USDA

United States Department of Agriculture

Forest Landscape Assessment Tool (FLAT): Rapid Assessment for Land Management

Lisa Ciecko, David Kimmett, Jesse Saunders, Rachael Katz, Kathleen L. Wolf, Oliver Bazinet, Jeffrey Richardson, Weston Brinkley, and Dale J. Blahna

Forest Service

Pacific Northwest Research Station

General Technical Report PNW-GTR-941

September 2016

Authors

Lisa Ciecko is a plant ecologist, Seattle Parks and Recreation, 1600 S Dakota Street, Seattle, WA 98108; **David Kimmett** is a natural lands program/project manager, King County Parks and Recreation Division, King Street Center, 201 S Jackson St., Room 700, Seattle, WA 98104-3855; **Jesse Saunders** is a resource information forester, American Forest Management, Inc., 11415 NE 128th Street, Suite 110, Kirkland, WA 98034; **Rachael Katz** is an environmental planner, Tetra Tech, 19803 North Creek Parkway, Bothell, WA 98011; **Kathleen L. Wolf** is a research social scientist and **Jeffrey Richardson** is a postdoctoral research associate, University of Washington, School of Environmental and Forest Sciences, Box 352100, Seattle, WA 98195; **Oliver Bazinet** is an environmental analyst, Seattle Parks and Recreation, 309 Pontius Ave. N, Seattle, WA 98109; **Weston Brinkley** is principal and owner, Street Sounds Ecology, LLC, Seattle, WA 98107; **Dale J. Blahna** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 400 N 34th St., Seattle, WA 98103.

Cover: (left) field data collection in a King County, Washington, forest reserve area, photo courtesy of Forterra; (upper right) forested green spaces provide opportunities for active living, and (lower right) field training for FLAT assessment volunteers, photo courtesy of King County Department of Natural Resources and Parks.

Forest Landscape Assessment Tool (FLAT): Rapid Assessment for Land Management

Lisa Ciecko, David Kimmett, Jesse Saunders, Rachael Katz, Kathleen L. Wolf, Oliver Bazinet, Jeffrey Richardson, Weston Brinkley, and Dale J. Blahna

U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Portland, Oregon
General Technical Report PNW-GTR-941
September 2016

Abstract

Ciecko, Lisa; Kimmett, David; Saunders, Jesse; Katz, Rachael; Wolf, Kathleen L.; Bazinet, Oliver; Richardson, Jeffrey; Brinkley, Weston; Blahna, Dale J. 2016. Forest Landscape Assessment Tool (FLAT): rapid assessment for land management. Gen. Tech. Rep. PNW-GTR-941. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p.

The Forest Landscape Assessment Tool (FLAT) is a set of procedures and tools used to rapidly determine forest ecological conditions and potential threats. FLAT enables planners and managers to understand baseline conditions, determine and prioritize restoration needs across a landscape system, and conduct ongoing monitoring to achieve land management goals. The rapid assessment process presents a cost-effective opportunity for landowners that include local governments, private owners, and nongovernmental organizations to use ecological data to guide decisionmaking and improve environmental outcomes on their lands. This report is an introduction to FLAT, providing an overview of its purpose, methods, and implications for land management in diverse regions. FLAT is executed in three sequential phases: Phase 1—Forest Cover Type Mapping, Phase 2—Field Assessment, and Phase 3—Management Prioritization. Overall, FLAT consists of onsite visual estimation (aided by remote sensing) of ecological conditions by a trained field team to produce a forest inventory. In addition to providing baseline data and a framework to prioritize actions, FLAT can be used as a monitoring tool to evaluate changing conditions and inform adjustments in management strategies and priorities. To illustrate FLAT implementation, the King County Department of Natural Resources and Parks case study details a pilot project conducted on 24,700 of the more than 26,000 ac of county lands. King County is using the results from FLAT to develop and implement forest stewardship plans and target efforts of its volunteer restoration program. Although the tool was initially used in lowland forests in the Puget Sound region, in concept, FLAT could be expanded and adapted for use in a wide variety of ecosystem types.

Keywords: Forest, assessment, stewardship, planning, ecology, baseline, monitoring, land management.

Executive Summary

The Forest Landscape Assessment Tool (FLAT) is a set of procedures and tools designed to provide local government agencies, nongovernmental organizations, land managers, and private landowners with a rapid, systematic, flexible, and inexpensive environmental evaluation. The technical information produced by FLAT provides a standardized baseline of ecological data.

This data can be used to evaluate forest parcels within the context of the broader landscape, providing information about key forest characteristics and potential threats. FLAT also provides a framework to identify high-ecological value, high-threat areas within a single site and across multiple holdings for potential management action. The results from FLAT provide an essential starting point for developing either a systemwide stewardship plan or management plans for single parcels. In addition to providing baseline data and a framework to prioritize actions, FLAT could also be used as a monitoring tool to evaluate changing conditions and inform adjustments in management strategies and priorities.

FLAT data provide the basis for forest stewardship or management plans.

FLAT was developed and piloted by the Green Cities Research Alliance. Key FLAT contributors include the USDA Forest Service Pacific Northwest Research Station, King County, Forterra, American Forest Management (formerly International Forestry Consultants), and the University of Washington. Work on FLAT began in 2009 to provide a comprehensive forest resource analysis for King County, an important first step toward developing a long-term, systemwide forest stewardship program on more than 26,000 ac of King County lands.

Based on principles of restoration and landscape ecology, as well as traditional forestry, FLAT is conducted in three broad sequential phases:

Phase 1—Forest Type Mapping: Aerial imagery and boundary data are used in a lab or office to divide a project area into management units (MUs), the unit of observation and measurement for the assessment. Data attributes are also developed during Phase 1 based on local conditions and assessment purposes (e.g., species composition, size and age classes, invasive species, tree-canopy vigor, etc).

Phase 2—Field Assessment: A trained field team visits the project area to collect estimates of each attribute for each MU. Such teams may include professionals, technicians, and volunteer stewards.

Phase 3—Management Strategies and Prioritization: The data, which provide a snapshot of ecological conditions in the project area (within and across all MUs), can be used to classify or rank each MU. The assigned values can be viewed spatially to provide a mapped, visual representation of landscape conditions. These results can then be used to prioritize where on-the-ground management actions would most improve ecological function and health, contributing to long-term sustainability of a forest area.

Owing to the success of local conservation efforts, property acquisitions, and various incentives to conserve open space, King County's resource managers have an extensive inventory of resource lands, but have little condition information to guide management efforts. Seeking to learn more about these diverse holdings and inform management decisions, FLAT was implemented on 24,700 ac of the more than 26,000-ac system.

For the first time, King County managers now have baseline ecological information about all of their forested parks and natural areas. A key finding was the prominence of red alder (*Alnus rubra* Bong.) and bigleaf maple (*Acer macrophyllum* Pursh) on many parcels. Both are relatively short-lived species, and a high percentage of these trees are 30 to 100 years old. These forests could benefit from active management and restoration, as the health decline of old trees signals the need for tree replacement and hazard management.

FLAT utilizes a straightforward rating scale of 1 to 9 to indicate a balance of species composition value (favoring larger native trees) and degree of health threat, particularly owing to invasive species cover. Overall, more than 5,000 ac of King County forest lands have a rating of 2 or 3, indicating high forest composition value and medium-to-high forest health threat values. In the case of McGarvey Park Open Space, as an example, a large portion of the forest cover is rated as 5 or 6, indicating that there is a medium composition value and medium-to-high presence of forest health threats. The ratings can become the basis for priority setting for both locations of management work, and for on-the-ground actions to conserve or restore forests.

FLAT can be used for both baseline and monitoring forest assessment.

King County is using FLAT results to develop forest stewardship plans for individual sites, as well as communicate and implement management priorities across the entire parks and open space system. In the future, FLAT may be conducted in recurring intervals to monitor progress and evaluate the effectiveness of restoration efforts. As a relatively new tool used in forested lands, FLAT has potential for further development, testing, and refinement.

Resource managers in other communities can learn from King County's experiences and modify the FLAT methods to conduct an assessment that addresses local conditions and priorities. Although currently designed for use in lowland forests of the Puget Sound region, the tool's basic framework and data variables could be adapted for a wide variety of ecosystem types. Future research could generate indicator and matrix tools that inform management prioritization for additional ecosystem types (such as pine forest or riparian systems). Practitioners may also be interested in applying FLAT as a practical method for general ecosystem monitoring focused on a particular ecosystem condition or outcome, such as biodiversity, wildlife habitat, or local effects of climate change.

Contents

Introduction

The Forest Landscape Assessment Tool (FLAT) is a set of processes and tools that produces an ecological assessment for environmental land use planning and management. In its pilot use, FLAT has proven to be a flexible, systematic, and low-cost process for land managers and related decisionmakers to achieve a rapid ecological survey of a portfolio of diverse parcels and land holdings.

FLAT is a flexible low-cost tool for rapid ecological field surveys.

FLAT can provide landowners with straightforward ecological information regarding the composition and overall health of their forest lands, and to understand potential threats. It is a tool that can readily be used by such landowners as local governments, private owners, and nongovernmental organizations (NGOs) with minimal training and time invested to achieve useful results. The data and rating framework provided by FLAT better prepare land managers and planners to make strategic land management and restoration decisions.

Assessments can potentially be repeated over time as a practical monitoring program to observe forest changes and gauge the effectiveness of management actions. A longer view can help managers understand how and why conditions are changing on the ground and enable them to adjust programs accordingly.

Although the FLAT protocols presented here have been developed for use in lowland forests of the Puget Sound region located along an urban-to-rural landscape gradient, the tool could be adapted for land managers working in other ecosystems as well.

This report provides an overview of the FLAT approach. The following sections will demonstrate its implementation and describe its data outputs, including assessment options. The "Background" section first reviews the importance of ecological assessment for effective land management, then describes FLAT, including its origins and function relative to other assessment methods. With this understanding, the "FLAT Methodology" section provides details on important project considerations and how to use FLAT. Additional method details are provided in the appendices. Next, the "King County Parks Case Study" section presents results and insights from a pilot FLAT project, and is one example of how FLAT has been successfully applied to support stewardship goals. The report concludes with discussion of FLAT's unique advantages, some key limitations, and potential next steps for management application, monitoring, and research.

Background

Importance of Assessment for Decisionmaking and Adaptive Management

The need for FLAT stems from the importance of having comprehensive, reliable, and unbiased data for decisionmaking. For instance, private firms recognize the importance of information to drive decisions. Private companies develop ways to access and purchase information to understand their clients and the markets they compete in, as well as their competitors. Having high-quality data is considered a defining element of rational strategic management and has been found to significantly influence decision effectiveness (Dean and Sharfman 1996). Access to good data for decision support is equally important for land use management and environmental planning.

An ecological assessment is an important component of the environmental planning process (fig. 1) (Randolph 2011). This is particularly true in situations in which initial data are minimal or lacking altogether. For example, designations of conservation easements (by NGOs and landowners) may happen opportunistically and result in public land managers having little information about lands for which they have become responsible. For many local agencies, data collection is low on the priority list owing to budget constraints and other pressing needs. In many

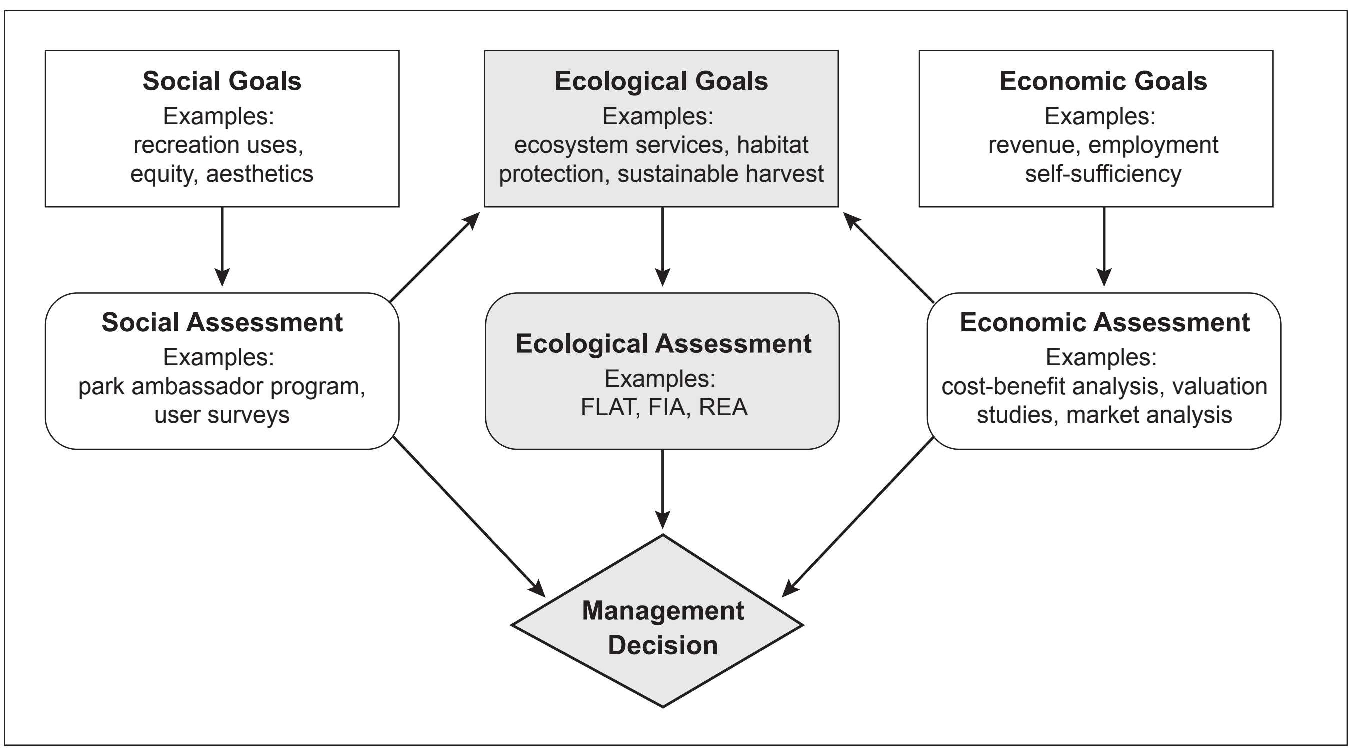


Figure 1—Importance of assessment in the land-management decision process. FIA = Forest Inventory and Analysis, REA = Rapid Ecological Assessment.

cases, even if information exists, it may not be comparable in methodology, completeness, or quality across different parcels. This lack of consistent information can make it difficult, if not impossible, to strategically prioritize sites for management actions or target resource allocations across a system.

For the forested landscapes considered by FLAT, management and planning decisions often address multiple, nested landscape scales. They may start from large, more broadly defined areas and system goals (such as a watershed), then be translated to site-specific plans (Marsh 1978). Some form of assessment ideally takes place at each of these scales so that strategies can be developed to achieve goals:

- Across a landscape system, by protecting specific, strategically located lands with easements, conservation status, or acquisition,
- That consider action alternatives, such as restoration, development, or harvest,
- Applied within a parcel or holding, for instance, by prioritizing certain areas for restoration work, and
- To address particular needs of any distinct system having a natural boundary (such as a riparian corridor or wetland).

FLAT generates assessment data across a system of lands for land units within a parcel.

FLAT is designed primarily for use on the landscape scale to provide key ecological information for each of any number of sites within an ecological system or parcel network. The data can be aggregated and analyzed to support a management approach that is successful and sustainable over time. FLAT data can also serve as a starting point for more detailed site-specific plans or monitoring.

Specifically, FLAT can provide critical inputs in the adaptive management cycle (fig. 2). Its use can provide both upfront baseline information—assessment—and evidence of change over time—monitoring. Ongoing, systematic land assessments allow managers to recognize important environmental gaps and potential tipping points. Cost savings are possible because planned actions can both prevent emergency conditions and optimize possible revenue. Ongoing assessment also helps landowners and decisionmakers tell the story of their land and its variety of public and private benefits that are worthy of investment and protection.

Of course, assessment is useful only when it is carried out successfully. As discussed later, FLAT fills a need for a rapid, low-cost method that can be applied in a range of environmental contexts, and particularly in the high-pressure interface of natural and urban or suburban areas.

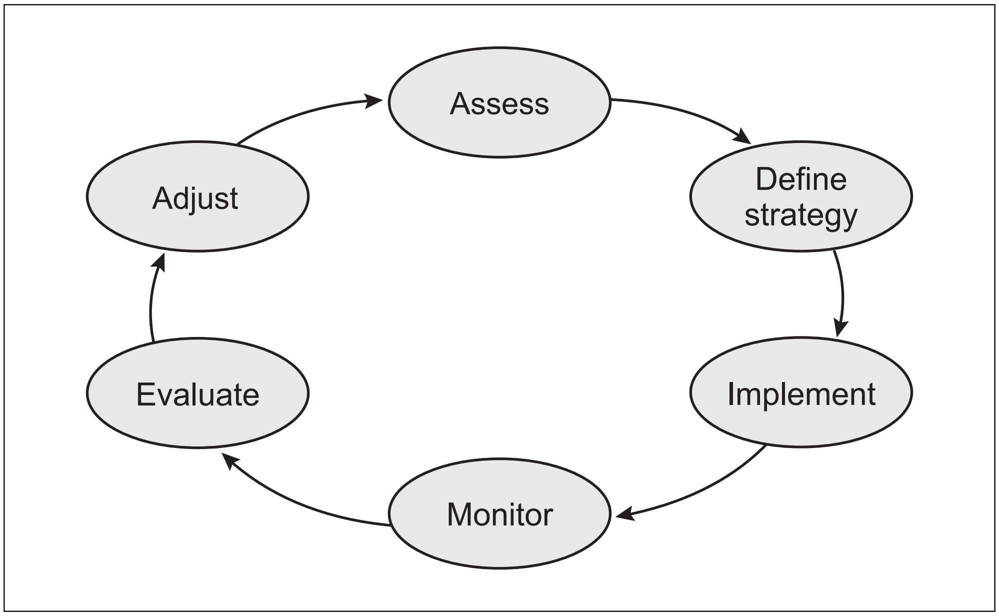


Figure 2—Assessment-based adaptive management cycle.

Overview of FLAT

FLAT is an assessment technique that provides land managers and planners with ecological information to:

- Make decisions at the broader, systemwide scale, and
- Prioritize different parcels or areas within parcels for specific land uses or actions.

Its advantage over more traditional forestry sampling, measurement, and extrapolation techniques is that it allows a rapid assessment of ecological conditions based on visual on-the-ground surveys of management units delineated from remote-sensing data. Although FLAT may not be as precise as more research-oriented sampling techniques, it efficiently provides accurate, practical descriptions of ecological conditions within and across a collection of sites. This “thumb-nail sketch” can be used to target where indepth assessment may be necessary.

Generally, FLAT consists of visual estimates of ecological conditions by trained individuals to produce a forest inventory. Although field teams should follow guidelines to calibrate their estimates, the assessment itself is generally qualitative and relies on carefully prepared estimates rather than precise measurements. FLAT is executed in three phases:

Phase 1: forest cover type mapping—

Aerial imagery and boundary data are used to divide each parcel within a project area (such as King County, as described below) into polygons, and to delineate management units (MUs). This work is accomplished and recorded using geographic information system (GIS) tools. Management units are the units of observation and measurement for the onsite assessment.

Phase 2: field assessment—
Trained field teams visit each MU within the project area to collect data for predetermined attributes. As an example, collected attributes might include vegetative or built land covers, nonnative species in order of abundance, and tree age-class distribution. A condition rating is also recorded, based on a matrix and flow-chart analysis (described as Tree-iage). Data are collected for each MU and stored (using a GIS or other data management system) for each parcel within the project area. Field teams may also verify the boundaries of MUs in this phase.

Phase 3: management strategies and prioritization—
The field procedures of FLAT provide a ranking of landscape conditions of the project area, both across numerous parcels and for subunits (the MUs) within a large parcel. Summary data and rankings are easily compared across the land management area. They can be used to establish management priorities for each MU, or aggregated to develop priorities at larger scales, such as across the entire open space or parks system.

FLAT provides a standardized baseline of ecological condition data. This information can be used to view each MU within the context of an entire land management system, as well as provide a starting point for developing a land-use or stewardship plan for particular parcels. Repeated over time, FLAT could serve as an effective monitoring tool for managers to review and then adapt management priorities and actions based on changing conditions.

This streamlined and systematic approach to ecological assessment applies principles of ecology and forestry to provide quality data that can inform land management priorities.

Foundations of FLAT

Starting in 2009, FLAT was developed and piloted by the King County Natural Resources and Parks Department, in collaboration with the U. S. Department of Agriculture (USDA) Forest Service and other partners. The resulting comprehensive resource analysis was an important first step toward developing a long-term, systemwide forest stewardship program on King County lands. FLAT incorporated the Tree-iage analysis approach that was initially developed in 2005 by the Green Seattle Partnership to prioritize restoration sites.

As its name suggests, the Tree-iage analysis is drawn from the medical practice of triage. Within the medical professions, triage emerged from the demands of war casualties, where medical providers were faced with a scarcity of resources and needed to rapidly assess each patient's condition, and, based on an established system or plan, determine the patient's specific treatment or treatment priority (Iserson and Moskop 2007).

Just as a nurse or doctor in an emergency department uses a systematic checklist of symptoms or a set of criteria to rapidly prioritize patient care, FLAT provides a systematic checklist of indicators that determine an actionable score for a designated forest area. A 9-point scoring matrix (fig. 3) combines observations of native tree and canopy composition with degree of invasive plant presence, particularly on the forest floor. Generally, low scores indicate lands that have good forest integrity and low invasive-species presence, thus merit management that will sustain their quality. High scores are indicative of highly altered forests combined with extensive invasive-species presence that require more resources to recover or restore.

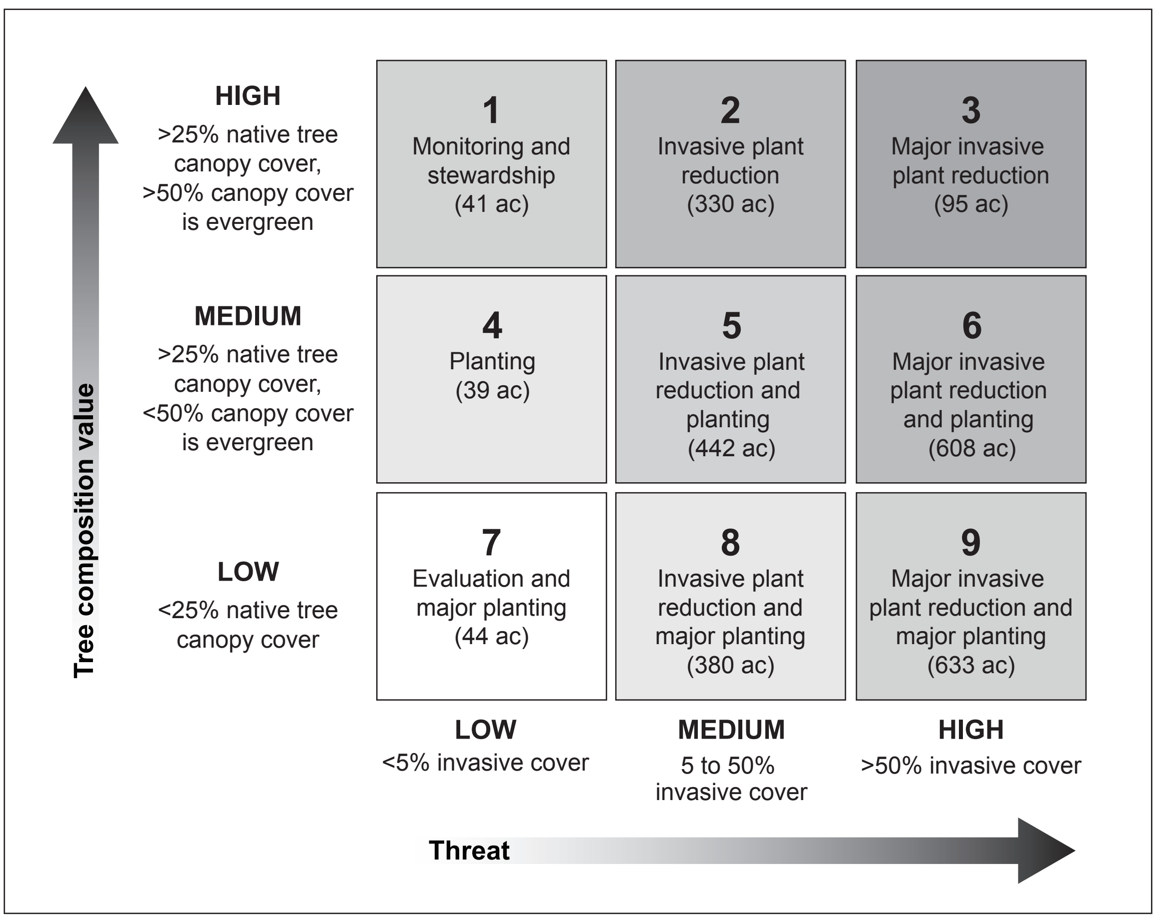


Figure 3—Original Green Seattle Partnership Tree-iage matrix, including acreage per category in Seattle, Washington.

The original Tree-iage matrix was enhanced for use in FLAT to serve more diverse needs and ecological conditions. Modified flowcharts accommodate additional ecosystem types such as wetlands. Additional data attributes include more indicators of forest health, adding new insight for management strategies. New attributes include stocking, crown closure estimates, and forest health indicators. Health indicator measures include low tree-canopy vigor, root rot, mistletoe, bare soils resulting from erosion, and the presence or lack of regenerating trees (canopy species less than 20 ft tall). Further, each visited stand is deemed "plantable" or "not plantable" based on whether site conditions are appropriate for tree seedling establishment.

Tree-iage was first used to evaluate forest condition of open spaces (of up to 100 ac) in highly urban areas in Seattle (fig. 3; Green Seattle Partnership 2006). The tool was exported to several other cities under the regional Green City Partnership model, including Everett, Kent, Tacoma, Kirkland, and Redmond. The development and use of FLAT in King County expanded use of the early tool for assessments of larger parcels (up to 2,500 ac). The FLAT team also prepared fieldwork protocols that are used for data-collection training of park staff and citizen volunteers.

The FLAT process borrows from a number of scientific disciplines. The axes and decision flowcharts of the Tree-iage matrix are based on principles of restoration ecology. Restoration ecology involves identifying prior or potential ecological conditions for a site that are then considered as goals or targets of the restoration effort and process. Such conditions (past and future) are shaped by a number of abiotic factors such as climate, elevation, moisture and precipitation cycles, nutrients, water bodies, fire cycles, and soil or substrate (Clewell and Aronson 2007).

FLAT has been used exclusively within western Washington thus far. The classification matrix and flowcharts therefore assume a desired condition of late-successional lowland native forests of the Puget Sound basin, characterized by mature conifer trees of mixed age classes and species, mixed with large deciduous trees. The matrix could be adjusted to acknowledge other Pacific Northwest ecosystems (such as shoreline, pine forest, or shrub-steppe) by specifying key ecological conditions and species indicators for the vertical and horizontal axes. To adapt FLAT for use in other ecosystems, goals of a desired condition or resource use would inform how the matrix and attributes were set up.

FLAT is based on the best practices of foresty, restoration ecology, and landscape ecology.

The FLAT process also incorporates knowledge from the field of landscape ecology, which makes explicit the importance of ecological diversity within the landscape (Turner 2005). When applied to land management, landscape ecology can provide insight on how bordering development, land use, or ecosystem types may influence restoration outcomes or ecosystem development within a particular management unit

(Turner 2005). One of the main products of FLAT is MU-specific information that can be viewed and queried in GIS together with information on neighboring MUs and other relevant spatial data or imagery. This integrated format allows managers to consider a landscape-scale perspective when making management decisions.

FLAT also includes aspects of traditional forestry field methods that were modified to include less data collection concerning timber evaluation. Associated data attributes in the FLAT include estimates of diameter at breast height (dbh) or size class, stocking, age class, and a number of forest health indicators as noted earlier (e.g., root rot, mistletoe, regenerating trees). This provides a critical starting point for developing silvicultural restoration actions that can promote forest stand recovery and long-term resilience. If a parcel is deemed to be suitable for harvest management, more detailed forest mensuration can be done.

Comparison to Existing Assessment Methods

In recent years, many approaches to landscape or resource assessment have emerged. The following summary and table 1 provide a comparison of FLAT with other assessment programs.

Forest Inventory and Analysis Forest Monitoring Program (FIA)—
Perhaps the most well-known forest inventory protocol is the one used by the Forest Service's Forest Inventory and Analysis (FIA) program. The FIA consists of "a three-phase sample used to track status and trends in forest extent, cover, growth, mortality, removals, and overall health" for the entire United States. Data collection takes place through stratified random sampling, selecting one site for every 6,000 ac of forest (USDA FS 2014). The FIA has produced a dataset that enables analysis on a scale that is appropriate and useful for national and some statewide management and decisionmaking.

Because of its plot sampling design, FIA may not provide data at the scale that most local or regional landowners would need to make management decisions. Further, the extensive range of detailed measurements involved may be much too costly and time-consuming for managers with a limited budget to consider. As an example, FLAT data variables for King County numbered just 28, while FIA's urban phase 2 protocol calls for more than a hundred variables to be carefully measured (USDA FS 2015). The advantage of FLAT compared to FIA is its lower cost, greater simplicity, and ability to provide information about each parcel and the management units within them. Nonetheless, in recent years, FIA has been extended to areas that are identified as urban. Urban FIA was launched in 2014, with Baltimore and Austin as the pilot cities. Data-collection protocols have incorporated i-Tree tools, and are being adapted to more directly reflect local community needs.

Table 1—Summary comparison of FLAT to other assessment methods

Key features	FLAT	FIA	i-Tree Eco	REA	NRCA
Geographic focus	Urban/suburban/rural	National	Urban	National	National Park System
	City/regional/county			International	
Scale	Management unit (MU)	Approximately one site per 6,000 ac across the United States	City or land-use type	Variable; often large-scale landscapes	National park unit (e.g., Olympic National Park)
Methods	GIS forest cover mapping	Field sample plots established for annual data collection	Stratified field sampling or inventories	Remote sensing or photo delineation of ecological units	Synthesis and analysis of existing data
	Field survey of MUs	100+ variables	Measurements focused on urban forest structure	Field sampling	Development of indicators for variety of ecosystem types
	Estimates of a limited set of variables focused on forest composition and health characterization	Detailed measurements	Model estimates ecosystem functions and economic values based on forest structure data	Measurements include flora and fauna	High-level park management prioritization
	Explicit management prioritization framework	Database open for variety of analyses		Unique analyses and workshops for each REA to review information and set priorities	

FLAT = Forest Landscape Assessment Tool; FIA = Forest Inventory and Analysis; REA = Rapid Ecological Assessment; NRCA = Natural Resource Condition Assessment; GIS = geographic information system.

I-Tree Eco—

A widely-used inventory and assessment tool that has been used in cities across the world is i-Tree Eco, also developed and supported by the Forest Service. The i-Tree Eco tool is set up to measure and monitor urban forests in order to estimate ecosystem functions and economic values for any metropolitan area. These estimates include urban forest structure and associated ecosystem services, such as carbon storage and sequestration, and air pollution removal, as well as residential building energy effects, rainwater interception, and public health benefits (Nowak et al. 2008). When applied to metropolitan areas or counties, this tool uses random or stratified sampling.

The i-Tree Eco model provides an important baseline for systemwide information, especially within a city. However, much like FIA, these techniques do not readily describe the status of a specific site. An entire city, or the land-use types within, is the unit of analysis in i-Tree and results can be used to help identify systemwide goals and opportunities. Because FLAT's unit of observation is a parcel (and even subunits within), it can be more readily used to create plans to meet place-based goals. Thus, although an i-Tree Eco assessment and analysis can be a useful complement to FLAT, its information is not tied as directly to site-specific management needs because of the difference in focus and scale of data collection. It should be noted that i-Tree Canopy and Landscape tools are applicable at the parcel scale, but do not address forest health and stand conditions.

The Nature Conservancy's Rapid Ecological Assessment—

The Rapid Ecological Assessment (REA) was developed by The Nature Conservancy to identify priority areas for conservation of biodiversity. In many ways, it is very similar to the FLAT process. In both, orthophotos or other remote-sensing technologies are used to classify and divide landscapes into ecological units, then field-based assessments are used to characterize the biota within these units. The purpose of REA is also to evaluate ecological conditions of specific units to support decisions about management priorities (Sayre et al. 2000).

There are a few key differences between REA and FLAT, however. Methodologically, REA field assessments (like FIA and i-Tree) consist of plot-based samples and interpolation of those measures across a much larger area. The REA also includes fauna explicitly in its sampling technique while FLAT focuses exclusively on flora. Unlike FLAT, REA was developed for use in lands more remote from human activity. The REA also involves a unique process of technical analyses and workshops in which scientists and managers review the information collected and decide on unit prioritization (Sayre et al. 2000). FLAT, on the other hand, has a predefined framework of matrices and flowcharts that can be used to readily translate assessment data into ecological management priorities.

National Park Service Natural Resource Condition Assessments—
The National Park Service (NPS) Natural Resource Condition Assessment (NRCA) serves a similar purpose to FLAT. These reports synthesize preexisting scientific information on a particular park to support the development of management plans and identify what additional information is needed, as well as to develop priorities across the National Park System. Although some of the data may be collected in the field, the majority of report content is expected to come from "existing data from NPS and other sources" (USDI NPS 2009). The NRCA reliance on existing data is one important distinction between it and the FLAT method.

Another important difference stems from the diversity of holdings within the National Park System. The FLAT process can be customized based on a general understanding of the range of ecosystems that natural area managers or planners might encounter, as well as the management challenges that may be present. Within this range, specific indicators as well as flowchart and matrix analyses are created to generate information that is directly helpful to prioritize MUs and management activity. The NRCAs, on the other hand, are a step earlier in the process. The NRCAs are oriented toward identifying which indicators should be used to set priorities going forward for each park across a much wider range of habitats and conditions. The NRCAs might be used to define each park's prioritization matrix and flowcharts for conducting FLAT. The differences between FLAT and the NRCAs are thus of process timing and scale.

Ecological Integrity Assessment of the Washington Natural Heritage Program—
An Ecological Integrity Assessment (EIA) rates the current ecological integrity of an occurrence of a plant association or ecological system. NatureServe and the Natural Heritage Network have developed the EIA as an index of ecological integrity based on metrics of biotic and abiotic condition, size, and landscape context. Each metric is rated by comparing measured values with the expected values under relatively pristine conditions. The ratings are aggregated into a total score or a scorecard matrix. The EIA can be applied to multiple spatial scales (e.g., landscape-or site-scale) and with a variety of data types (e.g., GIS or field-based). The EIAs are developed for ecological systems using a three-level-metrics approach: remote sensing, rapid ground-based, intensive ground-based. In summary, the EIA framework provides a standardized currency of ecosystem integrity across all terrestrial ecosystem types. This information can then be used for setting conservation priorities, identifying restoration strategies, and monitoring the effectiveness of conservation actions.

The EIA three-level-metrics approach may offer helpful concepts and methods for future updates of FLAT. The EIA is used to evaluate more pristine parcels for wildland conservation or management. FLAT is structured to enable land managers to integrate measures that reflect the local situations of urban and community forest systems. FLAT can be adjusted to reflect the "relative" value of natural parcels concerning desired attributes, whereas the EIA indicates "absolute" ecological values. Furthermore, although the EIA is intended to create a common currency of comparison between different ecosystem types, the metrics and methodologies employed in the field are detailed and ecosystem specific. FLAT, on the other hand, uses a consistent set of less detailed metrics in the field, without assuming prior knowledge of the ecosystem type. After FLAT is done, EIA could be used as a next step if more detailed assessment is needed within specific MUs.

Overall, FLAT fills an assessment role that traditional forestry assessments and the other methods discussed above do not address:

- Uses methods that are simple and adaptable to project-specific goals.
- Provides adequate, reliable, systematic, cost-effective, and local, site-based information.
- Informs decisions about where to initiate healthy forest management, stewardship programs, restoration activities, or stand management for harvest.
- Identifies where additional, more precise data may be needed.
- May be used to monitor conditions and progress over time.

FLAT Methodology

This section provides a summary of key project considerations and the basic methods for the three phases of FLAT.

Project Considerations and Planning

Before starting a FLAT project, managers should review and consider important factors for project planning, including the desired budget, staffing and training needs, equipment requirements, and a potential timeline.

Costs—

The cost of executing FLAT will vary considerably depending on the size and nature of the assessment area. By far, the highest cost of the assessment will be the staff or contractor time needed to do fieldwork. Expenses will grow as the size of the assessment area, number of sites, and distances between sites increases. In addition, project planning, forest type mapping and MU delineation, as well as field supply purchases, contribute to the total cost. The cost per acre can be expected to decrease as field crews and project coordinators become more experienced. Some of these relationships can be illustrated by comparing King County's costs to those of municipalities that implemented the same or similar programs. Appendix 5 illustrates the comparative costs in King County and the City of Everett where the same set of attributes data were collected.

Staffing and training—

There are four main project responsibilities within the FLAT protocol: forest-cover-type mapping, field assessment, database design and management, and project management and planning. Those considering using FLAT should review what their in-house capabilities are for each of these activities, especially for more specialized skills such as GIS and data processing, and decide what can be accomplished through training or seeking additional support. Training is most important for those doing field data collection and will help assure consistent and high-quality data. Training should include a walk-through of the protocols at a field site. In addition, it is helpful to pair new field staff with more experienced field staff, which helps to calibrate how estimates are done and improves consistency across field crews. The *FLAT Field Manual* provides guidance and detailed instructions that can support field staff training (see app. 6).

Equipment—

The basic equipment needed to conduct a FLAT assessment include GIS, navigation devices, a field data entry system, plant identification resources, and measurement tools. The actual equipment that is needed or desired will depend on the size of the project and desired application of the collected data. For an equipment list and considerations, see appendix 3.

Timeline—

In general, the FLAT timeline starts with a pre-field season to plan the project, purchase equipment as needed, train staff, and complete Phase 1 tasks (below). This is a critical time for FLAT projects to ensure that all components of a project are laid out adequately and that the plan for moving forward is understood by decisionmakers. The pre-field season is followed by one or more field seasons, most often but not necessarily during summer, to complete the field assessment (Phase 2). Fieldwork is the most time-consuming activity, so will differ based on condition and number of assessment sites. Lastly, post-fieldwork data management, analysis, and reporting should be estimated. Overall, the timeline will vary with the size and complexity of the project, and time requirements will decrease even for large projects as managers gain experience with FLAT implementation. To date, projects have ranged from a few months to a multiyear effort.

Phase 1: Forest Cover Type Mapping

Defining the project area—

A FLAT project area is determined in several steps using a mapping system, management boundaries, and vegetation cover information. See appendix 1 for detailed procedures. Existing geospatial data are needed, including aerial imagery, parcel boundaries, and other management boundaries, to set up this process. For an explanation of necessary data, along with potential sources and considerations, see appendix 2.

Step 1: Determine which properties will be included in the assessment. This involves establishing initial site boundaries based on existing ownership and management boundaries.

Step 2: Designate land cover type, such as King County designations of forested, other ecosystems, natural (vegetation but <25 percent canopy cover), open water, hardscape, and cultural landscape.

Step 3: Delineate MUs based on forest species associations, geomorphic conditions, and land cover.

The resulting polygons will be the MUs, the unit of measure for the FLAT process. Each MU should be assigned a unique identifier to be used throughout the project. This is especially important on projects having multiple sites (e.g., dispersed parks or land holdings) that are then delineated into MUs. Keeping good records of MUs identifiers and associated data is critical to ensuring that FLAT information is easy to use during the Phase 3 analyses (discussed below), and for using FLAT to monitor changes over time.

Defining the data attributes—

Field data collection is done using predefined attributes. The attributes are related to vegetation species, abundance, size and age classes, and identification of restoration opportunities. The list of attributes used during the King County pilot are included as appendix 4. Agencies or organizations using FLAT will have their own management priorities, so they may add a custom set of assessment attributes.

Defining the data attributes includes determining the level of measurement detail used during the field assessment. For example, forest overstory age classes may be divided into increments of 10 or 30 years. Selecting appropriate attributes and data-collection categories will require the expertise of people who are knowledgeable about the ecosystems being assessed, as well as those qualified to develop management priorities.

The attributes that are selected will shape the analysis that is done in Phase 3. Development of flowcharts and criteria that reflect potential management priorities should occur alongside data attribute selection. That is, managers should start the process of thinking through how their selected data attributes can be used to differentiate MUs and rank areas in order of urgency for management intervention. This can ensure that the most useful data for MUs classification are collected in the field (Phase 2). The actual flowcharts and criteria can then be refined and finalized as part of Phase 3.

Phase 2: Field Assessment

Assessment procedure—

The field procedure entails visual estimates of the data attributes defined during Phase 1. Teams of two or more people visit each MU, walk through it, and record an estimate for each data attribute. The following summarizes key processes and considerations. The *FLAT Field Manual*, found in appendix 6, further describes the field data-collection methods.

Provide attribute estimates for the entire MU—The field team walks through each MU and records an estimated average attribute value for each of the variables selected in Phase 1. There may be patches of unusual species or conditions, but a best effort is made to estimate for the entire MU. Teams should be observant, perhaps even keeping notes of what they see. Judgments are made for each attribute and are entered into a data entry device before leaving the MU.

Use measurement tools to calibrate estimates—Some variables, such as dbh, crown closure, age, and height of regenerating trees (e.g., those less than 20 ft in height) can be measured with tools while in the field. It may be helpful to do this once or twice in an MU to calibrate the field team's estimates. Determing the appropriate level of accuracy is important, as excessive measurement will slow the rapid assessment process.

Alter MUs as needed—Once in the field and seeing on-the-ground conditions, the crew will consider whether the boundaries of the MUs should be altered, and if so, how. Pervasive differences in composition or age classes for large areas of the MU may necessitate either redrawing boundaries or splitting the MU into multiple, smaller MUs.

Record additional notes and variables—Field teams may find that something important is in the MU that doesn't necessarily fit into any of the attribute categories. Examples include unanticipated environmental or social hazards, such as homeless encampments or trail damage, which could supplement management decision criteria. This information can be captured in the "notes" field in the data entry tool.

Decide when to leave the road or trail system—Each attribute determination will apply to the entire MU, thus it is important that enough of the MU is observed by the field team. Sometimes this will require leaving trails and traveling on challenging terrain. In other MUs, the view from a trail may be sufficient to make a judgment on most, if not all, of the attributes. Teams should be careful to recognize, and average into the MU estimate, any edge effect along trails where vegetation may have been influenced by trail activity or disturbance. If the area is large enough, the road or trail area may become a distinct MU. These decisions are left to the discretion of the field team; the desired speed of assessment must be balanced against the assessment's accuracy.

Check for completeness—Sometimes MUs will be strangely shaped so that the terrain or trails will lead teams to travel in and out of a number of MUs. Data may be entered for each MU in order of discovery, but should be checked for completeness before leaving the MU.

Data management—

Once the fieldwork is complete with MU attributes recorded using the data entry tools or field forms, the data should be checked and edited if needed, then entered into a database for analysis. The database type can be chosen according to the complexity of the project. For example, a small project could be managed with Microsoft Excel®, while a larger project with many different sites could be set up in Microsoft Access®, a server-based database management system, or a geo-database that includes the spatial information.[1]

The data from each field site can be compiled into one dataset across the project, then queried using the categories defined for each attribute. This system can help with data quality control, allowing managers to query data and check for discrepancies or abnormal values.

Phase 3: Management Prioritization

The last phase of FLAT translates the results of the preceding mapping and field assessment efforts into valuable ecological information that can be readily understood by landowners, managers, and the general public. Once the summary and analysis processes are done, FLAT provides an advanced snapshot of conditions on the ground and evidence-based input toward determining land management goals and priorities.

---

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Summary analysis—

The data can be summarized to meet the specific needs of the user at various scales. FLAT provides the opportunity to summarize key characteristics about the parks or open space system, one project parcel within the system, or a subset of MUs chosen for a specific analysis.

Simple queries or formulas can be put to the database to report the number of MU acres representing attributes that were reported in the field data. These basic summaries can be reported as charts or maps (such as land-cover areas). Any attribute(s) can be displayed for the entire system or any subset within.

More specific analysis can be done with vegetation attributes, such as species composition, forest health indicators, invasive species, and so forth. Examples of summary analyses can range from a very basic percentage or total acreage of MUs containing a single vegetation attribute of choice, to a combination of attributes. For example, King County has produced summary statistics about the area of land occupied by different primary overstory species, the percentage of stocking classes found in young regenerating tree species, sites where a health threat indicator was identified, and a type categorization for each MU describing the primary species size and stocking.

There are numerous possible strategies for queries. One can query to show management subunits within the area of a larger parcel, or use one or more key attributes as criteria to identify individual MUs across the entire land base being assessed. The prioritization framework discussed below allows FLAT users to review their project area data and develop clear, ecological management priorities.

Prioritization analysis—

Identifying and prioritizing areas in need of management is a key output of the FLAT process. Attributes assessed in the field are used to produce a qualitative value that combines two axes of a matrix. In King County, forest composition (y-axis) and forest threats (x-axis) were used (more detail is provided in the case study section that follows). The matrix combines the multi-attribute information to produce a classification value for each MU (e.g., fig. 4 is the matrix used for the King County project). This is the Tree-iage step of FLAT.

A flowchart can be used to determine MU values for the selected attributes. Generally, the resource composition flowchart and threat criteria are specific to each project's conditions and priorities; the King County project is but one example (see fig. 8 on p. 25).

Resource composition values and threat values are determined, then combined using the matrix to produce classification values for each MU. This value represents how important taking action may be for a particular MU in relation to other MUs

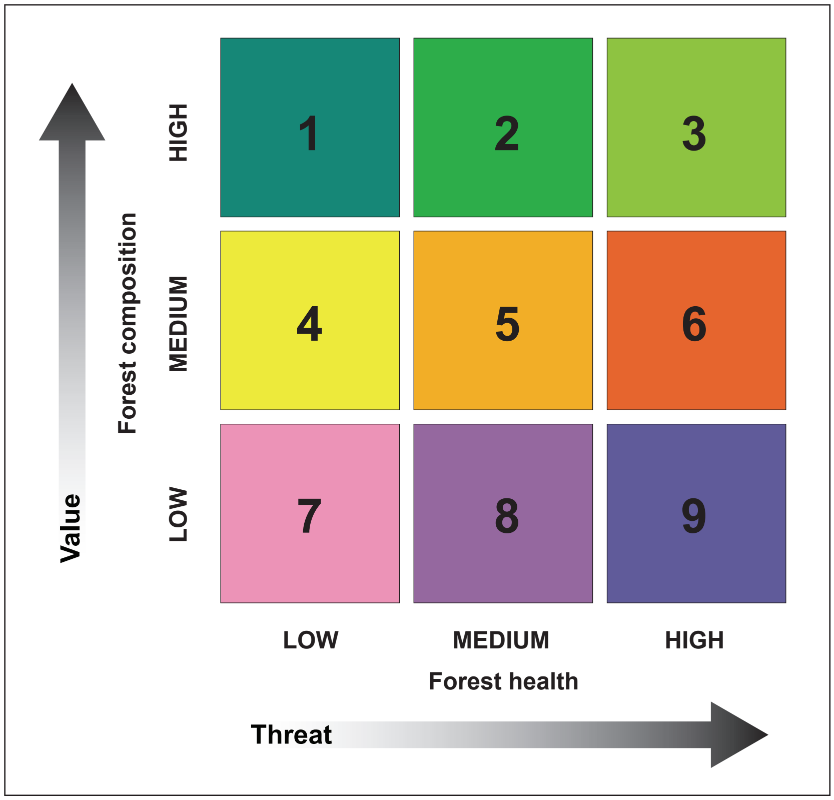


Figure 4—Management unit classification matrix (Tree-iage) example, King County, Washington.

within the site or larger system. The values suggest a ranking of priority for management actions. For example, in figure 4, values 1 through 3 represent MUs with a tree composition that has high ecological value, and so are important to protect and maintain. Values 2 and 3 also represent the presence of a forest health threat and could be prioritized for restoration or maintenance. On the other end of the spectrum, an MU with a value of 9 has a high threat presence and a lower quality tree composition, and therefore may not be as high a priority for management actions. A matrix value can be entered into the project database as an attribute for each MU and then mapped with GIS.

Based on the flexibility of this approach, other projects could use matrix tools that acknowledge project-specific ecosystems, threats, and management goals. As discussed in Phase 1, initial development of criteria and flowcharts should occur alongside data attribute development to ensure that desired data are collected in the field assessment. Then the flowchart(s) and criteria can be refined as needed to accurately reflect local conditions.

How the results of the matrix analysis are used in subsequent land management decisions is up to each FLAT user. FLAT provides an ecological input for land management decisionmaking. The combination of field data collection, flowchart processing, and classification of MUs using the matrix can be used to prioritize future management actions and monitoring. Resource managers will also consider other social and economic factors to create a strategic and feasible management approach for their lands. The following section details how FLAT was developed and tested in its pilot application in King County, an example of one way that FLAT has been used.

King County Parks and Open Spaces Case Study

The King County Natural Resources and Parks Division, Parks and Recreation Division, deployed FLAT for a landscape-scale assessment of county parklands from 2010 to 2013. The implementation of FLAT in King County is an informative case study that demonstrates the entire FLAT process from planning to final results. This case study presents the overall FLAT planning, implementation, and interpretation phases, as well as specific examples of park land assessment within King County.

The heterogeneity of forest lands within King County makes it an ideal case study. Although the west side of King County contains shoreline and pockets of urban forest within the large cities of Seattle and Bellevue, the east side consists predominantly of rural communities, agricultural lands, working forests, and wilderness. A long history of logging coupled with more recent rapid urbanization has created the diverse landscapes of today.

FLAT was used to open the condition of nearley 25,000 acres of parks and open spaces, including nearly 200 parcels.

In 1989 and 2007, voters in King County approved measures that provided a combined total of more than $201 million toward open-space acquisition and improvement (Trust for Public Land 2012). In addition, King County (as part of its growth management policy) implemented an incentive program that allows 1 ac of land to be reassigned from rural to urban zoning if an associated 4 ac are dedicated to the county as permanent open space. The resulting rapid land acquisition has led to a diverse portfolio of more than 26,000 ac managed by King County. Holdings differ in terms of the level of previous use and surrounding development and the type of land cover, size, ecosystem type, and biotic composition. King County's portfolio includes high-use active recreation parks, former agricultural lands and gravel mines, river floodplains, and working forests in the foothills of the Cascade Range, as well as Puget Sound coastline. More than 21,000 of the 26,000 ac are forested. Table 2 shows the number of acres and park sites per park classification.

Table 2—King County Parks distribution by designation, acreage, and number of sites

Park classification	Area	Number of parks
	Acres	
Working forest/resource	3,455	7
Multi-use open space	12,812	41
Natural areas	7,321	78
Active recreation parks	2,472	67
Total	26,066	190

The large and rapid expansion of land holdings left King County managers with little information regarding forest composition, health, and diversity across the different park lands. As noted earlier, FLAT was developed and piloted in collaboration with the Forest Service to provide a comprehensive forest assessment for King County Parks. Specific goals for the county included (1) assessing the timber resources and management needs within working forest lands, (2) assessing forest health and composition in forests managed for recreation and wildlife, (3) prioritizing areas for forest stewardship and management, and (4) minimizing expenses.

Project Process

Planning—

King County received funding from the American Recovery and Reinvestment Act of 2009 (in coordination with the USDA Forest Service) to support job creation and training. These funds were used to support the implementation of FLAT over 3 years. The total budget for the project was about $194,000 and was used for FLAT development, field planning, fieldwork, database management, and data analysis. Planning occurred during 2009 and 2010, with fieldwork commencing in the summer of 2010.

In total, 24,722 of the 26,000 ac of King County Parks were chosen for a FLAT assessment. These King County sites each contain a contiguous forest canopy component suited for a FLAT assessment. A FLAT assessment was performed on all of the multi-use, natural areas (lands managed to conserve and enhance ecological value and to accommodate passive recreational use), and working resource forest lands, which all are primarily heavily forested sites. Some recreation sites were assessed if they had a significant contiguous forest canopy. For example, Marymoor Park is a classic urban park with a traditional urban forest canopy of hundreds of single trees in a highly maintained park setting. Generally, these areas would be classified as “landscape” in the use of FLAT. However, Marymoor also has a significant riparian forest component along the river and lake that is classified as "forest" by FLAT guidelines. Regional multi-use trail corridors, such as the Burke Gilman Trail, were not assessed. Although most of these trails have a linear forest component, these were not considered to be a contiguous forest area, and would fall into the "landscape" category. Table 3 shows the land-cover-type results for the total King County FLAT project area across the different park designations.

Table 3—Acres of land-cover types in entire King County FLAT project area

Landcover type	Area
	Acres
Forested	21,058
Natural	2,024
Water	639
Hardscape	48
Landscape	953
Total	24,722

Phase 1: forest cover type mapping—

Several years of orthophotos were used in developing the MUs, including 2009 true color imagery having 0.5 ft per pixel resolution collected specifically for King County; 2009 and 2001 USDA Natural Aerial Imagery Program (NAIP) imagery with 1 m per pixel resolution; and online public access oblique angle imagery. Multiple datasets were used to reduce errors resulting from shadows, parallax, photo mosaicing, and varying light conditions. In addition, raster files developed from 2003 LiDAR data collected over King County were used for assessing tree height in GIS.

Site boundaries were provided by the King County GIS Center in Esri shapefile format and included, at a minimum, a unique facilities identification number and a site name. Sites that were smaller than the minimum mapping size, or where the land cover appeared to be homogenous in the imagery, were classified as a single MU. Sites that contained multiple MUs were first delineated based on general land cover type. The land cover type was classified as forested, natural (vegetation with <25 percent forest canopy cover), water, hardscape, or landscape. Small and isolated areas of landscape and hardscape were combined with surrounding cover types, as it was not the intent of this project to track such features. The remaining MUs categorized as forest and natural were then viewed with the aerial imagery to further delineate polygons containing similar vegetation types. Color, texture, tree shadows, and crown shape were used to determine MU edge breaks. Because these characteristics can appear differently depending on the imagery used, several available image sources were reviewed, as listed above. These provided views having different lighting, color balance, and resolution. A canopy height raster file generated from King County LiDAR ground and surface models was also used to provide guidance on stand heights.

McGarvey Park Open Space serves as an example of how Phase 1 was carried out in King County. The park was acquired by King County in 2000 through the 4:1 program, and is composed of 401 ac of forest (fig. 5). Photo interpretation was used to classify the park into 35 MUs as seen in figure 6, guided by differences in color and texture. For instance, MU 8 is a much lighter shade of green than the surrounding MUs.

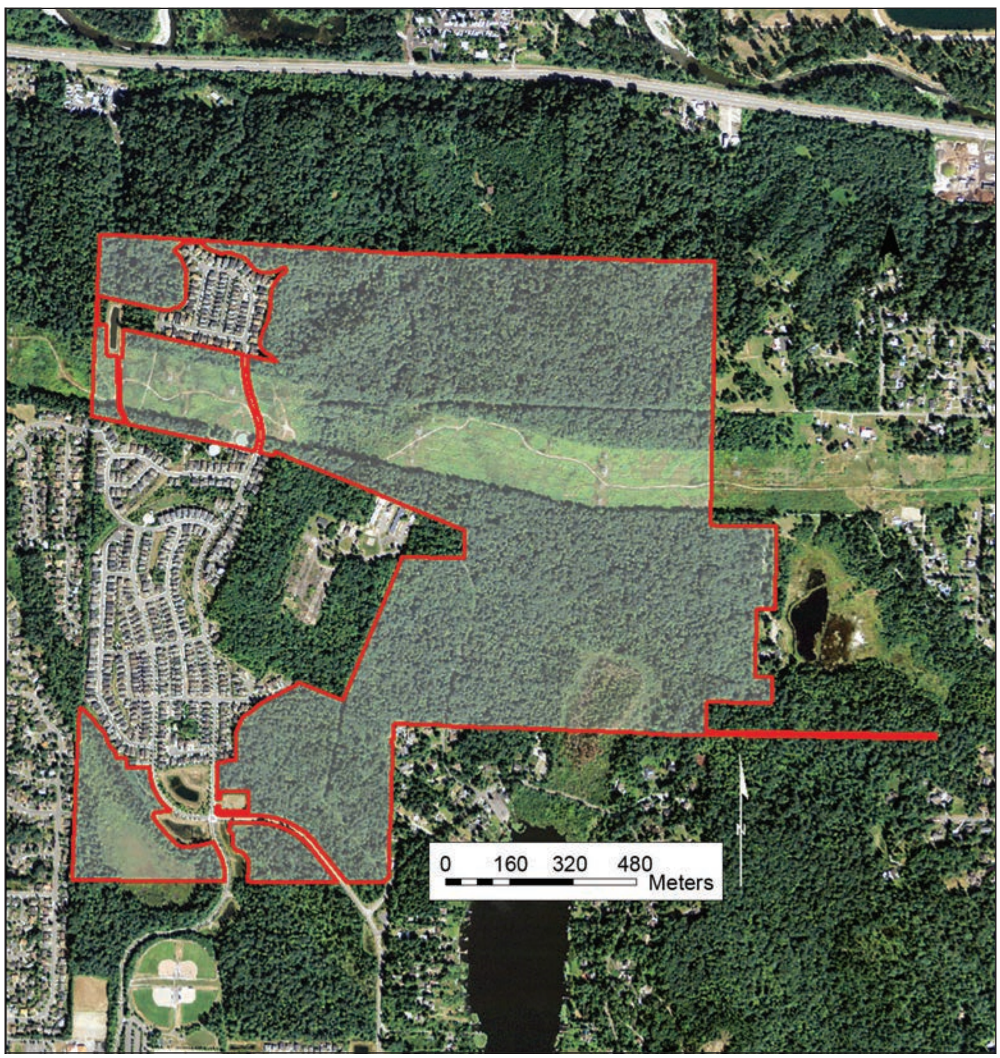


Figure 5—Boundaries of McGarvey Park Open Space.

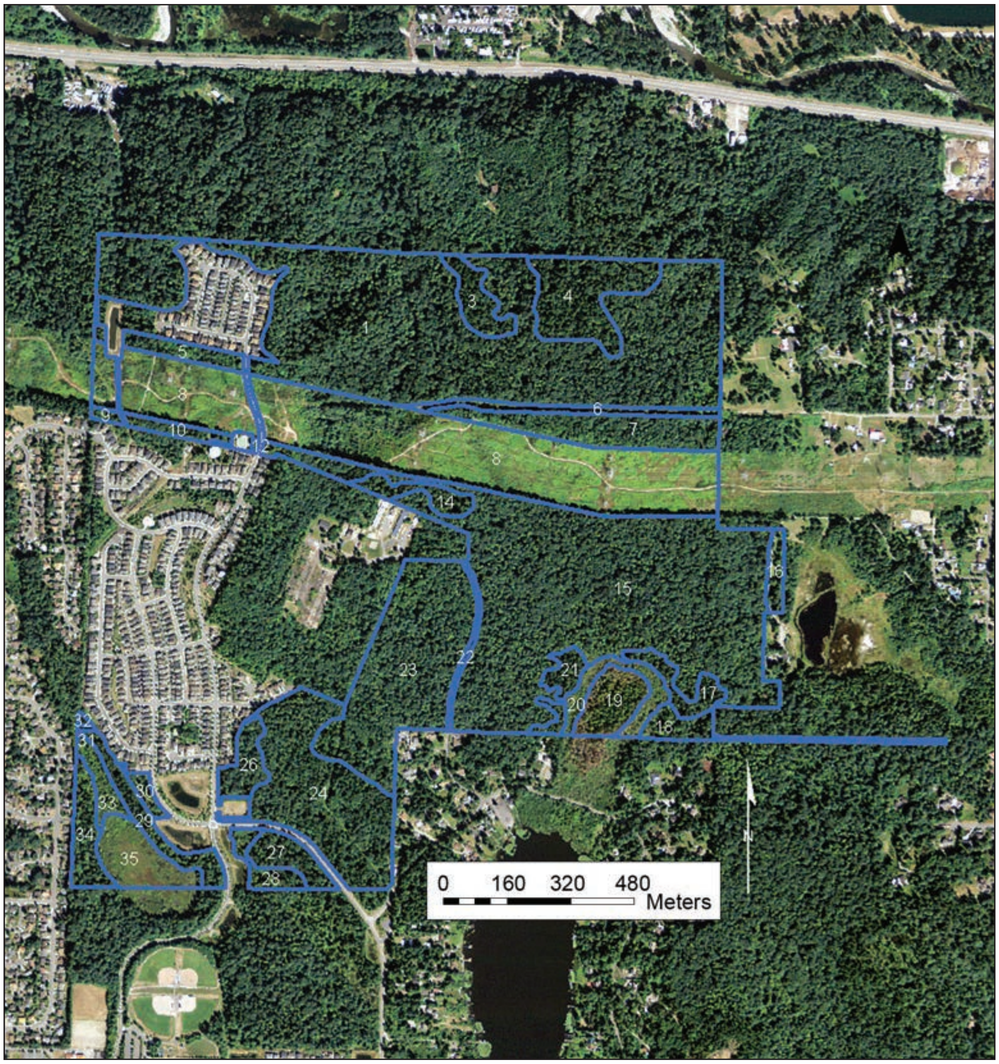


Figure 6—McGarvey Park Open Space management unit delineation.

Phase 2: field assessment—

Specific forest measurements and observations were selected to meet the specific King County objectives of assessing timber resources and assessing the integrity and health of forest ecosystems. Attributes such as overstory tree diameter, stocking, and age were collected to evaluate the timber resource within the MU, while attributes such as native tree composition, invasive species presence, and forest health were collected to evaluate ecological integrity. Attributes were separated into broad categories that could be quickly estimated in the field. A full list of data attributes used in the King County FLAT is in appendix 4.

The ideal crew size was found to be two people (fig. 7). The learning curve for the fieldwork was minor, but it was essential that all field personnel be able to identify native plants and common nonnative invasive plants and noxious weeds.

Figure 7—King County field staff Jack Simonson and Brett Roberts consult management unit maps.

The crews carried both hardcopy orthophotos and digital versions on field global positioning system (GPS) units. Crews surveyed MUs that were clustered geographically in the same day. To begin surveying an MU, crews would drive to the closest road access point. Some of the larger sites would require using multiple access points, while other sites had trail networks that allowed crews to easily move from MU to MU. Depending on the size of the MUs and the level of forest heterogeneity, a crew was able to survey between 3 and 20 MUs in one day. It was also important for crews to maintain their "ocular" calibration by measuring tree diameters and ages at least once on every site. Many of the forests in King County were clearcut in the last 100 years, and it was relatively reliable to assign most trees to the 50- to 99-year-old age class, but there are clusters of both younger and older trees. The *FLAT Field Manual* (app. 6) provides further information about the process.

The field campaign took three summer seasons to complete (2010–2012). Factors that affected the speed of the field crews were (1) heterogeneity of parks—parks with many separate MUs in a small geographic area took longer to survey than parks with a single forest type; (2) size of the park—larger parks required less driving time to get from MU to MU; and (3) distance between parks—parks within a small geographic extent required less driving time. The forests of multiple MUs also tended to be more similar, resulting in less time spent calibrating ocular estimates.

Phase 3: management prioritization—
Variables were selected to construct the matrix (fig. 4), which includes forest composition on the x-axis and forest health threats on the y-axis. The forest composition values were defined prior to the fieldwork using forest ecology principles. In the field, teams determined a high, medium, or low forest composition value for each MU using a flowchart (fig. 8). This flowchart was designed to appropriately rate important landscapes that may not necessarily support a full forest canopy, particularly wetlands.

The y-axis of the Tree-iage matrix for King County includes low, medium, and high threat values. In the Green Seattle Partnership analysis noted above, the extent of invasive species cover was used as the criterion for determining threat values (i.e., low = <5 percent invasive cover; medium = 5 to 50 percent invasive cover; high = >50 percent invasive cover). In this King County case study, managers used additional multiple criteria to describe forest health threats, including the presence of root rot, mechanical tree failure, low tree vigor, presence of mistletoe, bare soil (as an indicator of disturbance), and an "other" category that allowed field teams to record additional observations. Each health indicator was recorded as a yes/no

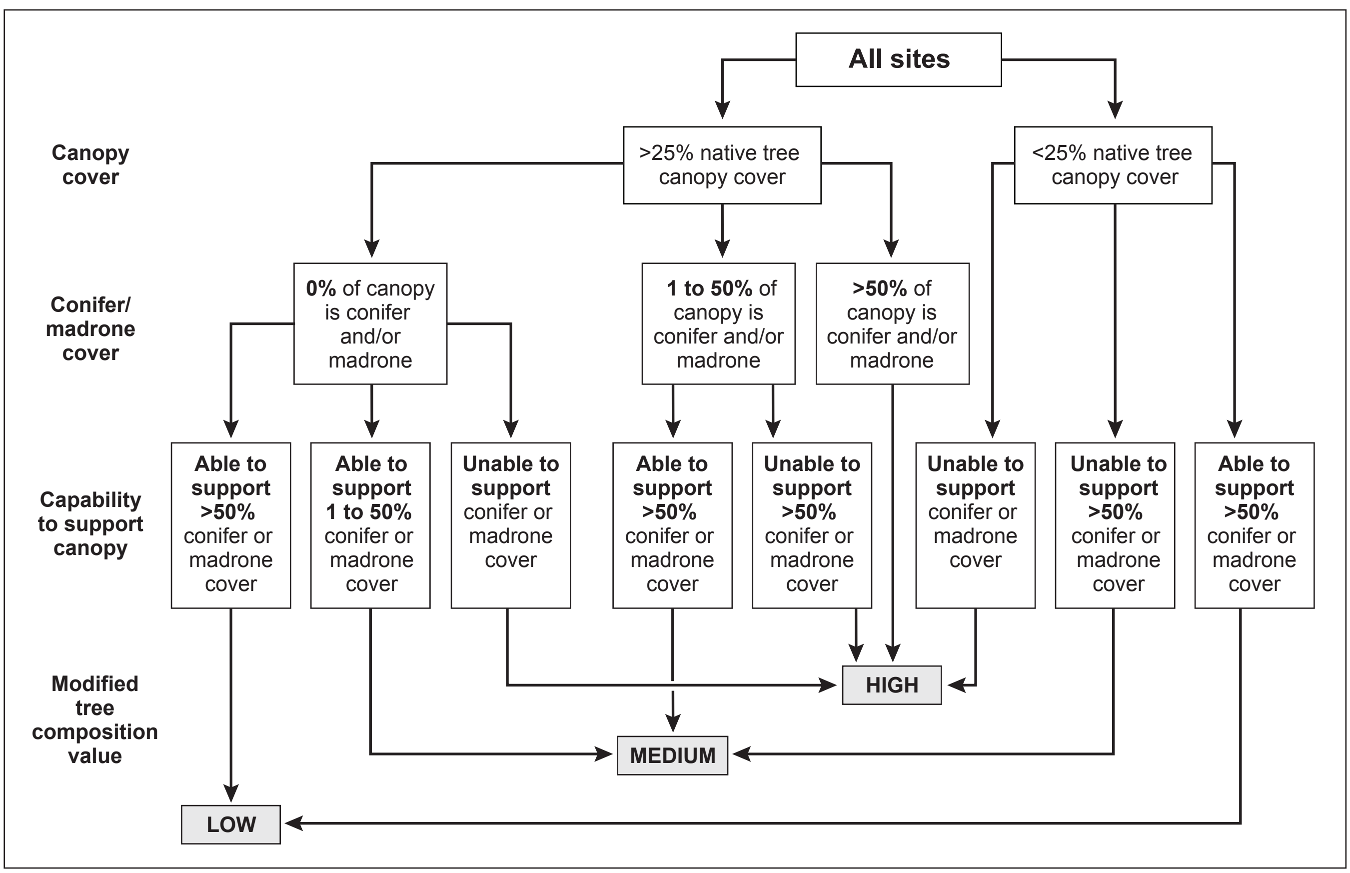


Figure 8—Forest composition flowchart for King County management units.

observation. To determine if an MU had a low, medium, or high threat value, the number of observed health threat indicators were tallied back at the office. Low is interpreted as no observed health threats, medium as one observed threat, and high as two or more observed health threats (table 4). Other projects may develop a tiered approach, creating a decision tree akin to the forest composition flowchart to differentiate between low, medium, and high threat levels incorporating multiple types of indicators.

Table 4—Methodology used to select management unit threat value

Threat value	Observed unhealthy forest values
Low	0
Medium	1
High	2 or greater

Results

An ArcGIS® geodatabase was assembled from the field data. It was used to produce maps, conduct database queries, and generate summary statistics.

Summary analysis of forest characteristics—

The forest variables collected using FLAT helped King County managers to understand baseline information about all of their forested parklands for the first time. Each of the forest attributes collected (app. 4) can be summarized across King County. For instance, the age class structure of the forest can be quickly viewed in figure 9. These data show that red alder (*Alnus rubra* bong.), bigleaf maple (*Acer macrophyllum*), and Douglas-fir (*Pseudotsuga menziesii* Pursh) dominate forest cover. Red alder and bigleaf maple are relatively short-lived species, and the large numbers of trees in age classes 2 (30 to 49 years old) and 3 (50 to 99 years old) suggest that these forests are in need of management and restoration.

Adding a third variable, stocking density, allows for creating type calls that can be useful for timber harvest planning and management (fig. 10). A type call is an integration of the major species (table 5), its size class, and the stocking class of that MU. Size class contains four categories: 1 = 0 to 5 inches dbh, 2 = 6 to 10 inches dbh, 3 = 11 to 20 inches dbh, and 4 = >21 inches dbh. Stocking also has four categories: 0 = <10 percent crown closure, 1 = 10 to 39 percent crown closure, 2 = 40 to 69 percent crown closure, and 3 = >70 percent crown closure. The FLAT data describes a hardwood-dominated forest structure at McGarvey Park (fig. 11).

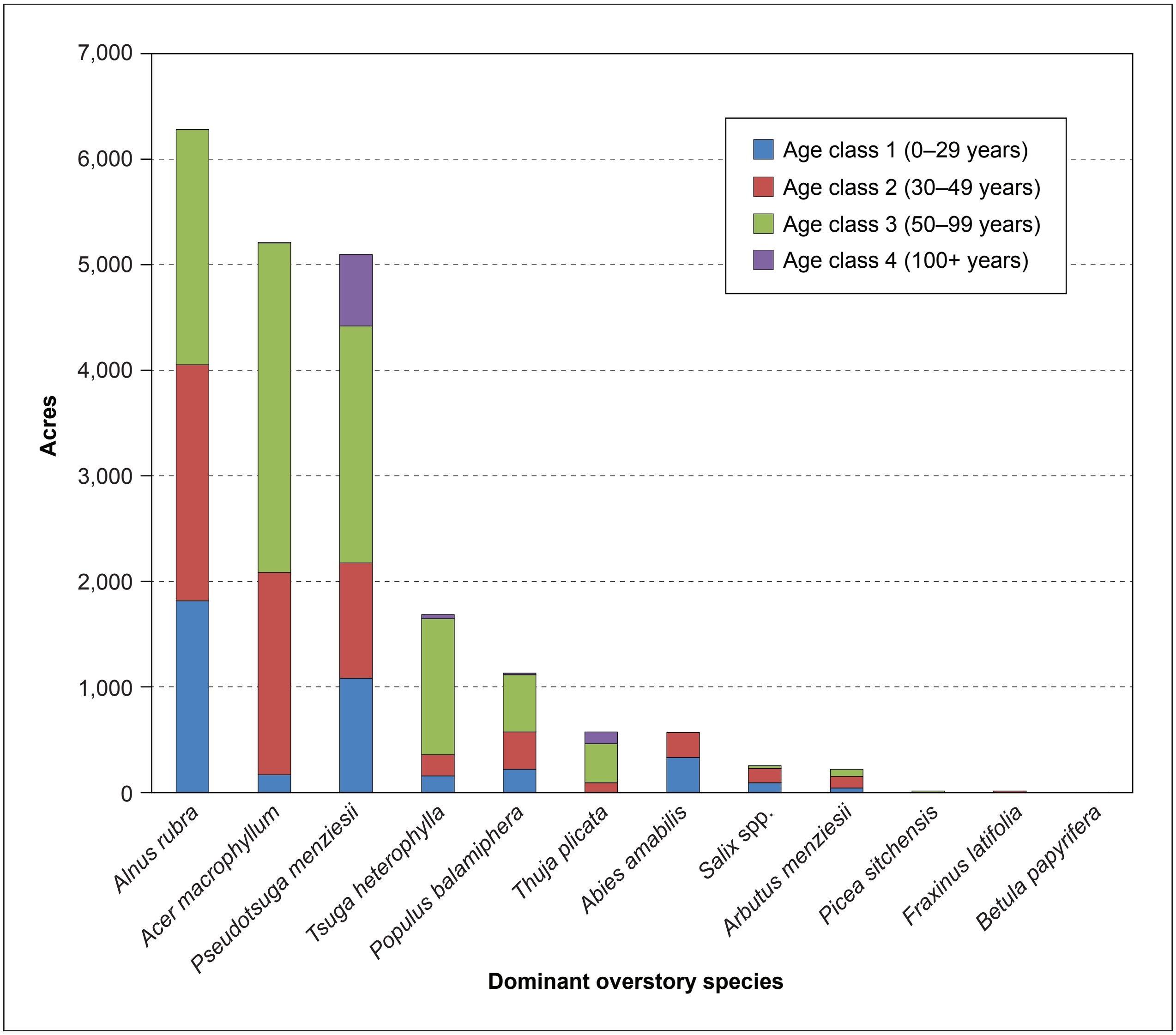


Figure 9—The predominant overstory species and age class across all management units surveyed in King County using FLAT.

Table 5—Major overstory species

Acronym	Scientific name	Common name
CW	*Populus balsamifera* L. ssp. *tricocarpa* (Torr. & A. Gray ex Hook.) Brayshaw	Black cottonwood
RA	*Alnus rubra* Bong.	Red alder
DF	*Pseudotsuga menziesii* (Mirb.) Franco	Douglas-fir
BM	*Acer macrophyllum* Pursh	Bigleaf maple
WH	*Tsuga heterophylla* (Raf.) Sarg.	Western hemlock
WI	*Salix* sp.	Willow species
SF	*Abies amabalis* (Douglas ex Loudon) Douglas ex Forbes	Pacific silver fir
RC	*Thuja plicata* Donn ex D. Don	Western red cedar

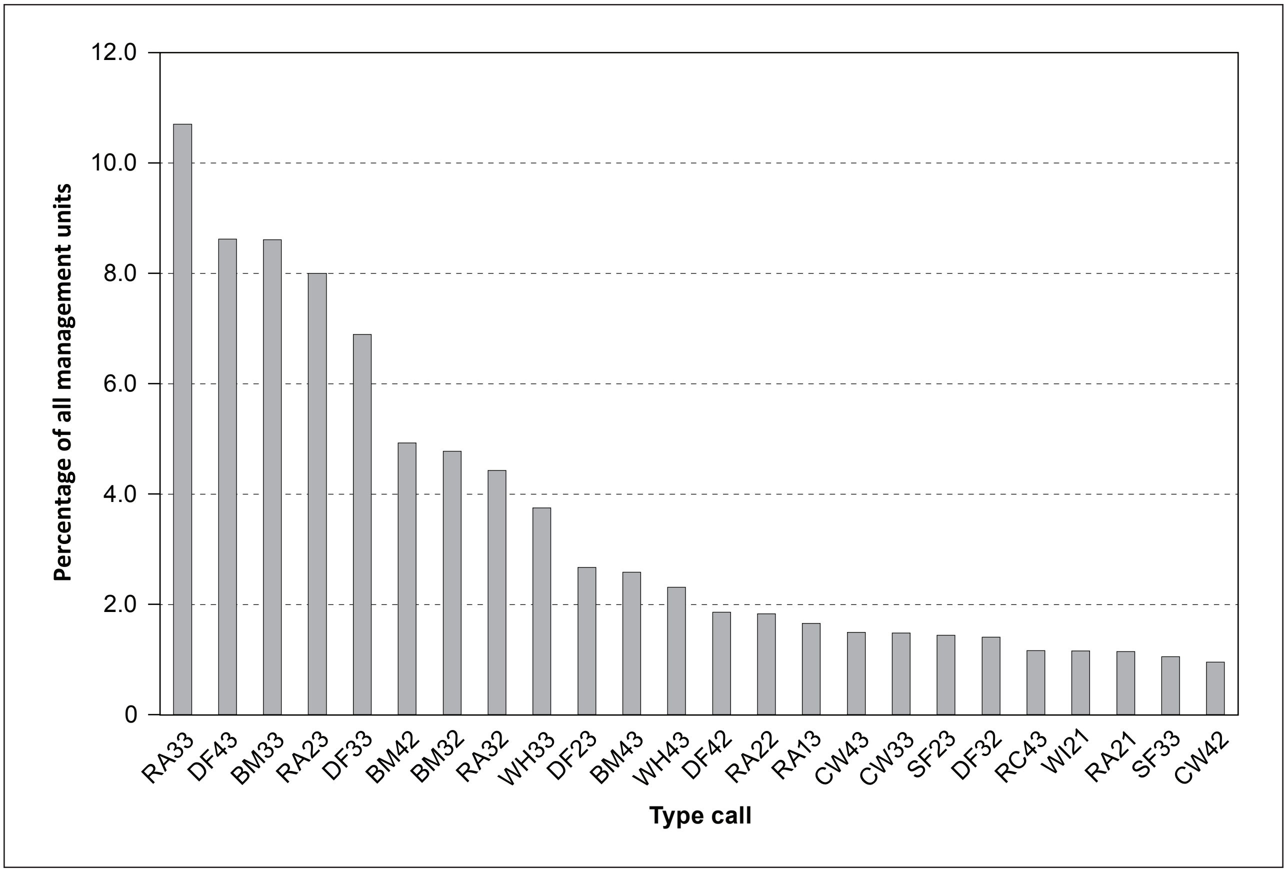


Figure 10—Type calls identified within the King County FLAT that comprised more than 1 percent of the project by area. Note: The type call includes an acronym for the major species, the first digit represents the size class, and the second digit represents the stocking class.

Prioritization analysis—

Because both variables of forest composition and forest health represent important concerns in King County's open space management, the matrix analysis immediately suggests management priorities (with #1 indicating the highest quality forest condition and #9 the lowest). The number of acres of each prioritization value is shown in figure 12, and these results mapped across King County are shown in figure 13.

The matrix values for McGarvey Park are shown in figure 14. Note that a large proportion of McGarvey Park is classified as 5 and 6, indicating that there is a medium composition value with forest health threats present. For example, an MU having **forest composition** keyed out to medium, and having **health threats** of both root rot and low vigor (keyed to high in table 4) would be placed in the matrix of figure 13 as a "6." At McGarvey Park, this translates to MUs that contain dominant red alder and bigleaf maple that are near the end of their productive lives, and have at least one area of conifers infected with root rot. The matrix value of an MU can inform decisions about the priority of action based on management goals.

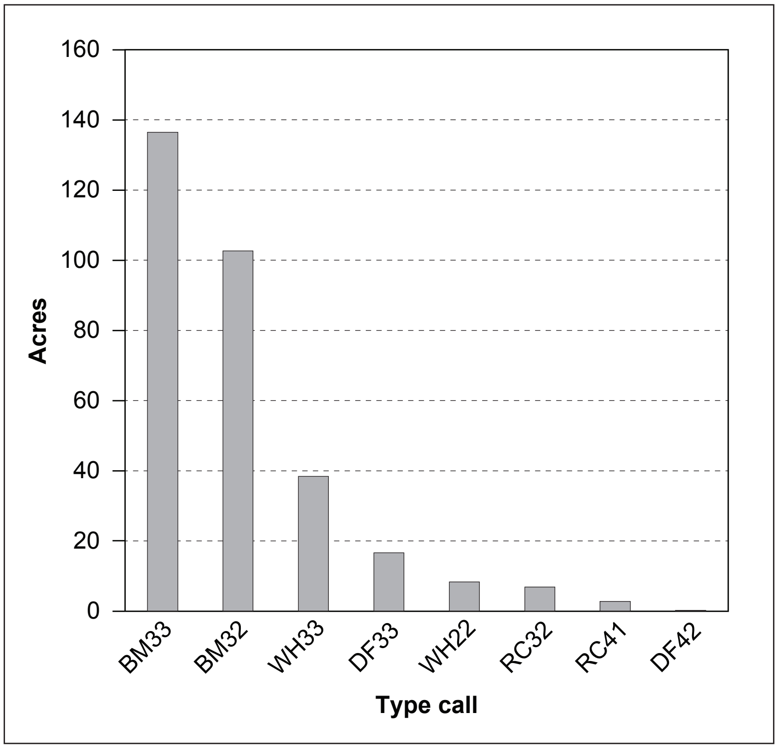


Figure 11—Type calls identified within McGarvey Park Open Space by acres. Note: The type call includes an acronym for the major species, the first digit represents the size class, and the second digit represents the stocking class.

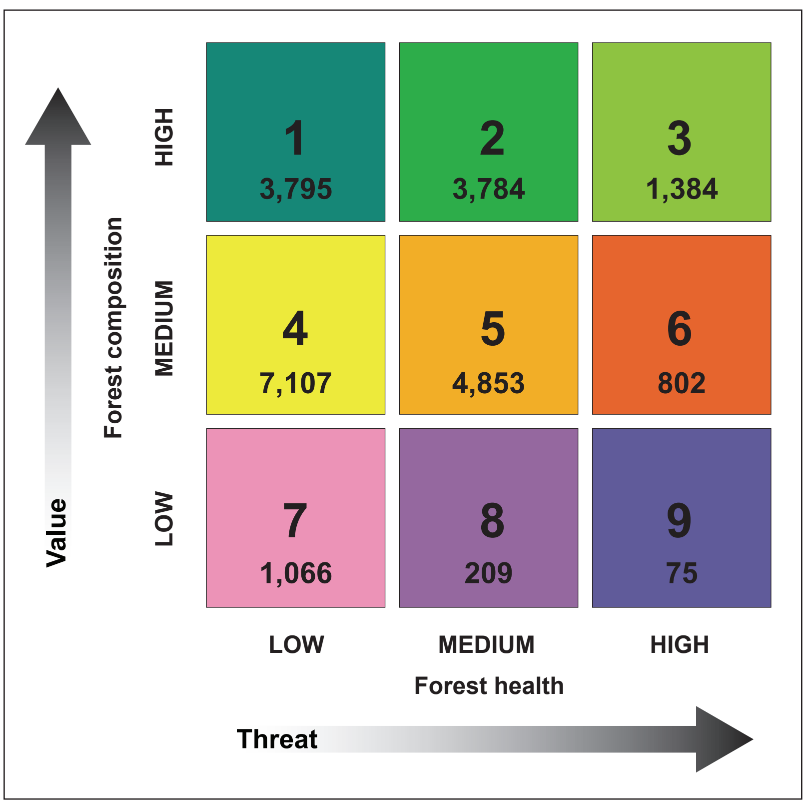


Figure 12—Priority matrix for King County parklands including number of acres of each ranked category.

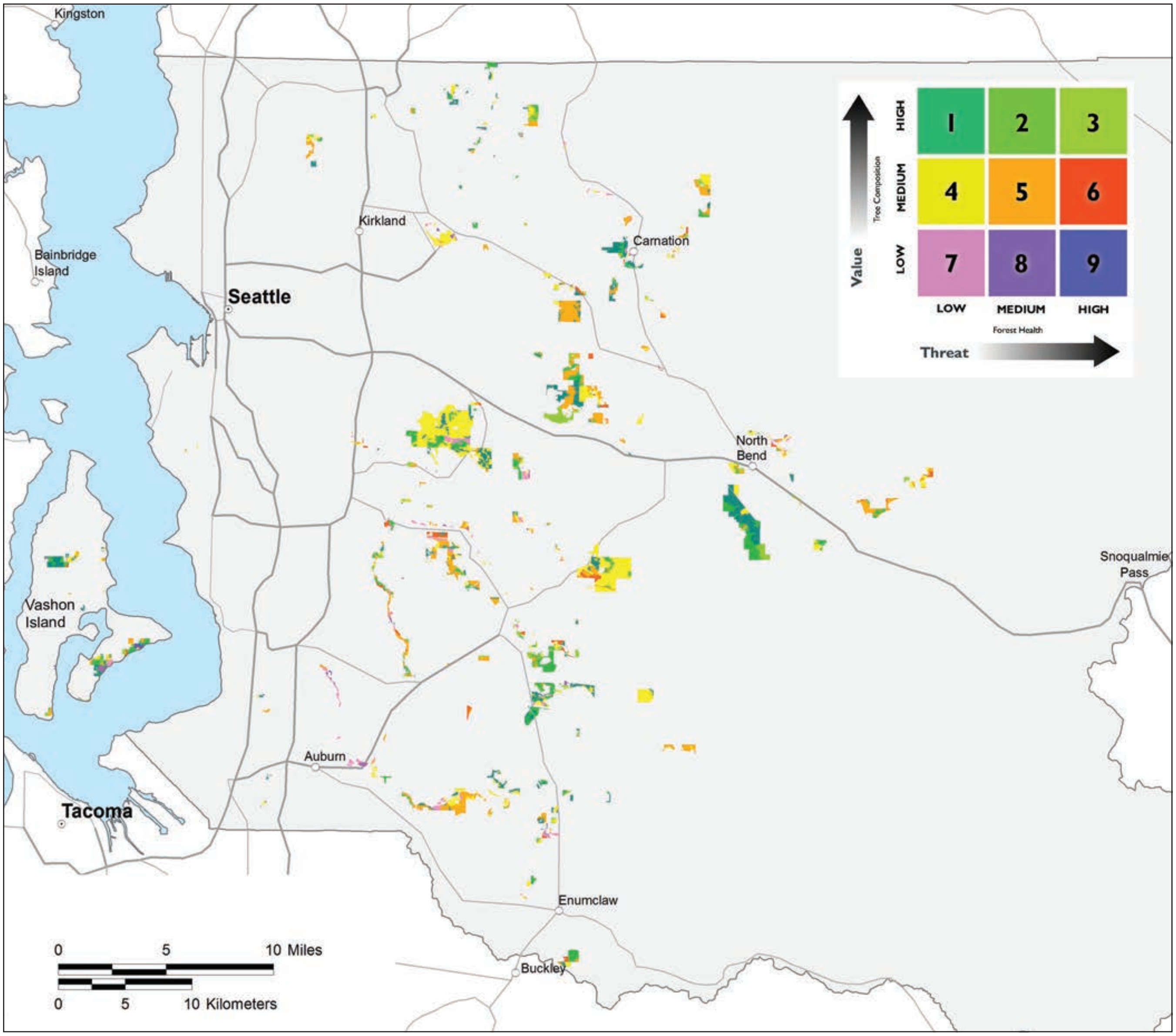


Figure 13—Distribution of management units classified by Tree-iage matrix values for all King County parks.

Management Implications

FLAT results were used immediately. For instance, in 2012, FLAT data guided forest management decisions for McGarvey Park, where old, dying, and diseased red alder and bigleaf maples were harvested for revenue. These areas were replanted with mixed conifers to meet forest restoration and future timber harvest goals. As FLAT data are updated during future monitoring phases, a shift should be seen in composition from older hardwood to vigorous conifers that return greater benefits. Note that to complete a timber sale, a supplemental timber cruise is required to establish the quantity of trees to be removed and subsequent value. More

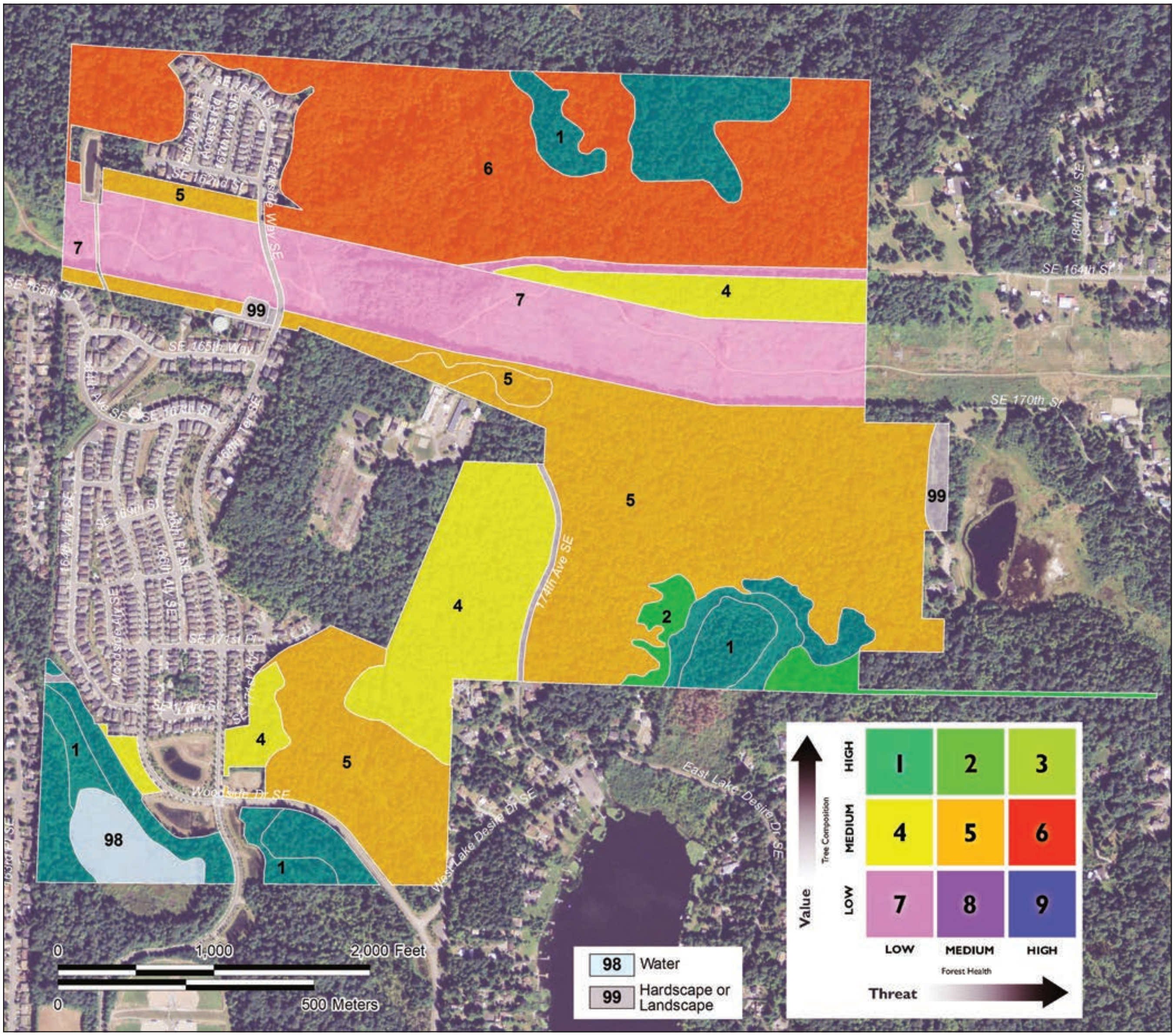


Figure 14—Distribution of management units classified by Tree-iage tree composition and health threat values for McGarvey Park Open Space.

information about how FLAT results were implemented can be seen in the McGarvey Park Open Space Stewardship Plan (King County 2011).

FLAT results are of value across the county's holdings, and will inform management decisions for years to come. With many recent acquisitions of forest land, King County Parks is using FLAT results as baseline forest data for forest stewardship strategies. For the 3,000 ac of designated working forests in King County, FLAT will support the creation or update of required forest stewardship plans. Of the other lands in the multi-use and ecological designations that do not require formal stewardship plans, FLAT will provide data to help King County identify specific MUs that need further attention because of forest health threats. Based on the field data collected through FLAT, King County has started to conduct additional site-specific analyses, including actions that target areas of root rot. With the data now in hand, King County managers can continue to assess their lands and designate planning resources strategically.

Conclusions

The purpose of FLAT is to provide a systematic survey of forested lands that supports the prioritization of future management actions in a landscape system. This information can be used widely to implement landscape-level planning, unit-specific management, and ecological knowledge building.

Local governments have used FLAT data to plan their forest stewardship and restoration programs.

Importance in Land Management

King County and the other municipalities that have implemented FLAT and FLAT-precursors have used the resulting data in a number of ways. Their primary use has been in the planning and budgeting for stewardship and restoration programs. A baseline understanding of the status of each MU gives natural resource managers the ability to estimate the costs of future action as well as determine where and what more detailed or site-specific assessments may need to take place. The rapid assessment process can also alert them to threats or land conditions they may not have anticipated or suspected.

The FLAT data can also be used in conjunction with other spatial data or information for decisionmaking. As an example, figure 15 shows how the Green Redmond Partnership used assessment data along with social information to prioritize restoration activities (Green Redmond Partnership 2009). Using GIS, FLAT data can be combined with demographic, ecological, or environmental data to investigate trends and identify relationships across a landscape or public lands system.

FLAT was designed to purposefully support adaptive management. FLAT can be iteratively applied and combined with other assessments. Also, as repeated FLAT assessments are conducted and management is carried out, the repeated measures can provide managers with a way to observe the effectiveness of management actions. This application of FLAT has not yet been done in King County. In principle, by supporting longer term observations of patterns of ecosystem response, FLAT can provide more than just a snapshot survey. As FLAT is a practical and fairly low-cost tool, it may be redone on a periodic basis (perhaps every 5 years) and become a monitoring tool for management assessment and improvement. Because it is straightforward to learn and do, a variety of participants can be involved in a data-collection cycle, from staff to volunteers to local stewardship groups.

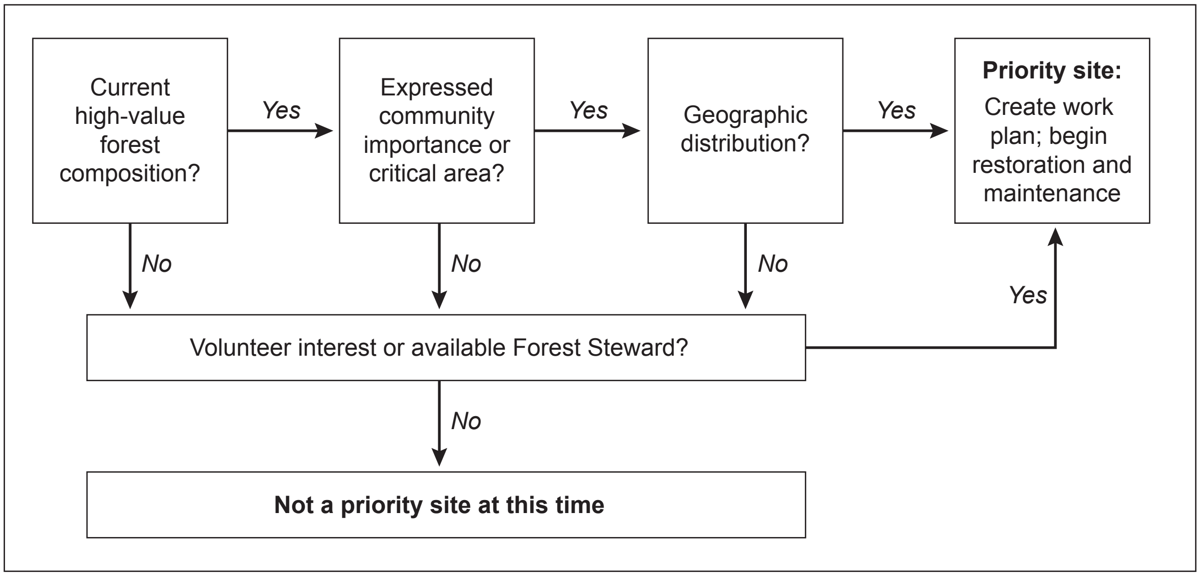


Figure 15—Green Redmond Partnership decision tree for prioritizing restoration sites.

FLAT Feasibility

Simplicity, flexibility, and low cost make FLAT an appropriate tool for many users. By assessing a limited set of variables and applying methods, including field protocols, that are easily teachable, FLAT makes forest assessment doable across a wide spectrum of landowners. Where forest condition information is lacking or piecemeal, FLAT can fill the gap and provide consistency without requiring significant time, training, or large equipment purchases.

In addition, the FLAT framework is inherently flexible for use on a wide range of land ownerships, from small and contained to large and complex. For any given project, there is also flexibility in how detailed to make the field assessment, matching procedures to the size of the forest and intended use of the data.

The simplicity and flexibility of FLAT allows it to be implemented within a tight budget. This is a crucial factor that makes FLAT feasible for cash-strapped local government, private, and NGO landowners. In addition to the reduced time, training, and equipment that normally make assessment more expensive, costs can also be kept low by using the growing interest in citizen science. Where appropriate, projects can support community involvement by using volunteers to conduct fieldwork. Project planning should then include training costs and field checks for data reliability.

Stewardship

The landscape assessment of King County's parks and open spaces revealed that there are natural systems that in some instances are robust and healthy and, in other cases, are in decline or face substantial threats. Ongoing forest resource management is needed across all these conditions, both to restore compromised landscapes and sustain those that are healthy or moving to an improved condition. Forest and landscape management is an intensive activity, involving strategic planning, technical and scientific input, and on-the-ground actions. To carry out these activities, a resource management agency can use its own staff or contracted consultants to do land-based work. Yet fiscal constraints in local government and environmental resource organizations can limit their capacity to address ecosystem needs and recovery.

In the face of limited and declining fiscal and technical resources for ecosystem management, communities and agencies must consider new solutions to restore and sustain natural systems, particularly in urban settings (Wolf et al. 2013). Engagement of people and social systems, from individuals to organizations, is another stewardship option (Wolf 2012). Environmental stewardship is an increasingly common response to the decline of natural systems in and around built environments (Romolini et al. 2012). Recent research in multiple U.S. cities suggests that stewardship may be an effective and viable strategy for ecosystem management (Svendsen and Campbell 2008), particularly in urbanized areas.

Stewardship organizations and volunteers can assist with FLAT data collection, contributing to better management of urban forests.

There is a great deal of variability in the organizational and administrative structures that support stewardship efforts. At one level, programs and projects may be activated by landscape-scale policies and associated regulations that are promulgated by community planners, agency officials, and policy decisionmakers (Brunckhorst 2002). Other stewardship groups are composed of citizens organized to address a defined ecosystem condition that has direct personal consequences, acting for change through place-based projects and resources. Some groups are formally self-organized and have 501(c)(3) status, some are informal organizations without legal status, and some are membership organizations facilitated by a public entity (Brinkley et al. 2010).

No matter who participates in stewardship, and whatever their motivations, better landscape health outcomes can be promoted using the information provided by a landscape assessment like FLAT. For instance, having full knowledge of parcel conditions can help a stewardship coordinator within an agency to prioritize stewardship programs across a landscape system, to ensure that the greatest work effort is assigned to places having the greatest need. In addition, those nonprofit organizations that host stewardship projects can use an assessment to assign volunteer work parties within their activity area, as well as communicate to the public about the high-health parcels that may deserve conservation status. Finally, a "friends of" group of citizen stewards can use assessment information to identify the most important project sites within a park or open space within their community, so that they achieve satisfying outcomes from their self-sufficient efforts. In all these situations, periodic reassessment can help the agency, organization, or group to better understand how their efforts contribute to better ecological health.

Limitations

FLAT is a useful tool for planning, budgeting, stewardship, and performance measurement. However, its application does have limitations that are important to consider. The qualitative nature of the field assessment makes the FLAT unsuitable as evidence of compliance with environmental standards or the creation of environmental impact statements under state or federal law. FLAT would also not be sufficient to develop a sustainable harvest plan, though it can serve as a first step to get a picture of resources on the land.

Another limitation of FLAT is the coarse-grain scale of the data. Management Unit sizes may limit use of FLAT as a tool for understanding fine-scale ecological structures and processes. Most MUs will be larger than the level at which some plant interactions take place. Attempts to scale the MU down to small land areas will greatly increase the number of MUs, increasing cost and time of the assessment. FLAT, therefore, does not take into account small pockets or sites within the unit. In theory, a unit with a number of concentrated pockets of invasive species would appear the same as a unit within which a similar proportion of invasive species are found throughout a more dispersed area. Although a classification of heterogeneity could be added, a more detailed assessment will likely be required to understand site-specific details and evaluate what type of action may be necessary within an MU. The purpose of FLAT is therefore to determine **where** these detailed assessments may need to take place.

While FLAT is limited in spatial scale, it is also limited in its scale of possible indicators. As more indicators are added, the speed and simplicity of the assessment—two of the primary advantages—will be reduced. For FLAT to retain these qualities, it may be necessary to exclude certain variables or indicators that may be useful in specific management situations. The current FLAT protocols and analysis are a reflection of both the priorities of King County as a pilot user and the need for FLAT to retain its rapid deployment character. Project managers will have to carefully weigh the tradeoffs of including more indicators based on their specific circumstances.

In addition, the current FLAT protocols do not include wildlife. If managers have a specific species or cohort of species in mind, attributes could be added that indicate habitat suitability or presence.

Next Steps

FLAT is a relatively new tool, and as such, has potential for future development, testing, and refinement. Formal testing would enhance the credibility of FLAT. Although it has already been informally tested through application to the satisfaction of practitioners, neither its reliability nor accuracy has been systematically evaluated. A reliability test might entail examining whether individuals with similar training and experience using FLAT on the same MU would produce similar results. An accuracy test might compare the results of a FLAT assessment for particular MUs with evaluations that involve random sampling and more traditional forest ecological data collection within those MUs.

Although used for forest assessment in this report, FLAT can be adapted for assessment of every ecosystem type in the Pacific Northwest region.

As it currently exists, FLAT is designed for use in the lowland forests of the Puget Sound basin and, to a limited degree, in wetlands. Expanding its use to other ecosystem types in other parts of the Pacific Northwest, the Nation, or the world would require revising the measures variables. In principle, however, the basic framework should work for any number of ecosystem types. As discussed in the "FLAT Methodology" section, the system is oriented to a project-specific selection of prioritized data attributes and criteria, in order to best achieve local management goals. Expanding FLAT's ecosystem range is thus a matter of degree, requiring additional work to develop appropriate data attributes and field test new implementations. Concerns about different land scales and vegetation associations would have to be addressed.

One way that this extension of FLAT might be facilitated would be the development of a publicly available clearinghouse that catalogs indicators, classification schemes for each indicator, and prioritization systems that have been developed for various ecosystem types. Practitioners planning a FLAT project could then devise a system built on the experiences of others, just as those in the Pacific Northwest can use the King County example as a starting point.

Lastly, future research may explore applying FLAT as a practical method of monitoring ecosystem changes not necessarily tied to natural resource management goals. For example, decisionmakers interested in more general information regarding emerging local effects of climate change, or changes in habitat quantity or quality, or shifts in biodiversity, or any number of other topics, may adapt FLAT to focus on such system-level questions.

Acknowledgments

This work was developed by the Green Cities Research Alliance (GCRA). In 2009, GCRA was initiated by the USDA Forest Service, Pacific Northwest Research Station, to build a program of research about urban ecosystems in the Puget Sound region. The GCRA is an integrated social-ecological research program that engages the social and biophysical sciences to meet the practical needs and concerns of local organizations and agencies. It also is an effort to coordinate science and community partners within the Pacific Northwest region and to link investigations to other U.S. urban areas. The goal of this collaboration is to increase the knowledge necessary to build healthy, sustainable urban environments. The GCRA pairs scientists with practitioners and local decisionmakers to co-design and implement research efforts that provide relevant and practical information. Major collaborators include the University of Washington, King County, Forterra, and the City of Seattle. For more information, visit http://www.fs.fed.us/pnw/research/gcra.

The GCRA's work on FLAT has been particularly informed and supported by the Green Seattle Partnership, with special thanks to Mark Mead for his efforts on developing the Tree-iage analysis tool. The Green Everett Partnership, Forterra, and American Forest Management have also been instrumental in sharing the FLAT analysis process and database. Additional thanks and acknowledgement goes to Ara Erickson (Forterra, now with Weyerhaeuser Company), Kim Frappier (Forterra, now with the City of Mercer Island), Bill Loeber (King County), and Ted Hitzroth (American Forest Management) for their help in developing FLAT. Project field implementation was provided by the King County Department of Natural Resources and Parks, led by Brett Roberts and Jack Simonson.

Major funding for this project was provided by the American Recovery and Reinvestment Act of 2009 (ARRA) and the USDA Forest Service Pacific Northwest Research Station.

References

Brinkley, W.; Wolf, K.L.; Blahna, D.J. 2010. Stewardship footprints and potential ecosystem recovery: preliminary data for Seattle and Puget Sound. In: Laband, D., ed. Emerging issues along urban/rural interfaces III: linking science and society (Proceedings). Atlanta, GA: 24–30. http://www.naturewithin.info/CivicEco/InterfacesIII%20Prcdngs_GCRA.Dec2010.pdf. (December 17, 2015).

Brunckhorst, D. 2002. Institutions to sustain ecological and social systems. Ecological Management and Restoration. 3(2): 108–116.

Clewell, A.F.; Aronson, J. 2007. Ecological restoration: principles, values, and structure of an emerging profession. Washington, DC: Island Press. 232 p.

Dean, J.W., Jr.; Sharfman, M.P. 1996. Does decision process matter? A study of strategic decision-making effectiveness. Academy of Management Journal. 39(2): 368–396.

Green Redmond Partnership. 2009. 20-year forest management plan. Redmond, WA: City of Redmond. http://forterra.org/wp-content/uploads/2015/05/FINAL_GRP_20_YP_InDesign_FORWEB.pdf. (December 17, 2015).

Green Seattle Partnership. 2006. 20-year strategic plan. Seattle, WA: Cascade Land Conservancy and Seattle Parks and Recreation. http://greenseattle.org/wp-content/uploads/2015/04/GSP_20YrPlan5.1.06.pdf. (April 25, 2016).

Iserson, K.V.; Moskop, J.C. 2007. Triage in medicine, part I: concept, history, and types. Annals of Emergency Medicine. 49(3): 275–281. doi:10.1016/j.annemergmed.2006.05.019.

King County. 2011. McGarvey Park Open Space forest stewardship plan. Seattle, WA: King County Department of Natural Resources and Parks, Water and Land Resources Division. http://your.kingcounty.gov/dnrp/library/2011/kcr2230.pdf. (December 17, 2015).

Marsh, W.M. 1978. Environmental analysis: for land use and site planning. New York: McGraw-Hill, Inc. 292 p.

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Hoehn, R.E.; Walton, J.T. 2008. A ground-based method of assessing urban forest structure and ecosystem services. Aboriculture & Urban Forestry. 34(6): 347–358.

Randolph, J. 2011. Environmental land use planning and management. Washington, DC: Island Press. 776 p.

Romolini, M.; Brinkley, W.; Wolf, K.L. 2012. What is urban environmental stewardship? constructing a practitioner-derived framework. Res. Note PNW-RN-566. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 41 p.

Sayre, R.; Roca, E.; Sedaghatkish, G.; Young, B.; Keel, S.; Roca, R.; Sheppard, S. 2000. Nature in focus: rapid ecological assessment. Washington, DC: Island Press. 202 p.

Svendsen, E.S.; Campbell, L.K. 2008. Urban ecological stewardship: understanding the structure, function and network of community-based urban land management. Cities and the Environment. 1(1): 5.

Trust for Public Land. 2012. TPL LandVote database. https://tpl.quickbase.com/db/bbqna2qct?a=dbpage&pageID=10. (December 17, 2015).

Turner, M.G. 2005. Landscape ecology in North America: past, present, and future. Ecology. 86(8): 1967–1974.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2014. The forest inventory and analysis phase 3 indicators database 6.0: description and user guide. Washington, DC. 203 p. http://www.fia.fs.fed.us/library/database-documentation/. (December 17, 2015).

U.S. Department of Agriculture, Forest Service [USDA FS]. 2015. Urban field data collection procedures. The Forest Inventory and Analysis database: database description and user guide for urban data. Washington, DC. 464 p. http://www.fia.fs.fed.us/library/database-documentation/urban/current/FIADB_user%20guide_urban_10_2015.pdf. (December 17, 2015).

U.S. Department of the Interior, National Park Service [USDI NPS]. 2009. NPS natural resource condition assessments (NRCAs): standards and guidelines. Washington DC. https://www.nature.nps.gov/water/nrca/assets/docs/NRCA_Standards_and_Guidelines_Sept2009.pdf. (December 17, 2015).

Wolf, K.L. 2012. The changing importance of ecosystem services across the landscape gradient. In: Laband, D.N.; Lockaby, B.G.; Zipperer, W., eds. Urban-rural interfaces: linking people and nature. Madison, WI: American Society of Agronomy/Soil Science Society of America/Crop Science Society of America: 127–146.

Wolf, K.L.; Blahna, D.; Brinkley, W.; Romolini, M. 2013. Environmental stewardship footprint research: linking human agency and ecosystem health in the Puget Sound Region. Urban Ecosystems. 16: 13–32.

Appendix 1: How to Develop the Assessment Area and Management Units

The forest-cover-type mapping process defines the boundaries and area for each management unit (MU). This process establishes boundaries based on existing ownership, management goals, and vegetation and land-coverage typing from aerial or satellite photos. This section describes the steps of this process.

STEP 1: Determine Which Properties Will Be Included in the Assessment

The project area should be defined in this stage based on relevant management programs and resource information needs (see fig. 16 for an example). It may help to consider if different sites will be managed by different crews or be located in different districts that will affect how management decisions are made, and may change desired assessment boundaries. Thought should also be given to regulatory designations such as wetland or riparian areas that may limit or specify management actions. Each site should have a unique name and number for identification throughout the project. For small projects, there may only be one site, having a single project area name and boundary.

STEP 2: Designate Land Cover Type

Once the assessment sites have been chosen and identified by property ownership or management blocks, the next step is to use aerial or satellite imagery to review, then delineate similar conditions within the predesignated site or project areas. The general purpose of this photo-typing is to identify zones based on the major differences in land or forest cover.

Sites should be divided into units that are given one of a number of broad land cover designations. The land cover designations for the King County pilot project are included below in table 6. Some Forest Landscape Assessment Tool (FLAT) users may wish to expand these designations to include types such as wetlands or shoreline, given the particular characteristics of the system they are evaluating.

The boundaries between land cover types should be based on breaks visible in the aerial or satellite photos. It is not necessary to precisely measure the forest canopy cover to differentiate between, for example, a forested or natural area designation. An estimate should be fine in these cases because the typing will be verified during field data collection (see the *FLAT Field Manual* in app. 6). The designations can be done largely based on viewing the photos, but some may choose to use software or tools like Feature Analyst.

When in doubt about a land cover type, a convention should be established and applied consistently throughout the process. In some cases, it may make sense to

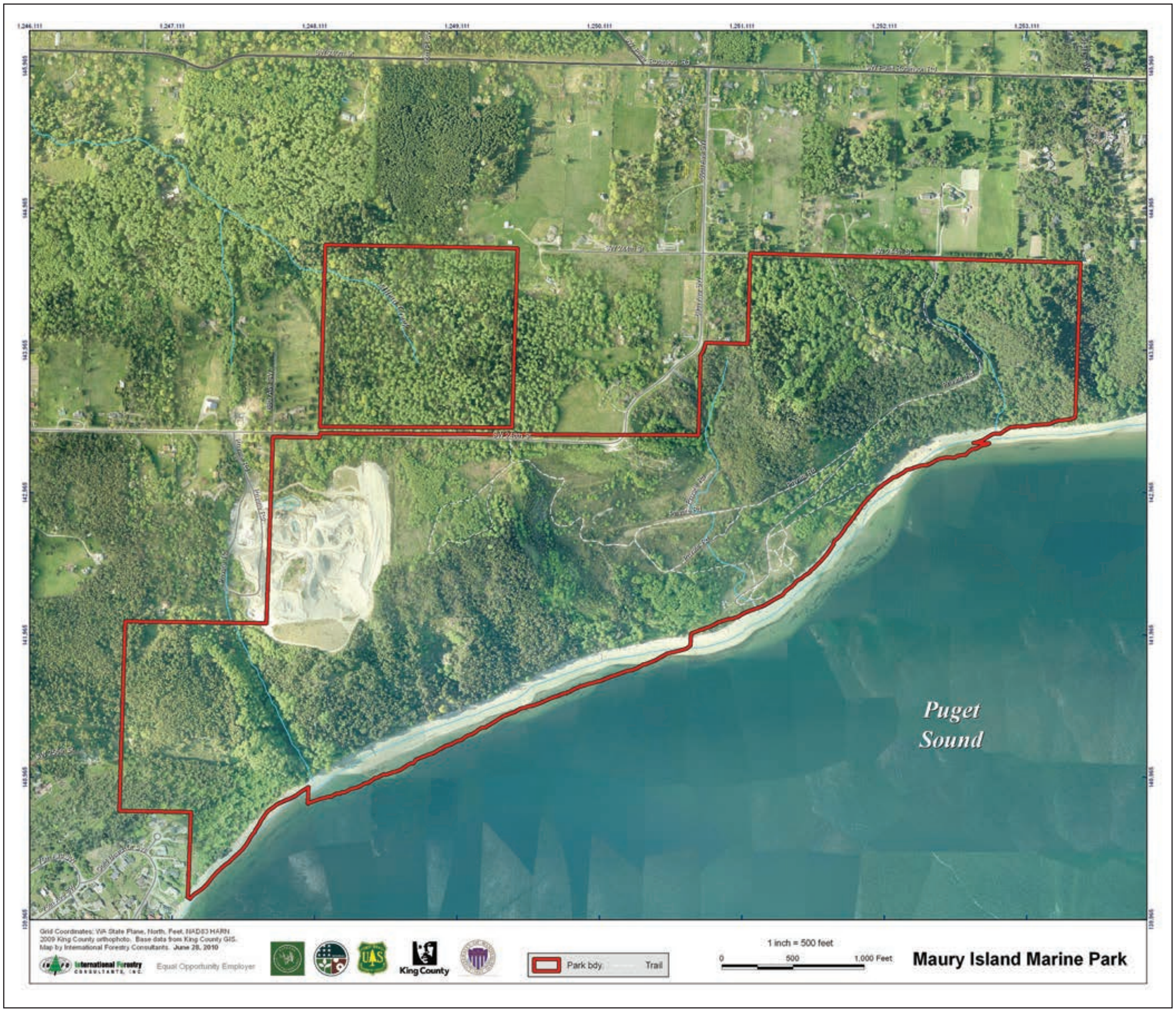


Figure 16—Forest Landscpe Assessment Tool assessment boundary for Maury Island Marine Park, a project site in King County, Washington.

create a new category that indicates the call will be made in the field assessment process. The conventions will likely change based on the team and their priorities, thus it is essential to make assumptions explicit so that users of the information later on will take that into consideration as they make decisions.

A threshold should be set for the minimum size of a land cover designation. In King County, significant and distinct nonforest areas were delineated down to 0.1 ac. It is not the intent of FLAT to map paved paths, tennis courts, or other facilities within site areas. These smaller developed features can be lumped into surrounding landscape or hardscape MUs.

Table 6—King County Parks Forest Landscape Assessment Tool land cover designations

Type	Acronym	Definition
Forested	FOR	≥25 percent of the area covered by forest canopy
Natural	NAT	Any natural vegetation that has <25 percent forest canopy cover
Open water	WAT	Open water without woody vegetation
Hardscape	HS	Impervious surface such as parking or buildings
Landscape	LS	Areas that are currently landscaped or have been mechanically maintained within the past year

STEP 3: Delineate Management Units Based on Vegetation Differences.

With property information and land cover differences delineated, the next step is to further divide a site according to vegetation differences (fig. 17). This applies specifically to land cover designations that fall within the purview of FLAT (i.e., not open water, hardscape, or landscape).

The forested and natural cover typing of Step 2 should be reviewed using aerial imagery to delineate polygons within that contain similar vegetation types. Areas with clearly different species, structural, or age composition should be placed into different MUs. Color, texture, tree shadows, and crown shape can be used to determine MU breaks. Because these characteristics can appear differently on different imagery, use of several image sources is recommended to provide views with varied lighting, color balance, and resolution (see app. 2 for further discussion of necessary data). This vegetation typing requires the most skill and experience with photo-typing and boundary delineation. In addition, if data are available and project staff have the needed expertise, remote-sensing ground and surface datasets (e.g., LiDAR) may be used to generate a canopy height layer for use in a geographic information system (GIS) to assist in differentiating stand heights.

The MU size will vary based on the amount of contiguous similar vegetation coverage as well as thresholds decided on by the FLAT project manager. As an example, King County established a minimum MU size of 5 ac, as it was determined that further subdivisions of MUs would add too significantly to the total number of MUs and time necessary to complete field data collection. This is a judgment call—what you may gain in precision, you may sacrifice in time. In smaller communities, cities, or systems of parcel holdings, it may make sense for MUs to be much smaller.

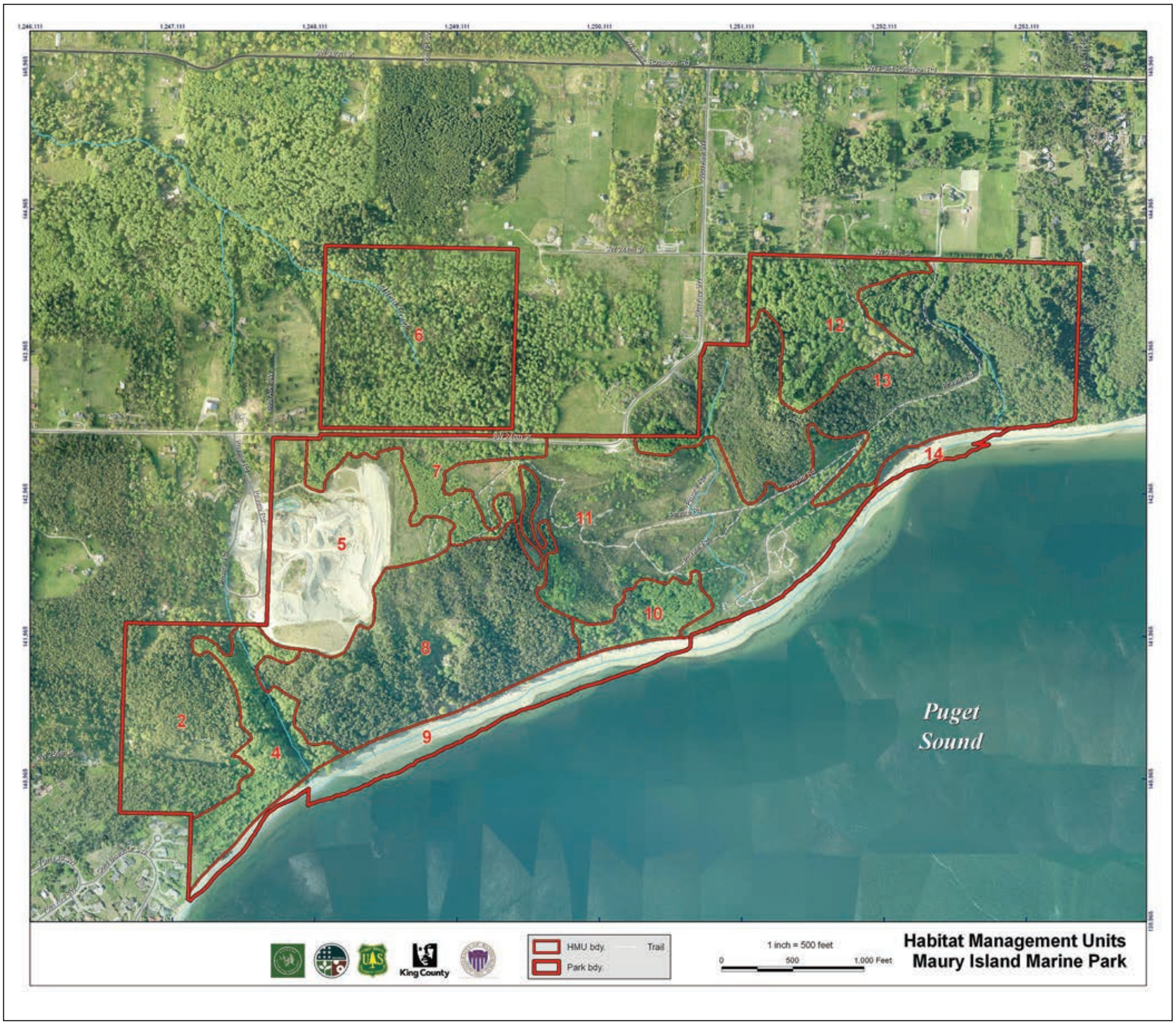


Figure 17—Delineated management units within Maury Island Marine Park, King County, Washington.

Data format—

If you are using digital GIS software to delineate management units, an attribute field should be created within the polygon layer so that each MU polygon feature has a unique identifying number. This unique identifier should reference both the site number and the MU number within the site. Table 7 shows an example of this as the FID_MU where the first four digits are from the site name and the two digits after the dash specify the MU within the site. It is important to track MUs in this precise manner as fieldwork may call for merging or splitting MUs, resulting in new polygons within a site that require careful data management updates. The MU should also have attribute fields for its land cover designation and site, as well as for any important administrative or legal boundaries. This georeferenced attribute table will form the basis of data entry for fieldwork, and into future assessments. Table 7 is an illustration of what this attribute table might look like at the end of this process.

Again, for small-scale projects, there may be only one "site," a single property, and, in that case, MU identifiers can be a simple sequential numbering system.

Without GIS software, the MU identifying number should be written directly onto the hardcopy aerial photos used to draw the MU boundaries. The same table should be created in a digital form such as Microsoft Excel or Access.

Table 7—A sample attribute table after type mapping and data collection

FLAT_MU								
FID_MU	**SITE_NAME**	**ACRE**	**LAND_COV**	**ASPECT**	**SLOPE**	**AGE_CLASS**	**OVR1_SPC**	**OVR1_SIZE**
4601-01	Sugarloaf Mountain Forest	10.6	FOR	72	54	2	PSME	3
4601-02	Sugarloaf Mountain Forest	273.6	FOR	165	34	1	ALRU	1
4632-01	Mirrormont Park	4.9	FOR	215	4	3	ALRU	3
4632-02	Mirrormont Park	4.2	FOR	215	5	3	PSME	4
4632-03	Mirrormont Park	1.7	LS	259	7			
4634-01	Fall City Natural Area	2	WAT	196	2			
4634-02	Fall City Natural Area	3.9	NAT	194	0	1	ALRU	2

Appendix 2: Necessary Data

Aerial Imagery

Aerial photographs or satellite imagery are important sources of information for initial management unit (MU) delineation and mapping. There are several considerations that will help determine your best source of data:

- If you are using geographic information system (GIS) software, it is important that the imagery used be geometrically corrected, or "orthorectified," and geographically referenced so that boundaries drawn using the photos will correspond to the correct places and distances on the surface of the earth.
- Resolution should be high enough to distinguish between different coverage types, and color makes this interpretation much easier. If tools such as Feature Analyst are being used to aid in the photo typing, there may also be resolution thresholds or requirements.
- Photos should be taken during the summer, when vegetation from both deciduous and evergreen trees and shrubs are visible, as vegetation types will be used to define MU boundaries. In some cases, having multiple image sets at different times of the year will be helpful.

For the King County pilot project, several sets of aerial imagery were used, in part to be able to compare conditions. These included:

- **King County 2009 natural color ortho photos** in 0.5 to 1 ft resolution. These data displayed significant parallax along mosaic edges, which made typing larger areas more difficult.
- **Arc® Online imagery.** Arc images can change without notice and there is no control over color balance, and the radiometric settings are more likely to have rectification errors. Overall, there are fewer parallax and mosaic issues.
- **U. S. Department of Agriculture National Aerial Imagery Program (NAIP)** 1 m orthophotos.

Parcels

Parcel data are important for delineating MUs. Aerial and satellite imagery can be used to type by natural conditions (such as vegetation cover, or surface water elements), but parcel boundaries are often the basis of management programs. Because the Forest Landscape Assessment Tool (FLAT) is a tool intended to support management decisions, MUs should be informed by ownership and management jurisdictions. In most cases, parcel data will be the source of legal boundary delineation. Some considerations:

- Parcel data should include attributes that indicate ownership or management goals for each feature. At the very least, it is important to determine if a parcel is managed by the organization conducting the FLAT assessment.
- Note that assessor parcel GIS layers often display approximate boundaries. Locations do not always match imagery and other layers. This is usually adequate for the level of mapping used for FLAT.

Other Management Boundaries

- Sometimes there may be other management program boundaries that should be taken into consideration when creating MUs.
- If there are existing stewardship plans in effect or additional information about a specific area, it may make sense to classify MUs to accommodate preexisting documents or delineations.
- Management systems will often be divided into subdistricts or areas, each having their own programs or assigned management staff. This may also be important information for dividing MUs and should be considered along with the parcel and ownership data.
- Legal designations that limit management actions or have additional regulatory requirements, such as riparian zones or wetlands, should also be indicated when delineating MUs.

Appendix 3—Equipment List

Traditional forestry tools and equipment are used in a Forest Landscape Assessment Tool (FLAT) assessment (table 8) to help field crews calibrate their visual estimates. Depending on the ecosystem type, management goals, and complexity of other FLAT projects, this list can be modified to incorporate additional or different tools. The most expensive piece of equipment is the global positioning system (GPS) unit. In lieu of a costly GPS unit, most smartphones have GPS capabilities and can be programmed with a background map. If a GPS unit or smartphone is unavailable or not desired, a FLAT assessment can be implemented with a hardcopy paper map and data sheet.

Table 8—King County, Washington, equipment list

Item	Considerations	King County pilot project
Geographic information system (GIS)	Having expensive GIS software such as ArcGIS® in which to track and query information is convenient for conducting FLAT but probably not necessary Free open source tools such as GrassGIS or even free “cloud-based” tools such as Google Earth® or Google Fusion Tables High-resolution orthophotos, maps and handwritten tables could qualify as a GIS if necessary	ArcGIS 10.0
Paper map	Boundaries of each management unit should be overlaid and labeled on the map	Yes
Camera	Photos of forest conditions are very helpful	Yes
Compass	Good for orientation	Yes
Global positioning system (GPS)	A smartphone could also be used in some cases instead of a GPS unit	Trimble Geo XT
Data entry tool	Microsoft Office® is compatible on most smartphones as well	Trimble Geo XT® with Microsoft Windows Mobile®
Paper data forms	Good for backup in case electronic devices are not working	Yes
Plant identification reference books	Very important that field crews are able to identify native and nonnative plants	Pojar and MacKinnon (2004)
FLAT Field Manual	This provides a quick reference to the data-collection procedures	Yes (early draft)
Diameter tape	For estimate calibration	Yes
Clinometer	For estimate calibration	Yes
Increment Borer	For estimate calibration	Yes
Densiometer	For estimate calibration	No

FLAT = Forest Landscape Assessment Tool.

Appendix 4: King County Data Attributes

Table 9 displays the data attributes included in the King County Parks pilot project. Attributes were chosen that described forest characteristics considered most relevant for setting land management priorities and subsequent development of land management plans for forested parks and resource lands in the county.

Table 9—King County, Washington, data attributes

Data attribute	Data field	Explanation/criteria
Site name	SITE NAME	GIS identifier
Management unit number	HMU_NO	GIS identifier
Date of data collection	DATE	
Assessors initials	CREW	
Land cover	LANDCOV	
Forested	FOR	≥25 percent forest canopy
Natural Area	NAT	<25 percent forest canopy
Open Water	WAT	No woody vegetation
Hardscape	HS	Buildings, parking
Landscaped	LS	Landscaped, mechanically maintained
Age class	AGECLASS	
Category 1	1	0 to 29 years
Category 2	2	30 to 49 years
Category 3	3	50 to 99 years
Category 4	4	100+ years
Overstory species	OVR1_SPC	Overstory species, most abundant dominant or codominant >20 ft
Overstory size	OVR1_SIZE	Overstory dbh size class
Category 1	1	0 to 5 inches dbh
Category 2	2	6 to 10 inches dbh
Category 3	3	11 to 20 inches dbh
Category 4	4	21+ inches dbh
Second overstory species	OVR2_SPC	Second overstory species, in order of abundance codominant >20 ft
Second overstory size	OVR2_SIZE	Overstory dbh size class, see size class chart above
Third overstory species	OVR3_SPC	Third overstory species, if present, in order of abundance codominant >20 ft
Third overstory size	OVR3_SIZE	Overstory dbh size class; see size class chart above
Stocking	STOCKING	Crown closure estimate, as viewed directly above
Category 0	0	Less than 10 percent crown closure
Category 1	1	10 to 39 percent crown closure
Category 2	2	40 to 69 percent crown closure
Category 3	3	70+ percent crown closure
Management unit composition	HMU_CMP	

Table 9—King County, Washington, data attributes (continued)

High composition	H	>50 percent conifer/madrone; **or**
		≤50 percent conifer/madrone with no capacity for restoration (includes wetlands)
Medium composition	M	1 to 50 percent conifer/madrone with capacity to support restoration to H; **or**
		<25 percent native cover with capacity to restore up to 50 percent conifer
Low composition	L	< 25 percent native cover with capacity for full restoration planting; **or**
		No conifer/madrone with capacity for full restoration
Low vigor	LOW VIGOR	Conifer: live crown ≤40 percent? Y or N
		Hardwood decline: top dieback or snags ≥5 percent? Y or N
Mechanical tree failure	FAILURE	Mechanical tree failure in ≥1 percent of MU, Y or N (e.g., windthrow, landslide)
Root rot	ROOT ROT	Root rot pockets present? Y or N
Mistletoe	MISTLETOE	Mistletoe present? Y or N
Bare soil	BARE SOIL	≥1% bare soil present from recent disturbance, erosion, etc.? Y or N
Other	OTHER	Present in ≥1 percent of MU? Y or N (*note in comments*)
Regeneration species	RGN1_SPC	Regeneration species <20 ft height, in order of abundance
Second regeneration species	RGN2_SPC	Regeneration species <20 ft height HT, in order of abundance
Regeneration stocking class	RGN_TPA	
Category 1	1	0 to 49 TPA (>30 ft spacing)
Category 2	2	50-149 TPA (between 30 and 16 ft spacing)
Category 3	3	150+ TPA (<16 ft spacing)
Plantable space	PLANTABLE	Suitable growing space for restoration planting? Y or N
Native shrub and herb species	GRD1_SPC	Native shrubs and herbs, most abundant
Native shrub and herb species	GRD2_SPC	Second native shrubs and herbs in order of abundance
Invasive species	INV1_SPC	Nonnative species, most abundant
Invasive species	INV2_SPC	Second nonnative species in order of abundance
Invasive species	INV3_SPC	Third nonnative species in order of abundance
Invasive species	INV4_SPC	Fourth nonnative species in order of abundance
Invasive species	INV5_SPC	Fifth nonnative species in order of abundance
Total invasive cover	INVCOV	Total invasive cover
High cover	H	> 50 percent
Medium cover	M	5 to 50 percent
Low cover	L	<5 percent
Notes	NOTES	Unique site conditions and other dominant trees present

Appendix 5—Cost Analysis

Table 10 compares the estimated costs associated with carrying out the FLAT assessment in two park systems, those of King County and the City of Everett, Washington. Staff costs include project management and fieldwork, while consultant costs include project development and phototyping, as well fieldwork during the first field season. For the King County Forest Landscape Assessment Tool (FLAT), the staff spent an estimated 2,880 hours implementing the project. The difference in supplies and materials costs can be explained by King County's fieldwork startup costs, whereas the Everett project made use of equipment owned by consultants.

Table 10—Comparative cost estimates of implementing Forest Landscape Assessment Tool (FLAT) in the city of Everett and in King County, Washington

Assessment attributes	King County parks	Everett parks
Total project area (acres)	24,724	605
Total time	Three summer field seasons	Two weeks
Cost in dollars:		
Staff	111,000	6,000
Consultant	72,000	15,000
Travel	7,400	200
Supplies/materials	3,600	200
Total cost	194,000	21,400

Appendix 6— Forest Landscape Assessment Tool (FLAT) Field Manual

This field manual was prepared by the project partners to provide a concise procedures manual for reference in the field, and to provide information for field crew training. Readers can cross reference the procedures described in this technical report with this appendix. In addition, a .pdf file of the manual can be downloaded at http://www.naturewithin.info/UF/FLAT_Field_Manual.pdf.

FLAT Field Manual

The Forest Landscape Assessment Tool

GREEN CITIES RESEARCH ALLIANCE

King County Parks Your Big Backyard King County

Department of Natural Resources and Parks
Parks and Recreation Division

Acknowledgements

The Green Cities Research Alliance was initiated by the USDA Forest Service Pacific Northwest Research Station in 2009 to build program of research about urban ecosystem in the Puget Sound region. GCRA pairs scientists with practitioners and local decision makers to co-design and implement research efforts that provide relevant and practical information. The Forest Landscape Assessment Tool was developed by the following partners:

King County Parks and Natural Resources
USDA Forest Service PNW Research Station
American Forest Management
Forterra
University of Washington

For more information, visit
www.fs.fed.us/pnw/research/gcra

Funding for this project was provided by the 2009 United States American Reinvestment and Recovery Act (ARRA) coordinated by the USDA Forest Service Pacific Northwest (PNW) Research Station.

Contents

First edition - December 2013

Front cover photo credit: King County Parks and Natural Resources, Ring Hill Forest

Project Background

The Forest Landscape Assessment Tool (FLAT) was developed by the Green Cities Research Alliance and coordinated by the USDA Forest Service Pacific Northwest Research Station, in partnership with King County, Forterra and the University of Washington.

FLAT was built on the framework of the Tree-iage tool, initially developed in 2005 by Green Seattle Partnership staff. Similar to medical triage, the approach allows land managers to rapidly assess landscape conditions, then prioritize restoration activities. Using high, medium, or low values for both forest canopy composition and forest health threats, each Management Unit (MU) is assigned one of nine descriptive categories. The model assumes that without disturbance, natural areas would be dominated by mature, evergreen conifer trees, such as western hemlock and Douglas-fir, with a medium- to high-density canopy, mixed age-classes, and species diversity. These high-quality forest stands, lacking invasive species, represent a typical Pacific Northwest lowland forest - the reference for the tree-iage analysis.

Based on input from King County Department of Natural Resources and Parks, American Forest Management (AFM, formerly International Forestry Consultants, Inc.), and Forterra, FLAT was developed to further support forest management needs. More attributes were added to refine outputs and new flowcharts created to accommodate alternative habitats. The tool was also modified to include a forest health value, presenting a new dimension to the tree-iage matrix analysis. The addition of type call information gives each MU a species-stocking-density code that can be used to stratify MU's for future management. This new tool captures information essential to developing management strategies for individual Management Units, as well as for drafting management plans at the park or forest scale.

The FLAT tool was piloted during 2010-2012 field seasons at 149 sites composed of 1,457 MU's, covering approximately 24,700 acres of King County parklands. FLAT was an important first step in developing a long term, system-wide forest stewardship program. Determining the condition and health of all forest lands will help guide King County in making critical forest management decisions.

This manual was developed to record the FLAT process and protocols for future use at King County Parks, as well as for land managers interested in an innovative rapid assessment tool.

Summary of the FLAT Process

At its core, FLAT consists of visual estimates of ecological conditions by trained staff to produce a forest inventory. While field teams may make some measurements to calibrate their estimates, the assessment itself is generally qualitative and relies on carefully prepared estimates rather than precise measurements.

FLAT is executed in three broad, sequential phases. These include:

Phase 1 – Forest Cover Type Mapping
Aerial imagery and boundary data of the lands under consideration are used to divide the area into polygons and delineate Management Units (MUs). This work is accomplished and recorded using Geographic Information System (GIS) tools. These MUs become the unit of observation and measurement for the on-site assessment.

Phase 2 - Field Assessment
Trained field teams visit each MU within the project area to collect predetermined attributes. As an example, collected attributes might include land cover, non-native species in order of abundance, and tree age class distribution. Data is collected for MUs and stored (using GIS or other data management system) for all surveyed parcels.

Phase 3 - Management Prioritization
The field procedures of FLAT provide a ranking of parcel conditions, both across numerous parcels and for subunits within a large parcel. Summary data can be used to establish management priorities for each MU, and aggregated to develop priorities at larger scales, such as the park or park system-scale (as presented in the King County example later in this report). This prioritization approach is based on a matrix and flow-chart analysis (called Tree-iage) that classifies each MU using ratings of landscape quality that are easily compared across land management units. The information produced by the FLAT provides a standardized baseline of ecological data for a variety of landscape types. This information can be used to view each MU within the context of an entire land management system, as well as provide a starting point for developing a land-use or stewardship plan for particular parcels. Repeated over time, FLAT serves as an effective monitoring tool for managers to review and then adapt management priorities and actions based on changing conditions.

This straightforward, systematic approach to ecological assessment applies principles of ecology and forestry to provide quality data and help determine land management priorities. The following discusses the origins and basis of FLAT.

Getting Started

Considerations

Staff
When possible, field assessments should be conducted by two or more people both as a safety precaution and for quality control reasons. Since the FLAT assessment relies on ocular estimates of ecological conditions, it is often helpful to have another set of eyes and a companion to compare findings.

Season
For the data collection component of the FLAT, field assessments should take place during the period when foliage is most visible and vigorous. This will allow field teams to positively identify plant species and make the best evaluation of site conditions.

Tools and Materials

Before leaving on a field assessment, a team should be properly equipped with required data collection tools as well as the '11 essentials' particularly when out in the field for a full day. All field teams should have:

- **Data entry tools**
  Hand-held electronic data recorder or field data sheets
- **Navigation devices**
  GPS
  Map (including overlay of the MU boundaries)
  Compass
- **Plant identification resources**
- **Camera**
- **Tree and canopy measurement tools**
  Recommended for training and calibration of ocular estimates but not required:
  Increment borer
  Diameter tape
  Densitometer (Moosehorn)
  Clinometer

THE "11" ESSENTIALS
FOR COMFORT AND SAFETY IN THE FIELD

1. Sun protection (sunglasses, lip balm, and sunscreen)
2. Bug repellent
3. Proper clothing and footwear to deal with harsh terrain or inclemate weather such as rain gear, waterproof hiking/work boots, gaiters, and insulation like gloves, hats, and jackets.
4. First aid supplies
5. Utility knife or muli-tools (e.g. Leatherman, Swiss army knife)
6. Food (plus an extra day's supply)
7. Lots of Water! (plus an extra day's supply)
8. Headlamp or illumination source
9. Fire (matches or lighter in waterproof container
10. Emergency shelter (tent, tarp, bivy, or reflective blanket)
11. Communication device like cell phone or two way radio

Photo credit: Lisa Ciecko

Quality Control Methods

Quality control consists of any procedures used to "calibrate" or review field assessments. Because of the qualitative nature of rapid assessment, it is expected that individuals will have slightly different interpretations of each attribute. The goal is to encourage similar or consistent interpretation and assessments.

Photo credit: Kim Frappier

To test consistency of field data employ the following quality control procedures:

Pre-assessment Training

- Perform the FLAT on a known MU that has already been assessed and compare your findings.

- Choose one or more MUs and have them assessed by two separate teams under the supervision of a crew leader familiar with FLAT. If the teams' attribute measures differ significantly, it suggests that some calibration may be necessary.

Daily - ongoing

- Self check each day. Example – Do an ocular estimate of diameter-at-breast height. After writing down your answer, take the measurements using a dbh tape and compare your estimates. This can be done for other data variables using other calibration devices such as tree age using a tree corer.

Forest Cover Type Mapping

Forest Cover Type Mapping is the process of dividing a parcel of land into areas of similar landcover and vegetation/forest types. The property you are to assess has been "forest-typed" using aerial photography into Management Units (MUs).

Ownership and Management Boundaries

Each property or parcel is first delineated by property ownership and management boundary. Next, orthophotographs or other aerial imagery are used to group and delineate the land into five broad landcover classifications. These are forested, natural, open water, hardscape, and landscape.

Vegetation Features

With property information and landcover differences delineated, the next step is to refine forested and natural sites according to their vegetation features. Large areas with clearly different species, structural features, or age composition are placed into different Management Units. LIDAR data can also be processed to display canopy heights. This is useful in interpreting stand boundaries, especially when stereo aerial imagery is not available.

NOTE: All MU boundaries are drawn directly into the GIS so that they do not need to be digitized post data collection.

Photo credit: King County Parks and Natural Resources
Bass Lake Natural Area

The Truth about Ground Truthing

The MUs are initially delineated without the benefit of ground truthing. Field teams are responsible for field verification and should adjust boundaries and land cover types if needed. Some issues that may be encountered include:

- Landscaping under canopy
- Changes that have occurred since the photo date, and
- Areas being restored to a natural condition
- Inaccuracies in interpretation due to deep shadows, parallax, and photo mosaic boundaries on aerial imagery

Transmission line corridors were assigned a "Natural" designation when typed in the GIS, but can be given a field designation of "Landscape" due to vegetation maintenance in those areas.

In areas of low canopy and shrubs, typically seen in wet areas, MUs were assigned a "Forest" call over a "Natural" call. These areas must have more than 25% canopy cover.

Field Technicians make the final call!

LANDCOVER DESIGNATIONS

MUs are assigned one of five broad land cover designations:

Forested (FOR)	≥ 25% of the area covered by forest canopy
Natural (NAT)	natural vegetation that has < 25% forest canopy cover
Open Water (WAT)	open water without woody vegetation
Hardscape (HS)	impervious surface such as parking or buildings
Landscape (LS)	landscaped or have been mechanically maintained within the last year.

Understanding Management Unit Delineation

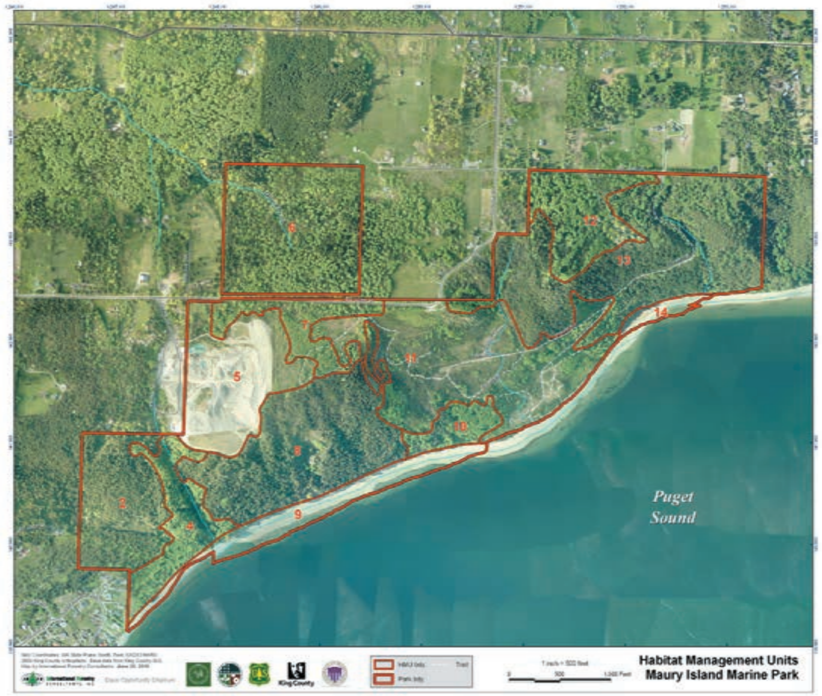


Image credit: King County Parks and Natural Resources
Maury Island MUs

Boundaries

Management Units were delineated based on forest composition so that heterogeneity within parks or parcels could be accounted for. MUs do not cross "administrative" boundaries, even if the cover type is identical on both sides.

Size

The minimum size for an MU is 5 acres, unless the type is surrounded by distinct non-forest types or property boundaries. Significant and distinct non-forest areas may be delineated down to 0.1 acre. It is not the intent of this assessment to map paved paths, tennis courts, or other facilities within landscaped areas. These smaller developed features are grouped with surrounding landscape or hardscape MUs.

Labels

Each park or parcel has a unique FID_MU identifier. FID refers to the park's Facility Identification number. The MU refers to the polygon number within that park. This identifier is specific to each polygon for ease of identification, sorting, and analysis of data. For example, the Duvall Park FID is 2598, and there are five MU's in that park. The FID_MU identifiers are 2598-01, 2598-02, 2598-03, 2598-04, and 2598-05.

Introduction to Field Procedures

The field procedures entail ocular estimates of predetermined forest qualities. Field teams of one or more people visit each MU, walk through it, and record an average attribute value for each of the variables listed in this field manual or data entry system. The field manual contains definitions for each variable to be assessed. As field teams walk through the MU, they should be observant and keep a mental catalog of what they see.

Things to keep in mind while conducting the assessment:

Provide attribute estimates for the entire MU

There may be patches of certain species or conditions, but a best effort should be made to estimate for the entire MU. This is why many of the attribute values will be entered upon leaving the MU.

Measurement tools can be used to calibrate your estimates

Some attributes such as DBH, crown closure, age, and regeneration trees (trees less than 20ft in height) can be measured with tools in the field. It may be helpful to do this once or twice on an MU to calibrate estimations. However, excessive measurement taking in the field will slow down the rapid assessment process.

Do the MU boundaries need to be altered? To split or lump?

The field team should ask themselves whether or not the boundaries of the MUs should be altered, and if so, how. There are often patches of different vegetation within an MU which is expected, but pervasive differences in composition or age classes for large areas of the MU may necessitate redrawing boundaries. This may involve combining or lumping smaller MUs into one larger one or splitting an MU into multiple, smaller MUs.

Additional Notes and Observations

Field teams may find that there is something important of note in the MU that doesn't necessarily fit into any of the attribute categories. For this reason it is good to include additional information in the "notes" field of the data entry tool or data collection sheet. Examples of additional notes include: any new tree or plant species, prevalence of a 4th overstory tree, unusual site or soil conditions, recent disturbances, and any recent or ongoing land management activities.

Check for completeness

Sometimes MUs will be strangely shaped so that the terrain or trails will lead teams traveling in and out of different MUs. Data may be entered for each MU in order of discovery but should be checked for completeness before leaving the MU.

When to leave the road or trail system

Each attribute determination will apply to the entire MU, thus it is important that enough of the MU is seen by the field team. Sometimes this will require leaving trails and traveling on challenging terrain. In other MUs the view from a trail may be sufficient to make a judgment on most, if not all, of the attributes. Teams should be careful to recognize, and average into the MU estimate, any edge effect along trails where vegetation may have been influenced by trail activity or disturbance. A good question to ask before bushwhacking through a site may be "How much greater understanding of the MU will I gain from the time it will take me to do this?"

Preparing the GPS unit or data forms for field assessments

- GIS staff or project leads should pre-load background images of vegetation overlayed with the MU maps in accordance with the hardware and software in use.
- Electronic data collection software or spreadsheet should be pre-loaded with the initial MU Landcover codes. If using a GPS with the background loaded, the image file name should correspond to the map number.
- Information on the MU landcover designation ***and*** boundaries must be included either on the map, within the data entry system, or on field forms.

Field teams will then be able to ground truth the landcover designation as well as know when they have entered or exited the MU.

Since different GPS units have very different instructions, this process will be device specific.

LANDCOVER

Landcover is initially assigned in the office by the GIS professional and needs to be field verified.

There are five landcover categories used for the King County FLAT assessment: Forested, Natural, Water, Hardscape, and Landscape. Using your field maps with MU boundaries, verify and record the MUs landcover classification.

Verify and record landcover using the following categories

Forested (FOR)	≥ 25% of the area covered by forest canopy
Natural (NAT)	natural vegetation that has < 25% forest canopy cover
Open Water (WAT)	open water without woody vegetation
Hardscape (HS)	impervious surface such as parking or buildings
Landscape (LS)	landscaped or have been mechanically maintained within the last year.

ASPECT AND SLOPE

Aspect and slope are processed in the office through available digital elevation model data in GIS for each MU. This is especially useful for larger MU's where aspect and slope vary throughout the unit. If a project calls for field determination then proceed as follows:

- Use a compass to determine the predominant direction of the slope on the site.
- Aspect is often described as the direction in which water flows off a site
- Code as follows: N, NE, E, SE, S, SW, W, NW or flat.
- Detailed instructions on use of a compass can be found in Appendix E.

OVERSTORY

Overstory refers to trees whose foliage forms the uppermost crown cover or canopy of a forest stand.

The forest assessment team will characterize dominant or co-dominant overstory tree species in order of abundance found in the MU including the size class of each species. Age class information will only be collected for the dominant overstory species.

The first, second, and third order of abundance should be determined by the two dimensional area that the species would occupy if looking at the aerial image. Field teams can use the aerial imagery to help identify the presence in the MU.

Collect the following overstory data

Overstory Species 1: The most abundant dominant or co-dominant overstory species greater than 20 feet in height.

- Species code *(Note: if the tree is not listed in the plant list in Appendix B, provide the 4 digit species code, common, and scientific names in the notes section)*
- Age Class
- Size Class

Overstory Species 2 and 3: The second and third most abundant co-dominant overstory species greater than 20 feet in height.

- Species code *(Note: if the tree is not listed in the plant list in Appendix B, provide the 4 digit species code, common, and scientific names in the notes section)*
- Size Class for each species.

Dominant versus Co-dominant

Dominance is a relative designation of tree crowns and is also referred to as crown class. Dominant trees are those with crowns above the general level of the canopy. Co-dominance refers to trees whose crowns form the general level of the canopy.

AGE CLASS

Age class is an estimate of the age range of the dominant overstory trees (see below). Age classes provide managers with an overview of which MUs have the opportunity for stand improvement operations, harvest, or preservation opportunities.

It is important to calibrate estimates of tree age using an increment borer. This should be done at the beginning of the assessment process to calibrate your ocular estimates and then spot check yourself throughout the field assessment. See Appendix F for instructions on how to use an increment borer.

External indicators of the associated age range can be used to estimate age class. These include tree size and growth characteristics (e.g. branch whorls on Douglas fir), bark appearance, nearby cut stumps or fallen trees. However, soil and site quality determine actual growth rates, so this should be taken into consideration when assessing the age class of the stand or management unit.

Test Yourself!

Remember that external indicators do not always provide sufficient information to determine the age class of a tree, so age coring similar trees can be done to calibrate your estimates. Age by eye, then core to confirm! How close was your estimate?

→ Record the average Age Class across the MU using the following categories

Code	Age Range (years)	Category	Description
1	0-29	Pre-merchantable	Stand of commercial species that have not yet grown large enough to be saleable
2	30-49	Submerchantable	Stand just coming into maximum value, but not ready for harvest.
3	50-99	Merchantable	Stand has grown large enough to be saleable and is ready for harvest and replanting
4	100 +	Mature	Potential for future old growth characteristics. May aim to improve health and retain mature trees.

SIZE CLASS

Second, record the size class or average diameter at breast height (DBH) for each dominant or co-dominant tree listed above. DBH is the diameter of a tree at 4.5 feet above the ground on the uphill side of the tree. Calibration trees can be chosen from average defect-free trees in the MU, keeping in mind the target classes listed in the table below. For more information on measuring tree diameter, see Appendix C.

→ Record Size Class using the following categories

Size Class Code	DBH in inches
1	0 -5″
2	6 - 10″
3	11 - 20″
4	21″+

Photo credit: Lisa Ciecko

STOCKING

Field teams will be using measures of canopy cover to estimate stocking in the MUs. Canopy cover is a vertical measure of the canopy (dominant and co-dominant tree crowns) as would be seen on an aerial photograph or looking up vertically from one point on the ground. Measures of cover assess the presence or absence of canopy vertically above a sample of points across a definitive area of forest and help assess forest structure (Jennings et al, 1999).

To measure canopy cover, stand in one location, and assess the canopy directly overhead (see Figure 1). Field staff can also compare on the ground measurements with the orthophoto of the site to aid in estimating cover. In order to capture the variability across large MUs, field crews must take this reading at different points across the MU and then average those conditions.

To calibrate ocular estimates, canopy cover can be measured using instruments such as a densitometer, sometimes called a "moose horn." The densitometer provides a point measure of canopy cover. See Appendix D for additional information about densitometers.

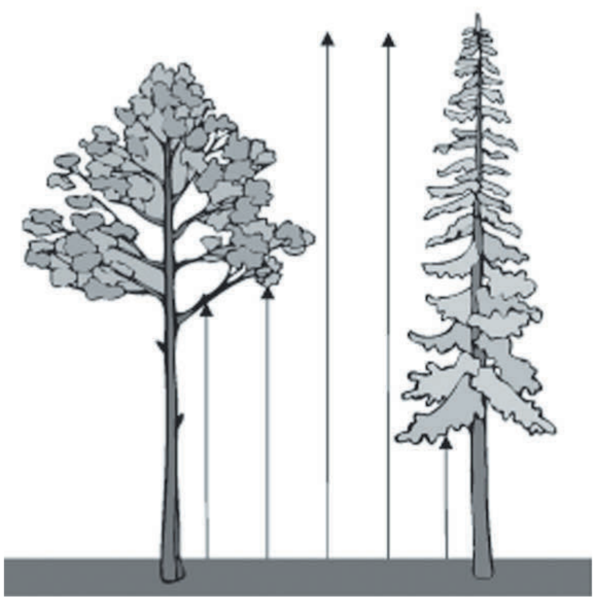


Figure 1. Canopy cover measured from one point on the ground. Image credit: Korhonen et al, 2006

What is stocking?

- Stocking (related to stand density) is a measure of the crowding of trees in a stand or the area occupied by trees relative to an optimum or desired level of density that supports growth for timber management.
- Stocking can be expressed quantitatively as the basal area or volume of trees per acre.
- The FLAT measures stocking in relative terms using canopy cover estimates as an indication of how crowded tree crowns are within a stand.
- Often stocking is described in relative terms, such as partially stocked, adequately stocked, or overstocked.

Record stocking using the following categories

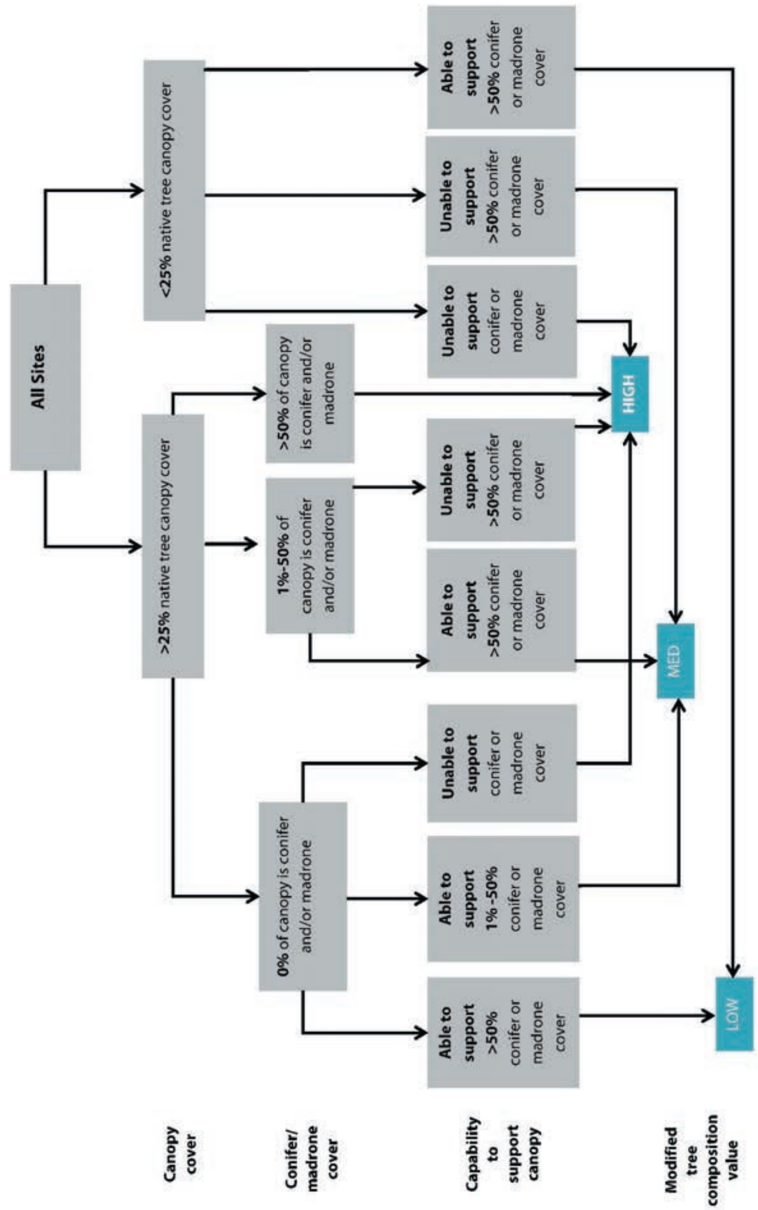
Stocking Code	Canopy Cover Range in Percent
0	Less than 10% canopy cover
1	10 - 39% canopy cover
2	40 - 69% canopy cover
3	Greater than 70% canopy cover

MU Tree Canopy Composition

Each MU is assigned a value (High, Medium, or Low) for tree canopy composition, based on percent native tree canopy cover, and percent of canopy cover made up by evergreens and/or madrones. Tree Canopy Composition is one of the variables (along with invasive threat cover) used to determine the Tree-iage Category of each MU.

Record Tree Canopy Composition as High, Medium, or Low based on the flow chart on page 18

Canopy Composition Flow Chart



Overstory Forest Health Threat Indicators

Forest health threat indicators refer to attributes indicative of poor tree health and canopy decline. These attributes negatively affect the long-term sustainability of the forest canopy and directly affect management strategies. The indicators must be present in *1% or more of the MU* to trigger recording a *"Yes."* If not observed in the walkthrough it will be recorded as *"No."*

Record the following Overstory Forest Health Threat Indicators

Low vigor

Determine low vigor by assessing the tree's live crown ratio. Crown ratio is a measure of the length of a tree's live crown relative to total tree height.

Record a "yes" call if conifers have a live crown of 40% or less of the total height of that tree. Hardwood decline in the form of snags or top dieback of 5% or greater also receive a "Yes" call.

What is 1% of an MU?

For a 10 acre parcel, 1%
= 1/10 of an acre
= 4,356 square feet
= 66 x 66 feet

Failure

Mechanical tree failure refers to the breakage of tree trunks and branches and the uprooting of trees caused by factors such as landslides, ice and snow damage, high winds, old age, parasites or disease. Record "Yes" if found in 1% or more of the MU.

Root Rot

A fungal root infection that attacks the live and dead roots of some conifers. Douglas-fir is highly susceptible along with true firs such as grand fir. Western redcedar is resistant to infection and hardwood trees are immune. For more information on root rot disease go to: *http://ext.nrs.wsu.edu/forestryext/foresthealth/notes/laminatedrootrot.htm*

Root rot symptoms to look for:

- Pockets of standing dead trees
- A clearing with many trees fallen to the ground
- Stunted root balls on fallen trees
- A yellow and thinning tree crown

(Overstory forest health threat indicators continued on pg 20)

Mistletoe

Mistletoe is a parasitic plant that causes growth reduction and deformities on trees. Infected trees will produce “witches brooms” which are abnormal growths of small twigs. Symptoms of infections on branches include a spindle-shaped, swollen appearance. On trunks, infections may cause the tree to swell to twice its original diameter. The most common species that infects conifers in Puget Sound forests is Dwarf mistletoe (*Arceuthobium sp.*). For more information go to: *http://ext.nrs.wsu.edu/forestryext/foresthealth/notes/dwarfmistletoe.*

Photo credit: Jesse Saunders

Field staff do not need to identify specific species of mistletoe, but simply note its presence or absence. If mistletoe is observed, a “Yes” call is given. Also, include which tree species have been infected in the notes field of your data collection sheet or GPS unit.

Bare Soil

1% or more of the MU is devoid of vegetation and has exposed bare soil due to unstable soils and/or recent disturbance, landslide etc.

Other

If “Yes” is recorded, details must be provided in the “notes” field of the data sheet or GPS unit. Examples of additional forest health concerns include but are not limited to:

- Bear damage
- Beetle damage
- Brown cubical butt rot
- Large gap in center of MU – potential root rot damage

Regeneration Species

Regeneration species refer to overstory canopy species under 20 feet tall. These are the trees that will become dominant and co-dominant species as the forest matures.

→ **Record the two most abundant overstory tree species under 20 feet tall**

Is that a SHRUB or REGENERATION TREE?

Refer to the FLAT plant guide in Appendix B if you have questions about whether a specific species is considered a tree (and therefore considered part of the overstory) or a shrub.

Example:

Willow species are considered trees whereas Vine maple is a shrub.

Regeneration Species Stocking Class

Record the combined estimated stocking class of the two most abundant regeneration tree species under 20 feet in the MU. This is measured in trees per acre (TPA).

→ **Record stocking class using the following codes:**

Stocking Code	Trees per acre	Reference
1	0-49 TPA	> 30 ft. x 30 ft.
2	50-149 TPA	Between 30 ft. and 16 ft. spacing
3	150 + TPA	< 16 ft. x 16 ft.

Plantable

This attribute provides information regarding presence of available growing space to promote tree seedling restoration to help shade out potential invasive species. Plantable areas may be observed as bare soil following current or future invasive removal, or large openings in forest cover resulting from extensive root rot or wind failures.

→ Record whether an MU is "plantable" using the following criteria

A *"yes"* call indicates a priority area for planting that is exposed to full sun and may have bare soil where invasive species could establish or expand if the area is not planted to native species in the short term.

A *"no"* call indicates that the majority of growing space is already occupied by native species and does not warrant immediate action.

Ground Species

Ground species are native herbs and shrubs in the understory of the forest. These include but are not limited to all understory shrubs and herbs found in the plant lists found in Appendix B. Note that ground species do not include saplings or regeneration trees of canopy species. Use the four letter species code to represent the species.
Example: *Polystichum munitum* (POMU)

Photo credit: Forterra

→ Record the two most abundant ground cover species present in the MU

Ground species must be listed in order of abundance:

- Ground species 1 – Primary or most abundant
- Ground species 2 – Secondary or second most abundant.

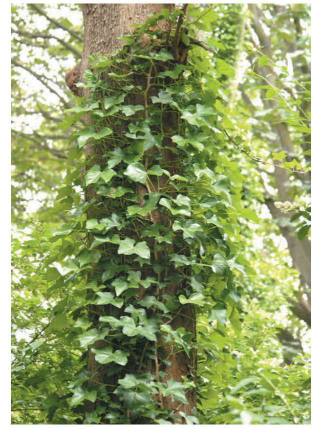


Photo credit: Forterra

Invasive Species

Each MU is assigned a value (High, Medium, or Low) for invasive cover threat, based on percent invasive plant cover. Remember that this is a qualitative assessment to reflect percent cover across the MU. Quantitative methods using a transect line or quadrat are not required. Invasive plant cover is one of the variables (along with tree canopy cover) used to determine the Tree-iage Category of each MU. If the invasive cover threat observation is uncertain and you are unsure whether the MU should be coded as Medium or High, be conservative and code the MU as High.

→ Assign each MU one of the following invasive cover-threat values

HIGH	MUs with more than 50% invasive species cover
MEDIUM	MUs with between 5% and 50% invasive species cover
LOW	MUs with less than 5% invasive species cover

What if I observe a species not included in the FLAT plant list?

Enter the 4-digit species code and record the common and scientific name in the notes section. This applies to overstory trees and all native ground and non-native invasive species.

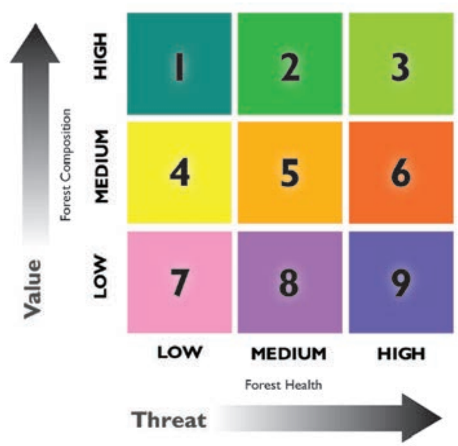
→ Record the species code of all invasive species present in order of abundance

Record all non-native invasive species present in the MU. These include herbaceous species as well as invasive tree species such as English holly. These must be recorded in order of abundance. See Appendix B for a list of the most common invasive species found in Puget Sound lowland forests.

Appendix A: Tree-iage Matrix Analysis

Identifying and prioritizing areas in need of management is a key output of the FLAT process. Attributes assessed in the field are used to produce a qualitative value for two axes of a matrix. In King County, forest composition (y-axis) and forest threats (x-axis) were used. The matrix combines the attribute information to produce a classification value for each MU.

In the figure at the right, values 1-3 represent MUs with a tree composition that has high ecological value, and so are important to protect and maintain. Values 2 and 3 also represent the presence of a forest health threat and could be prioritized for restoration or maintenance. On the other end of the spectrum, a MU with a value of 9 has a high threat presence and a lower tree composition, and therefore may not be not be as high a priority for management actions.



How the results of the matrix analysis are used in subsequent land management decisions is up to each FLAT user. FLAT provides an ecological input for land management decision-making. The combination of field data collection, flow chart processing, and classification of MUs using the matrix can be used to prioritize future management actions and monitoring.

Appendix B: Common Plant Species List

TREES

Code	Species	Scientific Name
ACMA	Bigleaf maple	*Acer macrophyllum*
PREM	Bitter cherry	*Prunus emarginata*
POBA	Black cottonwood	*Populus balsamifera*
CRDO	Black hawthorn	*Crataegus douglasii*
RHPU	Cascara	*Rhamnus purshiana*
PSME	Douglas fir	*Pseudotsuga menziesii*
ACGL	Douglas maple	*Acer glabrum*
QUGA	Garry oak	*Quercus garryana*
ABGR	Grand fir	*Abies grandis*
SAHO	Hooker's willow	*Salix hookeriana*
ABPR	Noble fir	*Abies procera*
FRLA	Oregon ash	*Fraxinus latifolia*
MAFU	Pacific crabapple	*Malus fusca*
CONU	Pacific dogwood	*Cornus nuttallii*
ARME	Pacific madrone	*Arbutus menziesii*
ABAM	Pacific silver fir	*Abies amabalis*
TABR	Pacific yew	*Taxus brevifolia*
SALU	Pacific willow	*Salix lucida*
BEPA	Paper birch	*Betula papyifera*
POTR	Quaking aspen	*Populus tremuloides*
ALRU	Red alder	*Alnus rubra*
PICO	Shore pine	*Pinus contorta*
ALCR	Sitka alder	*Alnus crispa ssp. sinuata*
PISI	Sitka spruce	*Picea sitchensis*
SASI	Sitka willow	*Salix sitchensis*
ACCI	Vine maple	*Acer circinatum*
TSHE	Western hemlock	*Tsuga heterophylla*
THPL	Western redcedar	*Thuja plicata*
PIMO	Western white pine	*Pinus monticola*
QUAL	White oak	*Quercus alba*

SHRUBS

Code	Species	Scientific Name
ROGY	Baldhip rose	*Rosa gymnocarpa*
COCO	Beaked hazelnut	*Corylus cornuta*
RULE	Blackcap	*Rubus leucodermis*
RILA	Black gooseberry	*Ribes lacustre*
VAME	Black huckleberry	*Vaccinium membranaceum*
SACA	Blue elderberry	*Sambucus caerulea*
KAMI	Bog laurel	*Kalmia microphylla*
ANPO	Bog rosemary	*Andromeda polifolia*
OPHO	Devil's club	*Oplopanax horridus*
MANE	Dull Oregon grape	*Mahonia nervosa*
VAOV	Evergreen huckleberry	*Vaccinium ovatum*
MEFE	False azalea	*Menziesia ferruginea*
ARDI	Goat's beard	*Aruncus dioicus*
ARCO	Hairy manzanita	*Arctostaphylos columbiana*
SPDO	Hardhack; spiraea	*Spiraea douglasii*
VIED	Highbush cranberry	*Viburnum edule*
OECE	Indian plum	*Oemlaria cerasiformis*
LEGR	Labrador tea	*Ledum groenlandicum*
PHLE	Mock orange	*Philadelphus lewisii*
RONU	Nootka rose	*Rosa nutkana*
HODI	Oceanspray	*Holodiscus discolor*
PYMY	Oregon boxwood	*Pachistima myrsinites*
PHCA	Pacific ninebark	*Physocarpus capitatus*
RHMA	Pacific rhododendron	*Rhododendron macrophyllum*
MYCA	Pacific wax myrtle	*Myrica californica*
SARA	Red elderberry	*Sambucus racemosa*
VAPA	Red huckleberry	*Vaccinium parvifolium*
CESA	Red stem ceonothus	*Ceanothus sanguineum*
COSE	Redosier dogwood	*Cornus sericea*
RISA	Red-floweringcurrant	*Ribes sanguineum*
GASH	Salal	*Gaultheria shallon*
RUSP	Salmonberry	*Rubus spectabilis*
AMAL	Serviceberry	*Amelanchier alnifolia*
SOSI	Sitka mountain ash	*Sorbus sitchensis*
SYAL	Snowberry	*Symphoricarpos albus*
RIBR	Stink currant	*Ribes bracteosum*
ROPI	Swamp rose	*Rosa pisocarpa*
MYGA	Sweet gale	*Myrica gale*
MAAQ	Tall Oregon grape	*Mahonia aquifolium*
RUPA	Thimbleberry	*Rubus parviflorus*
LOIN	Twinberry	*Lonicera involucrata*
SPBE	White spirea	*Spirea betulifolia var.lucida*

HERBACEOUS

Code	Species	Scientific Name
FRCH	Beach strawberry	*Fragaria chiloensis*
DIFO	Bleeding heart	*Dicentra formosa*
SIID	Blue-eyed grass	*Sisyrinchium idahoensis*
PTAQ	Bracken fern	*Pteridium aquilinum*
COUN	Bunchberry	*Cornus unalaschkensis*
TRIF	Clover species	*Trifolium sp.*
EQAR	Common horsetail	*Equisetum arvense*
HELA	Cow parsnip	*Heracleum lanatum*
BLSP	Deer fern	*Blechnum spicant*
CIDO	Douglas water-hemlock	*Cicuta douglasii*
MADI	False lily-of-the valley	*Maianthemum dilatatum*
SMRA	False Solomon's seal	*Smilacina racemosa*
EPAU	Fireweed	*Epilobium augustifolium*
TITR	Foamflower	*Tiarella trifoliata*
DIPU	Foxglove	*Digitalis purpurea*
TEGR	Fringecup	*Tellima grandiflora*
ALAC	Hooker's onion	*Allium acuminatum*
FAHE	Inside-out flower	*Vancouveria hexandra*
ARUV	Kinnikinnick	*Arctostaphylos uva-ursi*
ATFI	Lady fern	*Athyrium filix-femina*
POGL	Licorice fern	*Polypodium glycyrrhiza*
ADPE	Maidenhair fern	*Adiantum pedatum*
CLPE	Miners Lettuce	*Claytonia perfoliata*
GYDR	Oak fern	*Gymnocarpium dryopteris*
IRTE	Oregon iris	*Iris tenax*
OXOR	Oxalis; wood sorrel	*Oxalis oregana*
DIFO	Pacific bleeding heart	*Dicentra formosa*
HYTE	Pacific waterleaf	*Hydrophyllum tenuipes*
TODI	Pacific poison-oak	*Toxicodendron diversilobum*
PEFR	Palmate coltsfoot	*Petasites palmatus*
COMA	Poison hemlock	*Conium maculatum*
SAXI	Saxifrage species	*Saxifraga sp.*
ANMA	Pearly everlasting	*Anaphalis margaritacea*
TOME	Piggy-back plant	*Tolmiea menziesii*
GOOB	Rattlesnake plantain	*Goodyera oblongifolia*
COSC	Scouler's corydalis	*Corydalis scouleri*
LYAM	Skunk cabbage	*Lysichiton americanum*
TRLA	Starflower	*Trientalis latifolia*
VIGL	Stream violet	*Viola glabella*
URDI	Stinging nettle	*Urtica dioica*
POMU	Sword fern	*Polystichum munitum*
LIBO	Twinflower	*Lineae borealis*
ACTR	Vanilla leaf	*Achlys triphylla*

HERBACEOUS CONT.

Code	Species	Scientific Name
AQFO	Western columbine	*Aquilegia formosa*
TROV	Western trillium	*Trillium ovatum*
ASCA	Wild ginger	*Asorum caudatum*
FRVE	Wild strawberry	*Fragaria virginiana*
FRVE	Woodland strawberry	*Fragaria vesca*
ACMI	Yarrow	*Achillea millefolium*
MIGU	Yellow monkey-flower	*Mimulus guttatus*

GRASS-LIKE

Code	Species	Scientific Name
GRASS	Native grasses	
SCAM	American bulrush	*Scirpus americanus*
TYLA	Cattail	*Typha latifolia*
JUEN	Dagger-leaved rush	*Juncus ensifolius*
CADE	Dewey's sedge	*Carex deweyana*
ELMO	Dunegrass	*Elymus mollis*
SCAC	Hardstem bullrush	*Scirpus acutus*
FEID	Idaho fescue	*Festuca idahoensis*
CALY	Lyngbye's sedge	*Carex lyngbyei*
CAOB	Slough sedge	*Carex obnupta*
SCMI	Small-fruited bullrush	*Scirpus microcarpus*
CAPA	Thick headed sedge	*Carex pachystachya*
DECE	Tufted hairgrass	*Deschampsia cespitosa*
WEFE	Western fescue	*Festuca occidentalis*

VINES

Code	Species	Scientific Name
LOHI	Hairy honesuckle	*Lonicera hispidula*
LOCI	Orange honeysuckle	*Lonicera ciliosa*
RUUR	Trailing blackberry	*Rubus ursinus*

NON-NATIVE HERBS AND SHRUBS

Code	Species	Scientific Name	Weed Class
SODU	Bittersweet nightshade	*Solanum dulcamara*	Weed of concern **
POBO	Bohemian knotweed	*Polygonum x bohemicum*	Non-regulated ***
CIVU	Bull thistle	*Cirsium vulgare*	Non-regulated
BUDA	Butterfly bush	*Buddleia davidii*	Non-regulated
CIAR	Canada thistle	*Cirsium arvense*	Non-regulated
CLVI	Clematis; Old man's beard	*Clematis vitalba*	Non-regulated
VIMI	Common periwinkle	*Vinca minor*	None
TAVU	Common tansy	*Tanacetum vulgare*	Non-regulated
DIFU	Common teasel	*Dipsacus fullonum*	Non-regulated
RARE	Creeping buttercup	*Ranunculus repens*	Weed of concern
HEHE	English ivy	*Hedera helix*	Non-regulated
MYSP	Eurasian watermilfoil	*Myriophyllum spicatum*	Non-regulated
RULA	Evergreen blackberry	*Rubus laciniatus*	Non-regulated
LYVU	Garden loosestrife	*Lysimachia vulgaris*	Class B*
ALPE	Garlic mustard	*Alliaria petiolata*	Class A*
HEMA	Giant hogweed	*Heracleum mantegazzianum*	Class A
HIER	Hawkweeds	*Hieracium sp.*	Class B
GERO	Herb Robert	*Geranium robertianum*	Non-regulated
RUAR	Himalayan blackberry	*Rubus armeniacus*	Non-regulated
PLCU	Japanese knotweed	*Polygonum cuspidatum*	Non-regulated
CASE	Morning Glory; Hedge/Field bindweed	*Calystegia sepium*	Weed of concern
LEVU	Oxeye daisy	*Leucanthemum vulgare*	Non-regulated
COMA	Poison hemlock	*Conium maculatum*	Non-regulated
IMGL	Policeman's helmit	*Impatiens glandulifera*	Class B
LYSA	Purple loosestrife	*Lythrum salicaria*	Class B
PHAR	Reed-canary grass	*Phalaris arundinacea*	Non-regulated
CYSC	Scotch broom	*Cytisus scoparius*	Non-regulated
POHY	Smartweed; water-pepper	*Polygonum hydropiperoides*	None
SPAL	Smooth cordgrass	*Spartina alterniflora*	Class A
CEST	Spotted knapweed	*Centaurea stoebe*	Class B
PORE	Sulfur cinquefoil	*Potentilla recta*	Class B
SEJA	Tansy ragwort	*Senecio jacobaea*	Class B
LAGA	Yellow archangel	*Lamium galeobdolon*	Non-regulated
IRPS	Yellow flag iris	*Iris pseudacorus*	Non-regulated

** Washington State Weed Class A and B - control required in King County*

*** Weed of concern: applies to King County only; No state classification; control recommended but not required in King County*

**** Non-regulated Class B and C noxious weeds; control recommended but not required in King County*

NON-NATIVE TREES

Code	Species	Scientific Name	Weed Class
MALUS	Apple	*Malus sp.*	None
CRMO	Common hawthorn	*Crataegus douglasii*	Weed of concern
CUPP	Cypress	*Cupressus sp.*	None
ROPS	Black locust	*Robinia pseudoacacia L.*	None
PRLA	English laurel	*Prunus laurocerasus*	Weed of concern
ILAQ	English holly	*Ilex aquifolium*	Weed of concern
SOAU	European mountain ash	*Sorbus aucuparia*	Weed of concern
PONI	Lombardy poplar	*Populus nigra L.*	None
ACRU	Red maple	*Acer rubrum*	None
AIAL	Tree of heaven	*Ailanthus altissima*	Non-regulated
PRUN	Wild plum	*Prunus sp.*	None
ORNAM	Other hardwood ornamentals		None

** Washington State Weed Class A and B - control required in King County*
*** Weed of concern: applies to King County only; No state classification; control recommended but not required in King County*
**** Non-regulated Class B and C noxious weeds; control recommended but not required in King County*

Appendix C: How To Measure Tree Diameter-at-Breast Height

The standard protocol for measuring diameter at breast height is as follows:

- Using a diameter tape, measure the diameter at breast height to the nearest inches.
- Breast height is considered to be 4.5 feet above the ground on the uphill side of the tree.
- For trees with swellings, bumps, depressions, and branches at DBH, measure diameter above the irregularity where the trunk is no longer affected.

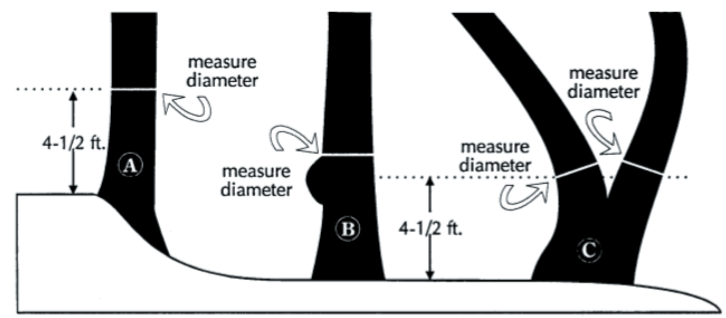


Image credit: www.woodlandstewardship.org

Appendix D: How To Use A Densitometer (Moosehorn)

Densitometers are small sighting instruments with crosshairs and a bubble level that allows the observer to determine whether canopy is present directly overhead.

Since the densitometer measures canopy cover (presence or absence) at a single point, multiple sample points must be measured to obtain a canopy cover estimate. Usually, sample points are spaced along a transect or arranged in a grid pattern to obtain an estimate for a specified area.

Note, because FLAT is a rapid assessment and data is not collected quantitatively, field staff should only use a densitometer (moose horn) as a quality control measure or training exercise to calibrate estimates.

For additional information go to: http://www.forestry-suppliers.com/product_pages/View_Catalog_Page.asp?mi=65121&title=GRS+Densitometer

Image credit: www.forestry-suppliers.com

Appendix E: How To Use A Compass

Important Vocabulary

Magnetic North
It is important to know that magnetic north is always moving and differs at different locations on the earth. Compass needles always point toward magnetic north.

True North
True north is the geographic north. It does not move, it is the fixed location on the earth where the North Pole is located.

Declination
This refers to the difference in degrees between magnetic north and true north. Here in Seattle in 2012 the declination is about 17 degrees East. This can change over time and location. Many compasses, including those provided in this monitoring program, are adjusted for declination. If using your own compass, it is recommended to have a compass that allows you to adjust for the declination so your reading is accurate and no math is needed.

Anatomy of a Compass

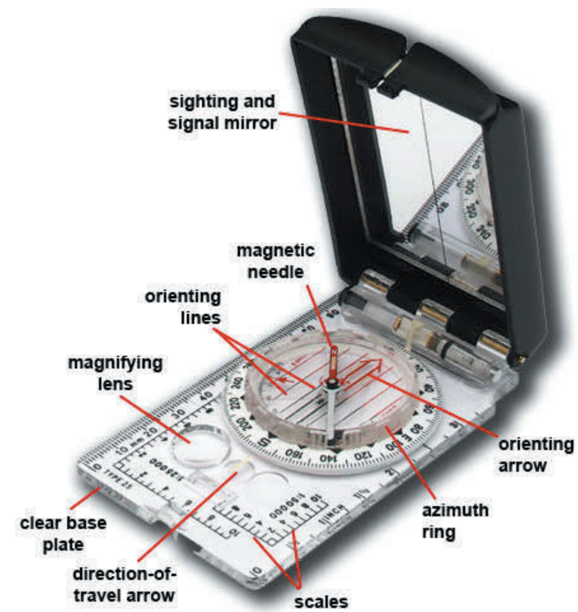


Image credit: www.offroad-ed.com

How to determine cardinal directions

1. Standing at plot center, hold your compass in your hand so that the baseplate is level and the lid is open at about 60 degrees. Hold it out in front of you with arm extended half way and the compass at eye level. You will be looking into the mirror, not directly at the dial.

2. Turn the compass dial until the direction you want to go is located at the top of the dial. For example, to go east, "E" would be located at the top of the dial.

3. Once you have the direction of travel determined, rotate your body until the red orienting arrow on the compass housing (outline of an arrow) lines up with the magnetic needle (the floating red magnetic arrow).

4. Use the line of sight (triangular notch in top of compass lid) as your point of direction. Have your monitoring team member stand at the edge of the plot and guide them left/right to align with your cardinal direction reading. Once in the right position, hang flagging to mark the plot edge at the cardinal direction. Repeat steps for each of the cardinal directions.

How to take a bearing

1. Hold your compass in your hand so that the baseplate is level and the lid is open at about 60 degrees Hold it out in front of you with arm extended half way and the compass at eye level. You will be looking into the mirror, not directly at the dial.

2. Turn your body until the desired target (e.g. a Douglas fir) is in sight. Use the triangular notch in the lid of the compass as your center of sight, aiming it at the center of the tree.

3. Make sure that the sighting line in the mirror runs through the middle of the capsule view.

4. Rotate the compass dial until the red orienting arrow on the compass housing (outline of an arrow) lines up with the magnetic needle (the floating red magnetic arrow).

5. You can read the bearing in degrees. Read from the top of the compass (where the compass and mirrored lid meet), there is a small indicator line (direction of travel arrow). Note: do not give cardinal directions; give exact degrees (ex. 76 degrees).

Appendix F: Use of Increment Borers to Determine Tree Age

Tree cores can be used to determine the average age of a forest stand or find an exact age of a single tree. An increment borer is the least invasive method used to count tree rings. This involves taking a small (0.2 inch diameter) straw-like sample from the bark to the pith of a tree. Though the hole is small, it can still introduce disease into the trunk.

Photo credit: www.redorbit.com

1. Assemble the increment borer by attaching the bit to the handle; set the extractor aside.

2. Drill in toward the center of the tree at breast height (4 ½ ft.).

3. When you have gone far enough to reach the center of the tree, insert the extractor and reverse the bit one full turn.

4. Slowly remove the extractor. If the increment core does not come out the first time, try again.

5. Once the core is out, set it and the extractor aside.

6. Immediately remove the increment borer from the tree, before it becomes stuck.

7. Once the increment borer is back out of the tree, count the rings on the increment core to determine breast height age. Add several years to estimate total age.

For the detailed explanation on increment borer use, go to: http://forestandrange.org/Virtual%20Cruiser%20Vest/lessons/lesson_06/Lesson_6_PDF.pdf

Photo credit: www.forestry-suppliers.com

Appendix G: FLAT Definitions At-A-Glance

Data Attribute	Data Field	Explanation
Site Name	SITE NAME	GIS identifier
Management Unit Number	MU_NO	GIS identifier
Date of data collection	DATE	
Assessors initials	CREW	
Landcover	LANDCOV	
Forested	FOR	≥ 25% forest canopy
Natural Area	NAT	< 25% forest canopy
Open Water	WAT	No woody vegetation
Hardscape	HS	Buildings, parking
Lansdscaped	LS	Landscaped, mechanically maintained
Age Class	AGECLASS	
category 1	1	0-29 years
category 2	2	30-49 years
category 3	3	50-99 years
category 4	4	100 + years
Overstory Species	OVR1_SPC	Overstory species, most abundant dominant or codominant >20ft)
Overstory Size	OVR1_SIZE	Overstory DBH size class
category 1	1	0 -5" DBH
category 2	2	6 - 10" DBH
category 3	3	11 - 20" DBH
category 4	4	21"+ DBH
Second Overstory Species	OVR2_SPC	2nd overstory species, in order of abundance codominant > 20ft

Data Attribute	Data Field	Explanation
Second Overstory Size	OVR2_SIZE	Overstory DBH size class, see size class chart above
Third Overstory Species	OVR3_SPC	3rd overstory species, if present, in order of abundance codominant > 20ft
Third Overstory Size	OVR3_SIZE	Overstory DBH size class, see size class chart above
Stocking	STOCKING	Canopy cover estimate, as viewed directly above
category 0	0	Less than 10% canopy cover
category 1	1	10 - 39% canopy cover
category 2	2	40 - 69% canopy cover
category 3	3	70% + canopy cover
Management Unit Composition	MU_CMP	
High Composition	H	> 50% conifer/madrone OR
		≤50% conifer/madrone with no capacity for restoration (includes wetlands)
Medium Composition	M	1-50% conifer/madrone with capacity to support restoration to H OR
		<25% native cover with capacity to restore up to 50% conifer
Low Composition	L	< 25% native cover with capacity for full restoration planting OR
		No conifer/madrone with capacity for full restoration

Data Attribute	Data Field	Explanation
Low Vigor	LOW VIGOR	Conifer: Live Crown ≤40%, Y or N; Hardwood decline: Top Dieback or Snags ≥ 5%, Y or N
Mechanical Tree Failure	FAILURE	Mechanical Tree Failure in ≥ 1% of MU , Y or N) ex.: windthrow, landslide
Root Rot	ROOT ROT	Root Rot Pockets present, Y or N
Mistletoe	MISTLETOE	Mistletoe present, Y or N
Bare Soil	BARE SOIL	≥1% Bare Soil present from recent disturbance, erosion, etc. Y or N
Other	OTHER	Present in ≥ 1% of MU, Y or N *Note in comments required
Regeneration Species	RGN1_SPC	Regeneration species <20FT HT, in order of abundance
Second Regeneration Species	RGN2_SPC	Regeneration species <20FT HT, in order of abundance
Regeneration Stocking Class	RGN_TPA	
category 1	1	0-49 TPA (> 30 ft spacing)
category 2	2	50-149 TPA (between 30 and 16 ft spacing)
category 3	3	150+ TPA (< 16 ft spacing)
Plantable Space	PLANTABLE	Suitable growing space for restoration planting? Y or N

Data Attribute	Data Field	Explanation
Native Shrubs and Herbs Species	GRD1_SPC	Native shrubs and herbs, most abundant
Native Shrubs and Herbs Species	GRD2_SPC	Second native shrubs and herbs in order of abundance
Invasive Species	INV1_SPC	Non-native species, most abundant
Invasive Species	INV2_SPC	Second non-native species in order of abundance
Invasive Species	INV3_SPC	Third non-native species in order of abundance
Invasive Species	INV4_SPC	Fourth non-native species in order of abundance
Invasive Species	INV5_SPC	Fifth non-native species in order of abundance
Total Invasive Cover	INVCOV	Total Invasive Cover
High cover	H	> 50%
Medium cover	M	5% - 50%
Low cover	L	<5%
Notes	NOTES	Unique site conditions and other dominant trees present.

References

Arney, J.D., K.S. Milner, and B.L. Kleinhenz. 2008. Biometrics of Forest Inventory, Forest Growth, and Forest Planning. Technical Report No. 12. Forest Biometrics Research Institute.

Jennings S.B., N.D. Brown, and D. Sheil. 1999. “Assessing forest canopies and understory illumination: canopy closure, canopy cover and other measures.” Forestry, Vol 72, No.1 pp 59-73.

Korhonen, L., K.T. Korhonen, M. Rautiainen, and P. Stenberg. 2006. “Estimation of forest canopy cover: A comparison of field measurement techniques.” Silva Fennica 40(4): 577–588.

Wolf, K. et al. 2013 [In Press]. Forest Landscape Assessment Tool General Technical Report. USDA Forest Service PNW Research Station.

Monitoring Data Collection Methods. 2013. Developed by the Green City Partnerships for the Regional Standardized Monitoring Project.

Ben Meadows. URL: www.benmeadows.com

The National Learning Center for Private Forest and Range Landowners. URL: www.forestandrange.org/Virtual%20Cruiser%20Vest/lessons/lesson_06/Lesson_6_PDF.pdf

Woodland Stewardship Online Resource. 2011. University of Minnesota. URL: www.woodlandstewardship.org

Notes

Pacific Northwest Research Station

Website	http://www.fs.fed.us/pnw/
Telephone	(503) 808–2592
Publication requests	(503) 808–2138
FAX	(503) 808–2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208–3890

Federal Recycling Program
Printed on Recycled Paper

U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW 3rd Ave.
P.O. Box 3890
Portland, OR 97208–3890