0.39	**$51.97**
Ralph Stover	Bucks	$1.59	$0.40	-	$0.13	$0.34	$0.01	$5.91	$1.23	-	$0.05	$0.53	$0.15	-	**$10.35**
Tyler	Bucks	$9.15	$6.31	-	$0.20	$0.64	$0.10	$47.23	$6.30	-	$6.07	$5.99	$1.26	-	**$83.26**
Marsh Creek	Chester	$9.06	$0.17	$2.23	$16.64	$12.81	*	$9.90	$4.93	$0.49	$0.28	$0.06	-	-	**$56.56**
White Clay Creek	Chester	$0.11	$0.04	-	-	$0.21	$0.12	$1.44	$0.41	$0.10	-	-	$0.07	-	**$2.50**
Ridely Creek	Delaware	$7.69	$0.66	-	-	$0.98	$0.05	$26.38	$3.49	$0.20	$0.10	$2.80	-	$0.09	**$42.43**
Evansburg	Montgomery	$1.27	$13.59	-	-	$1.68	$0.08	$1.30	$0.69	$1.43	*	$1.74	$1.44	$0.03	**$23.25**
Fort Washington	Montgomery	$7.85	-	-	-	$0.55	$0.16	$8.30	$1.36	-	$0.26	$2.20	$3.74	$0.14	**$24.55**
Total		**$53.38**	**$23.13**	**$8.46**	**$27.74**	**$27.62**	**$0.78**	**$147.65**	**$29.34**	**$8.47**	**$7.41**	**$16.89**	**$7.12**	**$0.65**	**$358.65**

Source: Loomis (2005), DCNR Bureau of State Parks
** Value less than 10000*

Table C.4

Total Willingness to Pay Values, Based on the Minimum Values from Loomis (2005) ($M per year)

Min	County	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail Use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping	Total
Delaware Canal	Bucks	$0.52	$0.03	-	$0.02	$0.02	$0.06	$13.67	$2.55	*	$0.04	-	$0.04	-	**$16.95**
Neshaminy	Bucks	$1.23	$0.06	$0.16	$0.55	$0.05	-	$10.67	$2.00	-	-	$0.12	-	-	**$14.84**
Nockamixon	Bucks	$0.89	-	$0.08	$1.71	$0.32	$0.02	$12.77	$4.08	$0.46	$0.32	-	-	$0.05	**$20.69**
Ralph Stover	Bucks	$0.25	$0.01	-	$0.03	$0.01	*	$5.22	$0.89	-	$0.03	$0.02	$0.01	-	**$6.47**
Tyler	Bucks	$1.45	$0.22	-	$0.04	$0.02	$0.01	$41.66	$4.57	-	$3.19	$0.21	$0.05	-	**$51.44**
Marsh Creek	Chester	$1.43	$0.01	$0.09	$3.52	$0.47	*	$8.73	$3.57	$0.04	$0.15	*	-	-	**$18.00**
White Clay Creek	Chester	$0.02	*	-	-	$0.01	$0.01	$1.27	$0.30	$0.01	-	-	*	-	**$1.62**
Ridely Creek	Delaware	$1.22	$0.02	-	-	$0.04	*	$23.27	$2.53	$0.01	$0.05	$0.10	-	$0.01	**$27.26**
Evansburg	Montgomery	$0.20	$0.47	-	-	$0.06	$0.01	$1.15	$0.50	$0.11	*	$0.06	$0.06	*	**$2.62**
Fort Washington	Montgomery	$1.24	-	-	-	$0.02	$0.02	$7.32	$0.99	-	$0.14	$0.08	$0.16	$0.02	**$9.98**
Total		**$8.45**	**$0.83**	**$0.33**	**$5.86**	**$1.03**	**$0.13**	**$125.72**	**$21.98**	**$0.62**	**$3.92**	**$0.59**	**$0.32**	**$0.08**	**$169.85**

Source: Loomis (2005), DCNR Bureau of State Parks
** Value is less than 10000*

Table C.5

Total Willingness to Pay Values using the Maximum Values from Loomis (2005)

Max	County	Picnic	Other	Swimming	Boating	Fishing	Envrmt'l Education	Trail Use	Bike Riding	Hunting	Winter Sports	Summer Sports	Wildlife Viewing	Camping	Total
Delaware Canal	Bucks	$6.01	$0.70	-	$0.20	$2.49	$0.06	$25.01	$2.55	$0.11	$0.05	-	$1.43	-	**$38.63**
Neshaminy	Bucks	$14.27	$1.41	$3.65	$5.12	$6.61	$0.00	$19.51	$2.00	-	-	$2.95	-	-	**$55.51**
Nockamixon	Bucks	$10.40	-	$1.88	$16.00	$38.55	$0.02	$23.35	$4.08	$27.70	$0.42	-	-	$0.46	**$122.87**
Ralph Stover	Bucks	$2.94	$0.33	-	$0.26	$1.54	*	$9.54	$0.89	-	$0.04	$0.43	$0.25	-	**$16.23**
Tyler	Bucks	$16.85	$5.22	-	$0.40	$2.89	$0.01	$76.22	$4.57	-	$4.25	$4.96	$2.15	-	**$117.51**
Marsh Creek	Chester	$16.68	$0.14	$1.98	$32.95	$57.44	*	$15.97	$3.57	$2.17	$0.19	$0.05	-	-	**$131.15**
White Clay Creek	Chester	$0.20	$0.03	-	-	$0.96	$0.01	$2.32	$0.30	$0.43	-	-	$0.12	-	**$4.38**
Ridely Creek	Delaware	$14.16	$0.55	-	-	$4.41	*	$42.58	$2.53	$0.88	$0.07	$2.32	-	$0.11	**$67.59**
Evansburg	Montgomery	$2.34	$11.24	-	-	$7.55	$0.01	$2.10	$0.50	$6.37	*	$1.44	$2.45	$0.03	**$34.03**
Fort Washington	Montgomery	$14.45	-	-	-	$2.48	$0.02	$13.39	$0.99	$0.00	$0.18	$1.82	$6.37	$0.16	**$39.86**
Total		**$98.31**	**$19.63**	**$7.51**	**$54.93**	**$124.92**	**$0.13**	**$229.98**	**$21.98**	**$37.65**	**$5.21**	**$13.97**	**$12.78**	**$0.77**	**$627.77**

Source: Loomis (2005), DCNR Bureau of State Parks

** Value is less than 10000*

To determine the willingness to pay for recreation opportunities afforded by municipal parks, the “unit-day-value" method was again used. The Army Corp of Engineers reports values for general recreational activities that vary by the quality of the experience. The values range from $3.19 for a low-quality experience up to $9.57 for a high-quality, with a mean value of $6.47 (Kitch, 2005).

The number of visits to each type of park (municipal, county, state, and federal) was obtained from the annual Outdoor Recreation in Pennsylvania Resident Survey conducted on behalf of the Pennsylvania Department of Conservation and Natural Resources (DCNR) (Graefe et. al., 2009). The annual Outdoor Recreation in Pennsylvania Resident Survey asks individuals how many times they or anyone in their household have visited any public outdoor recreation areas in Pennsylvania in the last month and also what percentage of those activities took place at local/municipal parks/recreation areas, county parks/recreation areas, state parks/forests/recreation areas, federal parks/forests/recreation areas, and private land.

Using data from the Outdoor Recreation in Pennsylvania Resident Survey[xxiii] the number of times that the average household participates in outdoor recreation in a year in Pennsylvania was estimated. It was found that the average study-area household participates in outdoor activities 36 times over the course of the year. Using data obtained from the U.S. Census Bureau on the total number of households in each county for 2008, the number of visits per year for residents in each county was estimated (Table C.6). Approximately 1.47 million households living in the study region participate in approximately 53 million outdoor activities in a year.[xxiv] The percentage of the average household’s outdoor recreation visits that occurred on each type of preserved open space was then estimated (see table C.7).

Table C.6

Estimated Total Number of Household Outdoor Recreational Activities

Average Visits per family = 36

County	Total Households	Total Visits Per Year
Bucks	227,655	8,195,580
Chester	175,047	6,301,692
Delaware	205,194	7,386,984
Montgomery	299,280	10,774,080
Philadelphia	563,837	20,298,132
Total	**1,471,013**	**52,956,468**

Source: US Census Bureau, Graefe et al. (2009)

Table C.7

Location of Outdoor Recreation Time

Type	Percent of Outdoor Recreation Time
Local / Municipal	38%
County	11%
State	17%
Federal	8%
Other / Private	26%
Total	**100%**

Source: Graefe et al. (2009)

Benefits[xxv]

According to the U.S. Census Bureau, there were approximately 1.47 million households in the 5-County study region. According to the Outdoor Recreation in Pennsylvania Resident Survey, the average household located in the study region participated in outdoor recreational activities 36 times in the last year. This amounts to approximately 53 million total visits to outdoor recreation areas by area residents each year (See table C.6.).

Municipal Parks

The Outdoor Recreation in Pennsylvania Resident Survey estimates that an average household in the study area spends approximately 38% of their outdoor recreation time at local or municipal parks each year, resulting in approximately 20 million recreational visits annually. Using the minimum, mean, and maximum values reported by Kitch, (2005), the willingness to pay for recreational benefits enjoyed at municipal parks was found to range from $64.1 million to $192.5 million, with likely value of $130.2 million (Table C.8 and C.8a). [xxvi]

Table C.8

Willingness to Pay for Local/Municipal Park
Recreational Activities ($M per year)

County	Total Visits	Recreational Benefits
Bucks	3,114,320 [T]	$20.1
Chester	2,394,643 [T]	$15.5
Delaware	2,807,054 [T]	$18.2
Montgomery	4,094,150 [T]	$26.5
Philadelphia	7,713,290 [T]	$49.9
Total	**20,123,457** [T]	**$130.2**

Source: Econsult Calculations

[T] *Figures not in $M*

Table C.8a

Min, Mean, and Max Willingness to Pay
for Local/Municipal Park Recreational Activities ($M per year)

	WTP Values:	*$3.19*	*$6.47*	*$9.57*
County	**Total Visits**	**Min**	**Mean**	**Max**
Bucks	3,114,320 [T]	$9.93	$20.15	$29.80
Chester	2,394,643 [T]	$7.64	$15.49	$22.92
Delaware	2,807,054 [T]	$8.95	$18.16	$26.86
Montgomery	4,094,150 [T]	$13.06	$26.49	$39.18
Philadelphia	7,713,290 [T]	$24.61	$49.90	$73.82
Total	**20,123,457** [T]	**$64.19**	**$130.19**	**$192.58**

Source: Econsult Calculations

[T] *Figures not in $M*

County Parks and Recreation Areas

The average household in the 5-county study region spends approximately 11% of their outdoor recreation time at County Parks and Recreation Areas, resulting in approximately 5.8 million total visits each year. Using the minimum, mean, and maximum values estimated by using data from Loomis (2005) and State Park usage data, it was found that willingness to pay for recreational benefits enjoyed at county parks and recreation areas can range from $156.6 million to $579.0 million, with likely value of $330.8 million (Table C.9 and C.9a).

Table C.9

Willingness to Pay for County Park Recreational Activities ($M per year)

County	Total Visits	Recreational Benefits
Bucks	901,514 [T]	$51.2
Chester	693,186 [T]	$39.4
Delaware	812,568 [T]	$46.1
Montgomery	1,185,149 [T]	$67.3
Philadelphia	2,232,795 [T]	$126.8
Total	**5,825,212** [T]	**$330.8**

Source: Econsult Calculations

[T] *Figures not in $M*

Table C.9a

Min, Mean, and Max Willingness to Pay for County Park Recreational Activities ($M per year)

	WTP Values	*$ 26.89*	*$ 56.79*	*$ 99.40*
County	**Total Visits**	**Min**	**Mean**	**Max**
Bucks	901,514 [T]	$24.24	$51.20	$89.61
Chester	693,186 [T]	$18.64	$39.37	$68.90
Delaware	812,568 [T]	$21.85	$46.15	$80.77
Montgomery	1,185,149 [T]	$31.87	$67.30	$117.80
Philadelphia	2,232,795 [T]	$60.04	$126.80	$221.94
Total	**5,825,212** [T]	**$156.64**	**$330.82**	**$579.02**

Source: Econsult Calculations

[T] *Figures not in $M*

State Parks and Recreation Areas

The average household in the 5-county study region spends approximately 17% of their outdoor recreation time at state parks and recreation areas, resulting in approximately 9 million total visits each year. Using the minimum, mean, and maximum values estimated by using data from Loomis (2005) and State Park usage date, the willingness to pay for recreational benefits enjoyed at state parks and recreation areas was found to range from $242.1 million to $894.9 million, with likely value of $511.3 million (Table C.10 and C.10a).[xxvii]

Table C.10

Willingness to Pay for State Park Recreational Activities ($M per year)

County	Total Visits	Recreational Benefits
Bucks	1,393,249 [T]	$79.1
Chester	1,071,288 [T]	$60.8
Delaware	1,255,787 [T]	$71.3
Montgomery	1,831,594 [T]	$104.0
Philadelphia	3,450,682 [T]	$196.0
Total	**9,002,600** [T]	**$511.2**

Source: Econsult Calculations

[T] Figures not in $M

Table C.10a

Min, Mean, and Max Willingness to Pay for State Park Recreational Activities ($M per year)

	WTP Values	*$ 26.89*	*$ 56.79*	*$ 99.40*
County	**Total Visits**	**Min**	**Mean**	**Max**
Bucks	1,393,249 [T]	$37.46	$79.12	$138.49
Chester	1,071,288 [T]	$28.81	$60.84	$106.49
Delaware	1,255,787 [T]	$33.77	$71.32	$124.83
Montgomery	1,831,594 [T]	$49.25	$104.02	$182.06
Philadelphia	3,450,682[T]	$92.79	$195.96	$343.00
Total	**9,002,600** [T]	**$242.08**	**$511.26**	**$894.87**

Source: Econsult Calculations

[T] Figures not in $M

Federal Parks and Recreation Areas

The average household in the 5-county study region spends approximately 8% of their outdoor recreation time at federal parks and recreation areas resulting in approximately 4.2 million total visits each year. Using the minimum, mean, and maximum values estimated by using data from Loomis (2005) and state park usage date, the willingness to pay for recreational benefits enjoyed at federal parks and recreation areas was found to range from $113.9 million to $421.1 million, with likely value of $240.6 million (Table C.11 and C.11a).

Table C.11

Willingness to Pay for Federal Park
Recreational Activities ($M per year)

County	Total Visits	Recreational Benefits
Bucks	655,646 T	$37.2
Chester	504,135 T	$28.6
Delaware	590,959 T	$33.6
Montgomery	861,926 T	$48.9
Philadelphia	1,623,851 T	$92.2
Total	**4,236,517** T	**$240.5**

Source: Econsult Calculations

T Figures not in $M

Table C.11a

Min, Mean, and Max Willingness to Pay
for State Park Recreational Activities ($M per year)

	WTP Values	*$ 26.89*	*$ 56.79*	*$ 99.40*
County	**Total Visits**	**Min**	**Mean**	**Max**
Bucks	655,646 T	$17.63	$37.23	$65.17
Chester	504,135 T	$13.56	$28.63	$50.11
Delaware	590,959 T	$15.89	$33.56	$58.74
Montgomery	861,926 T	$23.18	$48.95	$85.68
Philadelphia	1,623,851 T	$43.67	$92.22	$161.41
Total	**4,236,517** T	**$113.93**	**$240.59**	**$421.11**

Source: Econsult Calculations

T Figures not in $M

5-County Total

The 1.4 million households located in the study area enjoy approximately $1,212.9 million dollars in direct use benefits from the permanently protected open space, with a likely range of between $576.9 million to $2,087.6 million (Table C.12). This is equivalent to an average value per household of $825, with a likely range between $392 and $1,419 per household (Table C.13). This value can be thought of as the amount of money that an individual would be willing to pay for the same recreation experience that they obtain from the permanently protected open space in the private market. This value represents the amount of money that residents save by not having to go out in the private market and pay to enjoy the recreational activities provided for free by the protected open space.

Table C.12

Min, Mean, and Max Willingness to Pay for Recreational Activities ($M per year)

County	Total Households	Min	Mean	Max
Bucks	227,655 [T]	$89.3	$187.7	$323.1
Chester	175,047 [T]	$68.6	$144.3	$248.4
Delaware	205,194 [T]	$80.5	$169.2	$291.2
Montgomery	299,280 [T]	$117.4	$246.8	$424.7
Philadelphia	563,837 [T]	$221.1	$464.9	$800.2
Total	**1,471,013** [T]	**$576.9**	**$1,212.9**	**$2,087.6**

Source: Econsult Calculations

[T] *Figures not in $M*

Table C.13

Recreational Benefits per Household ($M per year)

County	Total Households	Min	Mean	Max
Benefits per Household	**1,471,013** [T]	$392	$825	$1,419

Source: Econsult Calculations

[T] *Figures not in $M*

Please note that the estimate for the 5-county region of $1,212.9 is only slightly more than the $1,076.3 million that Trust for Public Land (TPL) estimates is the recreational benefits of parks to the City of Philadelphia.[xxviii] TPL estimated that the total number of person-visits to Philadelphia parks by Philadelphia residents was 428,918,652 per year, which is equal to approximately 278 visits per-Philadelphian per-year (Trust for Public Land, 2008).

The mean estimate of $1,212.9 million in direct use benefits is likely a conservative estimate of the benefits provided by the permanently protected open space, so the choice to use the minimum estimate of $576.9 million in the report is doubly conservative. A knowledge gap exists with respect to local park use. With decreasing amounts of leisure time and busy schedules, the park or trail or recreation area closest to home may be the most important outlet for many Americans (Walls et al., 2009). The lack of detailed knowledge on the activities engaged in by local-park users required us to use the unit day values for the general recreation category, rather than the unit day values for the activities actually enjoyed by local park users; this likely resulted in an underestimate of actual recreational value of local and municipal parks.

One of the most notable trends in the past quarter century is the growth in conservation land trusts. Again, due to a lack of detailed data available through the SCORP survey, the recreational usage of Land Trust eased and owned lands was unable to be estimated. However, due to the fact that out of the approximately 200,000 acres of preserved open space, nearly 60,000 are owned by non-profit land trusts, the amount of individuals who may participate in recreational activities on this land may be significant, and so too might the value of the recreational benefits.

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[xxiii] The study team only used survey response data for respondents that live within one of the zip codes contained within the study area. This provided 302 responses.

[xxiv] The 36 activities is the average number of outdoor activities that the average household participates in at locations throughout Pennsylvania. It was noted that some of the outdoor recreation activities participated in by households that live in the study area may actually occur outside of the study area, and as such the benefits of these activities do not result from the permanently protected open space located within the study area. It was further noted that there are likely households that live outside of the study area that travel into the study area to participate in recreational activities, and as such the benefits of these activities do result from the permanently protected open space located within the study area. The analysis works off of the assumption that the number of recreational activities that households from the study area engage in while outside of the study area is roughly equivalent to the number of recreational activities within the study area that can be attributed to households from outside of the study area.

[xxv] Unlike with ecosystem service benefits and air pollution reduction benefits, recreational benefits are not based on the total amount of open space in the region, but rather on the total number of people located in the study area that use the preserved open space and the number of times the average individual participates in outdoor recreational activities on the open space. These benefits will increase as the number of people that use open space increases or as the number of times the average person uses open space increases, not as the amount of preserved open space increases. For example, if the amount of preserved open space was to double but the number of people participating in recreational activities was to stay constant, there would be no increase in the recreational benefits attributable to the preserved open space.

[xxvi] Due to the wide variety in the type, quality, and size of parks provided by local governments, there is likely a wide-variety of activities that occur at the local and municipal parks within the study area. Due to a lack of available data on the exact activities that users participate in on municipal parkland, the willingness to pay value assigned to the general recreation category had to be used; therefore, the estimated willingness to pay value of $130.2 million is likely underestimating the true willingness to pay for recreational benefits enjoyed at municipal parks.

[xxvii] Please note that the recreational values for State Parks/Recreation Areas are greater than the values reported in Tables C.3, C.4, and C.5. This is due to the fact that Tables C.3, C.4 and C.5 only contain usage statistics for the recreation that occurs at the state parks located in the study area, while the data reported in Tables C.10 and C.10a is based on usage estimated from the SCORP data which contains recreational activities that occurred not only at state parks, but also at state forests and on state gamelands.

[xxviii] This study's estimate for the City of Philadelphia was $464.9 million compared to TPL's estimate of $1,076.3 million.

The Economic Value of Protected Open Space

in Southeastern Pennsylvania

Technical Appendix D

The Health-Related Value of Protected Open Space

Health Care and Other Health Related Costs Savings

Introduction

The importance of physical activity in reducing morbidity and mortality from chronic diseases is well established in scientific and medical literature (Pratt et al., 2000). Physical inactivity has a high human cost in terms of health and quality of life. It shortens years of life, decreases quality of life, and limits functional independence. Many health problems can be prevented or alleviated through routine physical activity. Physically active people typically enjoy a variety of positive health outcomes, including lower incidence of cardiovascular diseases, diabetes, depression, and certain cancers as well as the prevention of obesity. Most of these conditions, especially cardiovascular disease, cancer, and diabetes, affect racially and ethnically diverse minority communities at rates significantly higher than the national averages. Furthermore, chronic diseases are the most common health problems and represent the biggest expense in current health care budgets (Cohen et al., 2006).

Parks, greenways, trails, and other types of preserved open space provide opportunities for people to be physically active and there is a growing consensus that the environment in which one lives helps determine how physically active an individual is on a daily basis. The results of Rosenberger et al. (2005) suggest that there is a positive relationship between rates of physical inactivity and demands for healthcare; that evidence also supports the hypothesis that populations with more opportunities for recreating are more physically active than populations with limited recreation opportunities.

Public parks and preserved open space may have an important role to play in facilitating physical activity, but parks are also used for purposes other than physical activity. Parks can play a role in facilitating physical activity, but do not necessarily do so (Cohen et al., 2007). Research suggests that the type, size and features of open space can have an impact on the amount of physical activity taking place on the open space. Kaczynski et al. (2008) found that particular park features were related more strongly to park-based physical activity than others. Parks with a paved trail, unpaved trail, or wooded area were more than 7 times as likely to be used for physical activity as were parks without these features.

The benefits estimated in this part of the report can be thought of in terms of cost savings that result from being physically active. The cost savings ultimately accrue to all of society. For example, the direct and indirect medical costs savings manifest themselves as savings in insurance premiums which accrue to either individuals or businesses, depending on who pays for health insurance. While the worker compensation costs and lost productivity costs are initially born by businesses, they are ultimately passed on to consumers through higher prices.

Methodology

Individuals who exercise for at least a half an hour three or more times a week at a moderate or strenuous level are considered to be physically active and, as such, enjoy significant health benefits. The percentage of adults located in the study area that meet the exercise criteria was estimated using data obtained from the Recreation in Pennsylvania Resident Survey conducted on behalf of the Pennsylvania Department of Conservation and Natural Resources (DCNR) (Graefe et. al., 2009).[xxix] The survey asked respondents how many times per week they exercised at a strenuous, moderate, and light pace and whether that exercise took place at a park/trail or indoors. This allowed for an estimate of the number of people who meet the moderate/strenuous exercise requirements. It was found that approximately 38% of the residents living in the suburban counties and 33% of City residents meet the exercise requirements. These percentages were then applied to the number of working age residents living in the 5-county study area in 2008 as obtained from the U.S. Census Bureau. Out of the approximately 2.8 million people 20 years or older, approximately 1.02 million were estimated to exercise three or more times per week at a moderate or strenuous level (Table D.1).

Table D.1

Strenuous/Moderate Exercisers

County	Total Population	Working Age Population	Proportion that Exercises	Total Active Population
Bucks	620,057	460,702	0.38	175,067
Chester	485,083	352,170	0.38	133,825
Delaware	553,234	399,988	0.38	151,995
Montgomery	775,304	575,276	0.38	218,605
Philadelphia	1,448,911	1,033,074	0.33	340,914
Total	**3,882,589**	**2,821,210**		**1,020,406**

Source: US Census Bureau, Graefe et al. (2009), Econsult Calculations

The number of individuals was then multiplied by the costs associated with physical inactivity. These costs fall into three main categories: healthcare (both direct and indirect), workers' compensation (both direct and indirect) and lost productivity (see table D.2). Direct medical costs include the costs of actually treating the illnesses/medical conditions caused and/or exacerbated by physical inactivity. These include cardiovascular diseases, diabetes, depression, and certain cancers as well as obesity. Indirect medical costs are an estimate of the impact that these health conditions have on the individuals' quality of life. Direct costs to businesses for lost productivity are the largest contributor to costs of physical inactivity cost. These costs arise from absenteeism, presenteeism (due to workers who are on the job but not fully functioning), and on-the-job injuries (due to lost work time for injuries that do not qualify for workers compensation). These costs include the inefficiencies associated with replacement workers, the hiring and training of replacement workers, and the reduced productivity from workers who are on the job but are not fully functioning due to injury or medical conditions related to physical inactivity. The cost data are presented in terms of the annual average costs per person of physical inactivity, so the benefits estimated in this section should be thought of as the costs that are avoided by people utilizing open space to exercise at a level that incurs positive health benefits.

Table D.2

Physical Activity Cost Savings ($M per year)

Costs	Low	Expected	High	Source
Direct Medical Care Costs	$308	$475	$642	Pratt et al (2000)
Indirect Medical Care Costs	$924	$1,425	$1,926	Chenoweth (2005)
Workers Compensation Costs	$6	$10	$12	Chenoweth and Bortz (2005)
Indirect Worker Compensation Costs	$24	$40	$48	Chenoweth (2005)
Lost Productivity	$1,630	$1,918	$2,112	Chenoweth and Bortz (2005)

The costs of physical inactivity fall into the following categories:

Direct Medical Costs: These include the costs to treat illnesses. Pratt et al (2000) estimated the direct medical costs related to physical inactivity to range from $214 to $446 with mean value of $330 (in 2000$). These costs include preventive, diagnostic, and treatment services (such as physician and hospital care). Due to the high medical-costs inflation rate that has been witnessed in recent years, the medical costs CPI calculated by the Bureau of Labor Statistics was used to inflate the estimates found in Pratt et al (2000) to 2009$. The medical cost inflation data used to convert 2000$ to 2009$ can be found in Table D.3. The values used in this analysis for direct health care cost savings range from $308 to $642, with a mean of $475.

Table D.3

Medical Cost Inflation Data ($M per year)

Year	Healthcare Cost Percent Change	Low	Expected	High
2000		$214	$330	$446
2001	4.60%	$224	$345	$467
2002	4.70%	$234	$361	$488
2003	4.00%	$244	$376	$508
2004	4.40%	$254	$392	$530
2005	4.20%	$265	$409	$553
2006	4.00%	$276	$425	$575
2007	4.40%	$288	$444	$600
2008	3.70%	$299	$460	$622
2009	3.20%	$308	$475	$642

Source: http://www.bls.gov/cpi/cpi_dr.htm#2000

Indirect Medical Costs: The indirect costs reflect any additional expense or lost opportunity that occurs in addition to the direct medical costs associated with a medical condition. These costs include pain and suffering due to the various medical conditions associated with physical inactivity, a reduction in quality of life, as well as shorter life expectancy attributable to physical inactivity. Chenoweth (2005) found the ratio of indirect to direct medical costs to range from 1.2:1 on the low end to 15:1 on the high end, with an average value of 6:1. In order to be conservative, an indirect/direct ratio of 3:1 was applied. The values used in this analysis for indirect health care cost savings range from $924 to $1,926, with a mean of $1,425.

Direct Workers' Compensation Costs: Several studies indicate that physically inactive persons are more likely to incur workers' compensation injuries, and, concomitantly, have longer recovery periods than physically active persons. These costs were calculated using the methods and data from Chenoweth and Bortz (2005). The values used in this analysis for the direct workers' compensation cost savings range from $6 to $12, with a mean of $10.

Indirect Workers' Compensation Costs: These include administrative costs that accrue to a company as a result of worker compensation claim on account of an injury due to the employee being physically inactive. A multiplier of 4 was used to estimate indirect workers compensation costs. The ratio of indirect/direct workers' compensation costs is generally higher than the ratio of indirect/direct medical costs due to the odds that extraneous circumstances will delay and/or impair an individual's return-to-work time frame and on-the-job-performance (Chenoweth, 2005). The values used in this analysis for workers' compensation cost savings range from $24 to $48, with a mean of $40.

Lost Productivity: Direct costs to businesses for lost productivity are the largest contributor to overall costs of physical inactivity. These costs include short-term disability days associated with physical inactivity-related health conditions, absenteeism,[xxx] and presenteeism,[xxxi] which is defined as the productivity lost when workers are on the job but are not fully functioning. These costs were calculated using the methods and data from Chenoweth and Bortz (2005). Lost productivity costs were based on the median salary paid to workers in the study area, the number of workers in the study area, and average hours lost due to physical inactivity. The values used in this analysis for lost productivity due to absenteeism range from $42 to $300, with a mean of $218. The values used in this analysis for lost productivity due to presenteeism range from $1,588 to $1,811, with a mean of $1,700. The total lost productivity cost savings range from $1,630 to $2,112, with a mean value of $1,918.

Table D.4 presents the minimum, mean, and maximum values of medical costs (both direct and indirect), workers' compensation (both direct and indirect), and lost productivity costs savings used in this analysis. Tables D.4a-f use the methods and data developed by Chenoweth and Bortz (2005) to calculate the lost productivity costs of physical inactivity for absences and presenteeism, respectively. Tables D.4a-f are based on the methods developed by Chenoweth and Bortz (2005) and include the following variables:

VARIABLE 1. Average Hours Lost per Year: This reflects the average number of hours lost per worker directly associated with physical inactivity. The hours in Chenoweth and Boritz (2005) were obtained from various scientific studies. The minimum, maximum, and the average values found by Chenoweth and Boritz (2005) were used in this analysis.

VARIABLE 2. Scheduled Work Load: This reflects the annual workload of the average worker. It was calculated by multiplying 40 hours per week by 50 weeks per year.

VARIABLE 3. Lost Hours as a Percent of Scheduled Workload: This reflects the percentage of annual workload that is lost due to absences and presenteeism. It was calculated by dividing variable 1 by variable 2.

VARIABLE 4. Median Compensation: This represents the median value of total compensation in which half of the workers earn more and half earn less. This data was obtained for the study area from the U.S. Census Bureau.

VARIABLE 5. Lost Compensation per Employed Individual: This was calculated by multiplying variable 3 by variable 4.

VARIABLE 6. Number of Workers: This represents the number of working age people living in the study area. This data was obtained for the study area from the U.S. Census Bureau and is equal to the number of employed individuals living the in study area between the ages 20 and 65 as of 2008.

VARIABLE 7. Total Lost Compensation: This was calculated by multiplying variable 5 by variable 6.

VARIABLE 8. Percent Physical Inactive: This value was calculated by taking the percentage of people who are physical active as estimated from the SCORP data and subtracting the figure from 100%.

VARIABLE 9. Total Lost Productivity Cost: This was calculated by multiplying variable 7 by variable 8.

VARIABLE 10. Per Capita Cost: This is equal to variable 9 / variable 6.

Table D.4

Total Lost Productivity Cost
Calculations ($M per year)

	Total Costs
Min	$1,630
Mean	$1,918
Max	$2,112

Source: Econsult Calculations

Table D.4a

Average Hours Lost due to Absenteeism

	Scheduled Annual Workload	Avg Hours Lost/Year (Chenoweth & Bortz)	Lost Hours as % of Workload
Minimum	2000 hours	3.50 hours	0.2%
Mean	2000 hours	18.08 hours	0.9%
Maximum	2000 hours	24.88 hours	1.2%

Table D.4b

Lost Compensation due to Absenteeism

	Median Compensation *(US Census Bureau)*	Lost Compensation per Worker	# Workers *(US Census Bureau)*	Total Lost Compensation
Minimum	$38,955	$68	617,187	**$42,074,112**
Mean	$38,955	$352	617,187	**$217,342,841**
Maximum	$38,955	$485	617,187	**$299,086,829**

Table D.4c

Lost Productivity Cost due to Absenteeism

	% Workers Physically Inactive *(PA SCORP)*	Total Lost Productivity Cost	Per Capita Lost Productivity Cost
Minimum	62.0%	**$26,085,949**	$42
Mean	62.0%	**$134,752,561**	$218
Maximum	62.0%	**$185,433,834**	$300

Table D.4d

Average Hours Lost due to Presenteeism

	Scheduled Annual Workload	Avg Hours Lost/Year (Chenoweth & Bortz)	Lost Hours as % of Workload
Minimum	2000 hours	131.50 hours	6.6%
Mean	2000 hours	140.75 hours	7.0%
Maximum	2000 hours	150.00 hours	7.5%

Table D.4e

Lost Compensation due to Presenteeism

	Median Compensation *(US Census Bureau)*	Lost Compensation per worker	# Workers *(US Census Bureau)*	Total Lost Compensation
Minimum	$38,955	$2,561	617,187	**$980,086,383**
Mean	$38,955	$2,741	617,187	**$1,049,027,820**
Maximum	$38,955	$2,922	617,187	**$1,117,969,258**

Table D.4f

Lost Productivity Cost due to Presenteeism

	% Workers Physically Inactive *(PA SCORP)*	Total Lost Productivity Cost	Per Capita Lost Productivity Cost
Minimum	62.0%	**$980,086,383**	$1,588
Mean	62.0%	**$1,049,027,820**	$1,700
Maximum	62.0%	**$1,117,969,258**	$1,811

However, it is likely that not all of these people exercise 100% of the time at a park or on a trail; if it was assumed that they did, there would be an overestimation of the healthcare related benefits of the permanently protected open space. To account for the fact that some people exercise both at a park or on a trail and also indoors or some other non-open space exercise venue, data was used from the Recreation in Pennsylvania Resident Survey that asked people how many minutes they exercised each week at a park or on trail and at other settings. This allowed for an estimate of the proportion of exercise that occurred at a park or on a trail. It was found that, on average, 41% of the moderate/strenuous exercise undertaken occurred at a park or on a trail. The total benefit was then multiplied by 41% to obtain the amount of healthcare related benefits that result from people exercising on preserved open space. Tables D.5a to D.9a present the total cost savings that result from people being physically active. The values in these tables were calculated by multiplying the number of physically active people by the respective costs savings found in Table D.2. Tables D.6b to D.9b present the cost of physical inactivity attributable to exercise undertaken on preserved open space. Tables D.6b to D.9b were calculated by multiplying the values in D.6a to D.9a by 41%.

Table D.5

Direct Medical Cost Savings Attributable to
Preserved Open Space ($M) per year

County	Total Active Population	Cost Savings
Bucks	175,067 [T]	$34.1
Chester	133,825 [T]	$26.1
Delaware	151,996 [T]	$29.6
Montgomery	218,605 [T]	$42.6
Philadelphia	340,914 [T]	$66.4
Total	**1,020,407** [T]	**$198.8**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.5a

Min, Mean, and Max Direct Medical Cost Savings ($M per year)

	Cost Savings	*$308*	*$475*	*$642*
County	Total Active Population	Min	Mean	Max
Bucks	175,067 [T]	$53.92	$83.16	$112.39
Chester	133,825 [T]	$41.22	$63.57	$85.92
Delaware	151,996 [T]	$46.81	$72.20	$97.58
Montgomery	218,605 [T]	$67.33	$103.84	$140.34
Philadelphia	340,914 [T]	$105.00	$161.93	$218.87
Total	**1,020,407** [T]	**$314.28**	**$484.70**	**$655.10**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.5b

Min, Mean, and Max Direct Medical Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Min	Mean	Max
Bucks	175,067 [T]	$22.11	$34.09	$46.08
Chester	133,825 [T]	$16.90	$26.06	$35.23
Delaware	151,996 [T]	$19.19	$29.60	$40.01
Montgomery	218,605 [T]	$27.61	$42.57	$57.54
Philadelphia	340,914 [T]	$43.05	$66.39	$89.74
Total	**1,020,407** [T]	**$128.86**	**$198.71**	**$268.60**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.6

Indirect Medical Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Cost Savings
Bucks	175,067 [T]	$102.3
Chester	133,825 [T]	$78.2
Delaware	151,996 [T]	$88.8
Montgomery	218,605 [T]	$127.7
Philadelphia	340,914 [T]	$199.2
Total	**1,020,407** [T]	**$596.2**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.6a

Min, Mean, and Max Indirect Medical Cost Savings ($M per year)

County	Total Active Population	Min	Mean	Max
	Cost Savings	*$924*	*$1,425*	*$1,926*
Bucks	175,067 [T]	$161.76	$249.47	$337.18
Chester	133,825 [T]	$123.65	$190.70	$257.75
Delaware	151,996 [T]	$140.44	$216.59	$292.74
Montgomery	218,605 [T]	$201.99	$311.51	$421.03
Philadelphia	340,914 [T]	$315.00	$485.80	$656.60
Total	**1,020,407** [T]	**$942.84**	**$1,454.07**	**$1,965.30**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.6b

Min, Mean, and Max Indirect Medical Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Min	Mean	Max
Bucks	175,067 [T]	$66.32	$102.28	$138.24
Chester	133,825 [T]	$50.70	$78.19	$105.68
Delaware	151,996 [T]	$57.58	$88.80	$120.02
Montgomery	218,605 [T]	$82.82	$127.72	$172.62
Philadelphia	340,914 [T]	$129.15	$199.18	$269.21
Total	**1,020,407** [T]	**$386.57**	**$596.17**	**$805.77**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.7

Direct Worker Compensation Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Cost Savings
Bucks	114,494	$0.5
Chester	88,725	$0.4
Delaware	92,413	$0.4
Montgomery	144,279	$0.6
Philadelphia	177,275	$.7
Total	**617,186**	**$2.6**

Source: Econsult Calculations

[T] Figures not in $M

Table D.7a

Min, Mean, and Max Direct Worker Compensation Cost Savings ($M per year)

	Cost Savings	*$6*	*$10*	*$12*
County	Total Active Population	Min	Mean	Max
Bucks	114,494	$0.7	$1.1	$1.4
Chester	88,725	$0.5	$0.9	$1.1
Delaware	92,413	$0.6	$0.9	$1.1
Montgomery	144,279	$0.9	$1.4	$1.7
Philadelphia	177,275	$1.1	$1.8	$2.1
Total	**617,186**	**$3.8**	**$6.1**	**$7.4**

Source: Econsult Calculations

Table D.7b

Min, Mean, and Max Direct Worker Compensation Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Min	Mean	Max
Bucks	114,494[T]	$0.3	$0.5	$0.6
Chester	88,725[T]	$0.2	$0.4	$0.4
Delaware	92,413[T]	$0.2	$0.4	$0.5
Montgomery	144,279[T]	$0.4	$0.6	$0.7
Philadelphia	177,275[T]	$0.4	$0.7	$0.9
Total	**617,186**[T]	**$1.5**	**$2.6**	**$3.1**

Source: Econsult Calculations

[T] Figures not in $M

Table D.8

Indirect Worker Compensation Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Cost Savings
Bucks	114,494[T]	$1.9
Chester	88,725[T]	$1.5
Delaware	92,413[T]	$1.5
Montgomery	144,279[T]	$2.4
Philadelphia	177,275[T]	$2.9
Total	**617,186[T]**	**$10.2**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.8a

Min, Mean, and Max Indirect Worker Compensation Cost Savings ($M per year)

	Cost Savings	*$24*	*$40*	*$48*
County	Total Active Population	Min	Mean	Max
Bucks	114,494[T]	$4.20	$7.00	$8.40
Chester	88,725[T]	$3.21	$5.35	$6.42
Delaware	92,413[T]	$3.65	$6.08	$7.30
Montgomery	144,279[T]	$5.25	$8.74	$10.49
Philadelphia	177,275[T]	$8.18	$13.64	$16.36
Total	**617,186[T]**	**$24.49**	**$40.81**	**$48.97**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.8b

Min, Mean, and Max Indirect Worker Compensation Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Min	Mean	Max
Bucks	114,494[T]	$1.1	$1.9	$2.3
Chester	88,725[T]	$0.9	$1.5	$1.7
Delaware	92,413[T]	$0.9	$1.5	$1.8
Montgomery	144,279[T]	$1.4	$2.4	$2.8
Philadelphia	177,275[T]	$1.7	$2.9	$3.5
Total	**617,186[T]**	**$6.10**	**$10.2**	**$12.1**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.9

Lost Productivity Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Cost Savings
Bucks	114,494[T]	$90.0
Chester	88,725[T]	$69.8
Delaware	92,413[T]	$72.7
Montgomery	144,279[T]	$113.5
Philadelphia	177,275[T]	$139.4
Total	**617,186[T]**	**$485.4**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.9a

Min, Mean, and Max Lost Productivity Cost Savings ($M per year)

	Cost Savings	*$1,630*	*$1,918*	*$2,112*
County	**Total Active Population**	**Min**	**Mean**	**Max**
Bucks	114,494[T]	$186.6	$219.6	$241.8
Chester	88,725[T]	$144.6	$170.2	$187.4
Delaware	92,413[T]	$150.6	$177.2	$195.2
Montgomery	144,279[T]	$235.2	$276.7	$304.7
Philadelphia	177,275[T]	$289.0	$340.0	$374.4
Total	**617,186[T]**	**$1,006.0**	**$1,183.7**	**$1,303.5**

Source: Econsult Calculations

[T] *Figures not in $M*

Table D.9b

Min, Mean, and Max Lost Productivity Cost Savings
Attributable to Preserved Open Space ($M per year)

County	Total Active Population	Min	Mean	Max
Bucks	114,494[T]	$76.52	$90.04	$99.14
Chester	88,725[T]	$59.30	$69.77	$76.83
Delaware	92,413[T]	$61.76	$72.67	$80.02
Montgomery	144,279[T]	$96.42	$113.46	$124.93
Philadelphia	177,275[T]	$118.47	$139.41	$153.51
Total	**617,186[T]**	**$412.47**	**$485.35**	**$534.43**

Source: Econsult Calculations

[T] *Figures not in $M*

Benefits[xxxii]

Of the approximately 2.8 million working-age residents located in the 5-county study area, approximately 1.02 million exercise 3 or more times per week at a moderate or strenuous pace for 30 or more minutes. This exercise results in annual direct medical cost savings of $198.8 million, with an expected range of $128.9 to $268.6 million (Tables D.5, D.5a, and D.5b); annual indirect medical cost savings of $596.2 million, with an expected range of $386.6 million to $805.8 million (Tables D.6, D.6a, and D.6b); annual worker compensation cost savings of $2.6 million with an expected range of $1.5 million to $3.1 million (Table D.7, D.7a, and D.7b); annual indirect worker compensation cost savings of $10.2 million, with an expected range of $6.0 million to $12.1 million (Table D8, D.8a, and D.8b); and lost productivity cost savings of $485.4 million, with an expected range of $412.5 million to $534.4 million (Table D.9, D.9a, and D.9b).

Total cost savings due to exercise attributable to preserved open space amounts to $1,618.3 million, with an expected range of $1,209.9 million to $1,983.1 million (Table D.10).

Table D.10

Min, Mean, and Max Cost Savings ($M per year)

County	Total Active Population	Min	Mean	Max
Bucks	175,067[T]	$207.58	$277.64	$340.23
Chester	133,825[T]	$158.68	$212.23	$260.07
Delaware	151,996[T]	$180.22	$241.05	$295.39
Montgomery	218,605[T]	$259.20	$346.68	$424.84
Philadelphia	340,914[T]	$404.23	$540.65	$662.53
Total	**1,020,407**[T]	**$1,209.91**	**$1,618.25**	**$1,983.06**

Source: Econsult Calculations

[T] *Figures not in ($M)*

Other Benefits

In addition to the health cost savings of treating physical ailments such as obesity, diabetes, heart disease, high blood pressure and others, outdoor recreation also provides a number of other health related benefits.

Research has found that outdoor recreation helps reduce an individual's level of stress. It is estimated that over 75% of all visits to primary care physicians are for stress related complaints and disorders; and people with high stress levels are more at risk for the common cold, heart attack, and some cancers. Furthermore, stress has also been linked to obesity, high systolic blood pressure, and elevated heart rates. Research has also found that stress is especially problematic for older adults due to the fact that aging is often accompanied by an increased level of physical, psychological, and social changes, all of which are potential stressors (Godbey 2009).

Godbey (2009) reports the results of several studies that examine the relationship between stress reduction and outdoor recreation. These findings include a statistically significant relationship between the use of urban green spaces and stress reduction, regardless of the respondent's age, sex, or socioeconomic status; the more often a person visits urban green spaces, the less often he or she reports a stress related illness. Additional research has found that negative moods decrease after spending time in a park and park users typically report lower levels of stress and sadness (Godbey, 2009).

Since there is little quantitative research on exactly how much nature/outdoor recreation reduces stress and how that reduced stress translates into benefits and/or costs savings, the dollar value for the stress reduction benefits was unable to be estimated. However, it appears that the stress reductions due to nature/outdoor recreation are significant and deserve at least a brief discussion in the final report.

In addition to stress reduction, research has also found numerous other psychological benefits for park users that arise from the proximity of parks and other preserved open space. Studies have found psychological benefits resulting from park use among a wide cross-section of the population, including: workers, college students, hospital patients, inner-city girls, public housing residents, and apartment residents (Bedimo-Rung et. al., 2005). Other studies have found that individuals also derive significant psychological benefits just from knowing that the park exists (Kaplan, 1981).

Research has also found that participation in activities that occurred in green outdoor places (protected open space) resulted in reduced symptoms and more positive after effects on symptoms for children suffering from attention deficit/hyperactivity disorder (ADHD) than did activities that occurred in other settings. Furthermore, the advantage of activities occurring in green outdoor places was found among children who lived in communities of different sizes, lived in different regions of the country and were of different household income levels. The benefits of green open space appear to hold despite significant variation in the type and quality of the green open space across the study sample (Kuo and Taylor, 2004). In a related study, children suffering from ADHD were also found to perform better on an objective test of concentration after exposure to a relatively natural green setting than after a carefully matched exposure to a less natural, urban setting (Kuo and Taylor, 2004).

[xxix] Only survey response data for respondents that live within one of the zip codes contained within the study area were used. This provided 302 responses.

[xxx] Absenteeism is defined as not being present or attending to duty or work.

[xxxi] Presenteeism is defined as the productivity loss that occurs when workers are on the job but are not fully functioning.

[xxxii] As with the recreational benefits above, these benefits are not based on the total amount of open space in the region, but rather on the total number of people located in the study area. These costs savings will increase as the number of physically active individuals increases not as the amount of preserved open space increases. For example, if the amount of preserved open space was to double but the number of physically active people was to stay constant, there would be no increase in the cost savings attributable to the preserved open space.

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The Economic Value of Protected Open Space

in Southeastern Pennsylvania

Technical Appendix E

The Value of Economic Activity on Protected Open Space

Economic Activity Benefits

Methodology

As a preface to this analysis, consider the nature of conflicts over development proposals involving open space. These often take place because one group believes that a proposed development will generate a significant amount of economic activity, employment opportunities, and tax revenue, while an opposing group believes that the open space deserves to be kept undeveloped. It would seem at first that this is a hopelessly irreconcilable discussion: one group is speaking in dollar terms, and an opposing group is speaking in non-dollar terms.

Without resolving the conflict as to what terms such a decision should be based on – solely in dollar terms, solely in non-dollar terms, or based in part on both – it is important to make sure that if a comparison is to be made in dollar terms, it must be made fairly. It is true that a new development will generate net new economic activity, economic opportunities, and tax revenue for and within a locality; but it may also generate net new expenditures for and within a locality. In some cases, those net new expenditures borne by a locality exceed the net new revenues generated for a locality; indeed, for this reason, many localities require fiscal impact studies as a part of the development application process, so that their decisions concerning new development can be informed in part by a rigorous estimate of net new revenues versus net new expenditures. It is thus not quite correct, when evaluating a proposed development in dollar terms, to simply consider its net new benefits; one must also consider its potential net new costs.

It is similarly not quite correct, when evaluating a proposed development in dollar terms, to assume that the present economic and fiscal impact associated with the open space in question is zero. There may in fact be two kinds of drivers of economic and fiscal impact associated with open space: 1) activity currently taking place on the open space, which can consist of 1a) protected farmland operated by private entities, or 1b) public parks operated by government entities; and/or 2) tourism activity attracted into the region as a result of the existence of the open space. These categories of job and revenue generators are considered in turn in this memo.

In addition to using estimates and assumptions to account for these direct impacts, one must also account for spillover effects associated with these direct impacts. In other words, the direct activities associated with protected open space also support ancillary activities, which result from two kinds of additional expenditures that occur as a consequence of any direct expenditure:

Indirect expenditures are those expenditures resulting from all intermediate rounds of production in the supply of goods and services. For example, economic activity on private farmland supports various contractors which have to make their own purchases of materials, thus creating a spillover effect on those suppliers.

Induced expenditures are those expenditures that are generated through the spending of earnings generated by the direct activities as well as by the indirect activities of supplying firms. For example, workers on private farmland will themselves spend their earnings on various items, such as food, clothing, and housing.

State and local economic impact, in the form of the sum of direct, indirect, and induced expenditures, and of the employment and earnings supported by that composition and scale of total expenditures, were estimated by utilizing an economic impact model developed by Econsult which incorporates data from the U.S. Department of Commerce's Bureau of Economic Analysis.[xxxiii] Econsult also developed a fiscal impact model to generate detailed estimates of the increases in state and local tax collections that result from these expenditures, employment, and earnings.[xxxiv]

It is important to consider these estimates as rough approximations; they cannot be and are not intended to be precise figures, and are rounded accordingly. The goal of this exercise is not to undertake a precise accounting of economic and fiscal impact, but to arrive at a reasonable and defensible estimate, so as to understand the scale and composition of impact. Where possible, assumptions will tend to err on the conservative side, so that estimated results are not seen as being overstated, and can instead be regarded as a lower bound, with the actual numbers likely being considerably higher.[xxxv]

Preserved Farmland and Other Privately Owned Protected Open Space

According to *Connections 2035: The Regional Plan for a Sustainable Future*; a recent publication by DVRPC; within the Philadelphia region, preserved farmland accounts for about 42,000 acres of land, and land trust or privately protected space represents an additional 59,600 acres of land. Thus, agricultural activity takes place on some of these acres, which results in economic activity and employment that should be accounted for. In considering the economic activity represented by protected open space that is privately owned and operated on, the following assumptions are made, with care to be conservative where possible:

Satellite imagery was used to back out forests and wetlands on preserved farmland, yielding potential agricultural uses on preserved farmland of about 35,700 acres (about 85% out of the 42,000 total acres).

Satellite imagery was used to back out forests, wetlands, and pastures on land trust or private protected space, yielding potential agricultural uses on land trust or private protected space of about 14,600 acres (about 24% out of the total 59,600 acres). It is likely that some of the 21,300 acres (an additional 36% out of the total 59,600 acres) on land trust or private protected space of land that is classified as pasture is used for agriculture; but to be conservative, none of these acres are included.

Not included in this analysis, or in DVRPC's inventory, are the thousands of smaller community gardens on which some commercial activity takes place in the form of cultivating food and non-food items for sale. Therefore, it is conservative to assume that the amount of commercial activity taking place within these community gardens is zero.

It is assumed that agriculture activity on preserved farmland, land trust, and private protected space is as intensive, in terms of commercial activity and employment density, as other agriculture activity within the Philadelphia region. Given the fact that forests and wetlands have been backed out of preserved farmland acres, and that forests, wetlands, and pastures have been backed out of land trust or private protected space, this seems to be a reasonable if not conservative assumption.

All told, it was estimated that about 50,300 acres of preserved farmland, land trust, and private protected space are assumed to house some agriculture activity within the Philadelphia region: 35,700 acres of preserved farmland, and 14,600 acres of land trust or privately protected space. According to the US Census Bureau and the US Department of Agriculture, there are about 289,300 acres of land in the Philadelphia region devoted to agriculture, consisting of at least $664 million in annual sales and about 7,600 employees.[xxxvi] That is, assuming a proportionate amount, by county, of direct activity on protected open spaces yields direct activity on protected open spaces of about $120 million in annual sales and about 1,300 employees (see Table E.1).[xxxvii]

Table E.1

Estimated Direct Annual Sales and Employment on Preserved Farmland and Other Privately Protected Open Space (all figures from 2007)

County	Acres Devoted to Agriculture	Private Preserved Farmland Acres Estimated to be Devoted to Agriculture	Estimated % Agricultural Land that is Private Preserved Farmland	2007 Market Value of Agriculture Sales ($M)	Estimated Market Value of Agriculture Sales on Private Preserved Farmland ($M)	Agriculture Full-Time Employment	Estimated Agriculture Full-Time Employment on Private Preserved Farmland
Bucks	75,883	11,862	16%	$70.6	$11.0	1,235	193
Chester	166,891	30,566	18%	$553.3	$101.3	5,401	989
Delaware	4,361	808	19%	$9.5	$1.8	147	27
Montgomery	41,908	6,925	17%	$30.0	$5.0	828	137
Philadelphia	262	158	60%	$0.5	$0.3	14	8
Total	**289,305**	**50,319**	**17%**	**$663.9**	**$119.4**	**7,625**	**1,354**

Source: Delaware Valley Regional Planning Commission (2010), US Geological Society (2010), US Department of Agriculture (2007), US Department of Commerce Bureau of Economic Analysis (2007), Econsult Corporation (2010)

Publicly Controlled Park Space

According to *Connections 2035*, publicly protected open space represents an additional 95,700 acres of land within the Philadelphia region. Thus, maintenance activity takes place on some of these acres, which generates public expenditures that should be accounted for. In considering the economic activity represented by protected open space that is publicly owned and maintained, the following assumptions are made:[xxxviii]

Federally-controlled parks – Budget data was obtained for Hopewell Furnace National Historic Site (of which one-third was assigned to Chester County, as the remaining two-thirds was assigned to Berks County), Valley Forge National Historical Park (Montgomery County), and Heinz National Wild Life Refuge (Philadelphia County). To be conservative, Independence National Historical Park in Philadelphia County was completely excluded because much of its grounds would not be considered open space.[xxxix]

State-controlled parks – Budget data for 12 parks were accounted for in this analysis, covering Delaware Canal State Park, Neshaminy State Park, Nockamixon State Park, Ralph Stover State Park, and Tyler State Park in Bucks County; French Creek, Marsh Creek, and White Clay Creek in Chester County; Ridley Creek in Delaware County; Evansburg State Park and Fort Washington State Park in Montgomery County; and Benjamin Rush State Park in Philadelphia County.[xl]

County- and municipally-controlled parks – Budget data for parks departments for all five counties were obtained and included in this analysis.[xli] Budget data was obtained for any municipalities that had more than 200 acres of municipally-controlled park space and that had available budget data. This accounts for 35 of 222 municipalities with municipally-controlled parks (16%) and 14,700 acres out of 34,500 acres of municipally-controlled parks (43%). It was conservatively assumed that there are similar budget levels for the other 57%of municipally-controlled parks (see Table E.2).[xlii]

Table E.2

Estimated Direct Annual Expenditures, Employment, and Salaries on Municipally Controlled Park Space[xliii]

	Estimated Park-Only Budget ($M)	Estimated Park-Only Salaries ($M)	Estimated Park-Only Employment
Bucks	$12.4	$6.8	165
Chester	$10.0	$6.1	125
Delaware	$10.6	$6.7	157
Montgomery	$13.8	$9.1	200
Total	**$46.8**	**$28.7**	**647**

Source: Various municipality budgets (2009, 2010); Delaware Valley Regional Planning Commission (2010); U.S. Geological Society (2010); Econsult Corporation (2010)

These conservative assumptions yield an estimated $92 million spent annually on publicly-controlled park space within the Philadelphia region, supporting 1,250 employees and $56 million in earnings (see Table E.3). These estimates represent only the direct economic activities that take place on protected open space, and do not include any spillover economic activities that support and are supported by those direct economic activities.

Table E.3

Estimated Direct Annual Expenditures, Employment, and Salaries on Publicly Controlled Park Space

Budgets ($M)	All Levels	Municipal	County	State	Federal
Bucks	$20.8	$12.4	$4.7	$3.7	$0.0
Chester	$17.7	$10.0	$6.2	$1.0	$0.5
Delaware	$12.7	$10.6	$1.5	$0.6	$0.0
Montgomery	$27.8	$13.8	$6.0	$0.8	$7.2
Philadelphia	$12.6	-	$12.6	$0.0	$0.0
Total	**$91.6**	**$46.8**	**$31.0**	**$6.1**	**$7.7**

Employment	All Levels	Municipal	County	State	Federal
Bucks	282	165	59	58	-
Chester	224	125	77	16	6
Delaware	185	157	18	10	-
Montgomery	385	200	75	13	97
Philadelphia	171	-	171	-	-
Total	**1,247**	**647**	**400**	**97**	**103**

Salaries ($M)	All Levels	Municipal	County	State	Federal
Bucks	$11.6	$6.8	$3.0	$1.8	$0.0
Chester	$11.0	$6.1	$4.1	$0.5	$0.3
Delaware	$7.8	$6.7	$0.9	$0.3	$0.0
Montgomery	$17.5	$9.1	$3.6	$0.4	$4.4
Philadelphia	$8.4	-	$8.4	$0.0	$0.0
Total	**$56.3**	**$28.7**	**$20.0**	**$3.0**	**$4.7**

Source: Various municipality/county/state/federal budgets (2009, 2010); Delaware Valley Regional Planning Commission (2010); U.S. Geological Society (2010); Econsult Corporation (2010)

Economic and Fiscal Impact from Preserved Farmland and Public Park Space

This composition and scale of direct economic activity taking place on preserved open space, whether in the form of privately-maintained preserved farmland or publicly-maintained park space, is conservatively estimated to annually generate within the Philadelphia region $380 million in total expenditures, supporting 5,100 jobs and $240 million in earnings; it is also conservatively estimated to generate $2.5 million in local tax revenues and $15 million in state tax revenues (see Table E.4).[xliv] These estimates represent the direct economic activities that take place on protected open space, as well as spillover economic activities that support and are supported by those direct economic activities.

Table E.4

Estimated Direct, Indirect/Induced, and Total Annual Impact
Associated with Privately Controlled Preserved Farmland and Publicly Controlled Park Space

	Bucks	Chester	Delaware	Montgomery	Philadelphia	Total
Direct Expenditures	$31.8	$119.0	$14.4	$32.8	$12.9	**$210.9**
Indirect & Induced Expenditures	$26.7	$89.1	$12.7	$28.7	$11.6	**$168.8**
Total Expenditures	$58.5	$208.1	$27.1	$61.5	$24.5	**$379.7**
Total Employment	755	3,033	331	755	291	**5,165**
Total Earnings	$31.1	$148.3	$14.0	$34.3	$14.2	**$241.9**
Total Local Taxes	$0.1	$0.5	$0.0	$0.2	$1.7	**$2.5**
Total State Taxes	$2.2	$9.2	$1.0	$2.2	$0.8	**$15.4**

Source: Econsult Corporation (2010)

Tourism Activity

In addition to economic activity that takes place on the protected open space within the Philadelphia region, economic activity is generated for the Philadelphia region by the protected open space in the form of tourism activity, which imports consumption from outside the region into the region.[xlv] Tourism, in general, is of course an industry of great significance in the Philadelphia region: Tourism Economics estimated for the Greater Philadelphia Tourism and Marketing Corporation that in 2008, the tourism industry represented $5.8 billion in direct expenditures, supporting 63,000 employees and $1.6 billion in earnings, creating a total impact of $9.3 billion supporting 87,000 employees and $2.8 billion in earnings (see Table E.5).

Table E.5

Estimated Direct, Indirect/Induced, and Total Annual Impact
Associated with All Tourism in Southeastern Pennsylvania

Expenditures ($M)	Direct	Indirect/Induced	Total
Bucks	$525.7	$319.1	$844.8
Chester	$545.6	$331.2	$876.8
Delaware	$473.1	$287.2	$760.3
Montgomery	$938.9	$569.9	$1,508.8
Philadelphia	$3,316.1	$2,013.1	$5,329.2
Total	**$5,799.4**	**$3,520.5**	**$9,319.9**

Employment	Direct	Indirect/Induced	Total
Bucks	8,507	3,223	11,730
Chester	6,957	2,636	9,593
Delaware	6,973	2,642	9,615
Montgomery	13,206	5,004	18,210
Philadelphia	27,720	10,516	38,236
Total	**63,363**	**24,021**	**87,384**

Salaries (in $M)	Direct	Indirect/Induced	Total
Bucks	$148.0	$107.6	$255.6
Chester	$150.6	$109.5	$260.1
Delaware	$137.1	$99.7	$236.8
Montgomery	$278.3	$202.4	$480.7
Philadelphia	$915.9	$666.3	$1,582.2
Total	**$1,629.9**	**$1,185.5**	**$2,815.4**

Taxes (in $M)	Federal	State	Local	Total
Bucks	$67	$31	$19	$117
Chester	$70	$31	$19	$120
Delaware	$60	$25	$17	$102
Montgomery	$120	$53	$33	$206
Philadelphia	$423	$175	$206	$804
Total	**$740**	**$315**	**$294**	**$1,349**

Source: Greater Philadelphia Tourism and Marketing Corporation (2009)

In order to estimate the marginal impact on the Philadelphia region of the existence of protected open space (or, said another way, the amount the Philadelphia region would suffer if all protected open space were removed),[xlvi] one must determine a reasonable proportion of that overall direct tourism activity that is induced to the region because of the protected open space. A useful frame of reference in making such a determination is a survey of international visitors conducted by International Trade Administration Office of Travel and Tourism Industries in 2007, in which respondents were asked which tourism activities they participated in during their time within the Philadelphia region, from among a selection of activities that included a number that may have involved protected open space (see Table E.6).

Table E.6

Percentage of International Visitors to Southeastern Pennsylvania
That Participated in A Particular Tourism Activity, Sorted by Popularity of Activity
(Highlighted Activities Are Those That May Involve Protected Open Space)

Number of Respondents	*921*	*659*	*382*
Visitor Type	**All Visitors**	**Leisure**	**Business**
Dining in Restaurants	86%	88%	87%
Shopping	83%	89%	73%
Visit Historical Places	54%	64%	34%
Sightseeing in Cities	51%	62%	31%
Art Galleries/Museums	33%	42%	17%
Cultural Heritage Sites	30%	35%	19%
Visit Small Towns	30%	39%	14%
Touring Countryside	22%	29%	10%
Concerts/Plays/Musicals	18%	21%	9%
Visit National Parks	18%	24%	7%
Guided Tours	17%	21%	10%
Amusement/Theme Parks	16%	20%	9%
Nightclubs/Dancing	13%	14%	10%
Attend Sports Events	12%	13%	6%
Water Sports/Sunbathing	12%	15%	6%
Casinos/Gambling	9%	10%	5%
Ethnic Heritage Sites	5%	6%	2%
Golfing/Tennis	5%	6%	5%
Camping/Hiking	3%	4%	1%
Cruises	3%	4%	1%
Environmental/Ecological Excursions	3%	4%	1%
Visit Native American Communities	3%	3%	1%
Hunting/Fishing	2%	3%	1%
Ranch Vacations	1%	1%	0%
Snow Skiing	1%	1%	1%

Source: International Trade Administration Office of Travel and Tourism Industries (2007)

Allowing for multiple responses, summing the proportion of users that participated in activities that may involve protected open space and dividing by the proportion of users that participated in all activities yields a proportion of 16% (18% for leisure tourists and 12% for business tourists). This is a survey of international visitors and not all visitors, but the number is probably not too inaccurate: at both a state and national level, studies have indicated that 17%of travel is outdoor-related.[xlvii]

Thus, the proportion of overall direct tourism activity that is induced to the region because of the protected open space, and that can be reasonably "counted" towards the contribution of protected open space to tourism activity within a region, is likely to be relatively large. Conservatively assuming that the existence of protected open space contributes two additional percentage points to tourism within the Philadelphia region,[xlviii] the aggregate direct impact is $116 million in direct expenditures, supporting 1,270 employees and $32 million in earnings, creating a total impact of $186 million supporting 1,750 employees and $56 million in earnings, as well as $6 million in state taxes and $6 million in local taxes (see Table E.7).

Table E.7

Estimated Direct, Indirect/Induced, and Total Annual Impact Associated with Tourism
That is Attributable to Protected Open Space
(assuming 2% of tourism activity is attributable to protected open space)

Expenditures ($M)	Direct	Indirect/Induced	Total
Bucks	$10.6	$6.4	$17.0
Chester	$11.0	$6.6	$17.6
Delaware	$9.4	$5.8	$15.2
Montgomery	$18.8	$11.4	$30.2
Philadelphia	$66.4	$40.2	$106.6
Total	**$116.2**	**$70.4**	**$186.6**

Employment	Direct	Indirect/Induced	Total
Bucks	170	64	234
Chester	140	52	192
Delaware	140	52	192
Montgomery	264	100	364
Philadelphia	554	210	764
Total	**1,268**	**478**	**1,746**

Salaries (in $M)	Direct	Indirect/Induced	Total
Bucks	$3.0	$2.2	$5.2
Chester	$3.0	$2.2	$5.2
Delaware	$2.8	$2.0	$4.8
Montgomery	$5.6	$4.0	$9.6
Philadelphia	$18.4	$13.4	$31.6
Total	**$32.8**	**$23.8**	**$56.4**

Taxes (in $M)	Federal	State	Local	Total
Bucks	$1.4	$0.6	$0.4	$2.4
Chester	$1.4	$0.6	$0.4	$2.4
Delaware	$1.2	$0.6	$0.4	$2.0
Montgomery	$2.4	$1.0	$0.6	$4.2
Philadelphia	$8.4	$3.6	$4.2	$16.0
Total	**$14.8**	**$6.4**	**$6.0**	**$27.0**

Source: Greater Philadelphia Tourism and Marketing Corporation (2009); Econsult Corporation (2010)

It is likely that tourism is not the only major economic activity that is drawn to the Philadelphia region as a result of the presence of protected open space. There is an increasing awareness of the role of outdoor amenities such as parks, trails, and waterfronts in attracting employers and employees to a region.[xlix] To the extent that protected open space can claim credit for the attraction and retention of firms and workers within the region, this represents a significant amount of economic activity, employment, and tax revenues. Conservatively, we do not assign a dollar amount to this economic value provided to the region by protected open space, but we speculate that the impact is positive and significant.

Economic and Fiscal Impact Summary

Combining the economic activity taking place on privately maintained preserved farmland or publicly maintained park space with the economic activity from tourism attracted to the region by protected open space, the annual economic impact within the Philadelphia region is conservatively estimated to be $566 million in total expenditures, supporting 6,900 jobs and $300 million in earnings, as well $8 million in local tax revenues and $22 million in state tax revenues (see Table E.8).[l] These estimates represent the direct economic activities that take place or are induced within the region by protected open space, as well as spillover economic activities that support and are supported by those direct economic activities.

Table E.8

Estimated Direct, Indirect/Induced, and Total Annual Impact Associated with Protected Open Space: Privately Controlled Preserved Farmland, Publicly Controlled Park Space, and Tourism Activities Attracted to the Region by Protected Open Space

	Economic Activities on Private Preserved Farmland and Public Park Space	Economic Activities from Tourism Attracted to the Region by Protected Open Space	Total
Total Expenditures	$379.7	$186	$566.3
Total Employment	5,164	1,748	6,912
Total Earnings	$242.0	$56	$298. 0
Total Local Taxes	$2.5	$5.8	$8.3
Total State Taxes	$15.4	$6.4	$21.8

Source: Econsult Corporation (2010)

Within the context of a region whose contribution to Gross State Product is well over $300 billion a year, and which employs roughly 1.7 million people, these are relatively small numbers. Yet, on another level, they are significant in that, as noted above, oftentimes the economic value of protected open space is seen as zero or close to zero, as compared to alternative development scenarios; so in that regard, these total economic and fiscal impacts are significant.[li]

[xxxiii] See Supplement E.1 for additional detail on Econsult's economic impact methodology.

[xxxiv] See Supplement E.1 for additional detail on Econsult's fiscal impact methodology.

[xxxv] Because this engagement is funded and supervised by advocates of protected open space, it is all the more important for the analysis methodology to err on the side of conservatism, to avoid any implication that numbers have been inflated in undue manner in order to support a particular point of view.

[xxxvi] Acreage is from the USDA National Agricultural Statistics Service's 2007 Census of Agriculture. Sales are from the 2007 USDA Census of Agriculture, and employment is from the U.S. Department of Commerce's Bureau of Economic Analysis.

[xxxvii] These estimates are based on 2007 figures and are not inflated into 2010 dollars. This is likely a conservative approach, since agricultural intensity on protected open space did not include uses not specifically allocated to agriculture, such as wetlands and pastures, while agricultural intensity throughout the county does in fact include such land use types.

[xxxviii] Budget figures are taken from the most recent years available. In some cases, future budget levels are anticipated to decrease due to fiscal challenges, while in other cases, future budget levels are anticipated to increase due to proposed plans. Forecasts as to whether, in the aggregate, budget amounts may increase or decrease in the near future were not attempted; estimates based simply on the most recent years available were instead used.

For park space that cuts across multiple counties, budget figures were assigned based on rough proportions of acreage.

[xxxix] No data was available for Heinz National Wild Life Refuge in Philadelphia County, so it is conservative that our analysis presumes that no direct economic activity takes place there.

[xl] Where employment or salary amounts were not available at a per-park level, they were estimated by assuming the same proportions for other parks within the same county for which per-park amounts were available. Seasonal employees were considered one half of one full-time equivalent employee. Marsh Creek's information as state game lands was conservatively not included in this analysis.

[xli] Where employment or salary amounts were not available at a per-park level, they were estimated by assuming the same proportions for other parks within the same county for which per-park amounts were available. Seasonal employees were considered one half of one full-time equivalent employee.

[xlii] See Supplement E.3 for information on municipalities for which direct information was available. Extrapolating expenditure amounts from the 43% of municipality-controlled park acreage for which we were able to obtain some budget information to the remaining 57% of municipality-controlled park acreage could be deemed conservative. This is becauseit is likely that, on a per-acre basis, maintenance expenditures are higher for those municipalities with less than 200 acres of municipality-controlled park acreage within their boundaries because of the lack of economies of scale.

Where municipalities did not separately break out park operations (i.e. where they only showed combined budgets for parks and recreation operations), parks-only amounts were estimated by calculating a weighted average of park budgets to combined budgets from among all municipalities whose budgets did separately break out park operations. Similarly, where municipalities did not separately break out salary amounts for park operations, salary amounts were estimated by calculating a weighted average of salaries to total budgets from among all municipalities whose budgets did separately break out salaries. Finally, employment for municipally controlled park space by county was estimated by calculating an average salary for park employees within each county based on estimates generated for federal, state, and county parks, and used those estimates of average salary for park employees by county to estimate employment for municipally controlled park space by county.

[xliii] Philadelphia is both a municipality and a county, and its amounts are accounted for in the county section. See Supplement E.4 for townships included in this analysis, including acres of municipally controlled park space.

[xliv] See Supplement E.4 for this figure broken out between privately controlled preserved farmland and publicly controlled park space. See Supplement E.1 for additional detail on Econsult's economic and fiscal impact methodologies.

[xlv] On a related note, protected open space has been shown to have an effect on another kind of import of economic activity: a 1997 survey ranked open space, parks, and recreation as number one among indicators for small business in terms of site selection: "An Empirical Study of the Role of Recreation, Parks and Open Space in Companies' (Re)Location Decisions," Journal of Park and Recreation Administration (1997). Therefore, the marginal impact on the Philadelphia region of the existence of protected open space (or, said another way, the amount the Philadelphia region would suffer if all protected open space were removed) would include some proportion of business activity that is induced to the region as a result of the protected open space. Conservatively, this impact was not accounted for.

[xlvi] In fact, figures are conservatively estimated using the second way of stating the question, which is more conservative. The amount of tourism presently associated with protected open space is likely significantly larger than the amount tourism would decline should protected open space completely disappear from the region, because tourists would partially substitute from protected open space activities to other activities. Thus, tourism would still decline, but not by the same magnitude as the amount of tourism presently associated with protected open space.

[xlvii] "Pennsylvania Outdoor Tourism Visitor Profile and Economic Impact," Commonwealth of Pennsylvania Department of Conservation and Natural Resources (March 1999); and "Outdoor Recreation in America," Clayne R. Jensen and Steven Guthrie (2006). The book by Jensen and Guthrie also notes that tourists participating in outdoor recreation spend $161 billion per year, and an additional $48 billion on outdoor equipment, including vehicles, which in total would represent about a third of real tourism spending, as reported by the US Department of Commerce Bureau of Economic Analysis ("Travel and Tourism Declines in Fourth Quarter 2009" [March 19, 2010]).

As another point of reference, the Philadelphia region is estimated to have received over 30 million visitors in 2007; among its top tourist attractions are such locations as Valley Forge National Historical Park (1.3 million visitors) and Longwood Gardens (730,000 visitors): "Greater Philadelphia: 30 Million Visitors Strong," Greater Philadelphia Tourism Marketing Corporation (2009), "2007 Book of Lists," Philadelphia Business Journal (2007).

[xlviii] It is difficult to directly determine what that proportion is, because tourism activity is often a combination of activities. It may be that a tourist partaking in activities on protected open space would, absent the existence of that protected open space, completely substitute to other tourism activities, thus resulting in no net loss in tourism activity; hence, even some tourism activity that is known to take place on protected open space should not be fully "counted" towards the contribution of protected open space to tourism activity within a region. Conversely, it may be that a tourist partaking in activities not on protected open space is also partaking in activities on protected open space, and absent the existence of that protected open space, he or she would choose another location and therefore not partake in activities not on protected open space; hence, even tourism activity that is known to not take place on protected open space should be "counted" in part towards the contribution of protected open space to tourism activity within a region. Secondly, some tourism activities tend to be complementary, which means the distribution of users is not random: a very high proportion of "visit national parks" tourists are likely to also be "camping/hiking" tourists.

So it is impossible to precisely determine what proportion of tourism to a region would not have occurred if protected open space did not exist in the region. It is probably too aggressive to presume that if outdoor tourism represents a certain percentage of tourism to a region, tourism in the region would be reduced by that same percentage if protected open space did not exist in the region. But it is safe to assume that tourism in the region would be reduced by some percentage. It follows, then, that the study's two percentage point reduction estimate is not too high and could in fact be far too low.

As points of reference, it was noted that the Outdoor Recreation Coalition of America estimated that outdoor recreation generated $40 billion in expenditures in 1996 in the US, supporting 768,000 employees and $13 billion in salaries; and that open space in New Hampshire was valued to contribute $8 billion to the local economy, supporting 100,000 employees and generating $891 million in state and local taxes: "Economic Benefits of Outdoor Recreation," Outdoor Recreation Coalition of America, (1997), "Study: Open Space Bolsters State Economy," Concord Monitor (February 7, 1999). It was also noted that the 2008 report by the Philadelphia Parks Alliance on the economic impact of the park system in Philadelphia calculated that 41% of tourists visited a park while in Philadelphia, and from that estimated that 20%of Philadelphia park visitors came because of the parks; this number should be and is much higher than the estimate used in this report, because, in considering protected open space and not public parks per se, the major tourist attractions within the Philadelphia park system, namely Independence National Historic Park, were not included.

Finally, it was noted that there may be some double-counting involved in estimating tourist impact as well as accounting for the public expenditures associated with maintaining publicly controlled protected open space. The vast majority of direct tourism expenditures are not in the form of payments to public entities but rather to private ones: accommodations, transportation, dining, and retail. Nevertheless, contained within the tourism estimates are some direct payments to public entities, in the form of permits for various recreational uses, such as fishing or hunting licenses, or stays in state-owned camping grounds. This influences the decision to be conservative in estimating the proportion of direct tourism expenditures that is attracted to the Philadelphia region by protected open space.

[xlix] See, for example, "A Tale of Ten Cities: Attracting and Retaining Talent," prepared for the 2nd Annual Meeting of the International Regions Benchmarking Consortium in Barcelona, Spain (November 2009).

[l] See Supplement E.3 for additional economic and fiscal impact charts.

[li] Furthermore, these impacts do not appear to have any risk of being double-counted with impacts associated with property value enhancement as a result of proximity to protected open space or to the value of environmental services provided by protected open space, and only minimal quality of life enhancements due to direct use of protected open space, to the extent that a portion of what people are valuing when they pay to use protected open space (i.e. in support of public sector parks budgets or as a part of tourism expenditures).

SUPPLEMENT E.1

Economic and Fiscal Impact Model Methodology

E.1.a Economic Impact Model

The methodology and input-output model used in this economic impact analysis are considered standard for estimating such expenditure impacts, and the results are typically recognized as reasonable and plausible effects, based on the assumptions (including data) used to generate the impacts. In general, one can say that any economic activity can be described in terms of the total output generated from every dollar of direct expenditures. If an industry in a given region sells $1 million of its goods, there is a direct infusion of $1 million into the region. These are referred to as *direct expenditures*.

However, the economic impact on the region does not stop with that initial direct expenditure. Regional suppliers to that industry have also been called upon to increase their production to meet the needs of the industry to produce the $1 million in goods sold. Further, suppliers of these same suppliers must also increase production to meet their increased needs as well. These are referred to as *indirect expenditures*. In addition, these direct and indirect expenditures require workers; these workers must be paid for their labor. Their wages and salaries will, in turn, be spent in part on goods and services produced locally, engendering another round of impacts. These are referred to as *induced expenditures*.

Direct expenditures are fed into a model constructed by Econsult Corporation and based on data provided by the U.S. Department of Commerce's Bureau of Economic Analysis through its Regional Input-Output Modeling System (RIMS II). The model then produces a calculation of the total expenditure effect on the regional economy. This total effect includes the initial direct expenditure effect, as well as the ripple effects described as indirect and induced expenditures.

Part of the total expenditure effect is actually the increase in total wages and salaries (usually referred to as earnings), which the model can separate from the expenditure estimates. Direct payroll estimates are fed into the "household" industry of the input-output model. Impacts of this industry are estimated using the personal consumption expenditure breakdown of the national input-output table and are adjusted to account for regional consumption spending and leakages from personal taxes and savings. The direct, indirect, and induced earnings represent a component of the total economic impact attributable to wages and salaries. Finally, the model calculates the total expenditures affecting the various industries and translates this estimate into an estimate of the total labor (or jobs) required to produce this output.[lii]

In short, the input-output model estimates the total economic activity in a region that can be attributed to the direct demand for the goods or services of various industries. This type of approach is used to estimate the total economic activity attributable to the expenditures associated with various types of spending in the region.

Figure E.1.a – Glossary of Terms for Input-Output Models

Multiplier Effect – the notion that initial outlays have a ripple effect on a local economy, to the extent that direct expenditures lead to indirect and induced expenditures.
Economic Impacts – total expenditures, employment, and earnings generated.
Fiscal Impacts – local and/or state tax revenues generated.
Direct Expenditures – initial outlays usually associated with the project or activity being modeled; examples: one-time upfront construction and related expenditures associated with a new or renovated facility, annual expenditures associated with ongoing facility maintenance and/or operating activity.
Direct Employment – the full time equivalent jobs associated with the direct expenditures.
Direct Earnings – the salaries and wages earned by employees and contractors as part of the direct expenditures.
Indirect Expenditures – indirect and induced outlays resulting from the direct expenditures; examples: vendors increasing production to meet new demand associated with the direct expenditures, workers spending direct earnings on various purchases within the local economy.
Indirect Employment – the full time equivalent jobs associated with the indirect expenditures.
Indirect Earnings – the salaries and wages earned by employees and contractors as part of the indirect expenditures.
Total Expenditures – the sum total of direct expenditures and indirect expenditures.
Total Employment – the sum total of direct employment and indirect employment.
Total Earnings – the sum total of direct earnings and indirect earnings.

Source: Econsult Corporation (2009)

FIGURE E.1.B Fiscal Impact Model

The RIMS II model provides estimates of the economic impact of a new project or program on the regional economy. It does not, however, estimate the fiscal impact of the increased economic activity on state and local governments. Econsult has constructed a model that takes the output from the RIMS II model and generates detailed estimates of the increases in state and local tax collections that arise from the new project. Those revenues are in fact a part of the total economic impact of a new project that is often ignored in conventional economic impact analyses.

The RIMS II model provides estimates of direct, indirect, and induced expenditures; earnings; and employment within the defined region. The Econsult fiscal impact model combines the RIMS II output with U. S. Census Bureau County Business Patterns data to produce estimates of the distribution of additional employment and earnings by county. In addition, the 2000 Census "Journey to Work" data on commuting flows are utilized to estimate income earned by residents of each county within the region, regardless of where they work. The fiscal model can then estimate the increase in earned income taxes by county and for the state as a whole resulting from the new project. For complex cases, like Philadelphia, the model can differentiate between residents and nonresidents and apply the proper wage tax rate. Pennsylvania state business and sales taxes, as well as business taxes in Philadelphia, are estimated based on the most recent data on average sales tax base per employee by major industry, as contained in publications from the Pennsylvania Department of Revenue.

[lii] In the input-output model, the estimate of increased employment will always be in terms of the employment required for a given level of production, usually referred to as *person-years* of employment. As such, these estimates cannot be interpreted as specifying *permanent jobs.*

SUPPLEMENT E.2

Estimated Direct Annual Expenditures, Employment, and Salaries FOR Municipally Controlled Park Space within the Philadelphia Region FOR WHICH DATA WERE AVAILABLE[liii]

Table E.9

Title

	# Townships w/Municipally Controlled Park Space	# Acres of Municipally Controlled Park Space	# Townships w/>200 Acres of Municipally Controlled Park Space	# Townships For Which Data Were Available	# Acres of Municipally Controlled Park Space For Which Data Were Available	Estimated Park-Only Budget for Municipalities For Which Data Were Available ($M)	Estimated Park-Only Salaries for Municipalities For Which Data Were Available ($M)	Estimated Park-Only Employment for Municipalities For Which Data Were Available
Bucks	53	13,382	23	14	6,781	$5.3	$2.9	70
Chester	68	8,591	15	9	3,403	$4.2	$2.6	51
Delaware	43	3,383	7	4	1,209	$4.5	$2.8	63
Montgomery	58	9,168	16	8	3,306	$5.9	$3.9	85
TOTAL	**222**	**34,524**	**61**	**35**	**14,699**	**$19.9**	**$12.2**	**269**

Source: various municipality budgets (2009, 2010), Delaware Valley Regional Planning Commission (2010), US Geological Society (2010), Econsult Corporation (2010)

[liii] Philadelphia is both a municipality and a county, and its amounts are accounted for in the county section.

SUPPLEMENT E.3

Municipalities with 200 or More Acres of Municipally Controlled Park Space, Sorted By Acres

Bucks County:

Lower Makefield Township	1,308.6
Middletown Township	1,211.1
Falls Township	692.7
Warwick Township	679.0
Northampton Township	581.4
Warminster Township	563.5
Doylestown Township	563.2
East Rockhill Township	506.9
Bensalem Township	493.7
Newtown Township	453.1
Bristol Township	450.4
West Rockhill Township	413.2
Richland Township	386.9
Springfield Township	376.2
Tullytown Borough	352.2
New Britain Township	340.8
Milford Township	340.3
Hilltown Township	309.5
Solebury Township	287.1
Buckingham Township	277.7
Bristol Borough	222.2
Wrightstown Township	220.7
Tinicum Township	209.4

Chester County:

East Goshen Township	548.3
East Bradford Township	482.8
West Bradford Township	405.7
North Coventry Township	399.7
West Pikeland Township	361.4
Tredyffrin Township	346.8
Uwchlan Township	342.2
Westtown Township	319.2
West Whiteland Township	315.3
South Coventry Township	287.1
Willistown Township	243.8
Elk Township	233.0
Charlestown Township	224.0
Caln Township	223.1
Kennett Township	217.3

Delaware County:

Radnor Township	417.9
Haverford Township	327.4
Thornbury Township	313.8
Upper Darby Township	256.6
Chester City	250.6
Concord Township	247.8
Marple Township	207.4

Montgomery County:

Lower Salford Township	715.7
Horsham Township	569.1
Lower Merion Township	528.6
Upper Hanover Township	496.3
Montgomery Township	471.5
Abington Township	451.1
Upper Dublin Township	417.6
Upper Providence Township	393.8
Whitpain Township	344.5
Cheltenham Township	303.5
Towamencin Township	290.1
Upper Merion Township	260.5
Lower Gwynedd Township	258.4
Hatfield Township	234.7
Marlborough Township	217.4
Upper Gwynedd Township	203.2

Source: US Geological Society (2010), Econsult Corporation (2010)

SUPPLEMENT E.4

Additional Economic and Fiscal Impact Charts

Figure E.10

Estimated Direct, Indirect/Induced, and Total Annual Impact within the Philadelphia Region Associated with Privately Controlled Preserved Farmland within the Philadelphia Region

	5-County Total	Philadelphia	Bucks	Chester	Delaware	Montgomery
Direct Expenditures	$119.4	$0.3	$11.0	$101.3	$1.8	$5.0
Indirect & Induced Expenditures	$86.2	$0.2	$8.0	$73.2	$1.3	$3.6
Total Expenditures	$205.6	$0.5	$19.0	$174.5	$3.0	$8.5
Total Employment	3,104	8	287	2,635	46	129
Total Earnings	$148.9	$0.4	$11.8	$128.9	$1.9	$5.9
Total Local Taxes	$1.3	$0.7	$0.1	$0.4	$0.0	$0.1
Total State Taxes	$9.5	$0.0	$0.9	$8.1	$0.1	$0.4

Source: Econsult Corporation (2010)

Figure E.11

Estimated Direct, Indirect/Induced, and Total Annual Impact within the Philadelphia Region Associated with Publicly Controlled Park Space within the Philadelphia Region

Open Space Activities	5-County Total	Philadelphia	Bucks	Chester	Delaware	Montgomery
Direct Expenditures	$91.6	$12.6	$20.8	$17.7	$12.7	$27.8
Indirect & Induced Expenditures	$82.6	$11.4	$18.7	$15.9	$11.4	$25.1
Total Expenditures	$174.1	$23.9	$39.5	$33.6	$24.1	$52.9
Total Employment	2,060	283	468	398	285	626
Total Earnings	$93.2	$13.9	$19.3	$19.5	$12.1	$28.5
Total Local Taxes	$1.3	$1.0	$0.0	$0.1	$0.0	$0.1
Total State Taxes	$5.9	$0.8	$1.3	$1.1	$0.8	$1.8

Source: Econsult Corporation (2010)

Figure E.12

Estimated Direct, Indirect/Induced, and Total Annual Impact Associated with Protected Open Space in the Philadelphia Region: Privately Controlled Preserved Farmland, Publicly Controlled Park Space, and Tourism Activities Attracted to the Region by Protected Open Space

Open Space Activities	5-County Total	Philadelphia	Bucks	Chester	Delaware	Montgomery
Direct Expenditures	$210.9	$12.9	$31.8	$119.0	$14.4	$32.8
Indirect & Induced Expenditures	$168.8	$11.6	$26.7	$89.1	$12.7	$28.7
Total Expenditures	$379.7	$24.4	$58.5	$208.2	$27.1	$61.5
Total Employment	5,164	291	755	3,033	331	755
Total Earnings	$242.0	$14.2	$31.1	$148.3	$14.0	$34.3
Total Local Taxes	$2.5	$1.7	$0.1	$0.5	$0.0	$0.2
Total State Taxes	$15.4	$0.8	$2.2	$9.2	$1.0	$2.2

Attracted Tourism	5-County Total	Philadelphia	Bucks	Chester	Delaware	Montgomery
Direct Expenditures	$116.2	$66.4	$10.6	$11.0	$9.4	$18.8
Indirect & Induced Expenditures	$70.4	$40.2	$6.4	$6.6	$5.8	$11.4
Total Expenditures	$186.6	$106.6	$17.0	$17.6	$15.2	$30.2
Total Employment	1,746	764	234	192	192	364
Total Earnings	$56.4	$31.6	$5.2000	$5.2000	$4.8	$9.6
Total Local Taxes	$5.8	$4.2	$0.3500	$0.3500	$0.4	$0.6
Total State Taxes	$6.4	$3.6	$0.6000	$0.6000	$0.6	$1.0

Total Economic and Fiscal Impact	5-County Total	Philadelphia	Bucks	Chester	Delaware	Montgomery
Direct Expenditures	$327.1	$79.3	$42.4	$130.0	$23.8	$51.6
Indirect & Induced Expenditures	$239.2	$51.8	$33.1	$95.7	$18.5	$40.1
Total Expenditures	$566.3	$131.0	$75.5	$225.8	$42.3	$91.7
Total Employment	6,910	1,055	989	3,225	523	1,119
Total Earnings	$298.4	$45.8	$36.3	$153.5	$18.8	$43.9
Total Local Taxes	$8.3	$5.9	$0.5	$0.8	$0.4	$0.7
Total State Taxes	$21.8	$4.4	$2.8	$9.8	$1.6	$3.2

Source: Econsult Corporation (2010)

Figure E.13

Distribution of Estimated Total Annual Output and Employment Associated with Protected Open Space in the Philadelphia Region: Privately Controlled Preserved Farmland, Publicly Controlled Park Space, and Tourism Activities Attracted to the Region by Protected Open Space

Rank	Industry	% of Total Output	Rank	Industry	% of Total Employ-ment
1	Other services	16%	1	Arts, entertainment, and recreation	18%
2	Agriculture, forestry, fishing, and hunting	11%	2	Other services	17%
3	Arts, entertainment, and recreation	11%	3	Agriculture, forestry, fishing, and hunting	16%
4	Accommodation and food services	9%	4	Accommodation and food services	12%
5	Real estate and rental and leasing	8%	5	Retail trade	9%
6	Retail trade	7%	6	Transportation and warehousing	7%
7	Manufacturing	6%	7	Health care and social assistance	4%
8	Transportation and warehousing	6%	8	Administrative and waste management services	3%
9	Finance and insurance	5%	9	Professional, scientific, and technical services	3%
10	Professional, scientific, and technical services	4%	10	Finance and insurance	3%
	All other industries	17%		All other industries	8%

Source: Econsult Corporation (2010)