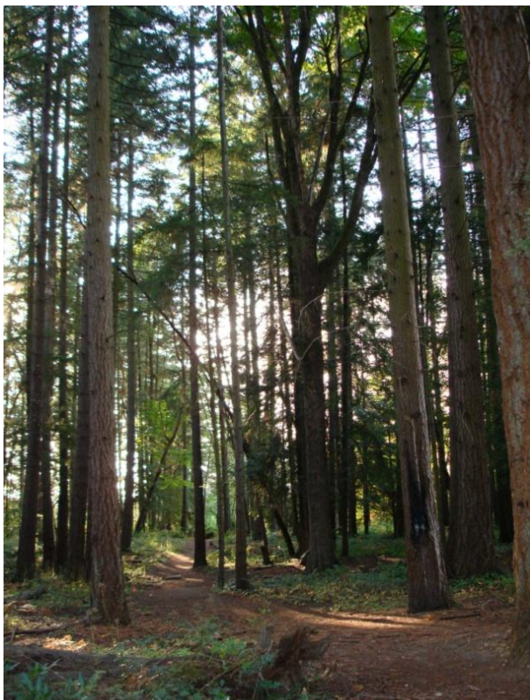
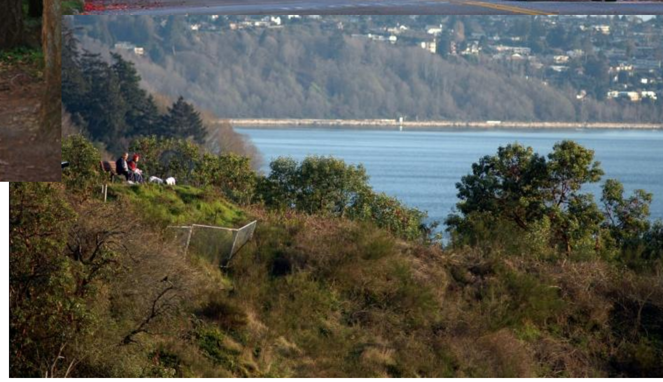
Shoreline, WA
Urban Tree Canopy Assessment
- Completed March 2011 -





Prepared for:
City of Shoreline, Washington

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Introduction

Figure 1: Shoreline City Boundary (Google)

The City of Shoreline envisions itself as a community of families, safe neighborhoods, cultural diversity, active partnerships, quality businesses, natural resources and responsive government. Trees have always been an important element of this community and were identified as a top priority by citizens during the initial City incorporation effort. To better realize this vision, the City Council set a goal in 2007 to "Create an Environmentally Sustainable Community."

In July 2008, City Council adopted the Shoreline Environmental Sustainability Strategy which includes a commitment to:

- Being stewards of our community's natural resources and environmental assets;
- Promoting development of a green infrastructure for the Shoreline community;
- Measurably reducing waste, energy and resource consumption, carbon emissions and the use of toxics in city operations; and
- Providing tools and leadership to empower our community to work towards sustainable goals in their businesses and households.

The overall health and long-term management of our urban tree canopy is an important piece in achieving environmental sustainability as a community. Our trees and other vegetation provide numerous environmental services, including reducing surface water runoff, contributing to carbon sequestration and overall air quality, mitigating urban heat island effect, buffering noise and visual impacts between developments, providing habitat for local wildlife, and are an essential part of the aesthetic of our urban landscape. Alternatives to engineered "grey" infrastructure that include green infrastructure such as trees don't carry the stigma of single function solutions and have greater capacity and cost-benefit ratio.

The City of Shoreline is continuing a multi-pronged approach to the long-term stewardship of our urban forests. The Public Works Department started in 2003 with an inventory and management plan for trees in the City's Right-of-Way. This inventory and management plan has guided the City's stewardship of street trees over the past seven years. Even today, when making decisions about maintenance, removal and planting of trees the City uses the 2003 inventory and management plan to inform these decisions. In 2009 the City's surface water management regulations were updated, including provisions for protecting trees in the low impact development standards. Public Works is currently revisiting the standards and policies for management of trees located on the City's Right-of-Way. The Parks, Recreation and Cultural Services Department is responsible for management of the trees in the City's parks and recently completed detailed inventories and vegetation management plans for four of the City's largest parks – encompassing 184 acres of urban forest.

At the beginning of 2009, the Planning and Development Services Department was tasked with updating the City's tree ordinance in response to recommendations in the City's Sustainability Strategy, comments and concerns from residents, and direction from City Council and the Planning Commission. The City Council specifically directed the Planning Commission and staff to:

> *"Establish a baseline urban forest canopy city-wide. This baseline would provide the context for the Council to make a policy decision … about a long-range City target for desired tree canopy. The target could be no-net loss of a city-wide percentage of canopy, or an increase or decrease of some magnitude, keyed to specific schedules. With such a baseline and target in place, the City could then monitor the overall City canopy, say every 5 years, to assess its health and identify any further programs or code amendments as needed."*

Shoreline City Council's 2010-2011 Goal 1 is to "Implement the adopted Community Vision by updating the Comprehensive Plan and key development regulations in partnership with residents, neighborhoods and businesses." This goal explicitly identifies adopting "updated tree regulations, including citywide goals for urban forest canopy" as a priority task. A baseline measure of Shoreline's tree canopy is essential to accomplishing this directive.

The purpose of this assessment was to provide a sound scientific basis for ongoing regulation and management of the urban tree canopy (UTC) on public and private property using the latest mapping technologies and canopy assessment protocols. The objective was to map the City of Shoreline's UTC and perform an initial, first-order assessment to calculate the value of the urban forest based on the benefits they provide to the community. This information will serve as the benchmark from which to measure the success of planning and urban forestry programs and to educate the public about the many benefits of trees.

Major Findings

In 2011, AMEC Earth & Environmental was contracted to conduct an analysis of the City of Shoreline's existing urban tree canopy and compare the results with analysis of 30-meter resolution national data available for 1992 and 2001. Shoreline has 30.6% tree canopy coverage (based on 2009 imagery). This is a slight increase in canopy from 1992, estimated at 30%, and essentially the same as in 2001, estimated at 31%. Overall Shoreline has 55.7% green cover comprised of grass, shrubs and tree cover. Almost three quarters of Shoreline's tree canopy is located in the low density residential zones, an area that represents approximately two thirds of the total land area in the City.

This study further identified Shoreline's "possible urban tree canopy" using methodology developed by the U.S. Forest Service Northern Research, and commonly used in UTC analysis. Possible UTC, split into Possible Vegetation UTC and Possible Impervious UTC, was defined as the areas where it is biophysically possible to plant trees, meaning all grass and open space vegetation and impervious area after excluding buildings, roads, and water bodies. This measurement takes into account all areas where it is biophysically possible to establish tree canopy, and while covering all of this area with trees may be unrealistic, it is a good tool for assessing what areas have the most availability. Land use should always be taken into account when using these numbers too, as schools and parks will have fields used for recreational purposes that are not suitable for tree planting, yet are included in Possible UTC estimates. The total Possible UTC is 3282 acres potentially available for planting, or 44.3% of area in addition to the 30.6% of existing UTC. This is comprised of 1609 acres (21.7%) of unforested vegetation, and 1673 acres (22.6%) of unforested impervious areas, such as parking lots.

The analysis also quantified some of the environmental and economic benefits of the City's tree canopy using CITYgreen software. Shoreline's 2009 tree canopy provides approximately $460,000 in indirect cost savings due to air quality improvement, 770 tons of annual carbon sequestration (removal of carbon from the atmosphere and storage as new tree growth), $900,000 annual cost savings for stormwater storage capacity that does not have to be built, and reductions of 3% to 10% in regulated stormwater pollutants, when compared to the scenario of no tree cover, in a typical storm.

Shoreline 2009 Land Cover at a Glance

Total City Area: 7,412 acres

Total Tree Canopy: 30.6% (2,270 acres)

Shrub Cover: 3.4% (253 acres)

Grass/Vegetation: 21.7% (1,612 acres)

Water: < 0.1% (24 acres)

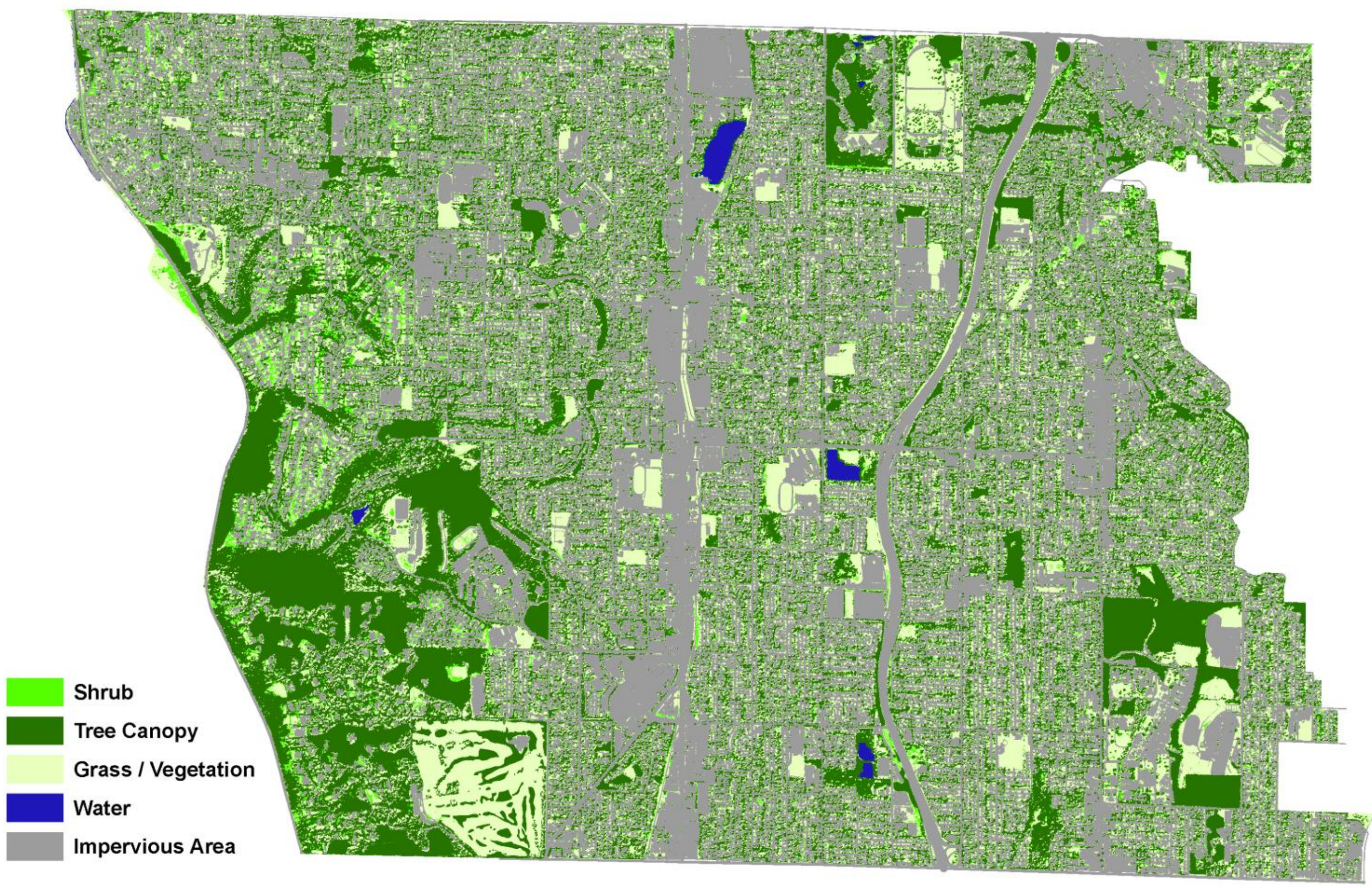
Impervious Area: 46.2% (3,427 acres).
(1.6%, 138 acres, is under tree canopy)

Key Terms:

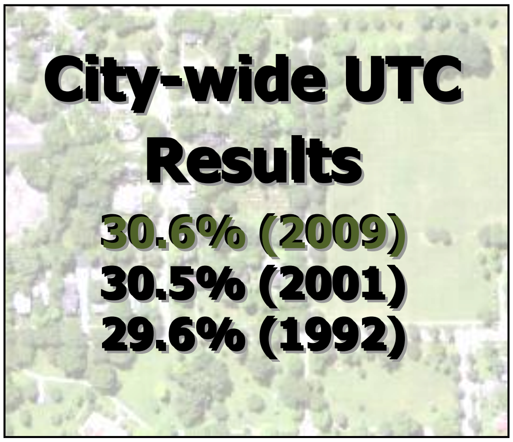
GIS – Geographic Information Systems
AOI – Area of Interest, referring to the study or project area
Urban tree canopy (UTC)* – the layer of leaves, branches, and stems of trees that cover the ground when viewed from above using aerial or satellite imagery
Land Cover* – features on the earth mapped from aerial or satellite imagery, such as trees, grass, water, and impervious surfaces
Possible UTC Vegetation * – grass or shrub area that is theoretically available for the establishment of tree canopy.
Possible UTC Impervious * – for this project this consisted of parking lots where it is theoretically possible to establish tree canopy

*Source: USDA Forest Service and/or University of Vermont Spatial Analysis Laboratory

Figure 2: Shoreline Land Cover Data – 5 class map



Shoreline Land Use and Urban Tree Canopy Trends



The City of Shoreline Urban Tree Canopy (UTC) assessment is based on Geographic Information Systems (GIS) analysis of July 2009 Orthophotography Satellite imagery. Through this process the existing land cover was classified into five categories: Tree Canopy, Shrub, Grass/Dry Vegetation, Impervious, and Open Water. This land cover data analyzed the UTC along with the general land use categories found in Shoreline (see Figure 3) and totals for the City as a whole. The methodology for this analysis is summarized in Appendix A.

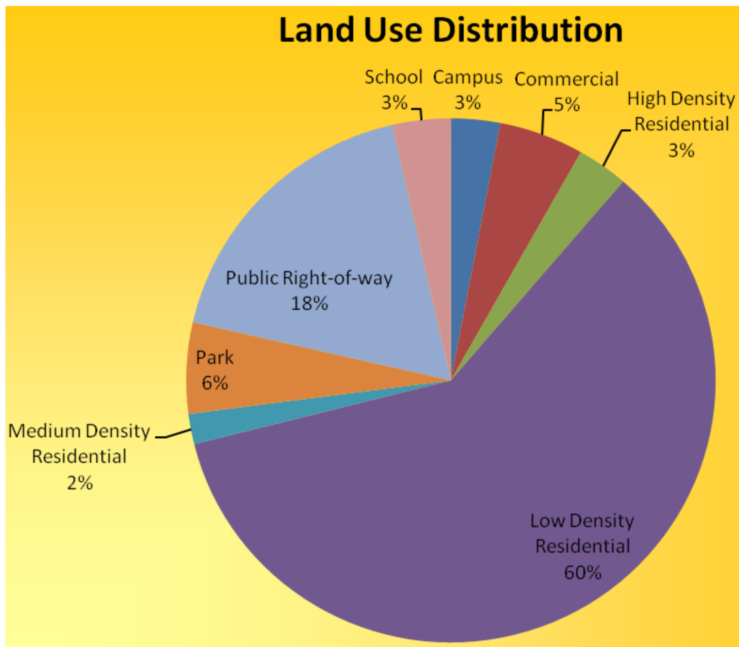
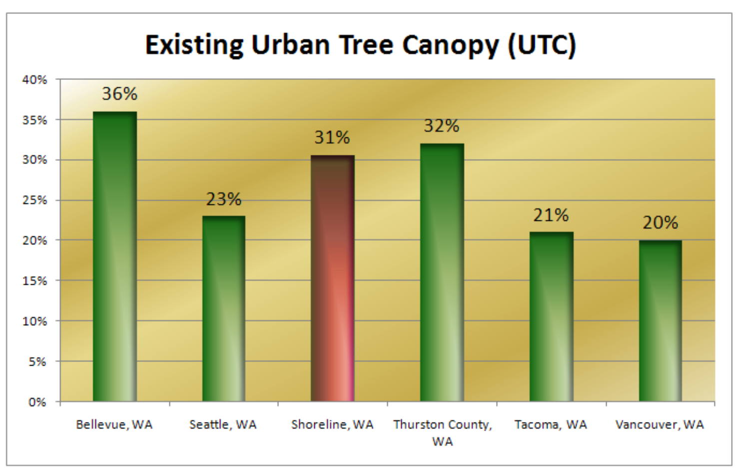


Figure 3. Percent Distribution of Land by General Land Use Types in Shoreline

National Land Cover Data 1992 and 2001, available from the US Department of Agriculture, was used to obtain rough estimates of historic tree cover for the Shoreline area. At 30 meter resolution, this data is more generalized than the land cover data generated for 2009 from the 2-foot resolution, satellite imagery. Despite the coarseness of the data, the total canopy estimates for the Shoreline city limits can be broadly compared to the 2009 results and indicate that there has been no significant change to the percent urban tree canopy since 1992. More detailed information on the U.S. Forest Service's i-Tree Vue software, process and results of the tree canopy for 1992 and 2001 is available in Appendix B. Historic Aerial photo images over the past 65 years are included in Appendix C.

When compared with other municipalities in the Puget Sound region, Shoreline has a reasonable urban tree canopy.

Figure 4. Comparing Shoreline's Existing UTC to that of other Pacific Northwest communities



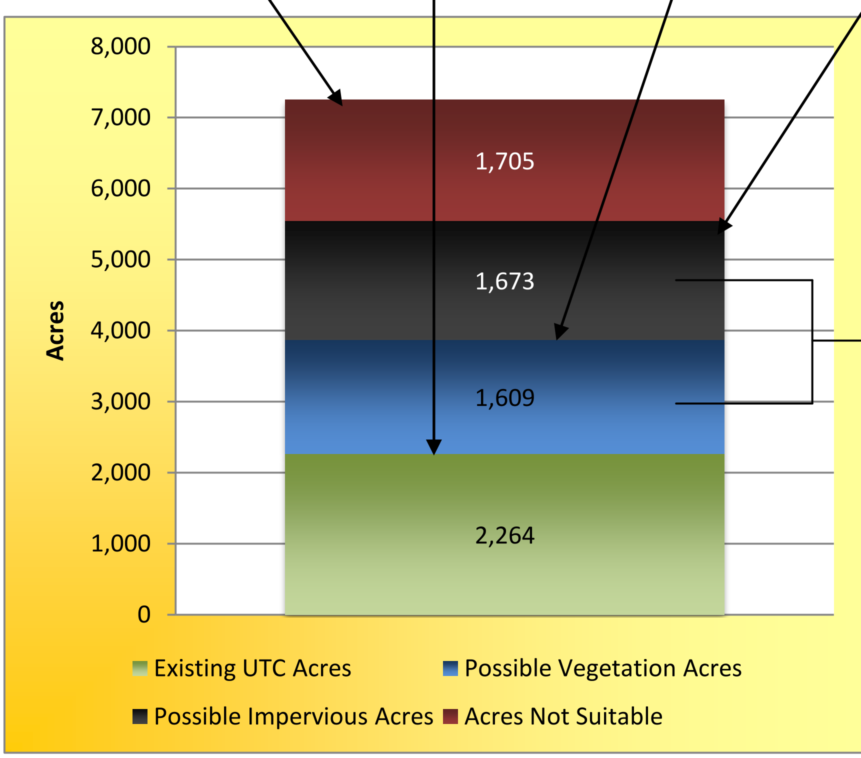
Possible UTC Results

In addition to existing tree canopy, the 2009 land cover analysis roughly estimated how much existing impervious (parking lots) and existing shrub and grass vegetation could possibly be replaced with tree canopy. This estimate of additional Possible UTC at 44.3% is high because it does not take utility corridors, proximity to intersections, property owner preference, park and school areas that are dedicated to recreational fields, or the underlying zoning into consideration. Possible UTC may also be under-valued slightly for the areas where trees can overhang roads and buildings, which make up for some of the realistic error. This number is a cost-effective way to identify areas where increase in UTC could be viable, and can be used to focus outreach to property owners in high Possible UTC areas or to target City education and tree planting programs.

Table 1 below illustrates the acres and percent of Shoreline that were analyzed to be existing tree canopy, unsuitable for tree canopy (roads and buildings) or possible grass, shrub and impervious areas where tree canopy could be established.

Table 1. UTC Metrics for the City of Shoreline

Total Acres	Not Suitable Acres	Not Suitable %	Existing UTC Acres	Existing UTC %	Possible UTC Vegetation Acres	Possible UTC Vegetation %	Possible UTC Impervious Acres	Possible UTC Impervious %	Total Possible UTC Acres	Total Possible UTC %
7,412	1,705	23.0	2,264	30.6	1,609	21.7	1,673	22.6	3,282	44.3



Possible UTC, split into Possible Vegetation UTC and Possible Impervious UTC, was defined as the areas where it is biophysically possible to plant trees, meaning all grass and open space vegetation and impervious area after excluding buildings, roads and water bodies (U.S. Forest Service Northern Research Station).

There are 1,673 + 1,609 (3,282) acres of "Possible UTC Planting Acres".

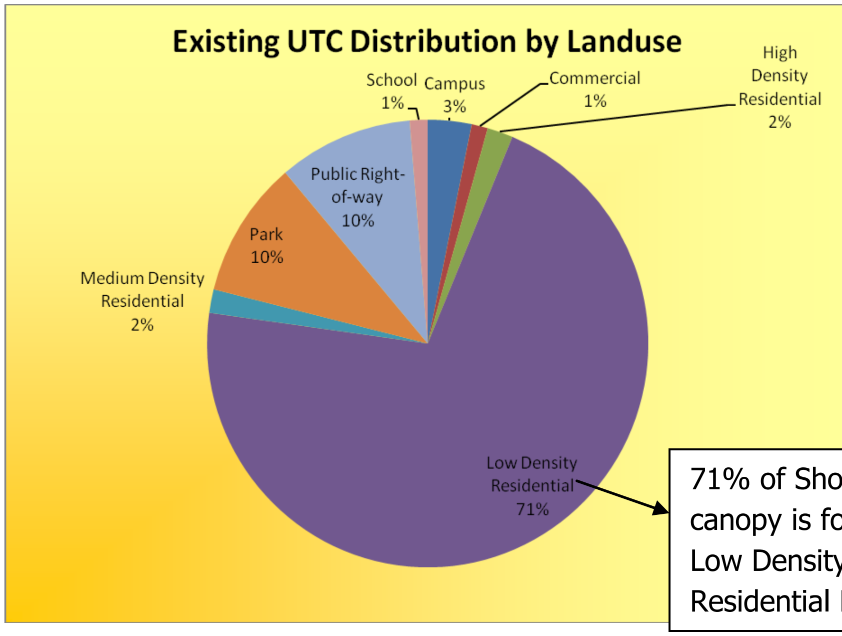
Figure 5. Overall Summary of UTC Assessment

UTC Results by Land Use Category

Almost three quarters of Shoreline's tree canopy is located in the low density residential zones, an area that represents approximately two thirds of the total land area in the City.

Parks and Right-of-Way represent 20% of the tree canopy, with the balance in the remaining land use areas.

Figure 6. Distribution of Existing UTC by General land use Type



71% of Shoreline's canopy is found in Low Density Residential LU

Table 2. Existing and Possible UTC Metrics within Each General Land Use Category

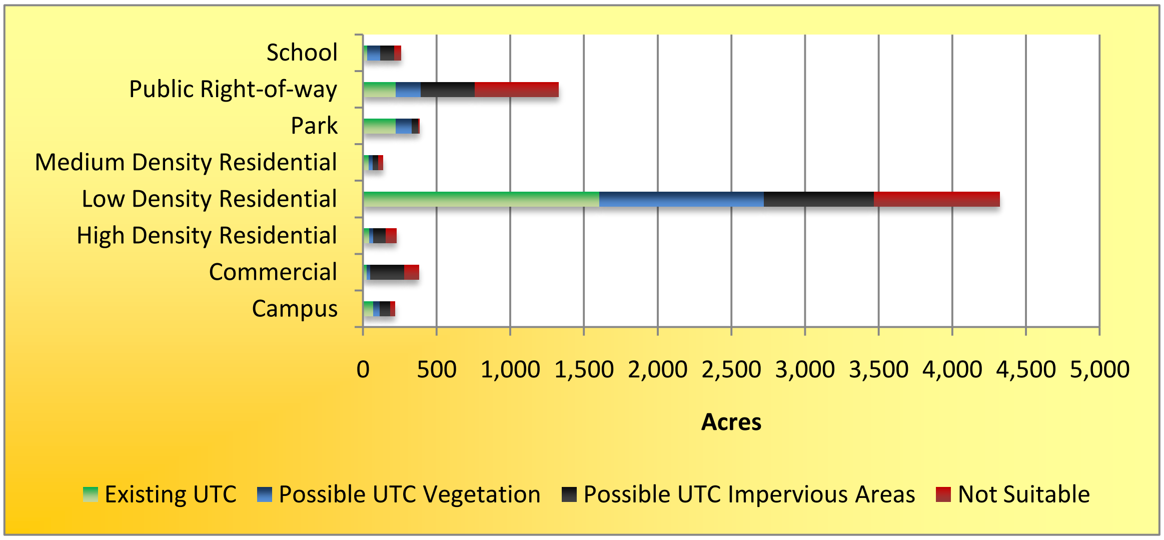
Land Use	Total Acres	Not Suitable	Not Suitable %	Existing UTC	Existing UTC %	Possible UTC Vegetation	Possible UTC Vegetation %	Possible UTC Impervious	Possible UTC Impervious %	Total Possible UTC	Total Possible UTC %
Campus	222	31	13.9	72	32.6	44	19.8	70	31.4	114	51.2
Commercial	382	99	25.9	27	7.0	23	6.0	230	60.2	253	66.2
High Density Residential	231	71	30.8	43	18.5	29	12.7	85	36.9	115	49.7
Low Density Residential	4,431	851	19.2	1,606	36.2	1,117	25.2	746	16.8	1,864	42.1
Medium Density Residential	138	32	23.1	39	27.9	30	21.9	36	26.0	66	47.9
Park	417	7	1.7	225	54.0	106	25.5	45	10.7	151	36.2
Public Right-of-way	1,325	568	42.9	223	16.9	170	12.8	368	27.8	537	40.6
School	263	46	17.5	30	11.3	90	34.1	93	35.3	182	69.4
Total		1,705		2,264		1,609		1,673		3,282	

* 36% of all Low Density Residential Property Area is covered by Trees

* 66% of all Commercial Property Area is indicated as Possible UTC. Commercial zones have parking and access requirements that must be met, however, and are allowed up to 90% hardscape.

Figure 7 below, compares the total acres of existing UTC, Possible UTC and not suitable for UTC by general land use category. While the model estimates that an additional 66.2% of all commercial areas might be available for new tree canopy, the total acres is relatively small. Even if these estimates are double the area that realistically could have tree canopy added, from a total acreage perspective the biggest gains City-wide could be made in the Right-of-Way and in Low Density Residential Zones (R-4 and R-6).

Figure 7. Acres of Existing UTC, Possible Vegetation UTC, Possible Impervious UTC and Not Suitable Metrics by Land Use Type



This study does not look at the overall health, composition or age of the existing urban tree canopy. For example, the recent vegetation study in Hamlin Park indicates that a significant portion of the forested area does not have healthy understory vegetation and little to no new trees that will replace the existing canopy as it dies due to age, disease, or other events.

Ecosystem Services Analysis

Trees, as green infrastructure, provide a wide variety of public benefits, including stormwater volume and quality improvement, air quality improvement, carbon removal from the atmosphere, and more. These benefits are referred to as ecosystem services. Grass and shrubs also provide ecosystem services, but to a lesser extent than trees. The benefits of these vegetative covers were not analyzed in this study. In the absence of trees, a municipality often has to provide similar services to protect the public, through construction of stormwater and water quality infrastructure or through regulation of uses that might generate these problems.

The ecosystem services, or environmental benefits, that trees and forests provide in cities are quantifiable in a variety of ways. Some techniques involve field data collection and statistical modeling to extrapolate environmental and economic benefits of urban tree canopy such as energy savings, air pollution removal and property value increase. In an effort to quantify the value to the City of Shoreline provided by tree canopy, the value of these ecosystem services was estimated using a nationally accepted modeling tool – CITYgreen developed by American Forests. This is just a baseline assessment, and a more detailed assessment is recommended, but outside of the scope of this project.

CITYgreen
calculating the value of nature

Assumptions

In this model, trees are 'removed' to show the impact on air quality, lost carbon storage and sequestration benefits, additional stormwater runoff and the percent change in contaminant loading (water quality). The water quality and quantity components require that a replacement land cover be used to replace trees in the model, as land cover that is more impervious than trees will increase runoff and pollutant loading, often more than a grass or shrub land cover (as assumed here), depending on factors such as soil type and the specific replacement land cover class chosen.

CITYgreen does not take into account species composition, height, or DBH of trees. Instead, the model uses US Forest Service data on trees and applies a per unit area value/benefit for air quality and carbon storage/sequestration, based on the species/size/composition of trees in various reference city. Seattle was used as the reference City for this analysis. The CITYgreen results an estimate based on the best science, but some assumed values. More in-depth analysis can be done, but falls outside the scope of this project.

Results

Shoreline's urban tree canopy contributes multiple environmental benefits to the community, including air and water quality improvement, stormwater quantity reductions, and carbon storage. For more detailed information on the basis for these estimates refer to Appendix D.

Air Pollution Removal

By absorbing and filtering out nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone (O3), carbon monoxide (CO), and particulate matter less than 10 microns (PM10) in their leaves, urban trees perform a vital air cleaning service that directly affects the well-being of urban dwellers. The current UTC improves air quality for the residents of Shoreline by approximately 203,000 lbs of these pollutants per year, valued at $457,000 in indirect cost savings such as avoided health care expenditures.

Figure 8. Pounds of air pollutants removed by tree canopy annually and estimated cost savings.

	Lbs. Removed/yr	Dollar Value
Carbon Monoxide:	12,202	$5,208
Ozone:	67,113	$206,186
Nitrogen Dioxide:	30,506	$93,721
Particulate Matter:	63,046	$129,318
Sulfur Dioxide:	30,506	$22,894
Totals:	**203,373**	**$457,326**

Carbon Storage and Sequestration

Trees remove carbon dioxide from the air through their leaves and store carbon in their biomass. Approximately half of a tree's dry weight is carbon. For this reason, large-scale tree planting projects are recognized as a legitimate tool in many national carbon-reduction programs. CITYgreen estimates the carbon storage capacity and carbon sequestration rates of trees in Shoreline to be:

Total Tons Stored: 98,175.44
Total Tons Sequestered (Annually): 764.32

This estimate does not directly account for tree removal, but is based on the estimated tree canopy.

Stormwater

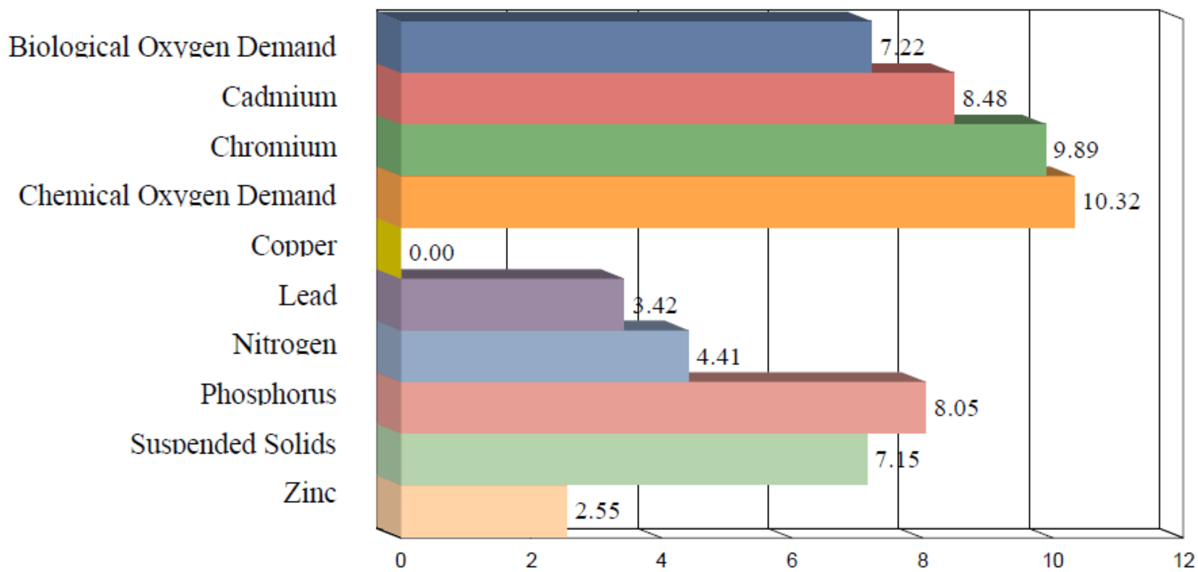
Shoreline's tree canopy slows stormwater and decreases the amount of stormwater storage needed by approximately 3.4 million cubic feet during a 2-year, 24-hour storm event. Based on a construction cost of $3/cubic foot this is valued at $10.3 million, or $900,000 annually over 20 yrs at 6%. Actual stormwater infrastructure construction costs for the City of Shoreline were not available at the time of this analysis so this amount is based on similar studies for cities in the Puget Sound region.

Water Quality

Cities must comply with Federal clean water regulations and Shoreline has developed a plan and adopted new regulations in 2009 to improve the quality of their streams and rivers. One way new development in Shoreline can meet these new standards is through the preservation of existing trees on site.

Trees filter surface water and prevent erosion, both of which maintain or improve water quality. The CITYgreen model estimates the change in the concentration of the pollutants in runoff during a typical storm event given the change in the land cover – in this case the difference between existing landcover with or without the existing tree canopy. Shoreline's existing 30.6% tree canopy is estimated to reduce pollutants and water quality indicators such as cadmium, chromium, lead, nitrogen and phosphorus and chemical and biological oxygen demand by 3 to 10% in a typical 2 inch, 24-hour storm event.

Figure 9. Percent reduction in Contaminant Loading with existing UTC vs. no tree canopy.



Setting Urban Tree Canopy Goals

American Forests recommends an overall goal of 40% canopy in Pacific Northwest communities. This metric is based on assessing and comparing land use, environmental quality goals, and existing canopy, where suburban areas are expected to have a 50% canopy and more urban areas near 25%. With 31%, Shoreline is in a good position to start to work towards that goal. The first 1% percent increase would take approximately 6,000 trees with a mature crown diameter of 30 feet and would be a very realistic goal to start with. This increase alone would provide a stormwater benefit increase of almost $500,000 (from CITYgreen), and sequester an extra 35 tons of carbon every year.

Reaching the long-term goal of 40% would mean maintaining the existing tree canopy and adding approximately 46,000 trees to the canopy at an average 30-foot crown diameter. While a 40% canopy is biophysically an attainable goal, it may be more realistic for budgetary and management reasons to set a more conservative goal of 35% unless significant support is realized. Along with planting of street trees and increasing the vegetation in public parks and schools, the City should consider an outreach program to educate the public on increasing the canopy on their property, as much of the potential canopy lies within private land. Cooperating with commercial and residential land owners will be crucial in maintaining and achieving canopy goals. Low density residential, parks, and public right-of-way also represent the biggest opportunities for maintaining and augmenting the existing tree canopy. It may benefit the city to perform a survey among its constituents on the desire to increase tree canopy on their property. 30.6% tree canopy cover may sound like a lot, but once it is realized how many possible planting spots exist around the City, more support can be garnered in the form of volunteers and backing from citizen organizations.

It is recommended a tree canopy study be performed every 5 years. This allows for a proper assessment of urban tree canopy improvement programs, development pressure over time, and how close the City is to its UTC goal. If possible, similar photographic data and analysis processes should be used, for the best comparison to the data generated in this project.

Conclusion

With 31% existing UTC, Shoreline has average or slightly above-average tree canopy cover compared with other similar-sized communities in the Puget Sound Region. This canopy provides social, environmental, and economic benefits, some of which have been assessed for the first time through this project.

Shoreline is dedicated through its Forevergreen sustainability program to ecological health and to setting a canopy goal for increasing canopy to a realistic level over a reasonable time frame. The data from this assessment and subsequent analysis will help meet the mission of this program. Using the tools and data provided, the City can communicate to the public the value of trees along with where, how and why to improve planting and maintenance programs. These results and data products should be used by the City of Shoreline and other stakeholders involved in green infrastructure development as a starting point for more detailed environmental studies, comprehensive planning, GIS analyses and targeted urban forestry implementation/outreach programs. Setting up an incentive program and providing the public with information and instruction on how to best site and plant their trees will not only help reach Shoreline's canopy goal, but also get the City's constituency directly invested in this program to improve Shoreline as a sustainable and green community.

About AMEC Earth & Environmental, Inc.

AMEC Earth & Environmental (AMEC) is a leading full-service environmental engineering and construction/remediation services firm in North America, providing environmental and geotechnical engineering and scientific consulting services. AMEC is a focused supplier of high-value consultancy, engineering, and project management services to the world's energy, power and process industries. We are one of the world's leading environmental and engineering consulting organizations. Our full service capabilities cover a wide range of disciplines, including environmental engineering and science, geotechnical engineering, water resources, materials testing and engineering, surveying, information management (GIS, remote sensing, database/application development) and program/project management.

Funding assistance provided by the USDA Forest Service and the Washington State Department of Natural Resources Urban and Community Forestry Programs.

APPENDIX A. 2009 Urban Tree Canopy Methodology

Summary

GIS and remote sensing technologies offer powerful analysis and decision support tools for managing urban natural resources. All UTC projects have at least 5 main elements in common regarding data inputs and outputs. These are: high-resolution imagery, supporting GIS layers from the community, land cover data, geographic boundaries in which to summarize tree canopy acres and percent cover, and reporting of the results through tables, graphs and maps. Urban Tree Canopy and Possible UTC are assessed at the larger-scale land use level and at the individual parcel level. The accuracy of this data is extremely high, and the delivered data can be manipulated using GIS programs by the community.

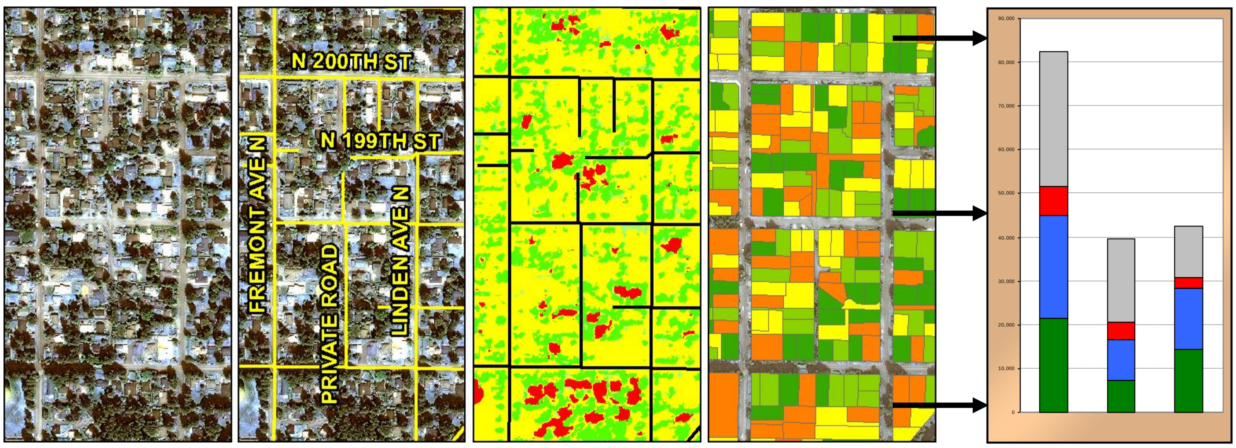
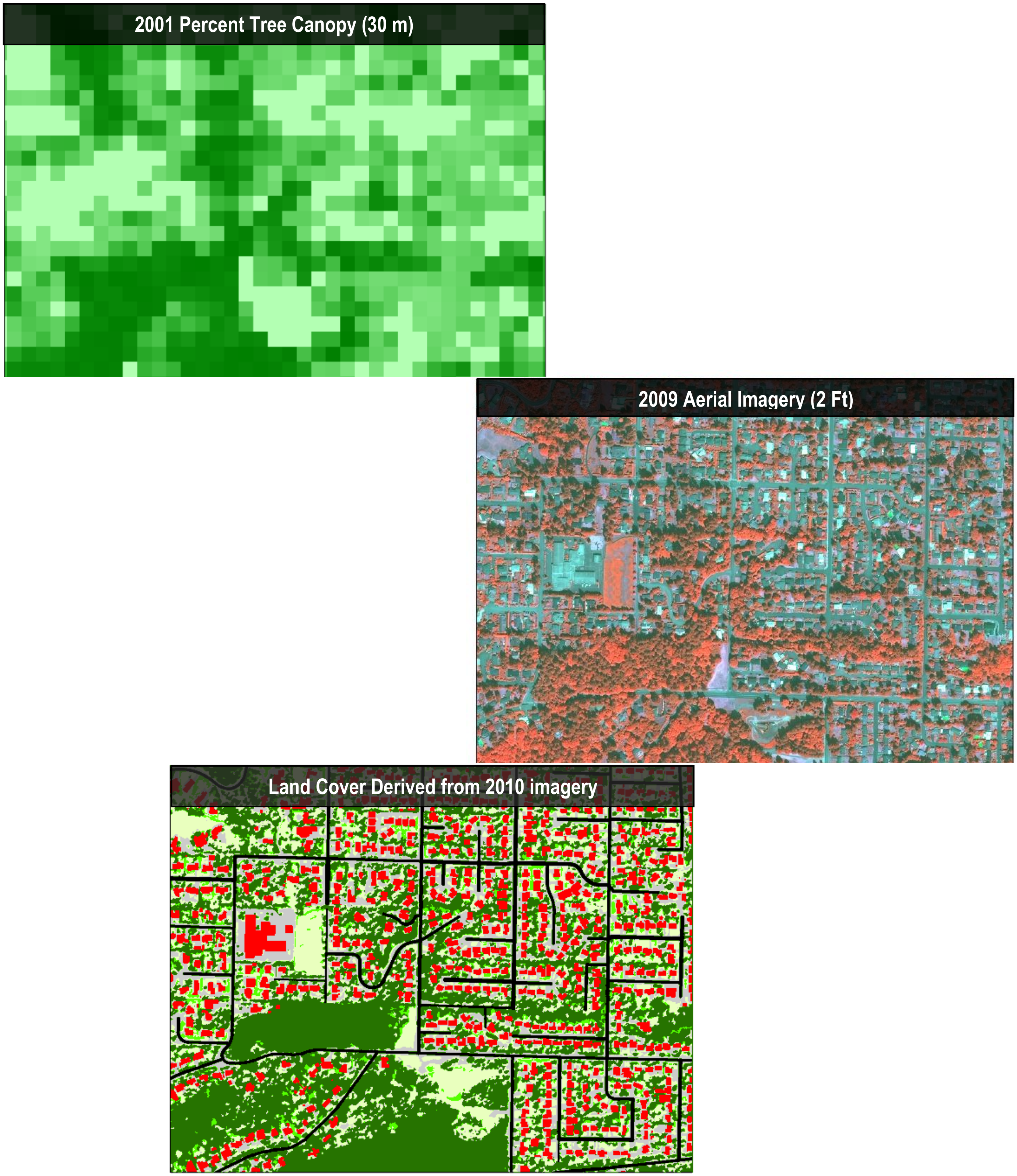


Figure 10. UTC Analysis Process

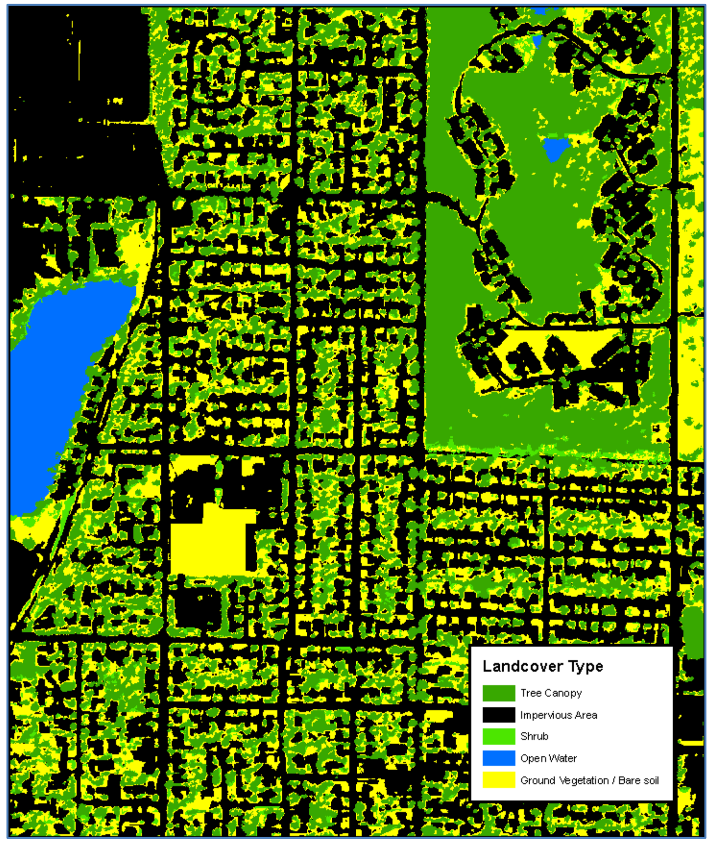
For this project, the City of Shoreline provided AMEC with the following GIS layers: city boundary, parcels, land use, parks, watersheds, hydrology (lakes and streams) and impervious surfaces (buildings, streets). Imagery was acquired by the city through eMap International, and this 2-foot, 4-band multispectral image was used for classification of trees and other land cover.

AMEC analyzed the multispectral imagery using a technique known as geographic object-based image analysis (GEOBIA) and developed a 5-class land cover dataset that included tree canopy, shrubs/vegetation, grass/ground cover, water and impervious surfaces. The GEOBIA approach provided a highly automated and cost-effective method for feature extraction by using algorithms that leverage spectral, spatial, textural, and contextual features in imagery, as well as incorporation of datasets provided by the City. The classification was refined with a manual quality assurance / quality control (QA/QC) process to finalize the land cover. Prior to this study, 2001 Land cover data was the only data available for assessing canopy cover. The images below illustrate how the increased resolution of imagery allows for a much more accurate land cover map. Figures 3-6 show more detailed examples of the results from this process.

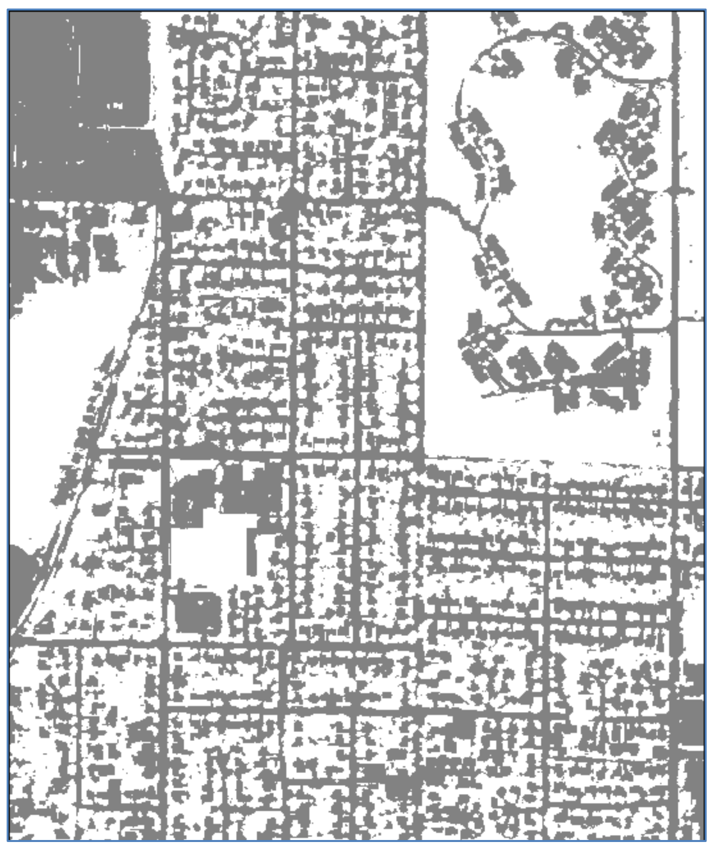
Figure 11. Comparison of 2001 data resolution and 2009 assessment data resolution. This increase in resolution allows for extremely accurate analysis of the tree cover, where the 2001 data can merely approximate the canopy cover



Figures 12 and 13. Color infrared aerial imagery and 5-class land cover data.

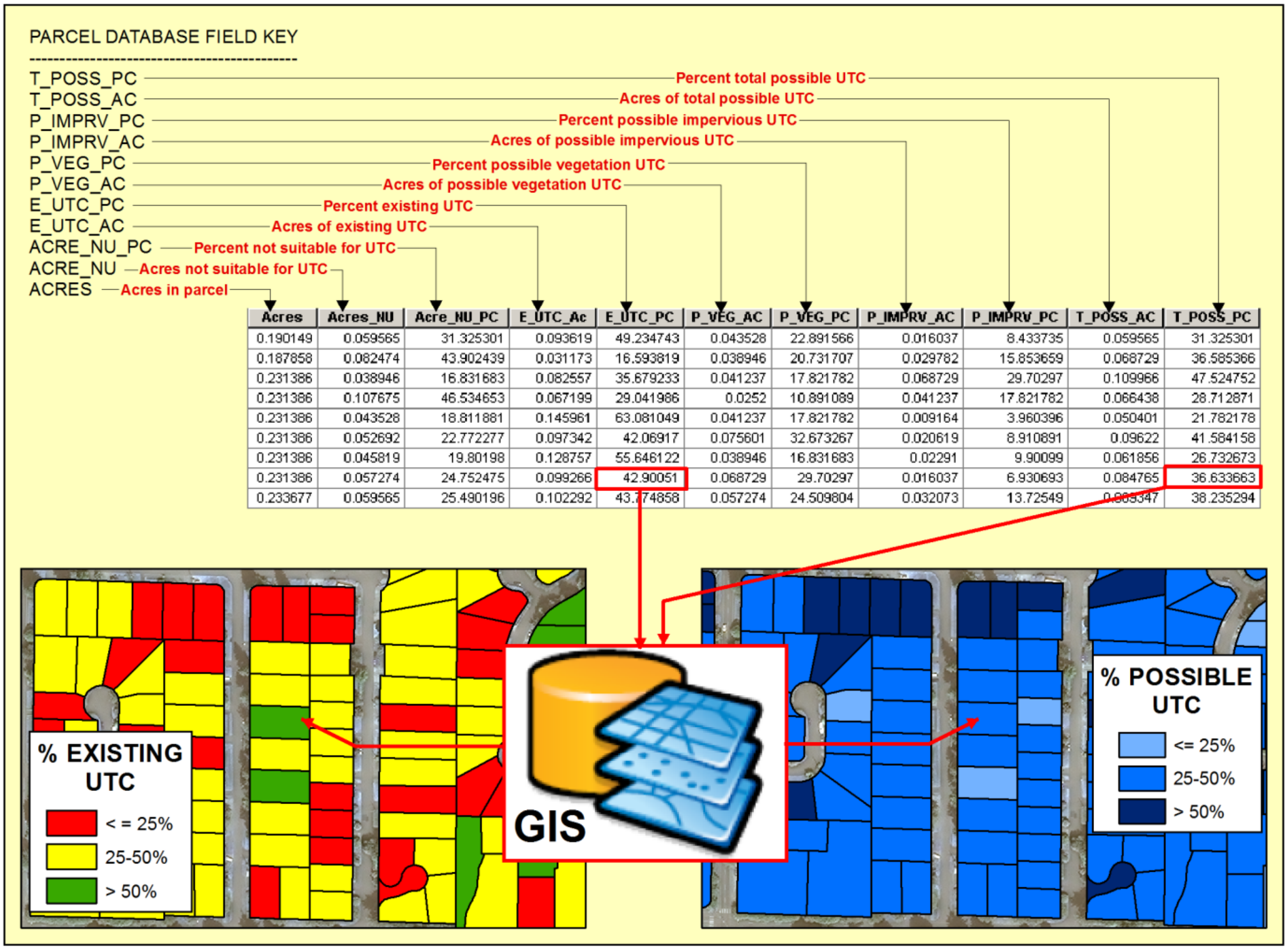


Figures 14 and 15. Trees and Impervious land cover data.



Analysis of UTC Metrics

Figure 7. Structure and Symbolizing of Existing and Possible UTC Metrics by Parcel and an Accompanying Screenshot of the Parcels UTC Attribute Table



Acres	Acres_NU	Acre_NU_PC	E_UTC_Ac	E_UTC_PC	P_VEG_AC	P_VEG_PC	P_IMPRV_AC	P_IMPRV_PC	T_POSS_AC	T_POSS_PC
0.190149	0.059565	31.325301	0.093619	49.234743	0.043528	22.891566	0.016037	8.433735	0.059565	31.325301
0.187858	0.082474	43.902439	0.031173	16.593819	0.038946	20.731707	0.029782	15.853659	0.068729	36.585366
0.231386	0.038946	16.831683	0.082557	35.679233	0.041237	17.821782	0.068729	29.70297	0.109966	47.524752
0.231386	0.107675	46.534653	0.067199	29.041986	0.0252	10.891089	0.041237	17.821782	0.066438	28.712871
0.231386	0.043528	18.811881	0.145961	63.081049	0.041237	17.821782	0.009164	3.960396	0.050401	21.782178
0.231386	0.052692	22.772277	0.097342	42.06917	0.075601	32.673267	0.020619	8.910891	0.09622	41.584158
0.231386	0.045819	19.80198	0.128757	55.646122	0.038946	16.831683	0.02291	9.90099	0.061856	26.732673
0.231386	0.057274	24.752475	0.099266	42.90051	0.068729	29.70297	0.016037	6.930693	0.084765	36.633663
0.233677	0.059565	25.490196	0.102292	[illegible]	0.057274	24.509804	0.032073	13.72549	[illegible]	38.235294

Alongside Analysis performed on the land use level, individual parcels were also analyzed for percentage tree canopy and possible planting area. This will allow the planning department to better assess where to focus outreach and target individual parcels for potential tree planting to increase the homogeneity of the canopy.

Existing and Possible UTC Assessment Process

Using the land cover classes described in the previous step, AMEC developed a series of geoprocessing models to calculate the area and percent of Existing and Possible UTC in both GIS and Excel format (see Figure 4 below). Existing UTC was defined as all area covered by trees and forest. Portions of this model were developed by the US Forest Service Northern Research Station and the University of Vermont Spatial Analysis Laboratory.

UTC GIS modeling workflow:

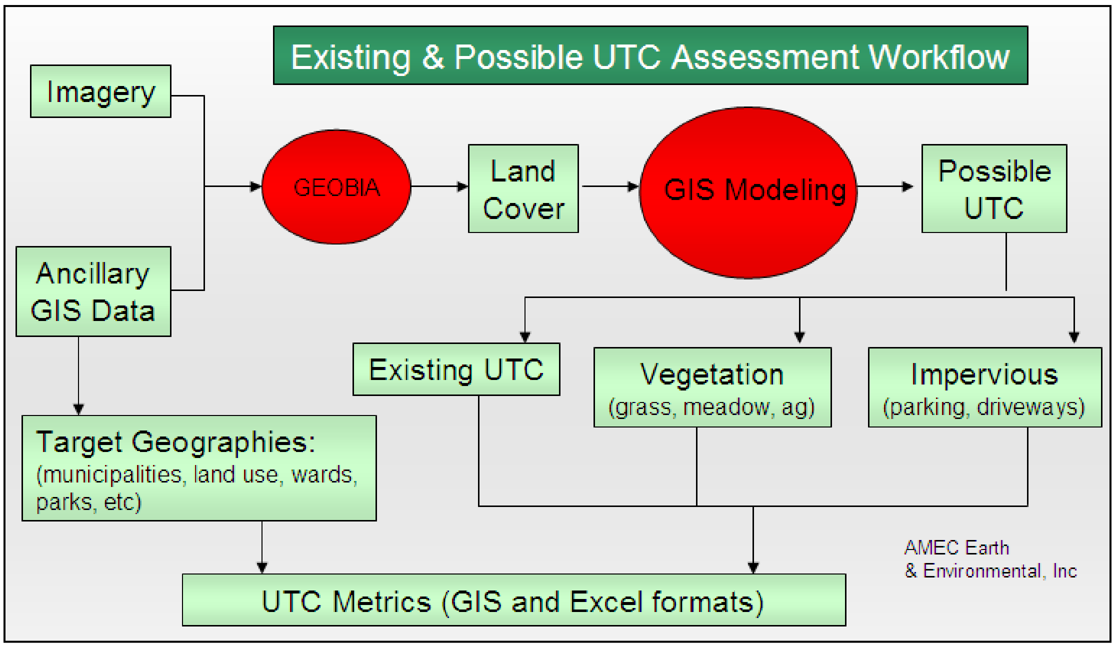


Figure 8. UTC GIS modeling workflow

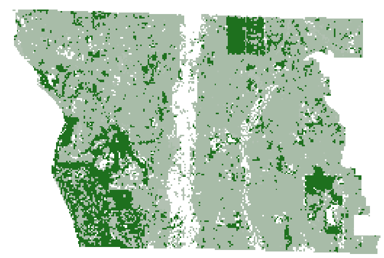
APPENDIX B. 1992 and 2001 i-Tree Vue Urban Tree Canopy

The City of Shoreline was interested in comparing the current tree canopy to historical canopy percentages. Because of the limitations of historical data, a landcover assessment as detailed as the 2009 assessment is unfeasible, however, using derived land cover data, a fairly good canopy cover estimate can be obtained, along with rough estimates on the historical benefit of tree canopy on pollution and runoff mitigation.

i-Tree Vue Analysis: Comparing current tree canopy to historical cover

i-Tree Vue allows a user to obtain rough estimates of canopy and impervious land cover based on coarse 30 Meter resolution land use data provided by the U.S. Department of Agriculture. Along with percent cover, an estimate of the annual benefits and current value of the urban forest can also be assessed. For Shoreline, data from 1992 and 2001 were analyzed using this program.

Figure 18. 1992 Canopy Cover



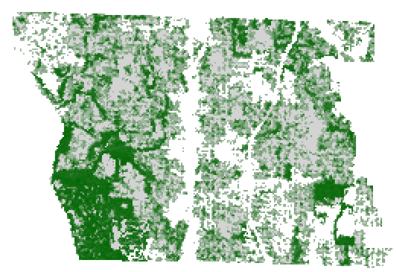
1992 iTree Vue analysis

	Area (acres)	Percentage of total area
Total Area	7412	
Impervious Cover	2701	36.60%
Existing Tree Canopy	2187	29.60%
Available Planting Space	2207	29.90%

	Weight (short tons)	Benefit per ton	Total Benefit
Carbon Storage	88010	$20.68	$1,820,047
Carbon Sequestration	2901	$20.68	$59,993
CO Pollution Removal	4.2	$1,276.41	$5,361
NO2 Pollution Removal	12.3	$8,986.57	$110,535
O3 Pollution Removal	33	$8,986.57	$296,557
SO2 Pollution Removal	10.5	$2,199.92	$23,099
Particulate Matter Removal	19.4	$6,000.12	$116,490

Overall Benefit:	$2,432,081
Annual Pollution Removal Benefit:	$612,034.38

Figure 19. 2001 Canopy Cover



2001 iTree Vue analysis

	Area (acres)	Percentage of total area
Total Area	7412	
Impervious Cover	2881	38.87%
Existing Tree Canopy	2261	30.50%
Available Planting Space	2308	31.14%

	Weight (short tons)	Benefit per ton	Total Benefit
Carbon Storage	91776	$20.68	$1,897,928
Carbon Sequestration	3026	$20.68	$62,578
CO Pollution Removal	4.4	$1,276.41	$5,616
NO2 Pollution Removal	12.8	$8,986.57	$115,028
O3 Pollution Removal	34.4	$8,986.57	$309,138
SO2 Pollution Removal	10.9	$2,199.92	$23,979
Particulate Matter Removal	20.2	$6,000.12	$121,202

Overall Benefit:	$2,535,469
Annual Pollution Removal Benefit:	$637,541.54

While development seems to have been strong in the period between 1992 and 2001, along with the current tree canopy of 30.6% the tree canopy seems to have stabilized around 30%. These values are approximates, however, and comparisons between the 2009 data and future canopy assessments will provide a more accurate picture of the trend in canopy growth in Shoreline. This data is generalized, and can therefore not be compared to the more detailed CITYgreen data.

APPENDIX C. Historic aerial photos illustrating visual change in tree canopy since 1944

The following aerial photo images illustrate the change in Shoreline's tree canopy over the past 65 years.

Figure 20. City of Shoreline area 1944 aerial photo.

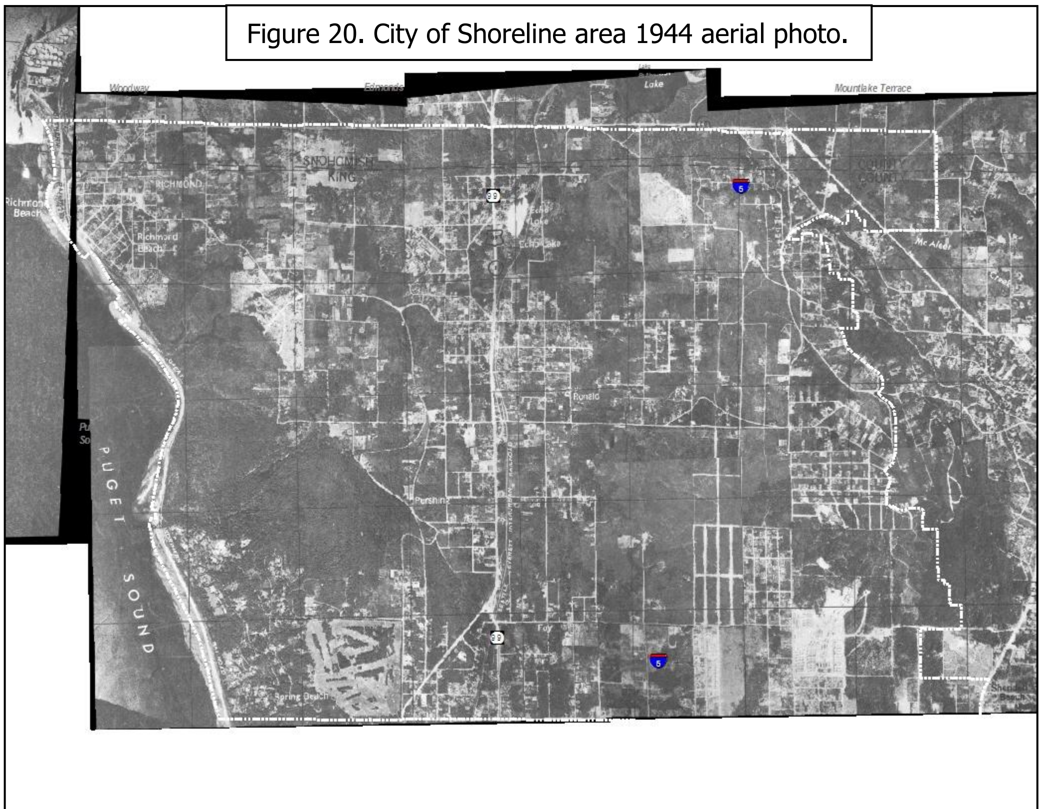


Figure 21. City of Shoreline area 1970 aerial photo.

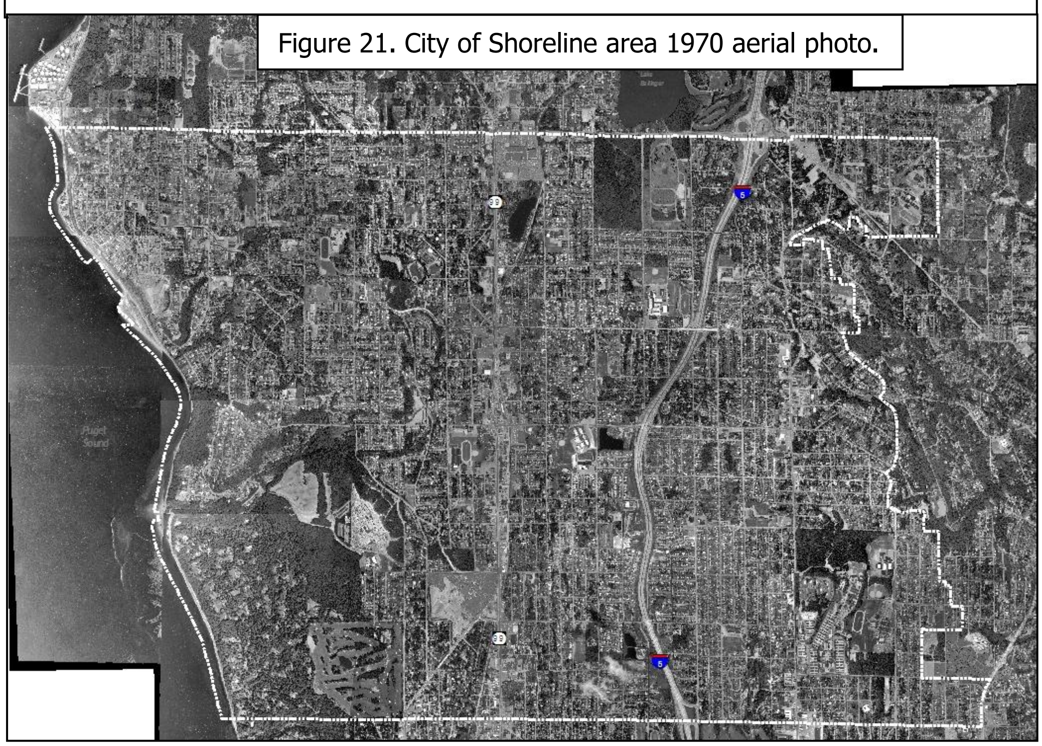
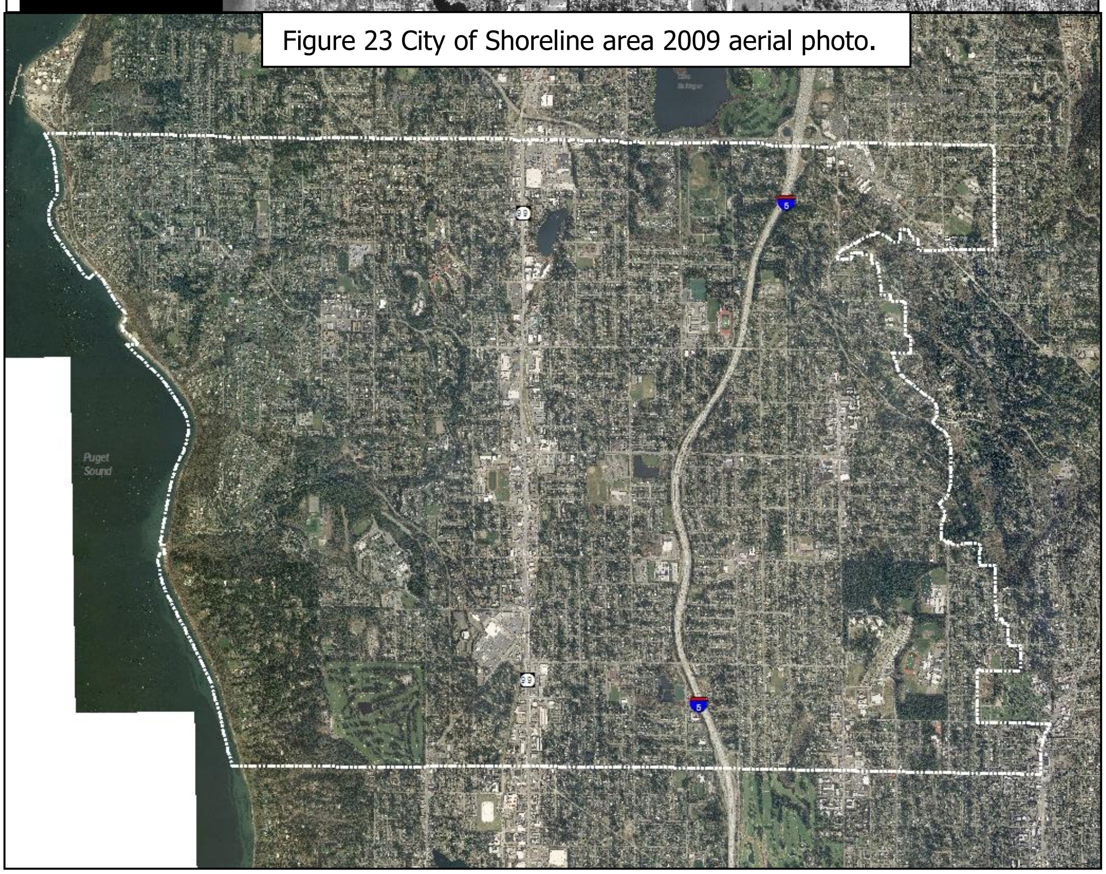


Figure 22. City of Shoreline area 1993 aerial photo.

Figure 23 City of Shoreline area 2009 aerial photo.



Appendix D. Ecosystem Services Analysis Methodology

CITYgreen is a software package developed by American Forests that analyzes and calculates the ecological and economic benefits provided by trees and other green space using GIS-based land cover data and environmental models. It estimates the air pollution removal capacity, carbon storage and sequestration, storm water runoff benefit and water quality impact of urban forests without the need for field data collection. CITYgreen allows one to use a local reference city for air pollution and carbon storage values with data originating from USDA Forest Service research that has been applied to represent the average benefit per unit area of tree canopy. For storm water and water quality modeling, CITYgreen applies the TR-55 model from the USDA Natural Resources Conservation Service (NRCS) and the long-term hydrologic impact analysis (L-THIA) spreadsheet from the U.S. EPA and Purdue University. The Curve Number (CN) method as implemented in TR-55 and other programs was created based on plotting curves of rainfall versus runoff for large storms in agricultural watersheds. It is extremely inaccurate for small storms, which make up the bulk of yearly rainfall. It is meant to be used to determine the runoff from a single storm, and assumes a soil wetness to start.

Air Pollution Removal

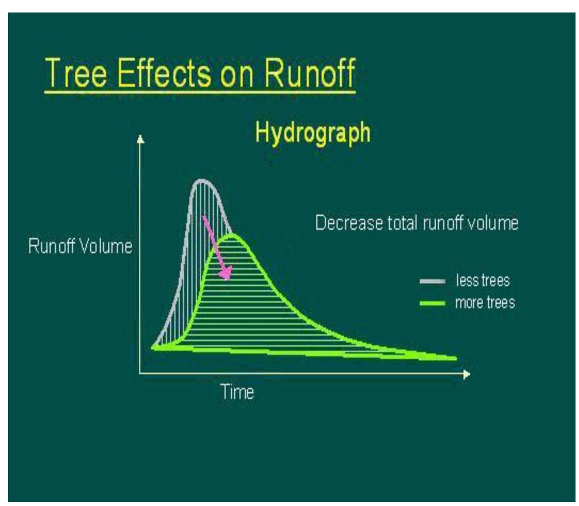
CITYgreen estimates the annual air pollution removal rate of trees within a defined study area for the pollutants listed below. To calculate the dollar value of these pollutants, economists use "externality" costs, or indirect costs borne by society such as rising health care expenditures and reduced tourism revenue. The actual externality costs used in CITYgreen of each air pollutant is set by each state's Public Services Commission. The values and estimated cost savings are based on data included in the model for the City of Seattle.

Carbon Storage and Sequestration

Trees remove carbon dioxide from the air through their leaves and store carbon in their biomass. Approximately half of a tree's dry weight, in fact, is carbon. For this reason, large-scale tree planting projects are recognized as a legitimate tool in many national carbon-reduction programs. CITYgreen estimates the carbon storage capacity and carbon sequestration rates of trees within a defined study area.

Stormwater

Trees decrease total stormwater volume helping cities to manage their stormwater and decrease detention costs. CITYgreen assesses how land cover, soil type, and precipitation affect stormwater runoff volume. It calculates the volume of runoff in a 2-year 24-hour storm event that would need to be contained by stormwater facilities if the trees were removed. This volume multiplied by local construction costs calculate the



dollars saved by the tree canopy. CITYgreen uses the TR-55 model developed by the Natural Resource Conservation Service (NRCS) which is very effective in evaluating the effects of land cover/land use changes and conservation practices on stormwater runoff. The TR-55 calculations are based on curve number which is an index developed by the NRCS, to represent the potential for storm water runoff within a drainage area. Curve numbers range from 30 to 100. The higher the curve number the more runoff will occur. CITYgreen determines a curve number for the existing landcover conditions and generates a curve number for the conditions if the trees are removed and replaced with the user-defined replacement land cover specified in the CITYgreen Preferences. The change in curve number reflects the increase in the volume of storm water runoff. The analysis run here used conservative values to assess the urban tree canopy's overall benefit. The construction cost of $3/cu. ft. is an estimate, and has been reported to be up to $11/cu. ft. in the Puget Sound region.

Figure 1. Shoreline's tree canopy benefits to stormwater quantity.

Water Quantity (Runoff)		
2-yr, 24-hr Rainfall:		
Curve Number reflecting existing		84
Curve Number using default replacement		86
Additional stormwater storage volume needed:	3,431,121 cu. ft.	
Construction cost per cu. ft.:	$3.00	
Total Stormwater	**$10,293,364**	
Annual costs based on payments over 20 years at 6% Interest:	**$897,422**	**per year**

Water Quality

Cities must comply with Federal clean water regulations and develop plans to improve the quality of their streams and rivers. Trees filter surface water and prevent erosion, both of which maintain or improve water quality. Using values from the US Environmental Protection Agency (EPA) and Purdue University's L-thia spreadsheet water quality model, American Forests developed the CITYgreen water quality model. This model estimates the change in the concentration of the pollutants in runoff during a typical 2 inch, 24-hour storm event, given the change in the land cover. This model estimates the Event Mean Concentrations of Nitrogen, Phosphorus, Suspended Solids, Zinc, Lead, Copper, Cadmium, Chromium, Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD). Pollutant values are shown as a percentage of change.