

Historical Aquatic Habitats in the Green and Duwamish River Valleys and the Elliott Bay Nearshore, King County, Washington



Project Completion Report to:

King County Department of Natural Resources and Parks
201 South Jackson Street
Seattle, WA 98104-3855

Prepared by:

Brian Collins and Amir Sheikh
Department of Earth & Space Sciences
Box 351310, University of Washington
Seattle, WA 98195

September 6, 2005

Project funded by the WRIA 9 Forum through the King Conservation District

Summary

We reconstructed historical (~1865) riverine and estuarine environments of the Duwamish River, historical lower White River (modern “lower Green” River), the Green River (modern “middle Green” River) and Elliott Bay (tidal marshes located historically at present-day West Point, Smith Cove, and Occidental Square area of Seattle), using maps and field notes of the General Land Office survey, early maps from the US Coast & Geodetic Survey and US Geological Survey, 1936 and 1940 aerial photos and other historical sources, and high resolution digital elevation model from lidar (light detection and ranging) imagery, with Geographic Information System (GIS) technology.

The physical template shaped processes and habitats in distinctly different ways throughout the study area, including in the Duwamish River valley; in the upper Duwamish valley, Holocene fluvial deposition elevated the river several meters above its floodplain, creating a number of depressional floodplain wetlands. By contrast, Holocene fluvial downcutting of the lower Duwamish, possibly driven by late Holocene seismic upwarping along the Seattle Fault, created dry terraces with fir forests flanking a relatively narrow floodplain and a consequently relatively small area of tidal wetlands. Two topographic factors shaped habitats in the broad, low gradient lower White River valley: similar to the upper Duwamish, the river has banks several meters above its floodplain; and Holocene alluvial fans created by the White River and Cedar River deflected channels and focused runoff. In the upper valley, the White River Fan concentrated runoff into the system of wetlands drained by present-day Mill Creek on the western valley margin. Downstream of about Kent, an extensive and complicated mosaic of wetlands and

network of channels existed in the floodplain, especially on the valley's east side. Inference from topography, corroborated by floodwater mapping from the record 1906 flood, show that once frequent floodwaters topped the lower White River's banks, water flowed northward in this extensive floodplain drainage system that paralleled the lower White River, and did not rejoin it until near the river's confluence with the Black, or after first joining the Black River. The Green River, in a narrower and steeper valley, meandered, migrated and created oxbow lakes in the lower-gradient downstream part of the valley, but upstream and more generally had a more branching form with a network of floodplain sloughs. (In this report "slough" refers to a floodplain channel primarily fed by and connected to the main channel and that often rejoins the river downstream.)

Hardwoods dominated riparian riverine forests, as reconstructed from General Land Office field notes from the 1860s. Trees that were both abundant and commonly attained a large diameter, and so would most commonly have contributed large wood to channels, included black cottonwood (*Populus trichocarpa*) and bigleaf maple (*Acer macrophyllum*), and secondarily western redcedar (*Thuja plicata*) and Douglas fir (*Pseudotsuga menziesii*).

The different physical templates that shaped the Duwamish, lower White, and Green river valleys is reflected in the amount, distribution, and relative dominance of different habitats in the three valleys. In the Duwamish valley, the tidally-influenced mainstem dominated channel area, blind tidal channels (channels created by tidal energy that connect tidal marsh to estuarine or riverine water) provided the largest component of channel edge, and the total wetland area was greater than combined channel area. The three small Elliott Bay estuaries area made a significant contribution to Elliott Bay's blind tidal channel habitat, accounting for one-fourth as much blind

tidal channel habitat as the Duwamish River estuary. Channel area in the lower White River was dominated by the mainstem and by the network of floodplain channels, and the latter dominated total channel edge habitat; total wetland area in the lower White was much greater than channel area. In the Green River valley, mainstem and slough habitats dominated channel area and floodplain sloughs dominated channel edge; and channel habitat was greater than pond habitat.

The emphasis in riverine restoration also differs for the different valley types in the study area. In valleys such as the Green River (modern “Middle Green”), where wood jams partially mediate frequent channel switching in a system of multiple, dynamic channels and floodplain sloughs, the emphasis is on restoring a dynamic river-forest connection by way of a linked restoration of the riparian forest, channel morphology, and a dynamic connection between the river and riparian forest. In contrast, meandering rivers in broad, low-gradient valleys such as the Duwamish and (historical) lower White River were avulsed much less frequently and by gradual bank lateral migration and meander cut-off within a meander belt that was narrow relative to the valley width; the emphasis is on restoring hydrologic connectivity to features within the narrow meander belt, and to the floodplain’s extensive system of wetlands and channels.

Landscape-scale reconstructions of historical environments include inherent uncertainties and biases, and lack sufficient spatial resolution to substitute for site-scale investigations. They do provide context for individual projects by describing the processes and mechanisms that historically created and maintained a landscape and its habitats, and by describing the types, distributions, and approximate amounts of physical habitats, they can contribute to various biological assessments such as limiting factors analyses and historical habitat and production estimates for salmonids.

Table of Contents

Summary	i
Table of Contents	iv
List of Figures	v
List of Tables	v
Introduction	1
Scope	1
Study Area	2
Methods	8
Mapping Sources	8
Channel Mapping	8
Land Cover Mapping	9
Elliott Bay Shoreline	15
Duwamish River Valley	19
Topography and the Channel Network	19
Wetlands in the Duwamish Valley	21
Lower White and Black River Valleys	28
Topography and the Historical Drainage Network	28
Historical Wetlands in the Lower White River Valley	33
Green River Valley	47
Forest Cover and In-Channel Wood	51
Watershed Overview	51
Duwamish River Valley	52
Lower White River Valley	53
Green River Valley	54
In-Channel Wood	55
Aquatic Habitat	67
Quantitative Summary	67
Implications for Restoration	68
Considerations in Using Historical Habitat Estimates	69
References Cited	77
Appendix 1: Wetland Descriptions	80

iv

List of Figures

1. Schematic drawing of study area	5
2. Valley width and gradient, and watershed area and channel gradient in South Puget Sound	6
3. Historical longitudinal profiles of Duwamish, Green, White and Cedar rivers	7
4. Historical tidal wetland complexes on Elliott Bay	17
5. Valley cross sections in the Duwamish River valley	24
6. Locations in the Duwamish River valley	25
7. Flow measurements in the Duwamish River valley during the 1906 flood	26
8. Historical landscape of the Duwamish River	27
9. Topography and location of valley cross sections in the lower White River	36
10. Valley cross sections in the lower White River	37
11. Historical landscape of the lower White River	40
12. Flow measurements in the lower White River valley during the 1906 flood	41
13. 1940 and 1990 aerial photos and relict channels in northern lower White River valley	42
14. Historical flooding in town of Kent	43
15. Historical sources map information on south Lake Washington nearshore area	44
16. Historical wetland in Southcenter area	45
17. Historical wetland in lower White River valley	46
18. Locations in the lower Green River	48
19. Valley cross sections in the Green River	49
20. Historical landscape of the Green River	50
21. Historical distribution of common tree species	58
22. Diameters of common tree species	60
23. Elevation of common tree species	61
24. Frequency and basal area of floodplain and terrace trees in the Duwamish River valley	62
25. Frequency and basal area of streamside and shoreline trees in the Duwamish River valley	63
26. Frequency and basal area of tree species in the lower White River valley	64
27. Frequency and basal area of tree species in the Green River valley	65
28. Historical channel area and edge in the study area	74
29. Quantitative summary of historical aquatic habitats	75

List of Tables

1. Map and photo sources	13
2. Diameter statistics of common trees in historical General Land Office field notes	56
3. Snags removed by Army Engineers from Duwamish and White Rivers, 1880-1910	66
4. Snags removed by Army Engineers from four north Puget Sound rivers, 1880-1910	66
5. Estimated historical habitat areas in the study area	73

Introduction

Scope

This report describes aquatic habitats reconstructed for approximately the mid 1860s, and accompanies Geographic Information Systems (GIS) data created for the Duwamish and Green river valleys and several coastal wetlands on Elliott Bay in King County, Washington (Figure 1). The GIS data and associated metadata include: (1) channels, water bodies, and land cover interpreted from a composite of sources, including General Land Office (GLO) plat maps and field notes, early USGS topographic maps, 1936 and 1940 aerial photographs and other sources (Table 1); (2) “bearing tree” data from General Land Office field notes (a bearing tree is a tree marked by surveyors to insure a land section corner or quarter corner could be found if the monument marking a corner was destroyed; surveyors marked the trees with prescribed marks, and noted their species, size, and distance and bearing to the survey point; see Collins et al. 2003, for more explanation). The GIS data includes the survey points, with characteristics of the associated bearing trees, including each tree’s common name, diameter, and distance from the survey point; (3) supporting geospatial data, including orthorectified 1936 and 1940 photomosaics, georeferenced GLO plat maps and early USGS topographic maps.

The present-day “lower Green” River valley historically was known as the White River, and herein it is referred to as the “lower White” River valley. The present-day “middle Green” River valley in this report is referred to as the “Green” River valley. This discrepancy between historical and current river names is because the White River historically flowed northward to

join the Green River—rather than southward to join the Puyallup, as it does now —and retained its name downstream past its confluence with the Green, to its confluence with the Black River. The lower White River then joined the Black River (which historically drained the Cedar and Lake Washington basins) to create the Duwamish River.

Study Area

This study area includes several coastal tidal marsh complexes on Elliott Bay from West Point on the north to Alki Point to the south (Figure 1), and the valley bottoms of the Duwamish, the lower White, Black, and Green rivers. The Duwamish River historically drained 4,000 km², and now drains 1,250 km²; the drainage basin is smaller than historically because the White River at Auburn was diverted into the Puyallup River in 1907, and the Cedar River and Sammamish River drainages were diverted to the Lake Washington Ship Canal in 1916. The valleys of the Duwamish River and the lower White River were sculpted in part during the late stages of the last Pleistocene glaciation by subglacial meltwater (Booth 1994), which incised a wide, low-gradient valley into the Puget Lowland's glacial fill. Similar to other valleys in the Puget Lowland having the same origins, they are wider and gentler-sloping than valleys that were created after deglaciation, by post-glacial fluvial incision into the lowland glacial fill (Figure 2A). For example, the Duwamish and lower White valleys are 1800 and 3600 m wide, respectively, while the Green River valley averages 800 m wide, several times narrower than the others; the Duwamish and lower White valleys have gradients of 0.0002 and 0.0006, respectively, while the Green River valley gradient is 0.003, about 10X greater than that of the other two valleys (Figure 2A). (Note in Figure 2A that the part of the lower White River valley dominated by the White River Fan is several times steeper than the lower White River valley

downstream of the fan.) The rivers in the Pleistocene valleys were considerably lower in gradient than rivers having comparable drainage areas in the post-glacial valleys (Figure 2B); the Duwamish and lower White Rivers had considerably lower gradients than the Cedar, Green, or upper White (Figure 3). The lower White River valley was a shallow embayment of Puget Sound until the mid Holocene, when the voluminous Osceola Mudflow [~ 5.7 kaBP (thousand years before present); Dragovich et al. 1994] and subsequent lahars from Mt. Rainier, including lahars as recent as 2.2, 1.6, and 1.1 kaBP (Zehfuss et al. 2003), cumulatively extended the Duwamish valley 50 km seaward to its present location (Dragovich et al. 1994; Zehfuss et al. 2003).

Geologic field evidence indicates the Osceola Mudflow blocked the early-Holocene outlet of the White River through South Prairie Creek and diverted the White River to its present location, eroding the canyon upstream of the present-day town of Auburn (Crandell 1963). This sediment from the excavation of the White River canyon augmented sediments from the Osceola and later events to create a large alluvial fan (herein termed the “White River Fan”) into the lower White River trough at the mouth of the upper White River valley (Figure 1). The Cedar River also created a large alluvial fan in the Renton area.

Puget Sound’s shoreline in the Duwamish embayment was approximately at the present-day neighborhood of South Park by ~ 2.0 kaBP. A lahar, 1.2 kaBP prograded the shoreline to near its present location (Zehfuss et al. 2003). About 1.1 kaBP, several meters of vertical movement on the Seattle Fault (Bucknam et al. 1992) appears to have upwarped the lower Duwamish valley. Subsequently, the Duwamish River partially excavated the valley to create its modern floodplain, creating terraces of the unexcavated portion of the 1.2 kaBP lahar surface. The north-side terrace (site of the present-day neighborhood of Georgetown) and south-side terrace (on which

archaeological excavations indicate continuous inhabitation for 1200 years) constrict the floodplain; at the narrowest it is about 700 m at the present-day Kellogg Island area.



Figure 1. Schematic of Duwamish, lower White and Green river valleys. Hatched areas, from south to north, show: the White River alluvial fan; the Cedar River alluvial fan, and lower Duwamish terrace presumed to have been created 1.1 kaBP and consisting of 1.2 kaBP Mt. Rainier lahar deposits.

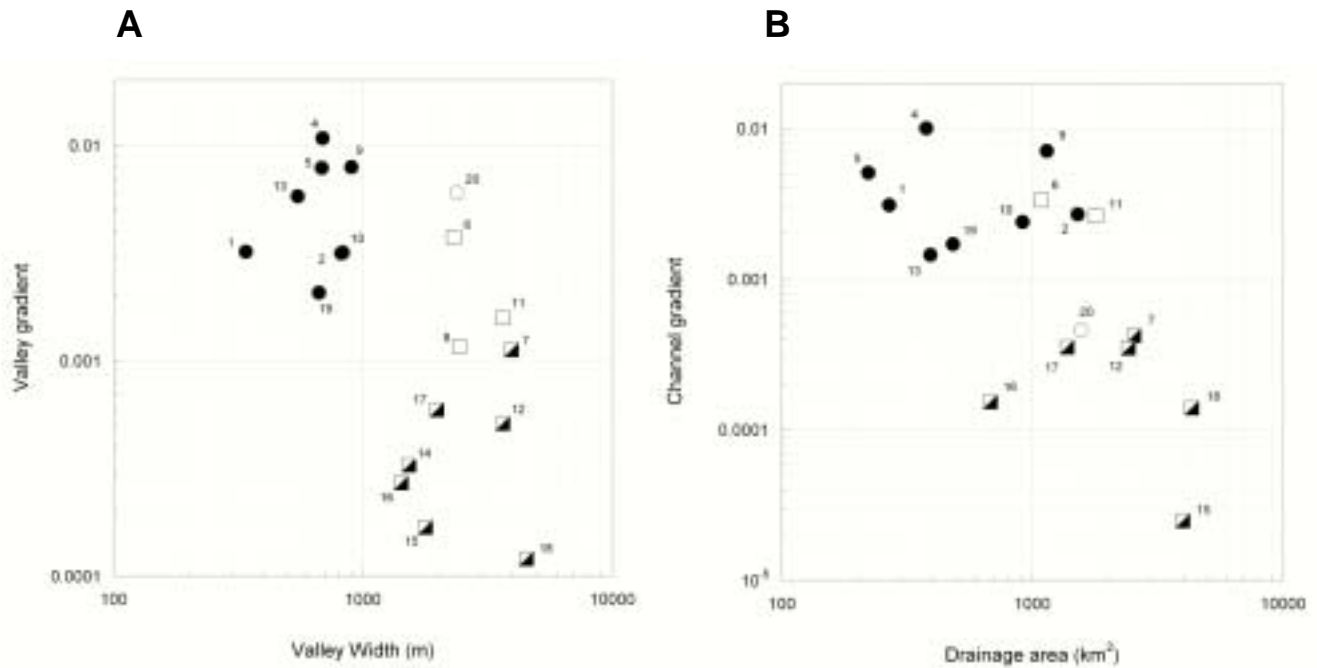


Figure 2. (A) Valley width and valley gradient (measured along the valley centerline) in valleys formed by Pleistocene subglacial fluvial erosion (black/white square symbols) and in valleys formed by post-glacial fluvial incision (solid circle symbols). White squares are segments of Pleistocene glacial valleys dominated by large alluvial fans. (B) Drainage area and historical channel gradient (measured along channel centerlines from reconstructed historical channel locations); valley type symbols are as in panel A. Numbers correspond to the following river valleys: 1) Deschutes; 2) Nisqually; 4) Carbon; 5) South Prairie Cr.; 6) Upper Puyallup; 7) Lower Puyallup; 8) Stuck; 9) White; **10) Green; 11) White (fan reach); 12) Lower White;** 13) Cedar; **14) Black; 15) Duwamish;** 16) Sammamish; 17) Snoqualmie; 18) Snohomish; 19) SF Stillaguamish; 20) Stillaguamish.

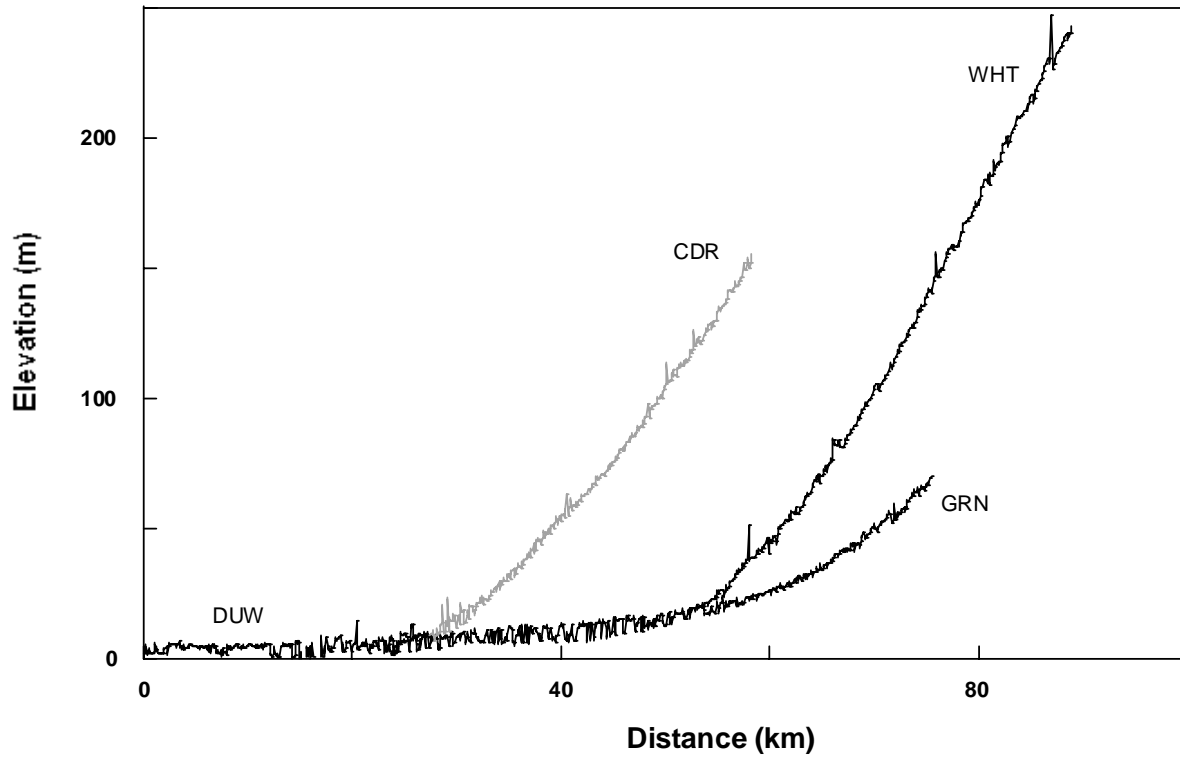


Figure 3. Longitudinal profile of the historical Duwamish, Green, White, and Cedar rivers. Spikes in the profiles are artifacts; elevations are along the historical courses of each river, but use modern elevations (from lidar).

Methods

Mapping Sources

Plat maps and field notes of the General Land Office survey are the primary source for mapping historical conditions (Table 1). Topographic sheets (“T-sheets”), plane table surveyed by the US Coast & Geodetic Survey (USC&GS), depict the lower Duwamish valley and Elliott Bay and the shoreline of Lake Washington (Table 1). The earliest US Geological Survey (USGS) topographic maps, at a scale of 1:125,000, supplemented the public land survey and Coast Survey records. We used 1:12,000-scale black-and-white 1940 aerial photographs, useful particularly for showing traces of former channels and remnant areas of historical wetlands. We also used USGS topographic maps, soils surveys, and the digital National Wetlands Inventory (NWI) as supplemental information for mapping and characterizing wetlands. We georeferenced (maps) or orthorectified (aerial photos) images and brought them into a GIS. We also made use of high-resolution digital elevation models (DEMs) from lidar (light detection and ranging) imagery, for the lower few river miles of the study area. The high-resolution topography showed topography and relict channels, although much of the area presently covered by lidar is highly developed. For more information on these sources and how we use them to interpret historical environments, see Collins et al. (2003).

Channel Mapping

The GLO surveyors generally “meandered” (field surveyed, using bearings and distances along the channel edge) channels shown as polygons on the plat maps (see White, 1991 for

detail); in this report we refer to these as “large channels.” Because they were field meandered, we generally considered these channels reliably mapped. Sometimes it was necessary to locally modify mapping to account for topography (e.g. where a channel is mapped on a valley wall, and is clearly in error). For channels along the south shore of Lake Washington we made use of the more refined US Coast & Geodetic Survey mapping (Table 1).

The GLO mapping of smaller channels—those shown on the plat maps as lines—typically is reliable only near section lines, because the surveyors did not meander these streams, only noting and measuring them where section lines intersected them. Early topographic maps are imprecise and show only the larger channels because of the small scale of the mapping. Because both of these early map sources either incompletely or inaccurately depict small channels, to map smaller channels, we made heavy use of the 1940 aerial photos, which show traces of relict stream channels. Our use of relict channels on aerial photos to locate historical channels creates the potential for interpretation error, as well as the potential that we are mapping channels that are older (or younger) than the time for which we are interpreting conditions. The GLO field notes are a unique source of small channel widths, field measured and recorded to the nearest half link ($1/2$ link = 10 cm). We used these field-measured channel widths to estimate widths of small channels in our GIS mapping.

Land Cover Mapping

Within the estuary of the Duwamish River and embayments along Elliott Bay, the USC&GS T-sheets were the primary source for land cover, supplemented by GLO field notes. Elsewhere, the GLO plat maps are the primary source for wetland mapping, forest openings (termed “prairies”

in the GLO notes), and forests. Similar to their treatment of small channels, the GLO survey generally noted and mapped wetlands only where encountered along a section line. In a few cases we could use the earliest USGS topographic maps to extend wetland boundaries between section lines, or to map wetlands entirely within section interiors, and USC&GS mapping was useful supplement to wetland mapping near the south Lake Washington shore. However, the topographic maps are limited in usefulness because they were made after many wetlands were drained, and because they were made at a coarse scale and don't show all wetlands. We supplemented these map sources in a few cases by using wetlands identified on 1940 aerial photographs, and by using NWI wetland mapping, the extent of organic soils shown on soils maps, and wetlands mapped on recent topographic maps (Table 1).

We assigned wetlands one of three general levels of certainty, or levels of evidence, to all wetlands we mapped. We assign a "high" relative level to those wetlands for which there is direct archival evidence, either from the USC&GS T-sheets, GLO plat maps, or 1895 USGS topographic maps or combination of these sources. Wetlands are assigned an intermediate level if they aren't shown on archival materials, but on more recent National Wetland Inventory (NWI) maps or recent USGS topographic maps, and they are either adjacent to a wetland mapped by the GLO or USC&GS, or there is equivocal evidence for them in the GLO field notes. We consider a mapped wetland to have a relatively low level of evidence if we mapped it solely on the basis of modern map information.

To characterize the historical seasonal inundation of wetlands, we rely primarily on observations of water depth in the GLO field notes. In cases where the notes provide sufficient information, we can determine the extent and seasonality of a wetland's inundation. However,

surveyors working in the Duwamish and Green River area seldom made quantitative observations, unlike the practice of surveyors in river valleys of the north Sound (Collins and Sheikh 2003).

In mapping in northern Puget Sound (e.g. see Collins and Sheikh 2003), hydric soil information associated with recent soils mapping was helpful in mapping wetlands, but older soils mapping available for the Duwamish and Green river areas was not helpful except for showing areas of organic soil. We have also found early aerial photos to be more useful in other, less-heavily developed areas than in the lower White River valley. For these reasons, many wetlands mapped in the Duwamish and Green valleys have relatively crude boundaries (e.g., relatively unmodified from the boundaries shown on the GLO maps).

We have not distinguished differences in forest communities other than identifying forests by geomorphic location (i.e., on floodplains, terraces, or fans, and whether immediately streamside or not). For the present purpose, we concentrated on characterizing the nature of wood that would have been recruitable to rivers. We used bearing trees from the GLO field notes to characterize the diameter, species frequency, and basal area of forest trees (basal area is the tree's cross sectional area, calculated using the tree's diameter at breast height measured by the land surveyors); see Collins et al. (2003) and Collins and Sheikh (2003) for explanation. We also gathered information on fluvial wood from Annual Reports of the Army Engineers (U. S. War Department, 1880-1910) and other accounts (e.g. Hilbert et al. 2001).

The plat maps and field notes include open patches in the forest cover, which federal surveyors generally referred to as "prairies." Because patches are generally small (generally between 2 and 25 hectares) relative to the square-mile grid used in the public land survey, the

GLO survey would have missed many of them and so the map shows only a fraction of the prairies. There is no description of these prairies in the field notes; it is possible that many of the forest openings were created and maintained with fire by indigenous populations as demonstrated in other Pacific Northwest environments (e.g., see Boyd 1999).

Table 1 (continued on following page). Map and photo sources used in interpreting historical conditions in the study area.

YEAR	SOURCE	PRIMARY USES	NOTES
1855-1856	“Plan of Seattle, 1855-6, Showing the position occupied by the Decatur’s Crew, Jany 26, together with the line of barricades erected and roads constructed,” revised edition 1930	Detail on lagoon and tidal marsh in present day location of Pioneer Square	Streets drawn on original map in 1930 revision makes it possible to approximately georeference.
1856 (T25N R3E) 1861 (T24N R4E) 1862 (T23N R4E, T24N R4E) 1863 (T22N R4E) 1865 (T23N R5E) 1867 (T22N R5E, T21N R5E) 1868 (T21N R4E) 1882 (T21N R6E)	General Land Office plat maps and field notes	Channel and land cover mapping; description of land cover, hydrology and land character	Primary source for river valleys. Maps strongest for navigable (meandered) channels. Creeks and land cover reliable near section lines only. Field notes invaluable source of descriptive information.
1867	USC&GS T-1064 “Map of Shilshole Bay, Admiralty Inlet, Washington Territory” 1:10,000	Shoreline and nearshore channels and wetlands in Elliott Bay and the Duwamish estuary	Primary source for estuaries. Tidal creeks drawn on maps on some maps may be schematic only; can only be confirmed as accurate where relict channels are visible on early aerial photos (not possible in Elliott Bay because of early date of filling and building).
1874	USC&GS T-1390b-1 “Sheet No. 1, D’wamish Bay, Washington Territory” 1:10,000		
1875	USC&GS T-1406 “Duwamish Bay (part of), Washington Territory” 1:10,000		
1895	USGS topographic map “Tacoma” 1:125,000 USGS topographic map “Snohomish” 1:125,000	Channel and land cover mapping	Imprecise because of small scale of mapping. However, useful supplement to GLO for historical wetlands because GLO wetlands generally mapped only along section lines.

Table 1 (continued). Map and photo sources used in interpreting historical conditions in the study area.

YEAR	SOURCE	PRIMARY USES	NOTES
1899	USC&GS T-2421 “Topographic resurvey of Seattle Bay and City, Washington, City Front and Head of Bay” 1:10,000	Shoreline and nearshore channels and wetlands in Elliott Bay and the Duwamish estuary	
	USC&GS T-2422 “Topographic resurvey of Seattle Bay and City, Washington, Shilshole Bay to Alki Point” 1:10,000		
1902	USC&GS topographic sheet T-2609 “Lake Washington, Southern Sheet, Washington” 1:10,000	Used for shoreline and nearshore channels and wetlands along south end of Lake Washington	T-sheets, created by plane table survey, are generally very accurate and detailed, mapped at 1:10,00 scale. Limited to nearshore areas.
1907	US Army Corps of Engineers “Duwamish-Puyallup Surveys, 1907” 1:4,800	Land cover notations and 1906 flood notations useful for mapping land cover and geomorphic surfaces.	Map has detailed notations and measurements on depths, speeds and directions of water flowing on the floodplain from November 1906 flood.
1940	1:12,000-scale black-and-white aerial photographs	Relict channels; wetland remnants	Critical supplement to GLO for small channels, because small channels on GLO plat maps are unreliable except where crossed by section line.
1973	USDA SCS Soil Survey, King County WA	Soils indicating historical wetlands	Soil survey is out of date and lacks information on hydric soils. In Green River study area primary use is incidence of organic soils.
1990s	USGS 1:24,000 scale topographic mapping	Wetlands	Supplementary information used in a few cases to map wetlands with a low certainty.
	National Wetland Inventory (NWI)	Wetlands	Supplementary information used primarily to extend wetland boundaries a few cases to map historical wetlands with a low certainty.

Elliott Bay Shoreline

Elliott Bay exclusive of the Duwamish included three tidal marsh complexes: West Point, Smith Cove, and in the present-day Occidental Square area of Seattle (Figure 4). The Smith Cove area (Figure 4B) was the largest of the three. (In this report, the term “tidal marsh” is used inclusive of estuarine wetlands and riverine tidal, or tidal freshwater, marshes). According to T-1390b-1 (1874), the cove was protected at the mouth by a sand spit (2.4 hectares) attached to Magnolia Bluff, with a linear strand of saltmarsh (3.4 hectares) on the spit’s shoreward side. The northern, innermost part of the cove (in present-day Interbay Neighborhood) was a salt marsh (18.9 hectares including channel area) fed by a single large tidal channel network. The tidal network entered on the western side of the cove, and the marsh was bounded by a grassy sand accumulation (5.5 hectares) on its south side. Snohomish resident and newspaper publisher Eldridge Morse, writing in 1885, indicated that

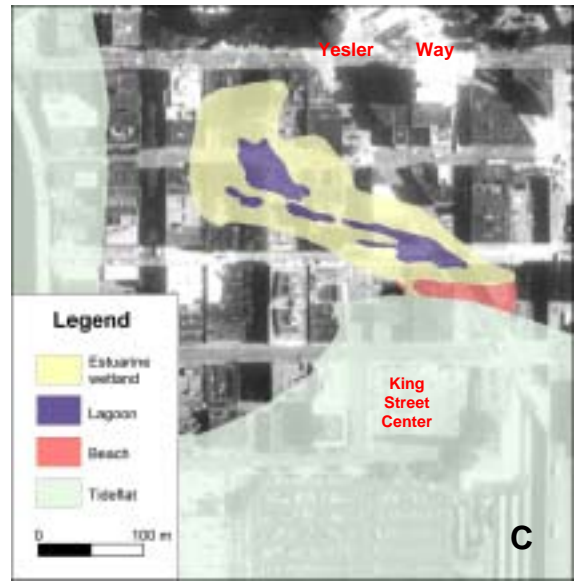
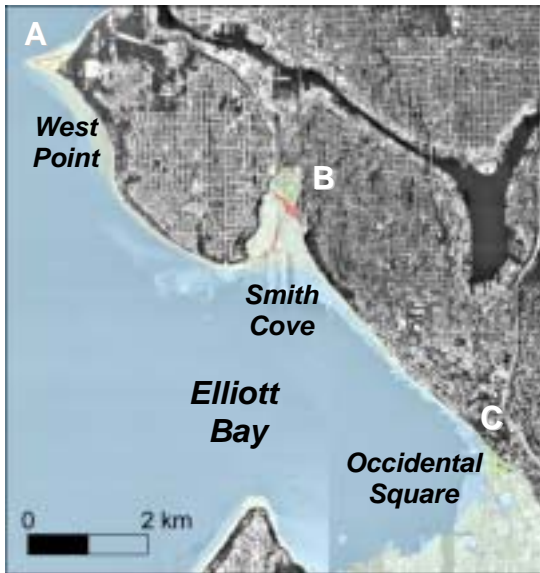
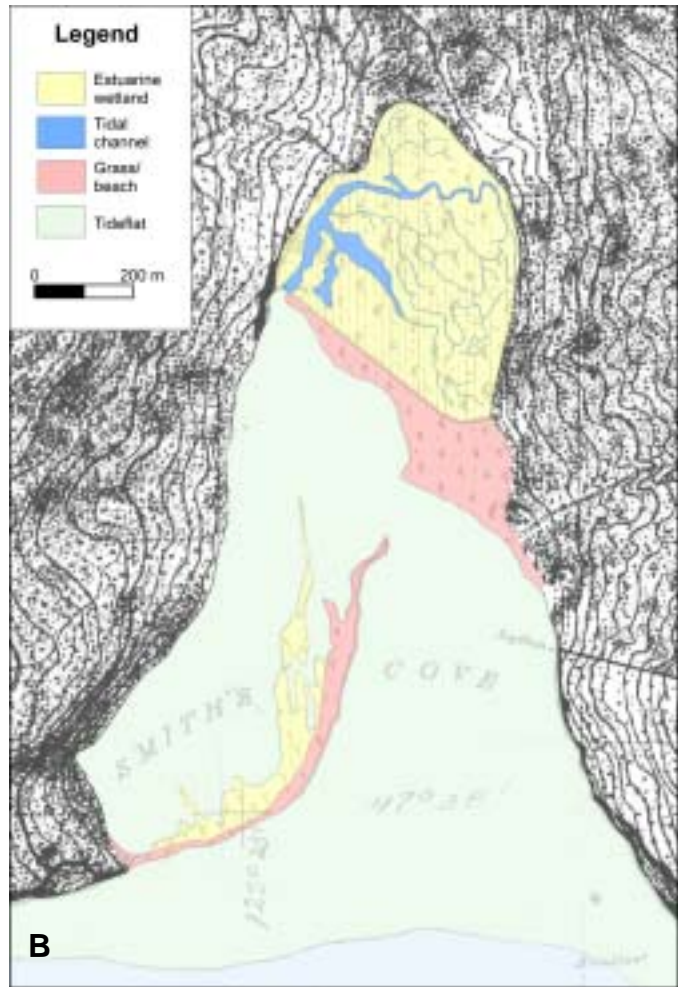
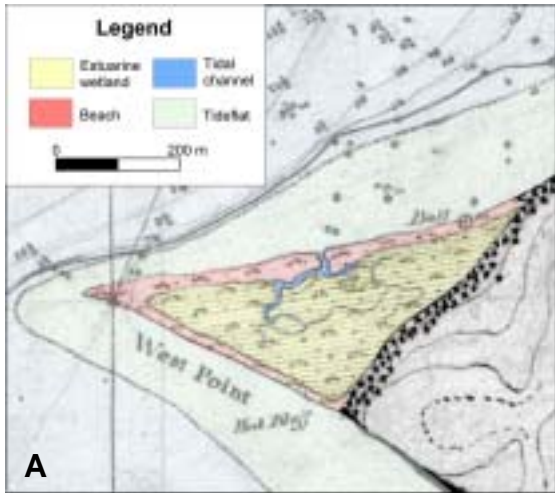
“...all the tide marsh [in Smith Cove] was diked in 1877. In front of the marsh is a sand spit across the head of the cove. The sand blown up on the edge of the marsh was used to build the dike, which was supported on the inside by cedar lagging driven into the marsh” (Nesbit 1885).

However, the Smith Cove saltmarsh and sand spit appears the same on T-2422 (1899) as on T-1390b-1 (surveyed 25 years earlier in 1874), except for the railroad trestles shown on T-2422; possibly the early diking Morse described was ineffective. Mapping a decade later (Mangum et al. 1909) shows more development in the outer cove, but none in the marsh area.

The shoreline south from Smith Cove is shown as a bluff or bank on T-1390b-1 (1874) and T-1406 (1875) up to the area of the early settlement of Seattle in the Pioneer Square area, where the shoreline had been modified and docks built by that time. The area of the Occidental Square area lagoon-marsh complex (Figure 4C) had already been filled and streets platted by the 1875 T-1406 map, and the only map record we are aware of is from the sketch map made for military purposes in 1855-1856 during the Battle of Seattle (see Table 1). The map was revised in 1930 to show streets then present, which made it possible to crudely georeference the map. A sand barrier (0.2 hectares) with a central opening for tidal flow bounds the complex (2.6 hectares, 2.1 hectares of which was mapped as marsh and the rest lagoon) at its opening to Elliott Bay (Figure 4C). Most of the complex is labeled “tide marsh” and shows several isolated lagoons.

West Point, a cusped foreland that was bounded by a beach barrier, included a marsh (6.8 hectares including channel area) completely bounded by the barrier (2.4 hectares) except for a single channel network that opened on the north side of the point (Figure 4A). The western one-third of the West Point marsh had been diked and drained by the 1899 T-2422, and Mangum et al.’s (1909) map shows no marsh on West Point. Collins and Sheikh (2005) places these three tidal marshes, and the Duwamish River estuary, into the context of all tidal marshes in the Puget Sound region.

Figure 4 (following page). Tidal wetlands on Elliott Bay exclusive of the Duwamish River estuary (see overview map in bottom left hand corner). (A) West Point, from USC&GS T-1064 (1867). (B) Smith Cove, from USC&GS T-1390b-1 (1874). (C) Tidal lagoon-wetland system in Occidental Square area of Seattle, from Plan of Seattle (1855-1856, revised 1930). For location reference, historical mapping is superimposed onto 2000 USGS orthophotos. King County Center building is approximately 60 m south of lagoon inlet (in area shown on photo as parking lot). The street intersection approximately 50 m to the northwest is Yesler Way and First Ave; Pioneer Square is about 50 m NNW of the northwest corner of the wetland-lagoon complex.



Duwamish River Valley

Topography and the Channel Network

The valley bottom morphology and landforms, and historical land cover and habitats, differed in the lower part of the Duwamish River valley from the upper part. In the upper Duwamish, the riverbanks are (and were) 3 to 4 m higher than the lowest point on the floodplain (Figure 5A and 5B). An early Army Engineers surveyor noted the upper valley's topography on an inspection of the White and Duwamish rivers in 1897:

“...[the land near the Duwamish River] is usually higher than that near the foot of the flanking hills, but the difference in elevation is but slight compared with that along White River [see earlier portion of this quote later in this report]. The area of cultivated land is less in proportion to the area of the valley [compared to the lower White River], and the area of the waste and swampy land is greater.” (Ober 1898).

The elevation of the riverbanks above the floodplain indicates that this portion of the river has been aggrading in the several hundred years since the valley was last inundated by a Mt. Rainier lahar. Depressional wetlands formed in these topographic lows.

In contrast, the river banks of the lower Duwamish River valley is lower in elevation than the rest of the valley bottom, which includes at least one terrace level (Figures 5C and 5D). We have mapped the terrace on the basis of five lines of evidence. The first is that the large surface that broadly includes the neighborhood of Georgetown on the river's right bank (see Figure 6 for modern geography) is 2 to 3 meters higher in elevation than the riverbanks (Figures 5C and 5D).

The second line of evidence is that mapping of floodwaters by the Army Engineers during the record flood of 1906 (likely to remain the largest flood of record, because the drainage basin of the Duwamish is now less than one-third the area it was in 1906, and much of the remaining area is regulated by dams) showed the area we have mapped as a terrace was not inundated, while elsewhere in the Duwamish flood depths were as great as 15 feet over the floodplain (Figure 7). The Army Flood mapping also indicates a symbol that appears to mark an escarpment, along the west side of higher-elevation area; the apparent escarpment is coincident with the boundary between forest vegetation and marshland shown on USC&GS T-1406. The boundary shown between the forest and estuarine vegetation by the Coast Survey cartographers is a third line of evidence for mapping a river terrace.

The fourth line of evidence is soils and vegetation data contained in the General Land Office field notes. The line description between S. 19 and S. 20, T24N R4E (the section line coincides with 1st Ave S. northward from its intersection with E. Marginal Way roughly to the northern end of the Federal Building South) reads, “Land high dry level bottom. Soil sandy, [emphasis added] good 2 rate. Timber-fir & cedar. Undg’th sallal and fern.” Walking along the line between S. 28 and S. 29, T24N R4E, which traverses both sides of the river valley, the surveyors contrasted the land on the two sides of the river: “Land on W. side of Dawamish River [currently the Boeing Co. buildings to the SW of Boeing Field; historically the Duwamish River snaked along what is now Boeing Field], in places low and liable to inundation 30 or 40 ins, but the E. side [currently the north end of Boeing Field] high, dry sandy bottom [emphasis added].” Fir was the dominant bearing tree (see later in report, Figure 24) in the area, consistent with the dry soil conditions described. Finally, the fifth line of evidence is the indigenous place name for the land on the north side of the river within S. 20, T24N R4E, in the present day vicinity of S. Lucile St. and 6th

Ave. S. “tcE’btEbid” was translated by T. T. Waterman as “fir trees on the ground,” and “natives went there to get dry bark for fuel” (Hilbert et al. 2001).

Several meters of vertical movement on the Seattle Fault 1.1 kaBP (Bucknam et al. 1992) may have created the terrace (or series of terraces; see Figures 5C and 5D) in the lower Duwamish River valley. The surface of the terraces is black sand from a Mt. Rainier lahar from 1.2 kaBP, which prograded the shoreline of the Duwamish River from roughly the location of South Park to near the mid-19th century shoreline. The black sand is consistent with the GLO surveyor’s observing sandy soils. The lower Duwamish valley has thus been in a degradational setting in the late Holocene—downcutting and creating a terrace or set of terraces—in contrast to the aggradational setting of the upper valley, where the river is building up above the floodplain.

Wetlands in the Duwamish Valley

The extent of historical tideflat shown in Figure 8 was taken from USC&GS T- 1406 (in this report we use “tideflat” to refer to tidal mudflats seaward of tidal marsh). In general the Coast Survey’s topographic sheets generalize the line of mean lower low water, which hydrographic sheets (H-sheets) show with more detail. The historical extent of tideflats is roughly coincident with the outer limit of artificial fill and development in the last century and a half (Figure 8).

The extent of tidal marshes of the Duwamish River estuary was relatively small (approximately 170 hectares), considering the river’s size, because the recent river terraces narrowed the floodplain, to about 700 m at its narrowest point at Kellogg Island, which is also roughly the upriver extent of estuarine marsh. Most estuarine marsh existed on two large islands (Kellogg Island is the upstream-corner remnant of the larger, 65 hectare island), a few smaller

islands, and a smaller amount of estuarine marsh on the north shore of the river (Figure 8). The USC&GS T-sheets do not show tidal channels in the Duwamish estuarine marsh, and any relict evidence of them would have disappeared by the time of the earliest aerial photographs in 1940; this lack of information is reflected in Figure 8.

A similar amount (approximately 170 hectares) of tidal marsh was probably dominantly freshwater, and extended upstream in two lobes, one to South Park, roughly even with Slip Number 4 waterway (a remnant of the historical, meandering Duwamish River), and the other within a bend of the Duwamish River, to eastward of the intersection of West Marginal Way and Highway 99 (Figure 6). We mapped these wetlands along the river as riverine-tidal wetland, rather than estuarine. (Riverine-tidal wetlands are freshwater wetlands inundated in part by the tidal influence on river levels.) We mapped as emergent marsh (marsh having non-woody vegetation) those areas noted by the land survey as “prairie” or “tidal prairie,” and scrub-shrub marsh (marsh containing woody vegetation that is less than 6 m tall) those areas noted as “crabapple thicket” or “willow and crabapple thicket;” see Appendix 1 for detail.

We mapped about 200 hectares of freshwater marsh in depressional wetlands on the Duwamish floodplain (Figure 8). A great deal of water would have been funneled during flood from the watershed through the relatively narrow Duwamish valley. The Army Engineers during the 1906 flood mapped the floodplain as having up to 4.6 m (15 ft) of standing water, including a depth of 1.1 m (3.5 ft) above the levee top. Because most of the upper valley was lower than the riverbanks, it is likely that these wetlands would have had standing water from floods for long periods of the year.

Most of these floodplain depressional areas were symbolized as wetland by the Land Office surveyors, and simply described as “swamp” and in one case “cranberry marsh” (see Appendix 1). We mapped a few areas not intersected by section lines (and so not visited by the Land Office surveyors) as wetland because they were shown as wetland on the 1:125,000-scale 1895 USGS topographic map (Table 1) or because of descriptions on the Army Corps 1907 flood map (e.g., “low marshy ground;” “low and marshy”).

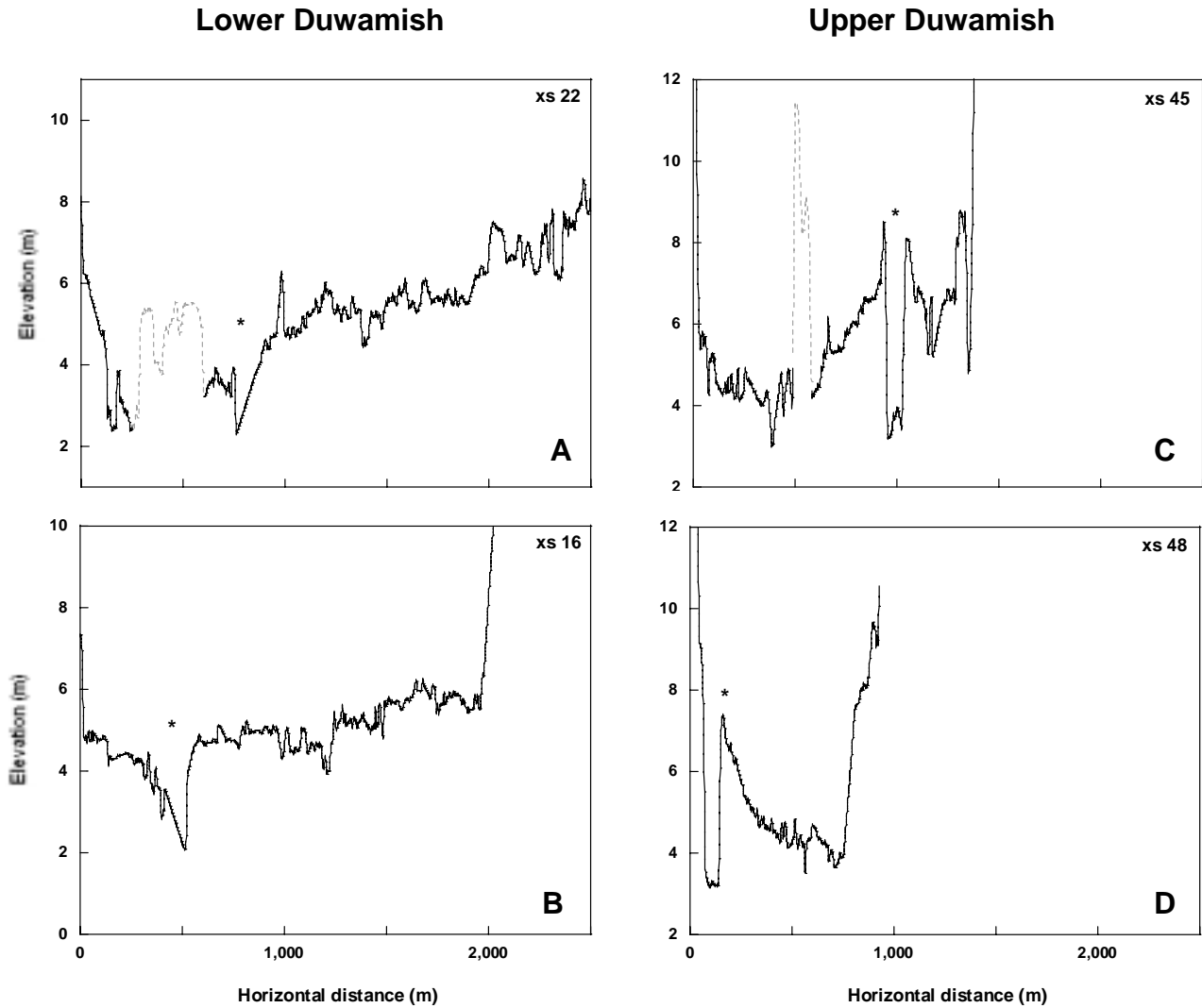


Figure 5. Valley cross sections in the upper and lower Duwamish River valley, generated from lidar DEM; see Figure 6 for locations. Stars indicate Duwamish River channel. Each cross section has a 10-m vertical axis, and a vertical exaggeration of 200x. (A) and (B) The gray-dashed portion of panel A corresponds to built up area of Highway 509 and Highway 99. In both cross sections, historically the left valley side included a tidal wetland (now South Park), and the right side was a forested terrace (now Georgetown neighborhood). (C) The gray-dashes indicate area built up for Highway 599. (D) Cross section is through neighborhood of Allentown.

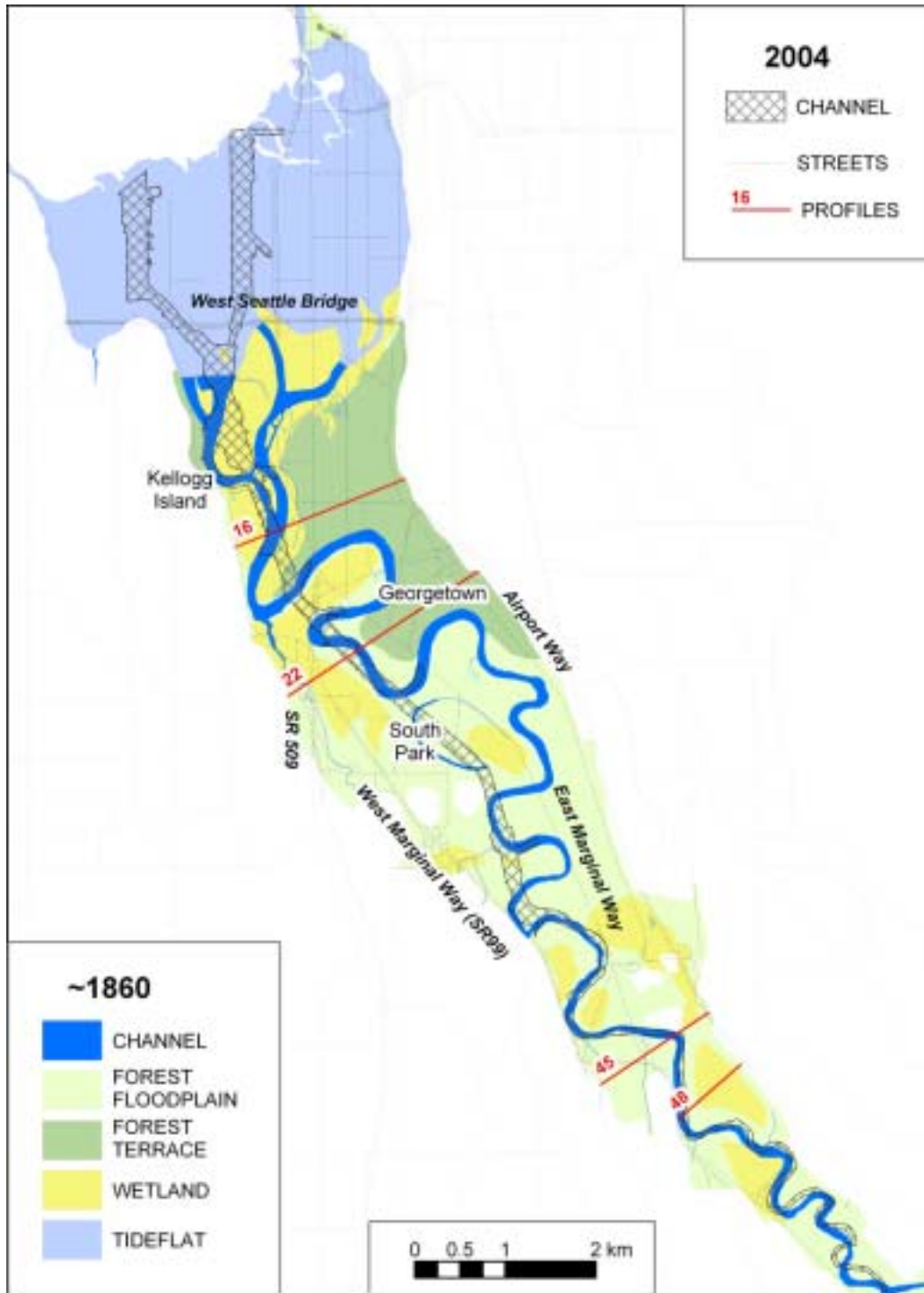


Figure 6. Modern cultural features overprinted on historical land cover and channels in the Duwamish River valley. Representative profiles from lidar DEM shown in Figure 5.

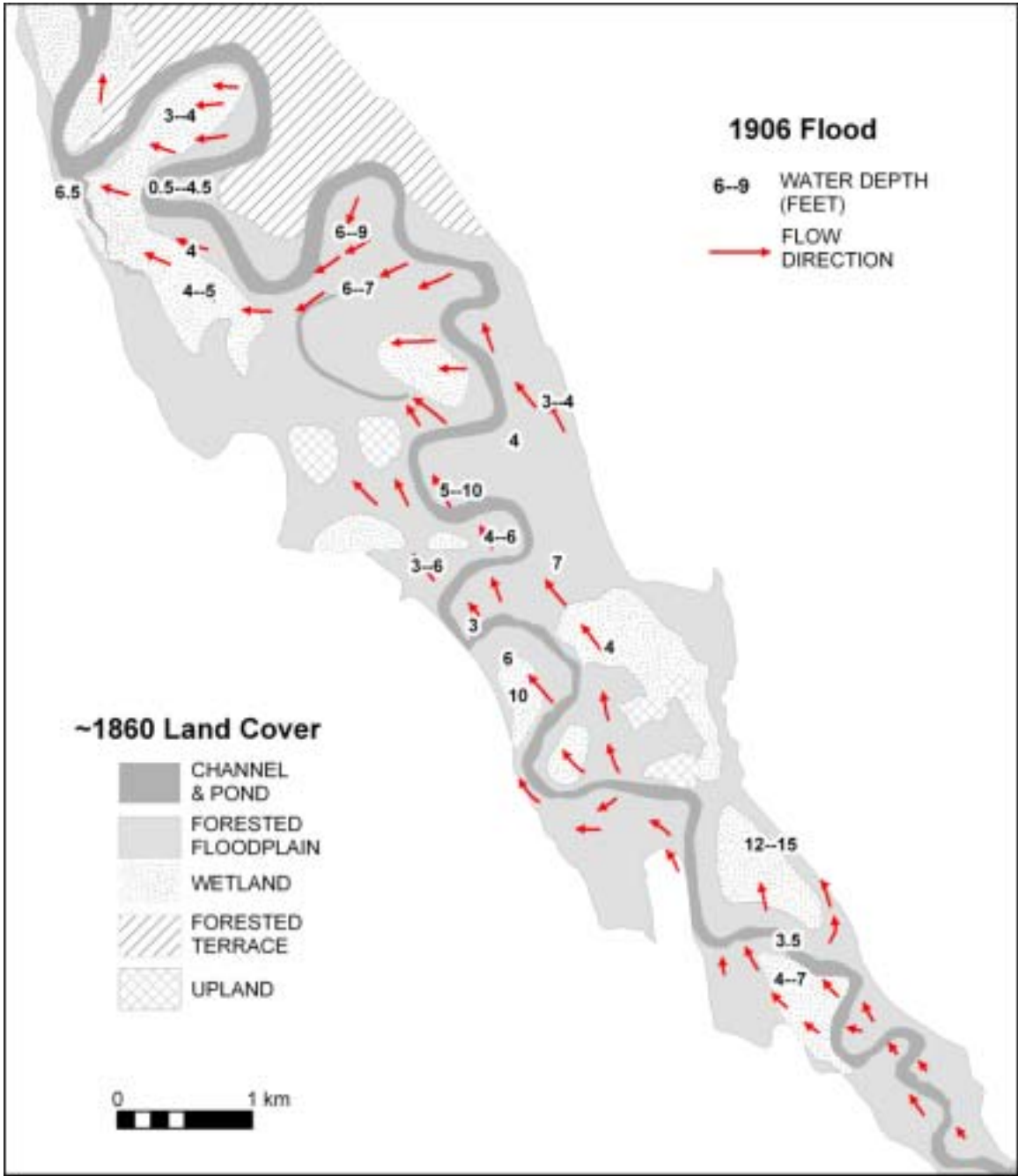


Figure 7. Field observations of the 1906 flood in the Duwamish River valley, from ACOE (1907). Arrows showing direction of flood flow over the floodplain have been generalized. Point depths of floodplain water are in feet. Depth of 3.5 ft in upstream part of valley was the depth over the levee top.

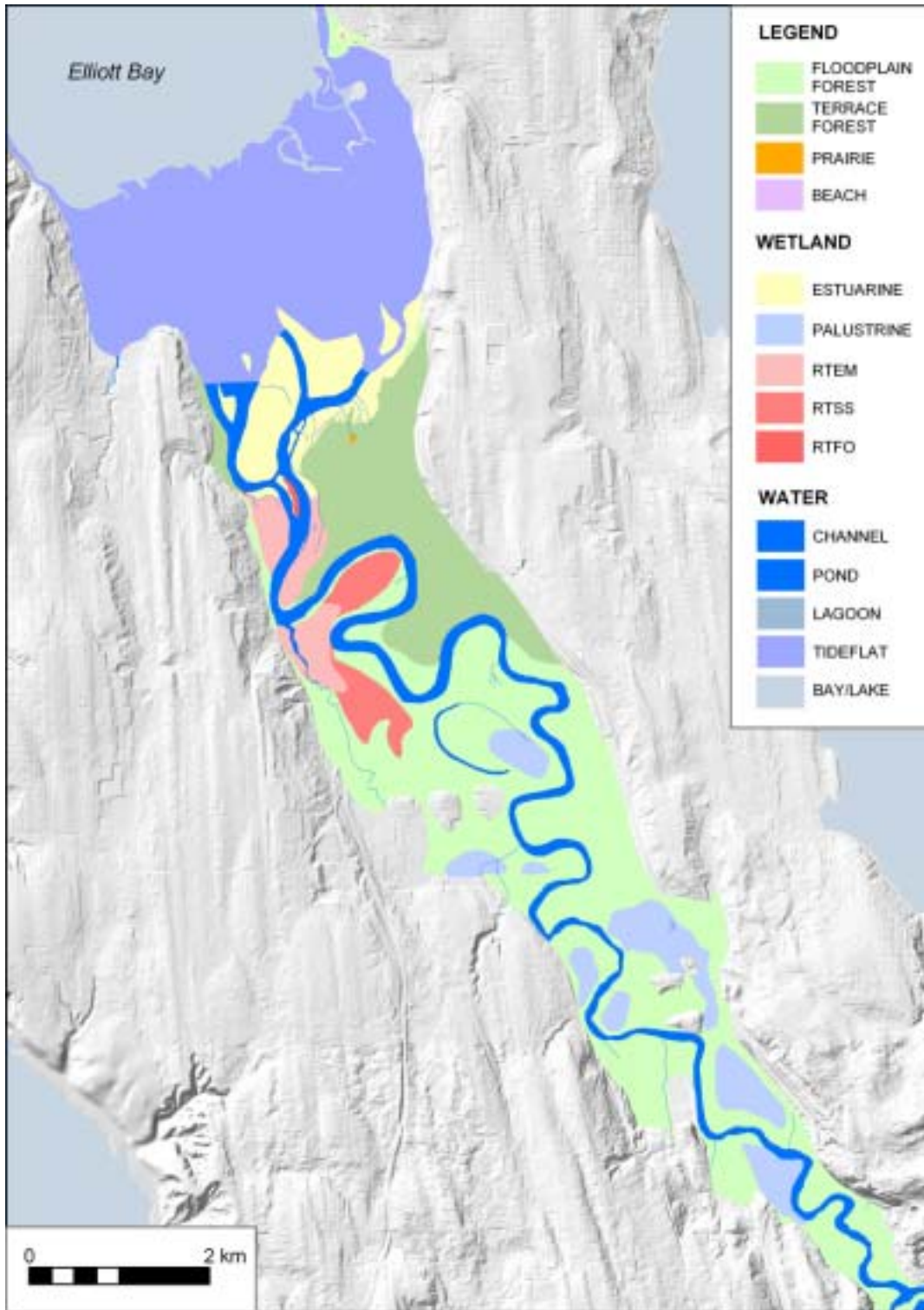


Figure 8. Historical landscape conditions, ~1865, in the Duwamish River valley. RTEM: Riverine-tidal emergent; RTSS: riverine-tidal scrub-shrub; RTFO: riverine-tidal forested.

Lower White & Black River Valleys

Topography and the Channel Network

The valley topography in the Lower White River valley is influenced largely by the legacy of Pleistocene glacial erosion and post-glacial (Holocene) fluvial sedimentation patterns. Panels A through G in Figure 10, which show profiles across the valley, indicate that the riverbanks are about 2-4 m higher in elevation than the valley bottom. This cross-valley topographic pattern is similar to that in the Duwamish and other valleys formed by Pleistocene glaciation [e.g. the Snoqualmie, Snohomish, and lower Nooksack valleys; Collins et al. (2003)]. It is presumed to result from the deposition of natural levees and the gradual deposition of sediments in the riverbed in the low-gradient valley. Early Army engineering surveyors observed the topography and commented on its causes in the lower White River valley in 1898:

“Successive freshets by depositing the sediment, which is carried by the current in discontinuous suspension, have, in the course of ages, built up the banks of the river and the area adjacent to a considerable height above the general level of the valley. This superelevation ranges from 3 to 8 feet. The low ground is generally found near the foot of the flanking hills...” (Ober, 1898).

The channel of the lower White River had (and has) a meandering pattern, and a narrow meander belt. Wetlands formed historically in low-elevation parts of the valley outside of the meander belt (see below); in both respects the lower White River was similar to other Pleistocene valleys in the region (Collins et al. 2003).

However, because the lower White River is a north-south trending valley with three major east-west flowing rivers that deposit their sediment into it, the resulting patterns of Holocene sediment deposition by these tributaries also strongly influenced the topography and drainage network. The profiles in Figure 10 illustrate the importance of these tributary drainages in shaping the valley bottom of the lower White River. Starting at the upper (south) end of the valley, Figures 10I through 10K show how very strong east-to-west cross-valley gradient (a land gradient of approximately 1m: 200m or 0.005) created by the White River Fan. Topographic effects of the White River fan dominate the form of the channel network for about one-third of the White River valley (measured from the King County line to the north end of the valley; Figure 9). The elevation difference from the White River Fan from its head to the historical marshes in the Mill Creek area is substantial—about 24 m. Floodwaters from the upper White River would have diverged and flowed down the fan, in a number of shifting and ephemeral flood channels to the southwest and south to the Stuck River drainage (Figure 11). Other channels drained to the northwest and west to Mill Creek, which drained the marsh-filled lower elevation western part of the lower White River valley at the western margin of the Auburn fan. The channels drawn in Figure 11 reflect a combination of streams shown on the GLO maps and flood channels evident on the 1940 aerial photographs. Some of the channels mapped from the photographs may have been created more recently than the 1860s. Many of the channels were mapped as discontinuous because it was not possible to trace them on the photographs; in the GIS layers they are coded as “ephemeral” and are not included in channel area estimates (see later in report). The White River Fan also deflects the Green River northward as the Green River emerges from its valley (Figure 9 and Figure 10H).

Downvalley of the White River Fan, the cross-valley topography is dominated by the effects of Holocene deposition within the lower White River's meander belt (Figure 9 and Figure 10A through 10G), with the lower White River elevated several meters above the valley bottom. Between Kent and Auburn, the valley was dominated by a system of wetlands fed by drainages shed by the White River fan, which drained northward (Mill Creek) into the Green River near Kent (Figure 11).

Downstream (north) of Kent, numerous channels on the eastern part of the lower valley flow to the north, caused, at least in part by, and draining, White River floodwaters. The regular, large-amplitude meanders of the main floodplain channel suggest it could have been an abandoned main channel at some time in the late Holocene (but prior to the 1861 land survey). Floodwater mapping from the 1906 flood (Figure 12) shows that during flood the lower White River would spill over its banks and into the floodplain, which funneled floodwaters northward toward the Black River. In other words, because the lower White River was elevated above most of the valley, once the river flooded, its floodwaters then drained into and northward through the largely independent channel network that did not rejoin the lower White River until the north end of the valley, primarily after having first flowed into the Black River (Figure 11). A system of north and northwest flowing channels in the Kent area, evident on the 1940 aerials and on the GLO plat maps, apparently originated from small drainages entering the White River valley from the east, and which may also have been responsible over time for creating the small east-to-west cross-valley gradient in this area (see Figure 10F).

The northward flowing channel network draining the eastern part of the lower valley joins what appear to be historical avulsion channels of the Black River (Figure 13). The 1940 aerials

show a relatively recent channel, 30-90 m wide, flowing southward from the Black River just west of the I-405 and SR 167 junction. This channel appears to have been a distributary of the Black River (a distributary is a branch of a river that flows away from the main channel), rather than a tributary, based on the north to south topographic gradient indicated by the lidar DEM. This apparent paleo-channel of the Black River may have then flowed to the Green River or rejoined the Black to the west, along with the outflow of the northward flowing channel network on the lower, eastern floodplain. This interpretation is consistent with the 1906 flood mapping.

This apparent historic avulsion channel of the Black River reflects the topographic influence of the Cedar River Fan (see Figure 9). The upper Black River is similar to the lower White River in the vicinity of the White River Fan in being deflected, in this case northwestward, to the base of its fan. Topographic constraint of the valley wall to the north then forces the Black River onto the fan, explaining the apparent historic avulsion channel. The Cedar River Fan, which has about 7 m of relief from the fan head to the center of the lower White River valley, had flood channels, evident on the 1940 photos, similar to those mapped on the White River Fan (Figure 11 and Figure 13).

The topographic effect of the Cedar River fan concentrated or funneled the northward flowing floodwaters of the White River system into the Black River. The extensive valley depression accounted for most of the valley width in the lower White River valley (see Figures 10 B and 10 C), and is evident today in the remnants of wetlands that historically formed in the area (Figure 11). However, to the north, while the valley sloped down and east from the lower White River, it also flowed down and west on the Cedar River fan (Figure 10A) funneling flow into the Black River in the area of the present-day Springbrook Creek ditch.

Flooding must have been very frequent in the lower White River valley. Evidence for this includes the dense network of flood channels shed from the three fans described above, mapped in Figure 11. While the river was not gauged prior to 1937, historical photographs provide an indication of the frequency of flooding in the valley. Images of the town of Kent under floodwaters appear in a number of years. For example, an Internet search found photos of nine years in which the town of Kent was under enough floodwater to warrant photographic documentation, in the forty-year period between 1906 and 1946 (Figure 14). This entire period (1906-1946) is *after* the entire flow of the White River had been diverted to the Puyallup River to the south, so flooding would have been even greater before the photographic record.

The field-mapped floodwaters from the 1906 flood (Figure 12) reiterate and confirm elements of the preceding discussion of the topographic influences on channel networks. Figure 12 shows: (1) Flow patterns of Cedar River floodwaters show how the Cedar's position on a fan caused water to diverge to the north (to Lake Washington and its nearshore wetlands) and to the southwest; (2) The floodwaters that diverged to the southwest flowed down the fan, consistent with ephemeral flood channels mapped from the aerial photos, and toward a confluence with floodwaters coming from the south, in the Springbrook Creek complex; (3) Floodwater poured out of the White River channel and into the Springbrook Creek drainage complex, all along the White River's course from Kent to within a few kilometers of the Black-White confluence. Both the White and Cedar funneled much of their flood flow through this Springbrook Creek drainage complex, back into the Black River, and then into the Duwamish valley. The flood-flow map also substantiates floodwater from the White River as a mechanism for recharging the floodplain wetlands of the lower White River. For example, the flood flow was mapped into the wetland in

the present-day Southcenter area and into a few additional wetlands farther up-valley (Figure 12).

Wetlands in the Lower White River Valley

Detail on individual historical wetlands can be found in Appendix 1. Mapped historical wetlands in the lower White River valley can be grouped into five broad areas having similar topographic and hydrographic settings (Figure 11). Working generally north to south, these groupings are:

A. *Wetlands associated with south shore of Lake Washington (BLK230501)*. Wetlands on the south fringe of Lake Washington and surrounding the Black River as it exits Lake Washington are shown on several early map sources, the most detailed being a US Coast & Geodetic Survey 1:10,000 scale sheet (Figure 15). Based primarily on the USC&GS sheet, the wetland is mapped as about 118 hectares. The GLO field notes do not describe the wetland's characteristics.

B. *Wetlands on west side of lower White River in the downstream half of the valley*. These wetlands are presumed to form largely from their location in low-elevation areas marginal to the elevated meander belt. Larger individual wetlands in this grouping include the Southcenter Mall area wetland WHT_LOW230406 [in Lushootseed, wetland was called “besx^wuqid,” or “where there are cranes” (Hilbert et al. 2001)] about 159 hectares (Figure 16), and wetland WHT_LOW220401, about 109 hectares (Figure 17). WHT_LOW230406 is shown on 1895 USGS Tacoma 1:125,000 scale topographic map, along with an oxbow pond (Figure 16). The 1940 photos, after the wetland has been drained, show a relict central channel in the former wetland that appears to be an abandoned mainstem channel. WHT_LOW220401, unique among

wetlands in the area, is symbolized on the GLO plat map with numerous springs (Figure 17) and is described in the notes as a “cranberry marsh;” in Lushootseed, “Pa’IEqw,” for “marsh, spring” (Hilbert et al. 2001).

C. Wetlands on the east side of the lower White River in the downstream half of the valley.

These wetlands exist in lower-elevation areas marginal to the meander belt. They appear to have been fed by flood channels from the upland to the east, from the Cedar River Fan, avulsion channels from the Black River, and overbank flooding from the White River. Numerous floodplain creeks in the area existed in a complex drainage pattern, including a main channel having large-amplitude meanders suggestive of having been an abandoned main channel. Larger wetlands in this zone include WHT_LOW230502 (121 hectares) and WHT_LOW230504 (31 hectares) at the east margin of the valley in Tukwila, WHT_LOW220404 (54 hectares) north of O’Brien and WHT_LOW220410 (30 hectares) immediately north of the older part of Kent at the valley wall. The boundaries of these wetlands are generally poorly constrained, mapped primarily from the GLO. They are commonly described as “swampy” and as “willow thicket” (see Appendix 1). Our mapping shows the system of creeks that feed and drain this complex draining into the Black River to the east (upstream) of the present day location of Springbrook Creek, which had been ditched prior to the 1940 aerials. The location is based on (a) relict channels discontinuously visible on the 1940 aerials, (b) that the GLO survey did not note a channel crossing the section line between S. 13 and S. 24 in T23NR5E, and (c) Hilbert et al. (2001) in this vicinity show the place name “ct³u’IEgwEli” for “resembling a trail’ for a creek draining a swamp.” Waterman’s Indian informants indicated “they caught lots of salmon trout (‘silver salmon’) in it” and that they “built a little fish weir in the middle course of it” (Hilbert et al. 2001).

D. *Lower Mill Creek wetlands*. The main wetland, WHT_LOW220411, about 443 hectares, was fed by runoff from the White River fan, by tributary drainages, and from upper Mill Creek and its wetlands. It was mapped by the GLO in 1863 and does not appear on the 1895 USGS topographic map. The GLO surveyors described it as “overflowed land” in late March of 1863.

E. *Upper Mill Creek wetlands*. Wetland WHT_LOW210401 (357 hectares), continuous with STK210403 (285 hectares), which drained to the Stuck River, was at the western margin of the valley at the base of the White River Fan. The GLO mapped discrete patches of wetland in this area, but we grouped them into a larger wetland to include the area shown by soils mapping as having organic soils. The area was fed by floodwaters from the White River Fan and tributaries from the west valley side. It was variously described as “swamp” and “cranberry marsh.”

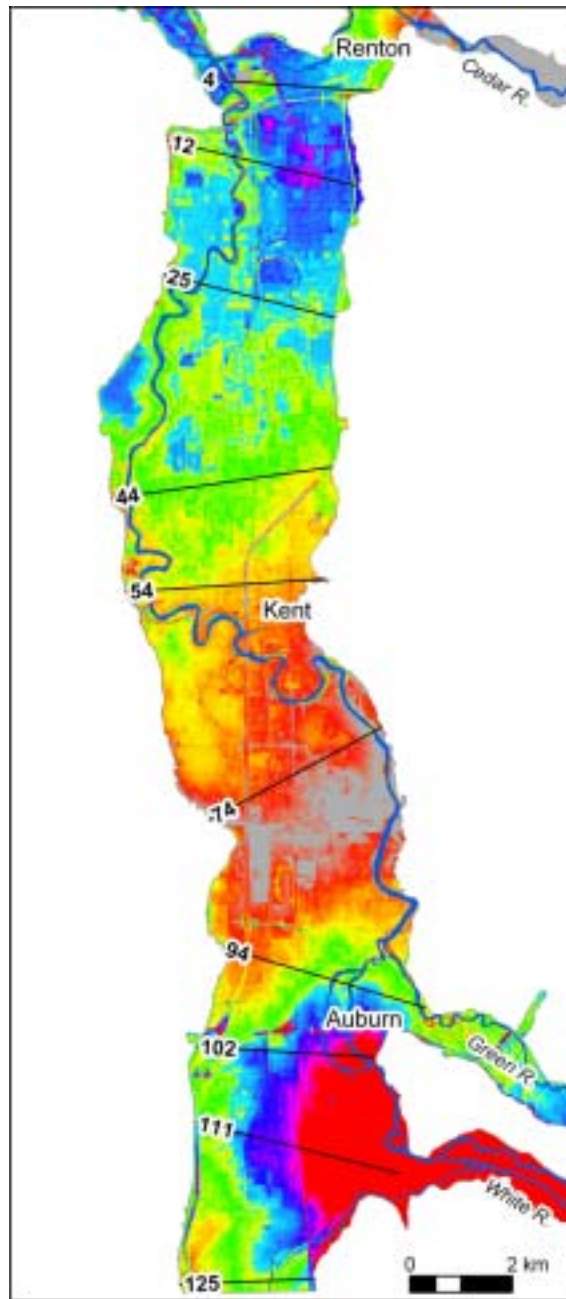


Figure 9. Location of valley profiles shown in Figure 10. Topography shown by lidar DEM. Each color ramp (purple through gray to between profiles 74 and 94, and inverted to gray through purple up-valley from this point) encompasses 14 m of elevation difference.

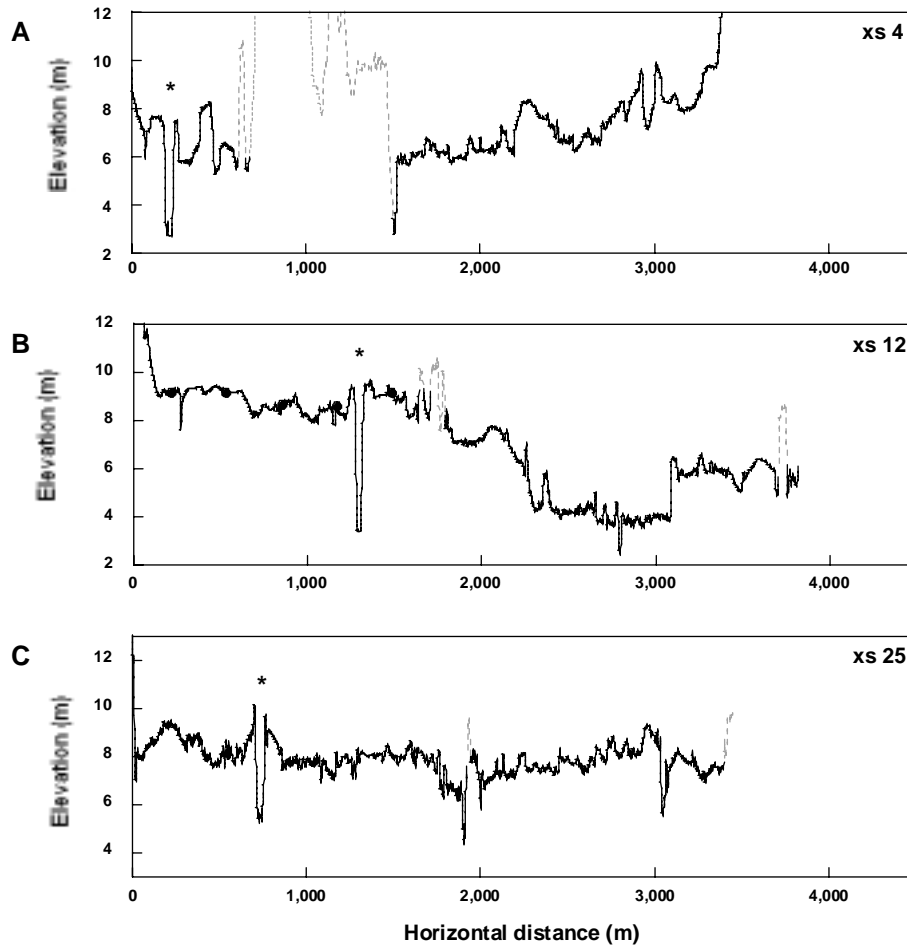


Figure 10 (continued on following pages). Valley profiles across the Green River generated from lidar DEM. Panels A through K progress in an up-valley direction (see Figure 9). Each cross section has a 10-m vertical axis, and a vertical exaggeration of 200x. Asterisks indicate Lower White River channel in panels A, B and C. The gray-dashed portions of panels correspond to conspicuously built up ground, generally highways or railroads; in panel A the large built up area corresponds to a wastewater treatment plant (Metro’s South Treatment Plant). The gray-dotted portion of panel A corresponds to upland. The lowest elevation in panels A, B and C (outside the Green River channel) corresponds to Springbrook Creek.

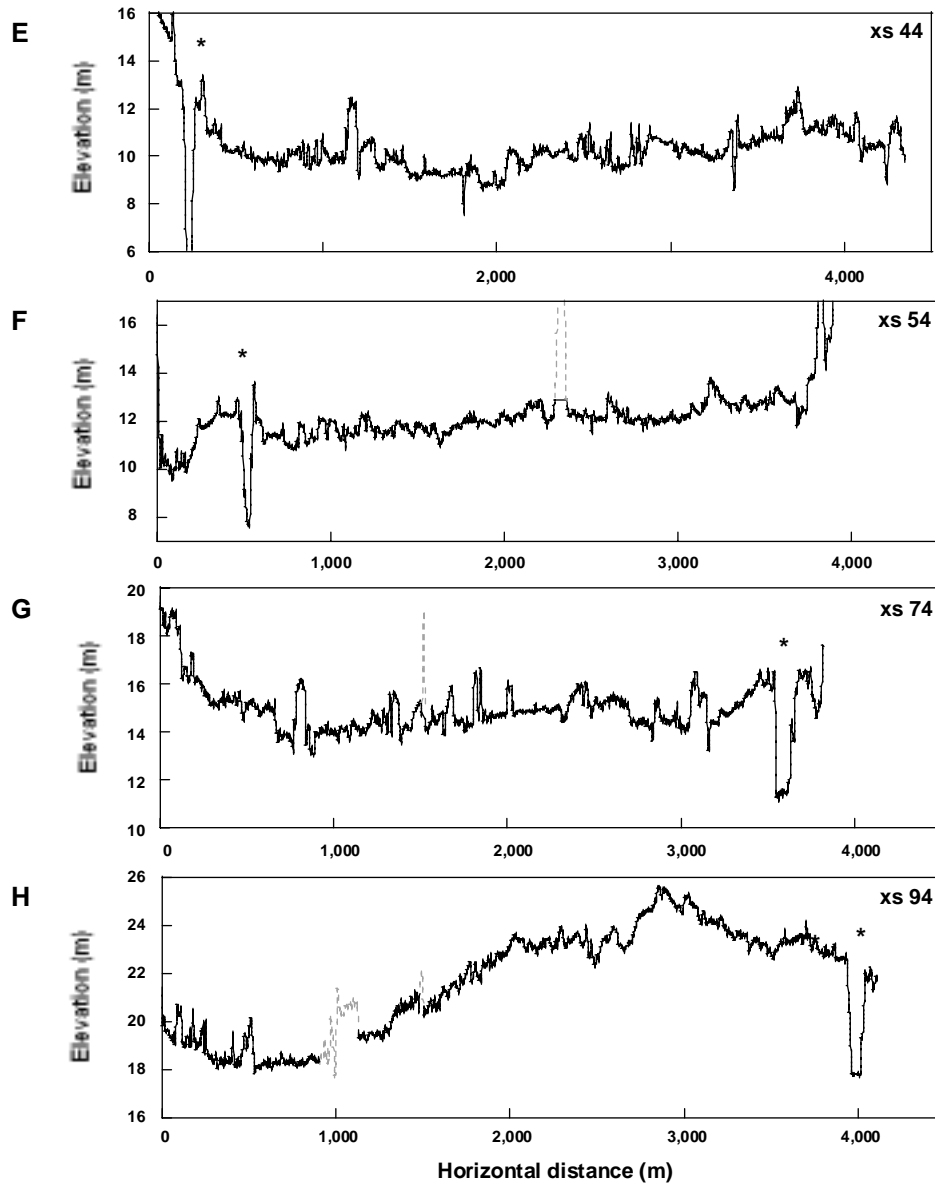


Figure 10 (continued). Asterisks indicate Lower White River channel in panels E, F and G; star represents Green River in panel H (see Figure 9). Each cross section has a 10-m vertical axis, and a vertical exaggeration of 200x. The gray-dashed portions of panels correspond to roads and railroads on conspicuously built-up ground.

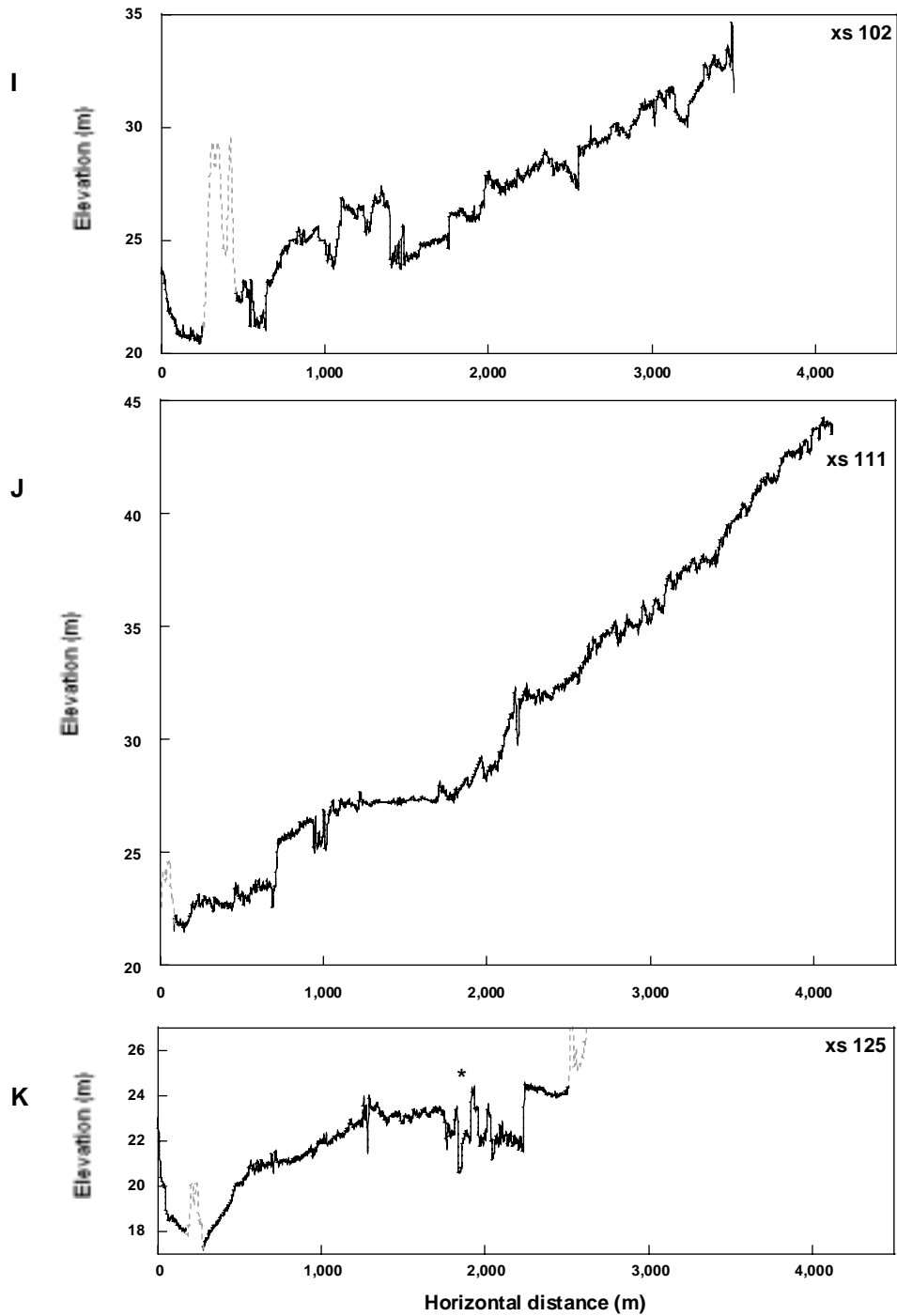


Figure 10 (continued). Asterisk indicates White River channel in panel K. Panels have a vertical exaggeration of 200x and the same horizontal axis as in panels A-H. The gray-dashed portions of panels correspond to roads and railroads on conspicuously built-up ground.

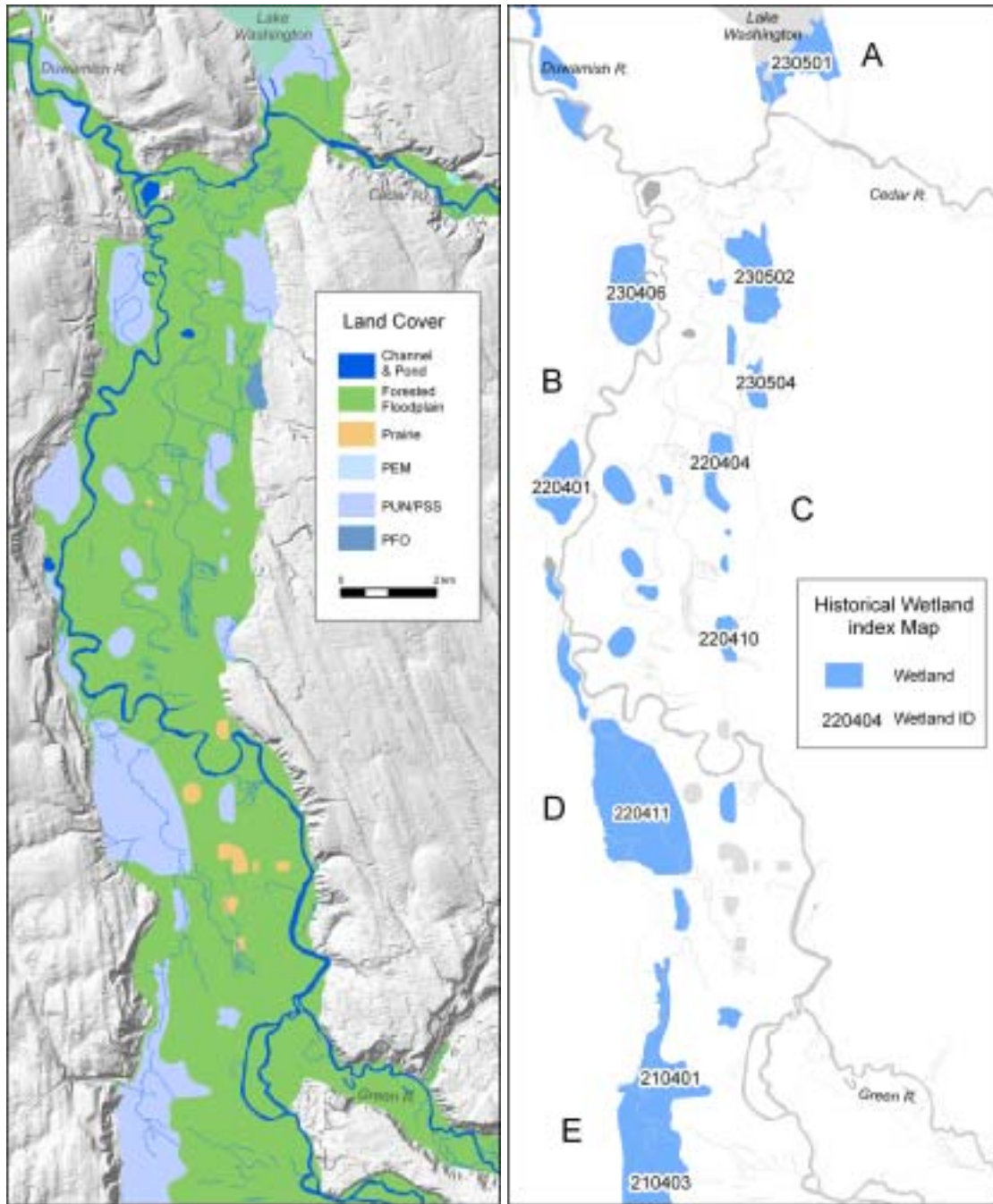


Figure 11. Historical landscape condition of the lower White River valley. PEM: palustrine emergent wetland; PUN: palustrine wetland, undifferentiated cover type; PSS: palustrine scrub-shrub wetland; PFO: palustrine forested wetland. Index map on right hand side of page identifies wetlands mentioned in the text within five geographic groupings “A” through “E.”

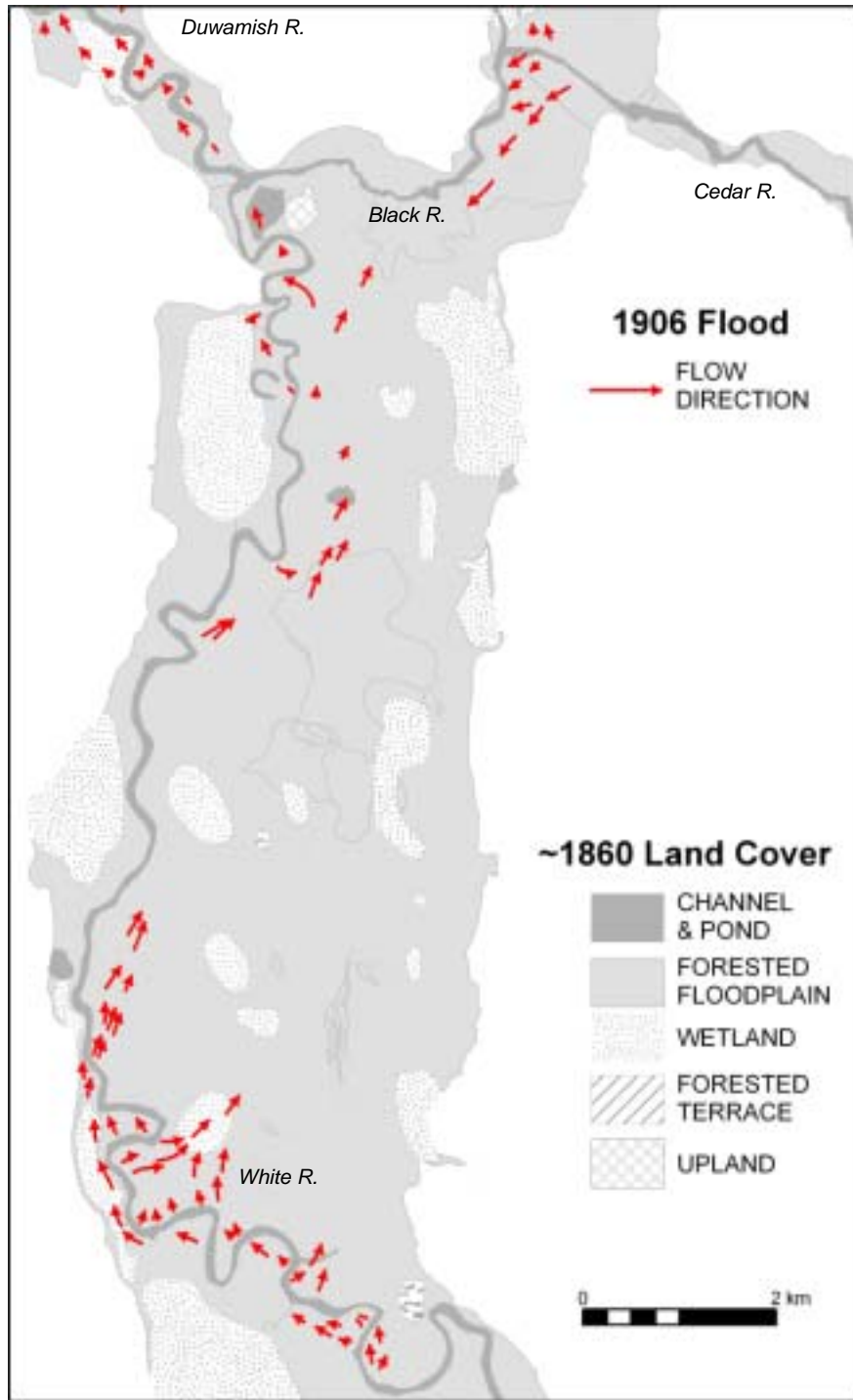


Figure 12. Flow directions in 1906 flood, mapped by Army Engineers (see Figure 7 caption).

Figure 13. 1940 and 1990 aerial photographs of the northern lower White River valley. Blue lines drawn on 1940 photo are channels inferred for ~1865 conditions.

Arrows show (right to left) inferred direction of flow of Black River distributary and tributaries and, including a Black River tributary that drained most of lower White River valley.



Flooding in Kent



Figure 14. Photographs of flooding in Kent between 1906 and 1946: “Interurban station in a flood, Kent, ca. 1906,” White River Valley Museum Photograph Collection (WRVM) #1161; “Flood in Kent, November 12, 1911,” WRVM #1362; “Kent Interurban Power Station flood, Kent, ca. 1915,” WRVM #55; “Hallock Garage, exterior, during flood, Kent, ca. 1920,” WRVM #922; “Pay’n Takit store in flood, Kent, ca. 1931,” WRVM #3877; “Flood in downtown Kent, ca. 1933,” WRVM #287; “Flooded road at entrance to Kent, 1936,” Museum of History and Industry Photograph Collection (MOHAI) # PI23103; “People leaving flooded house during Green River flood, Kent, 1938,” MOHAI #PI23110; “Flooded street, Kent, August 14, 1946,” MOHAI #PI23132.

South Lake Washington shoreline area, Renton

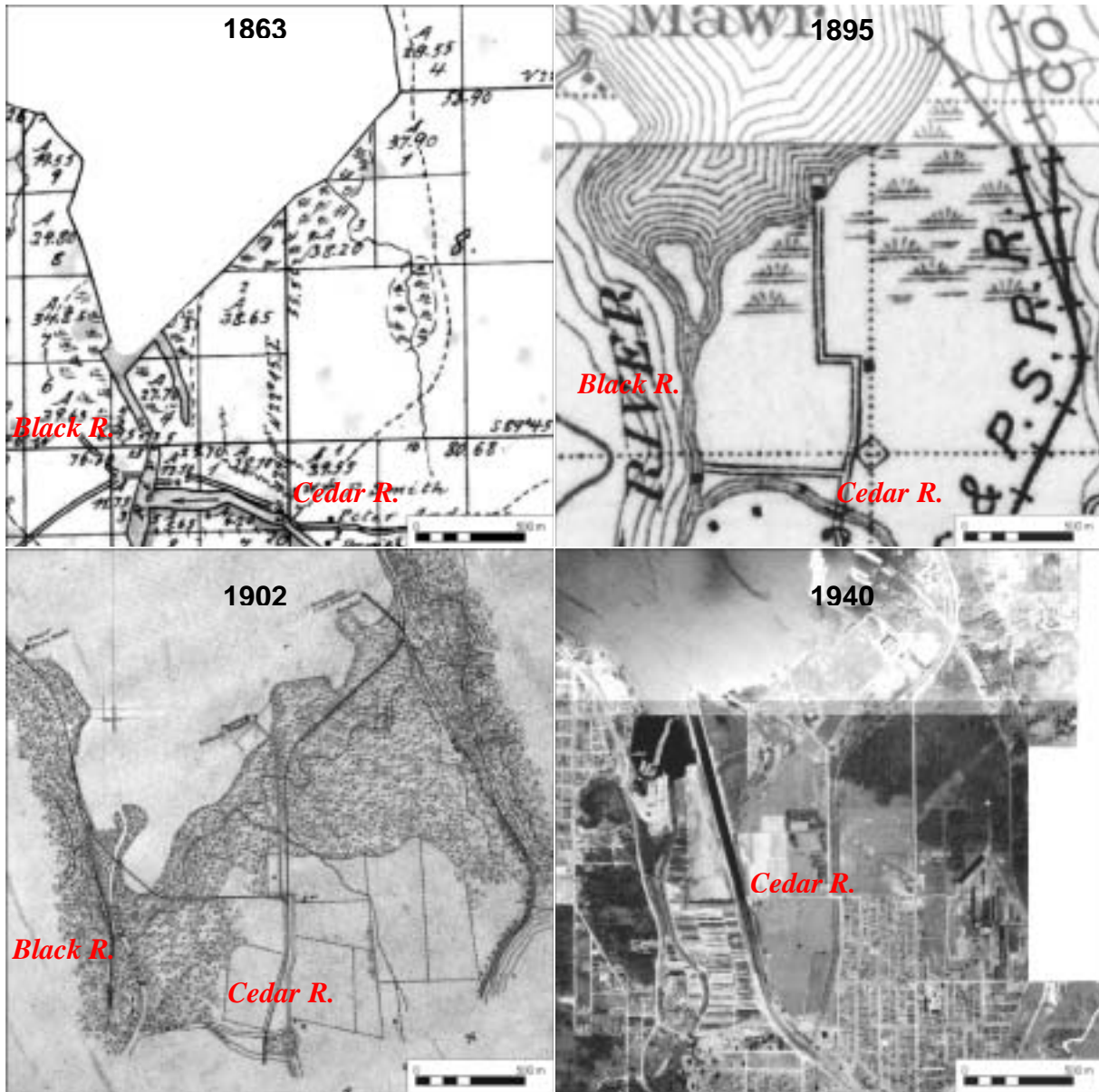


Figure 15. Maps and photos of the south Lake Washington area, 1863-1940: 1863 land survey plat map; 1895 1:125,000 USGS topographic maps Tacoma and Snohomish; 1902 1:10,000 USC&GS sheet T-2609 (“Lake Washington, Southern Sheet” surveyed by O. B. French); 1940 1:12,000 aerial photograph.

Southcenter Mall area, Tukwila



Figure 16. Wetland WHT_LOW230406 and oxbow pond present in 1895 (USGS topographic map Tacoma 1:125,000) to west of lower White River immediately south of Black River confluence. In 1940 photo, wetland has been drained but relict channel, probably an earlier location of the lower White River, and relict oxbow pond, are visible. By 1990 (USGS digital orthophotoquad), area (Southcenter Mall area) is heavily built up.

Figure 17. Wetlands (WHT_LOW220401 to west of river and WHT_LOW220402 to east of river) in 1863 in area south of Tukwila and west of O'Brien. Symbols in large wetland to west of river indicate springs (symbol is not used on other wetlands in GLO maps for the study area). Wetlands were drained and cultivated by 1940 (1:12,000 scale aerial photographs) and partially developed by 1990 (USGS digital orthophotoquad).



Green River Valley

The Green River valley is about one-fifth as wide as the lower White River valley—the Green River valley averages 0.8 km wide; the lower White River valley averages 3.8 km wide—and about five times steeper—the Green River valley averages 0.00309 and the lower White valley averages 0.000610 (Figure 2A) and the channel was steeper in gradient than the lower White River (Figure 2B).

The river meandered and created oxbow ponds, especially in the lower river where the gradient declines (Figure 3). However, in general the Green River historically was more straight and branching than the meandering lower White River, and was characterized by numerous floodplain sloughs. The network of floodplain sloughs shown in Figure 20 was interpreted from GLO mapping and from channels and relict channels on 1940 aerials in conjunction with their topographic expressions on the lidar DEM. Figure 20 likely under-represents the number of sloughs that would have existed on the floodplain. In addition, in different parts of the valley sloughs are more or less underrepresented, because the record of relict channels is obscured in those areas where the channel had migrated in the several decades preceding the 1940 aerial photos.

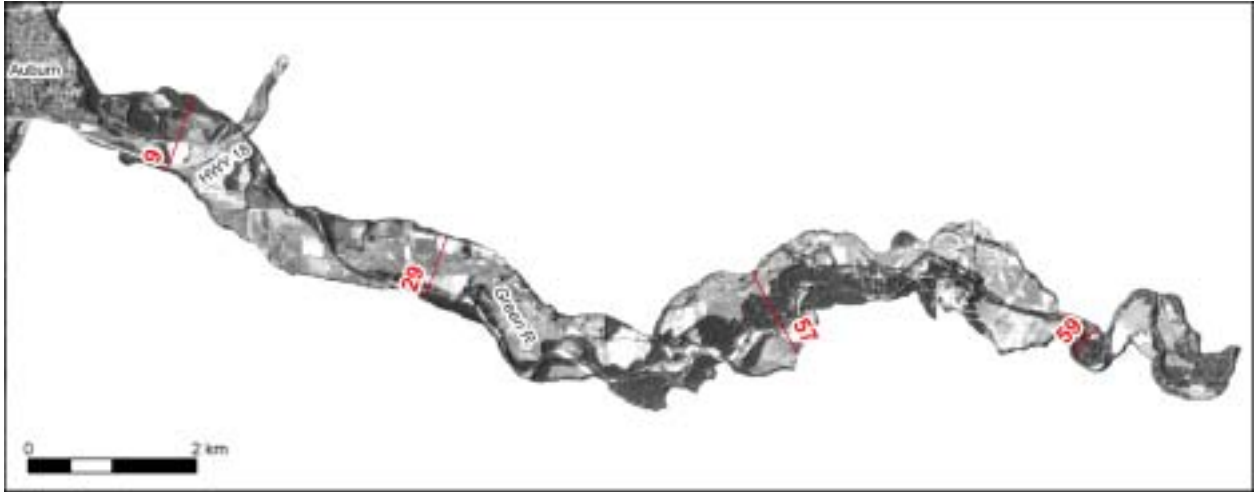


Figure 18. Location of representative valley profiles in the Green River valley shown in Figure 19. Background image is 1990 USGS DOQQ.

Green River

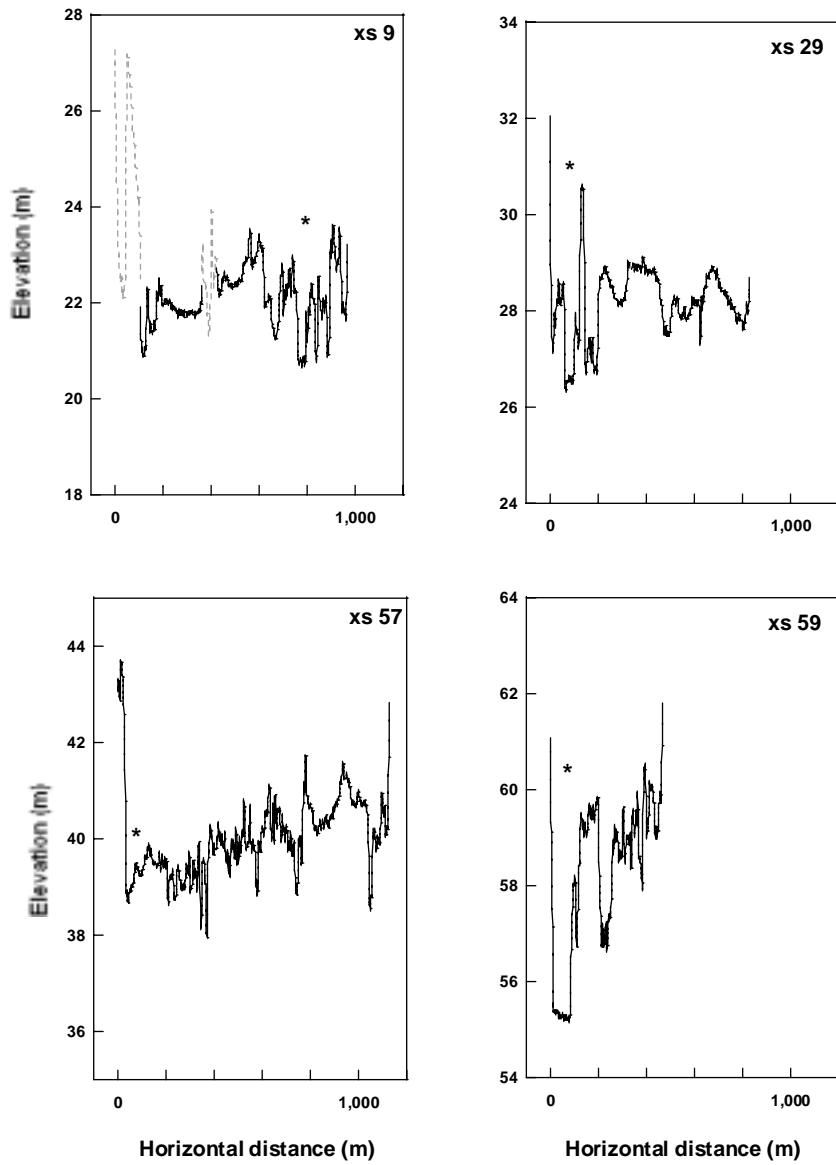


Figure 19. Valley cross sections across the Green River, from lidar DEM. Stars indicate Green River channel. Each cross section has a 10-m vertical axis, and a vertical exaggeration of 200x. Panels (A) through (D) represent locations in a downstream to upstream location (see Figure 18), respectively. The gray-dashed portion of panel A, moving from the left bank to the right bank, respectively, correspond to built up area of Highway 18 and a road and railroad.



Figure 20. Historical environment of the Green River valley, from confluence with the White River to the Green River Gorge.

Forest Cover and In-Channel Wood

Watershed Overview

The following discussion of historical forest composition draws primarily on bearing tree data from the General Land Office field notes because it is the most systematic, quantitative, and consistent data available. Throughout the valley network of the Duwamish system (i.e. inclusive of the Duwamish, White, Green, and Cedar river valleys) hardwoods were considerably more common than conifers (Figure 21 and Table 2). Conifers were most common in the lower Duwamish and in the Cedar, Green, and upper White river valleys. Hardwood trees were most common in the lower White River valley (Figure 2).

The largest diameter bearing trees in the Duwamish-White-Green-Cedar river valleys (Figure 22 and Table 2) were western redcedar (*Thuja plicata*) and black cottonwood (*Populus trichocarpa*), averaging 71.0 cm (median 50.8 cm) and 55.6 cm (median 50.8 cm) respectively. Other species commonly having a large diameter were Douglas fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*) and bigleaf maple (*Acer macrophyllum*). Their diameters averaged, respectively, 46.3 cm (median 29.2 cm), 46.4 cm (median 41.9 cm), 39.3 cm (median 30.5 cm). [It is possible that a few surveyors incorrectly identified Sitka spruce (*Picea sitchensis*) as “fir.” The reason for suspecting this is that very few spruce were identified (Table 2), and more important, none in the Duwamish River estuary. Instead, firs were identified in tidewater locations where Sitka spruce would be expected, based on forest composition in other estuaries. Because of this, firs may be overrepresented, and spruce underrepresented in the sample.]

The bearing tree records indicate that common tree species occurred in broad elevation zones throughout the valley network (Figure 23); for example Sitka spruce occurred in lower elevations, with western redcedar and Douglas fir spanning a wide range of elevations, with most individuals at higher elevations. Among hardwoods, Pacific crabapple (*Malus fusca*), willow spp. (*Salix spp.*), Indian plum (*Oemleria cerasiformis*), and Oregon ash (*Fraxinus latifolia*) were common at lower elevations. Red alder (*Alnus rubra*) were common at all elevations, black cottonwood (*Populus trichocarpa*) was most common at intermediate elevations, and bigleaf maple (*Acer macrophyllum*) and vine maple (*Acer circinatum*) at a wide range of elevations.

Duwamish River Valley

The Duwamish valley bottom forest was diverse, (Figure 24); it was dominated in frequency by red alder and Oregon ash (*Fraxinus latifolia*). However, few hardwood trees were large, as indicated by the overwhelming dominance by western redcedar (*Thuja plicata*) and to a lesser extent Douglas fir (*Pseudotsuga menziesii*) in basal area (Figure 24). [As indicated previously, the fir identified in the lower Duwamish may have included some Sitka spruce (*Picea sitchensis*). Edwin Richardson, who surveyed four townships in the Duwamish-White-Green system, identified only one spruce, while E. M. Meeker identified 10 spruce in two townships. Other river deltas on the east side of Puget Sound also suggest that spruce would be the dominant tidewater tree.] Forests on the surface we have mapped as an alluvial terrace in the lower Duwamish (see earlier in the report) contrasted markedly with those in the valley bottom, being dominated by conifers (primarily Douglas fir (*Pseudotsuga menziesii*) and secondarily western redcedar (*Thuja plicata*) both by number and in basal area (Figure 24).

Streamside forests were broadly similar to valley bottom forests in composition and basal area dominance (Figure 25). Streamside tree species being both relatively common and large in diameter, and thus would have been likely to contribute large wood to the Duwamish River include Douglas fir (*Pseudotsuga menziesii*, which may actually have been partially or dominantly Sitka spruce, *Picea sitchensis*), western redcedar (*Thuja plicata*), bigleaf maple (*Acer macrophyllum*), and black cottonwood (*Populus trichocarpa*).

Lower White River Valley

The most common streamside bearing trees in the lower White River valley, in decreasing abundance, were red alder (*Alnus rubra*), willow (*Salix spp.*), black cottonwood (*Populus trichocarpa*), bigleaf maple (*Acer macrophyllum*), and vine maple (*Acer circinatum*) (Figure 26).

An Army engineer reflects this species mix in an 1898 description:

“The banks of the White River are covered with a dense growth of alder, willow, and vine-maple brush, which overhangs the low-water line...” (Ober, 1898)

(The engineer went on to indicate, “This brush affords complete protection against the washing and undermining effects of the current. In a majority of cases where the brush has been removed the river has begun to eat into the bank.”) The same hardwood species common in the streamside were also common among the valley bottom bearing trees, with the addition of Oregon ash (*Fraxinus latifolia*) (Figure 26). Conifers were uncommon, accounting for 15% of valley bottom bearing trees and only 5% of streamside trees (Figure 26).

Cottonwood (*Populus trichocarpa*) was the most common tree commonly attaining a large diameter (Figure 26). Cottonwood accounted for 17% of bearing trees in the valley bottom sample, and 42% of the basal area. Cedar (*Thuja plicata*) fir (*Pseudotsuga menziesii*) and maple (*Acer macrophyllum*) were less abundant large-diameter trees. The large-diameter bearing trees that were immediately streamside would have produced the wood most likely to function in river channels: in immediately streamside areas, cottonwood accounted for 16% of trees and 40% of basal area; bigleaf maple (*Acer macrophyllum*) accounted for 10% of trees and 22% of basal area. This indicates that black cottonwood and bigleaf maple would most commonly have contributed wood large enough to function as key pieces in jams, or create stable snags; cedar and fir would also have contributed functional wood, but considerably less than cottonwood and maple.

Green River Valley

Forests in the Green River valley bottom (Figure 27) had less cottonwood (*Populus trichocarpa*) and more maple (*Acer macrophyllum*) and cedar (*Thuja plicata*) than the lower White valley, and streamside forests had more maple (*Acer macrophyllum*). Figure 27 and Figure 21 show an overall greater abundance of conifers in the Green River valley compared to the lower White River valley.

In-Channel Wood

Records of the Army Engineers snagging operations provide a small amount of information on the nature of wood in the Green River. Snagging was conducted irregularly, and may have been primarily in the Duwamish River, downstream of the Green (Table 3) and in no case was

likely to have occurred upstream of Kent, then the upstream limit of navigation. The number of snags removed from the river system was small relative to other rivers maintained by the Army's snagging program (Table 4). The spotty channel maintenance presumably was in part because there was relatively little commerce on the Green River. According to the Army Engineers report, within a few years after the snagging program first began in Puget Sound, the railroad between Seattle and Tacoma all but eliminated steamer traffic:

“Previous to the operation of the Northern Pacific Railway between Seattle and Tacoma, some three years ago [1887], stern-wheel steamers made regular trips up the Duwamish and up the White River for 15 miles farther, but since that time they have discontinued the business, having found it impossible to compete with the railroad...No steamers have ascended the Duwamish as far as the mouth of Black River for several months, for the reason that there was nothing for them to carry (McMillan, 1890, in War Department, 1891)

Later in the 1890s, the snagboat operator reported only limited commercial traffic: “The Duwamish River has no regular steamer on its waters: an occasional one goes up a short distance and freights out some hay and other produce” (Jefferson, in War Department, 1897).

Because the river was not regularly maintained, a number of snags existed in the Duwamish and White rivers, many of which may have been put into the river by streamside farmers:

“There are quite a number of submerged snags in the river that make navigation somewhat dangerous, and I have been informed that the most of these snags have been put into it by farmers living along its banks, while clearing their lands” [McMillan, in

War Department, 1891).

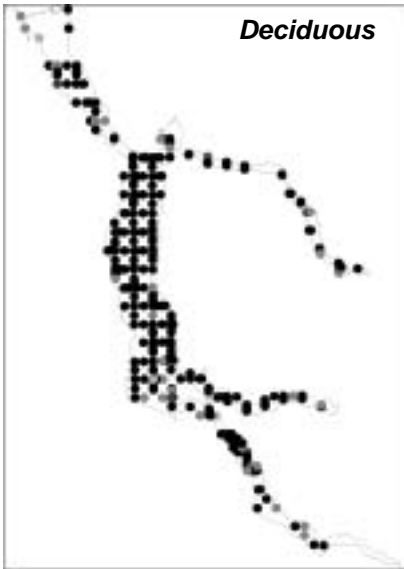
“White and Duwamish rivers are obstructed throughout by snags whose roots are embedded in the mud bottom, by overhanging trees, and by trees which have slipped bodily into the river through the undermining of the banks. The snags are instrumental in the formation of bars by causing eddies which catch a great deal of sediment” (War Department, 1898).

Early 20th century ethnographer T. T. Waterman describes a jam that had existed near Kent [about 1 km upstream of 212th St. river bridge; see map 5.16 in Hilbert et al. (2001)]. The village of Stook [StEq³ in Hilbert et al. (2001), “a big jam of logs”) was on the east bank of the White River at the lower end of a large wood jam. Upstream of Stook choo-tuhb-AHLT’w [Tcu’t³ap-alt^u in Hilbert et al. (2001), “flea’s house”) was on the east bank of the river upstream of the jam. About the jam, T. T. Waterman wrote that “people had to haul their canoes around it” and that it was old enough that “grass and bushes grew on it.”

Table 2. Diameter statistics of bearing trees in the Duwamish-Black-Cedar-White-Green river valleys system. The sample includes all trees in the study areas (e.g., immediately streamside, in valley bottom forests, and wetlands). Species are listed by decreasing mean diameter.

USAGE IN GLO NOTES	PROBABLE TREE SPECIES	N	MIN (CM)	MAX (CM)	MEAN (CM)	MEDIAN (CM)
Cedar	Western redcedar <i>Thuja plicata</i>	61	7.6	254	71.0	50.8
Cottonwood	Black cottonwood <i>Populus trichocarpa</i>	108	7.6	203.2	55.6	50.8
Spruce	Sitka spruce <i>Picea sitchensis</i>	12	15.2	91.4	46.4	41.9
Fir	Douglas fir <i>Pseudotsuga menziesii</i>	78	7.6	152.4	46.3	29.2
Maple	Bigleaf maple <i>Acer macrophyllum</i>	98	7.6	152.4	39.3	30.5
Hemlock	Western hemlock <i>Tsuga heterophylla</i>	6	7.6	76.2	34.3	33.0
Ash	Oregon ash <i>Fraxinus latifolia</i>	60	7.6	76.2	27.8	25.4
Alder	Red alder <i>Alnus rubra</i>	241	7.6	86.4	23.4	20.3
Bearberry	Indian plum <i>Oemleria cerasiformis</i>	17	7.6	50.8	20.2	20.3
Crabapple	Pacific crabapple <i>Malus fusca</i>	26	7.6	27.9	14.7	12.7
Willow	Willow spp. <i>Salix spp.</i>	111	5.1	38.1	14.6	12.7
Vine maple	Vine maple <i>Acer circinatum</i>	83	7.6	101.6	13.8	12.7

Figure 21 (following page). Spatial distribution of common bearing trees in General Land Office field notes for the valleys of the Duwamish, Black, Cedar, lower White, Green, and upper White rivers. Gray-scale symbols correspond to percent of trees at individual survey point. For example, if 2 of 4 trees at a survey point are alder, symbol is 50% gray. Possible values are 20%, 25%, 33%, 50%, 67%, 75%, and 100% (black). Species abbreviations: THPL: *Thuja plicata* (western redcedar); PSME: *Pseudotsuga menziesii* (Douglas fir); ALRU: *Alnus rubra* (red alder); SALIX: *Salix spp.* (willow); POBAT: *Populus trichocarpa* (Black cottonwood); ACMA: *Acer macrophyllum* (bigleaf maple); FRLA: *Fraxinus latifolia* (Oregon ash).



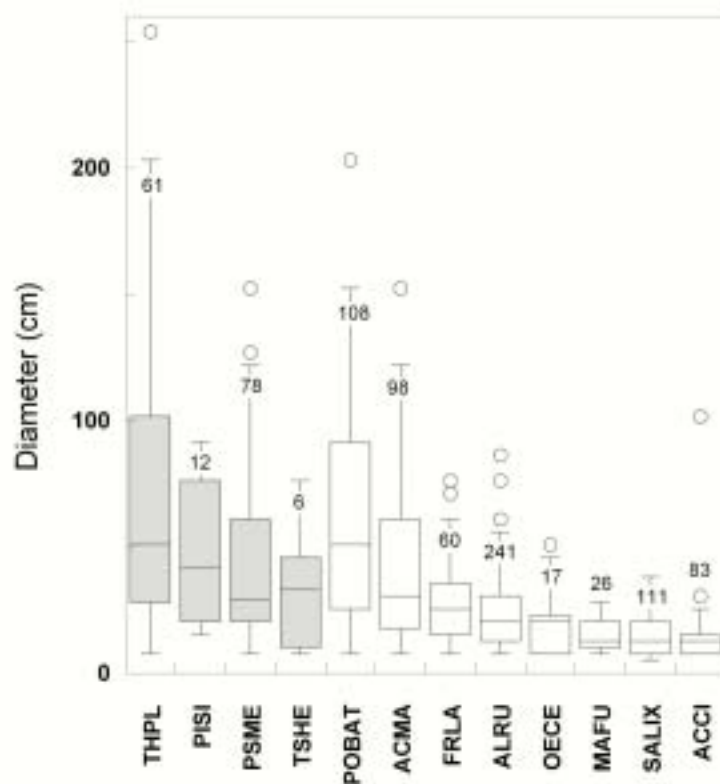


Figure 22. Diameters of common bearing tree species in General Land Office field notes for the valleys of the Duwamish, Black, Cedar, lower White, Green, and upper White rivers. Boxes for conifer species are shaded. Boxes enclose 50% of the data. Horizontal line within box represents median. Lines extending from top and bottom of boxes indicate minimum and maximum values, excepting outlier values (circles) greater than the upper quartile plus 1.5 times the inner two quartiles. Species abbreviations: THPL: *Thuja plicata* (western redcedar); PISI: *Picea Sitchensis* (Sitka spruce); PSME: *Pseudotsuga menziesii* (Douglas fir); TSHE: *Tsuga heterophylla* (western hemlock); POBAT: *Populus trichocarpa* (Black cottonwood); ACMA: *Acer macrophyllum* (bigleaf maple); FRLA: *Fraxinus latifolia* (Oregon ash); ALRU: *Alnus rubra* (red alder); OECE: *Oemleria cerasiformis* (Indian plum; “bearberry” in field notes); MAFU: *Malus fusca* (Pacific crabapple); SALIX: *Salix spp.* (willow); ACCI: *Acer circinatum* (vine maple).

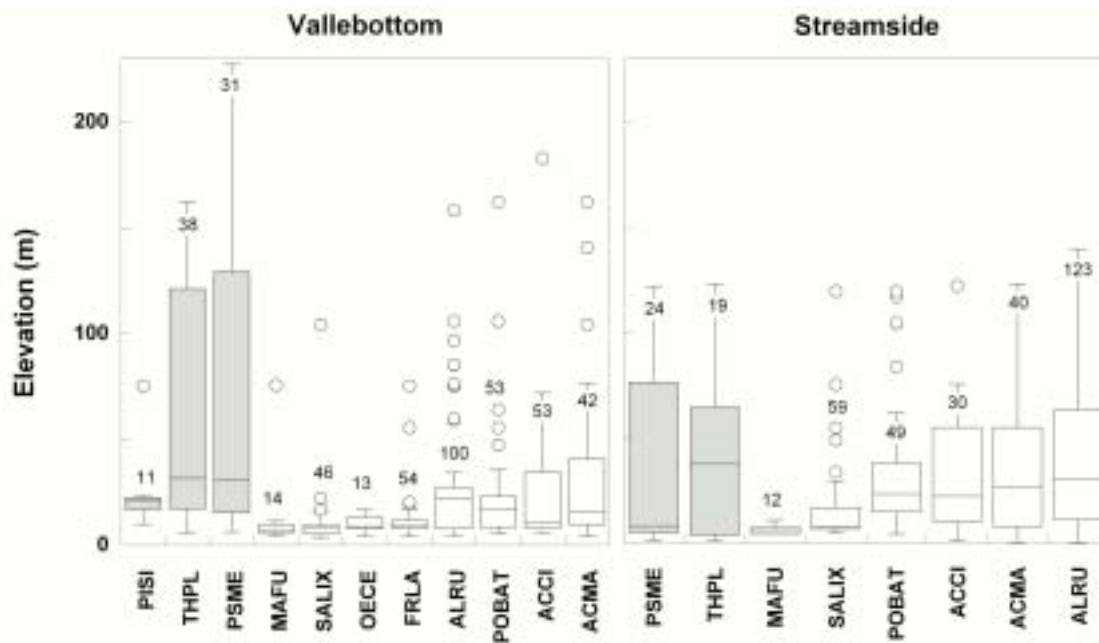


Figure 23. Elevation of the most common bearing trees in General Land Office records for the Duwamish, Black, Cedar, lower White, Green, and upper White river valleys. Elevation is taken from digital elevation model (DEM) made from lidar. See caption for Figure 22 for explanation of format and for species abbreviations.

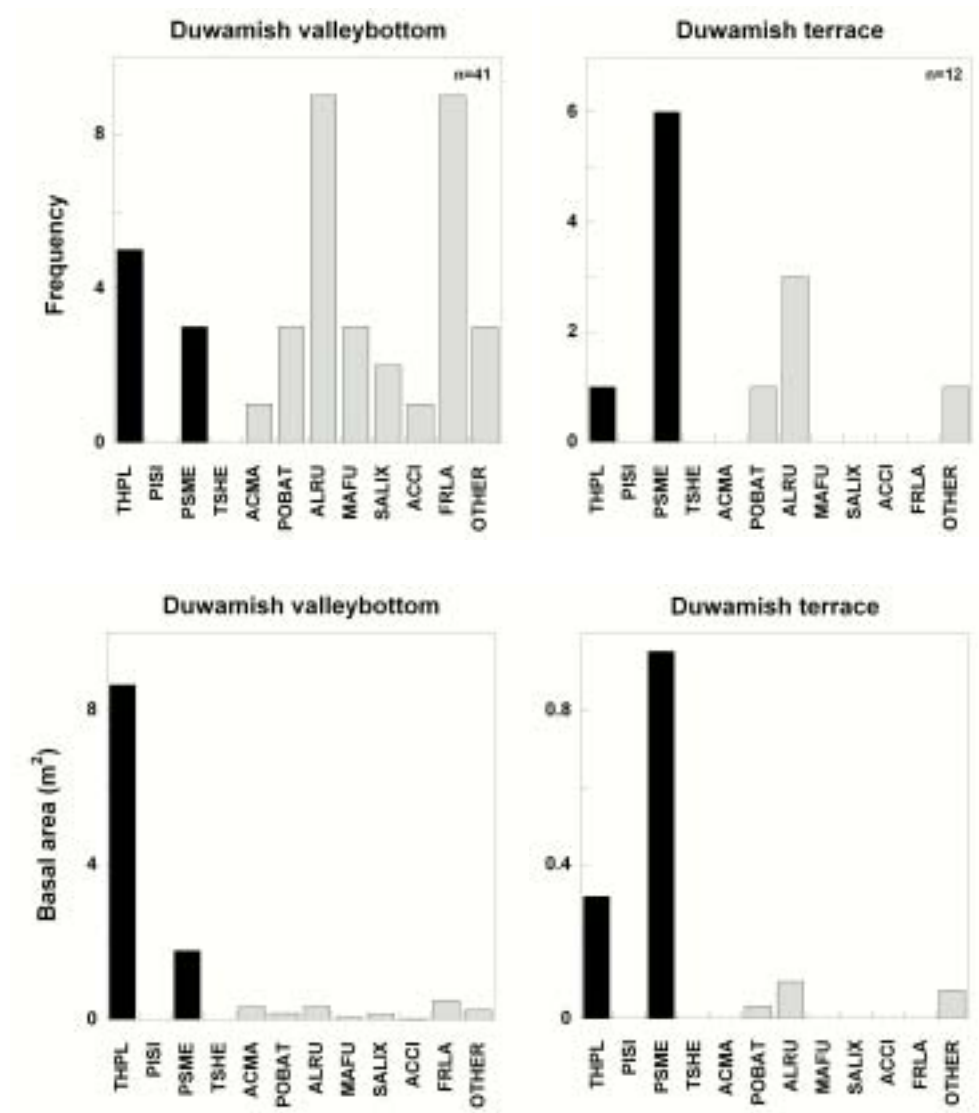


Figure 24. Frequency and cumulative basal area of bearing trees in General Land Office field notes for the Duwamish River valley. Coniferous species have black bars and hardwoods light-gray bars. Species abbreviations are as in Figure 22. “Other” in the Duwamish valley bottom sample are *Oemleria cerasiformis* (Indian plum; reported as “bearberry” in field notes) and *Corylus cornuta californica* (beaked hazelnut); in the Duwamish terrace sample, grand fir (*Abies grandis*, “white fir” in field notes). Note that scale of y-axis varies from panel to panel in this and subsequent (Figures 25-27) plots of basal area.

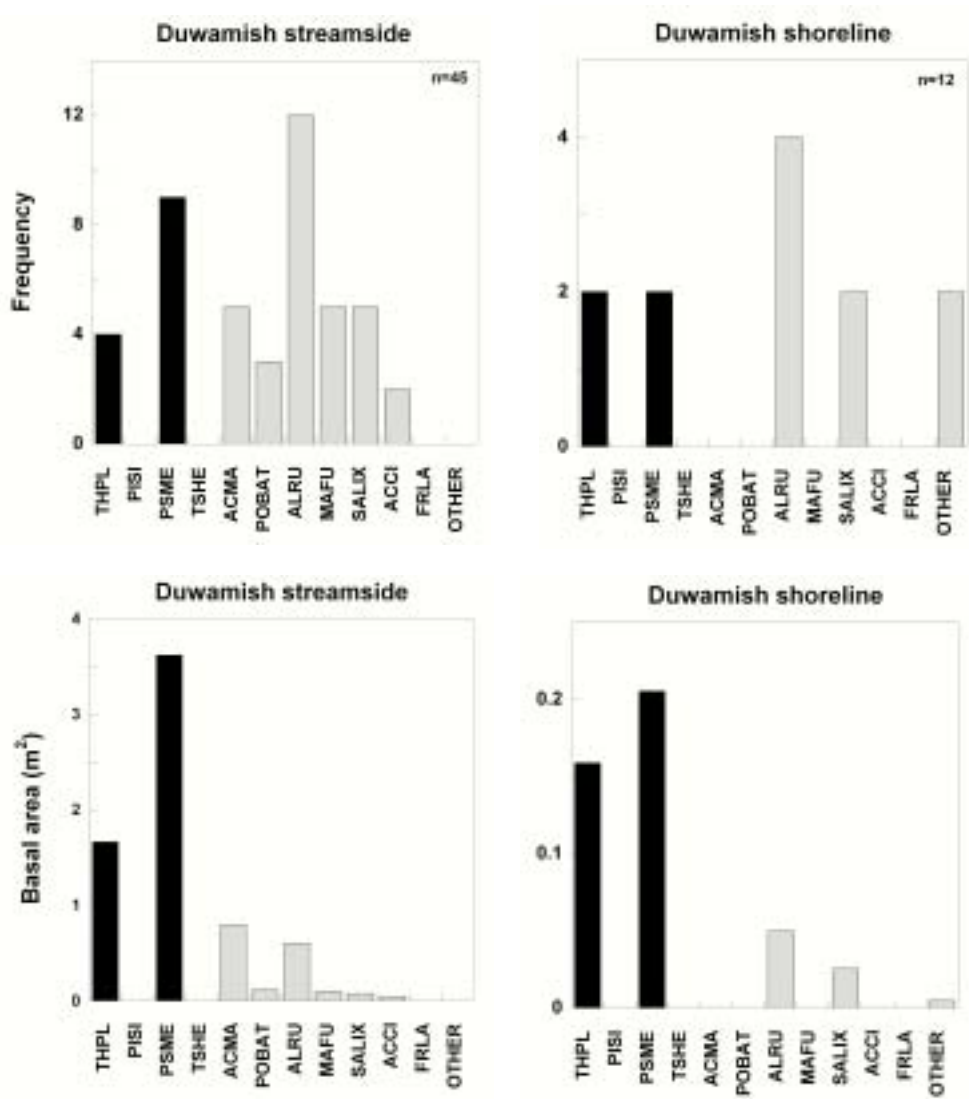


Figure 25. Frequency and cumulative basal area of bearing trees in General Land Office field notes for the Duwamish River valley. Species abbreviations are as in Figure 22. “Other” in the Duwamish shoreline sample is *Cornus nuttallii* (Pacific dogwood). Note that scale of y-axis varies from panel to panel.

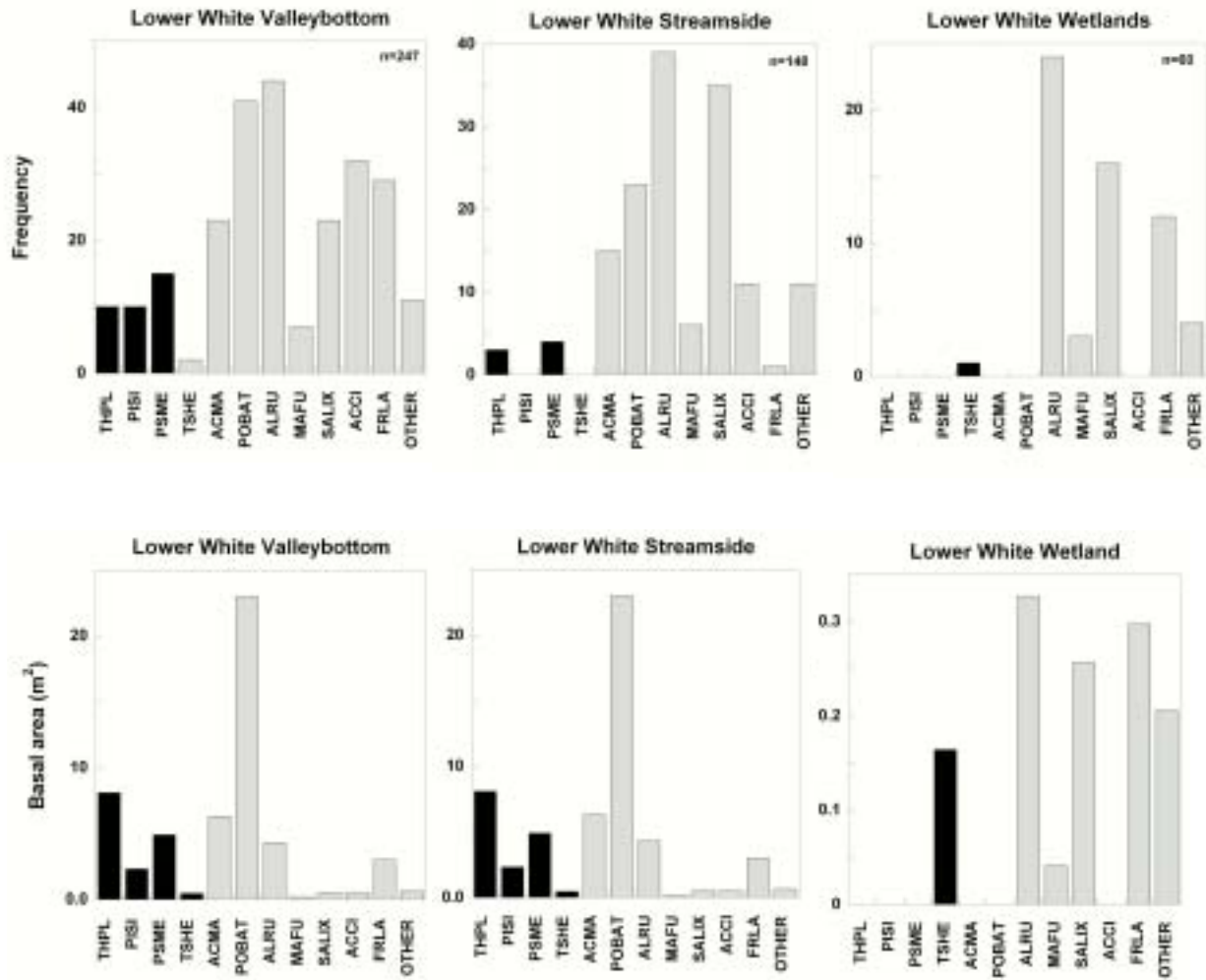


Figure 26. Frequency and cumulative basal area of bearing trees in General Land Office field notes for the Green River study area. Species abbreviations are as in Figure 22. “Other” includes: *Cornus nuttallii* (Pacific dogwood), *Oemleria cerasiformis* (Indian plum; reported as “bearberry” in field notes); *Corylus cornuta californica* (beaked hazelnut); *Fraxinus latifolia* (Oregon ash). Note that scale of y-axis varies among panels.

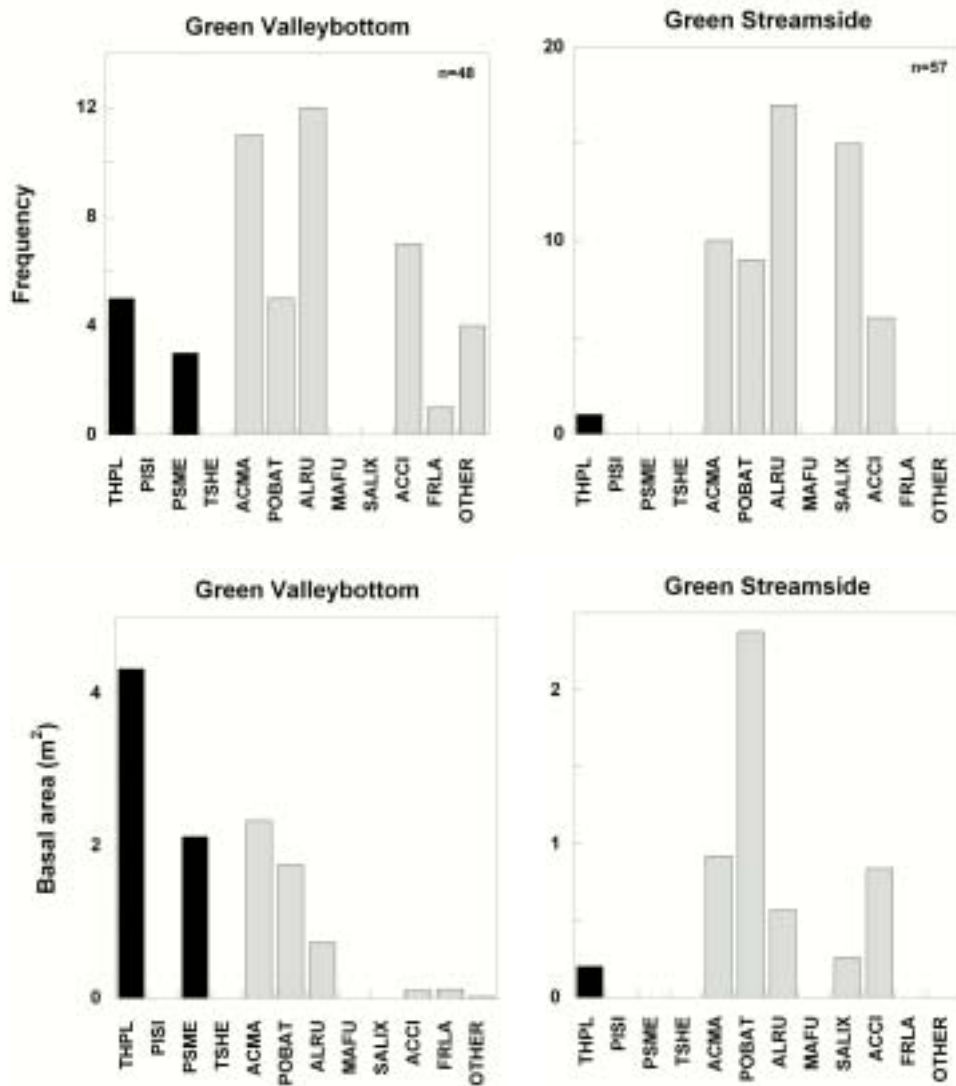


Figure 27. Frequency and cumulative basal area of bearing trees in General Land Office field notes for the Green River study area. Species abbreviations are as in Figure 22. “Other” includes: CONU: *Cornus nuttallii* (Pacific dogwood), PREM: *Prunus emarginata* (bitter cherry); *Fraxinus latifolia* (Oregon ash).

Table 3. Snags and leaning trees removed from the Duwamish and White rivers, 1880-1910 (from Annual Reports of the Chief of Engineers). There were no snagging activities in the years that lack entries in the table.

YEAR	SNAGS	LEANING TREES	COMMENTS
August 1893	29	0	"... snagging near the mouth of the Duwamish River..."
December. 1894	78	0	"...some necessary work of removing a drift jam in the Duwamish River..."
January 1897	25	53	"...working...under unfavorable conditions...the water in the Duwamish being too high for profitable work."
1903-1904	426	30	Snagging was in Duwamish River.
1904-1905	384	1	Snagboat visited both the Duwamish and White rivers; the leaning tree was from the White River.
1905-1906	9	0	Snagging was in Duwamish River.
1893-1906 TOTAL	951	84	-

Table 4. Snags removed from four north Puget Sound rivers, 1880-1910 (from Annual Reports of the Chief of Engineers).

RIVER	DRAINAGE AREA (km ²)	1881-1890	1891-1900	1901-1910	TOTAL 1881-1910
Nooksack		1,552	758		2,310
Skagit	7,800	776	21,553	14,369	36,698
Snohomish, Snoqualmie, and Skykomish	4,645	920	2,898	6,527	10,345
Nooksack	2,072	1,462	758	1,850	4,070
Stillaguamish	1,770	87	956	1,021	2,064

Aquatic Habitat

Quantitative Summary

The total area of channel, pond and wetland mapped for the Duwamish, lower White and Green rivers study area is shown in Table 5. Mainstem channel dominated the channel area, but tributary area was also large in the lower White River—primarily the system of channels that collected floodwater in the lower White floodplain downstream of Kent—and in the Green River—primarily tributary streams that flowed downstream on the floodplain before joining the main river (Figure 28A).

The dominant types of channel edge, estimated as double the channel length, varied from one river valley to another (Figure 28B). Blind tidal estuarine channels dominated the Duwamish River. The area and length of these channels was estimated using relations between channel length and marsh area in the Skagit and Snohomish River estuaries (see Collins and Sheikh 2003) because of the absence of information on tidal channels in the Duwamish estuary (see earlier in report). We also estimated the area and length of small tidal channels in the Smith Cove and West Point saltmarshes; while the T-sheets show small tidal channels in these two saltmarshes, we have found channels depicted with lines (as opposed to polygons) in saltmarsh on other T-sheets to be schematic.

Tributaries draining extensive depressional areas of the floodplain dominated channel edge in the lower White River. Sloughs dominated edge in the Green River valley. The blind tidal

estuarine channels in the three Elliott Bay estuaries (West Point, Smith Cove, and Occidental Square) would have included a significant amount of channel edge.

Wetland area dominated other habitat types mapped in this study (channels, ponds, and tidal lagoons) except in the Green River valley (Table 5 and Figure 29).

Implications for Restoration

The Duwamish estuary and the other three tidal wetlands described in this report have each been heavily modified, and extensive efforts have been underway for a number of years to identify, rank, design and build projects that would rehabilitate or create habitats. The historical assessment in this study can augment these efforts by contributing to an understanding of the historical amounts, types, and overall distribution of habitats in the estuary and by adding information on the estuary for basin-scale salmonid habitat limiting factors analysis. It also provides the basis for understanding the relative regional importance of Duwamish estuary and Elliott Bay habitats; for example, in the Central Sound sub-basin in which the Duwamish estuary and Elliott Bay are located (the “Central Basin” minus the “West Sound Inlets” sub-basin of Burns 1990; see Figure 2-1 in Collins and Sheikh 2005), proportionately less of the historical tidal wetlands remain than in any other sub-basin of the Puget Sound region; it has the lowest percentage of remaining historical tidal wetlands by number of wetlands, and the lowest percentage of its historical tidal wetland area (Collins and Sheikh 2005).

The study area’s rivers and their associated valley bottoms differ in fundamental character—in topography, landforms, river morphology and dynamics, and historical habitats—in large part because of two contrasting geologic histories; restoring riverine processes and habitats differ

accordingly. Collins et al. (2003) outline a broad difference in restoration emphasis between valleys such as the Duwamish and the (historical) lower White River (modern “Lower Green”) valleys, in contrast to valleys like that of the Green River (modern “Middle Green”). In the narrower, steeper post-glacial valleys (Figure 2), the steeper rivers were highly dynamic, with frequent channel-switching avulsions of the anastomosing channel and its floodplain sloughs, within a proportionately large amount of the floodplain. In these environments, the emphasis for a self-sustaining restoration is on restoring a *dynamic river-forest connection* in a linked “restoration succession” of the riparian forest, the morphology and habitats of rapidly avulsing channels and sloughs, and a dynamic connection between river, forest and wood jams (Collins and Montgomery 2002). By contrast, rivers in the broad, low-gradient valleys such as the Duwamish and lower White River were considerably less dynamic, avulsing much less frequently by gradual bank lateral migration and meander cut-off, within a meander belt that was narrow relative to the valley width. Water from overbank floods would have a long residence time in the valley, because the floodplain is several meters lower than the riverbanks; floods would recharge extensive wetlands and sustain flow in relatively stable floodplain channels. In these environments, emphasis is more on restoring *hydrologic connectivity* to oxbow lakes within the narrow meander belt, and to the floodplain’s extensive wetlands and channels.

Considerations in Using Historical Habitat Estimates

While using cross-referencing sources can help reduce uncertainty, historical reconstructions will always be incomplete and subject to both known and unknown biases. Reconstructions such as that described in this report are most reliably used as qualitative explanations of how landscapes were structured and the processes and elements that structured them. When using

these data for the purpose of quantitative habitat assessments it is important to keep in mind the nature of the source data, and the assumptions with which we used those data to make these quantitative estimates of historical habitats. A summary of specific considerations, made earlier in the report, include the following:

(1) The mapping of floodplain channel is not uniform or complete. It is not possible with historical sources to map all floodplain channels that would have existed (in this or any study area). Small channels are obscured by most land uses, although high-resolution DEMs are helpful in finding subtle topographic evidence of former channels in areas where the original land surface still exists (e.g., in agricultural or forested areas). However, in much of the northern part of the lower White River and much of the Duwamish River land-shaping development was extensive by 1940. In addition, the resolution with which small channels can be mapped is uneven from one part of a floodplain to another: channels migrate through time, including between the 1860s and 1940 in the case of this study area, and this migration obscures former channels. This phenomenon is important in the Green River valley, where the river has migrated and avulsed significantly, and results in a lower mapped density of small channels in those areas where historical movement of the channel obscures topographic and visual evidence. This effect is not an important factor in the lower White and Duwamish valleys, where mainstem locations have been relatively static. In summary, mapping underestimates the amount of small channels that existed historically, and this underestimate is spatially uneven.

(2) The location of small channels is often based on lower levels of evidence. As discussed earlier, the GLO surveyors did not follow small channels, but only noted their presence, the direction in which they flowed, and their width where they crossed section lines. This means that

we have had to rely on other, less direct sources to map the course of these channels between section lines, including 1895 topographic maps and channels, relict channels on 1940 or 1936 aerial photographs, and lidar DEM. The early topographic maps are less accurate and less detailed owing to their small scale (1:125,000). Interpreting channels or relict channels on early photos is problematic on a number of accounts: development was extensive in the study area by the time of the early photos and obscures or eliminates evidence; it is not always possible to determine whether or not a channel on the photos has been moved and ditched; channels evident on photos may predate or postdate the 1860s. In some cases it was not possible to map a channel continuously, and the map includes some channel segments that are discontinuous for this reason. In general, we made use of all lines of cross-referencing evidence available for mapping each channel to improve certainty. The sources of data and assumptions involved, and the relative certainty associated, with each channel segment, is coded in the GIS coverage and explained in the metadata, which should be consulted, especially for any site-specific work based on the GIS coverage.

(3) Large channels taken from GLO maps incorporate errors in those maps. Large channels (those shown as polygons on original source materials) taken from the GLO incorporate some inaccuracy in the transfer by the GLO draftsmen of field data to the plat map. We have found in north Puget Sound valleys that the river widths shown on the plat maps may vary from the field-measured width, from surveyor to surveyor, and from township to township and that on average the map widths were a few percent higher than field measured widths. Platting of channels was also pictorially crude, as evident by the jagged, geometric shape to many of the channels in the GIS mapping (e.g. Figs. 11 and 20). However, where it has been possible to independently corroborate large channels shown on GLO maps, their location is relatively accurate.

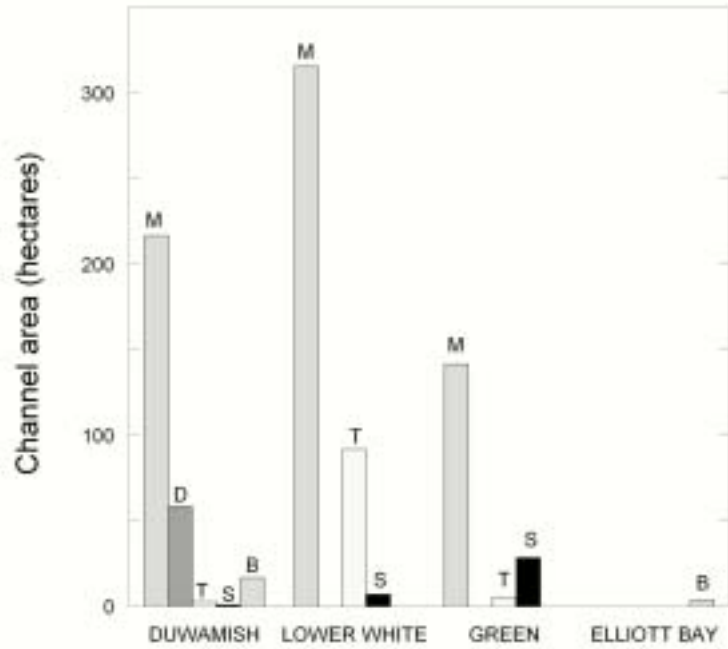
(4) Wetland boundaries are in many cases approximate and generalized. Because the GLO surveyors did not follow wetland boundaries between section lines, refining, corroborating, and extending boundaries of wetlands mapped by the GLO surveyors relies on other, independent sources. In the study area, we lacked some of these corroborating sources that have been available elsewhere (e.g., detailed soils maps of hydric soils, which elsewhere have corresponded highly to GLO-mapped wetlands; high-resolution DEM, potentially useful in refining boundaries of wetlands partially controlled by elevation). For the same reason, we have missed some smaller wetlands that would not have been crossed by the GLO section line survey. In applying the data at a site scale or for quantitative purposes, wetland source codes in GIS coverages should be consulted.

(5) Wetland descriptions are incomplete. There is not enough evidence to systematically determine the seasonal hydrology of wetlands. We did not find enough evidence in this study area to characterize the seasonal wetland inundation, as we have found it possible to do elsewhere. We also found less information in this study area for characterizing the vegetation type (e.g., emergent, scrub-shrub, or forested) in many wetlands.

Table 5. Estimated historical habitat areas in the Duwamish, lower White and Green River study areas, measured from GIS coverages. See text for explanation.

HABITAT FEATURE		HABITAT AREA (HECTARES)				
HABITAT FEATURE	CHANNEL OR WETLAND TYPE	ELLIOTT BAY	DUWAMISH	LOWER WHITE	GREEN	TOTAL
CHANNEL		4	296	415	175	889
Freshwater	Mainstem	0	0	316	142	457
	Tributary	0	2	92	5	99
	Tributary-fan	0	0	0.3	0.1	0.5
	Slough	0	1	7	29	37
Tidal-freshwater	Mainstem	0	217	0	0	217
	Tributary	0	0.7	0	0	0.7
	Blind	0	3	0	0	3
Estuarine	Distributary	0	58	0	0	58
	Blind	4	14	0	0	18
POND		0	5	29	5	39
LAGOON		1	0	0	0	1
WETLAND		30	534	1,696	0	2260
	Palustrine	0	194	1,696	0	1890
	Riverine-Tidal	0	166	0	0	166
	Estuarine	30	174	0	0	204
ALL		35	835	2140	180	3190

A



B

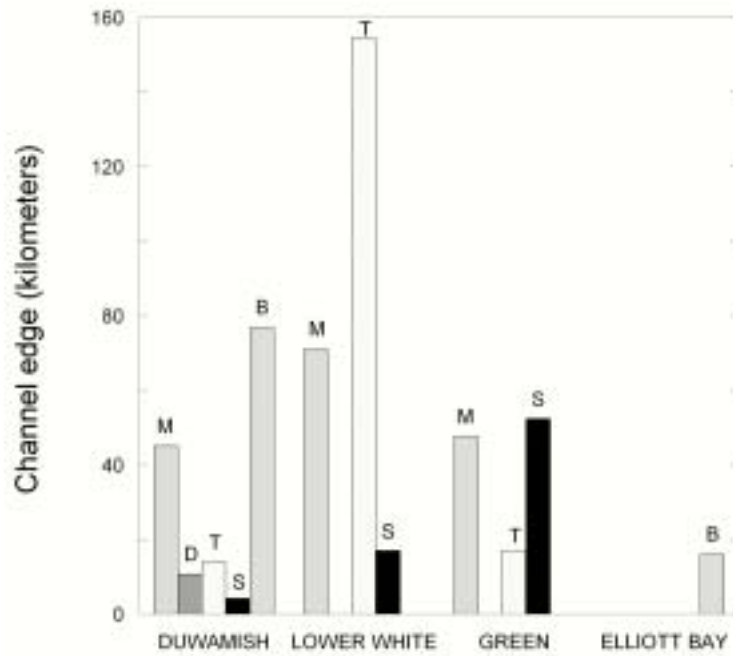


Figure 28. (A) Area of mapped channels in the lower White and Green River study areas. M: Mainstem; D: Distributary; T: tributary; S: slough; B: blind tidal. (B) Channel edge of mapped channels.

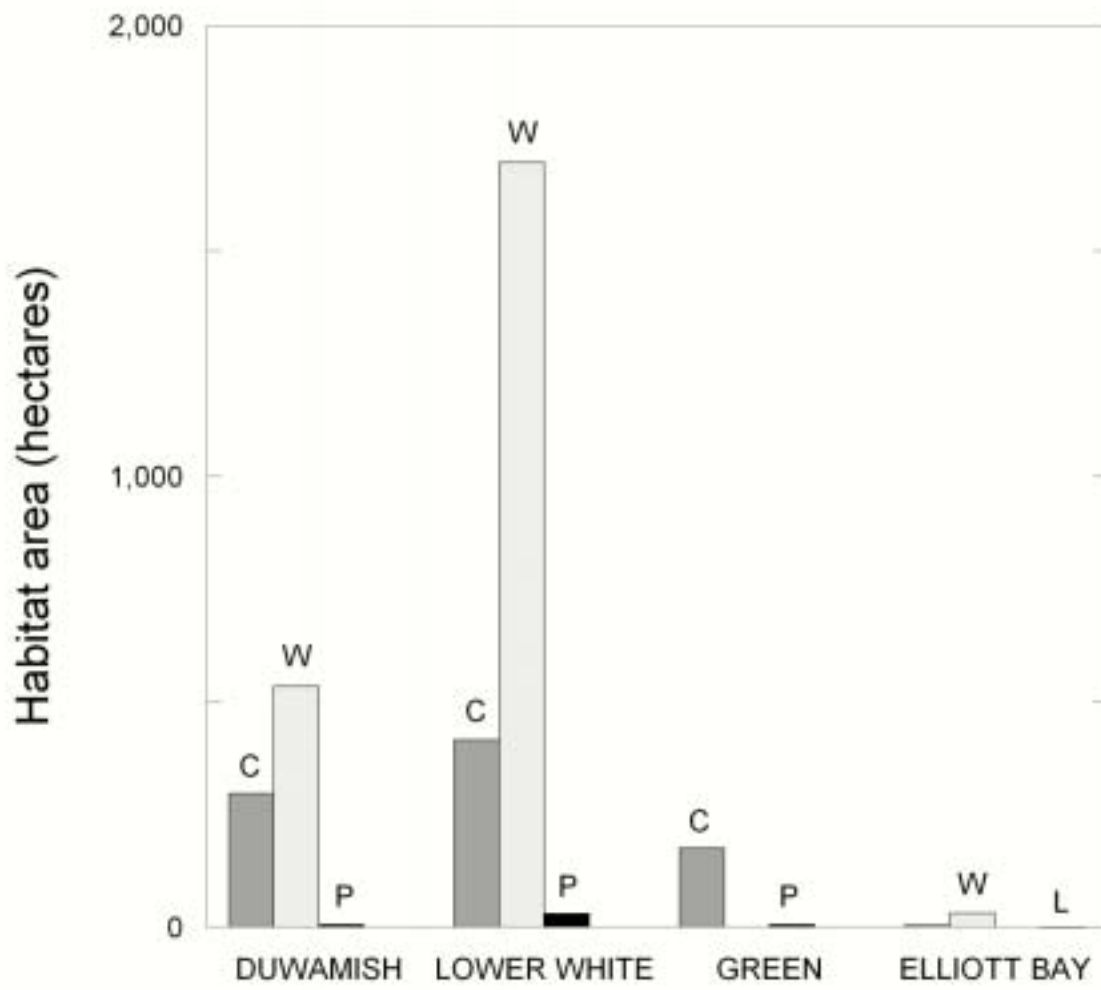


Figure 29. Summary of aquatic habitat areas in the study area; data from Table 5. C: channel; W: wetland; P: pond; L: lagoon.

Acknowledgements

Funding for this work was provided through a grant from the King Conservation District and through a Memorandum of Agreement between King County and the Department of Civil and Environmental Engineering of the University of Washington. We thank Lorin Reinelt at the County and Derek Booth in the Department of Civil Engineering for their assistance. We thank Charles Kiblinger for processing images used in GIS mapping. Some source materials used in this analysis (georeferenced T-sheets and GLO plat maps, and orthorectified 1936 and 1940 aerial photos) are available at <http://riverhistory.ess.washington.edu>. This project is a contribution of the Puget Sound River History Project, supervised by Dr. David Montgomery, in the Quaternary Research Center and Department of Earth & Space Sciences at the University of Washington. More information on the Puget Sound River History Project can be found at <http://riverhistory.ess.washington.edu>.

Cover photo credit: Cassells Point, Duwamish River, ca. 1891. Photographer: Frank LaRoche. University of Washington Libraries, Special Collections.

References Cited

- Booth, D. B. 1994. Glaciofluvial infilling and scour of the Puget Lowland, Washington, during ice-sheet glaciation. *Geology* 22: 695-698.
- Boyd, R.(ed.). 1999. *Indians, Fire and the Land in the Pacific Northwest*. Oregon State University Press, Corvallis, OR, 313 p.
- Burns, R. E. 1990. The shape and form of Puget Sound. Puget Sound Books, A Washington Seagrant Publication, University of Washington Press, Seattle, WA. 100 p.
- Collins, B. D. and A. J. Sheikh. 2005. Historical reconstruction, classification, and change analysis of Puget Sound tidal marshes. Project completion report to Washington Department of Natural Resources, Aquatic Resources Division, Olympia, WA. Puget Sound River History Project, University of Washington Department of Earth and Space Sciences, June 30, 2005. http://riverhistory.ess.washington.edu/research/tidal_marshes.php
- Collins, B. D., D. R. Montgomery, and A. J. Sheikh. 2003. Reconstructing the historical riverine landscape of Puget Sound. P. 79-128 in Montgomery, D. R., S. Bolton, D. B. Booth, and L. Wall (eds.) *Restoration of Puget Sound Rivers*. University of Washington Press, Seattle. 505 p. Online: http://riverhistory.ess.washington.edu/pubs/cms_03.pdf.
- Collins, B. D. and D. R. Montgomery. 2002. Forest development, wood jams and restoration of floodplain rivers in the Puget Lowland. *Restoration Ecology* 10(2): 237-247.

- Crandell, D. R. 1963. Surficial geology and geomorphology of the Lake Tapps quadrangle, Washington: *U. S. Geological Survey Professional Paper 388-A*, 84 p.
- Dragovich, J. D., P. T. Pringle, and T. J. Walsh. 1994. Extent and geometry of the mid-Holocene Osceola Mudflow in the Puget Lowland—Implications for Holocene sedimentation and paleogeography. *Washington Geology* 22: 3-26.
- Hilbert, V., J. Miller, and Z. Zahir (eds.) 2001. *Puget Sound Geography, Original Manuscript from T. T. Waterman*. Lushootseed Press, Federal Way, Washington. 375 p.
- Mangum, A. W. and Party. 1909. *Reconnaissance Soil Survey of the Eastern Part of Puget Sound*. U. S. Soils Bureau, Government Printing Office, Washington, D.C.
- McMillan, A. J., 1891, October 28, 1890 Report of Mr. A. J. McMillan, in “Preliminary examination of Duwamish and Black rivers, Washington,” Appendix WW15 in Annual Report of the Chief of Engineers, U. S. Army.
- Nesbit, D. M. 1885. Tide marshes of the United States. U. S. Department of Agriculture Miscellaneous Special Report No. 7.
- Ober, R. H., 1898, Report of Mr. R. B. Ober, Surveyor, in “Report of Capt. Harry Taylor, Corps of Engineers,” in “Survey of Duwamish River and its tributaries, Washington,” Appendix VV17 in *Annual Report of the Chief of Engineers, U. S. Army*.

Jefferson, E. H., 1897, Report of E. H. Jefferson in “Improvement of Puget Sound and its tributary waters, Washington,” Appendix SS4 in *Annual Report of the Chief of Engineers, U. S. Army*.

U. S. War Department (ARCE). 1880-1910. *Annual report of the Chief of Engineers, U. S. Army, to the Secretary of War*. Government Printing Office, Washington, D. C.

White, C. A., 1991. *A History of the Rectangular Survey System*. U. S. GPO, Washington, D. C.

Zehfuss, P. H., B. F. Atwater, J. W. Vallance, and H. Brenniman. 2003. Holocene lahars and their by-products along the historical path of the White River between Mount Rainier and Seattle, in: Swanson, T. W., ed., *Western Cordillera and adjacent areas: Geological Society of America Field Guide 4*, Boulder, CO.

Appendix 1: Wetland Descriptions

C_ELT250301 (22 hectares). Smith Cove tidal marsh, mapped from USC&GS T-1390b-1 (1874).

C_ELT250302 (7 hectares). Tidal marsh on West Point, mapped from USC&GS T-1064 (1867). T-1064 shows single tidal channel network opening on the north side of the point, with grass-covered sand mapped surrounding the marsh.

C_ELT2404010 (2 hectares marsh and 0.5 hectares lagoon). Pioneer Square area tidal marsh and lagoon. Mapped from Plan of Seattle (1855-56, revised 1930).

DUW240401 (174 hectares). Estuarine tidal marshes; insufficient information to distinguish emergent from scrub-shrub. Mapped as salt marsh on T-1406; 1907 Army Corps flood map includes notation “salt marsh.” Westward between S. 18 and S. 19 “[illegible] of the river bottom and island mostly liable to inundation during very high tides from 10 to 20 in.” on September 28, 1861. Northward between S. 17 and S. 18 at 7.5 chains “Intersect prairie brs. E. & W.” on September 27, 1861.

DUW240402 (49 hectares). Tidal marshes flanking the Duwamish River, upstream of the mouth, presumed to be dominantly freshwater. Westward between S. 19 and S. 30 at 16.39 chains “Intc’t tide prairie brs. N. 30 E. seldom overflows” but in the line description “Land in bottom level and on the left bank of the river liable during highest tides to inundation 20 or 30 in.” on September 27, 1861.

DUW240403 (38 hectares). Upstream most tidal “prairie” just downvalley of present day South Park. Northward between S. 29 and S. 30 at 19.00 chains “Enter wet prairie brs. E. & W.” and at 31.5 chains “Leave the prairie & enter crabapple thicket” on September 24, 1861.

DUW240404 (3 hectares). Tidal wetland on island of Duwamish River shown as forested on T-1406.

DUW240405 (43 hectares). Willow and crabapple thickets that are continuous with and upstream of the tide prairies of DUW240403. In the area of South Park and SE Georgetown. Northward between S. 29 and S. 30 at 31.50 chains “Leave the prairie & enter crabapple thicket” then at 35.50 chains “leave the thicket & enter [illegible] cotton-wood timber.” At 65.00 chains “In’ct. willow & crabapple thicket E. & W.” on September 24, 1861. Eastward between S. 29 & S. 32 at 8.50 chains “Enter willow & crabapple thicket wet land brs. N. & S.” and at 24.00 chains “Leave the thicket and wet land, enter fir and alder timber N. & S.” At 32.00 chains “Enter low wet land and crabapple thicket N. & S.” and at 44.00 chains “Leave the wet land and thicket & enter a small prairie b’ring N & S...” The line description includes “Land nearly level. Soil 1st rate. In places liable to inundation 30 in.” on August 15, 1861.

DUW240406 (32 hectares). Similar to DUW240405. Northward between S. 29 and S. 30 at 65.00 chains “In’ct. willow & crabapple thicket E. & W.” on September 24, 1861. Line notes between S. 29 and S. 20, from September 26, 1861: “Land on w. side of Dawamish river [almost entirely within map unit DUW240406], in places low and liable to inundation, 30 or 40 ins.”

DUW240407 (24 hectares). Within S. 33 of T23 N R4E, and not shown on GLO map. Wetland is drawn with generalized boundary to include locations of notations on Army Corps of

Engineers 1907 flood map “marsh” and “swamp.” Wetland is likely larger; GLO survey was conducted in dry months of August and September 1861, and mentions wet areas: Between S. 32 and S. 33, on August 5, 1861 “In places wet, liable to inundation 20 or 30 in....” On August 15, 1861, between S. 29 and S. 32, “...in places wet liable to inundation 30 in.” On September 22, 1861, northward between S. 28 and S. 29 at 15.5 chains “Enter the margins of low bottom land liable to inundation 20 or 30 in.”

DUW240408 (4 hectares). Marsh southeast of South Park and near to river. Westward between S. 4 and S. 33 (T23NR4E) at 45.00 chains “Enter Swamp of about 15 acres brs. N. 70 W.” and at 53.83 chains “Leave [Swamp of about 15 acres brs. N. 70 W.]” on September 9, 1861.

DUW240409 (15 hectares). Cranberry marsh south (upstream) of South Park. Northward between S. 32 & S. 33 at 9.5 chains (plat map shows the marsh beginning at 0 chains) “Enter a swamp brs. N. 70 W.” and at 10.5 chains “Leave the [swamp brs. N. 70 W];” the line description includes “Land nearly level. Soil 1st rate, in places wet, liable to inundation 20 or 30 in.” on August 15, 1861. Westward between S. 32 and S. 5 (T23NR4E) at 21.00 chains “Enter cranberry marsh, descends E. & brs. N. E.” and at 31.50 chains “Leave cranberry marsh N. E. and Enter fine growth of fir & cedar timber brs. N. E.” on August 15, 1861.

DUW230401 (61 hectares). Northward between S. 3 and S. 4 at 37.15 chains “Intersect Swamp brs. N.20E.” and at 55.00 chains “Leave Swamp brs. E. & W.” on June 4, 1862. Eastward between S. 3 and S. 10 at 41.00 chains “Intersect a swamp brs. N & S.” and at 48.00 chains “Leave the swamp and ascend” on June 2, 1862. Northward extension of wetland appears on USGS 1905 (?) quadrangle. On Army Corps of Engineers 1907 flood map: “Ground 4’ under water.”

DUW230402 (13 hectares). Appears on USGS 1895 topographic map. Army Corps of Engineers 1907 flood map: “Low and marshy” and “Average 6’ under water.”

DUW230403 (38 hectares). Within S. 10. On Army Corps of Engineers 1907 flood map: “Very low here. 12’ to 15’ water at high flood. Water remained here all winter” and “Low marshy ground” and “Water up to shingles on house near here.”

DUW230404 (30 hectares). Eastward between S. 10 and S. 15 at 65.00 chains “Intersect the Swamp brs. S. 20 E.” and at 75.00 chains “Leave the Swamp” on May 29, 1862. Army Corps of Engineers 1907 flood map: “4 to 7 ft. water here in high flood.”

DUW230405 (10 hectares). Eastward between S. 4 and S. 9 at 67.83 chains “Intersect a swamp brs. N. & S.” and at 77.5 chains “Leave the swamp” on June 10, 1862. Northward between S. 14 and S. 15 at 49.50 chains “Intersect Swampy bottom brs. N. 20 W.” and at 76.00 chains “Ascend dry rich bottom.” The line description for the latter transect includes “Land: bottom level. Soil 1st rate liable to inundation 15 to 30 in.” on May 20, 1862.

BLK230501 (119 hectares). Shown on plat maps as three patches, one in the middle of S. 8, with a stream that drains it to Lake Washington, a second along Lake Washington in the NW of S. 8 and NE of S. 7, and at the Black River where it exits Lake Washington. The 1895 Tacoma USGS topographic quadrangle shows a single wetland that encompasses the first two wetland patches and links to the third; the wetland complex is mapped as a single unit. A small part of the southern margin was added to the unit from its appearance in the 1940 aerial photos.

WHT_LOW230502 (122 hectares). West between S. 19 (T23NR5E) and S. 30 (T23NR5E) at 35.00 chains “Intersected impassable swampy bottom overflowed by Beaver dams bears N29W and South....I run an offset line as follows South 5.00 chs. To overflowed bottom land, less swampy” and at 45.00 chains “Leave overflowed bottom and enter Willow thicket.” The line notes include “...liable to annual inundation to the depth of 30 inches” on January 21, 1865. Northward between S. 19 and S. 24 (T23NR4E) at 8.20 chains “A wet prairie brs. N. E.” and at 20.00 chains “Leave wet prairie and enter willow and alder thicket bears E & W” and at 23.00 chains “Leave willow and alder thicket and enter timber.” The line notes indicate “...in places liable to inundation 24 in. seldom overflows” on July 26, 1861.

WHT_LOW230503 (12 hectares). North between S. 31 and S. 36 at 45.00 chains “Enter Swampy bottom N. & S.” Line notes describe “Land level. Soil 1st rate, last 35 chs. Subject to inundation 15 in.” on July 24, 1861.

WHT_LOW230504 (31 hectares). Within interior of S. 31 and not described by GLO or shown on Tacoma 1895 topographic map. Most of area appears forested on 1940 aerial photograph.

WHT_LOW230406 (159 hectares). Southcenter Mall area. The wetland as mapped appears on the Tacoma 1895 USGS topographic sheet. In the GLO notes, northward between S. 25 and S. 26, the line description includes “Land nearly level, in places wet. Liable to inundation 36 in.” on February 14, 1862.

WHT_LOW230407 (9 hectares). Appears on USGS topographic map Renton 1994. The wetland is within S. 25 and not described by the GLO surveyors.

WHT_LOW220401 (112 hectares). Northward between S. 2 and S. 3 at 52.00 chains “Leave the cranberry marsh brs. S. 70 W & N 30 E” on April 18, 1863. Eastward between S. 3 and S. 10 at 38.00 chains “The foot of hill when intersect a cranberry marsh brs. N & S.” Northward between S. 10 and S. 11 on April 15, 1863, at 60.00 chains “Intersect an extensive Cranberry Marsh and about 300 acres brs. N 10 E & S 10 W.” Eastward between S. 2 and S. 11 at 5.00 chains “Leave the cranberry marsh.” The GLO plat map symbology includes numerous springs, not seen elsewhere in the study area.

WHT_LOW220402 (37 hectares). Eastward between S. 2 and S. 11 at 32.00 chains “Intersect a swamp brs. N 10 W & S 5 E” and at 60.00 chains “Leave the Swamp here brs. N. W.” on April 18, 1863.

WHT_LOW220403 (9 hectares). Eastward between S. 1 and S. 12 at 12.50 chains “Intersect low overflowed bottom water 30 in. deep runs N 45 W” and at 22.00 chains “Leave overflowed bottom” on April 9, 1863.

WHT_LOW220404 (60 hectares). The GLO notes indicate eastward between S. 1 and S. 12 at 57.00 chains “Intersect overflowed bottom brs. N 10 E & S 10 W” and at 68.00 chains “Leave overflowed bottom brs. N & S” on April 9, 1863. Northward between S. 1 and S. 6 at 23.00 chains “Enter willow swamp” on July 2, 1861. Northward between S. 7 and S. 12 at 54.50 chains “Enter swamp” and at 63.00 chains “Leave” on July 1, 1861.

WHT_LOW220405 (20 hectares). Eastward between S. 11 and S. 14 at 50.64 chains “Intersect a swamp brs. N.W. & S. E.” and at 69.00 chains “Leave the swamp” on April 15, 1863.

WHT_LOW220406 (1 hectare). Northward between S. 7 and S. 12 at 30.15 chains “Enter swamp” and at 34.00 chains “Leave.”

WHT_LOW220407 (4 hectares). Eastward between S. 12 and S. 13 at 70.00 chains “Intersect swamp brs. N & S” on April 9, 1863.

WHT_LOW220408 (10 hectares). Northward between S. 13 & S. 14 at 42.00 chains “Intersect Swamp brs. 70 E & N 75 W” and at 55.00 chains “Leave swamp” on April 3, 1863.

WHT_LOW220409 (27 hectares). Eastward between S. 14 and S. 23 at 35.00 chains “Intersect a swamp brs. N 10 E & S 10 W” and at 59.00 chains “Leave the swamp” on April 14, 1863.

WHT_LOW220410 (30 hectares). Eastward between S. 13 and S. 24 at 68.00 chains “Swampy bottom brs. N. 5 E. & S. 5 W.” on April 2, 1863. Northward between S. 13 and S. 18 at 25.00 chains “Leave Swamp” on July 2, 1863.

WHT_LOW220411 (464 hectares). Mill Creek area marsh. Most of map unit was mapped by GLO survey; additional area to the west and north is shown in NWI mapping. Eastward between S. 26 and S. 35 at 38.00 chains “Intersected overflowed land & a deadening on White River bottom brs N. 15 E. and N. 15 W.” on April 11, 1863. Northward between S. 25 and S. 26 at 45.00 chains “Leave the overflowed bottom brs. S. 15 E. & N. 80 W.” on March 31, 1863. Eastward between S. 25 and S. 36 at 20.00 chains “Leave the overflowed deadening here brs. N. 10 W. & S. 10 E.” Northward between S. 35 and S. 36 “The line begins in a deadening of overflowed bottom the western border of which brs. N 20 W.” and at 80.00 chains “...in water 12 in. deep running N. 20 W.” on March 30, 1863. Westward between S. 1 and S. 36 at 10.50

chains “Small prairie ____ two acres brs. N & S” and at 14.00 chains “Leave the prairie & enter thicket [both witness trees at 40 chains are 3” diameter willows]” on March 25, 1863.

WHT_LOW220412 (25 hectares). Eastward between S. 25 and S. 36 at 70.00 chains “Intersect W. overflowed bottom N. & S.” on March 31, 1863. Northward between S. 31 and S. 36 at 49.00 chains “Enter swamp [at 80.00 chains witness trees include two willows and two ash].”

WHT_LOW220413 (46 hectares). Within the interior of S. 15; south of and adjacent to pond mapped by GLO. Most of the pond is mapped as wetland on USGS Des Moines 1995 topographic. The northern part of is shown on the Des Moines quadrangle and in the NWI, and the southern part on the NWI only.

WHT_LOW210501 (17 hectares). Westward between S. 7 and S. 18 at 63.92 chains “...at this point leave open land and enter gooseberry thicket” on September 24, 1867.

WHT_LOW210402 (23 hectares). Mapped from NWI.

WHT_LOW210401 (358 hectares). This large wetland map unit has been created by linking six areas mapped or described in the GLO maps and notes. Areas not mapped by GLO were either mapped by the NWI survey or shown as organic soils in the 1971 soils mapping. The GLO field notes include: northward between S. 23 and S. 24 at 38.18 chains “...leave swamp and enter open dead timber” on October 8, 1867. Eastward between S. 24 and S. 25 at 35.00 chains “Leave brush & swamp and enter timber bears N & S” on October 7, 1867. East between S. 13 and S. 24 on October 8, 1867, at 19.84 chains “a Slough, water stagnant caused by Beaver dams bears N & S,” at 35.00 chains “Leave Slough,” at 60.00 chains “Leave swamp and enter vine maple brush.”

The line description includes “Land level, good soil wet, underbrush Vine maple & willow.”

This map unit is continuous with *PUY210403*. GLO notes for *PUY210403* include: northward between S. 25 and S. 26 at 16.00 chains “Leave thick brush & enter cranberry marsh scattering brush and timber” and at 46.00 chains “Leave cranberry marsh and enter thick brush.” The line description includes “underbrush black birch willow & hardhack” on October 7, 1867.