Urban Tree Canopy Assessment Report

July 2011

Prepared by
AMEC Environment & Infrastructure

RENTON. AHEAD OF THE CURVE.

City of Renton

Acknowledgements

Mayor
Denis Law

Councilmembers

Terri Briere, Council President
King Parker, Council President Pro-Tem
Randy Corman
Marcie Palmer
Don Persson
Greg Taylor
Rich Zwicker

Chief Administrative Officer

Jay Covington

Parks Commission

Larry Reymann (Chair)
Al Dieckman (Vice Chair)
Cynthia Burns
Mike O'Donin
Tim Searing
Troy Wigestrand
Marlene Winter

The USDA is an equal opportunity provider and employer." Funding assistance for this assessment was provided by the USDA Forest Service and the Washington State Department of Natural Resources Urban and Community Forestry Programs.

Administrative and Judicial Services

Marty Wine, Assistant Chief Administrative Officer
Preeti Shridhar, Communication Director
Bonnie Walton, City Clerk

City Attorney

Larry Warren

Community & Economic Development

Alex Pietsch, Administrator
Chip Vincent, Planning Director
Robert MacOnie, Jr, Mapping Coordinator
Adriana Abramovich, Planning Technician

Community Services

Terry Higashiyama, Administrator
Leslie Betlach, Parks Planning and Natural Resources Director
Kelly Beymer, Parks and Golf Course Director
Terry Flatley, Urban Forestry and Natural Resources Manager

Finance & Information Services

Iwen Wang, Administrator
Mehdi Sadri, IT Director
Tim Moore, GIS Coordinator
Donna Visneski, Engineering Specialist

Public Works
Gregg Zimmerman, Administrator
Ronald Straka, Utility Engineering Supevisor
Steven Lee, Civil Engineer

AMEC Environment & Infrastructure, Inc.
Ian Hanou, Project Manager
Jennifer Leach, Forester/Ecologist/Multi Media
Dan Gwartney, Remote Sensing Analyst
Michael Flynn, GIS Specialist
Kim Soulliere, GIS Technician

Cover Photo Credit: Denis Law, Sugar maples in Coulon Park

City of Renton

2011 Urban Tree Canopy Assessment Report

Table of Contents

2011 Urban Tree Canopy Assessment Report

Vision

Renton's urban and community forest is healthy, diverse, and sustainable, contributing to Renton's identity in the region.

Mission

Renton will create a sustainable and exemplary urban forest, enhancing the livability of the community through education, coordination, stewardship, and conservation.

Burnett Linear Park

Executive Summary

Renton's Urban and Community Forestry Development Plan was completed in 2009 and included numerous goals, objectives and strategies along with an action timeline (for further information please see the following link: http://rentonwa.gov/living/default.aspx?id=16702). Objective 2.2 of the Plan identified the need for an inventory of the existing urban forest to establish canopy goals and management needs. Part A of this objective specifically dealt with mapping the City's tree canopy to quantify the environmental benefits and to measure change over time. This tree canopy study is Renton's next step to assess existing tree cover, gains and losses in canopy, and the value of the urban forest on public and private property.

This study provides new data and management objectives on the best places to increase canopy cover, protect remaining natural stands of forest, and the value of doing so. The results will be used to improve land use planning policies related to new development and further urban forestry programs that positively affect the public.

A Unique Assessment

This project was unique from other tree canopy mapping studies in many ways. This study:

- Assessed existing and past canopy cover at different scales
- Identified and prioritized potential tree planting sites using multiple parameters and GIS data layers
- Identified forest preservation areas at the parcel-level
- Provided results in several formats for technical and non-technical audiences including Google Earth and interactive PDFs

Renton's Existing Urban Tree Canopy (UTC)

Renton's urban tree canopy was mapped using 2010 1.5-foot resolution satellite imagery; in 2010 there were 4,804 acres (28.6%) of tree canopy. This is less than Bellevue (36%), Kirkland (40%) and Shoreline (31%) but more than Seattle (23%). This section of the report shows canopy cover results within six zoning categories including the public right-of-way (streets), by public and private properties, and for each of Renton's ten community planning areas.

Urban Tree Canopy Gains, Losses and Forests at Risk

Renton had a net loss of 52 acres of tree canopy between 2002 and 2010. The loss would have been higher if not for the growth of existing trees and new tree planting. This report provides a detailed overview of gains and losses in tree canopy from 2002-2010 by zoning categories, Community Planning Areas (CPAs) and individual properties (parcels). Results demonstrated that up to 1,300 acres of Renton's natural forest stands (27% of the urban forest) may be at risk from development.

28.6
Percent of Renton covered by Tree Canopy in 2011

44,000
Approximate number of large mature trees needed to meet American Forests recommended goal of 40% tree cover

-11
Percentage below American Forests Recommended Tree Canopy of 40%

2,000 and 62,000
Number of Vacant Street Tree Planting Sites and Potential Tree Planting Sites in Renton, respectively

$960,000
Value of Air Pollution removed annually by Renton's urban forest

2,390
Estimated number of gallons of stormwater runoff intercepted annually by each mature large tree

Potential Urban Tree Canopy, Prioritizing Locations and Goal Setting

American Forests Organization, a not-for-profit conservation organization has developed tree canopy guidelines by land use as a starting point for Renton to set their canopy goals. This report compares Renton's existing tree canopy with the guidelines suggested by American Forests.

Cities and communities set Urban Tree Canopy (UTC) goals as a planning tool to achieve greater environmental standards. Results showing specific gaps in canopy targets by zoning category were used in a "Tree Canopy Calculator" tool to assist in Renton's goal setting process. For example, while 55% of Renton is zoned residential, this land makes up 75% of the potential tree planting sites. Additionally, GIS analysis was used to map and prioritize nearly 62,000 potential tree planting sites to assist in goal setting for tree planting programs. This interactive database enables the city to target the highest value tree planting opportunities by zoning type and environmental benefit.

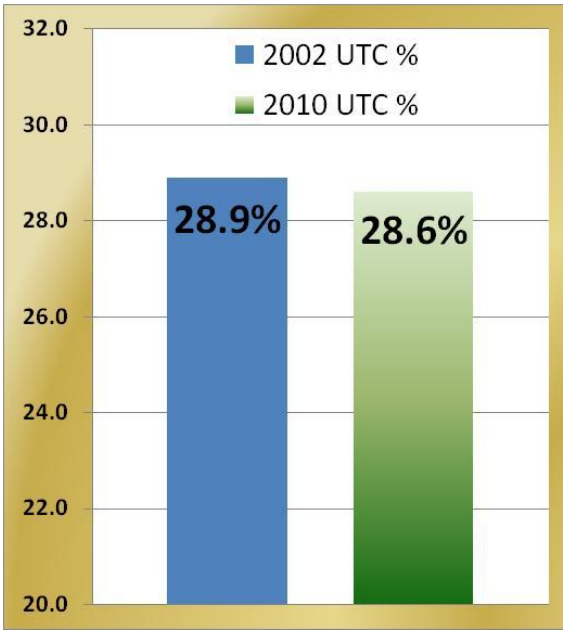
Urban Tree Canopy and Ecosystem Services

Urban and community forests provide numerous types of benefits sometimes referred to as "ecosystem services". Services such as improving air quality and reducing stormwater runoff, erosion control, and energy use are benefits trees provide that we tend to take for granted because they are not assigned a dollar value. Results of analyzing some of the economic and environmental benefits of Renton's urban forest are provided in this section. Placing a value of the direct and indirect quantifies the many benefits of a "working" urban forest.

Urban Tree Canopy Cover and Management Objectives

Management objectives are provided to assist Renton in meeting proposed UTC goals. Continuing to implement objectives in the Urban and Community Forestry Development Plan is critical to maintaining and improving canopy cover. In addition, integrating urban forest objectives with other city plans, utilizing the data from this study to discuss canopy cover goals, developing public and private planting programs, and modifying development regulations are important next steps.

Figure 1. Citywide urban tree canopy cover in Renton in 2002 and 2010



Summary

The results of this study show that Renton's urban forest has lost canopy in the last 8 years. Roughly 40,000 large trees are needed to reach American Forests recommendation of 40% tree canopy. The additional carbon storage, air pollution prevention, stormwater benefits and increased property values are compelling reasons for increasing tree canopy. Other results provided illustrate promising trends in canopy growth from tree planting by the city, new development and the public.

Urban Tree Canopy Cover and Management Objectives

This canopy cover analysis has created some inherent management objectives for increasing tree canopy. The management objectives listed below are broad-based and each require further refinements through discussions with all City departments.

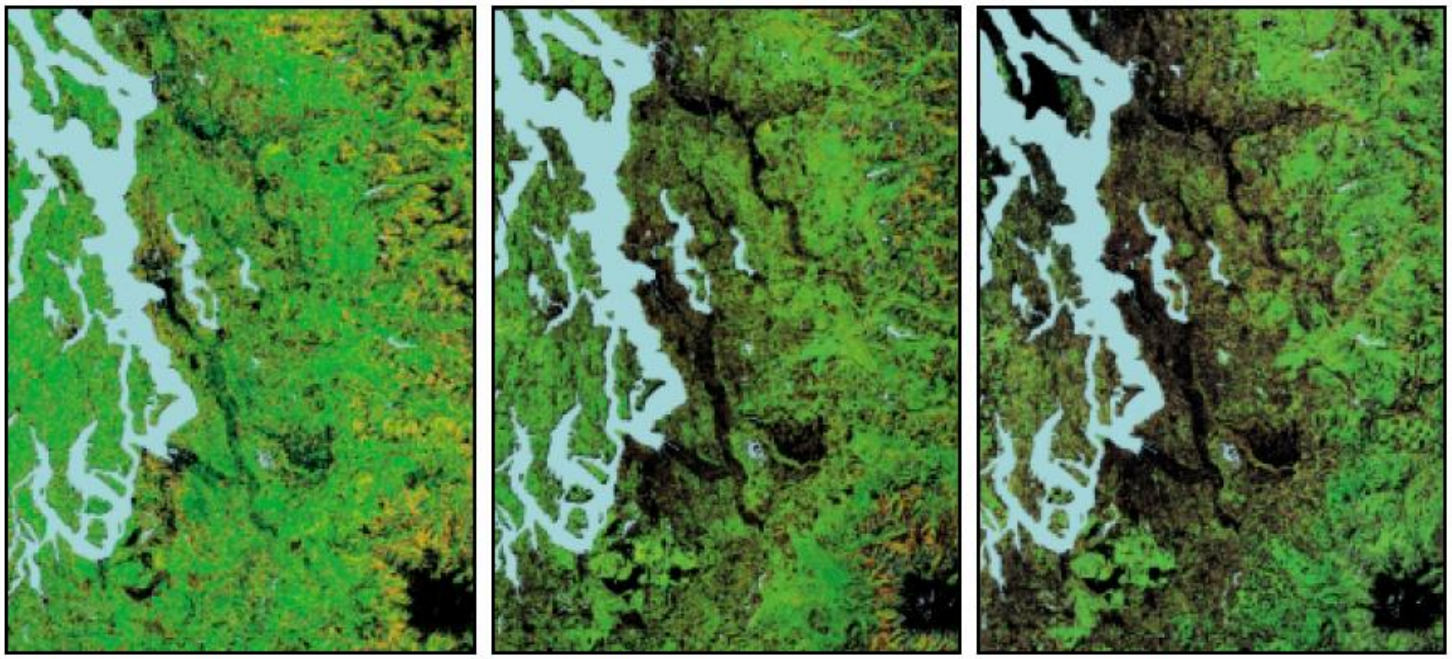
Management Objectives:

- Continue to implement the strategies of the Urban and Community Forestry Development Plan.
- Implement other city plans especially the City Center Plan and the Renton Clean Economy Strategy in relation to increasing tree canopy.
- Include the Urban Forestry Program as a major element in future Comprehensive Plan updates with emphasis on increasing urban tree canopy cover.
- Utilize CommunityViz software to run different options for prioritizing tree planting in developing realistic canopy cover goals (see Appendix, Page 37).
- Initiate interdepartmental review of the Urban Tree Canopy Report to discuss Renton's own canopy cover targets using American Forest guidelines.
- Develop a Public Tree Planting Program.
- Include tree planting strategies into an Urban Forest Management Plan developed for trees on public property.
- Disseminate the Urban Tree Canopy Report to the public in several formats and forums.
- Create an Urban Tree Canopy Program that residents can utilize for increasing tree canopy on private property.
- Modify development regulations as a result of an interdepartmental discussion and review of this Report.
- Include the Urban Tree Canopy Report into future planning documents as a reference where applicable.

Introduction

Renton's urban and community forestry program is working to achieve vision and mission statements laid out in the 2009 Urban and Community Forestry Development Plan. This includes conducting tree inventories to improve management practices and better understand the city's tree population on public lands. Communities use tree canopy mapping from aerial and satellite imagery to see the bigger picture "urban forest" across public and private property. A land cover study of the Puget Sound region was performed by American Forests in 1998 (Figure 1) which highlighted a downward trend in forest cover at the regional scale.

Figure 2. Puget Sound land cover change at a regional scale (American Forests 1998), with green as vegetation types including tree canopy and black as impervious surfaces.



With funding support from the U.S. Forest Service Urban & Community Forestry Program and the Washington Department of Natural Resources, AMEC Environment & Infrastructure, Inc. was contracted in January 2011 to assist the City in performing this analysis using Geographic Information Systems (GIS) and satellite imagery. The general objectives of this report are:

- Increase awareness of urban forest benefits
- Offer canopy goals; determine management objectives
- Compare Renton with other cities in the region
- Benchmark the existing tree canopy cover

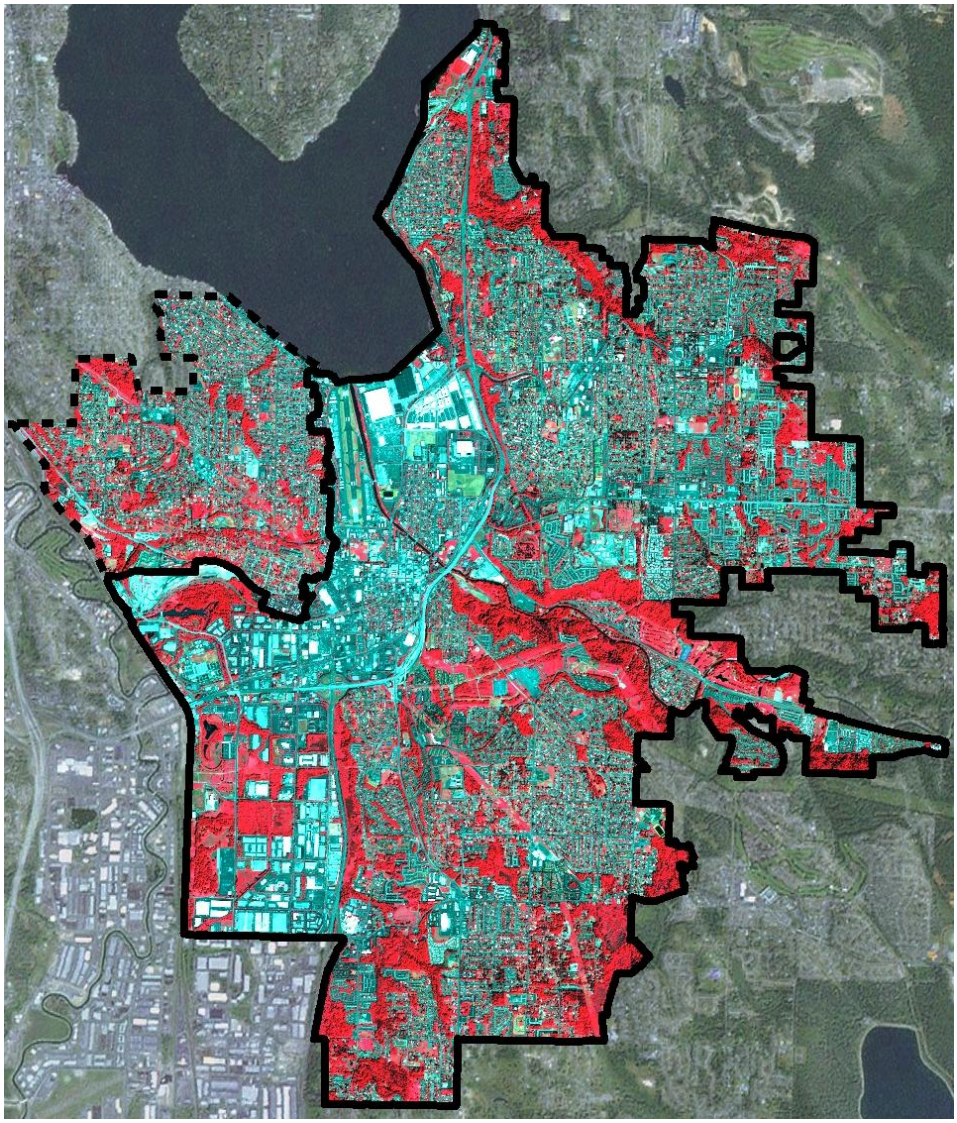
Geographic Information Systems (GIS) offer powerful tools for supporting decision-making through mapping, analysis and visualization of data spatially. Urban Tree Canopy (UTC)

assessments are a cost-effective method to measure tree cover over time and place a value on urban forests using other software programs developed specifically for valuing forests. Between the mapping information and assessment of ecosystem services described above in the Executive Summary, sound decisions can be made to effectively serve the public with a robust "working" urban forest.

In this report, Renton's tree canopy cover is measured against guidelines suggested by the conservation organization American Forests. Based upon land cover percentages in urban areas across the country, American Forests has developed suggested tree canopy guidelines as a starting point for communities to set their own goals. Following the completion of the urban tree cover analysis and this report, Renton should develop tree cover targets based upon the community's unique mix of climate, geography, land cover and land use patterns. The American Forests canopy cover goals are first presented in Table 2 (Page 15) and other tables that follow.

The study covered an area of approximately 26.3 square miles including the City of Renton and the proposed West Hill Potential Annexation Area. Figure 3 shows the study area with color-infrared satellite imagery. With color-infrared imagery, vegetation appears in shades of red where chlorophyll is present and reflected in the near-infrared band. Note that the West Hill Potential Annexation Area is shown with a dashed black outline.

Figure 3. 2010 imagery using 1.5-foot resolution showing canopy cover in color-infrared.



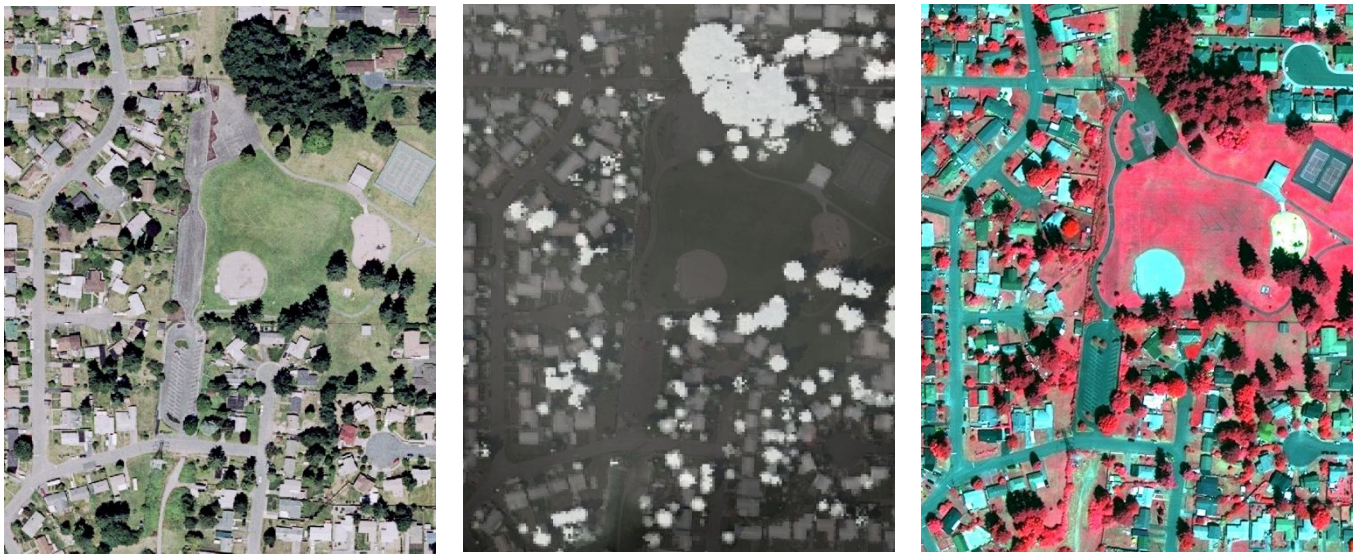
The final products were provided in several formats:

- GIS files
- Excel spreadsheet
- Google Earth files
- Interactive PDFs
- Tables, charts, and maps included in this report

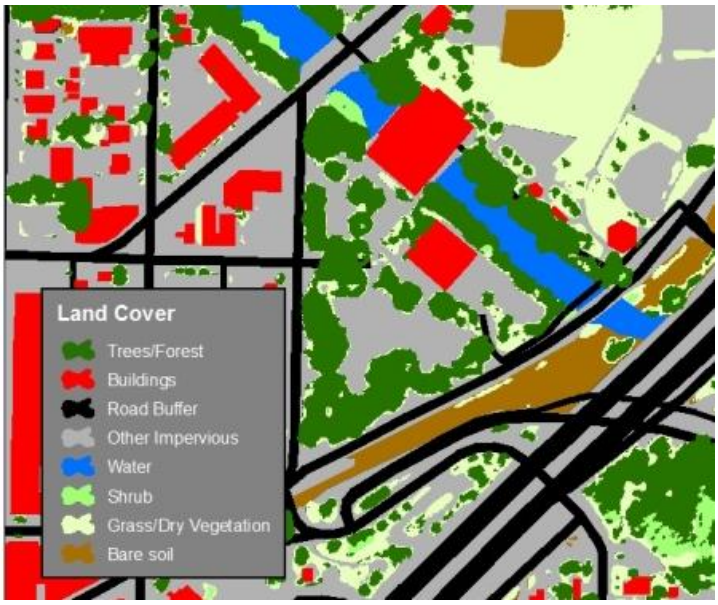
Data Inputs and Land Cover Mapping

Renton's UTC assessment required the use of geographic information systems (GIS), aerial and satellite imagery, and numerous GIS data layers from the city. These inputs were used to map six (6) land cover types citywide. The examples in Figures 4-8 below show the different types of imagery used in Renton for the analysis followed by examples of the tree canopy layer and detailed land cover layer. More technical descriptions on the data inputs and land cover methodology are provided in the Appendix.

Figures 4, 5 and 6. From left to right: natural color aerial imagery (2002), Light Detection and Ranging (LiDAR, 2001), and color-infrared satellite imagery (2010). LiDAR records elevation values which are provided in grayscale where lower elevations are darker and higher elevations such as trees and buildings are lighter.



Figures 7 and 8. Tree canopy mapping (left, dark green polygons) and detailed land cover (right). Buildings and streets were provided by the city while other classes were derived using image analysis software.



Urban Tree Canopy (UTC) Assessment Methodology

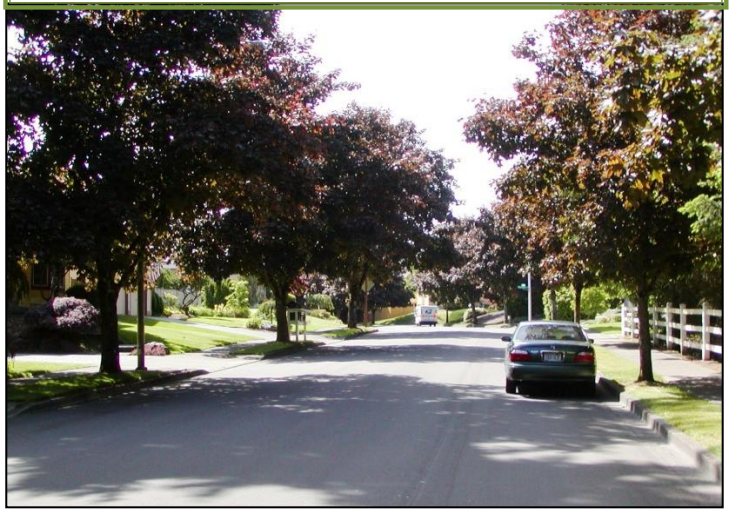
Canopy assessment involves mapping and analyzing existing tree cover and where there is potential to increase tree canopy. Examples from Renton are provided at right. Renton's land cover data was used to calculate the area and percent of existing tree cover citywide, for zoning types, for Community Planning Areas, and for individual parcels.

Developed by the U.S. Forest Service and several universities, non-profits, and other organizations, the following definitions exist for quantifying additional UTC:

- **Possible Urban Tree Canopy** (with sub-categories of Vegetation and Impervious): non-road, non-building, and non-water land, essentially where it is biophysically feasible to plant trees
- **Preferable Urban Tree Canopy**: areas to plant trees that are needed and desirable
- **Potential Urban Tree Canopy**: the economic feasibility of tree planting based on available incentives and cost-effectiveness

For this project, the term "Potential" was chosen as it best described where UTC can be established based on detailed analysis. The following pages provide results of assessing the Existing UTC, change in tree canopy from 2002 to 2010, and the number of planting sites. Results are first shown in tables, maps and charts starting at the citywide scale.

Existing Urban Tree Canopy



Potential Urban Tree Canopy – Streets

Potential Urban Tree Canopy – Parking Areas

Major Findings

Based on the analysis of satellite imagery, land cover, land use and the resulting GIS mapping data, the following represent the major findings from this study:

- ***Renton's land cover consists of 28.6% trees and 42.6% impervious surfaces. The remaining 28.8% is comprised of shrub, herbaceous vegetation/grass, water, and bare soil.***

- ***69% of the urban forest is on private land; 31% is on public properties.***

- ***The West Hill Potential Annexation Area has 28% tree canopy.***

- ***Public rights-of-way (ROW) make up 17% of Renton's land base and have 14% canopy cover. This represents 8% of the city's total tree canopy. Other public property lands comprise 23% of the total canopy cover.***

- ***1,312 acres of Renton's urban forest is at risk from being developed (see description in Table 3, page 21).***

- ***The average large sized tree (50-foot crown spread) prevents 2,390 gallons of stormwater annually from becoming runoff and polluting water resources. Using the stormwater value per gallon from the Western Washington Community Tree Guide (U.S. Forest Service), this equals $63 in annual stormwater benefits.***

- ***Annually, Renton's urban forest provides $963,000 in air pollution removal services and sequesters 1,610 tons of carbon dioxide.***

- ***From 2002-2010, Renton had a net loss of 52 acres (1.1%) in tree canopy cover.***

Land Cover, Urban Tree Canopy and Canopy Trends from 2002 to 2010

The City including the West Hill Proposed Annexation Area encompasses 16,814 acres, of which 4,804 acres (28.6%) is covered by forests and trees in 2010. 1,489 acres (30%) of the urban forest is found on public lands which have gained canopy since 2002 (19 acres). 3,315 acres (70%) of Renton's urban forest is found on private lands which have lost canopy since 2002 (71 acres). Considering public and private urban tree cover together, a net loss of 52 acres (1.1%) has occurred between 2002 and 2010. The increase in canopy cover on public lands indicates that tree planting initiatives and existing tree growth have offset any losses unlike on private lands where large forested tracts were lost to development.

Table 1. UTC results from 2002 to 2010.

Area	Total Acres	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Change in UTC Acres	Change in UTC %	Raw Change in UTC %
City of Renton	14,628	4,228	28.9	4,179	28.6	-49	-1.2	-0.3
West Hill PAA	2,186	628	28.7	625	28.6	-3	-0.5	-0.1
Public	5,397	1,491	27.6%	1,510	28.0%	19	1.3	0.4
Private	11,418	3,365	29.5%	3,294	28.9%	-71	-2.1	-0.6

Citywide, there are 7,167 acres (42%) of paved, impervious surfaces such as buildings, roads and parking lots. The land cover data could be used to calculate the amount of each impervious surface type to develop metrics and goals to reduce impervious cover over time. The remaining 4,843 acres is comprised of shrub, herbaceous vegetation/grass/open space, water, and bare soil. See Figure 9 below.

Figure 9. Distribution and Acreages of 6 Land Cover Classes in Renton

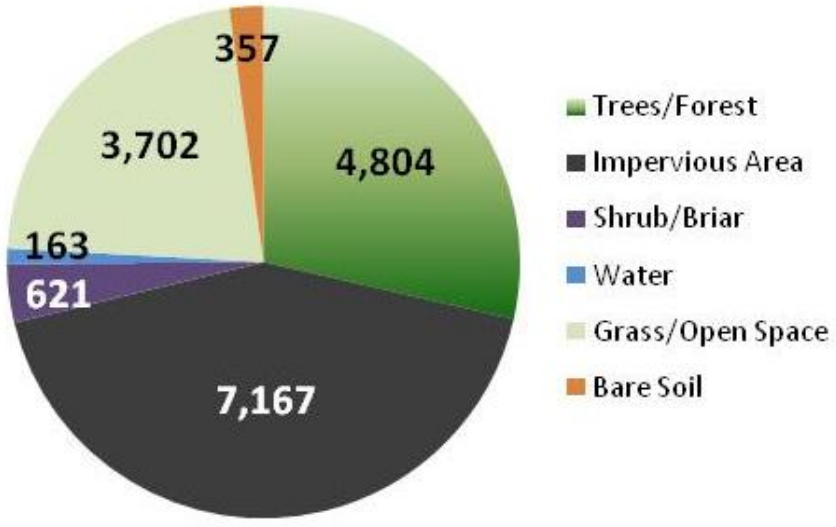
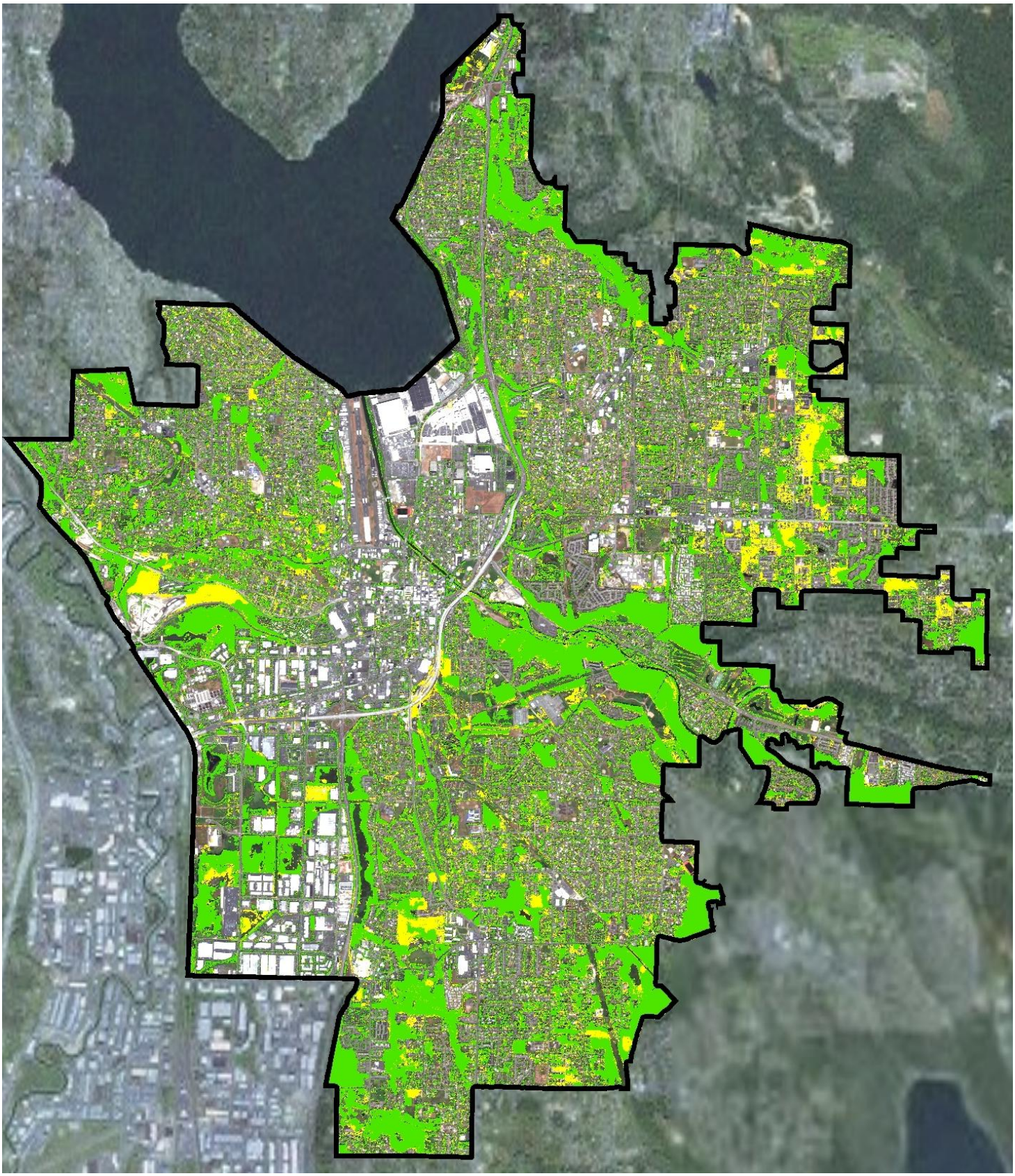


Figure 10. Map comparing Renton's tree canopy cover between 2002 and 2010. Green = 2010; Yellow = 2002 (canopy removed during an 8-year period).



Zoning Results for Urban Tree Canopy (UTC) and Canopy Trends from 2002 to 2010

Six zoning categories were chosen to assess the existing tree canopy, potential canopy, and canopy change from 2002 to 2010. The map in Figure 11 illustrates the distribution of these zoning types in Renton in 2010. More results are on the next page.

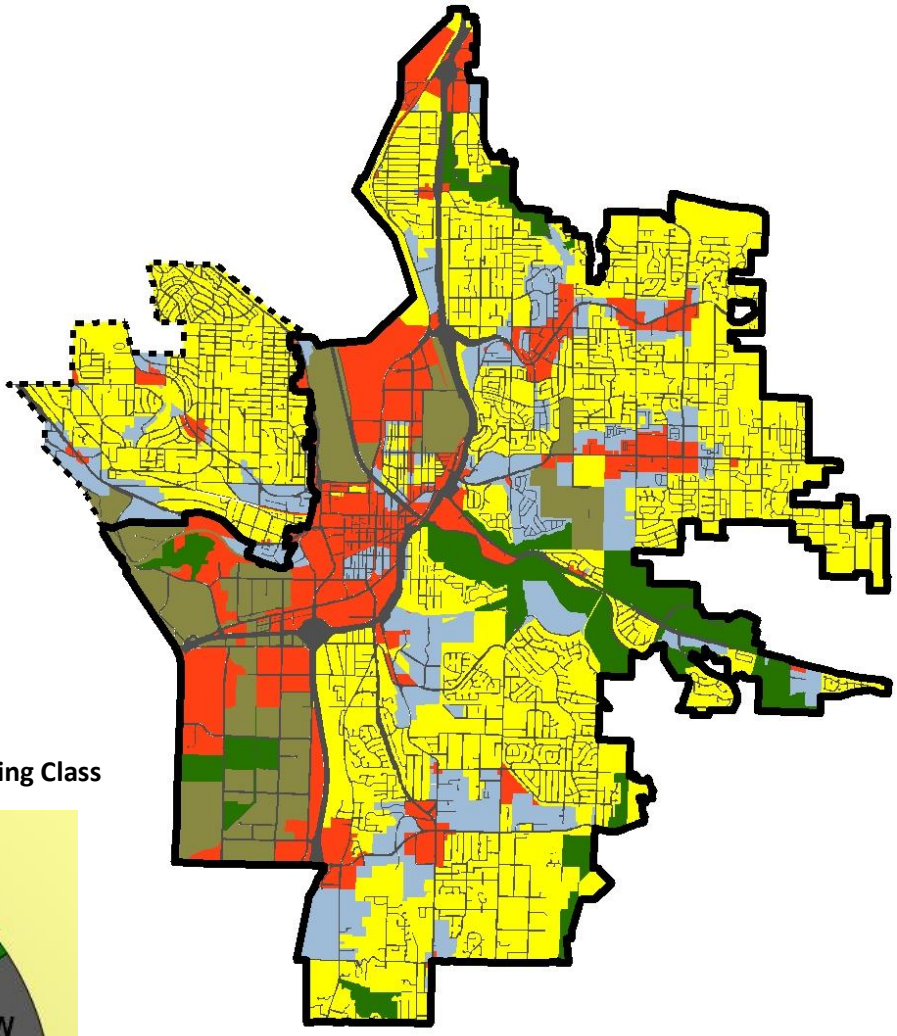
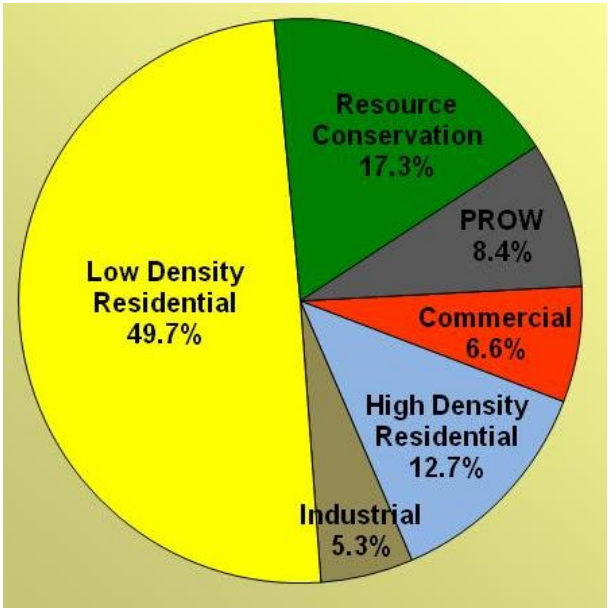


Figure 11. Parcels: Zoning

Figure 12. Distribution of 2010 UTC by Zoning Class



Did you know?

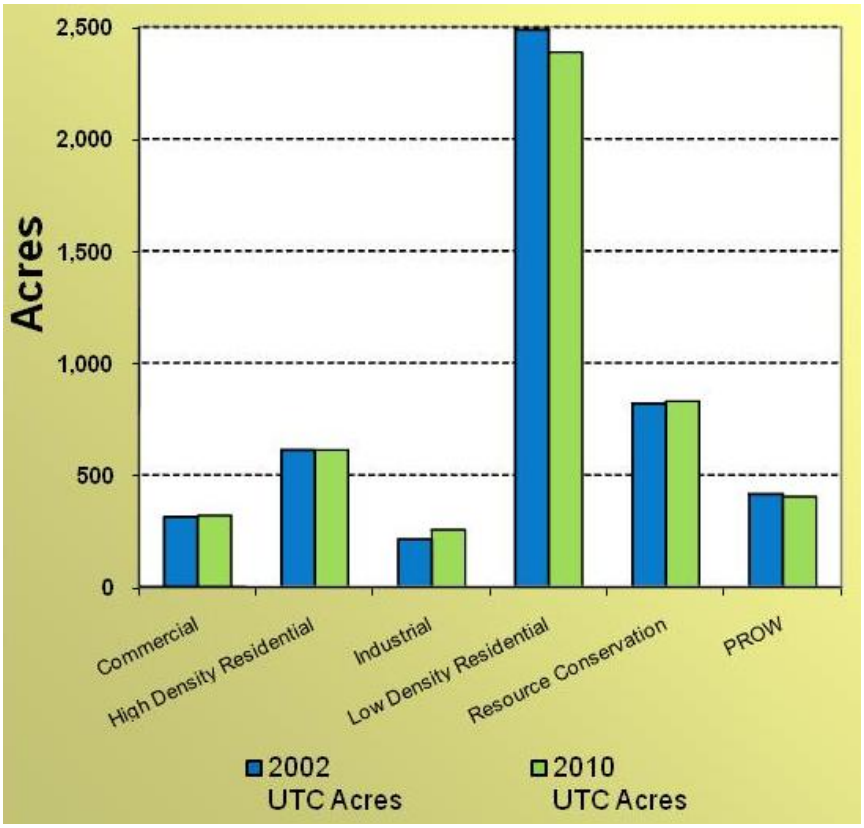
- 55% of Renton is zoned residential; 62.4% of the city's tree cover is in residential zoning areas
- Resource Conservation (RC) zoned lands make up 7% of land; 17% of the city's tree canopy is found on RC land. RC land had 68% tree canopy in 2010 (see Table 2).
- Commercial and Industrial zoning make up the smallest portion of Renton's canopy
- Public rights of way make up 17% of land; 8% of the city's tree canopy is found on ROW land.

In Table 2 below, Renton's tree canopy cover is compared to guidelines suggested by the conservation organization American Forests. The suggested tree canopy guidelines have been modified to fit Renton's zoning. Following the completion of this project, Renton can develop tree cover targets based upon the community's unique mix of climate, geography, community values, land cover and land use patterns.

Table 2. Existing Tree Canopy and Canopy Change by Zoning Type Compared to American Forest Goals

General Zoning Classification	Total Acres	2002 UTC %	2010 UTC %	Relative Change in UTC*	American Forests Goal	% Above or Below American Forests Goal
Commercial	2,053	15.2%	15.6%	1.9%	15%	0.6%
High Density Residential	1,881	32.5%	32.5%	0.0%	25%	7.5%
Industrial	1,488	14.2%	17.1%	20.3%	25%	-7.9%
Low Density Residential	7,323	34.0%	32.6%	-4.1%	50%	-17.4%
Resource Conservation	1,215	67.3%	68.2%	1.3%	25%	43.2%
PROW	2,854	14.5%	14.1%	-2.7%	25%	-10.9%
Total	**16,814**	**28.9%**	**28.6%**	**-1.1%**	**40%**	**-11.4%**

Figure 13. Comparison of 2002-2010 Tree Canopy Acres by Zoning Category



Tree Canopy Cover for Community Planning Areas

There are ten Community Planning Areas in Renton. Community Planning Areas (CPA) are geographic subdivisions of the city. These were established by the City Council in consideration of a number of factors that included, but not limited to:

- Shared Community Identity
- Physical Features
- Schools
- Districts and Boundaries
- Access to and from a Community

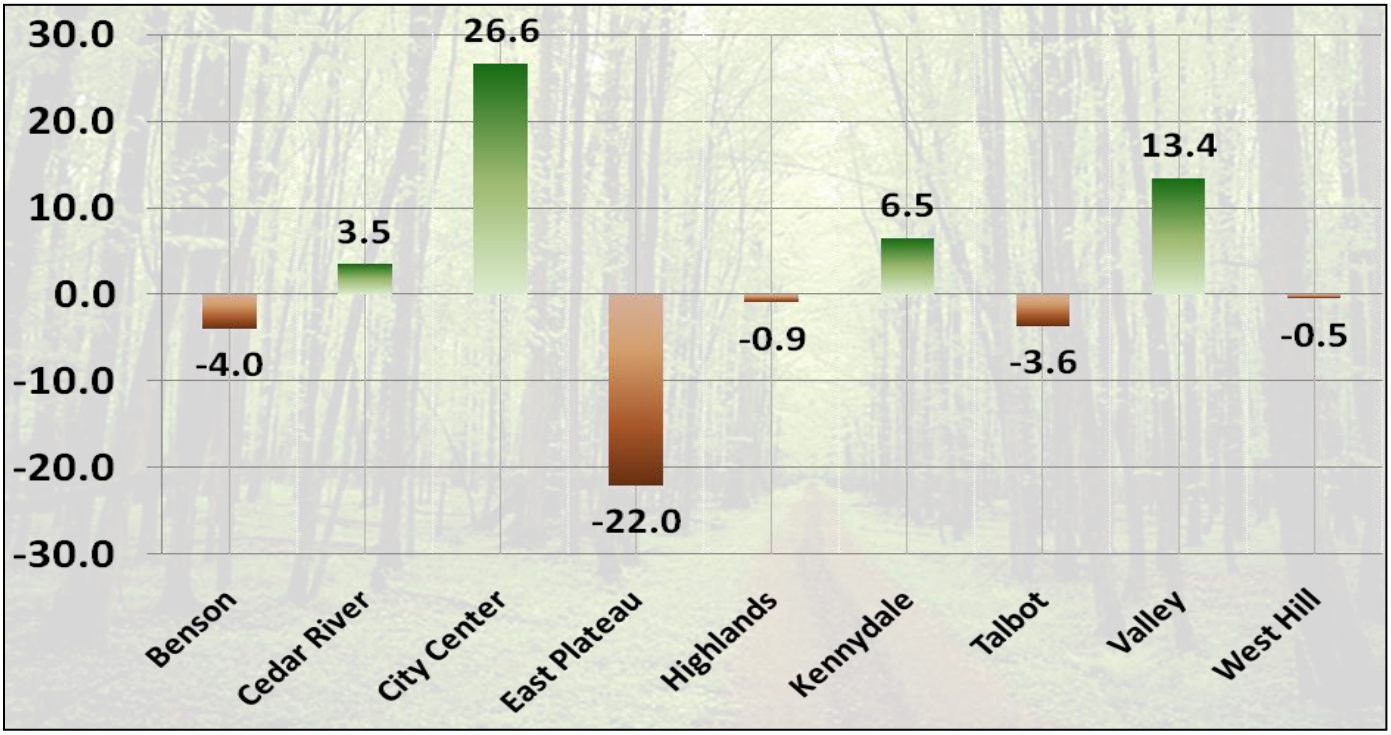
Renton's Community Planning Areas (excluding Fairwood) were assessed for tree canopy cover in 2002 and 2010. This scale provides neighborhood-level planning data with greater detail than at a citywide scale but less than at the individual property level described further below.

Maps are provided on the next page. Complete details of 2002 and 2010 UTC as well as land cover by Community Planning Area are provided in the Appendix.

Existing Canopy and Change by Community Planning Area

- Cedar River: 48.7% tree canopy; largest tree canopy area in 2010
- City Center: 11% tree canopy but gained 27% since 2002
- Valley: gained 13.4% tree canopy
- East Plateau: lost 121 acres (22%) of its tree canopy since 2002

Figure 14. Percent UTC Change from 2002 to 2010 by Community Planning Area



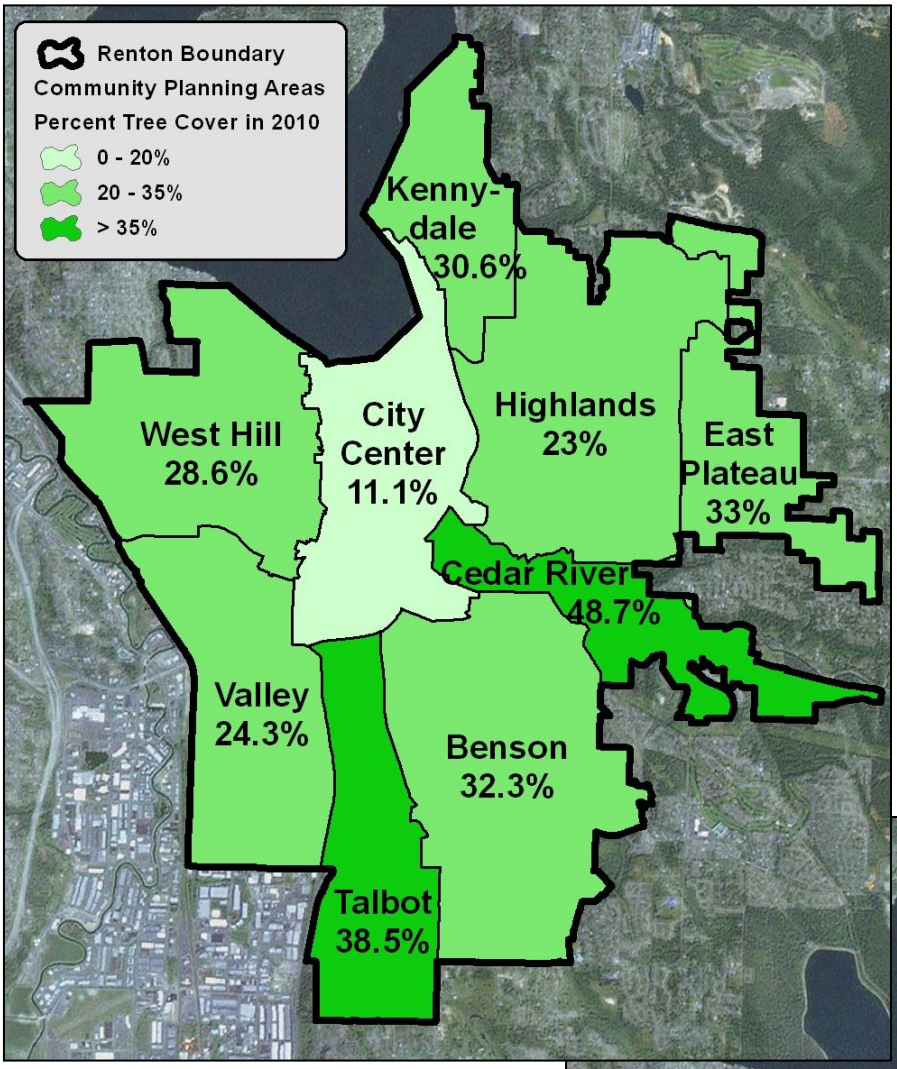
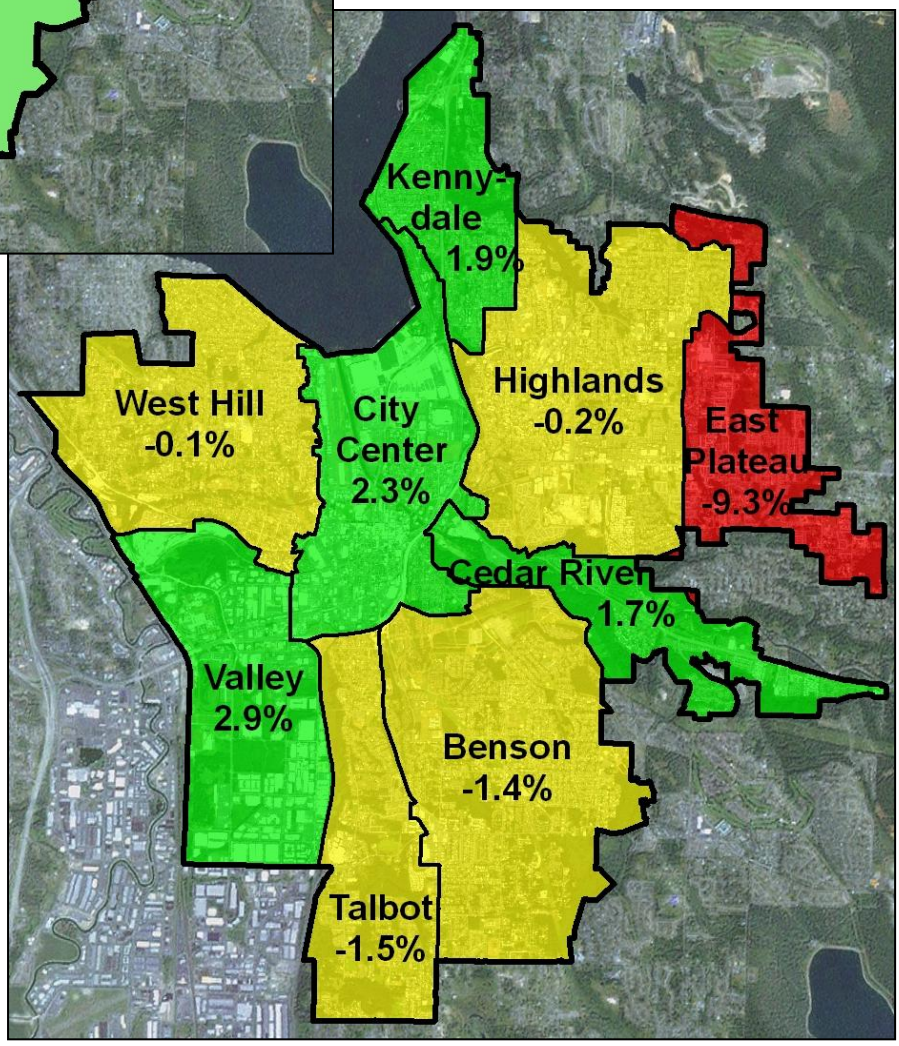


Figure 15. 2010 Tree Canopy Percentage by Community Planning Area

Figure 16. Tree Canopy Change from 2002 to 2010 by Community Planning Area



- 2010 canopy cover in the Community Planning Areas ranged from 11.1% to 48.7%
- Canopy cover change, between 2002 and 2010, in Community Planning Areas ranged from -9.3% to 2.9%.
- The East Plateau CPA had 42.3% UTC in 2002 and 33% UTC in 2010 for a change of -9.3%. This represents a 22% decline in UTC acreage from 2002 to 2010.

Tree Canopy and Individual Parcels

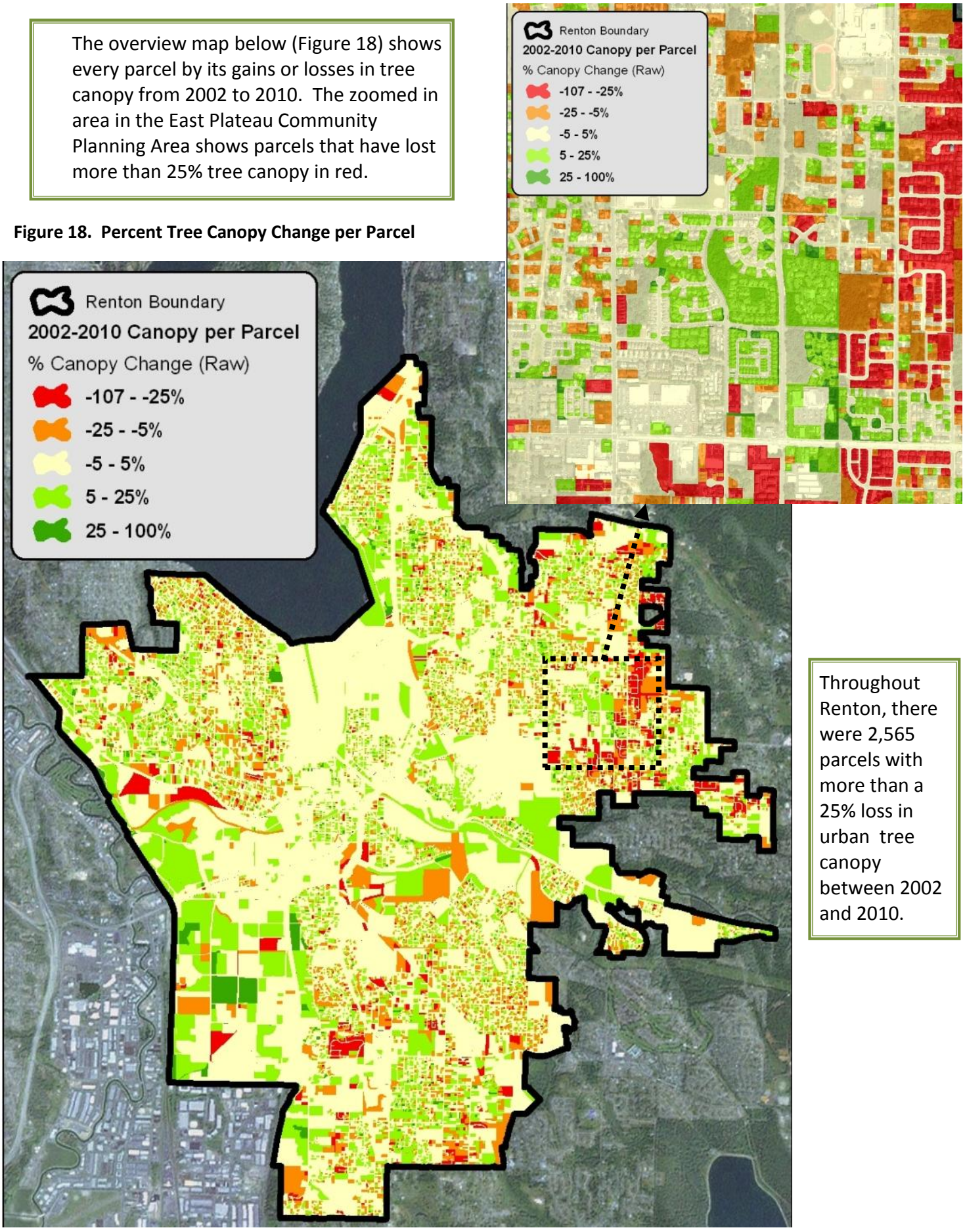
Tree canopy metrics were also calculated for parcels (property) boundaries in the city (29,843 lots). For every parcel, the database includes the acres and percent of 2002 and 2010 tree canopy, the change of UTC, and the number of potential planting sites. The parcels can therefore be symbolized by any of these attributes. As an example, Figure 17 below shows parcels color-coded by the percent (%) of existing tree cover per parcel. Darker indicates a higher tree canopy cover percentage.

Figure 17. Example of Canopy Cover Percentages in Downtown Renton at the Individual Parcel Level

- American Forests recommends a 20% canopy cover for commercial districts
- 17,110 parcels out of 29,843 throughout Renton have less than 20% tree canopy cover
- 6,683 parcels have less than 5% tree cover
- 2,574 parcels have 0% tree canopy

The overview map below (Figure 18) shows every parcel by its gains or losses in tree canopy from 2002 to 2010. The zoomed in area in the East Plateau Community Planning Area shows parcels that have lost more than 25% tree canopy in red.

Figure 18. Percent Tree Canopy Change per Parcel

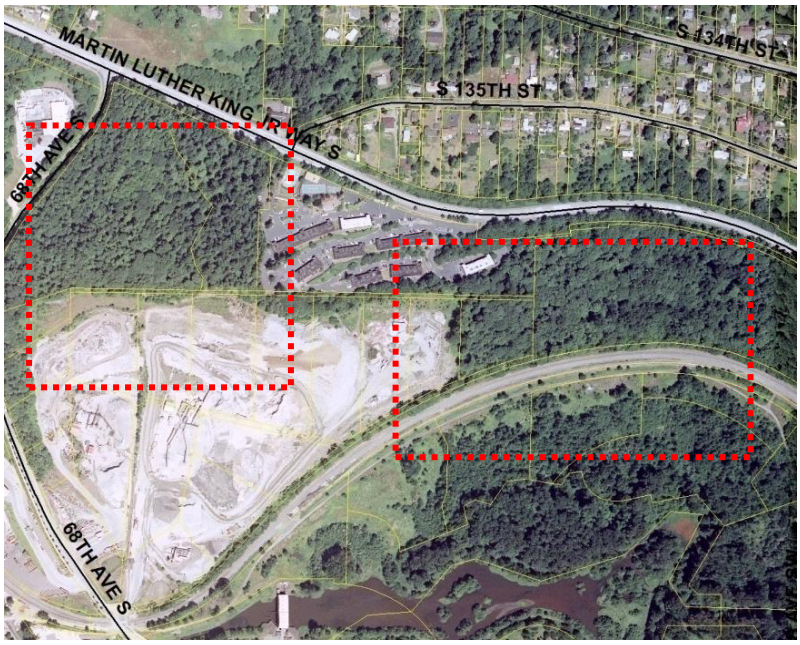


Throughout Renton, there were 2,565 parcels with more than a 25% loss in urban tree canopy between 2002 and 2010.

Forest Protection and Preservation

Renton had a net loss of 52 acres (1.1%) of tree canopy between 2002 and 2010. More specifically, the city lost over 1,000 acres due to tree removal. 50% of that loss (482 acres) occurred on forest stands over ½ an acre in size. The net loss of tree canopy was offset by growth in existing canopy and tree planting by the city, businesses, development in new subdivisions, and residents between 2002 and 2010.

Figures 19 and 20. An example of forest loss between 2002 and 2010 in the northern part of the Valley Community Planning Area



- In the red boxes highlighted at left, parcels lost a total of 16.7 acres of forest cover during development
- The tree canopy cover was 75% for these parcels and is now 25%
- The lost air quality value is equal to $3,349 annually
- The lost carbon storage value is equal to 719 tons
- 1,522 parcels out of 29,843 in Renton lost more than 50% of their tree cover from 2002 to 2010

A relationship between development and preservation of natural forest stands can be developed to enable the city to assess tree protection guidelines. GIS was used to select properties based on their zoning type, number of structures (buildings), amount of tree canopy, and slope. High slopes are a constraint to development. Forested parcels with less than 25% slopes were defined as having the greatest risk of conversion to development.

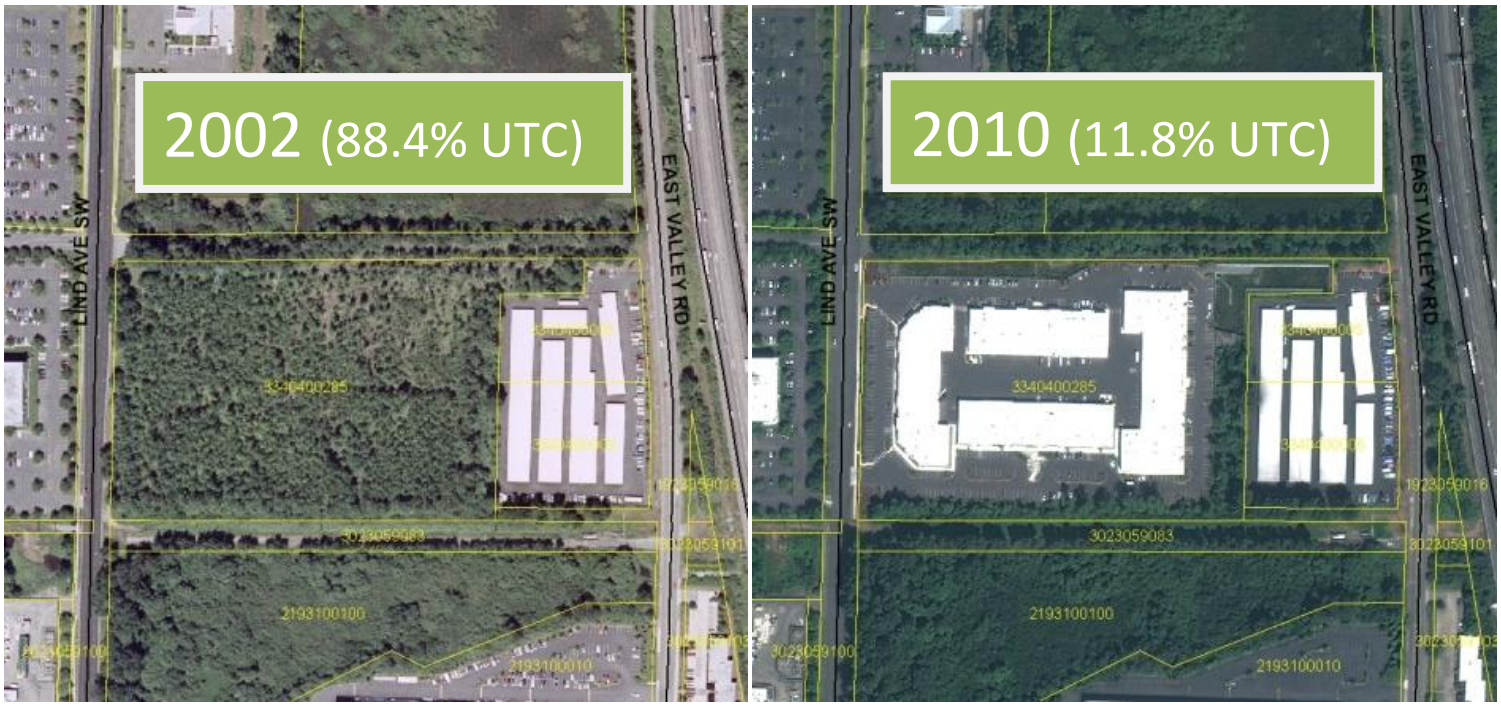
An analysis of the information showed that:

- 1,625 parcels contain trees and forests at risk from development
- On these parcels, there are 1,312 acres of trees and forest
- With 4,804 acres of tree canopy citywide, 27.3% of Renton's urban tree canopy is at risk from development

Table 3. Existing Forest Cover with Less Than 25% Slope Subject to Development Pressure

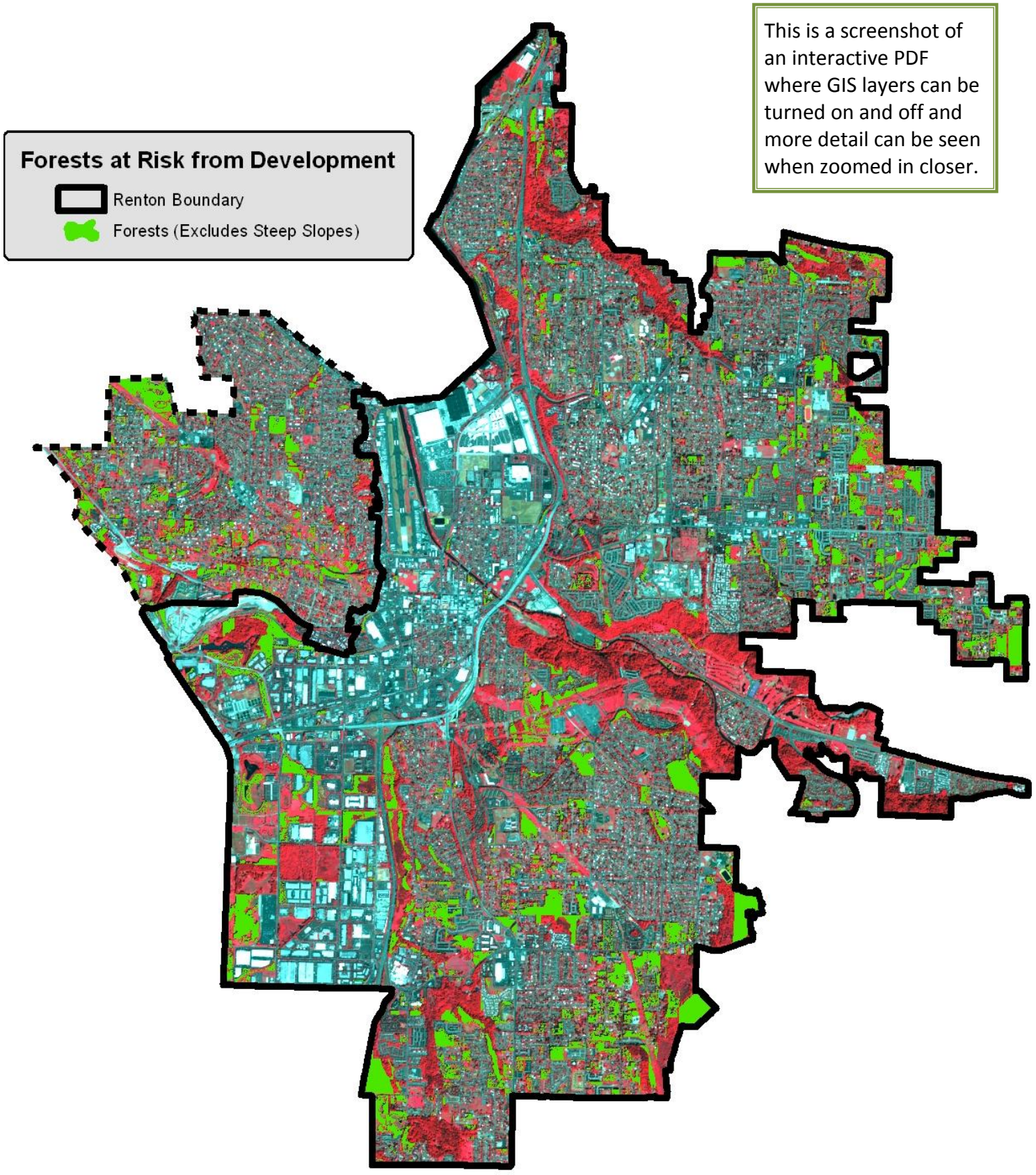
Number of Parcels with Forests at Risk	Forest Acres at Risk	Percent of Urban Forest at Risk	Total Forest Acres Citywide	Number of Individual Forest Stands at Risk Greater than .5ac
1,625	1,312	27.3%	4,804	778

Figures 21 and 22. Example of Forest Lost to New Development



The parcel shown here is 12.3 acres and had 10.9 acres (88.4%) of tree canopy in 2002. After development, the parcel now has 1.45 acres (11.8%) of tree canopy for a loss of 9.4 acres.

Figure 23. Parcels Containing Slopes Less Than 25% and at Greatest Risk of Conversion



Potential Urban Tree Canopy

This study analyzed existing land cover and zoning to map potential planting sites to assist in UTC goal setting. Two (2) definitions are provided below in order to expand on methods described on page 9:

- Potential urban tree canopy is the additional capacity in a city where tree canopy can be increased
- Available planting sites exist where there is a lack of trees and adequate planting area in shrub, grass or other herbaceous cover

To get a more realistic estimate of where trees could be practically planted, exclusions such as recreational fields, power line corridors and airports, and constraints such as distance to infrastructure (street lights and intersections) were used. Complete details on the exclusions and constraints are shown on the next page.

Potential urban tree canopy amounts provide long range goals for increasing tree canopy based upon the American Forests Organization recommendations. However, the City may wish to modify these canopy cover goals when preparing urban forest management plans.

Table 4. Planting Sites by Zoning Category (after constraints/exclusions)

General Zoning Classification	No. Planting Sites
Commercial	5,576
High Density Residential	6,996
Industrial	2,730
Low Density Residential	39,239
Resource Conservation	5,791
PROW	1,597
Total	**61,929**


Photo Credit:
Denis Law
Arbor Day Event

Table 5. Planting Sites by Community Planning Areas

Community Planning Area	Total Acres	2010 UTC %	American Forests Goal (%-avg)	% Above or Below American Forests Goal	No. Planting Sites	No. Planting Sites per Acre
Benson	2,931	32.3	40	-7.7	12,288	4.2
Cedar River	1,161	48.7	50	-1.3	2,713	2.3
City Center	1,926	11.1	15	-3.9	4,494	2.3
East Plateau	1,307	33.0	40	-7.0	5,549	4.2
Highlands	2,780	23.0	40	-17.0	12,608	4.5
Kennydale	1,119	30.6	40	-9.4	4,440	4.0
Talbot	1,498	38.5	40	-1.5	5,257	3.5
Valley	1,908	24.3	40	-15.7	4,377	2.3
West Hill	2,186	28.6	40	-11.4	10,203	4.7
Total	**16,814**	**28.6**	**40**	**-11.4**	**61,929**	**3.6**

Potential Planting Sites Methodology

For the GIS analysis of potential planting sites, constraints (exclusions) were used to determine where trees could be planted. The complete list of these exclusions and their definition is provided below, along with a graphic illustrating the interim and final outputs from left to right.

Table 6. Description of exclusions and constraints used in Renton to map potential planting locations

GIS Layer(s)	Rule Applied	Reason
Tree canopy and street tree inventory	Buffered by 10-feet	To allow room for spacing and growth of existing trees
Buildings	Buffered by 4-feet	To avoid tree and building conflicts
Power line corridors	Buffered by 6, 10, 24 or 60 feet	To avoid utility and tree conflicts. Buffer varied based on voltage.
Golf Courses	Excluded entirely	Difficult to request tree planting or known where they could or should be planted
Airports	Excluded entirely	Avoid line of sight and safety conflicts
Recreational fields	Remove fields	Areas needed for sports, etc.. Potential plantings on periphery of these properties were included
Luminaire (street lights)	Buffered by 30-feet	To avoid light and tree conflicts
Street intersections	Center point buffered by 55-feet	To avoid line of sight and safety conflicts per city ordinance
Initial Planting Results	Collapse 2 sites to 1	Avoid sites being too close and unrealistic

Figure 24. Interim and final stages of the planting sites analysis viewed from left to right.

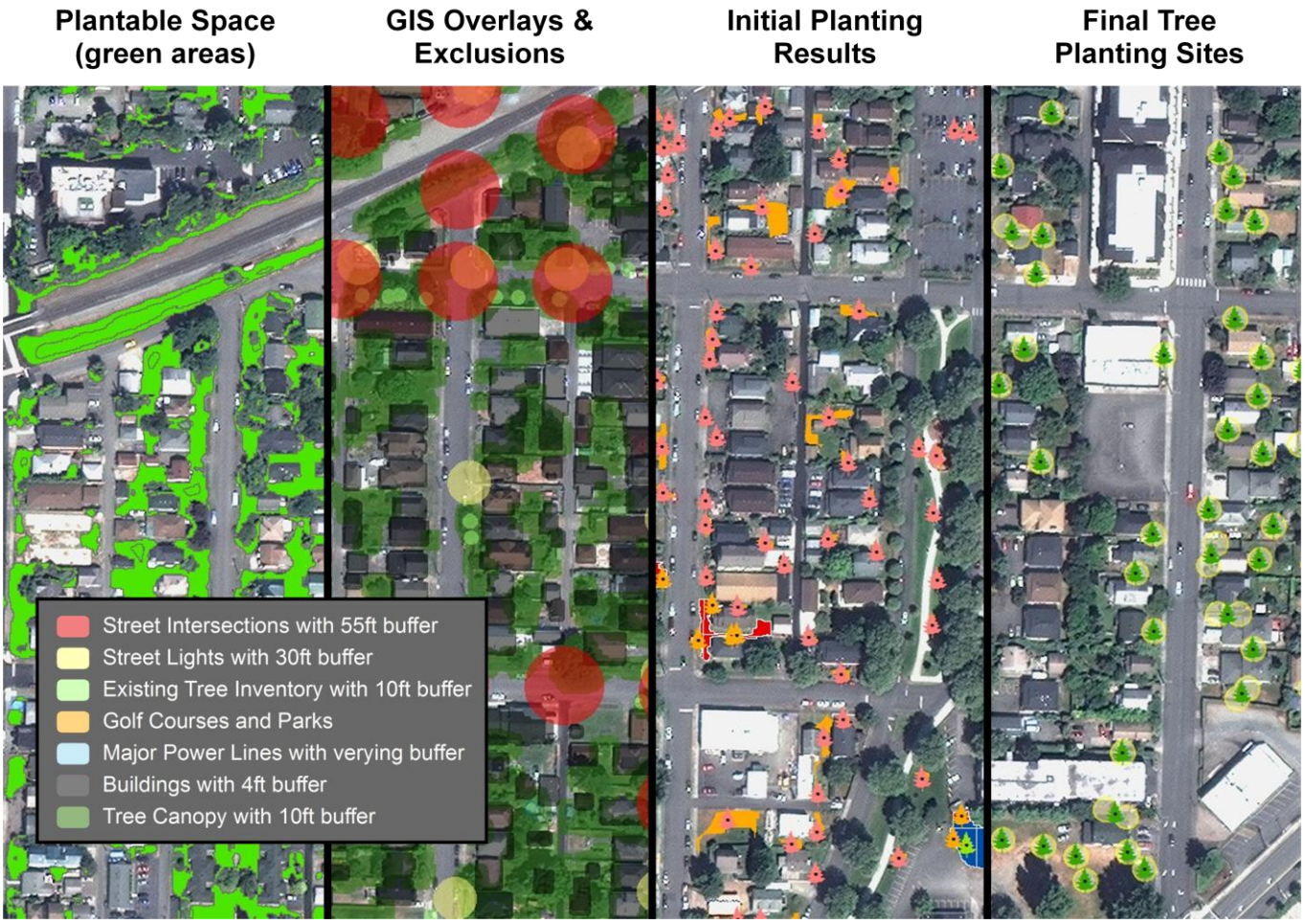
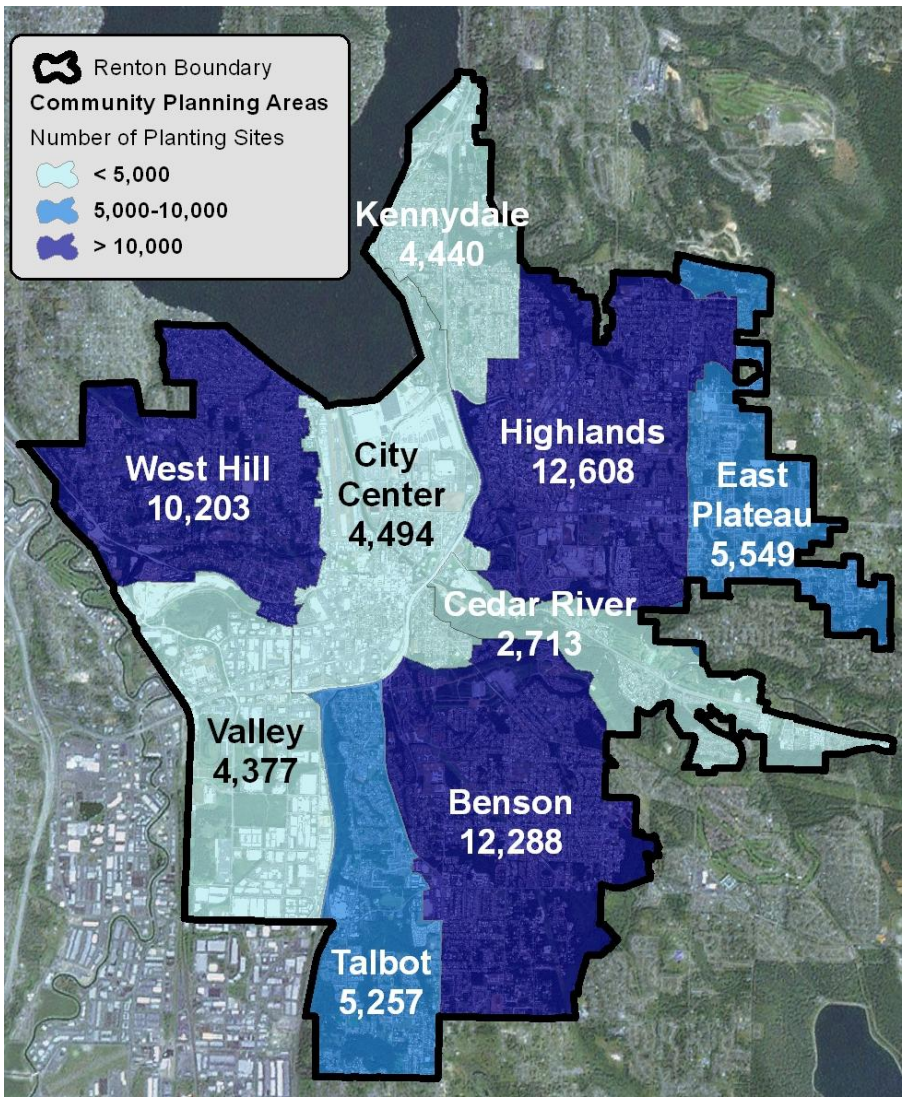


Figure 25. Example of Potential Tree Planting Sites (GIS points in yellow) after exclusions and constraints that provided realistic spacing between planting sites, existing trees, and vegetation.

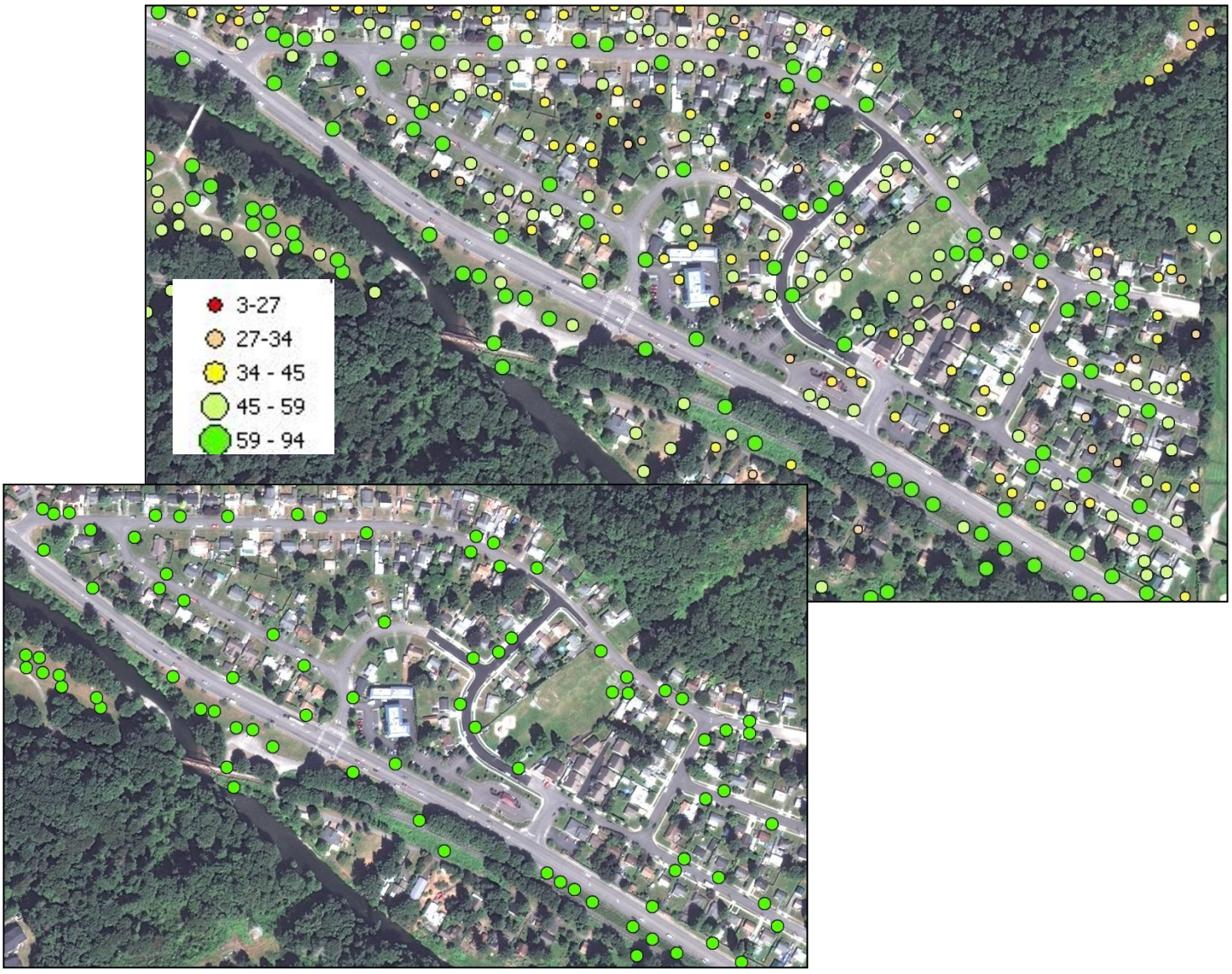
Figure 26. Number of Potential Planting Sites (after exclusions) by Community Planning Area



Prioritizing Planting Locations

With 62,000 potential tree planting sites, where do you begin planting trees? A GIS suitability model was used to rank sites that would provide the most benefit. Factors for ranking included areas of low tree canopy, high impervious surfaces, distance to streams or bike paths, and other environmental and economic factors. A complete listing is in the Appendix, Page 37. Each site received a "suitability score" between 0 and 100 (see example in map legend below). Figures 27 and 28 below show sites symbolized by size and color based on their score or ranking. Large green tree planting points met the criteria the best. Note that sites rank higher than others when near a stream, building, or areas with low UTC and high paved surfaces. Figure 28 at bottom only shows the top 20% of sites in this sample subdivision as an example of prioritizing planting.

Figures 27 and 28. An example in the Maplewood Park Subdivision showing further prioritization of potential planting. Sites have been color-coded and sized based on a suitability score from 0 and 100. The same area is shown below after a filter was applied and only the top 20% of sites are visible.



Urban Tree Canopy and Ecosystem Services

The Urban and Community Forestry Development Plan describes ways in which urban forests contribute to improving quality of life. These forest benefits are referred to as "ecosystem services", the direct and indirect benefits trees provide that we tend to take for granted because they are not assigned a dollar value.

Examples include:

- Providing habitat and protecting biodiversity
- Decreasing stormwater utility costs, erosion, and flooding
- Reducing urban heat island effect and cooling costs
- Improving property values, tax revenues, recreation opportunities, and public health and well being
- Absorbing carbon dioxide annually through carbon sequestration and through carbon storage
- Improving air quality, water quality and groundwater recharge

The following software packages were used to estimate the benefits of Renton's existing and potential urban tree canopy. Descriptions and results of each are provided below.

- U.S. Forest Service Community Tree Guides
- CITYgreen software
- Western Washington Hydrology Model (WWHM)

Community Tree Guides

The U.S. Forest Service Community Tree Guide for the Pacific Northwest provides cost and benefit values for public and private urban trees. Over a 40-year period, the guide breaks out benefit values for different types of trees by aesthetics and other benefits (including property value), stormwater and air pollution mitigation, energy savings (heating and cooling), and carbon sequestration. The guide includes cost for planting, maintenance (pruning, watering and infrastructure conflicts), and removal. Additionally, the guides offer guidelines on selecting and siting trees to maximize long-term tree benefits. As an example, one could use the guide to show the value of a bigleaf maple tree over its lifespan and compare it with a Douglas fir.

The guide for Western Washington shows that:

- The average large tree in Renton provides as much as $17 in annual energy savings. Trees provide energy savings by shading homes and buildings in summer, transpiration which cools the air, and blocking wind in winter which leads to heat loss.
- Over 40 years, this tree provides $2,120 in total "net" benefits. Net benefit is the result of subtracting tree planting and maintenance costs from the benefits.

CITYgreen

CITYgreen, a GIS software developed by American Forests and the U.S. Forest Service, was used to calculate current and potential benefits related to carbon storage (cumulative amount of carbon stored in trees over time), carbon sequestration (the rate that carbon is captured), and air pollution removal by trees annually. CITYgreen can put a dollar value estimate on the stormwater benefit of urban forests, however, the Western Washington Hydrology Model was used instead because it provides more locally specific modeling parameters.

Figure 29. CITYgreen reports estimating air pollution and carbon benefits of Renton's existing tree canopy (28.6% cover) and the value at American Forests recommendation of 40% tree canopy.

Total 2010 Tree Canopy: 4,804 acres (28.6%)

Air Pollution Removal

Nearest Air Quality Reference City: **Seattle**

	Lbs. Removed/yr	Dollar Value
Carbon Monoxide:	27,803	$11,854
Ozone:	141,556	$434,500
Nitrogen Dioxide:	64,092	$196,726
Particulate Matter:	132,713	$271,973
Sulfur Dioxide:	64,359	$48,256
Totals:	**430,523**	**$963,310**

Carbon Storage and Sequestration

Total Tons Stored:	**206,759.40**
Total Tons Sequestered (Annually):	**1,609.68**

Potential Total Tree Canopy: 6,725.6 acres (40.0%)

Air Pollution Removal

Nearest Air Quality Reference City: **Seattle**

	Lbs. Removed/yr	Dollar Value
Carbon Monoxide:	38,926	$16,597
Ozone:	198,190	$608,337
Nitrogen Dioxide:	89,734	$275,433
Particulate Matter:	185,809	$380,785
Sulfur Dioxide:	90,109	$67,562
Totals:	**602,767**	**$1,348,714**

Carbon Storage and Sequestration

Total Tons Stored:	**289,408.55**
Total Tons Sequestered (Annually):	**2,253.12**

Renton's existing urban forest stores over 200,000 tons of carbon.

At 40% UTC, Renton's urban forest would provide over $1.3M in annual air quality benefit.

Western Washington Hydrology Model

Stormwater modeling on the benefits of trees was conducted using the Western Washington Continuous Simulation Hydrology Model (WWHM). The model was developed by the State of Washington Department of Ecology and was chosen due to its local reference data and ability to model hydrologic benefits of forests versus other pervious and impervious surfaces. Both rainfall interception and infiltration were modeled using slope, land use, land cover data and potential planting locations. The outputs include changes in peak flow and runoff volume based on the number of potential tree planting sites and average parcel size in each zoning category. The existing urban forest canopy cover was not modeled for stormwater benefit, and the WWHM does not provide dollar value benefit. Community Tree Guide dollar values for stormwater benefit are used in the Summary of this report.

This modeling showed that:

- A large tree with a 50-foot crown diameter intercepts 2,390 gallons of stormwater runoff annually having an annual value of $63 (value based upon USFS Community Tree Guides). This is an estimated amount on the cost to treat 2,390 gallons of water using engineered detention facilities.
- If half of Renton's 61,929 vacant planting sites were planted and reached mature size, this would equal 74,000,000 gallons intercepted by these new trees annually.
- Low Density Residential parcels would see a 10% reduction in peak flow for a 100-year storm event with the potential planting sites at 50' crown diameter.

If the future tree plantings can be achieved within the City of Renton, the runoff response will not only be peak reduction, reduced runoff volume, and water quality benefits, but help address duration, velocity, and frequency.

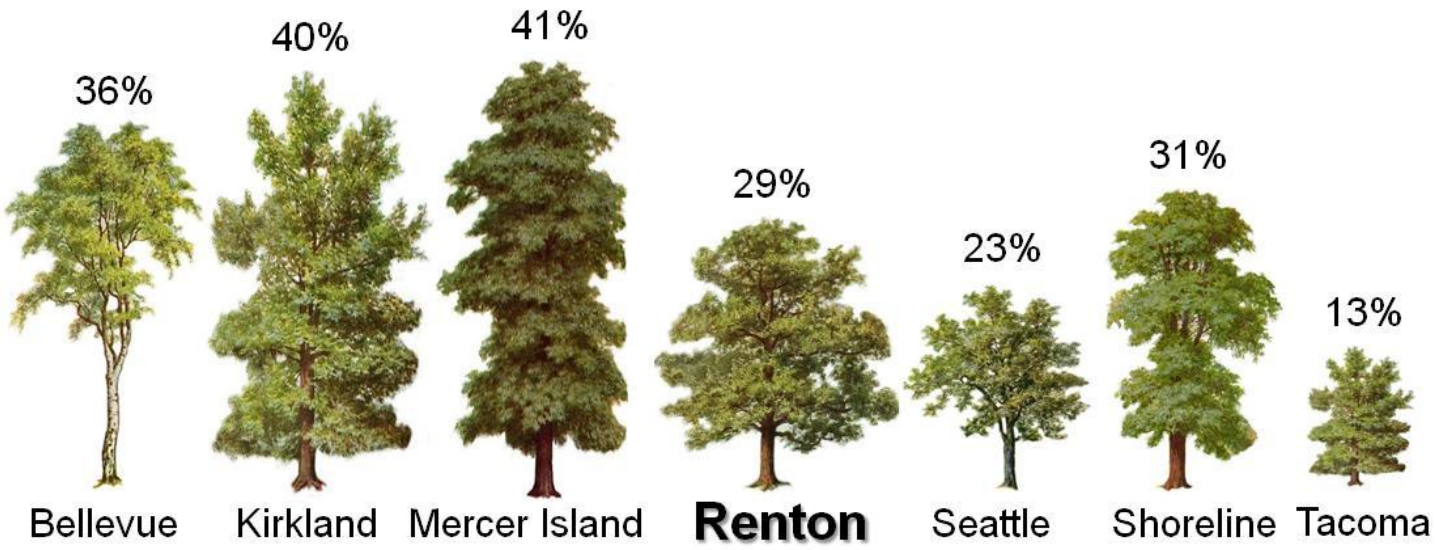
Full details of modeling the stormwater benefits of trees are provided in the Appendix on pages 39-42.

Summary

Trends between 2002 and 2010 were identified in this study such as increased canopy cover in industrial properties overall and in the Cedar River, City Center, Kennydale, and Valley Community Planning Areas. Renton lost 52 acres (-1.1%) of canopy cover the past 8 years. Some areas have seen losses in forest cover such as the East Plateau Community Planning Area (-22%). Correlated with this is the loss of 4.1% of UTC in Renton's low density residential zoning category. Additionally, the City's overall canopy would have decreased substantially more than 1.1% had it not been for the growth of existing newly planted trees in all zoning categories.

Renton has average canopy cover compared to nearby communities, less than Mercer Island, Shoreline and Bellevue but more than Seattle or Tacoma. See Figure 30 below. Improvements to regulatory policy such as a tree preservation ordinance would safeguard 27% of Renton's urban forest at risk from development.

Figure 30. Comparison of percent urban tree canopy (UTC) in Renton to that of neighboring cities



Renton's Urban and Community Forestry Development Plan includes realistic and important strategies for increasing canopy cover. Over 2,000 tree planting locations exist along city streets and medians which could curb the loss of 2.7% of the canopy in these areas between 2002 and 2010. Meanwhile, a public education and tree planting campaign is called for in the Plan. To implement this objective, the City should use the canopy results by zoning type, Community Planning Area, and at the individual parcel level along with the GIS locations of 62,000 vacant planting sites identified and prioritized in this study.

Renton has a clear vision and mission for the urban forest of their future. Balancing new development with the protection and conservation of environmental values (related to forest cover such as salmon habitat, air quality, and climate adaptation related to carbon storage and

energy conservation will be an ongoing work item. The economic benefits of urban tree canopy are an incentive to continue in this direction.

Renton's urban forestry program should be consistent with the comprehensive plan. Policies encouraging tree planting and preservation will ensure that livability and urban forestry are the cornerstones of the community.

The Urban Forest along the Cedar River

Appendix

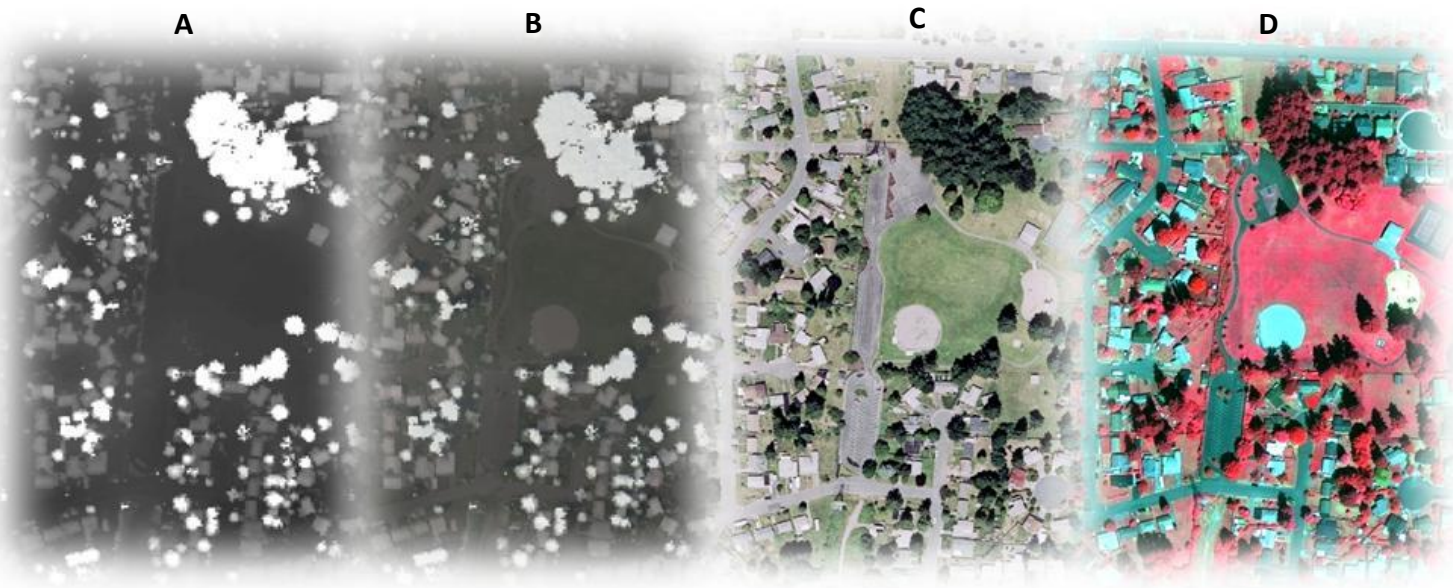
Appendix

The appendix provides additional details on the methods used in the assessment including software, technologies, criteria, and formats of the data. The appendix follows the order in which the steps of the project were taken. It can be used as a reference when certain aspects such as land cover classification or stormwater modeling are performed for monitoring purposes.

Land Cover Classification Methodology

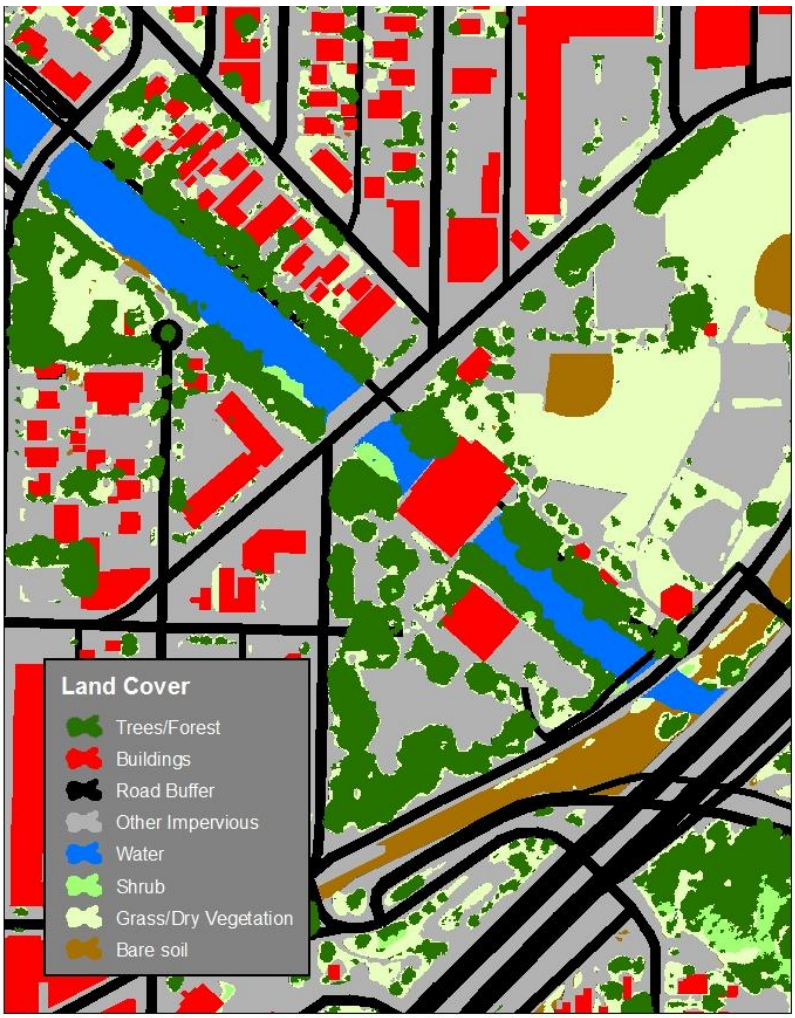
The land cover classification task of a UTC project requires good technical capabilities and attention to detail given that all metrics in which to make improved decisions from stem from this data. AMEC's classification process used Feature Analyst software version 5.0 and a technique known as object-based image classification (OBIA), which is particularly useful for classifying high-resolution multispectral aerial and satellite imagery. For 2002, film-based natural color aerial imagery was used along with 2001 Light Detection and Ranging (LiDAR) data. For 2010, 1.5-foot resolution WorldView-2 satellite imagery was used. Both imagery datasets were collected during summer with "leaf-on" conditions. Only tree canopy data was mapped from the 2002 timeframe while the 2010 analysis included trees/forest (including conifer vs. deciduous classes), shrub, open space/grass, impervious surfaces, water, and bare soil / dry vegetation.

Figure 31. 2001 LiDAR (A), semi-transparent overlay with aerial imagery (B), 2002 King County natural color aerial photography (C) and 2010 WorldView-2 color infrared satellite imagery (D)



Semi-transparent overlay between the 2001 LiDAR and 2002 aerial photography. LiDAR data is flown with a specialized airborne sensor and records vertical elevation values. Whiter objects (pixels) shown have a higher elevation value than darker areas. LiDAR and color-infrared imagery (right) are helpful in automated classification of trees and forests.

Figure 32. 2010 Land Cover Data



Land cover classification

Renton provided AMEC with their existing GIS layers for buildings and street which were incorporated into the land cover classification. Street center lines were buffered by a conservative width to form polygons. Both files were used "as-is" (some features were out of date). "Other" impervious surfaces included parking lots, sidewalks, and patios. Shrub was a separate class based on interpretation of shadows and texture in vegetation. Bare soil also includes dry vegetation (non-photosynthetic). Conifer trees were found to make up roughly 20% of the urban forest (slightly underestimated due to small conifers that were missed). Land cover data was used for all other aspects of the study including Existing UTC, potential planting locations, CITYgreen analysis, and stormwater modeling.

Figure 33. 2010 tree canopy (green), impervious surfaces (black), and areas where tree canopy overhangs impervious surfaces (yellow)

By intersecting the impervious surface GIS layer with the tree canopy layer, the areas in yellow form what is called the "trees with an impervious understory" GIS layer. Only 2% of Renton's trees cover impervious surfaces and only 1.3% of impervious areas are covered by trees. Tree canopy overhanging impervious surfaces provides numerous physical, economic, ecological and quality of life benefits. These include reducing urban heat island effect from shade and evapotranspiration, mitigating pollutants from reaching surface water such as streams, and making walking, biking and shopping more comfortable.

Complete Land Cover and UTC Results

The following tables provide greater detail on the distribution of land cover (2010) by Community Planning Area (CPA) and by each broad zoning category assessed.

Table 7. Acres and percent of land cover per Community Planning Area.

NAME	Total Acres	Tree Acres	Trees %	Impervious Acres	Impervious %	Shrub Acres	Shrub %	Water Acres	Water %	Grass Acres	Grass %	Soil Acres	Soil %
Benson	2,931	948	32.3%	1,049.8	35.8%	151.5	5.2%	0.2	0.0%	752.4	25.7%	29.0	1.0%
Cedar River	1,161	565	48.7%	248.6	21.4%	50.9	4.4%	30.7	2.6%	237.9	20.5%	28.1	2.4%
City Center	1,926	214	11.1%	1,308.2	67.9%	18.9	1.0%	48.3	2.5%	275.7	14.3%	60.9	3.2%
East Plateau	1,307	431	33.0%	470.5	36.0%	50.8	3.9%	7.3	0.6%	326.4	25.0%	20.8	1.6%
Highlands	2,780	639	23.0%	1,363.6	49.1%	42.1	1.5%	1.0	0.0%	680.4	24.5%	53.7	1.9%
Kennydale	1,119	343	30.6%	429.5	38.4%	35.3	3.2%	44.4	4.0%	248.9	22.2%	18.3	1.6%
Talbot	1,498	577	38.5%	501.8	33.5%	69.7	4.7%	0.5	0.0%	336.7	22.5%	11.7	0.8%
Valley	1,908	463	24.3%	928.1	48.7%	111.2	5.8%	21.1	1.1%	278.2	14.6%	106.1	5.6%
West Hill	2,186	625	28.6%	866.8	39.7%	90.5	4.1%	9.3	0.4%	565.3	25.9%	28.8	1.3%
	16,814	4,804		7,166.8		621.0		162.8		3702.0		357.5	

Table 8. Acres and percent of land cover per zoning type.

General Zoning Class	Tree Acres	Trees %	Impervious Acres	Impervious %	Shrub Acres	Shrub %	Water Acres	Water %	Grass Acres	Grass %	Soil Acres	Soil %	Total Acres
Low Density Residential	2,387	32.6%	2,276.1	31.1%	269.8	3.7%	61.2	0.8%	2,230.4	30.5%	98.7	1.3%	**7,323**
High Density Residential	611	32.5%	747.1	39.7%	82.9	4.4%	2.9	0.2%	406.6	21.6%	30.0	1.6%	**1,881**
Commercial	319	15.6%	1,229.5	59.9%	66.5	3.2%	31.2	1.5%	316.9	15.4%	90.0	4.4%	**2,053**
Industrial	255	17.1%	875.5	58.8%	48.6	3.3%	4.6	0.3%	204.4	13.7%	99.9	6.7%	**1,488**
Resource Conservation	829	68.2%	55.4	4.6%	110.7	9.1%	18.9	1.6%	188.1	15.5%	13.6	1.1%	**1,215**
Public Right-of-Way (ROW)	403	14.1%	1,983.2	69.5%	42.5	1.5%	43.9	1.5%	355.7	12.5%	25.3	0.9%	**2,854**
	4,804		7,166.8		621.0		162.8		3,702.0		357.5		**16,814**

Table 9. Complete Urban Tree Canopy results per Community Planning Area.

Community PlanningArea	Total Acres	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Change in UTC Acres	Relative Change in UTC	Raw Change in UTC	No. Planting Sites	No. Planting Sites per Acre	American Forests Goal (%-avg)	Delta (% Above or Below)
Benson	2,931	987	33.7	948	32.3	-39	-4.0	-1.3	12,288	4.2	40	-7.7
Cedar River	1,161	546	47.0	565	48.7	19	3.5	1.6	2,713	2.3	50	-1.3
City Center	1,926	169	8.8	214	11.1	45	26.6	2.3	4,494	2.3	15	-3.9
East Plateau	1,307	552	42.3	431	33.0	-121	-22.0	-9.3	5,549	4.2	40	-7.0
Highlands	2,780	645	23.2	639	23.0	-6	-0.9	-0.2	12,608	4.5	40	-17.0
Kennydale	1,119	322	28.8	343	30.6	21	6.5	1.9	4,440	4.0	40	-9.4
Talbot	1,498	599	40.0	577	38.5	-22	-3.6	-1.5	5,257	3.5	40	-1.5
Valley	1,908	408	21.4	463	24.3	55	13.4	2.9	4,377	2.3	40	-15.7
West Hill	2,186	628	28.7	625	28.6	-3	-0.5	-0.1	10,203	4.7	40	-11.4
Total	**16,814**	**4,856**	**28.9**	**4,804**	**28.6**	**-52**	**-1.1**	**-0.3**	**61,929**	**3.6**	40	-11.4

Table 10. Complete Urban Tree Canopy results per zoning category.

General Zoning Classification	Total Acres	% of Total Area	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Change in UTC Acres	Relative Change in UTC*	Raw Change in UTC	Distrib. Of 2010 UTC by Zoning	No. Planting Sites	American Forests Goal (%-avg)	Delta (% Above or Below)
Commercial	2,053	12%	313	15.2%	319	15.6%	6	1.9%	0.3%	6.6%	5,576	20%	-4.4%
High Density Residential	1,881	11%	611	32.5%	611	32.5%	0	0.0%	0.0%	12.7%	6,996	35%	-2.5%
Industrial	1,488	9%	212	14.2%	255	17.1%	43	20.3%	2.9%	5.3%	2,730	25%	-7.9%
Low Density Residential	7,323	44%	2,488	34.0%	2,387	32.6%	-101	-4.1%	-1.4%	49.7%	39,239	50%	-17.4%
Resource Conservation	1,215	7%	818	67.3%	829	68.2%	11	1.3%	0.9%	17.3%	5,791	25%	43.2%
PROW	2,854	17%	414	14.5%	403	14.1%	-11	-2.7%	-0.4%	8.4%	1,597	25%	-10.9%
Total	**16,814**	**100%**	**4,856**	**28.9%**	**4,804**	**28.6%**	**-52**	**-1.1%**	**-0.3%**	**100.0%**	**61,929**	**40%**	**-11.4%**

Prioritizing Potential Planting Sites

AMEC applied a unique GIS process for prioritizing tree planting locations based on environmental, economic and social factors. The process entails GIS overlay analysis, determining the criteria that influence planting suitability, ranking those factors based on a 0-10 weight, and then generating a suitability score between 0 and 100 for each of Renton's 62,000 potential planting sites. The location of planting sites can be queried in GIS ("How many sites are near riparian areas on public property where the canopy is less than 10%?"), symbolized by their suitability score where larger and darker green indicate more factors are met with a given site, or sorted in descending priority in Excel.

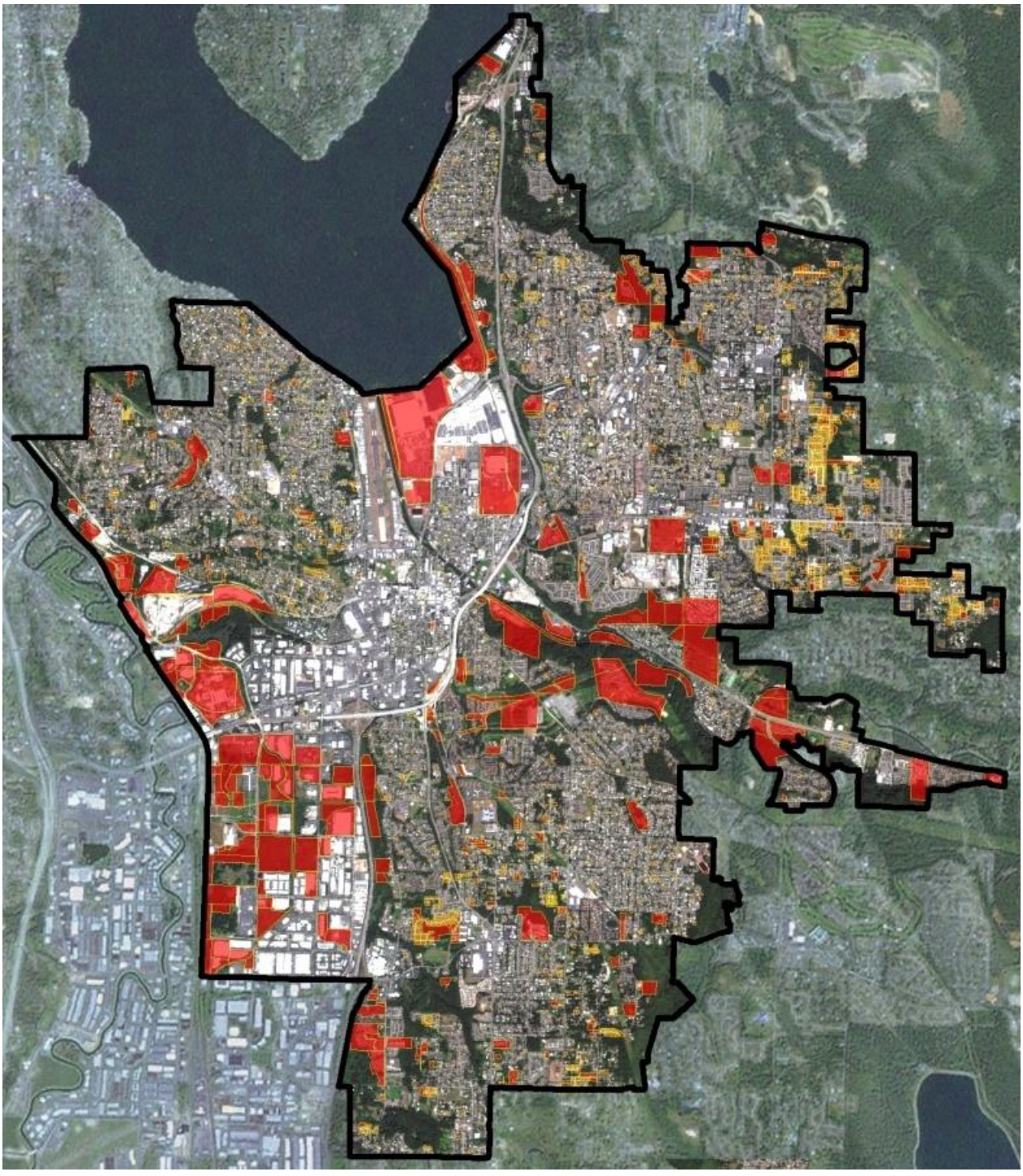
At right in Figure 34 is a "slider bar" tool from CommunityViz software showing the weights that were applied to each factor in the analysis. In general, sites were weighted higher where existing canopy is low, impervious area is high, where canopy has decreased from 2002 to 2010, or if the site is near a building, stream, floodplain or on public property. A site that meets all of these criteria will receive a score near 100. Factors less influential were given lower weights, however the city can use these attributes to select plantings that meet a particular goal such as providing shade along bike paths and trails.

Figure 34. Factors and weights (0-10) in a slider bar for each planting site which can be used to rank or prioritize tree planting sites.

Forest Loss from 2002 to 2010 at the Parcel Level

Forest loss at the parcel level can be seen in Figure 35 below. The parcels that are visible (semi-transparent red with an orange outline) had more than .5 acre or more than 25% forest was lost between 2002 and 2010. This is a sample query. The GIS query to produce the map below looks like this: ["UTC_AC_CHG" > .5 OR "UTC_PC_CHG" < -25]. Any number of similar queries can be made of the Parcels_UTC database delivered in this project.

Figure 35. Example of using the UTC metrics in Renton's parcels database to show forest loss trends



Modeling Urban Forest Benefits for Stormwater

Tree canopy can have profound effects on the hydrology of an ecosystem due to their large size and broad intercepting surface area. Benefits include raising the water table, decreasing stormwater runoff and erosion, and improving water quality. In addition, evapotranspiration and storage from the canopy are major influences in the hydrologic water balance.

The elevation range across the City of Renton is from 555' to 3' at Lake Washington. The soils within the watershed consist of Hydrologic soils groups A, B, C, and D as defined by the Natural Resources Conservation Service.

The City of Renton consists of approximately 52.7% low density residential, 13.4% high density residential, 14.6% commercial, 10.5% industrial, and 8.7% resource conservation. The tree canopy hydrologic analysis focused on these 5 land uses for categorical comparison.

A hydrologic analysis of the City of Renton focused on parcel level hydrologic analysis between baseline conditions and future conditions that incorporated GIS-based potential tree planting sites. This analysis was performed for each of the identified land use categories on a spatially averaged parcel basis.

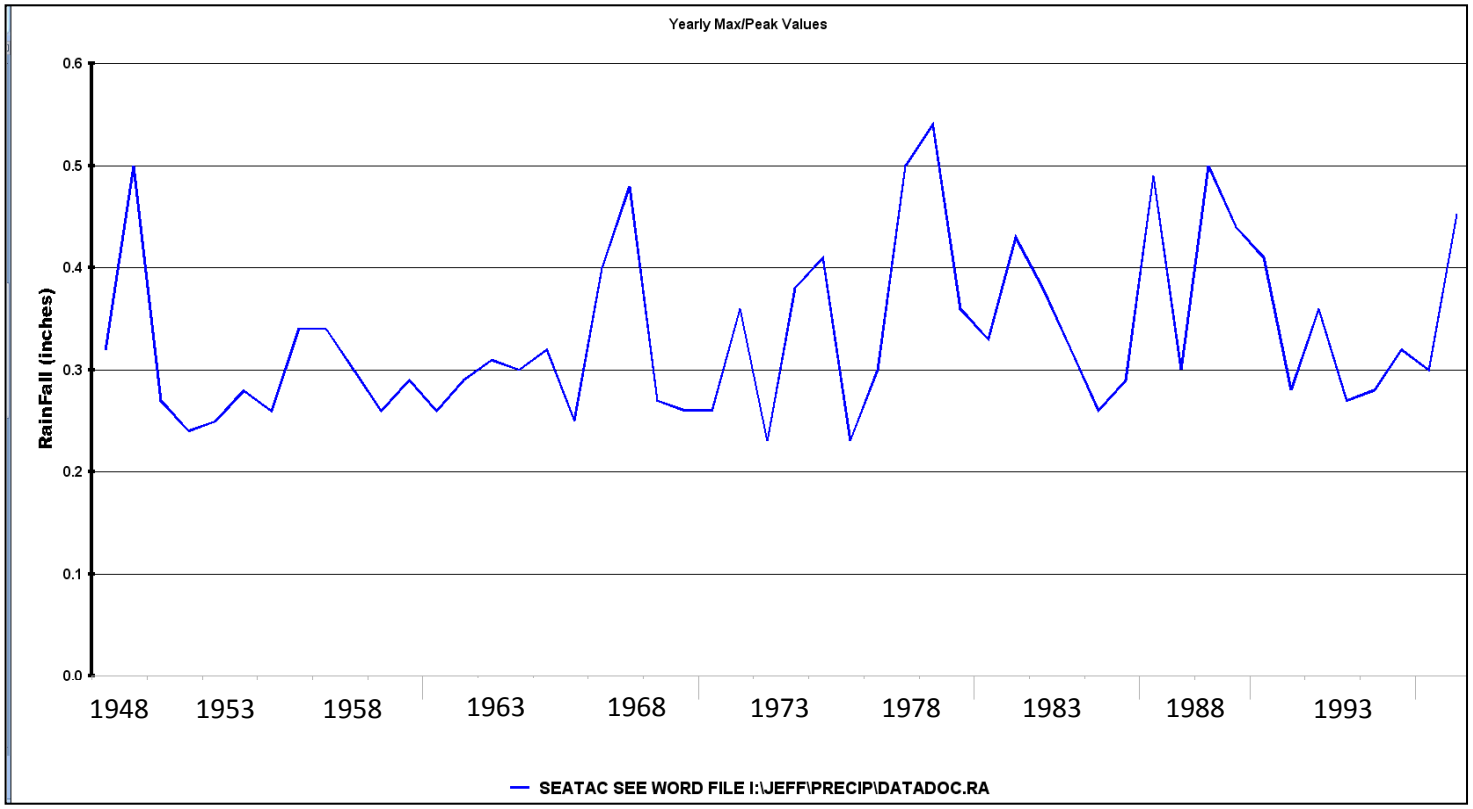
Design rainfall, physical runoff characteristics, and runoff hydrographs for the baseline hydrologic model were developed and derived using the Western Washington Hydrologic Model 3.0 (WWHM), specifically for peak flow and volume measures based on interception and infiltration calculations. WWHM is the preferred model for the 19 counties in Western Washington and is based on continuous simulation hydrology (HSPF), long-term recorded precipitation data, long term pan evaporation data, and regional HSPF parameters.

Note: "Pan evaporation is a measurement that combines or integrates the effects of several climate elements: temperature, humidity, rain fall, drought dispersion, solar radiation, and wind" (Wikipedia).

Design Rainfall

Long term precipitation data from the Seatac gauge was used to perform continuous simulation hydrology. The precipitation data used for continuous simulation was from 10/01 1948 through 09/30 1998. The continuous simulation depths from 10/01 1948 through 09/30 1998 are presented in Figure 36.

Figure 36. Yearly Max Peak Values



Parcel Characteristics

Parcel Determination

The City of Renton was not delineated in watershed components for hydrologic assessment but rather in average parcel land use watersheds. Each unique spatially distributed parcel was categorized by land use type (High Density Residential, Low Density Residential, Commercial, Industrial, and Resource Conservation). Statistical analysis was performed on the each land use category to determine the average parcel size within the City of Renton for each of the land use categories. The average land use size was used as the baseline watershed size for each land use category. Table 11 shows the average parcel size for the land use category.

Table 11. Average Parcel Size per Land Use

Land Use Category	Average Size (acre)
High Density Residential	0.604
Low Density Residential	0.301
Commercial	1.114
Industrial	4.413
Resource Conservation	7.595

Land Cover

Land cover categories for WWHM are categorized as forest, pasture, lawn, roads, roof tops, driveways, sidewalks, and parking lots. There is not a category for urban trees. Each land cover

category was spatially intersected with the parcel land use data to determine polygons with unique land use and land cover categories.

Soils Information

Several Natural Resources Conservation Service (NRCS) soil types are present within the City of Renton. The significant majority of NRCS soils within the Littles Creek watershed are classified as hydrologic soil classification C. Refer to Appendix A and B of the Western Washington Hydrology Model Version 3.0 user's manual for HSPF infiltration parameters with their associated land use, land cover, hydrologic soil group, and percent grade.

Basin Area Determination

Using Renton's parcel land use information, the land cover data from this project, hydrologic soil group information, and ground slope information, the City was intersected into 155 unique categories that all were summarized by land use type. This provided spatially correct distribution of all hydrologic parameters normalized to the average land use category. This provided a baseline hydrologic model for each of the land use categories with spatially distributed land cover/soils/slope on an average basis.

Future Conditions

Future conditions parcel characteristics were determined by using spatially distributed potential tree planting sites. These future tree planting sites were categorized as forest land cover and replaced the corresponding baseline conditions land cover. This resulted in a net change of land cover from lawn/pasture to forest for future conditions. It was assumed that the diameter of each tree crown at full growth was to be 50 feet. Table 12 shows the potential tree planting in trees/acre and tree plantings per average parcel size for each land use category in future conditions.

Table 12 Future Conditions Tree Plantings

Land Use Category	Future Conditions	
	Tree Plantings (per acre)	Tree Plantings (per average parcel size)
High Density Residential	3.70	2.23
Low Density Residential	4.99	1.50
Commercial	2.69	2.99
Industrial	1.85	8.18
Resource Conservation	1.30	9.85

As an example from the analysis, Low Density Residential zoning in Renton averages roughly 5 potential tree planting sites per acre. Taken into account average parcel size for this zoning type, there are 1.5 tree planting sites per parcel. Note that average parcel size is not shown.

Analysis and Results

Flow frequency analysis was performed for both baseline and future conditions hydrologic models. The flow frequency analysis return periods are for the 2-year, 5-year, 10-year, 25-year, 50-year and the 100-year events. Table 13 shows the percent reduction in return period events between baseline conditions and future conditions.

Table 13 % Peak Flow Frequency Reduction between Future and Baseline Conditions

Land Use Category	Flow Frequency Return Period					
	2-year	5-year	10-year	25-year	50-year	100-year
High Density Residential	-3.6%	-4.7%	-5.1%	-5.7%	-6.1%	-6.6%
Low Density Residential	-5.7%	-7.2%	-8.0%	-8.9%	-9.4%	-10.0%
Commercial	-2.0%	-2.4%	-2.7%	-3.1%	-3.3%	-3.5%
Industrial	-1.2%	-1.5%	-1.7%	-2.0%	-2.1%	-2.3%
Resource Conservation	-2.2%	-2.6%	-2.7%	-2.9%	-3.1%	-3.2%

As an example, an average 8% reduction in peak flow is seen on Low Density Residential (LDR) parcels for a 10-year storm event given that tree plantings reach the 50-foot modeled crown diameter. This is higher than in other zoning types due the greater number of potential planting sites in LDR zoning seen in Table 12 above.

Continuous simulation hydrology from 10/01/48 through 09/30/98 provides runoff volume for both the baseline and future tree planting conditions. The baseline conditions average runoff volume for any given year from 1948 through 1998 was compared to the average runoff volume for the future tree plantings condition. Table 14 shows the average yearly runoff volume reduction as a result of future conditions tree planting interception. Rainfall interception from the tree canopy is the only assumed volume reduction during this analysis. Understory considerations were also factored into the tree canopy evaluation.

Table 14. Future Conditions Volume Reduction

Land Use Category	Future Conditions	
	Average Yearly Runoff Volume Reduction (gallons)	Average Yearly Runoff Volume Reduction per Tree Planting (gallons)
High Density Residential	5,330	2,390
Low Density Residential	3,585	2,390
Commercial	7,146	2,390
Industrial	19,550	2,390
Resource Conservation	23,542	2,390

The results show a significant reduction is both percent peak runoff and runoff volume for the 5 average parcel land use types within the City of Renton. The above mentioned quantitative benefits for the City of Renton would not only provide peak flow reduction and runoff volume reduction, but achieve water quality benefits as well. If the future tree plantings can be achieved within the City of Renton, the runoff response will not only be peak reduction, reduced runoff volume, and water quality benefits, but help address duration, velocity, and frequency. The benefits for future tree plantings provide an effective and readily implemented compliance tool that serves to incentivize site design strategies enhancing and avoiding impacts to the natural or existing hydrologic response of the site.

WWHM REFERENCES

Clear Creek Solutions, *Western Washington Hydrology Model – version 3.0*

Clear Creek Solutions, *Western Washington Hydrology Model – version 3.0, Users Manual, August 2006*