FINAL REPORT:
Paleoecology of Fort Vancouver

Fort Vancouver is located on the Fort Plain Prairie, the lowest of several terraces deposited by Missoula floods at the end of the last glaciation. The Plain, surrounding landscapes, and nearby archaeological sites (Figure 1) provide an opportunity to assess the potential of paleoecological analyses to reconstruct past human uses of plant materials, past vegetation, and past fire regimes. The goals of this research were to: 1) evaluate whether plants used by Fort Vancouver residents can be identified through analysis of soil pollen in archaeological sites, and 2) reconstruct vegetation and fire

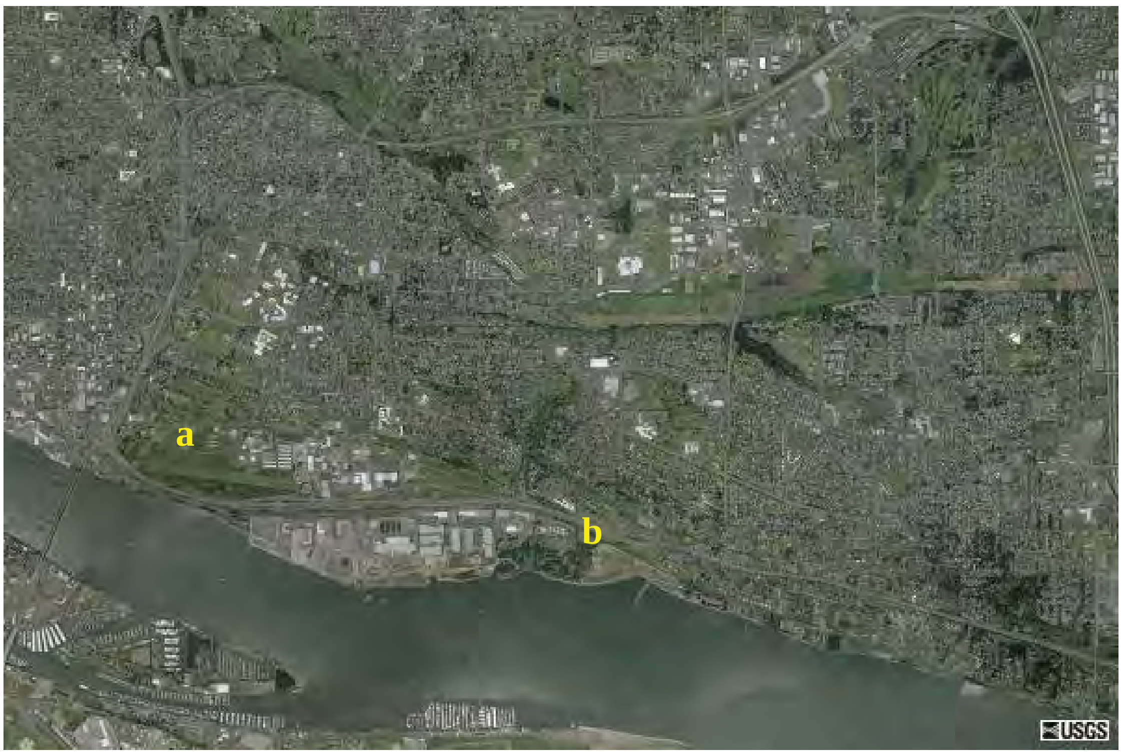


Figure 1. Aerial photograph of the Fort Vancouver (a) and wetland site (b) used for paleoecological analyses.

history at the extreme eastern edge of the Fort Plain Prairie through the analysis of pollen and charcoal in wetland sediments. This report is organized around these two goals, with separate analyses and interpretations of materials from 1) archaeological samples and 2) a wetland site at the eastern edge of the Plain (Figure 1).

Study Area History and Current Status:

In 1824 Governor Simpson of the Hudson's Bay Company established the Hudson's Bay Company headquarters at the Fort Vancouver site (Figure 2), writing that "a farm to any extent may be made there, the pasture is good" and that there were "many nutricious roots" for swine herds to feed on (Hussey 1957). This statement suggests that the site was not covered by dense conifer forests, which was the typical landcover of lowlands west of the Cascade Range in Washington. Soon thereafter, EuroAmerican activities altered the environment of the Plain and surrounding area. By 1828 there was a burgeoning lumber industry, and by the mid-19th century shipbuilding activities were located on the site. However, by the 1840's settlers began to bypass the Fort on their way to the Willamette Valley. Eventually the headquarters of the Hudson's Bay Company were moved, and the Fort was destroyed by fire in 1865 (Hussey 1957). In June 1894 a major flood (Figure 3) reached > 36 ft above the current level of the Columbia River, inundating much of Portland (Figure 4) and the Fort Plain Prairie. In 1907 the railroad was constructed at the southern edge of the Fort Vancouver grounds. This rail line currently forms the northern border of the wetland site cored in this study. Thereafter, the city of Vancouver grew rapidly, and in the mid 20th century Washington State Highway 14 was expanded parallel to the railroad. The Fort Vancouver site was also actively used by the United States military during the Second World War.

Figure 2. Fort Plain Prairie ~1928.

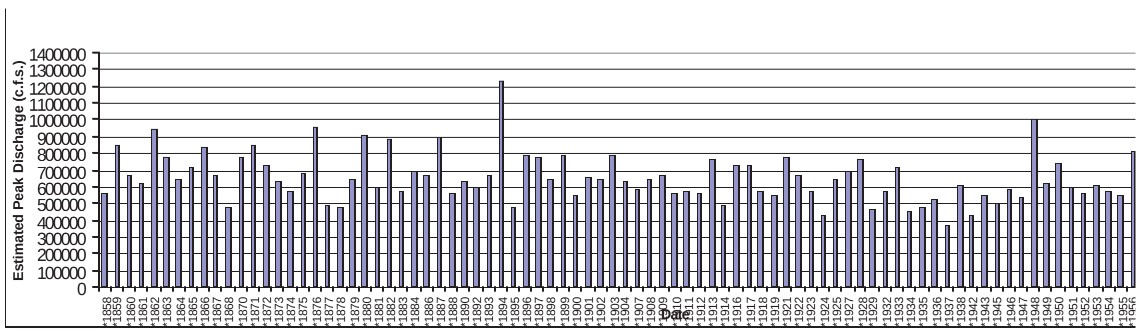


Figure 3. Columbia River flow (1858-1956), showing highest flow in 1894.

The Fort Vancouver site, in the western portion of the Plain, is approximately 30 ft above the water level of the current Columbia River. Its current vegetation is mowed grass fields with areas of restored prairie forbs. Dense urban developments surround Fort Vancouver, with the transition to second-growth Douglas-fir forests >10 km from the site.

Figure 4. Photograph of Portland during the flood of 1894.

The wetland coring site is located at the extreme eastern edge of the same terrace. The wetland is bounded by the railroad and State Highway 14 to the north, a sewage treatment facility to the west, and new constructions to the east. The current wetland vegetation is dominated by grasses (Poaceae), sedges (Cyperaceae), cattail (*Typha*), and numerous other wetland plant taxa. The wetland is rimmed by stands of black cottonwood (*Populus trichocarpa*).

Research Rationale:

Archaeological samples: In theory, pollen analysis of soil samples from the floors of human dwellings offers the potential to identify plant materials used for food and household items. Differences between pollen in dwelling floors versus natural sedimentary deposits may reveal plant taxa used by human residents. Unfortunately, pollen is poorly preserved in the dry, oxidizing environments that are typical of soil surfaces. Thus the preservation of pollen in floor surfaces must be verified by a preliminary study such as this before a large-scale study can be initiated to reconstruct past human uses of plant materials based on soil pollen.

Wetland site: The analysis of pollen and charcoal in small wetlands and lakes can reveal changes in fire regimes and vegetation related to climate and human impacts. There is a strong theoretical and empirical basis for interpreting these types of records (e.g., Higuera *et al.* 2005, Bunting *et al.* 2004, Bronström *et al.* 2004, Sugita 1994, 1993). The primary uncertainty in interpreting these types of records results from the ambiguity of attributing past vegetation and fire regimes to human versus climatic controls.

Methods:

Archaeological samples:

The archaeological soil samples were collected during field excavations in 2002 (Figure 5). Most of the samples received for pollen analysis were extracted from larger sediment samples taken in 50x50 cm quadrants, 1-3 mm deep at the beginning of each excavation level. Three other samples were collected exclusively for pollen analysis from specific contexts: underneath a plank of wood (#219), a sediment feature of interest (#703) and a pit feature (#22) from Fort Clatsop near Astoria, Oregon. Although not a part of the proposed research, the Fort Clatsop sample provided an opportunity to evaluate whether pollen might be preserved in pit features of this region.

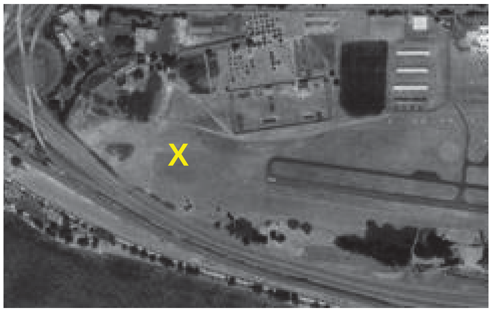
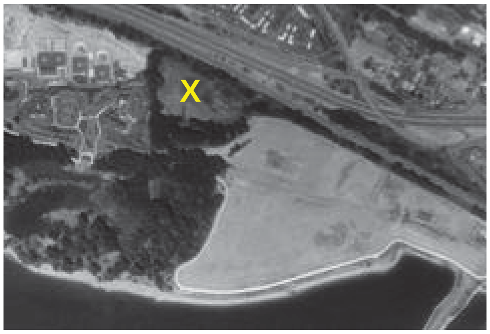


Figure 5. Aerial photograph of Fort Vancouver. Approximate location of the archeological samples is indicated by the X.



Figrue 6. Aerial photograph of wetland cored. Coring site is indicated by the X.

Attempt 1:
Six of the archaeological soil samples

(FOVA 3011 #222, #477, #556, #398, #688, #734) were chosen to be processed and analyzed for pollen based on visual inspection of the sediment matrix, in an attempt to avoid high amounts of sand, gravel and other coarse grained materials that indicate poor preservation context. Six cubic centimeters of sediment was processed from each sample according to pollen extraction procedures adapted from Faegri and Iveresen (1964). Halfway through the process, a small amount of pollen was present in some samples, but by completion not enough pollen was present to allow analysis of any sample.

Attempt 2:
Two samples collected from specific archaeological contexts (FOVA 3011 #219 and #703) were chosen for processing. Ten cubic centimeters of dry sediment was processed for each sample. The pollen extraction was followed as above, with the addition of a heavy liquids gravity separation procedure. For this procedure, each sample was soaked in a solution of sodium poly-tungstate with a specific gravity of 2.0. This results in the flotation of pollen grains while more massive, mineral particles sink. The supernatant (including pollen) was then sieved through a glass filter using a Buchner suction funnel system. The glass filter was then digested by hydrofluoric acid releasing any trapped pollen grains and organic matter. At this stage in sample #219, a small amount of identifiable pollen was recognized. There appeared to be no pollen present in sample #703. Both samples were processed through acetolysis and staining before being stored in silicone oil. Upon examination under the microscope, there was not enough pollen in either sample for identification and analysis.

Attempt 3:
Sediment from the pit feature at Fort Clatsop (FOCL 125 #22) was sub sampled for pollen extraction. Five cubic centimeters of sediment was processed as outlined above including a gravity separation in sodium poly-tungstate before acetolysis, staining, and storage in silicone oil. This sample contained sufficient pollen and spores for counting.

<u>Wetland core</u>:

Field collection:
In late spring 2002, a 126 cm core was retrieved from the center of the wetland east of the Water Resource Facility (Figure 6), using a modified Gavin sampler (Higuera *et al.* 2005). Core drives were extruded, described, and wrapped in saran wrap and aluminum foil in the field. The core was stored in a cold room at 4º C at the Quaternary Research Center, University of Washington.

Core Subsampling and Sediment Description:
The sediment core was sliced in 0.25 cm sections in the laboratory. A one cubic centimeter (1 cc) subsample was removed from each section for charcoal analysis. At every 5 cm, a 1cc subsample was also removed for pollen extraction and analysis.

Charcoal analysis:
Each 1 cc charcoal subsample was soaked for 3 days in a sodium metaphosphate solution to deflocculate clastic minerals. The sodium metaphosphate was then rinsed through a 53 micron sieve, and the residue on the sieve was soaked in hydrogen peroxide for 8 hours to bleach all non-charcoal organic materials. The samples were then rinsed through a series of nested screens, resulting in 3 classes of charcoal: >500 micron, 150-500 micron and 53-150 micron. The 2 largest size classes were examined under a dissecting microscope and the charcoal pieces tallied.

Pollen analysis:
Pollen was processed using a series of acid and base washes adapted from the generally accepted procedure presented by Faegri and Iversen (1964), including acetolysis. For each sample, a known concentrate of *Lycopodium* spores was added. The pollen grains were stained using safranin and stored in silicone oil. From each sample, one or more slides were made and approximately 300 pollen grains per sample were identified and counted under 400x magnification. Identification of crumpled or corroded grains was made at 1000x magnification. Pollen concentrations per sample were calculated from the ratio of pollen to *Lycopodium* spores. Pollen and spore percentages are expressed as percent of total pollen.

Radiocarbon dating:
An Accelerator Mass Spectrometry (AMS) date was obtained from a macrofossil (unknown seed) extracted at the bottom of the core (126 cm). The seed was processed through a series of acid washes before being sent to Lawrence Livermore Laboratories to be dated. An attempt was made to isolate pollen (following the protocol outlined by Brown 1994) and other macrofossils for dating, but these attempts failed and no other dates were obtained.

Results and Interpretations:

<u>Archaeological Samples</u>:

With one exception, the archaeological samples contained no pollen or so few pollen grains that interpretations were not possible. Only FOCL 125 #22 contained sufficient pollen for analysis (Table 1). The pollen and spores in this sample likely reflect the general vegetation from the area around Fort Clatsop rather than human exploitation of specific plant materials. In particular, the high percentage of alder pollen is expected in a disturbed, open area with moist soils. Alder has a high pollen production rate and often saturates pollen records. Unfortunately, plants that are important for

TALBE I

Taxa	Count	Percentage
Pine undiff:	5	1.71
Western hemlock:	14	4.79
Spruce:	2	0.68
True fir:	0.5	0.17
Cedar-type:	2	0.68
Alder Undiff:	265	90.60
Willow:	3	1.03
Rose family:	1	0.34
Sedge family:	2	0.68
Aster type:	1	0.34
Mustard type:	1	0.34
Cattail type:	1	0.34
Monolete spores:	138	47.18
Bumpy monolete:	17	5.81
Trilete spores:	1	0.34
Bracken fern:	7	2.39
Unknown:	2	0.68
Unidentifiable:	9	3.08
Total Pollen grains:	462.5	n/a
Lycopodium tracers:	57	12.32

human foods are typically insect pollinated and produce little pollen. As a result, food plants are poorly represented in sediment records (Dincauze 2000).

Wetland core:

Chronology:
The chronology for the wetland core is based on one AMS date of ~1150 AD on an unidentified seed at 126 cm and on the assignment of 1894 to the inorganic interval at ~65-82 cm and of 1865 to the charcoal peak at 84 cm. These dates are sufficient to infer approximate dates of major changes in the pollen and charcoal record. Additional radiocarbon dating of the record would not likely increase chronological control, since major changes in C^{14} content of the atmosphere result in ambiguous dating between *ca.* 1400 AD and present (Stuiver *et al.* 1998).

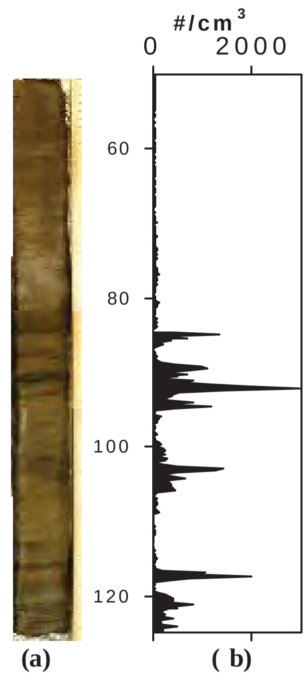


Figure 7: (a) Photograph of wetland core (50-126 cm sediment depth) showing gray silts ~65-82 cm and numerous dark charcoal bands below 82 cm. (b) Charcoal concentrations (50-126 cm).

Sediment stratigraphy and interpretation:
The 126 cm core is easily divided visually into two distinct sections. Sediments between 126 and ~ 82cm are characterized by fine organic material with several alternating dark and light layers. From ~65 to the surface, the core is uniformly dominated by coarse organic material. A distinct layer (~65-82 cm) of light-gray silty sediment separates these major stratigraphic units (Figure 7).

Charcoal stratigraphy and fire history:
Charcoal concentrations varied between 20- 3500 pieces/cm^3 (Figures 7- 9). Distinct peaks (>1000 pieces pieces/cm^3) occurred below ~82 cm, but charcoal concentrations were uniformly low (<100 pieces/cm^3) in samples above this level.

Our interpretation of past fire regimes relies on the findings of Higuera *et al.*'s (2005) calibration study, which documented charcoal records of different-severity fires within 50 m of small wetlands on Orcas Island, Washington. All high severity fires resulted in distinct charcoal peaks, but mixed and low severity left distinct peaks in only 50% of the cases. Charcoal peaks unrelated to nearby fires were rare (~3%). These results suggest that most charcoal peaks at the Fort Plain wetland represent high-severity fires that killed all or most trees near the site; some of the charcoal peaks may represent mixed severity or low severity fires and some fire events may be missing from the record.

We interpret that the charcoal peak immediately below the inorganic (1894 flood) layer records the major conflagration of Fort Vancouver in 1865. The series of 3 closely spaced charcoal peaks 90-95cm may represent one fire with irregular charcoal deposition or 3 separate fires closely spaced in time. The Yacolt burns in the early 20^{th} century indicate that repeated fires are possible in forests along this part of the Columbia River. If one assumes that the 3 closely-spaced charcoal peaks represent 3 fires and that 1-2 undetected fires occurred between 1150 and 1865 AD, the Mean Fire Return Interval (MFRI) for the lower portion of the core is ~ 90-100 years. A more conservative estimate of the MFRI for this period (the triple peaks represent 1 fire) is ~120 years. In both scenarios, the MFRI is lower than the typical estimates for the Western Hemlock Zone of western Washington (Agee 1993).

The extremely low charcoal concentrations and absence of charcoal peaks above the 1865 charcoal peak indicates that fires have been rare over the past ~140 years.

Pollen and charcoal stratigraphy and inferred vegetation and fire history:
The pollen and charcoal record is divided into two zones, corresponding to the major sediment units described above (Figures 8 and 9).

<u>Zone 1 (~126 to 82 cm)</u>. Pollen assemblages are dominated (10-50%) by Douglas-fir (*Pseudotsuga menziesii*), pine (*Pinus*), sedge and grass, with moderate percentages (2-10%) of western hemlock (*Tsuga heterophylla*), cedar (Cupressaceae), ash (*Fraxinus*), and alder (*Alnus*). Oak (*Quercus*) pollen is consistently <2% of total pollen. Pollen percentages of other herbaceous and shrub taxa are very low (generally <1%).

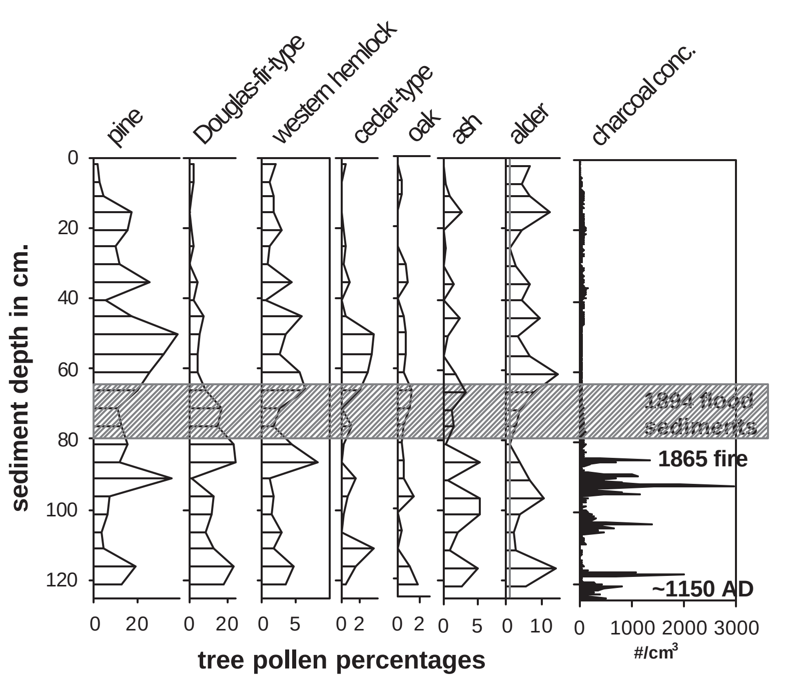


Figure 8. Wetland pollen and charcoal diagram showing tree pollen types. Shading indicates silty sediments deposited by the flood of 1894. Sediment stratigraphy and AMS date used to establish chronology are shown on right.

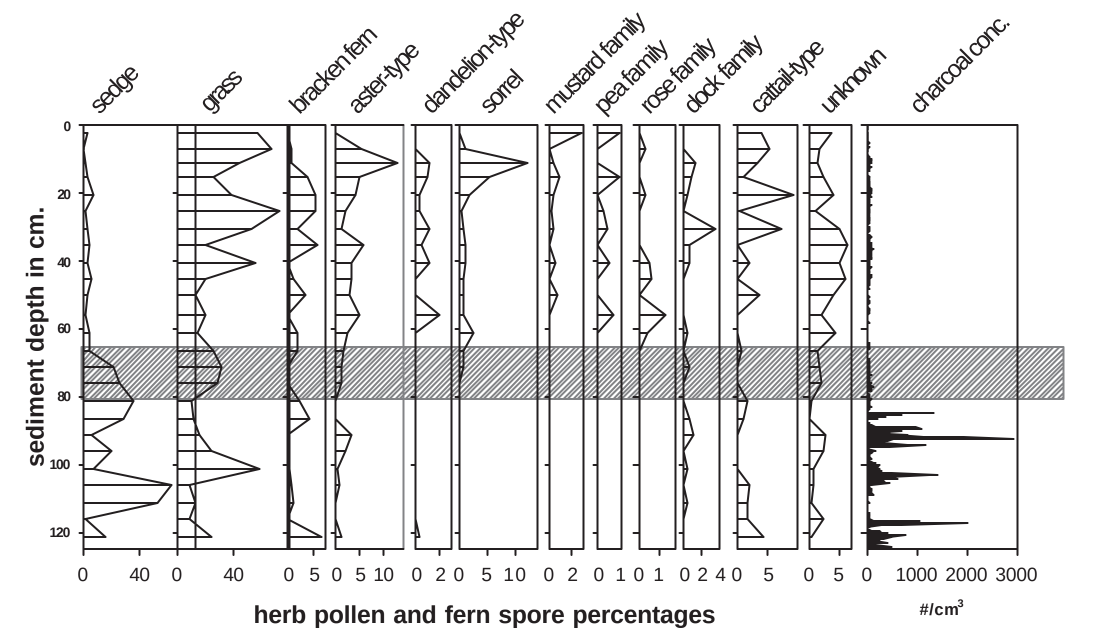


Figure 9. Wetland pollen and charcoal diagram showing herb pollen types and spores. Shading indicates silty sediments deposited by the flood of 1894.

This zone begins approximately 650 yrs before the arrival of EuroAmerican settlers at the Fort Vancouver site. The relatively high percentages of Douglas-fir pollen indicate that this species dominated forests near the wetland. Closed Douglas-fir forests probably covered the hills north of the prairie. The moderate pollen percentages of ash, a low pollen-producing species, suggest that the wetland was rimmed by ash trees. The minor amounts of oak pollen suggest that scattered oaks were present on the prairie. Sedge pollen most likely originated from plants growing on the wetland surface, as sedge species dominated PNW wetlands prior to major EuroAmerican disturbances (K. Ewing personal communication 2005). Though the moderate percentages of grass pollen may indicate grasslands or oak savannahs on the Fort Plain Prairie, it is impossible to rule out that grass pollen originated from species growing on the wetland surface. Unfortunately, the inability of pollen to distinguish between wetland and upland grass species limits the interpretation of vegetation during this period.

The numerous distinct charcoal peaks in Zone I indicate that fires repeatedly burned the vegetation near the site. Several factors suggest that these fires burned trees encroaching onto the prairie rather than burning solely herbaceous vegetation cover of the prairie. First, the location of the wetland at the transition between the hillslope and terrace landforms suggests that this site was at the ecotone between continuous forests and prairie/savannah. Second, the large magnitudes of the charcoal peaks suggest that fires burned woody vegetation rather than low fuels of grassland. Third, the intervals between charcoal peaks suggest MFRI of 100-200 years, which is more typical of forests than prairies. Fourth, the decline in Douglas-fir at ~90 cm corresponds to a large charcoal peak, suggesting that a major fire destroyed closed forests near the site. The increase in pine pollen percentages at this time probably reflects the reduction in local forest cover.

Pine pollen is dispersed long distances, and its percentages would increase due to the decrease in local pollen productivity. Thus the charcoal record of the wetland site probably reflects major fires that maintained the ecotone between prairie and forests.

This zone ends at the distinct interval of inorganic sediments (82-65 cm) with very low pollen concentrations (not shown). This interval undoubtedly records the Great Flood of June 1894, which inundated numerous towns along the Columbia, Snake and Fraser Rivers.

Zone 2: (~65 to 0 cm). This zone is characterized by decreased percentages of Douglas-fir (<10%), sedge (<10%), and ash (<~2%), and increased percentages grass (>~20%), aster-type (>~4%), dock-type (>~1%), cattail (>~4%), and unkown types (~5%). Pollen of several disturbance-adapted herbaceous taxa is restricted to this zone (e.g., sorrel (*Rumex acetosella*), mustard (Brassicaceae), pea (Fabaceae), rose (Rosaceae), dock (Plantagenaceae)). Pollen of other tree taxa remains relatively stable.

The diminishing percentages of Douglas-fir pollen reflect the extensive clear-cutting of nearby and regional forests. Some of the earliest logging activities in the Pacific Northwest occurred in this area, due to its prime location on the Columbia River near Portland. Logging and/or the construction of roads and railroads to the north of the wetland probably altered the hydrology of the site, resulting in a shift from sedge to grass species. Continued urbanization and the active use of the plain by the US military during World War Two allowed herbaceous, disturbance-adapted species to increase in the region and near the site. A definitive indication of these Euro-American impacts is the appearance and increase in sorrel, an invasive weedy species native to Europe. Sorrel pollen is a ubiquitous indicator of Euro-American land clearance in North America. As sorrel produces small amounts of pollen, it is likely that sorrel was present on the plain decades before it was abundant enough to show up in the pollen record. The first appearance of pollen of other herb taxa favored by disturbance (e.g. rose, pea, mustard) support the conclusion of increased human impacts.

The scarcity of charcoal in Zone 2 reflects the effects of forest removal, urbanization, and fire suppression. With the loss of forests and their replacement by urban developments where fires are actively suppressed, few fires burned near the wetland.

ASSESSMENT:

Interpreting the records:

Archaeological samples:
The absence or extremely low concentrations of pollen in most archeological samples is consistent with previous observations that pollen preservation in soils is poor due to bacteria, oxidation, decay and desiccation (Dincauze 2000). The only sample with good pollen preservation is from a pit feature at Fort Clatsop. Pit features are likely to provide anaerobic or acidic conditions that preserve pollen. However, pollen recovered from a pit feature does not necessarily indicate that the identified taxa were used by humans. Pits

often reflect vegetation assemblages from the surrounding area only at a different level of preservation than nearby soils (Lennstrom and Hastorf 1995). In order to draw conclusions about human exploitation of plant materials recovered from a pit feature, the context of the pit feature within the site and any associated artifacts should also be considered (Lennstrom and Hastorf 1995). The pollen assemblage of this sample shows strong similarity to modern regional pollen samples from the Pacific Northwest (Minckley and Whitlock 2000). Particularly, the high percentage of alder (90%) is indicative of highly disturbed, post settlement forests in western Washington and Oregon. The virtual absence of pollen and spore types associated with human foods (e.g., mustard family, pea family, rose family, bracken fern) indicates that these samples do not contain evidence of past human plant exploitation.

Wetland site:
The undisturbed stratigraphy and the excellent pollen and charcoal preservation of the wetland core allowa a rich reconstruction of the vegetation and disturbance history of this site. Prior to the arrival of EuroAmerican settlers, Douglas-fir forests dominated uplands north of the wetland and the Fort Plain Prairie, Oregon white oak probably occurred as scattered trees on the Fort Plain Prairie, and Oregon ash was common at the wetland's edge. Fires repeatedly burned the vegetation near the site, maintaining the ecotone between the prairie and adjacent forests. The Great Flood of 1894 deposited a thick silt layer on the wetland. The pollen and charcoal record following this event indicate extensive deforestation, reduced importance of fires, altered wetland hydrology and increase in disturbance-adapted species. All of these changes can be attributed to the increasing impacts of EuroAmerican activities.

<u>Future Research Potential.</u>

Archaeological Samples:
Based on the poor pollen preservation and lack of distinctive pollen assemblages in archaeological samples, we see little potential for interpreting human uses of plant materials through pollen analyses of samples from dwelling floors and materials associated with human artifacts. Isolating sufficient pollen from soil samples requires very large bulk samples that are costly and time consuming to process. Bryant and Hall (1993) recommend that interpretations not be made on pollen samples from archaeological sites when the samples are characterized by identified grains from only a few taxa, low overall concentration levels and high percentages of unidentifiable grains. Under poor preservation environments, pollen grains will be more structurally durable and/or more easily identifiable in a decayed state leading to biased data (Bryant and Hall 1993). Even in archaeological sites with excellent preservation conditions, recovery of sufficient pollen for analysis is rare (Bryant and Hall 1993).

Wetland Site:
This wetland offers excellent potential for reconstructing past vegetation, extreme floods and fire events. Pollen is well preserved, and charcoal and flood deposits occur in distinct, recognizable layers. Given the emphasis of this study on the recent past, we did not attempt to determine the depth of the sediment record. Nevertheless, it is reasonable

to assume that this site contains a multi-millennial record of vegetation and disturbance regimes of the eastern Fort Plain Prairie.

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