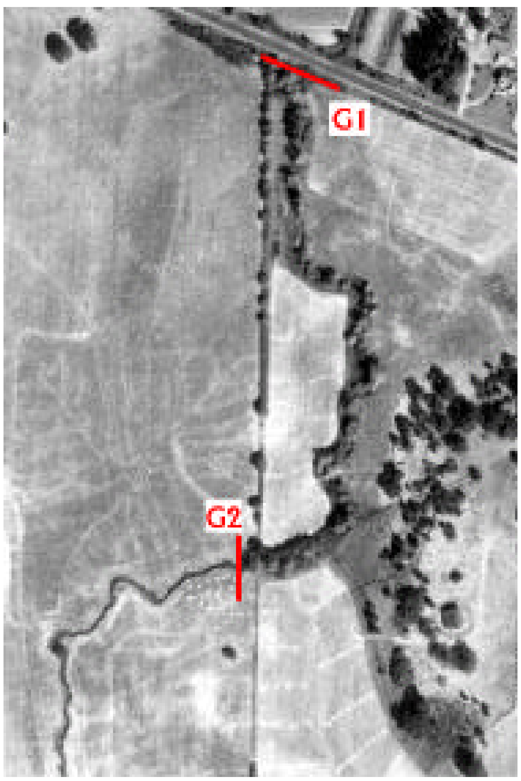
Changes in Tree Canopy on Fanno Creek:

Englewood and Greenway Parks



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Geography 410U/510, Professor Heejun Chang

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Abstract

Fanno Creek is a heavily urbanized tributary watershed of the lower Tualatin River, draining southwestern suburbs of Portland, Oregon. Fanno Creek is listed for temperature under the federal Clean Water Act, resulting in a temperature Total Maximum Daily Load (TMDL). Oregon Department of Environmental Quality (DEQ) has designated percent effective shade as the measure of non-point anthropogenic heating. Goals for planting trees along Fanno Creek include shading for temperature reduction and improved wildlife habitat.

We assess historical changes in tree canopy on Fanno Creek in Greenway and Englewood Parks, with particular focus on changes from 1963 to 2001.

We test whether canopy has increased in the subject reach of Fanno Creek as a result of habitat protection and enhancement, and show opportunities for additional tree planting to improve heat loading.

We compare canopy from 1963 and 2001 aerial surveys. We survey published counts of trees planted in enhancement projects to test whether the projects have impacted canopy. We use DEQ data on effective shade to determine opportunities for planting to reduce heat load.

Our estimates confirm an increase of canopy in Greenway, and a decline in Englewood. Data tying canopy increases to protection and enhancement is weak.

Gaps in canopy remain: planting can contribute to a substantial long-term increase in effective shade. Maintenance is required to ensure the permanent establishment of restored vegetation. Significant increase in canopy will require at least twenty more years.

Design of streamside plantings should focus on effective shade to address the temperature TMDL. Sources are identified to approximate pre-settlement plant communities. Additional benefits include bank stability, habitat and wildlife. Aerial surveys and effective shade data provide guidance for locating plantings.

Keywords: effective shade; native habitat; temperature; TMDL; tree canopy; tree planting.

Introduction

The Fanno Creek watershed is a heavily urbanized area of about 32 square miles in the southwestern suburban area of Portland, Oregon. Fanno Creek is a tributary of the lower Tualatin River, whose watershed covers 712 square miles of urban, agricultural and forest land. The Tualatin drains to the Willamette River south of Portland. Figure 1 shows the Tualatin Watershed in the context of the Willamette Watershed and the state of Oregon.

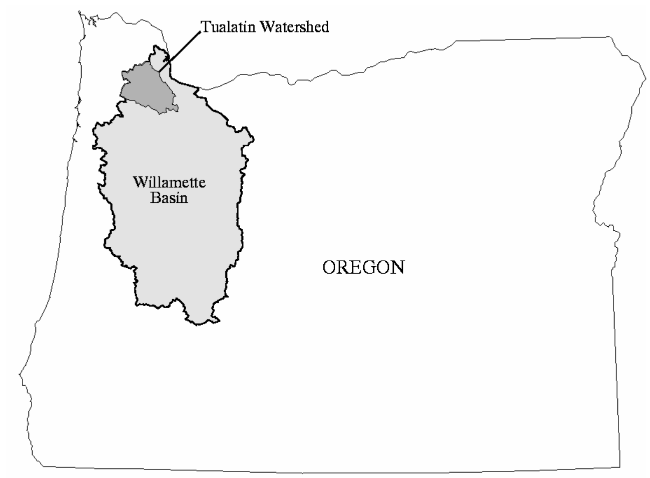


Figure 1. The Tualatin River Watershed (TRWC, 1999)

Fanno Creek has been identified by the Oregon Department of Environmental Quality (DEQ) as a “water-quality limited” tributary, and is on the Clean Water Act 303(d) list for temperature (ODEQ, 2001a). Planting trees along Fanno Creek has been undertaken since at least 1992, with the goals of shading for temperature reduction and improving habitat for birds and other wildlife (Kurahashi, 1997; Fans, 2001). This paper assesses the impact of habitat protection and tree planting projects applied to the Fanno Creek reach from RM 5.3 (N. Dakota Rd, near the Ash Creek confluence) to RM 7.3 (Hall Blvd.). The reach encompasses Greenway and Englewood Parks, owned respectively by the Tualatin Hills Parks and Recreation District (THPRD) and the City of Tigard.

Our study assesses changes in tree canopy along the subject reach of Fanno Creek between 1963 and 2002, evaluates the effectiveness of enhancement projects and suggests improvements for planning and monitoring future projects.

We address the effectiveness of tree planting in reducing solar heating of the creek by testing these hypotheses:

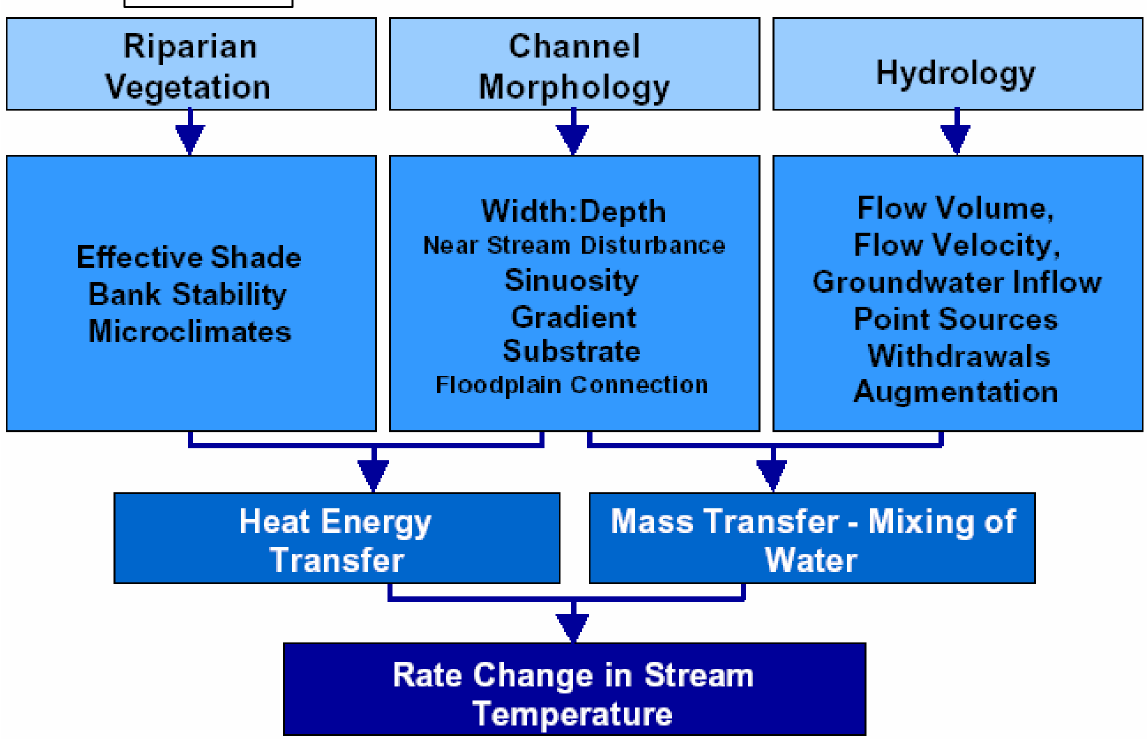
1. Between 1963 and 2001 there was a net increase in tree canopy on the Fanno Creek mainstem between RM 5.3 and RM 7.3.
2. The increase was due in part to habitat protection and enhancement projects on this stream reach.
3. Candidate sites for tree canopy enhancement provide an opportunity to significantly reduce incoming solar radiation in this reach.

The Oregon DEQ proposed new total maximum daily loads (TMDL's) for the Tualatin, with allocations to tributary streams under Section 303(d) of the Clean Water Act, in 2001. Among the Tualatin River Subbasin Stream Segments on the 303(d) list for temperature, Fanno Creek is listed from "mouth to headwaters." (ODEQ, 2001a) The temperature standard is designed to protect cold water fish (salmonids), the most sensitive beneficial use. The Oregon Department of Fish and Wildlife (ODFW) and others have documented various current uses of all Fanno Creek reaches by salmonids. These include spawning, rearing and migration by steelhead, coho salmon and cutthroat trout (Ward, 1995; Blowers, 2000; Houck 2000; ODEQ, 2001c; Leader, 2002). Oregon DEQ, with input from ODFW staff, has identified Fanno Creek as supporting coldwater aquatic life, including salmonids and cold-water invertebrates.

The owners of the two parks undertook enhancement projects, including tree planting, in collaboration with other agencies and Fans of Fanno Creek, a citizens' restoration and advocacy group. Fans involvement dates to the planting project of March, 1992. The Unified Sewerage Agency (USA, which became Clean Water Services in July, 2001) of Washington County included tree planting and vegetative buffers as two of their "structural water quality improvement techniques" planned for the Fanno Creek Basin. USA's planners expected tree planting to address temperature and habitat improvement, and vegetative buffers to help address temperatures, in-stream erosion and habitat (Sutherland, 1997). For the Englewood project, beginning about 1998, partners included Fans of Fanno Creek, USA, the cities of Tigard and Beaverton and the Oregon Division of State Lands (TRK, 1998).

Planting and successful establishment of trees on stream banks has multiple beneficial impacts on stream temperature, as illustrated in Figure 2 (ODEQ, 2001b). Note the impact of riparian vegetation on effective shade, bank stability and microclimates, all of which influence heat energy transfer. Anthropogenic non-point heat sources contribute 49% of the current heat load in the Tualatin basin during the summertime critical condition. Solar radiation is considered anthropogenic due to human disturbance of riparian vegetation. Oregon DEQ attributes high summer temperatures to increased solar heating. This includes both direct heating of the water and heat transfer from stream banks. Both types of heat transfer result from disturbance and removal of vegetation near streams (ODEQ, 2001b).

Figure 2. Stream Heating Processes in the Tualatin River Subbasin



We summarize available historic data on plant communities and tree canopy for the years 1851, 1936, 1963 and 2001. Our discussion draws from data on the progression from early settlement conditions through recent impacts of urbanization, proceeding with habitat protection and enhancement projects to current conditions of tree canopy and streamside plant communities. We estimate percentage tree canopy for the Greenway and Englewood Park reaches based on analysis of aerial surveys done in 1963 and 2001. We then compare the canopy percentages for each site to test hypothesis 1. We summarize data on tree-planting projects, drawn primarily from contemporary news articles. We use this data to test hypothesis 2. We draw directly from an Oregon DEQ summary of effective shade to test hypothesis 3 and demonstrate the opportunity for future planting projects to influence incoming solar radiation.

Study Area

The Fanno Creek Watershed lies within the Portland region's urban growth boundary. Of its 32 square mile (20,500 acre) extent, about two-thirds is managed by Clean Water Services, formerly Unified Sewerage Agency (USA) of Washington County. The remaining third is managed by the City of Portland's Bureau of Environmental Services and the City of Lake Oswego. USA's 1997 management plan describes the watershed as "land that drains water from the Tualatin Mountain Range, Sexton Mountain, Cooper Mountain, and Bull Mountain down to the Tualatin River. Approximately 117 miles of streams are within the Fanno Creek Watershed, including 2 major tributaries (Ash and Summer Creeks) and 12 smaller tributaries." (Kurahashi, 1997) Figure 3 shows the Tualatin River watershed and its subwatershed boundaries. The Fanno basin is included in the Lower Tualatin subwatershed. Figure 4 is an insert expanded from the subwatershed map. It encompasses the Fanno Creek watershed.

Figure 3. Tualatin River Subwatershed Boundaries (Pacific U., 2001)

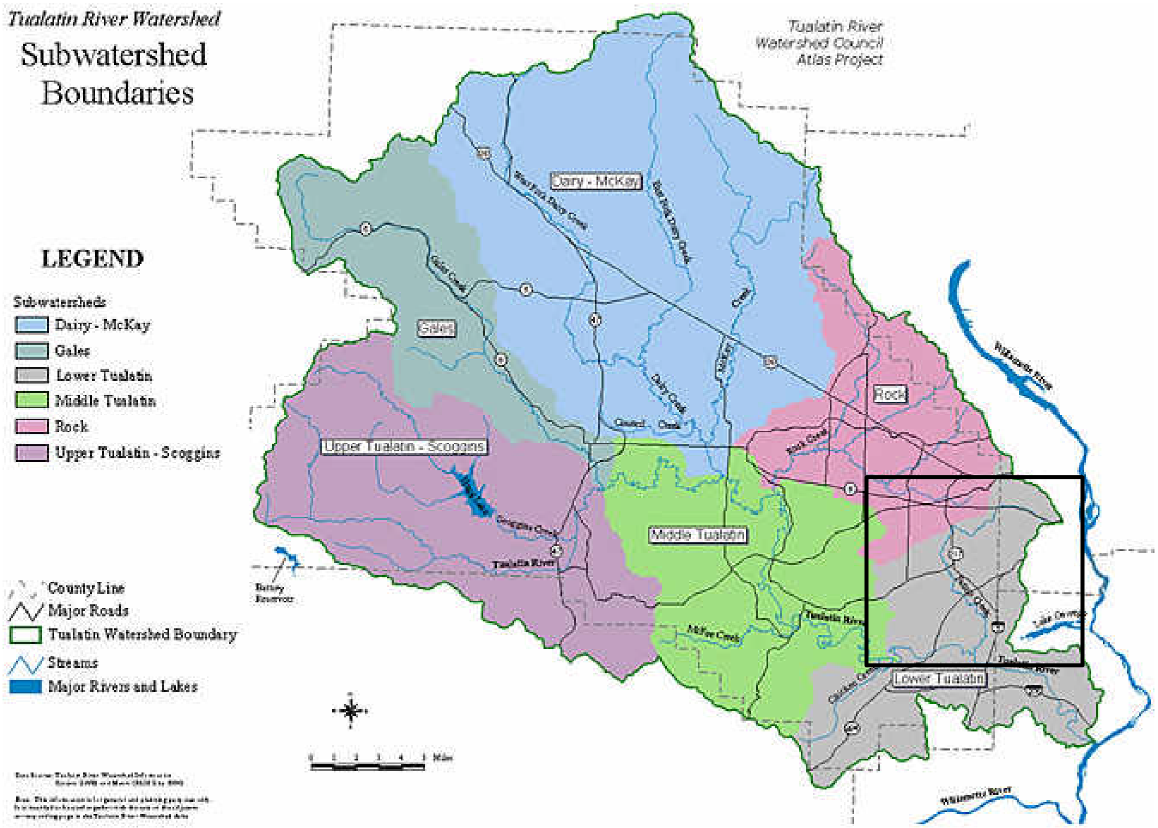
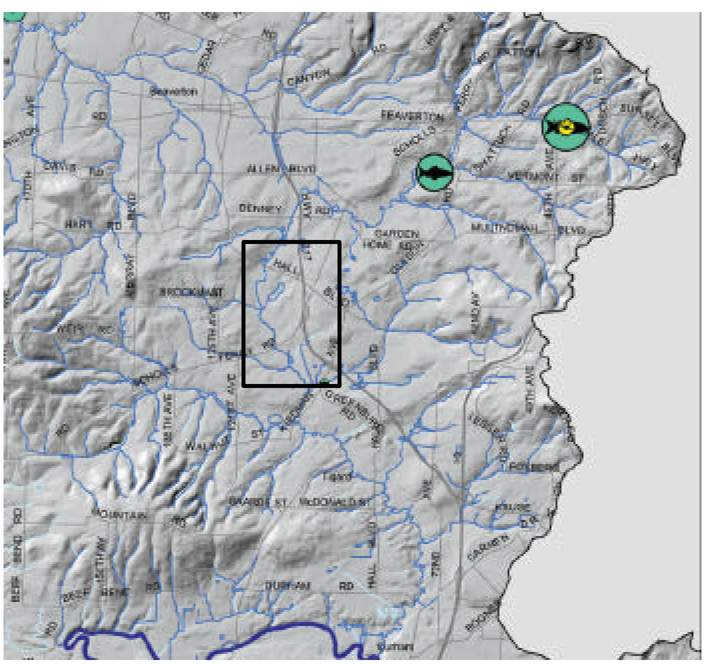


Figure 4. Fanno Creek Insert (Greenway-Englewood reach marked.) (Clean Water Services, 2002)



The USA plan further describes the watershed and its streams:

> "The headwater tributaries, located predominantly in the City of Portland, drain water through the steep valleys of the southwest hills. Headwaters of Pendleton, Vermont, and Woods Creek drain to the main stem from the hills. The stream gradient changes to a moderate slope (.2 percent) from the Sylvan-Pendleton-Fanno confluence down to Highway 217. The stream gradient then drops to less than .1 percent from Highway 217 down to Fanno's confluence with the Tualatin River. The floodplain is wide and the creek meanders considerably throughout the lower reach. Ash and Summer Creeks enter the main stem midway down this lower section. Ash Creek drains the Progress, Garden Home, and Metzger area west to Fanno. Summer Creek drains east from Sexton, Bull, and Cooper Mountains." (Kurahashi, 1997)

Based on early 1850's data, Hawksworth describes the plant cover of the valleys of the Tualatin basin as "forested with Douglas-fir, which was often associated with western redcedar, and bigleaf maple." The open forest along Middle Fanno Creek had a "dominant undergrowth of fern, salal, thimbleberry, rose and briers." "Surveyor accounts only mention white oak in the Middle Fanno Creek area," associated with fir and yellow pine. (Hawksworth, 2001). A GIS database obtained from the Nature Conservancy describes two patches encompassing the Greenway Park reach. The upper patch was a closed upland forest with white oak, Douglas fir and ponderosa pine. The lower patch was thinly timbered woodland, with the same tree species, and "brushy undergrowth of hazel, bracken, etc." A patch encompassing the Englewood site was "closed riparian and wetland forest: Ash-Alder-Willow Swamp, sometimes with bigleaf maple. Often with vine maple, ninebark, hardhack, cattails and course gr[asses]. Ground very soft, mirey or muddy, usually with extensive beaver d[ams]." We have no historic data, but Guard lists the understory and groundcover species typical of ash swales in Oregon interior valleys (Guard, 1995).

The population of Washington County, which encompasses most of the Tualatin basin, was 2,652 in 1850. Since World War II, population growth has been rapid in the county. Urbanization is concentrated in the eastern portion, where most of the Fanno Creek watershed lies. Population grew from 61,269 in 1950 to about 376,500 in 1997 (TRWC, 2002). This growth reflects national trends of westward migration and suburbanization, as well as the development of global industry and trade, especially in the electronics industry (Dow, 2000). For the Tualatin Basin, widespread disturbance has resulted from agriculture, forestry and urbanization: "Monocultures and low-diversity disturbed urban and rural environments have greatly diminished the habitat variability that characterized the area prior to human settlement. Natural riparian areas are narrow or lost entirely, large areas of wetlands have been drained or filled, and only scattered old growth trees remain." (TRWC, 1999; Falkenmark, 2002). Smith reported that "roads, culverts, dams, commercial and residential development, and removal of native vegetation has greatly fragmented the riparian corridors" in the Fanno Creek basin, reflecting the broader disturbance pattern on a sub-watershed scale (Smith, 1996).

The specific area addressed by this study is the reach of Fanno Creek which traverses Englewood and Greenway Parks, approximately from RM 5.3 near N. Dakota Rd. to RM 7.3, Hall Blvd. Figure 4 shows the parks and surrounding major roads.

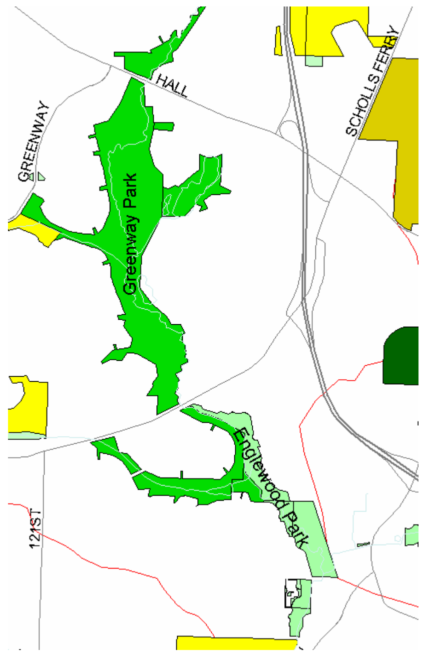


Figure 4. Greenway and Englewood Parks

(Metro, 2002)

Greenway Park was acquired by THPRD in a series of donations between 1973 and 1982. (J. Reilly, personal communication.) A THPRD study describes Greenway as a "diverse-habitat community and natural area park,… encompassing close to 86 acres of natural area wetlands, uplands, and maintained picnic and mowed turf sites." There are numerous maintained recreational areas, including about three miles of asphalt paths. The natural areas make up about 60% of the park. The park is heavily used by "joggers, bike riders and people walking their dogs." Regarding the park's natural features: "The creek is not in properly functioning condition, restricted to a narrow, steep-sided channel without adequate access to its floodplain, except during very heavy rain events. …The diverse habitats of Greenway contain many native plant species, including very large Oregon ash and Oregon white oak. However, reed canary grass and Himalayan blackberry are the dominant vegetation in many areas." (THPRD, 2000)

Despite the impact of human disturbance, there are some remnant plant communities in Greenway and Englewood. Smith observed "a large patch of oak and ash forest with Indian plum, oceanspray, sedges, woodland grasses, fringecup, etc. is present about midway up the Park" in Greenway. In Englewood there are "patches of trees and shrubs" (Smith, 1996). Non-native vegetation is a problem throughout both parks. (Smith, 1996; THPRD, 2000).

The Index of Biological Integrity (IBI) integrates biological indicators as a measure of the "ecological health of a river and its watershed." (Karr, 2000) The Oregon Department of Fish and Wildlife (ODFW) measured the IBI of Tualatin Basin streams in two studies done in 1993-95 and 1999-2001. Fanno Creek's stream mean IBI score (over four seasons and three reaches) was 44.0 in the later study. This is considered "severely impaired." Nonetheless, summer IBI scores in Fanno Creek and its tributaries improved between the two studies. (Leader, 2002)

Englewood Park was acquired by the City of Tigard in 1974-76. In the park, "the open floodplain area is dominated by reed canary grass. Shading of the creek is 0% throughout most of the reach. Patches of willow occur near and further away from the creek. Bank erosion is moderate to severe. There is little to no large woody debris in the channel and the creek is straight for long segments. … Low to moderate wildlife value exists throughout the reach. Patches of trees and shrubs are the primary areas of higher wildlife habitat value." (Smith, 1996.)

We chose this reach for study because it is easily accessible and contains a large and diverse habitat encompassing most of the concerns and factors affecting Fanno creek. It has also been protected and enhanced since the 1970's by various stakeholders and interest groups to improve water quality and wildlife habitat. The management of the site has a significant impact on Fanno Creek water quality and habitat, in particular, on TMDL's. This stream reach is publicly owned, facilitating the channels of input into management plans by watershed advocates. Tualatin Riverkeepers and Fans of Fanno Creek are active citizen stakeholders. (Fans, 2002; Tualatin Riverkeepers, 2002)

Data and Methods

For the analysis of tree canopy in Greenway and Englewood parks, the highest resolution imagery publicly accessible was chosen. This was oriented with north at the top, cropped and turned into a mosaic to simplify analysis by showing only the necessary portions of Fanno creek, including the water and riparian regions to either side. (Appendix B contains all the mosaics.) The Greenway and Englewood reaches of Fanno creek were marked on the mosaics as subreaches, based on average canopy cover over Fanno creek. Cover was unambiguous for most of the length studied, because the imagery clearly depicted either complete shade with dense trees and brush or the other extreme of little or no shade, few trees and just grass along both banks. For the subreaches with ambiguous percent canopy, the determination of cover was more subjective, involving adding the open space with the covered space and surmising an overall average for that reach.

We measured straight-line distances between the subreach markings, rather than stream distances. We determined subreach lengths as follows: all mosaics were printed on 8 1/2 X 11" paper. Scale was determined for each mosaic (ft/cm). This was done by using the known scale bar on the year 2001 photos, then estimating the distance between two points which could also be identified on other photos. (For example, the Englewood reach from Scholls Ferry Rd. to N. Dakota Rd. was measured.) The two points define an equal distance on the 1963 and 1936 mosaics. This enables computing a scale for these mosaics. Knowing the scale for each mosaic allowed the computation of lengths of subreaches measured from the photos. This procedure was complicated somewhat by the fact that the north and south photos of Greenway printed at slightly different scales. We measured the distance between common sets of points on each such north-south pair of mosaics and adjusted the scale for each half of the mosaic accordingly. Each subreach length was then computed as the length measured fromthe photo ("Photo Distance (cm)" in Appendix A) multiplied by the scale ("Scale (ft/cm)"). We expect the length reach distances ("Total" under "Ground Distance (ft)") to differ slightly from year to year, since the same points were not used in different year's photos to mark subreaches.

We validated the scales of the mosaics to give us a common means of expressing ground distances. We did this by measuring a straight length of road with end-points identifiable in both the 1936 and 1963 photosets. Common distances on all the mosaics for each stream reach were then compared. The maximum error in scale was about 6.0%. This error does not significantly impact the estimates of percent canopy, since the canopy percent coverage computation for a given mosaic is independent of scale.

Each subreach length was multiplied by its percent of canopy cover. The average coverage for each reach was computed as:

> (Sum over all the subreaches of the products of percent canopy multiplied by the subreach length) divided by (sum of all the subreach lengths.)

This yielded the figures in Table 1 (in Results and Discussion section). Appendix A contains a spreadsheet showing the details of subreach measurements, canopy estimates and calculations.

Errors enter the measurements mostly due to fact that the images themselves were not internally coded with photogrammetry data, meaning that even if the analyst had access to the appropriate software the images would still have to be measured by hand for scale and length. Furthermore the actual percent of tree cover determination was primarily based upon the skill of the photo interpreter and the resolution quality of the images themselves but also upon actual on the ground viewing of the study area itself. Measuring subreach chords rather than actual stream distances is an additional source of error. However, since the final percentage is an overall average of multiple measurements, we are confident that it reasonably estimates changes to average tree canopy coverage over Fanno creek for our study areas during the years 1936, 1963 and 2001.

Fans of Fanno Creek exemplifies citizens' nonprofit organizations which "are leaders in the contemporary restoration movement." (Riley, 1999; Fans, 2002) Since 1992, Fans has participated annually with various public agencies in tree planting along Fanno Creek tributaries. Some data was available from Fans' newsletter and web site. We also searched the Tualatin Riverkeepers and *The Oregonian* archives for data on these projects. We found limited data to document the number of trees planted. Patterson estimated that in March, 1994, 800 volunteers "planted 12,000 native alder and willow seedlings … along riparian areas in Beaverton and Tigard." This article reported that Fans' Dan Heagerty estimated this was twice the size of the 1993 planting, suggesting that about 6,000 trees planted were in 1993 (Patterson, 1994). Fans reported in May, 2000 their volunteers' "efforts to install one thousand trees and shrubs each year is reinforced by watering, mulching, and clearing weeds." (*The Fans Flash*, May, 2000). They also installed irrigation in Englewood Park. In 2001 year they reported that their volunteers had planted "over nine hundred trees" that March. (*The Fans Flash*, May, 2001). The estimates above for the plantings in 1993, 1994, 2000 and 2001 total about 19,900 trees. In their 2000 survey, THPRD reported restoration and mitigation in two areas of Greenway Park. In one upland meadow, the report states "numerous trees and shrubs have been planted and are currently healthy." (THPRD, 2000). We have no data on the distribution of these plantings on Fanno Creek and its tributaries, on survival rates or on the number of trees planted in 1992 or 1995-1999.

Recent plantings in Englewood Park are doing well. Along the Fanno floodplain trail "the indefatigable Fans of Fanno Creek have planted young maples, red-cedars, red-osier (creek) dogwoods, wild roses, red alders and ninebark bushes." (Peter, 2002) The authors surveyed Greenway and Englewood Parks on two occasions in November, 2002. Near the floodplain trail in Englewood Park, Mullinax observed healthy streamside plantings of trees and shrubs in a reach of about 320 yards, starting about 150 yards downstream from the Scholls Ferry Bridge. These included willow (typically 6 to 12 feet in height), Western redcedar (4 to 6 feet), red osier dogwood (5 to 8 feet) and black cottonwood (8 to 15 feet). Matt Stein, City of Tigard Urban Forester, reported that he is continuing plantings in Englewood. The plantings are designed to "out-compete" the dominant invasive reed canary grass. These trees are also being protected against nutria. (Personal communication.)

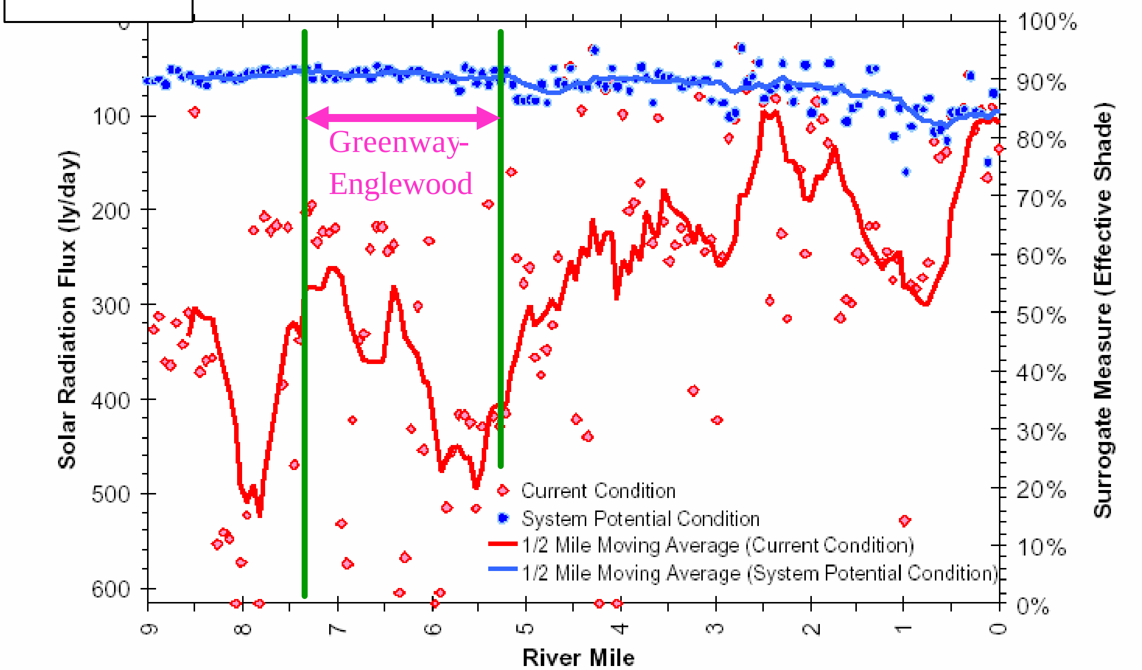
Because the solar heat loading capacity is of limited use in guiding water quality management activities, Oregon DEQ defines percent effective shade as a surrogate for the solar radiation loading capacity. Effective shade is the percent reduction in potential solar radiation delivered to the water surface. As shown in Figure 5, effective shade translates linearly to solar radiation flux. Because of the relationships of factors impacting water temperature, the restoration and protection of riparian vegetation which increases effective shade also reduce stream bank erosion and stabilize channels while they reduce the intensity and area of solar radiation (ODEQ, 2001a).

Effective shade is influenced by a complex of factors, including season, time, stream characteristics, geographic position, and solar position. The vegetative characteristics that influence effective shade are the height, width and density of streamside buffers. (ODEQ, 2001b) We estimate tree canopy as a percentage of linear distance along the stream. We assume that this measure of the presence or absence of canopy reasonably approximates the changes in effective shade between 1963 and 2001.

Figure 5 graphs both current and system potential effective shade against river mileage on Fanno Creek. The end-points of the combined Greenway-Englewood reach are marked. Individual data points represent current and system potential conditions per 100 meter reach. System potential for non-point sources "reflects a riparian vegetation condition without human disturbance."

We deduce opportunities for riparian vegetation enhancement directly fromthe effective shade graph, by estimating overall averages of effective shade and counting data points with effective shade no greater than 20%.

Figure 5. Fanno Creek Surrogate Measure for Non Point Sources – *Effective Shade*



Source: Oregon Department of Environmental Quality, 2001, *Tualatin Subbasin Total Maximum Daily Load (TMDL)*, Appendix A, "Temperature Technical Analysis" (annotated)

Figure 6. Fanno Creek Existing Vegetation Heights and Buffer Widths at Each 100-foot Model Reach.

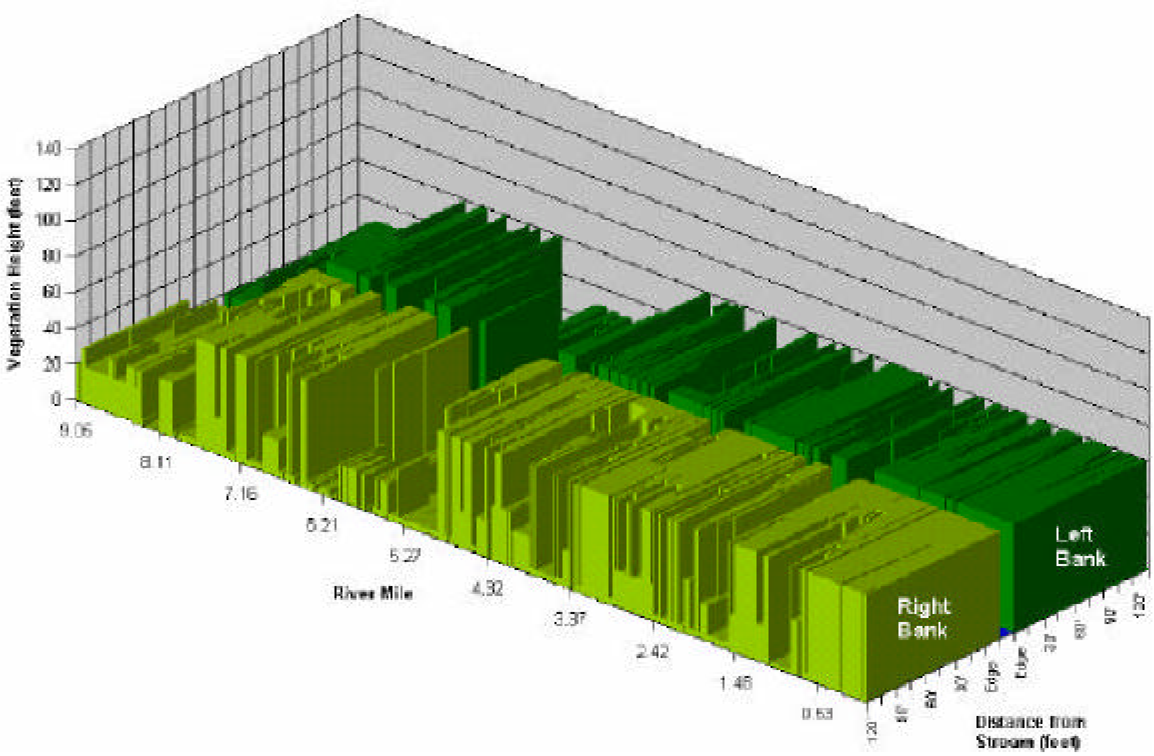


Figure 6 graphs vegetation heights and buffer widths along Fanno Creek. We have no comparable data from 1963.

Results and Discussion

Table 1 shows the results of our tree canopy analysis.

Table 1 – Tree Canopy Changes			
Reach	**1936**	**1963**	**2001**
Greenway	55%	48%	60%
Englewood	27%	29%	7%

This data supports hypothesis 1 for Greenway Park. Canopy for Englewood Park actually decreased substantially between 1963 and 2001. The decrease in Englewood represents thinning and destruction of the riparian buffer in the lower part of the reach, from approximately 1200 ft. upstream of N. Dakota Rd. down to the stream crossing of that road. We have no data on the cause of the reduction. We know that it occurred between 1963 and 2001, but cannot place it more precisely in time.

Data from published accounts we collected gives us an estimate of at least 19,900 trees planted along Fanno Creek and its tributaries between 1992 and 2001. It is reasonable to assume that several thousand more trees were planted in the years for which we have no records. We have no detailed data on the distribution of plantings or survival rates.

Our observations on the progress of recent plantings in Englewood are encouraging. The young trees downstream from the Scholls Ferry bridge are well-established. They were not sufficiently mature to impact our 2001 canopy data. These trees include many fast-growing black cottonwood and western redcedar. They have the potential to increase canopy in the reach described as they mature. The irrigation after planting and protection against destructive nutria should help survival rates.

Protection of the parks under public ownership began with their acquisition between 1973 and 1982. The tree plantings we documented span the years 1992-2001. Thus, protection has been in place from 20 to 29 years, depending on the time of parcel acquisition. Plantings have had one to nine years to mature. Joe Blowers, present president of Fans writes, “Since Fans has been planting for 10 years I wouldn't expect to see much change in tree canopy from our efforts. Even a fast growing doug fir might be ~25 feet tall and provide no more than ~10 feet of canopy cover. Most increases in canopy cover would probably come from stuff planted (or natural) from 20+ years ago.” (Personal communication.)

The number of trees planted over the years and limited data about survival suggest a future impact on canopy, assuming continued protection and maintenance. However, data does not support plantings as a cause of any observed increase in canopy (hypothesis 2). Trees planted or naturally propagated more than twenty years ago have been protected since park acquisitions began in 1973. Canopy increases in Greenway since 1963 suggest, but do not fully support protection as a cause of increased canopy. In Englewood, hypothesis 2 is not supported. Overall there is limited support for hypothesis 2.

The Oregon DEQ effective shade data clearly shows gaps representing opportunities to reduce solar stream heating. Gaps in tree canopy are corroborated by inspection of the 2001 aerial mosaics, by our data determined from those mosaics, and by the DEQ data on vegetation height and buffer widths. The difference between the system potential for effective shade and the current condition is large. System potential for effective shade is at least 90% in the Greenway-Englewood reaches. Current conditions for Greenway average less than 55% effective shade while those for Englewood are less than 30%. Nine data points in the combined reaches show 100 meter sub-reaches with effective shade no more than 20%, including five sub-reaches less than 10%. These results support hypothesis 3: Reaches with low effective shade and high system potential are an opportunity to reduce stream heating by enhancing tree canopy.

Conclusions

Human impact on the ecosystems and hydrology of the Fanno Creek basin has been extensive and severe since Euro-American settlement. Vegetation has been “eliminated or highly modified” along most reaches of the creek (Smith, 1996). Agriculture reduced the width of vegetative buffer in the Greenway-Englewood reaches. Rapid urbanization has impacted stream flows and introduced non-native vegetation. Surveys of the 1850's suggest that tree canopy was extensive and nearly complete in the subject reaches. By 1936, the buffer had been reduced to a narrow strip along much of the Greenway reach, and to near 0% coverage on much of the Englewood reach. Additional tree removal thinned the Greenway buffer further through 1963. Our data demonstrates an overall increase in canopy in the Greenway reach since 1963, and a decline canopy in the Englewood reach. Since the 1970's, these reaches have been protected and enhanced by public owners, agencies and citizens groups. The enhancement includes planting and some maintenance of thousands of trees and shrubs from 1992 to 2001. Our data does not demonstrate that protection and enhancement have resulted in any tree canopy increases (hypothesis 2), although the increase in Greenway canopy is probably a result of protection. Immature plantings in both Greenway and Englewood Parks should increase canopy, given time and maintenance. Assessment of the Englewood plantings' success in out-competing reed canary grass is an interesting topic for future study.

Gaps in tree canopy and effective shade represent an opportunity for stakeholders to reduce solar heating and address the temperature TMDL in this and other stream reaches. Oregon DEQ has published effective shade profiles for all the major Tualatin River tributaries (ODEQ, 2001b). Aerial surveys for many areas are freely available on the Internet. These are effective tools for watershed managers to guide both selection of stream reaches for plantings and the design of plantings.

Continued riparian planting will have a long-term benefit. Design should emphasize increasing height, width and density of the vegetative buffer. Some information on early plant communities is available from historic sources. This information can be supplemented by more recent observations of existing communities. These combined sources should be considered in the design of plantings (ODEQ, 2001b). Protection and enhancement projects should address the reduction of non-native plant species. Plantings have benefit to habitat, wildlife and bank stability, as well as to stream temperatures (Sutherland, 1997; ODEQ, 2001b). Maintenance, including summer watering, plant protection and monitoring of site conditions are required to ensure successful establishment of plantings.

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Appendix A: Tree Canopy Computations

Steve Mullinax, December 6, 2002, Rev 1

Greenway, 1936

Reach	Photo Distance (cm)	Scale (ft/cm)	Ground Distance (ft)	%Shade	Product
G1-G2	4.9	207	1014	30%	304
G2-G3	5.3	207	1097	0%	0
G3-G4	3.3	207	683	15%	102
G4-G5	12.2	207	2525	100%	2525
Totals			**5320**	**55%**	**2932**

Greenway, 1963

Reach	Photo Distance (cm)	Scale (ft/cm)	Ground Distance (ft)	%Shade	Product
G1-G2	9.0	110	990	90%	891
G2-G3	11.0	110	1210	5%	61
G3-G4	12.2	125	1525	100%	1525
G4-G5	7.4	125	925	15%	139
G5-G6	6.8	125	850	5%	43
Totals			**5500**	**48%**	**2658**

Greenway, 2001

Reach	Photo Distance (cm)	Scale (ft/cm)	Ground Distance (ft)	%Shade	Product
G1-G2	8.7	116	1009	100%	1009
G2-G3	7.0	116	812	5%	41
G3-Ref3	2.6	116	302	95%	287
Ref3-G4	4.2	125	525	95%	499
G4-G5	2.7	125	338	30%	101
G5-G6	7.5	125	938	100%	938
G6-G7	6.7	125	838	55%	461
G7-G8	6.5	125	813	5%	41
Totals			**5573**	**60%**	**3334**

Englewood, 1936

Reach	Photo Distance (cm)	Scale (ft/cm)	Ground Distance (ft)	%Shade	Product
E1-E2	18.4	143	2631	5%	132
E2-E3	6.4	143	915	90%	824
Totals			**3546**	**27%**	**955**

Englewood, 1963

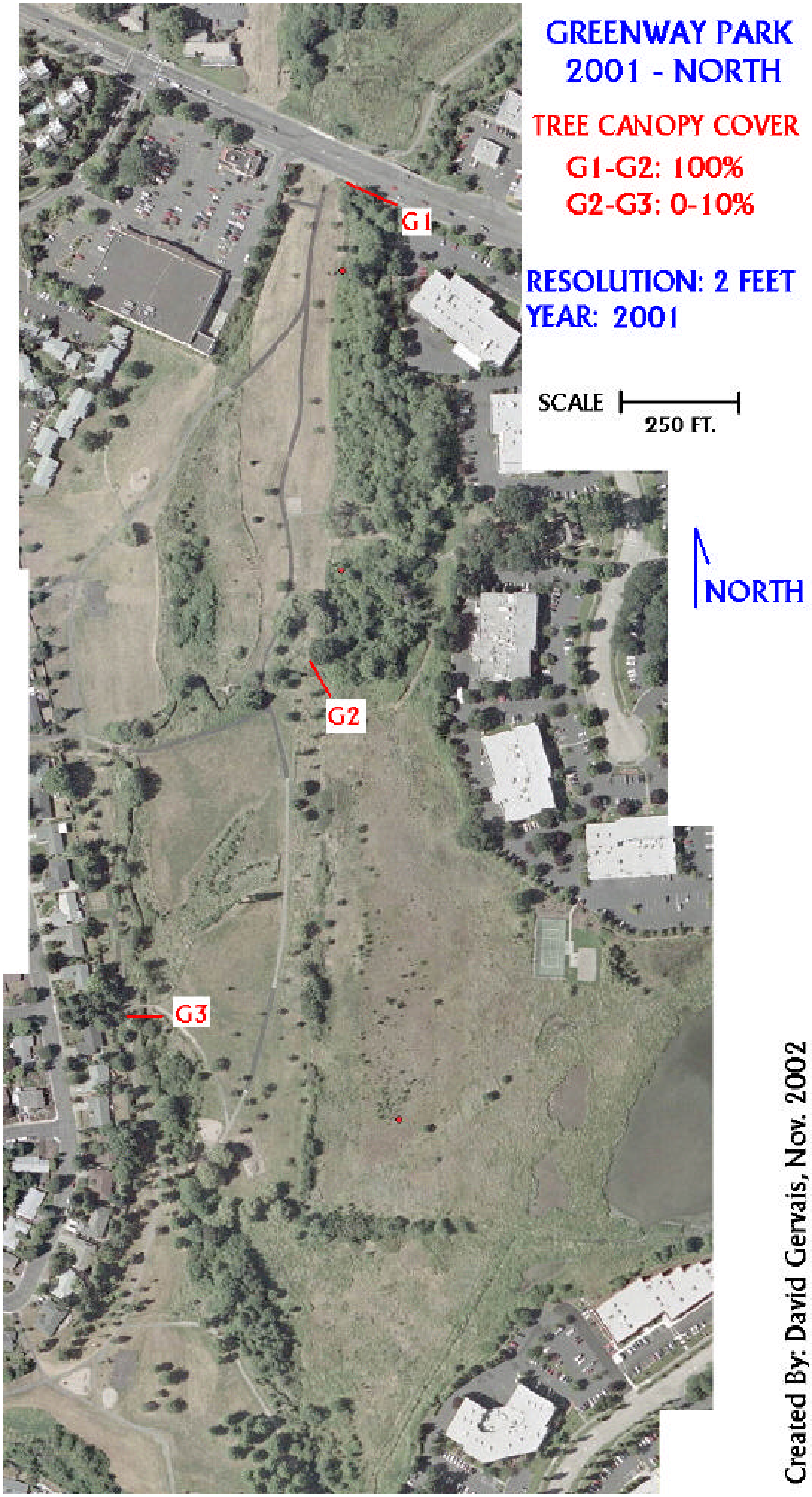
Reach	Photo Distance (cm)	Scale (ft/cm)	Ground Distance (ft)	%Shade	Product
E1-E2	1.3	131	170	15%	26
E2-E3	17.7	131	2319	0%	0
E3-E4	8.7	131	1140	90%	1026
Totals			**3629**	**29%**	**1051**

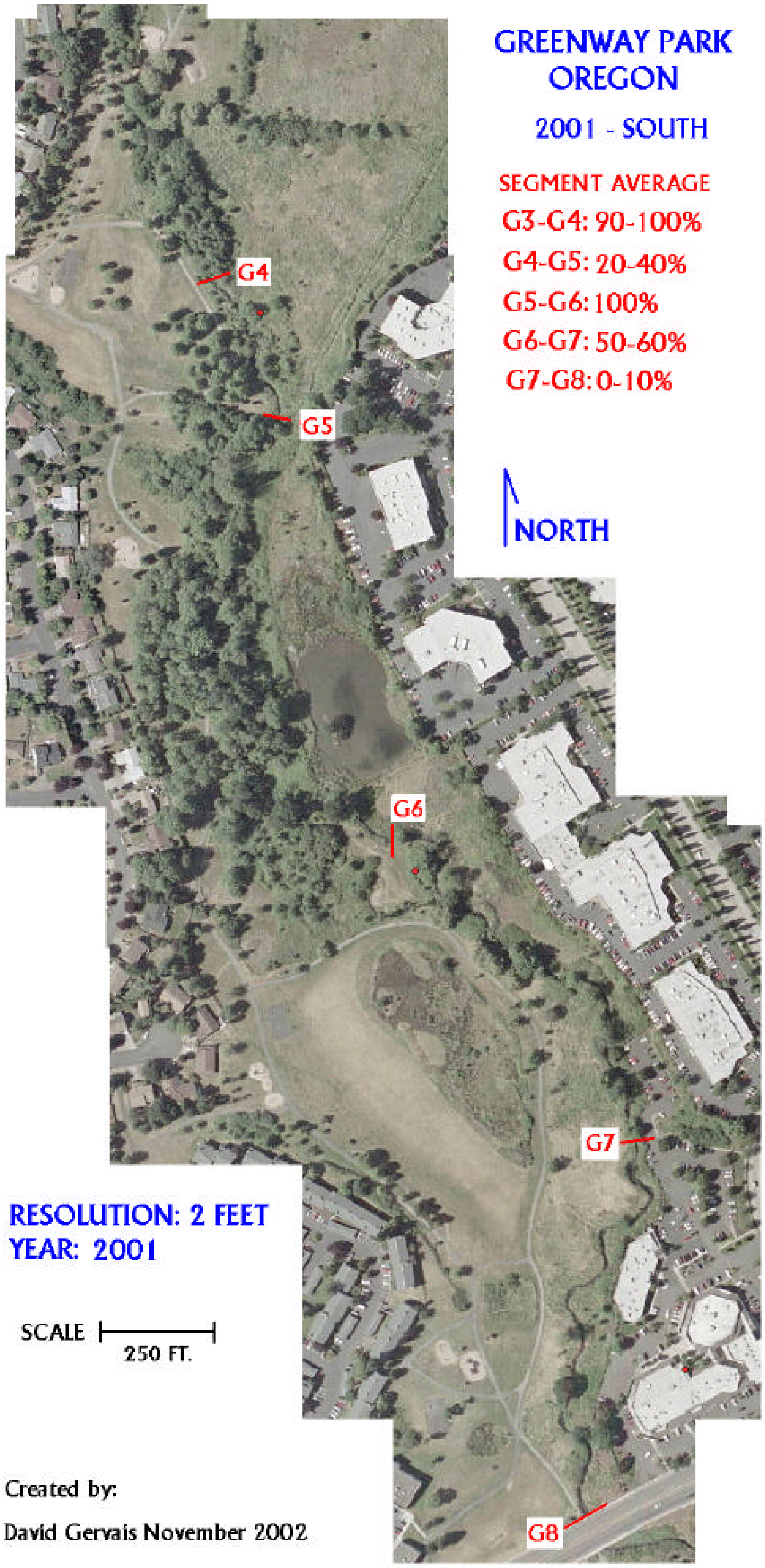
Englewood, 2001

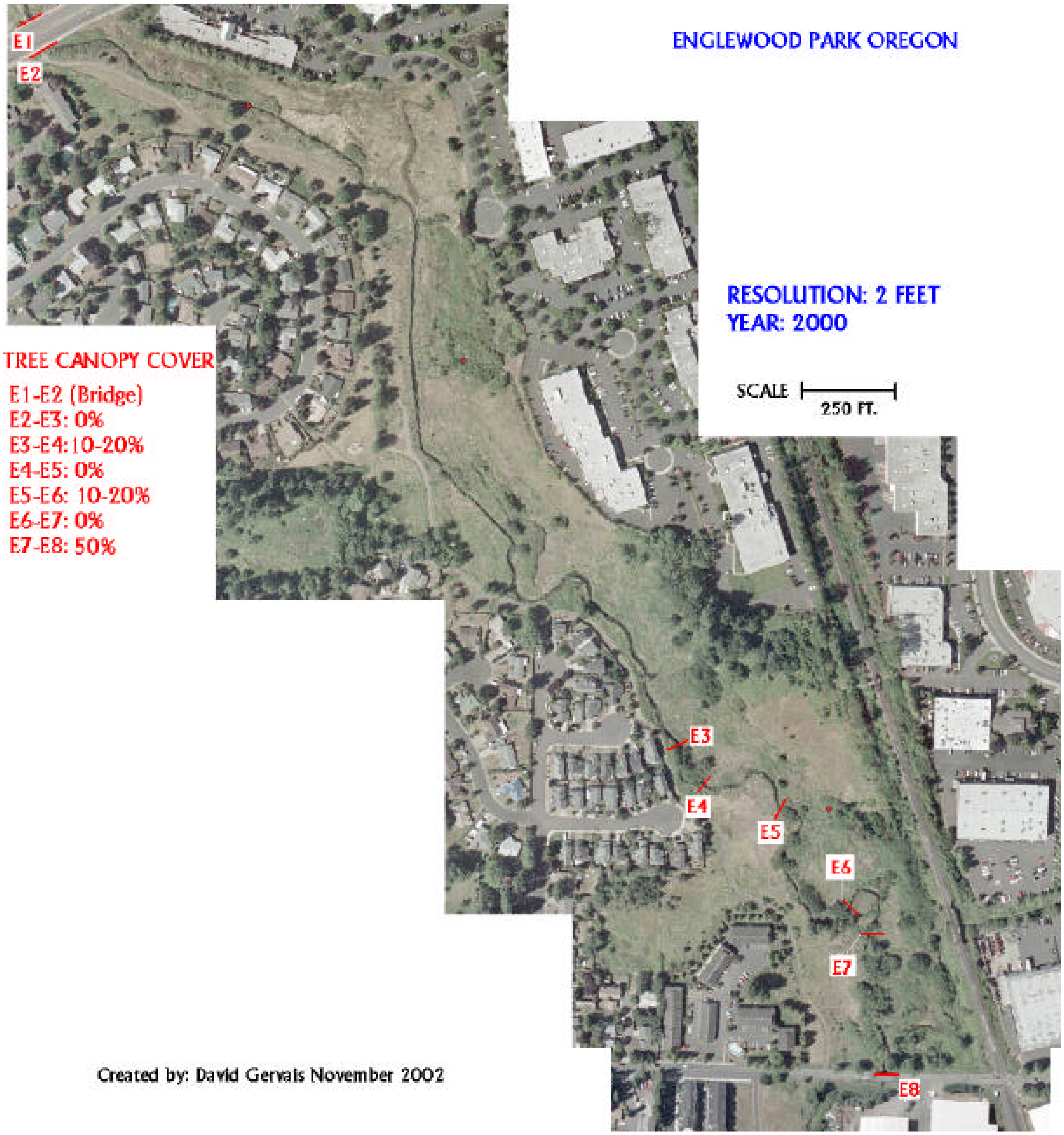
Reach	Photo Distance (cm)	Scale (ft/cm)	Ground Distance (ft)	%Shade	Product
E2-E3	18.0	139	2502	0%	0
E3-E4	0.9	139	125	15%	19
E4-E5	1.6	139	222	0%	0
E5-E6	2.3	139	320	15%	48
E6-E7	0.8	139	111	0%	0
E7-E8	2.7	139	375	50%	188
Totals			**3656**	**7%**	**254**

Appendix B: Fanno Creek Tree Canopy Cover Photo-Mosaics

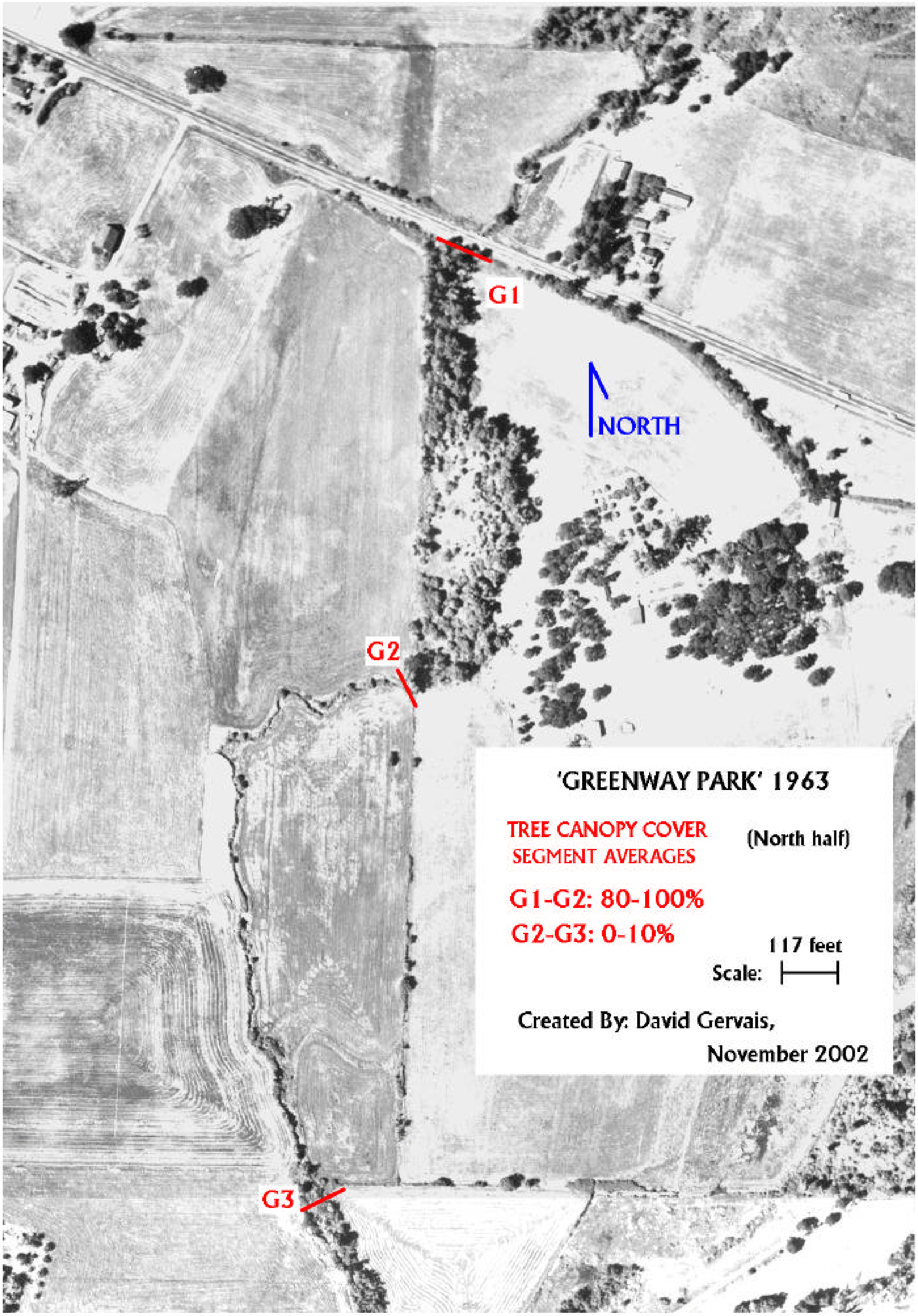
December 2002

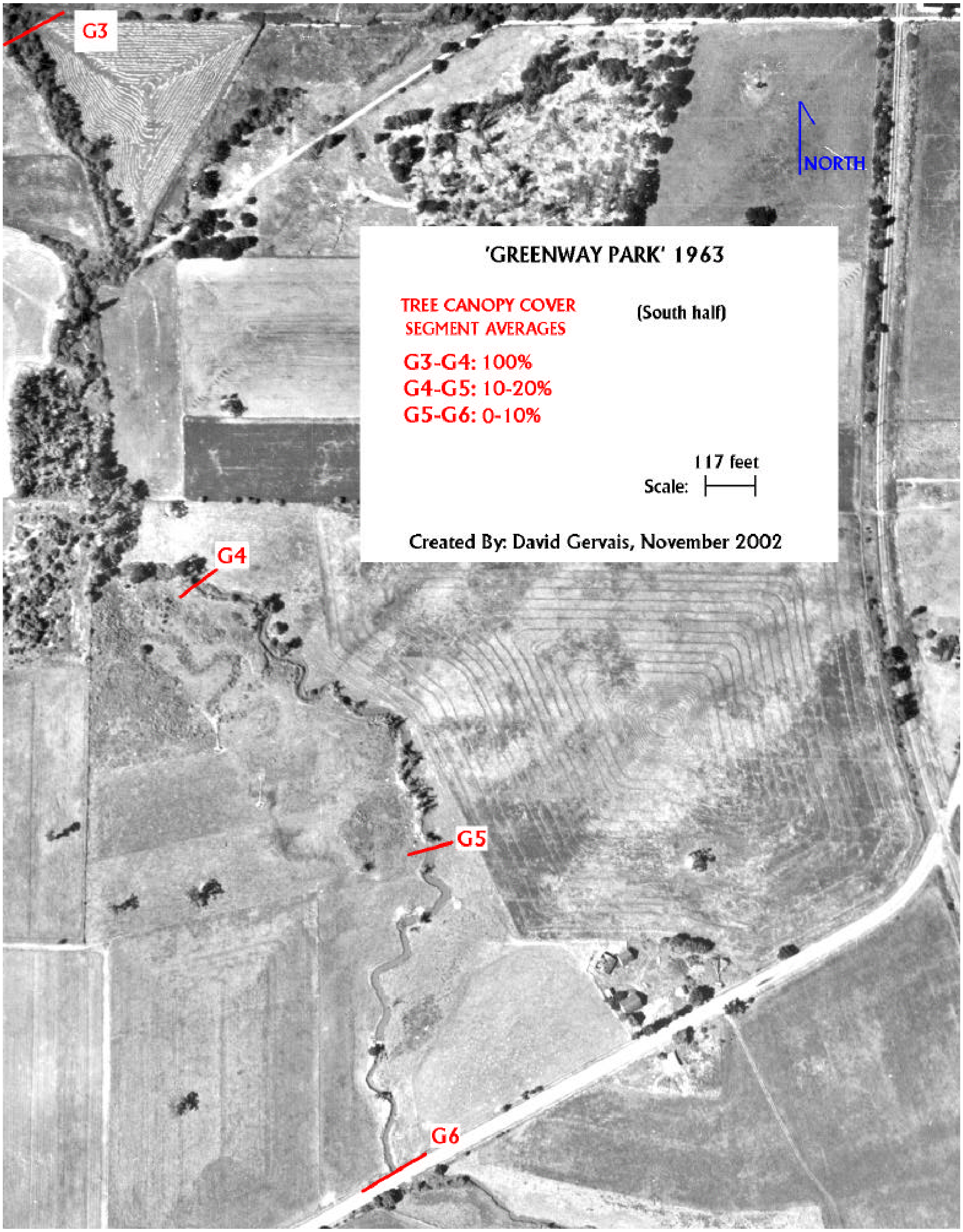

GREENWAY PARK
2001 - NORTH
TREE CANOPY COVER
G1-G2: 100%
G2-G3: 0-10%
RESOLUTION: 2 FEET
YEAR: 2001
SCALE
250 FT.
NORTH
G1
G2
G3
Created By: David Gervais, Nov. 2002

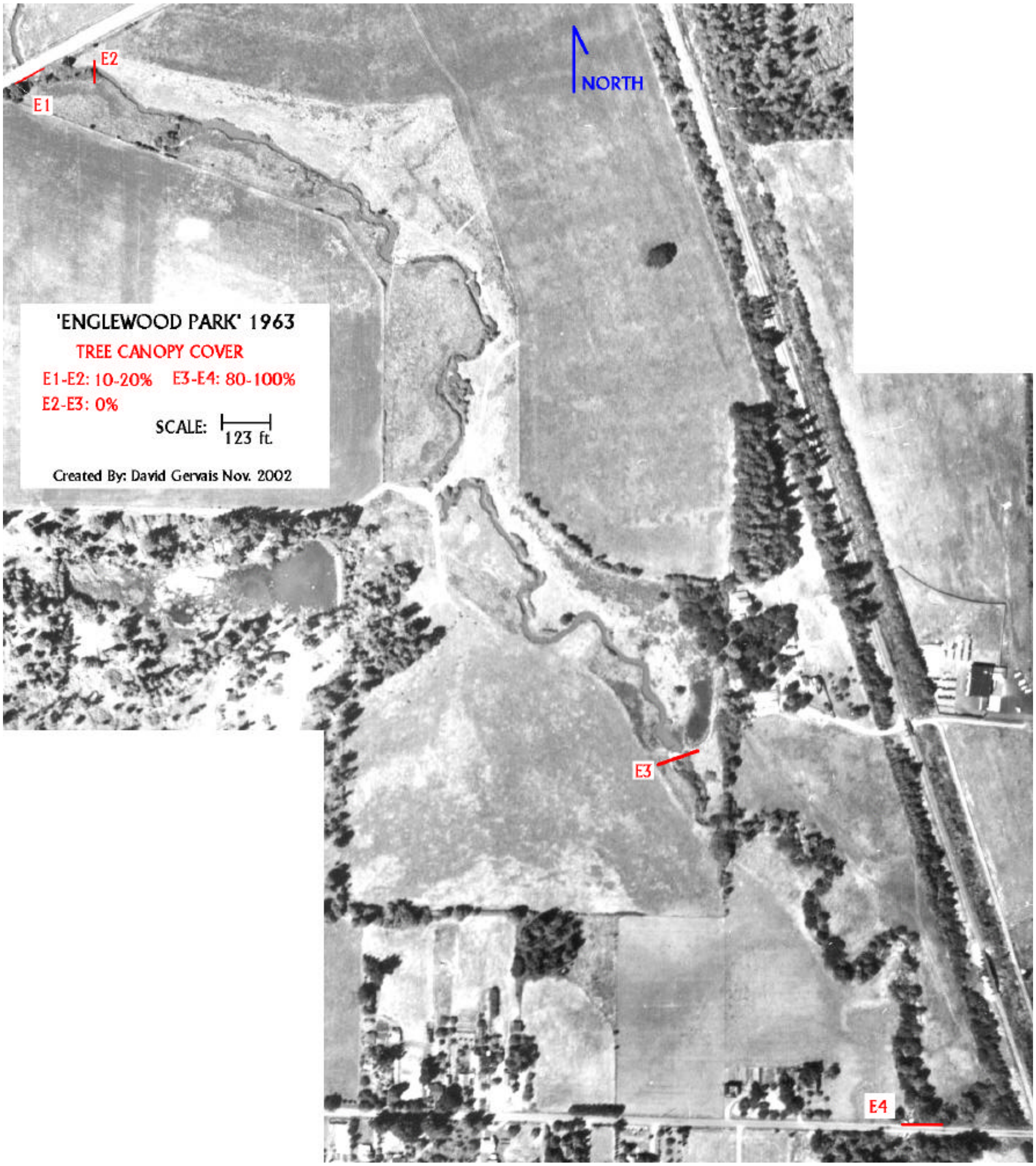

GREENWAY PARK
OREGON
2001 - SOUTH
SEGMENT AVERAGE
G3-G4: 90-100%
G4-G5: 20-40%
G5-G6: 100%
G6-G7: 50-60%
G7-G8: 0-10%
NORTH
G4
G5
G6
G7
G8
RESOLUTION: 2 FEET
YEAR: 2001
SCALE
250 FT.
Created by:
David Gervais November 2002

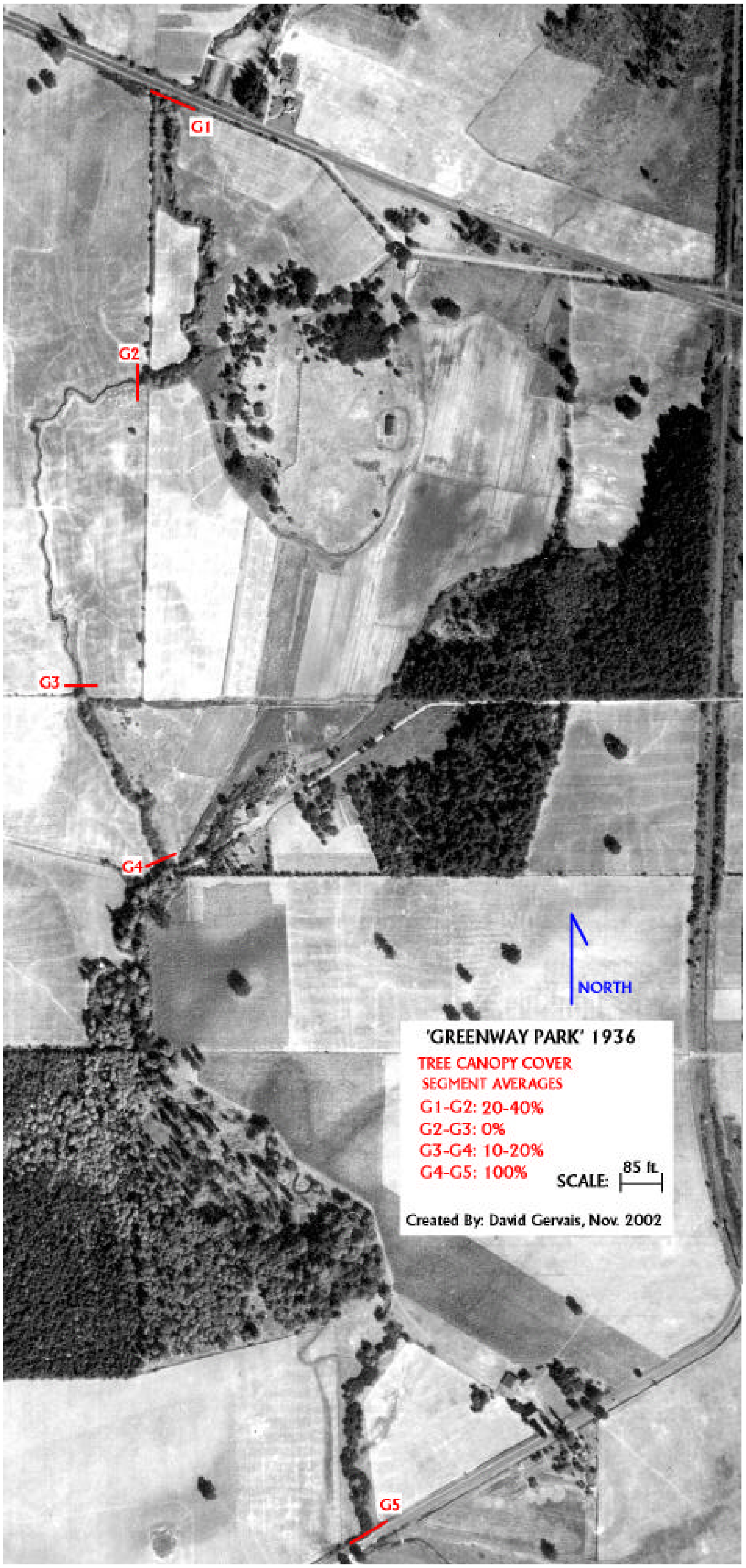


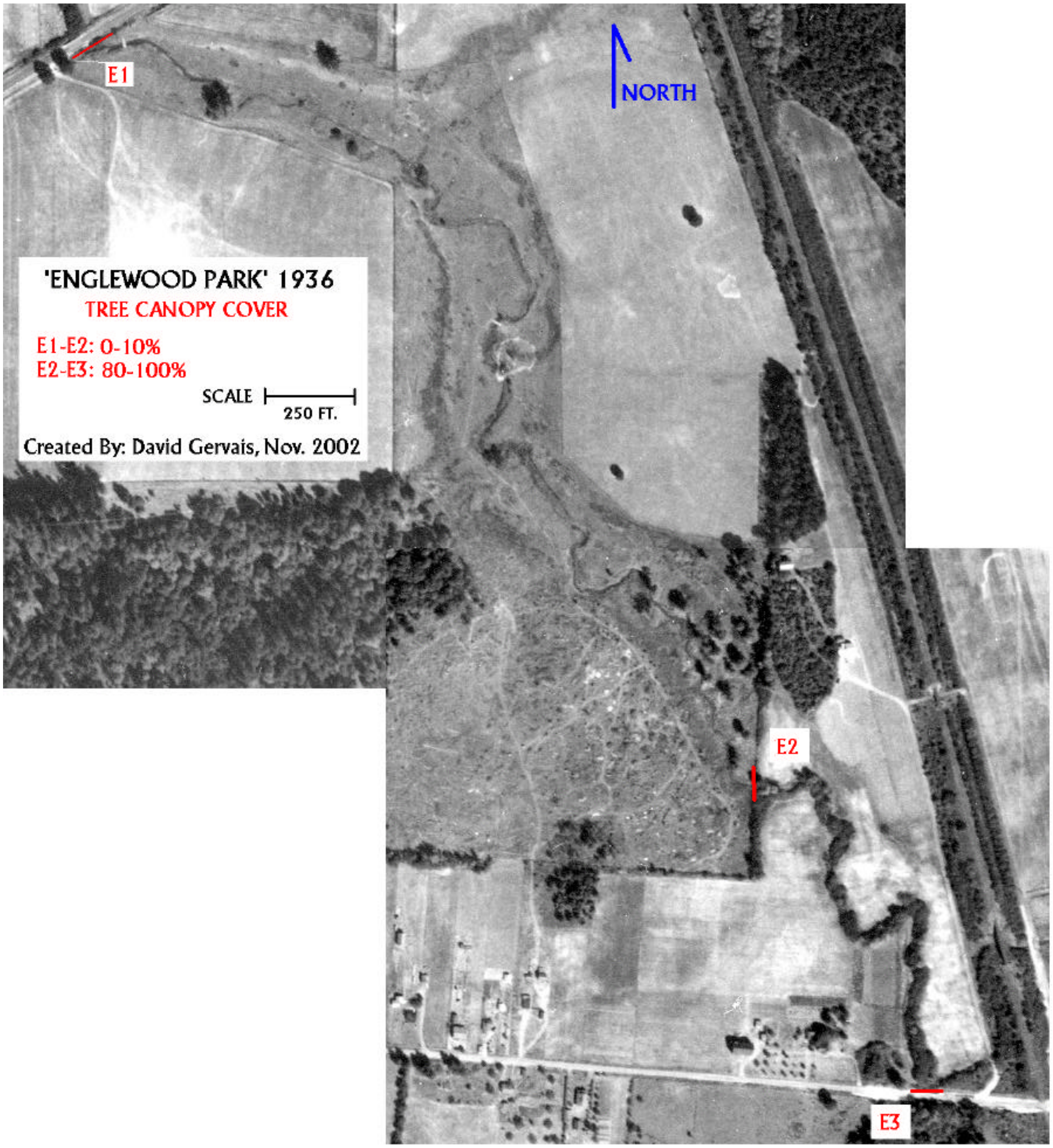
ENGLEWOOD PARK OREGON
RESOLUTION: 2 FEET
YEAR: 2000
SCALE
250 FT.
TREE CANOPY COVER
E1-E2 (Bridge)
E2-E3: 0%
E3-E4: 10-20%
E4-E5: 0%
E5-E6: 10-20%
E6-E7: 0%
E7-E8: 50%
E1
E2
E3
E4
E5
E6
E7
E8
Created by: David Gervais November 2002


G1
NORTH
G2
G3
'GREENWAY PARK' 1963
TREE CANOPY COVER
SEGMENT AVERAGES
(North half)
G1-G2: 80-100%
G2-G3: 0-10%
117 feet
Scale:
Created By: David Gervais,
November 2002


G3
NORTH
'GREENWAY PARK' 1963
TREE CANOPY COVER
SEGMENT AVERAGES
(South half)
G3-G4: 100%
G4-G5: 10-20%
G5-G6: 0-10%
117 feet
Scale:
Created By: David Gervais, November 2002
G4
G5
G6


'ENGLEWOOD PARK' 1963
TREE CANOPY COVER
E1-E2: 10-20%
E3-E4: 80-100%
E2-E3: 0%
SCALE:
123 ft.
Created By: David Gervais Nov. 2002
NORTH
E1
E2
E3
E4


G1
G2
G3
G4
G5
NORTH
'GREENWAY PARK' 1936
TREE CANOPY COVER
SEGMENT AVERAGES
G1-G2: 20-40%
G2-G3: 0%
G3-G4: 10-20%
G4-G5: 100%
SCALE: 85 ft.
Created By: David Gervais, Nov. 2002


'ENGLEWOOD PARK' 1936
TREE CANOPY COVER
E1-E2: 0-10%
E2-E3: 80-100%
SCALE
250 FT.
Created By: David Gervais, Nov. 2002
NORTH
E1
E2
E3