city of kirkland
washington

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URBAN TREE CANOPY ASSESSMENT REPORT

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Executive Summary

The City of Kirkland is committed to preserve, protect and sustain its natural resources while meeting the demands of a growing suburban city. To achieve balanced growth, Kirkland's Comprehensive Plan established a citywide 40 percent tree cover goal as recommended by the American Forest's 1998 ecosystem analysis of the Puget Sound area. In support of the policies outlined in the Comprehensive Plan, the City implemented comprehensive tree regulations in 2006. This study measures Kirkland's urban tree canopy cover, analyzes canopy gains and losses, and explores the potential for tree canopy maintenance and enhancement.

Trees are a valuable natural resource for the City of Kirkland that provide multiple benefits including increased property value, pollutant removal, stormwater runoff reduction, carbon sequestration, energy savings, and other valuable ecosystem functions.

With a recent annexation nearly doubling Kirkland's area, it is vital to gauge canopy cover as a performance measure for a sustainable urban forest and a healthy environment. The data provided by this local level canopy analysis will enable Kirkland's leaders and citizens to continue with its legacy of stewardship.

Kirkland's Existing Urban Tree Canopy

Mapped from 1.5-foot 2010 satellite imagery with "leaf-on" conditions, Kirkland was found to have 2,450 acres (36.0%) of tree canopy, not including the recent annexation area. As a comparison, this rate coincides with the current canopy cover in Bellevue (36%), is higher than Renton (28.6%) and Shoreline (31%), and slightly less than Mercer Island (41%). When including the annexation area, Kirkland's current canopy cover is 40.7%.

This report provides existing canopy cover results within 6 zoning categories including the public right-of-way (streets), by public and private properties, and for each of Kirkland's 15 drainage basins.

Change in Urban Tree Canopy Change Since 2002

This study includes mapping 2002 tree canopy within Kirkland's boundaries before annexation, then comparing canopy within the same boundary with current imagery. The baseline year was selected for the best imagery available prior to the City's tree codes' effective date. Comparing baseline canopy data to 2010 imagery helps verify trends in canopy gain or loss and allows detailed analysis by zoning classification and parcels. Despite development pressure within the region, Kirkland gained 4.4% tree canopy between 2002 and 2010, compared to more substantial canopy loss of nearby cities.

UTC Goal Setting Process

This study is a comprehensive and scalable inventory of Kirkland's tree canopy: a top-down map of Kirkland's green infrastructure. As in any business model, stakeholders need an asset inventory in order to effectively manage the asset, set goals and monitor progress towards the goals.

Cities and communities set Urban Tree Canopy (UTC) goals as a planning tool to achieve greater environmental, human health and social standards. Adopting the City's tree regulations was a laudable first step towards reaching the recommended canopy goal for the region. However, even with canopy goals and tree protection policies in place, communities need to gauge their progress and determine how effective their tree protection has been over time. This study:

- Measures Kirkland's canopy in the pre-annexed area during a benchmark year prior to the adoption of the City's trees regulations
- Compares benchmark year canopy data to current canopy data within the same area
- Analyzes canopy statistics by land use, zoning, watershed, and parcel level detail to calculate canopy gain or loss in the pre-annexed areas
- Includes canopy data in the newly-annexed area for future canopy studies

Results showing specific gaps in canopy targets by zoning category were used by AMEC to assist in Kirkland's goal setting process.

Strategies and Recommendations

To meet and maintain Kirkland's UTC goals, it's important to use a diversity of strategies including education and outreach efforts, offering incentives to increase urban tree canopy, and supporting the City's goals and objectives with regulatory measures.

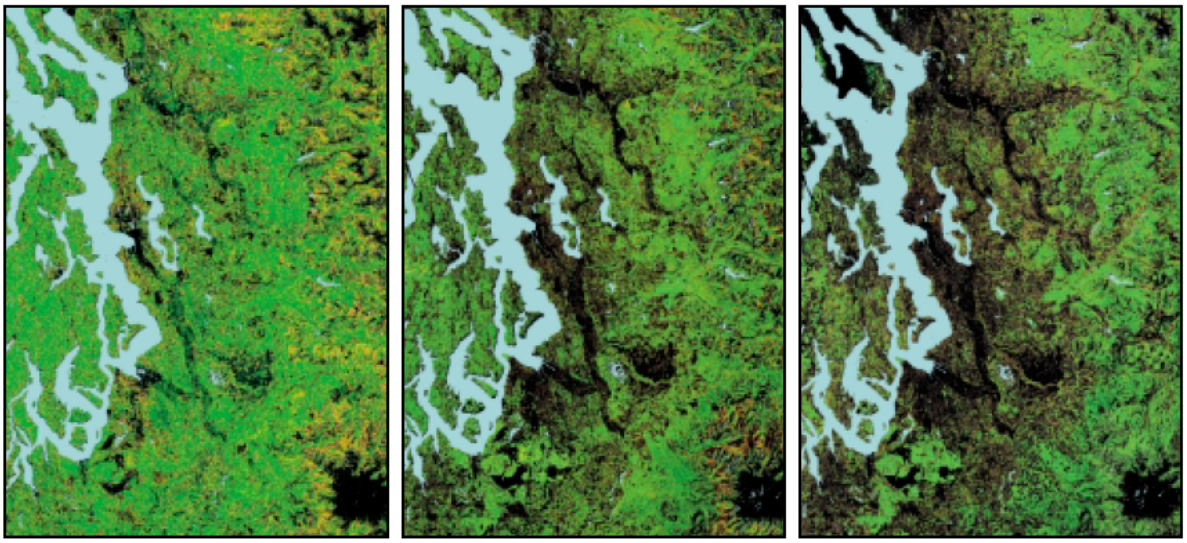
With 36 percent existing tree canopy cover in the previous city limits, the focus in Kirkland should be enhancing canopy in the areas identified in this study. When considering the current canopy data in the newly-annexed area, the City should protect and maintain the existing healthy urban forest by continued efforts outlined in the city's 20-Year Forest Restoration Plan and Chapter 95 of the Kirkland Zoning Code. In addition, an Urban Forest Management Plan could detail appropriate strategies to proactively manage the City's urban forest resources.

Kirkland volunteers maintaining a healthy urban forest

Introduction

In 1998, a study was performed by American Forests which highlighted alarming downward trends in forest cover at the regional scale (Figure 1).

Figure 1. Land cover change showing increased development (in black) in the Puget Sound region

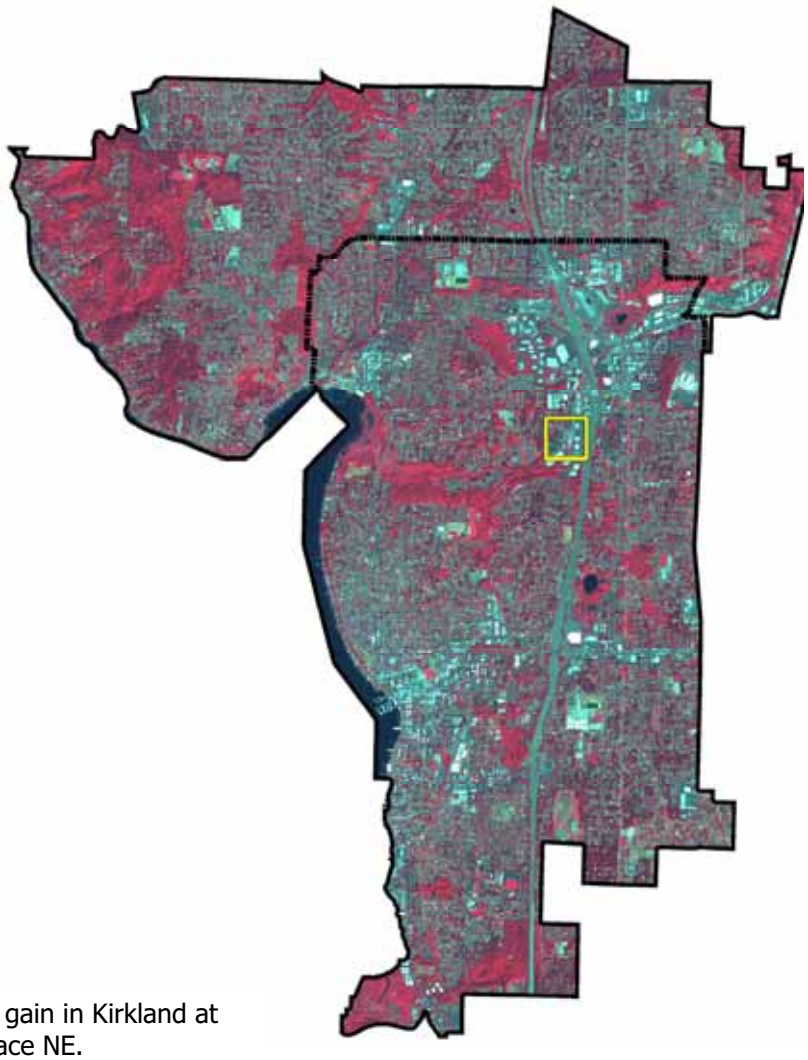


When Kirkland's Comprehensive Plan was drafted, the City had not planned how to measure or monitor its tree canopy. When the City's tree regulations were adopted in 2006, the City Council requested that a tree canopy assessment be undertaken in 2010 to evaluate the effectiveness of the regulations.

With funding support from the U.S. Forest Service and the Washington Department of Natural Resources Urban & Community Forestry Program, AMEC Environment & Infrastructure, Inc. was contracted in March 2011 to assist the City in performing this analysis using Geographic Information Systems (GIS) and satellite imagery. The results of this report are meant to inform the public, City staff and decision-makers of Kirkland's canopy status, compare Kirkland's UTC metrics with other cities in the region, provide recommendations to maintain or enhance canopy towards the City's visions and goals, and increase awareness of urban forest benefits.

Geographic Information Systems (GIS) offer powerful tools for supporting decision-making through mapping, analysis and spatial visualization of data and information. Urban Tree Canopy (UTC) assessments are a cost-effective method to assess tree cover over time. UTC assessments, together with other software programs available through U.S. Forest Service and other organizations can be used to place a value on urban forests.

Figure 2. 1.5-foot resolution WorldView-2 satellite imagery (DigitalGlobe) shown in color-infrared where vegetation appears in shades of red. The yellow box references the location of the inset images in Figure 3 below.



The comparative study area covers the existing city limits prior to annexation. In addition, current data was compiled on the newly-annexed areas of Finn Hill, North Juanita and Kingsgate neighborhoods were included, an area which approximately totals 18 square miles. Figures 2 and 3 show the combined project area with color-infrared satellite imagery and an example of tree canopy gain from urbanized landscaping.

The land cover data, including impervious surfaces and 'Existing' and 'Possible' UTC GIS layers are the most comprehensive sets of data the City has compiled to date for potential stormwater, carbon and other environmental modeling.

Figure 3. Example of 2002 to 2010 tree canopy gain in Kirkland at the intersection of NE 112th Street and 117th Place NE.

Major Findings

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

- *In Kirkland, 2,450 acres (36.0%) of tree canopy exists, not including the annexation area.*
- *In the pre-annexed area, a gap of 4.0% UTC was calculated from the City's Comprehensive Plan 40% UTC goal.*
- *In the pre-annexation area of Kirkland, planting approximately 5,600 additional large trees (50-foot crown spread at maturity) would attain the 40% UTC goal.*
- *Citywide, Kirkland had a net gain of 4.4% UTC from 2002-2010 from 31.6% to 36.0%. Recent tree canopy regulations appear to be very effective at increasing and maintaining tree canopy.*
- *Relative to 2002, this represents a 13.9% increase in canopy.*
- *The Holmes Point drainage basin has the highest UTC (63.3%) while the Houghton Slope A drainage basin has the lowest (27.1%).*
- *Industrial and Single Family Residential (LDR) zoning are below American Forest's recommendation of 25% and 50% canopy cover respectively.*
- *Park and Open Space zoning makes up just 9% of Kirkland, however 15% of the City's tree canopy is found in this zoning type, which has 66% tree canopy in 2010.*
- *By zoning type, the largest gains were found in Commercial, Multifamily Residential, and Public Rights-of-Way at 5.4%, 7.1% and 6.9% respectively.*
- *The only zoning type with marginal increase was Parks and Open Space.*
- *All six zoning types assessed saw an increase in canopy cover. Single Family Residential provided the greatest acres of gain (117) with Right of Way and Commercial next (77 and 65 acres respectively).*
- *Including the annexed neighborhoods of Finn Hill, Juanita and Kingsgate, the City of Kirkland has 4,637 acres of tree cover or 40.7% UTC.*
- *Kirkland's newly-annexed existing tree canopy is higher compared to UTC studies in Bellevue, Mercer Island, Renton, Seattle, Shoreline, and Tacoma*

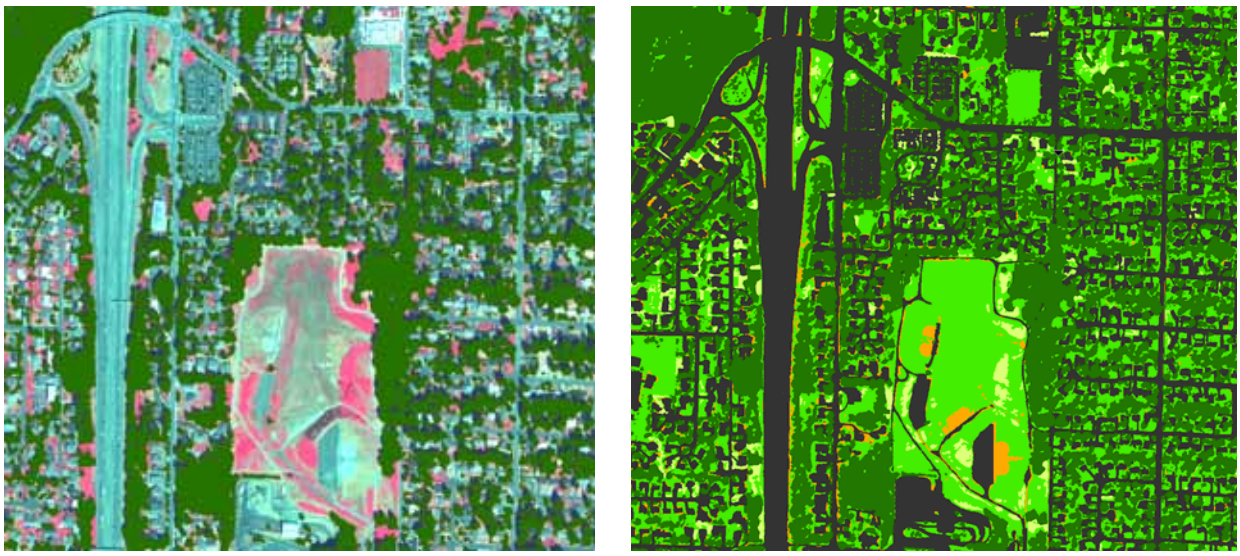
Data Inputs, Methodology and Land Cover Results

UTC assessments require geographic information systems (GIS), aerial or satellite imagery, and GIS data layers from the community. These inputs are used to map land cover data and summarize the area and percent of UTC for various boundaries. Additional information is provided in the Appendix.

Figure 4. Imagery used in Kirkland's UTC Assessment

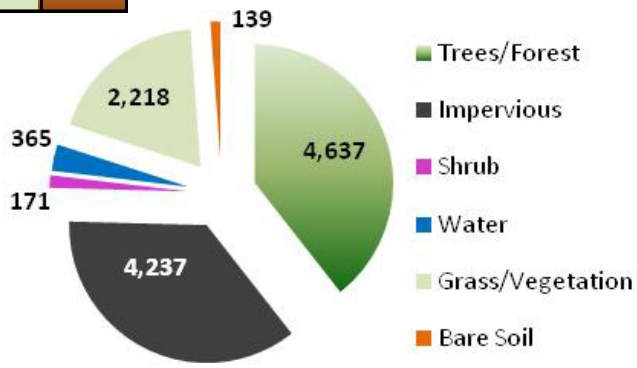
For this project, 2001 LiDAR (Figure 4, left panel), 2002 aerial natural color imagery (center panel), and 2010 multispectral satellite imagery (right panel) were used to map tree canopy (Figure 5 below). Five other land cover classes were mapped (Figure 6 below). Canopy cover percentage (%) is based on land area only.

Figures 5 & 6. Tree canopy shown in green areas (left). Other land cover classes (right)



	Total Acres	Trees %	Impervious %	Shrub %	Water %	Grass %	Soil %
City of Kirkland	11,768	39.4%	36.0%	1.5%	3.1%	18.8%	1.2%

Table 1 & Figure 7. Current city-wide land cover distribution in Kirkland including the recent annexation. Although a land cover classification, water is excluded when calculating UTC metrics.



Existing Urban Tree Canopy and Trends from 2002-2010

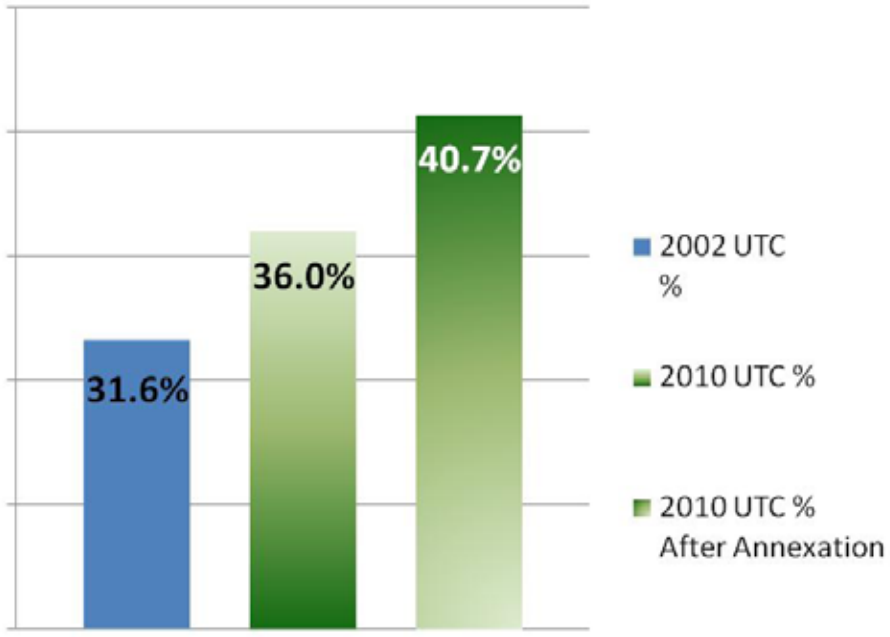
The primary scope of this project was to measure tree canopy cover in Kirkland prior to annexation to assess the effectiveness of the City's tree regulations. The study also allows the City to assess where they are in relation to the 40% UTC goal. Canopy change from 2002 to 2010 was calculated only for the pre-annexation area.

Prior to annexation, the City's land area covers approximately 6,806 acres, of which 2,450 acres (36.0%) was covered by trees based on 2010 imagery. Using 2002 imagery, the City's tree canopy was found to be 2,151 acres or 31.6%. This represents a net gain of 299 acres of tree canopy or 4.4%. When considering the change in canopy cover relative to the acres in 2002 and the acres in 2010, this is a 13.9% gain in tree canopy. The City's gap to achieving 40% UTC in the pre-annexed area is 4.0% or 272 acres.

The citywide (post-annexation) land area covered approximately 11,403 acres of which 4,637 are tree covered (40.7% UTC).

City of Kirkland	Total Land Acres	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Change in UTC Acres	Relative Change in UTC (%)	Raw Change in UTC (%)
Pre-Annexation	6,806	2,151	31.6	2,450	36.0	299	13.9	4.4
Post-Annexation	11,403	--	--	4,637	40.7	--	--	--

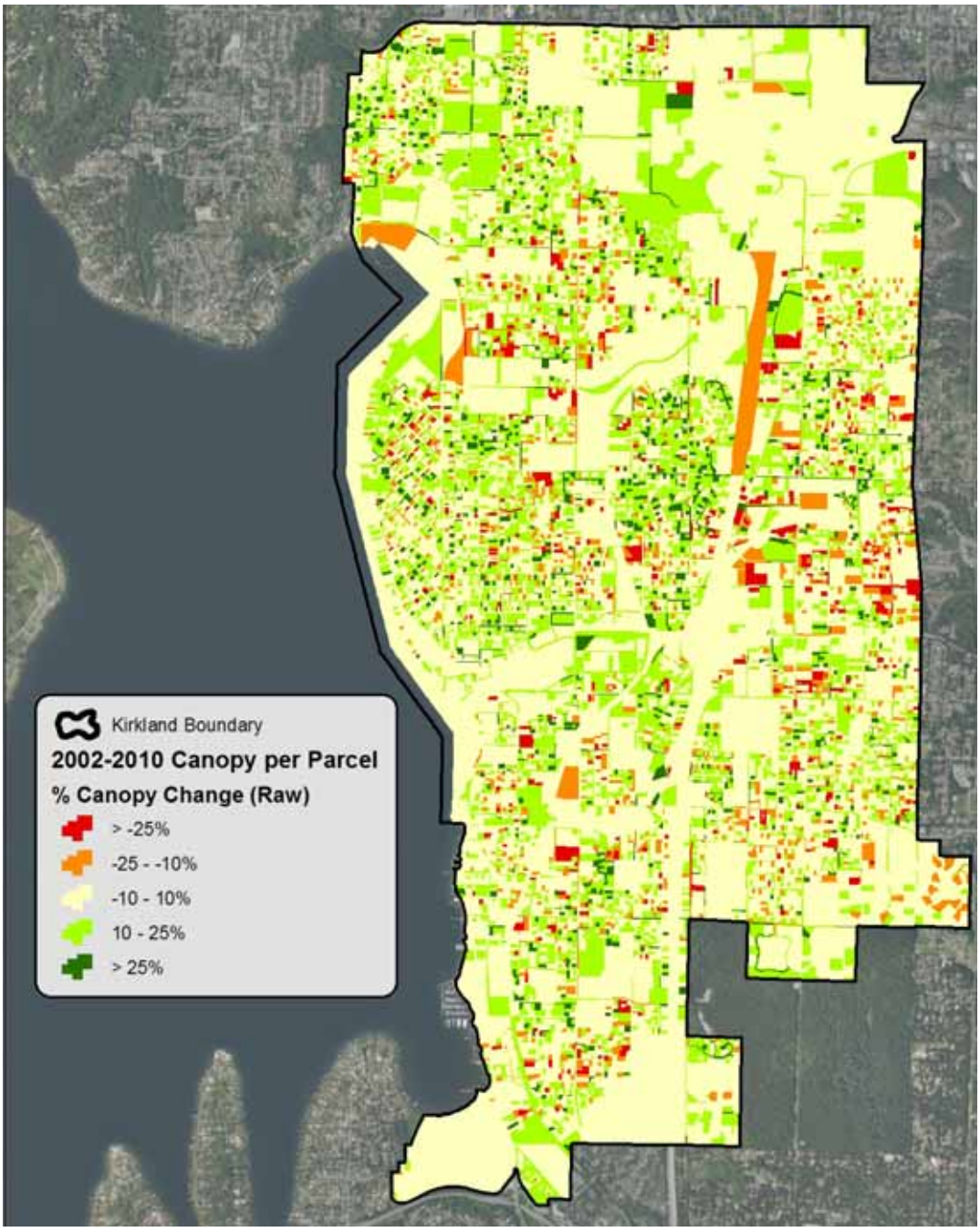
Table 2 (above) **& Figure 8** (below)**.** UTC metrics for 2002, 2010 and post-annexation.



Parcel Level

For improved planning and to assist with goal-setting, tree canopy cover was calculated for each parcel (property) boundary. The GIS and Excel databases delivered as part of this project include the area calculations, 2002 and 2010 tree canopy percentages and change of UTC ratios. By identifying these attributes on a parcel level, the information becomes another tool in which to study trends in the City's urban tree canopy. Figure 9 below shows individual parcels color-coded by the percent (%) of tree canopy change. Dark red indicates higher tree canopy loss; dark green indicates higher canopy gain.

Figure 9. Map of canopy change per parcel from 2002 to 2010



Results for Generalized Zoning Categories

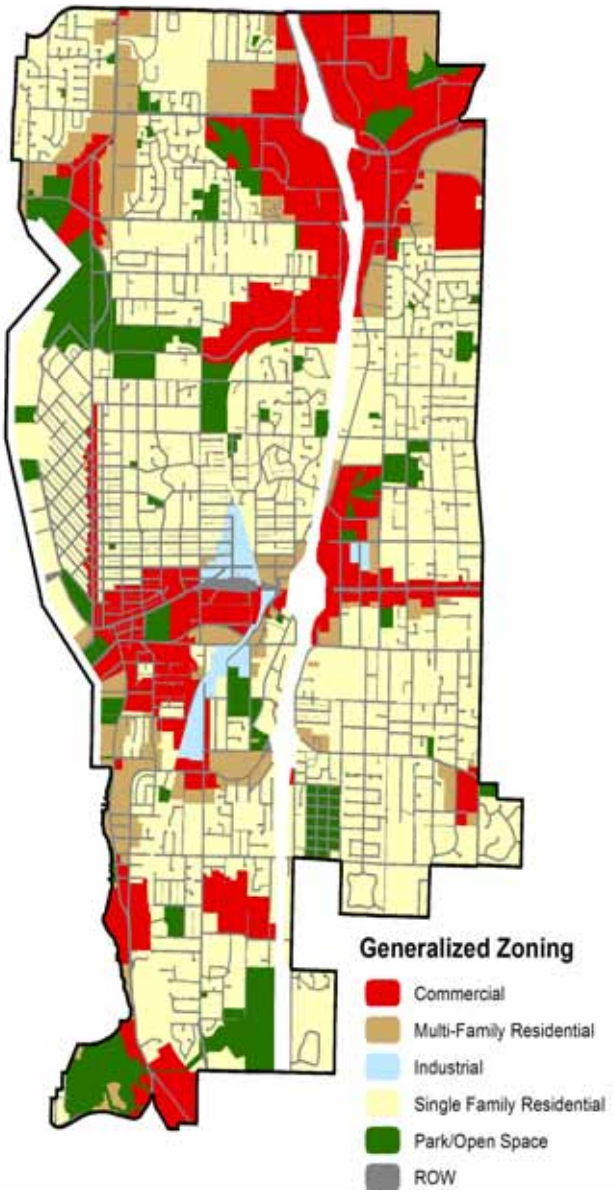
Kirkland's 144 different land use zoning districts were consolidated into six zoning categories. These Generalized Zoning Categories were then mapped to assess the existing, potential and change in tree canopy from 2002 to 2010. The map at right illustrates the distribution of these broad zoning types within the pre-annexed area of Kirkland.

The distribution of zoning and percent of 2010 UTC by zoning is shown in Figures 11 and 12 (below).

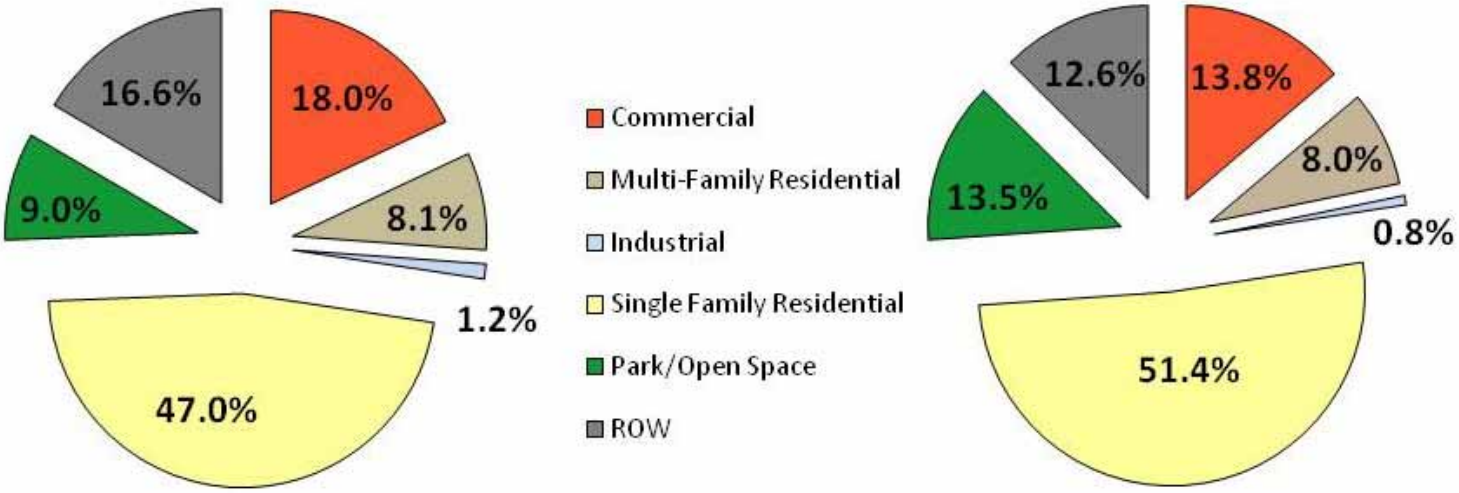
Did you know?

- *Prior to annexation, 55.1% of Kirkland was zoned Single or Multi-family Residential, yet this land use zone makes up 59.4% of the city's tree cover.*
- *While only 9% of Kirkland is zoned "Parks/Open Space," this represents 13.5% of the City's entire tree canopy.*

Figure 10. Generalized zoning map



Figures 11-12. Generalized zoning distribution (below left) and percentage of Kirkland's UTC by zoning category (below right)



Existing UTC and Canopy Change by Zoning Type Compared to American Forest Goals in the Pre-Annexation Area

Table 3. 2002-2010 UTC Zoning comparison to American Forest's recommended goals for land use in the Puget Sound

General Zoning Classification	% of Total Area	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Distrib. Of 2010 UTC by Zoning	Change in UTC Acres	Relative Change in UTC*	Raw Change in UTC	UTC Goal	Delta (% Above or Below)
Commercial	18%	266	22.0%	331	27.5%	13.8%	65	24.5%	5.4%	20%	7.5%
Multi-Family Residential	8%	153	28.2%	192	35.3%	8.0%	38	25.0%	7.1%	35%	0.3%
Industrial	1%	16	18.8%	18	22.1%	0.8%	3	17.3%	3.2%	25%	-2.9%
Single Family Residential	47%	1,114	35.5%	1,232	39.2%	51.4%	117	10.5%	3.7%	50%	-10.8%
Park/Open Space	9%	318	52.7%	324	53.8%	13.5%	6	2.0%	1.0%	25%	28.8%
ROW	17%	225	20.3%	302	27.2%	12.6%	77	34.2%	6.9%	25%	2.2%
Total	**100%**	**2,092**	**31.3%**	**2,398**	**35.9%**	100.0%	**307**	**14.7%**	**4.6%**	**40%**	**-4.1%**

From a percentage standpoint, UTC in the right-of-way increased more than any other zoning type.

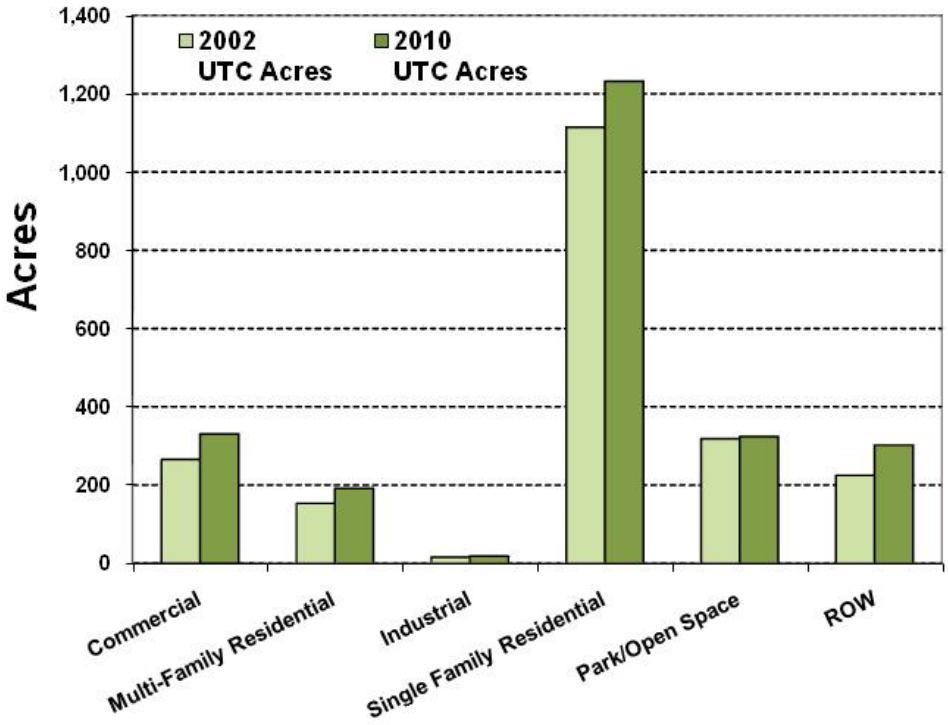
Single Family Residential properties gained the most UTC acres (117) but are 10.8% below American Forest's recommended goal.

At 27.5% UTC, commercial zoning is above American Forest's recommended goal for this zoning type.

54% of Kirkland's parks are tree-covered.

Kirkland's Industrial areas have the lowest tree cover (22%) of all zoning classes.

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



Note: Total zoning area does not include water or land area in the Interstate-405 corridor

2010 Urban Tree Canopy (UTC) Results by Zoning Category including Finn Hill, North Juanita and Kingsgate

For future monitoring purposes, the analysis included UTC results taking into consideration Kirkland's new city boundary with the City's annexation June 1, 2011.

The annexation increased Kirkland's UTC from 36.0% to 40.7% due to a large presence of single family residential (SFR) and park/open space zoning (see Figure 14 at right) which had high canopy cover. The annexation increased Kirkland's SFR from 47% to 55%. As a result, 60% of all tree canopy is found on SFR properties (see Table 4 below).

Total acres and UTC percent do not incorporate the Interstate 405 corridor.

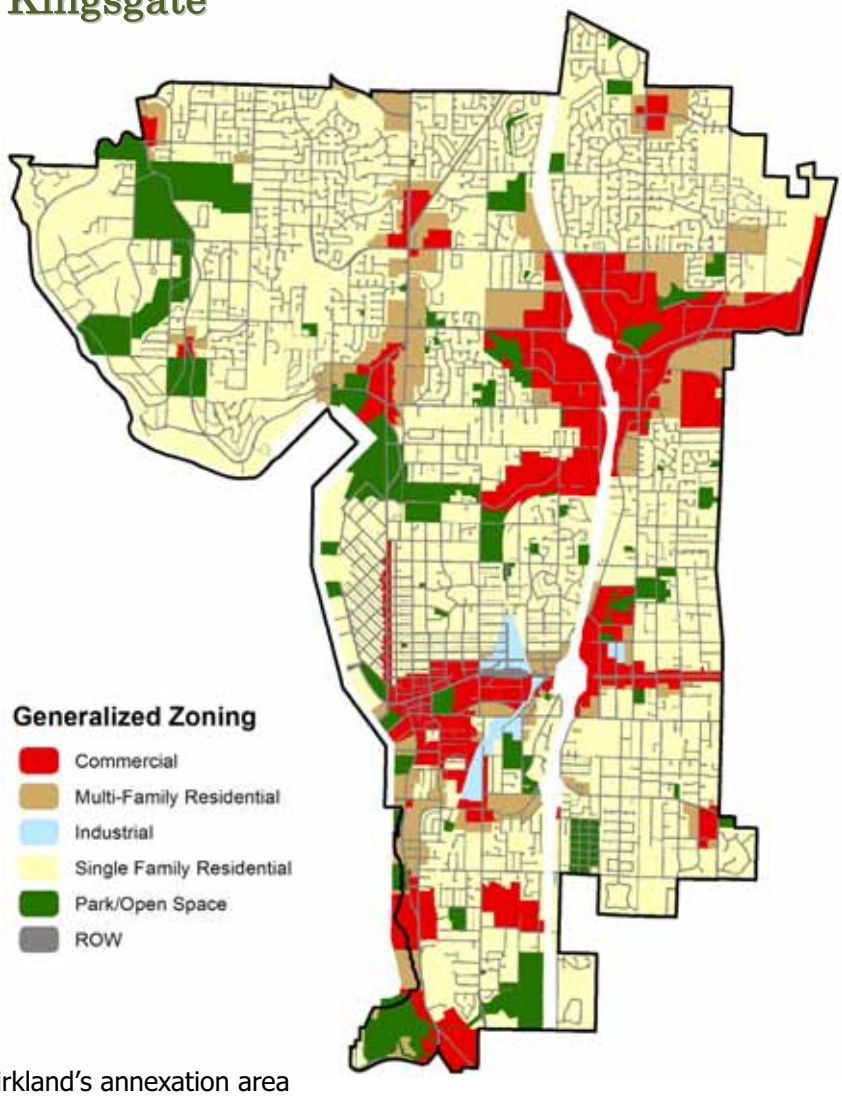


Figure 14. (above) Map illustrating the Generalized Zoning Categories in Kirkland including the annexed areas.

Table 4. 2010 UTC Results by Zoning including Kirkland's annexation area

General Zoning Classification	Total Acres	% of Total Area	2010 UTC Acres	2010 UTC %	Distrib. Of 2010 UTC by Zoning
Commercial	1,387	12%	364	26.3%	8.0%
Multi-Family Residential	794	7%	282	35.5%	6.2%
Industrial	83	1%	18	22.1%	0.4%
Single Family Residential	6,185	55%	2,740	44.3%	60.1%
Park/Open Space	1,007	9%	664	66.0%	14.6%
ROW	1,837	16%	494	26.9%	10.8%
Total	**11,293**	**100%**	**4,563**	**40.4%**	**100.0%**

Results by Drainage Basins for Existing UTC

Kirkland's Drainage Basins were assessed for current tree canopy cover, including the newly annexed areas. Urban Tree Canopy (UTC) measured at this scale is extremely useful information for watershed- and neighborhood-level planning. Kirkland's drainage basins or watersheds were delineated for the percent of 2010 existing UTC. Canopy cover in the northeastern annexed area is very high with Holmes Point Basin at 63.3% UTC and Denny Creek Basin at 55.9% UTC.

Evidence supports the link between higher UTC in watersheds to decreased contaminants from urban runoff into Lake Washington. Higher percentages of tree cover and other vegetation within watersheds correlates directly to quality creek, stream and lake habitat, reduced runoff and improved surface water quality.

A full table of results by drainage basin is included in the Appendix.

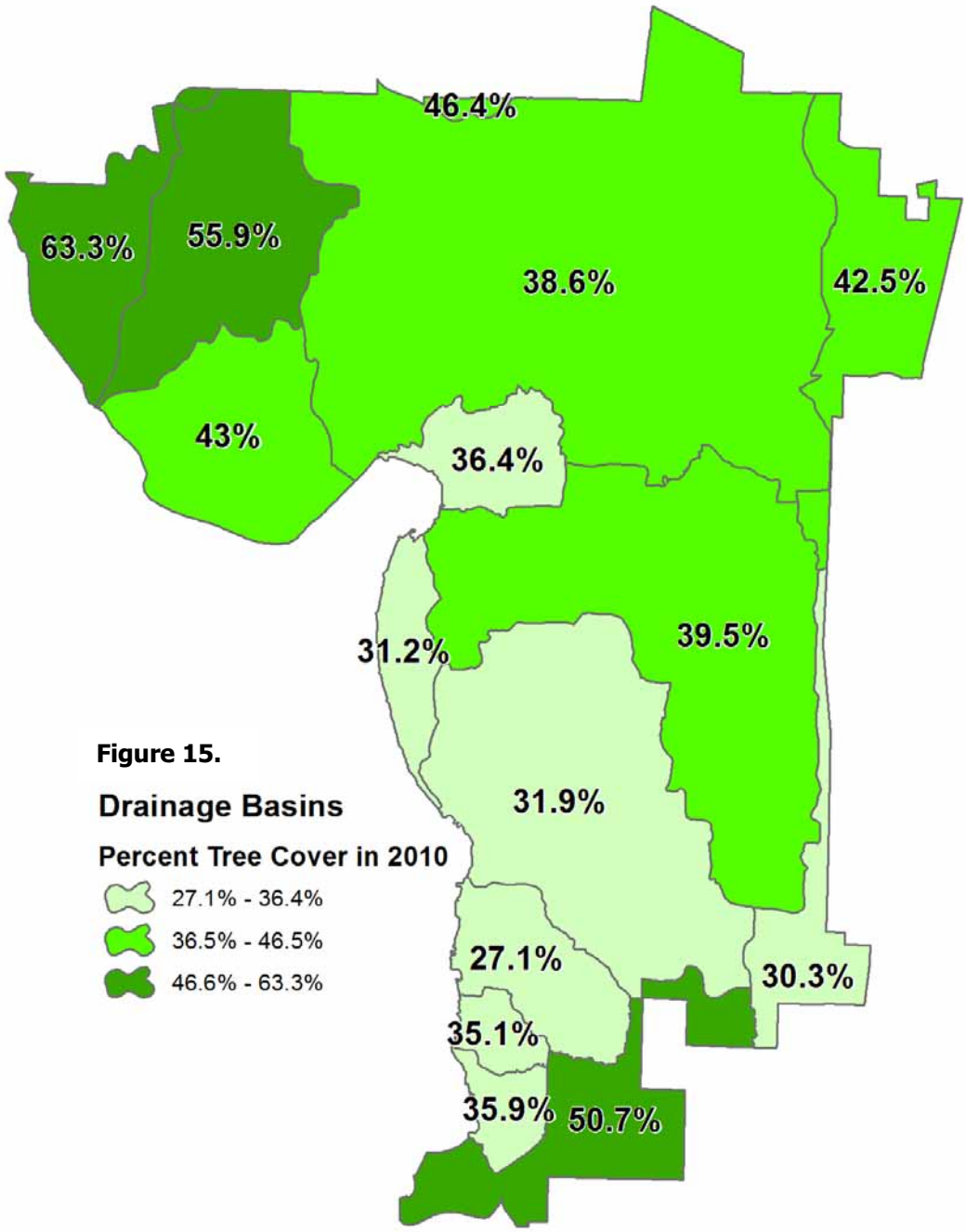


Figure 15.

Assessing Kirkland's Possible UTC

Goal setting involves a number of stakeholders and accurate data from which to base decisions on. Using Kirkland's 2010 land cover data and supporting GIS layers, this study involved an analysis of Kirkland's "Possible UTC". Possible UTC is defined in two categories: Possible UTC Vegetation and Possible UTC Impervious.

Existing UTC

All vegetated areas not covered by trees, forest or shrub, typically lawn and open space areas are Possible UTC Vegetation. After removing buildings and roads, the remaining impervious areas, which are typically parking lots, driveways, patios and other paved surfaces define the Possible UTC Impervious areas. Both areas represent US Forest Service protocols for where it is biophysically feasible to establish tree canopy. Possible UTC is liberal by including all of these areas but conservative where tree canopy can overhang other areas.

Possible UTC Vegetation

With 1,491 acres of Possible UTC Vegetation and 703 acres of Possible UTC Impervious (Table 5 below), more opportunities exist for potentially increasing canopy in Single Family Residential zoning than any other zoning category.

Recommendations are provided below using the results of this analysis for targeting specific tree planting and policy opportunities.

Possible UTC Impervious

General Zoning Classification	Total Acres	2010 UTC %	Possible UTC Vegetation Acres	Possible UTC Vegetation %	Possbile UTC Impervious Acres	Possible UTC Impervious %	Total Poss. Acres	Total Poss. %	UTC Goal	Delta (Above or Below)
Commercial	1,387	26.3%	140	10.1%	455	32.8%	595	42.9%	20%	6.3%
Multi-Family Residential	794	35.5%	113	14.2%	143	18.0%	256	32.2%	35%	0.5%
Industrial	83	22.1%	8	9.6%	32	38.4%	40	48.0%	25%	-2.9%
Single Family Residential	6,185	44.3%	1,491	24.1%	603	9.8%	2,094	33.9%	50%	-5.7%
Park / Open Space	1,007	66.0%	188	18.7%	31	3.1%	219	21.7%	25%	41.0%
ROW	1,837	26.9%	194	10.6%	201	10.9%	395	21.5%	25%	1.9%
Total	**11,293**	**40.4%**	**2,134**	**18.9%**	**1,465**	**13.0%**	**3,599**	**31.9%**	**40%**	**0.4%**

Table 5. Possible UTC by Zoning Categories including difference between Existing and UTC Goals

Recommendations

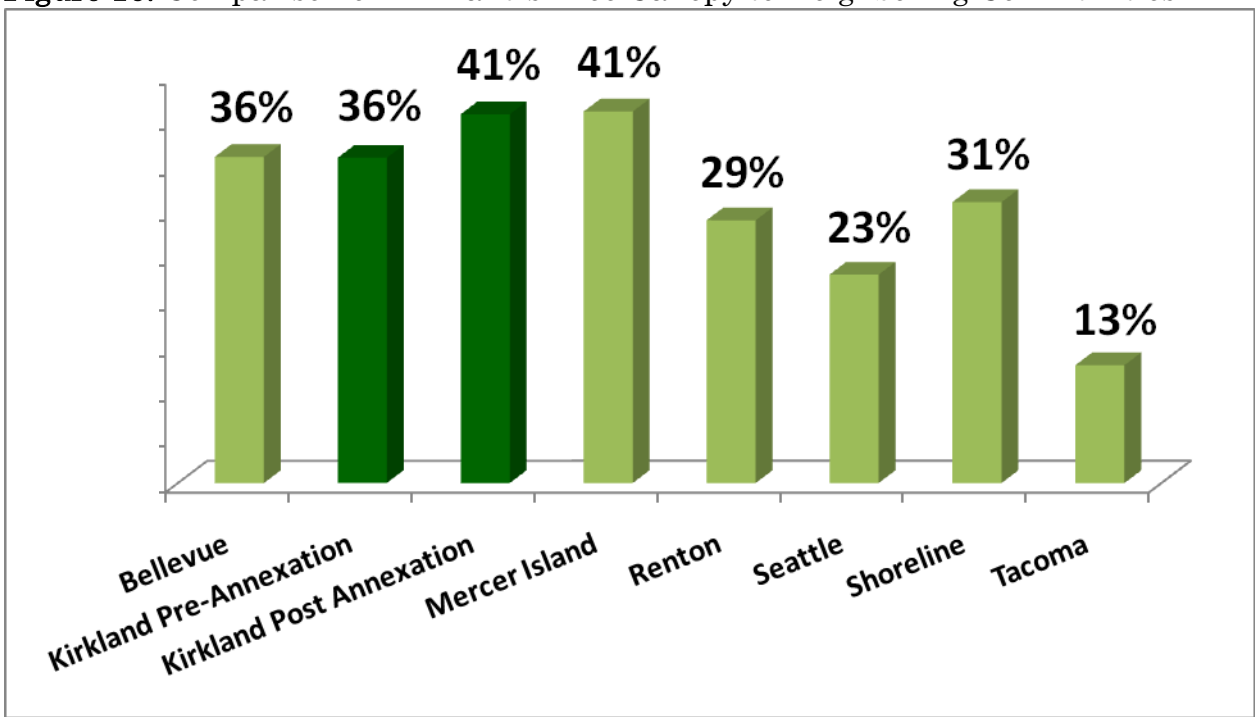
Strategies and management recommendations for meeting tree canopy goals:

- Enhance canopy in the pre-annexed areas to meet the 40% canopy goal
- Prevent further loss by preserving and maintaining canopy within the newly-annexed City limits. Identify and target tree planting to areas that are at highest risk for potential canopy loss UTC that remains at risk from development based on city-wide zoning
- Outline a strategic urban forest management plan to get an accurate depiction of how the City is currently managing its city-wide urban forest attributes to prioritize efforts and establish best management practices
- Increase awareness of UTC information by education/outreach efforts
- Identify stakeholders for tree protection, maintenance, and planting efforts
- Establish a long-term plan for continued UTC monitoring at regular intervals
- Sustain a healthy canopy succession by new tree planting efforts and retention tactics (development standards, heritage tree program, forest restoration programs etc.)
- Offer incentives such as public and private tree planting programs, "tree registration" to contribute to the UTC goal, stormwater credit or rebates for tree planting, reduced utility bill or development permit fees for tree retention, etc.
- Work with private landowners to increase open space areas by creating Native Growth Protection Easements
- Continue support and stewardship of public open space areas per the Green Kirkland Partnership's 20-Year Forest Restoration Plan
- Utilize canopy data for city-wide stormwater modeling, LID feature impacts, Green Building code implementation, and regional sustainable sites initiatives
- Generate an ecosystem services analysis by utilizing software to calculate the environmental cost benefit analysis of a healthy urban forest, ie: quantify stormwater filtration and reduction of runoff, improved air quality, and carbon sequestration
- Explore all potential partnerships: corporate sponsors, volunteer opportunities, non-profit organizations, neighborhood associations, etc.
- Further analyze the effectiveness of tree protection policies, code, and ordinances in a comparative study with adjacent municipalities to correlate trends in canopy gain or loss
- Use UTC metrics from parcel level and street tree inventory data to prioritize sites and implement tree planting on public and private property to increase canopy city-wide

Summary

The Kirkland City Council adopted a goal statement on the environment that states: "We are committed to the protection of the natural environment through an integrated natural management system." The goal is to "protect our natural environment for current residents and future generations". This commitment, supported by City policies and programs, appears to be a key factor in the city's upward trend in tree cover. Ordinances requiring landscaping on multi-family/commercial sites, frontage improvement requirements such as street trees with development, tree removal limitations, tree removal replacement requirements and minimum tree density credits for single family development exceed adjacent municipality's tree protection requirements, where canopy loss has been a recent trend. Below is a comparison of existing tree canopy in Kirkland to other neighboring communities.

Figure 16. Comparison of Kirkland's Tree Canopy to Neighboring Communities



The City should consider the results of this report while making any changes to its policies regarding the protection of its forestry resources. Recommendations have been provided to assist in this process. Continuing in this positive direction, the City should continue to engage, educate and increase public awareness on the benefits of healthy, working urban forests.

About AMEC Environment & Infrastructure, Inc.

AMEC Environment & Infrastructure (AMEC) is a leading full-service environmental engineering 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 environmental, energy, power and process industries. We are one of the world's leading environmental and engineering consulting organizations. AMEC‟s Puget Sound offices in Bothell, Lynnwood, Seattle, and Tacoma employ 116 full-time professional, technical, and support personnel who provide geotechnical engineering, environmental consulting, natural resources and planning, and related services. 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.

The team involved in this project has collectively developed and completed urban tree canopy (UTC) assessment projects with more than thirty (30) cities and counties. Clients range from municipal foresters, non-profits, universities and state urban forestry coordinators. AMEC's project manager has presented this topic at well over a dozen state and national conferences, workshops and webinars.

In addition to UTC assessments, we have extensive experience in and knowledge of ecosystem services analysis. Examples of these services include air quality improvements through pollutant removal and urban heat island mitigation, energy benefits from savings due to reduced heating and cool costs, stormwater and water quality mitigation by improved infiltration, interception and erosion control, and carbon storage and sequestration. We have experts in air quality modeling and monitoring related to non-attainment and State Implementation Plans and are a recognized leader in green infrastructure modeling, design, and policy development, currently leading GI programs for the City of Indianapolis and Nashville, Tennessee. Our team has conducted more than a dozen projects that involved training on, collecting field data for, and applying tools such as CITYgreen from American Forests and the U.S. Forest Service Community Tree Guides and i-Tree site of tools (Eco, Streets, Hydro, Vue, Canopy and Design). Experience with custom stormwater models includes the Western Washington Hydrology Model (WWHM) and the EPA's Stormwater Management Model (SWMM) Low Impact Development (LID) module.

Appendix

The appendix of this report provides additional details on the methods used in the assessment including software/technology f the data deliverables. Generally speaking, the appendix follows the order in which the steps of the project were taken. It should be used as a reference in future urban tree canopy or land cover mapping projects for monitoring purposes and consistency.

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). This technology is particularly useful for classifying high-resolution multispectral aerial, LiDAR and satellite imagery. For the 2002 tree canopy mapping, 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, shrub, open space/grass, impervious surfaces, water, and bare soil / dry vegetation.

Kirkland provided AMEC with their existing GIS layers for buildings and streets which were incorporated into the land cover classification. Both files were used "as-is" (some features were out of date). Shrub was a separate class based on analysis of shadows and texture in vegetation. Note that "grass" includes all open space, lawn area and low-lying herbaceous cover this is not shrub or forest and that "soil" includes barren/exposed soil and dry vegetation. Land cover data was used for all other aspects of the study including Existing and Possible UTC.

AMEC performed a manual, visual review and editing process on the automated land cover classification at approximately 1":2,000" scale with particular emphasis on tree canopy accuracy and consistency between 2002 and 2010. The specification was to achieve 95% overall accuracy for tree canopy and 90% for other land cover classes. Minimum mapping units for each were as follows: trees/forest (~75-sq.ft., shrub (~2,500-sq.ft.), grass/meadow (~100-sq.ft.), impervious surfaces (200-sq.ft.), bare soil (~2,500-sq.ft.), and water (~2,500-sq.ft.). These accuracy levels were met after AMEC's quality control/quality assurance (QA/QC) step and by comparing to other datasets where detailed accuracy assessments were performed and yielded 96-97% accuracy.

Note: LiDAR data is flown with a specialized airborne sensor where a series of mirrors record vertical elevation values. Whiter objects (pixels) in Figure 4, left panel, on page 7 have a higher elevation value than darker areas. LiDAR and color-infrared imagery (right) are helpful in automated classification of trees and forests.

Complete Tables of UTC Metrics

Complete tables of the results from this study are provided below. Some results were provided in the main body of the report where appropriate. Due the large number of records that cannot be shown in a table, parcel-level results of Existing UTC were provided in GIS format.

Table 6. Citywide results pre- and post-annexation for 2002, 2010 and Possible UTC

City of Kirkland	Total Land Acres	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Change in UTC Acres	Relative Change in UTC (%)	Raw Change in UTC (%)	Poss. UTC Veg Acres	Poss. UTC Veg %	Poss. UTC Imp. Acres	Poss. UTC Imp %	Total Poss. UTC Acres	Total Poss. UTC %
Pre-Annexation	6,806	2,151	31.6	2,450	36.0	299	13.9	4.4	--	--	--	--		
Post-Annexation	11,403	--	--	4,637	40.7	--	--	--	2,193	19.2%	1,515	13.3%	3,708	32.5%

Table 7. UTC Results by Zoning type (Pre-Annexation)

General Zoning Classification	% of Total Area	2002 UTC Acres	2002 UTC %	2010 UTC Acres	2010 UTC %	Distrib. Of 2010 UTC by Zoning	Change in UTC Acres	Relative Change in UTC*	Raw Change in UTC	UTC Goal	Delta (% Above or Below)
Commercial	18%	266	22.0%	331	27.5%	13.8%	65	24.5%	5.4%	20%	7.5%
Multi-Family Residential	8%	153	28.2%	192	35.3%	8.0%	38	25.0%	7.1%	35%	0.3%
Industrial	1%	16	18.8%	18	22.1%	0.8%	3	17.3%	3.2%	25%	-2.9%
Single Family Residential	47%	1,114	35.5%	1,232	39.2%	51.4%	117	10.5%	3.7%	50%	-10.8%
Park/Open Space	9%	318	52.7%	324	53.8%	13.5%	6	2.0%	1.0%	25%	28.8%
ROW	17%	225	20.3%	302	27.2%	12.6%	77	34.2%	6.9%	25%	2.2%
Total	**100%**	**2,092**	**31.3%**	**2,398**	**35.9%**	100.0%	**307**	**14.7%**	**4.6%**	**40%**	**-4.1%**

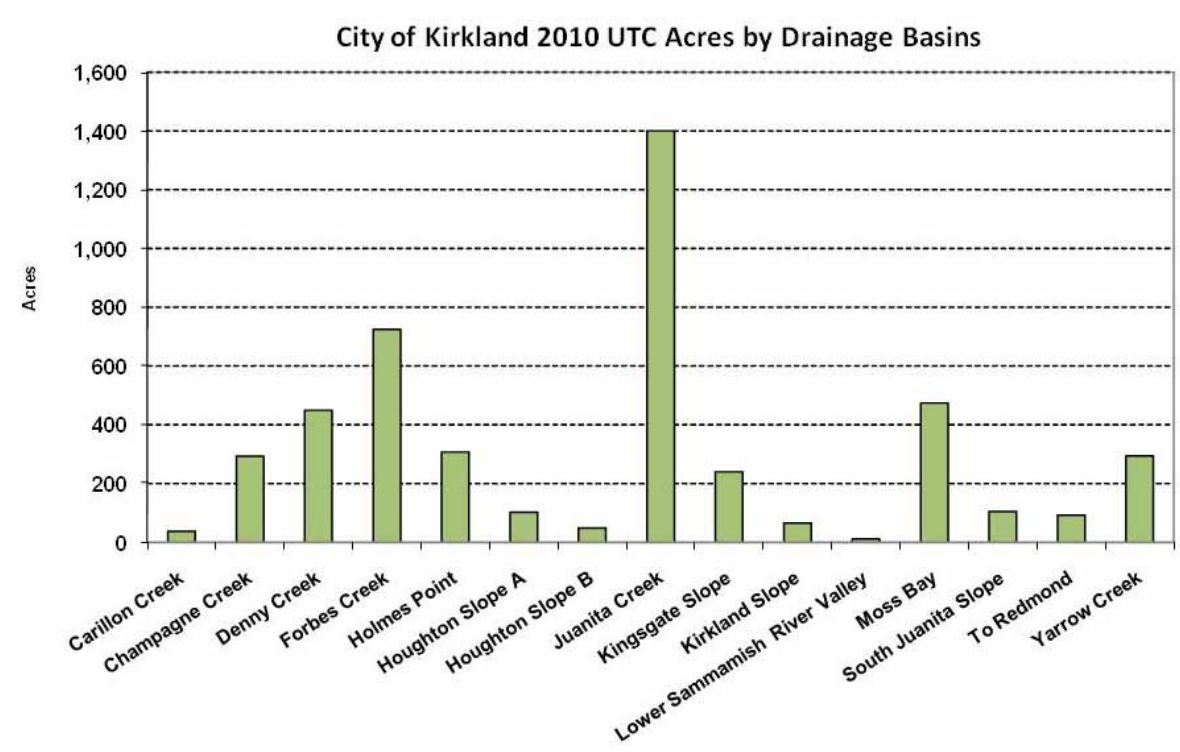
Table 8. Citywide UTC Results by Zoning type (Post-Annexation)

General Zoning Classification	Total Acres	% of Total Area	2010 UTC Acres	2010 UTC %	Distrib. Of 2010 UTC by Zoning	Poss. UTC Veg Acres	Poss. UTC Veg %	Poss. UTC Imp. Acres	Poss. UTC Imp %	Total Poss. Acres	Total Poss. %	UTC Goal	Delta (% Above or Below)
Commercial	1,387	12%	364	26.3%	8.0%	140	10.1%	455	32.8%	595	42.9%	20%	6.3%
Multi-Family Residential	794	7%	282	35.5%	6.2%	113	14.2%	143	18.0%	256	32.2%	35%	0.5%
Industrial	83	1%	18	22.1%	0.4%	8	9.6%	32	38.4%	40	48.0%	25%	-2.9%
Single Family Residential	6,185	55%	2,740	44.3%	60.1%	1,491	24.1%	603	9.8%	2,094	33.9%	50%	-5.7%
Park/Open Space	1,007	9%	664	66.0%	14.6%	188	18.7%	31	3.1%	219	21.7%	25%	41.0%
ROW	1,837	16%	494	26.9%	10.8%	194	10.6%	201	10.9%	395	21.5%	25%	1.9%
Total	**11,293**	**100%**	**4,563**	**40.4%**	**100.0%**	**2,134**	**18.9%**	**1,465**	**13.0%**	**3,599**	**31.9%**	**40%**	**0.4%**

Table 9. UTC Results by Drainage Basin

City of Kirkland Drainage Basins	Total Acres	2010 UTC Acres	2010 UTC %
Carillon Creek	106	37	35.1%
Champagne Creek	680	293	43.0%
Denny Creek	804	449	55.9%
Forbes Creek	1,837	725	39.5%
Holmes Point	485	307	63.3%
Houghton Slope A	377	102	27.1%
Houghton Slope B	134	48	35.9%
Juanita Creek	3,631	1,400	38.6%
Kingsgate Slope	563	240	42.5%
Kirkland Slope	211	66	31.2%
Lower Sammamish River Valley	24	11	46.5%
Moss Bay	1,487	474	31.9%
South Juanita Slope	287	105	36.4%
To Redmond	303	92	30.3%
Yarrow Creek	579	294	50.7%
Total	**11,508**	4,642	**40.3%**

Figure 17. Acres of UTC by Drainage Basin



Additional Examples of Kirkland's 2010 UTC by Parcel Data

Figures 18 & 19. Example of UTC Analysis at the Parcel-Level. Parcels with less than 20% urban tree canopy are shown in red (below left). Parcels with more than 20% canopy loss or more than .1 acre of canopy loss are shown in yellow (below right).