REPORT ON BUSH'S PASTURE PARK OAK WOODLAND

SOIL CONTDITIONS AND GENERAL ANALYSIS

MISSION STREET PARKS
CONSERVANCY

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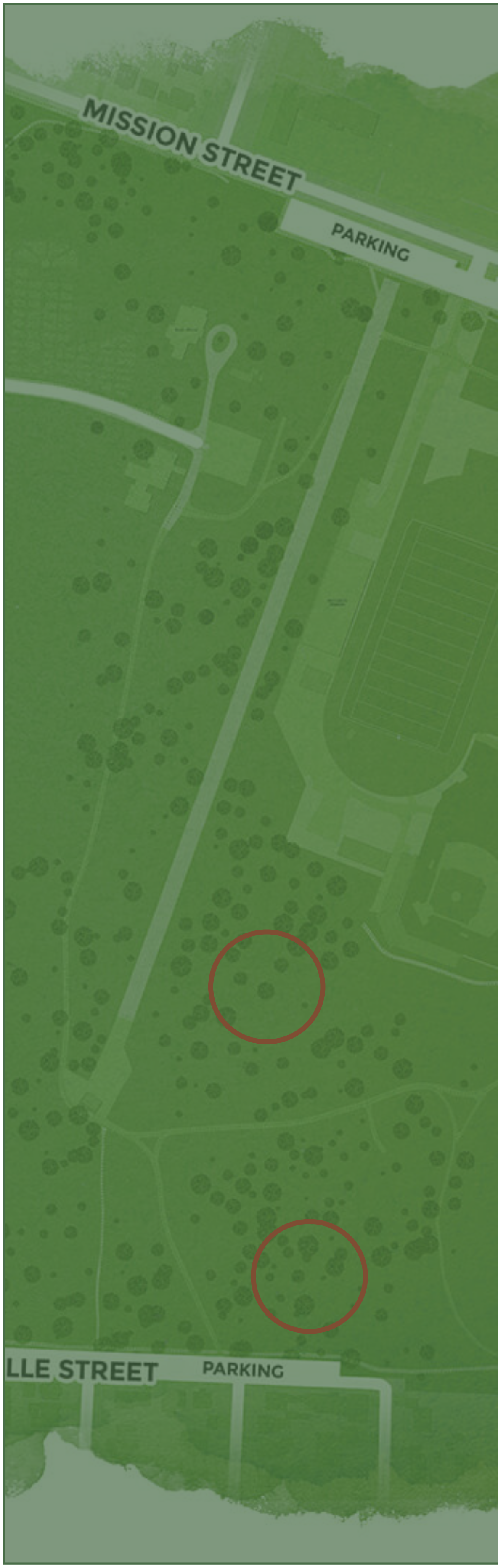

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1. INTRODUCTION

Arboriculture International LLC, Emergent Tree Works LLC and Native Ecosystems Northwest LLC (hereafter referred to as 'the consulting arborists') have been retained by Mission Street Parks Conservancy (hereafter referred to as MSPC) to create a narrative report detailing conditions and recommendations for the management of Oregon White Oak (*Quercus garryana*) woodlands (hereafter referred to as Oak woodlands) in Bush's Pasture Park in Salem, Oregon. This agreement grew out of discussions between Michael Slater, Ellen Stevens and others with knowledge of the Oak woodlands on site on August 15th, 2018. Based on this site visit and subsequent correspondence, a formal proposal for services was submitted on September 13th, 2018 **(see Appendix document 1)** and accepted by MSPC shortly afterward. Field work for this report took place between October 2018 and March 2019.

Key components of this report include:

- Soil analysis to determine nutrient availability, density, and composition;
- Tree stand analysis to understand long-term succession needs;
- Analysis of major human impacts on the White Oaks; and,
- Recommendations for management of the park to promote health and resiliency of the Oak woodlands.

1.1 Purpose

The goal of this report is to provide the opinion of the consulting arborists on the condition of the Oak woodlands at Bush's Pasture Park. These opinions will be largely qualitative in nature and will be presented in narrative form, though relevant data collected from the field, historical documents, and outside analysis will be referenced. Relevant data and documents will be included in the appendix. The purpose of the report is to provide the opinions of the consulting arborists into the condition of the Oak woodland, and what might be done to maintain and improve that condition in the future. Historical information will be considered as it pertains to the current condition of the Oak woodland, but providing opinions on past management decisions is not a main goal. Important facts and history may not be included in this report, and the pages below should not be considered the final word on historical nor current conditions of the trees in the park. The consulting arborists aim to provide professional opinions and create vital context inform managers of this park for future management decisions.

1.2 Disclaimers

This report was prepared the MSPC. The content presented in this report is property of the authors. Unless otherwise specified, permission to reference or to include a URL to reference this information for non-commercial purposes is permitted, provided that each reference acknowledges that this information is the work of the authors listed on page 1 of this report.

This report is not a tree inventory, nor is it a tree risk assessment. When we have encountered obvious hazards, we have reported them to MSPC representatives, but none of our work should be considered as an analysis or endorsement of the safety or stability of any specific tree or grove at Bush's Pasture Park. The consulting arborists emphasize that trees are dynamic, living beings and make no guarantees as to the current or future viability of specific trees or groves at Bush's Pasture Park.

The consulting arborists will make themselves available to answer reasonable questions arising from this report. However, they are not presently retained for any future consultations by MSPC, and submission of this report will constitute completion of their obligations as outlined in the original proposal for services.

Additionally, though we have taken measurements and provided objective data to backup elements of the report, the consulting arborists stress that this report is fundamentally a work of opinion, and therefore subjective.

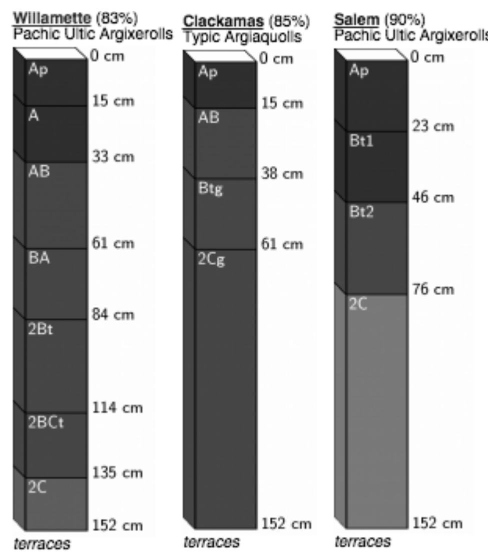
2. SETTING

2.1 Park Profile

Bush's Pasture Park covers 90.5 acres and is located south of downtown Salem. The park's terrain is typical valley terrain with an upland terraced plateau and relief to lower flatland that is influenced by a shallow channeled creek. The terraced slope is approximately 12%, descending east and flanking from the north to south. Site elevation ranges from 215 feet to 142 feet above mean sea level (msl). It is characterized by Oregon . hite Oaks (*Quercus garryana*), Douglas-fir (*Pseudotsuga menziesii*) and camas (*Camassia quamash*) fields. Understory plants consist of snowberry (*Symphoricarpos albus)*, Indian plum (*Oemleria cerasiformis*), thimbleberry (*Rubus parviflorus*), cascara (*Rhamnus purshiana*), serviceberry (*Amelanchier alnifolia*), Oregon grape (*Mahonia aquifolium)*, poison oak (*Taxicodendron diversilobum*) and patches of licorice fern (*Polypodium glycyrrhiza*). Bush's Pasture Park's annual precipitation is 40-45 inches. The annual temperature is 52 to 54 degrees F. The length of the frost-free season is 200 to 210 days. These climatic conditions are synonymous with Oregon White Oak growing conditions.

2.2 Soils

The park is underlain by three main types of surface soil. These soils vary in composition and drainage potential due to factors such as past floods, erosion and climate. The three main types of soil are Willamette silt loam (WIA), Salem gravelly silt loam (Sa), and Clackamas gravelly loam (Ck). There are two other soil types in the park, (Am) and (2224A), but (WIA), (Sa) and (Ck) are the focus of this report. All three soil types are commonly found to range in elevations between 100 and 600 feet.



SoilWeb: Soil profiles from Ca Soil Resource lab, 2008. USDA-NCSS SSURGO and STATSGO Soil Survey Products.
Soil Survey of the Marion County Area, Oregon 1972 – nrcs.usda.gov

2.3 Oregon White Oak, (*Quercus garryana)*

This report focuses on the portions of the park dominated by Oregon White Oak, which is the climax species for large portions of the upper Willamette Valley. To understand healthy Oregon White Oak woodlands, we must first consider the environments they prefer. This species thrives in poorly drained clay, silt and loam soils found throughout lowland valleys of Oregon and Washington. The native range for this species extends from southern British Columbia (lat 49° N) to southern California (lat 34° N). This species is also well known for thriving in challenging conditions, including south facing rocky outcroppings where few other tree species can survive. Associated tree species such as Pacific madrone, Oregon ash, Douglas-fir, white alder, serviceberry and big-leaf maple are frequently found growing in mixed Oak groves, and the presence or absence of these related species provide clues to the climatic and soil conditions of the Oak habitat.

Fire suppression regimens introduced in the 19th century have significantly altered many Oregon White Oak habitats, and more recent 'Oak release' projects have attempted to mimic the effects of fire to these ecosystems by removing or disadvantaging competing tree species, especially Douglas-fir.

2.4 Rooting Habit
Oregon White Oaks often have a deep taproot and well-developed lateral root system; they are generally wind firm even in wet areas. Fast taproot extension and sparse development of laterals are shown by seedlings in the first few weeks of growth. However, as the tree matures a high percentage of Oak roots are found in upper soil layers. In an OSU study, only 11 percent of the total number of Oak roots were found below 30 inches in depth in Willakenzie soil. In contrast, 28 percent of the total Douglas-fir roots in the same soil were found below 30 inches. Oregon White Oaks therefore should be considered relatively vulnerable to damage from soil compaction.

2.5 Climate
Oregon White Oak grows across a diverse range of climates, most of which have moderate to extreme summer drought. Oregon White Oaks are well adapted to hot, dry conditions. With adequate moisture early in the season, relatively large trees may develop on sites where severe summer drought limits other species. Extensive stands of small, shrubby Oregon White Oak, often mixed with Pacific madrone (*Arbutus menziesii*), will grow on sites too dry to support other tree species.

2.6 Conclusion
The Oak woodlands at Bush's Pasture Park represent a rare and cherished link to the past. Although these lands have been managed for centuries, first by Native American tribes and more recently by agriculturalists and municipal park managers, a direct line exists from the Oregon White Oak ecosystem which has thrived here for millennia and the state of the park today. The trees in this park are in an environment they are well suited to, and the trees at this site likely derive from the exact provenance where they grow today. This sort of continuity is incredibly rare in the center of an urban space and adds to the value of this already invaluable resource.

3. SAMPLE SITE DESCRIPTIONS

Eight sample sites were chosen throughout the park. Sites were arbitrarily chosen to represent the variety of Oregon White Oak woodland characteristics present at the park. Sites were also chosen to offer representation of high to low human impact areas. Each sample site area has a reference GPS location at the center. Measurements for each site were gathered within a 100ft radius of the sample site GPS location; this includes physical soil samples and penetrometer readings **(see 5.1 Penetrometer Methodology,)** as well as stand density and height measurements in the case of Site 4 and Site 8.

Site 1 (N44° 55.600' W123° 02.179'Appendix photo 1
The soil type at this location is Clackamas gravelly loam (CK). The pH is 5.2 with 78.6% clay. The soil at this site is prone to compaction. Surface soil depth above gravel ranges widely between 3-20 inches. Six large Oregon White Oaks are found at this site. The oldest in this small grove may be as old as 300 years and is the largest found in the park. This area of the park is frequently used for sporting events. The soil in this area is irrigated and mowed during the summer.

Site 2 (N44° 55.641' W123° 02.411'Appendix photo 2
The soil type at this location is Willamette silt loam (WIA). The pH is 5.5 with 84.6% silt and clay. The soil at this site is highly prone to compaction. Two trees within and near this area have toppled due to Armillaria root rot (*Armillaria mellea*). This area has grass understory. Irrigation in this part of the park has been reportedly reduced during summer seasons since 2016. The leaves at this site are gathered and moved off site in the fall. Pedestrian use of this area is near constant, and traffic from maintenance vehicles is common. This area hosts many of the activities from the Salem Art Fair.

Site 3 (N44° 55.780' W123° 02.348'Appendix photo 3
The soil type at this location is Willamette silt loam (WIA). The pH is 5.4 with 82.6% silt and clay. The soil at this site is highly prone to compaction. This area has grass understory. This area is near a drainage from the upper plateau. The grove at this site is mixed Oregon White Oak and Douglas-fir. Pedestrian use of this area is frequent, though less than Sites 2 and 4. Vehicle traffic appears to be less than nearby sites as well.

Site 4 (N44° 55.627' W123° 02.322'Appendix photo 4
The soil type at this location is Willamette silt loam (WIA). The pH is 4.9 with 90.6% silt and clay. The soil at this site is highly prone to compaction. The area has grass understory. This area, along with Site 2, receives the most regular pedestrian and vehicular traffic of all sites we examined. This area is discussed at length in the 'Stand Composition' section.

Site 5 (N44° 55.618' W123° 02.268'Appendix photo 5
The soil type at this location is Willamette silt loam (WIA). The pH is 5.9 with 81.2% silt and clay. The soil at this site is prone to compaction. This area is sloped and the soil is thickly mulched with chips/compost for understory rhododendron garden. This area is irrigated during the summer. Oregon ash (*Fraxinus latifolia*) saplings observed in the area are an indicator of overly wet conditions.

Site 6 (N44° 55.715' W123° 02.307'Appendix photo 6
The soil type at this location is Willamette silt loam (WIA). The pH is 5.2 with 81.2% silt and clay. The soil at this site is prone to compaction. This area has an understory made up of mixed camas, snowberry, trailing blackberry (*Rubus ursinus*), thimbleberry, poison oak and Oregon grape. Site 6 is located along a slope and thriving understory plants indicate a low impact area.

Site 7 (N44° 55.830' W123° 02.086'Appendix photo 7
The soil type at this location is Salem gravelly silt loam (Sa). The pH is 5.6 with 51.2% silt and clay. The soil at this site is only marginally prone to compaction. This area has camas and licorice fern understory and the grove is a mix of Oregon White Oak and Douglas-fir. It is located near Pringle Creek and has the lowest elevation of the eight sites.

Site 8 (N44° 55.750' W123° 02.105'Appendix photo 8
The soil type at this location is Salem gravelly silt loam (Sa). The pH is 6.0 with 53.2% silt and clay. The soil at this site is only marginally prone to compaction. Understory is made up of camas and patches of licorice fern. This area is discussed at length in the 'Stand Composition' section.

Reference: Soil Conditions Summary Table **(see Appendix Document 6)**

4. SOIL ANAYSIS

4.1 Sampling Methodology
Soil samples were taken within a 100 ft radius of each site's GPS point using a soil corer **(see Appendix Photo 9)** according to USDA recommendations and the methodology recommended by Waypoint Analytical, the company contracted to analyze the samples. Samples represent the surface soil only, though the depth and composition of the subsoil also impacts tree growing conditions. For example, while the surface soil composition in Site 1 is similar to that of Sites 2, 3 and 4, in Site 1 the depth of surface soil is much shallower above subsoil gravel, while surface soil depth in sites 2, 3 and 4 is much greater. Therefore, while surface soil composition is similar in these sites actual growing conditions are significantly different.

4.2 Soil Particle Composition
The textures of the soils shown in **Table 1** below are based off the USDA classification system. The soils' estimated infiltration rates, also shown in **Table 1**, are based on analysis of the soil composition and may vary from that actually found in the field. The reasons for this are soil compaction and the presence of soil pores. Organic content levels range from moderate at 3.2% in the Site 2 sample to high at 11.7% in the Site 7 sample by total dry weight of the samples.

For the 8 sites we chose, here are the USDA soil classification and estimated soil infiltration rates:
TABLE 1

Sample ID	USDA Soil Classification	Est. Infiltration Rate (in. /hr.)
Site 1	Clay	0.13
Site 2	Silty Clay Loam	0.19
Site 3	Silty Clay Loam	0.19
Site 4	Silty Clay Loam	0.18
Site 5	Silty Clay Loam	0.19
Site 6	Silt Loam	0.20
Site 7	Sandy Clay Loam	0.27
Site 8	Loam	0.32

The combined silt and clay in these samples ranges from 51.2% in Site 7 to 90.6% in the Site 4 sample. Sites 7 and 8 have the lowest amount of combined silt and clay at 51.2% - 53.2%. Looking at the bottom line of the comprehensive soil analysis chart **(see Appendix Document 2)** we can see that sites 1-6 are composed of varying proportions of mostly smaller soil particles. These are commonly referred to simply as 'clay' soils. These soils have a high-water holding capacity, though they are also very susceptible to compaction. Sites 7 and 8 in contrast have much lower percentage of silt and clay particles and higher amounts of larger soil particles. This makes them more resistant to soil compaction, but also their water holding capacity is far less than the soils found at sites 1-6.

4.3 Soil pH and Nutrient Availability
The pH of soils is an important indicator of nutrient availability for trees and other plants. When pH is too acidic or basic, important nutrients can become unavailable to plants and degrade plant health. Our 8 samples range from strongly acidic (4.9) in the Site 4 sample to moderately acidic (6.0) in the Site 8 sample. Based on USFS research, White Oaks typically prefer a pH between 4.8 to 5.9.

Nitrogen levels were found to be optimum in the Site 7 sample, low optimum in Sites 1, 3 and 8, and low in the remaining samples. Phosphorus levels are low in Sites 1, 2 and 3, low optimum in Sites 4, 7 and 8 and optimum in the remaining samples. Potassium is low in Sites 1 and 2 and optimum in Sites 3 and 4. Potassium is well supplied in the remaining four samples.

Generally speaking, Oregon White Oaks are well adapted to low fertility soils, and decomposing leaf litter typically provides sufficient essential elements for trees growing in unaltered, native soils. Established native trees should not need additional nutrient inputs except in cases where soil chemistry has been altered by human activities or abnormal circumstances. Addition of nutrients or alteration of soil chemistry in an established Oak woodland should only be undertaken with great care; the potential for harm to the woodland is great and the potential benefit is generally minor (except in cases where soil chemistry has been degraded.) For these reasons, we do not recommend any program of soil amendment, fertilization or soil chemistry alteration be undertaken at this time.

5. SITE ANALYSIS

5.1 Penetrometer Methodology
A Penetrometer is a simple device for measuring soil compaction. As the tip of the device is manually forced into the soil, a pressure measurement (in PSI) is relayed to the operator through a dial on the handle. Because soil resistance is greatly affected by moisture content, we were careful to take measurements at an appropriate time when the soil would not be saturated but not be dry either. The Cornell University Soil Health Laboratory recommends to take readings at field capacity (2-3 days after free drainage for well-drained soils, longer for poorly drained soils). After weeks of wet and snowy weather, from February 26th– March 4th there was no precipitation, and this prepared the soil for measurements taken on March 5th, 2019.

A total of 15 penetrometer readings where taken at each sampling site. We found a range of compaction and decided we would limit maximum depth for this report at 10 inches. Some soils had depths as low as 3 inches before contacting subsoil gravel. 4 readings at Site 7 had a depth less than 1 inch: these readings were listed as N/A and are not included in our average for the site.

5.2 Results
Site 1 (average resistance 233psi) showed very high soil resistance is some areas and less in others. Though average resistance was 233 psi, in the penetrometer data chart **(see Appendix Document 4)** you can see a great deal of inconsistency from one reading to another. Although Site 1 has very dense clay soil, much of Site 1 has a thin layer of surface soil above gravel subsoil. It is possible that the drainage and oxygen availability provided by this subsoil may mitigate the negative effects of dense, compacted surface soil.

Sites 2 (279psi), 3 (256psi) and 4 (292psi) all showed dense, compacted soil that was deeper than 10". It is notable that Sites 2 and 4 showed more resistance than Site 3, a site which showed less visual indication of pedestrian and vehicular traffic. These three sites represent soils which are naturally dense and deep, but Sites 2 and 4 likely have increased resistance due to human caused compaction.

Site 5 (76psi) has very low resistance, which likely means our measurements mostly captured decomposing mulch which has been added to the soil over time. Even in very undisturbed native soil we would expect higher resistance. This site has penetrometer measurements more like garden soil than the native soil of an Oak woodland.

Site 6 (168psi) is our control site, and it was largely chosen because it had many of the visual indicators of uncompacted, minimally disturbed soil. Our penetrometer results are consistent with this visual assessment. This site could be considered a best case scenario of what Sites 2-4 could look like if future soil compaction were eliminated and the soil was rehabilitated through leaf debris and understory plantings.

Site 7 (155psi) and Site 8 (139psi) both show relatively low resistance. This is mostly due to the different soil type at these sites, which is looser and composed of a higher percentage of large particles. These sites showed little visual indication of soil compaction and the soil type naturally resists compaction to a greater extent than the soils of Sites 1-6.

5.3 Discussion
Soil compaction is one of the main issues that will affect the health and longevity of the trees of the upper grove (Sites 2-4) and field sites (Site 1.) The results shown above **(and in Appendix Document 2)** confirm our visual assessment of these sites, and in particular confirm our first impressions of Sites 2 and 4 as having dense, likely compacted soil. According to Cornell University and Penn State research, at or above 300psi most plant roots are unable to physically penetrate soils and therefore root density and activity will be negatively affected.

It is important to note that penetrometer measurements do not capture the presence or absence of soil pores. In soils that register as having high resistance (above 250psi) soil pores provide crucial pathways for root colonization and activity. Additionally, in soils composed mostly of very small particles (Sites 1-6) larger soil pores (sometimes called macropores) allow for water drainage and access to oxygen while smaller soil pores (sometimes called micropores) allow the soil to hold water during drought periods. Soil pores of all sizes are easily destroyed by compaction from human activity, and indeed most of the symptoms we commonly associate with soil compaction are caused by the loss of soil pore structure. Soil pore structure is rebuilt over time through physical forces such as drought/rain and freeze/thaw cycles, and through biological forces such as bacterial and fungal activity, plant root growth and earthworm activity.

While the dense soils of Sites 1-4 provide a good substrate for large, healthy Oregon White Oak trees, they are composed primarily of very small particles and are naturally at the far end of the spectrum as far as density. Compacting the already dense soils of these sections of the park can deprive the roots of oxygen and water and damage tree health.

5.4 Human Activities and Tree Health

Human activity and park usage can have a range of impacts that can adversely affect tree health. We can improve tree health by understanding these impacts, then creating and implementing impact reduction plans. Additionally, we can educate park users, as parts of this park are cared for by the people that use its space. The main activities which impact the health of the Oak woodlands at Bush's Pasture Park are covered in sections **5.5** through **5.8**.

5.5 Soil Compaction from Pedestrian Traffic

Soil compaction through pedestrian traffic is an important concern in the upper grove sites (Sites 2, 3 and 4,) and the field site (Site 1) as the soil types here are highly susceptible to compaction and significant pedestrian traffic is noted.

An average human pedestrian creates pressure of 8 PSI on the ground as he/she walks over it. While this may not seem like much, it is enough to change soil oxygen and water retention ability, which impacts tree health. Frequent heavy pedestrian traffic can cause significant soil compaction, which is often visually indicated by a lack of understory plants and grasses.

Soil compaction from pedestrian traffic can be mitigated in a number of ways. Limiting the areas of compaction through establishment of pedestrian trails is a common strategy which is already in use throughout the park. Another strategy for limiting pedestrian traffic is the removal of turf and installation of understory plants around sensitive trees and groves. Creating areas of understory plantings can create a physical barrier to pedestrians and also negate the need for lawn mowing equipment, which is another source of soil compaction (see below.)

The Salem Art Fair is correctly recognized as a significant source of concern for pedestrian soil compaction. Potential mitigations to the impacts of this event are many, and some are already in effect. Soil is most resistant to compaction when it is dry, hence the timing of the event in July is helpful. Keeping pedestrian traffic confined to established walkways as much as possible will limit compaction, and adding mulch in the form of high quality wood chips prior to the event will significantly reduce compaction by distributing the load and therefore the pressure applied to the soil. Plywood or reusable ground pads can also serve to distribute weight, mitigating compaction from pedestrians and small vehicles. Such measures should be considered especially important if unseasonably wet weather precedes high-impact events such as the Salem Art Fair.

5.6 Soil Compaction from Vehicle Traffic

Soil compaction through vehicular traffic is an important concern in the upper grove sites (Sites 2, 3 and 4,) and the field site (Site 1) as the soil types here are highly susceptible to compaction.

Though vehicle traffic is less frequent than pedestrian traffic, it can have much more significant impacts. The pressure exerted by a standard passenger car or pickup truck is approximately 30 PSI, and that of construction vehicles can be many times that. Even infrequent or one-time use of these vehicles on the root zone can significantly damage soil pore structure in a way that can take years or decades to recover from. Heavy construction vehicle traffic can also physically break roots underground, creating wounds the tree must address in addition to the negative effects on the soil.

Every effort should be made to limit vehicular traffic in the Oak woodlands to established routes which are either paved or mulched. Riding mower use should be limited during times when soil is wet. Use of heavy vehicles such as construction equipment or large trucks should be limited or eliminated to the extent possible.

In recent documents presented to the Salem City Council **(see Appendix Document 3,)** Public Work Directors have claimed that 'To address soil compaction in Bush's Pasture Park, the City limits use of motor vehicles.' It is unclear to the consulting arborists what rules or procedures are in place currently, as they have been presented with photos of heavy machinery driving through the critical root zones of Oaks in the upper grove as recently as April 2017 **(see Appendix Photos 10 and 11.)** Additionally, during our site visits from October 2018- March 2019 we repeatedly observed maintenance trucks driving through the upper grove lawn (off paved roads) to access restrooms and other facilities **(see photo above.)**

5.7 Abiotic Buttress Damage
Mechanical damage has been observed in the upper grove (Sites 2, 3 and 4.) Mulch circles are in place and appear to be adequately protecting trees in the field site (Site 1.)

During site visits we noted many trees which had mechanical damage on the roof flare or buttress consistent with damage from lawn mowing equipment **(see Appendix Photos 12 and 13.)** Riding mowers are a common culprit, though string trimmers also frequently cause buttress damage. The most common preventative measure to address this is the creation of mulch circles around the trees' buttresses so that mowing near the root flare is not needed. Mulch depth need not be more than a few inches, and mulch should never be piled against the root flare itself. Speaking with park maintenance staff and showing the impacts of mower damage on trees should also be undertaken.

5.8 Irrigation
Irrigation is a major concern for the field site (Site 1) which receives extensive irrigation and contains the largest and oldest trees in the park, and at the Rhododendron garden (Site 5.) Irrigation is also a concern in the upper grove (Sites 2, 3 and 4).

As has been noted many times previously **(see Appendix Document 3)** irrigation can be very harmful to mature Oregon White Oak trees. These trees are adapted to summer drought conditions and alteration of this moisture regimen, especially when the trees are already mature, can lead to lack of oxygen in the root zone, increased soil compaction (since soil compacts more readily when it is wet,) and better conditions for growth of root decay organisms such as Armillaria mellea (see Armillaria section.)

While very limited irrigation can be beneficial in conditions where soil has limited soil water holding capacity, it is usually better to address these issues by building the soil's water holding capacity through mulch and understory plantings. Areas where annual leaf drop can remain below the crowns of trees can help greatly improve these conditions.

In heavy use areas of the park where retaining leaves, mulching and understory planting are not possible, summer irrigation will increase the risk of soil compaction. Therefore, it is recommended to limit irrigation in areas used by the Salem Art Fair to reduce soil compaction susceptibility.

Despite the many negative impacts of irrigation on native Oak woodlands, removal of irrigation should be done slowly over several years, so that trees which have come to rely on additional summer water have a chance to adapt to the new soil moisture regimen.

6. STAND COMPISITION

6.1 Purpose

To highlight the differences between the Oak woodlands of the upper and lower groves, additional data was collected from Sites 4 and 8. The purpose of this additional data collection and analysis was to compare and contrast the stand density, tree size and height of these two different types of Oak woodland. Visually, one can see the difference in these groves as the presence of larger trees which are more spread out in the upper grove sites (Sites 2-6) and smaller trees which grow closer together in Sites 7 and 8.

Often in the Willamette Valley, dense stands of Oregon White Oak trees will develop in areas that are under fire suppression regimens, which presently includes most of the valley. The conditions present in these stands differ from pre-European settlement conditions in that historically, burning from Native American tribes would have lead to more extensive savannas interspersed with fewer, large Oregon White Oak trees. With settlement from European-descended Americans, fire suppression regimens were introduced which altered the ecology of these areas, creating dense stands of smaller trees, often interspersed with conifers such as Douglas-fir and ponderosa pine. Our goal in this section is to elucidate the difference in these groves to inform our recommendations for management.

6.2 Methodology

Starting at the GPS coordinates for sites 4 and 8, 200 ft diameter circles were created using a tape measure and ground stakes. All trees within these circles were measured for diameter at breast height (DBH) using a measuring tape and height using a laser inclinometer/rangefinder.

6.3 Results

The Site 4 plot contained 25 trees with an average DBH of 19” and an average height of 68’. The Site 8 plot contained 89 trees with an average DBH of 11.5” and an average height of 47’. The Site 8 plot had just over 3.5 times as many trees, but the trees in the Site 4 plot were on average 1.65 times as large by area and 1.44 times as tall.

The largest tree in Site 4 plot was 34” DBH and 76’ tall, while the largest in Site 8 plot was 18” DBH and 57’ tall. Total tree basal area (sqft) in (Site 4) is 44.71, while in (Site 8) it is 64.1, which is nearly 20% greater **(see Appendix Document 5.)**

6.4 Discussion

In the above section titled ‘Soil Particle Composition’ we noted that Sites 7 and 8 have soils which are quite different than other sites we analyzed at the park. The soils here are composed of a greater number of large particles, and our soil probes also indicated that surface soil depth in these groves is relatively thin atop coarse, rocky subsoil. This likely adds up to relatively poor moisture retention and availability compared to soils elsewhere in the park.

We believe that wide differences noted in stand density and tree size between sites 4 and 8 (and by extension between Sites 1-6 and Sites 7-8) are largely due to differences in the soil composition. Trees in Site 4 are larger with more open space between them is most likely because of greater water holding capacity of the soil allows individual Oaks to grow larger. The trees in Site 8, by comparison, are relatively small and densely packed because the soil cannot support larger trees such as those found in the upper grove.

With this in mind, we do not recommend any sort of thinning, fuel reduction or Oak release work be undertaken in the lower grove. The lower grove represents a healthy stand of trees functioning as it should on suboptimal soils. Additionally, we see no cause for concern with the presence of Douglas-firs in some parts of the lower groves. Douglas-firs are often unwelcomed in Oregon White Oak woodlands as they can compete with Oaks. The Douglas-firs in the lower groves of the park all appear to be a similar age as the Oaks, and do not appear to threaten Oregon White Oak dominance at this time.

7. ARMILLARIA

Armillaria mellea, commonly referred to as honey mushroom, shoestring fungus or simply Armillaria, is a species of fungus found in most, if not all, Willamette Valley soils. It is a root rot or root decay fungus, which primarily affects the large, woody structural roots and root flare of infected trees. Trees can be infected through contact with mycelium and rhizomorphs (the distinctive 'shoe string' structures) or contact with infected roots of nearby trees. It is able to grow on living as well as dead tissue, and therefore its growth is not moderated by a need to avoid killing its host. Armillaria is a white-rot fungus, which primarily breaks down the lignin component of wood cells, leaving the wood soft and spongy, and often flecked with white mycelial growth.

In general, Armillaria can exist in Oregon White Oak trees for long periods without directly leading to the tree's death. In some tree species, infection with Armillaria will be visually indicated by stunted form, small leaf size and tip dieback; however, these symptoms are usually not observed in Oregon White Oaks even when infection is widespread. Therefore, the only reliable visual indicator of Armillaria presence is the distinctive honey-colored mushrooms, which can be observed around the base of infected trees in the fall and winter. Cankers in the root flare, with mycelial fans and shoestring rhizomorphs visible underneath dead bark, can sometimes be an indicator of extensive infection.

Armillaria is of particular concern to park managers and property owners in the Willamette Valley because it is often associated with failures of large trees at the roots, sometimes in calm weather with seemingly no indication of distress. Because of this, it is often an underlying cause of high-profile tree failures which put people and property at risk. The purpose of this section of the report is to provide general recommendations to mitigate Armillaria damage to the Oak trees at Bush's Pasture Park and should not be considered an investigation into its extent or the stability of these trees. In no way should this report be construed as a tree risk assessment report, or as an opinion on the stability of any specific trees.

No chemical treatment exists for Armillaria infection in trees, and eradication from the soil is not feasible. Removal of above or below ground portions of infected trees is unlikely to reduce future instances of infection in a grove. Therefore, the best course of action to limit Armillaria growth is through a series of environmental and cultural measures. Chief among them is limiting irrigation. Irrigation of mature Oak trees, which have lived for decades or centuries without supplemental water, changes the environment for the roots in fundamental ways. Trees which otherwise would have little to no growth of Armillaria can develop extensive Armillaria infections when their root zones receive irrigation.

Mild soil compaction of the root zone, such as that caused by pedestrian or small vehicle traffic, can change the root environment in similar ways to irrigation by depriving the roots of oxygen and limiting the growth of beneficial soil organisms. This can make the root tissue more susceptible to Armillaria growth. Severe soil compaction, the kind caused by heavy machinery and construction equipment, can physically break roots underground in addition to compacting the soil. These damaged woody roots can become an easy site for Armillaria to become established in the tree's roots and lead to infection of the undamaged portion of the root system.

While the upper grove has seen Oregon White Oak root failures which appear to be associated with Armillaria infection, during a dozen site visits from August 2018 to March 2019, we searched for Armillaria mushrooms and found them present only in very small numbers (see photo on this page, which shows mushrooms from what appears to be a modest Armillaria infection.)

8. OREGON WHITE OAK HABITAT

Management of Oregon White Oak woodlands both before and after European settlement in the Willamette Valley has resulted in structurally diverse populations of trees now seen in the park. The pre-European history of management, combined with different uses of the park area in the last 150 years have created a diverse set of groves which run the spectrum from open grown trees to dense, even-age stands. This gradient of tree structure attributes create diverse habitat types based on animals' light preference, acorn production, cavities for thermal regulation and reproduction, and ability to host native understory plants.

There are numerous opportunities to enhance existing Oak habitats within the park's boundaries that will benefit adjacent native ecosystems, including Minto Brown Island Park. Although these natural areas are no longer directly connected by land, they are well within flight distances for birds and insects.

Rather than (site emphasis, this section of the report will mostly represent quadrants of the park. This is because habitat condition improvement recommendations are parkwide and vary due to habitat types.

8.1 Habitat Enhancement - Northeast Quadrant of the Park
In areas at the northeast end of the park (Site 8) that are not as heavily used by park-goers, mostly closed-canopy, even-aged Oak woodlands have developed, some with dense understories of Camas (Camassia quamash and/or Camassia leichtlinii). These areas should be preserved and protected, since they are extremely valuable for a wide variety of wildlife. These stands occur mostly in the northeastern portion of the park. Policies could be created to restrict park use to specified trails in sensitive wildlife areas such as these.

We do not recommend shrub planting underneath the Oaks where Camas spp. is extensive. We would recommend understory plantings in areas to the northeast where conifers represent a significant portion of the tree species. Any efforts to increase plant diversity and canopy structure within the conifer stands would benefit wildlife significantly. Care should be taken to avoid creating ambiguity with mowing, so distinct and clearly outlined planting boundaries should be developed and implemented.

Moving west/southwest towards the tennis courts and across a service road, there are larger, more open-grown Oaks. These areas are beginning to show adverse reactions to human encroachment, primarily through vehicular traffic and parking. It is highly recommended that these areas be protected from future vehicular traffic and parking. Critical root zones should be measured and marked for root and soil cordoning off. Early indications of adverse impacts is the sparsity of Camas and the existence of pasture grasses and various weed species, which tend to favor disturbed areas and can readily occupy lower quality and/or compacted soils. These areas could benefit from restoration and enhancement efforts.

Recommendations for Three Woodland Types in the NE quadrant of the Park

Closed-canopy, even-aged Oak woodlands (see Appendix Document 7)

a. This woodland is valuable for a wide variety of wildlife in current condition; we recommend preserving current Oak density and condition and to preserve dense understory of Camas
b. No additional shrub or tree planting.
c. Leave all tree debris (leaves, wood, etc.) for wildlife habitat and nutrient inputs into soil and adjacent waterways. This aids development of microhabitats for arthropods, small mammals, reptiles and amphibians.

d. Limit pedestrian access to avoid disturbances to natural environments.

Conifer groves (see Appendix Document 8)

a. Plant understory species to increase plant diversity and canopy structure to benefit wildlife.
b. Leave all tree debris outside of groomed areas.

Open-grown mature Oaks (vehicle disturbance) (see Appendix Document 9)

a. Identify large areas which can be planted with understory species.
b. Leave all tree debris (leaves, wood, etc.) for wildlife habitat and nutrient inputs into soil and adjacent waterways. Beneficial microhabitats develop for arthropods, small mammals, reptiles and amphibians.
c. Create distinct and clearly delineated planting boundaries where mowing and maintenance activities are not needed.
d. Limit pedestrian access to avoid disturbances to natural environments.

Recommended tree, shrub and forb species list for NE quadrant woodlands. Once established over-seed with native grasses.

TREES/SHRUBS

Arbutus menziesii	Pacific madrone
Crataegus douglasii	Black hawthorn
Quercus garryana	Oregon white oak
Cornus nuttallii	Pacific Dogwood
Amelanchier alnifolia	Western serviceberry
Arctostaphylos uva-ursi	Kinnikinnick
Mahonia aquifolium	Tall Oregon grape
Ceanothus sanguineus	Red-stem ceanothus
Holodiscus discolor	Oceanspray
Oemleria cerasiformis	Indian plum
Philadelphus lewisii	Mock orange
Physocarpus capitatus	Pacific ninebark
Ribes sanguineum	Red-flowered currant
Rosa gymnocarpa	Bald-hip rose
Rubus ursinus	Trailing blackberry
Symphoricarpos albus	Snowberry

FORBS

Achillea millefolium	Common yarrow
Allium amplectons	Slimleaf onion
Anaphalis margaritacea	Pearly everlasting
Aquilegia formosa	Red columbine
Aster halii	Hall's aster
Brodiaea hyacinthine	Hyacinth brodiaea
Camassia leichtlinii	Leichtlin's camas
Camassia quamash	Common camas
Delphinium menziesii	Menzie's larkspur
Dodecotheon hendersonii	Shooting Star
Eriophyllum lanatum	Wooly sunflower

Erythronium oregonum	White fawn lily
Frageria vesca	Woods strawberry
Frageria virginiana	Mountain strawberry
Geum macrophyllum	Largeleaf avens
Gilia capitatus	Common gilia
Iris tenax	Oregon iris
Lilium columbianum	Tigerlily
Lomatium utriculatum	Common lomatium
Lotus purshianus	Spanish clover
Lupinus albicaulis	Sickle-keeled lupine
Lupinus latifolius	Broad-leaf lupine
Mimulus guttatus	Monkey flower
Plectritis congesta	Rosy plectritis
Potentilla gracilis	Slender cinquefoil
Prunella vulgaris	Self-heal
Sidalcea virgata	Checker mallow
Sisyrinchium idahoense	Blue-eyed grass
Solidago canadensis	Canada goldenrod
Tellima grandiflora	Fringecup
Thalictrum occidentale	Western meadowrue
Tolmeia menziesii	Piggyback plant
Viola adunca	Early-blue violet
Wyethia angustifolia	Narrow-leaf wyethia

8.2 Habitat Enhancement - Southwest Quadrant of the Park (see Appendix Document 10)
In the southwest corner of the park (Sites 2 and 4), in areas outside of where the art festival is held, understory plantings could be considered for the improvement of wildlife habitat, canopy structure, pollinator opportunities and soil conditions. Plant species should be chosen carefully if the park wants to maintain line-of-sight through these forested areas. Taller shrubs could be selected only if planting locations are carefully chosen. Consider low-density patches close to existing trees. Again, care must be taken to avoid creating ambiguity with mowing, so distinct and clearly delineated planting boundaries should be created.

Recommendations for the SW corner of the park (outside art festival areas)
a. Planting understory species to increase plant diversity and canopy structure to benefit wildlife.
b. Leave standing or shortened stems of dead trees were possible.
c. Leave all tree debris (leaves, wood, etc.) for wildlife habitat and nutrient inputs into soil and adjacent waterways. Beneficial microhabitats develop for arthropods, small mammals, reptiles and amphibians.
d. Discourage off-trail pedestrian use to avoid disturbances to natural environments.

Recommended tree, shrub and forb species list for SW corner woodlands. Once established over-seed with native grasses.

TREES/SHRUBS

Arbutus menziesii	Pacific madrone
Quercus garryana	Oregon white oak
Cornus nuttallii	Pacific Dogwood
Amelanchier alnifolia	Western serviceberry
Arctostaphylos uva-ursi	Kinnikinnick
Mahonia aquifolium	Tall Oregon grape
Holodiscus discolor	Oceanspray
Oemleria cerasiformis	Indian plum
Philadelphus lewisii	Mock orange
Physocarpus capitatus	Pacific ninebark
Ribes sanguineum	Red-flowered currant
Rosa gymnocarpa	Bald-hip rose
Rubus ursinus	Trailing blackberry
Symphoricarpos albus	Snowberry

FORBS

Achillea millefolium	Common yarrow
Allium amplectons	Slimleaf onion
Anaphalis margaritacea	Pearly everlasting
Aquilegia formosa	Red columbine
Aster halii	Hall's aster
Brodiaea hyacinthine	Hyacinth brodiaea

Camassia leichtlinii	Leichtlin's camas
Camassia quamash	Common camas
Delphinium menziesii	Menzie's larkspur
Dodecotheon hendersonii	Shooting Star
Eriophyllum lanatum	Wooly sunflower
Erythronium oregonum	White fawn lily
Frageria vesca	Woods strawberry
Frageria virginiana	Mountain strawberry
Geum macrophyllum	Largeleaf avens
Gilia capitatus	Common gilia
Iris tenax	Oregon iris
Lilium columbianum	Tigerlily
Lomatium utriculatum	Common lomatium
Lotus purshianus	Spanish clover
Lupinus albicaulis	Sickle-keeled lupine
Lupinus latifolius	Broad-leaf lupine
Mimulus guttatus	Monkey flower
Plectritis congesta	Rosy plectritis
Potentilla gracilis	Slender cinquefoil
Prunella vulgaris	Self-heal
Sidalcea virgata	Checker mallow
Sisyrinchium idahoense	Blue-eyed grass
Solidago canadensis	Canada goldenrod
Tellima grandiflora	Fringecup
Thalictrum occidentale	Western meadowrue
Tolmeia menziesii	Piggyback plant
Viola adunca	Early-blue violet
Wyethia angustifolia	Narrow-leaf wyethia

8.3 Habitat Enhancement - Site 1 and Other Isolated Groves (see Appendix Document 11)

We highly recommend that vehicular traffic is strictly limited or restricted within the critical root zones of these types of groves. High quality wood chips and/or garden mulch could be used as additional soil/root protection from foot traffic. Low-growing plantings could be installed sparingly, and only within the trees' driplines for the benefit of pollinators, birds and small mammals while providing soil/root protection through exclusion.

Recommendations for Site 1 Oak grove and other isolated groves

a. Create dripline and/or island-like understory plantings.

b. Leave all tree debris (leaves, wood, etc.) for wildlife habitat and nutrient inputs into soil and adjacent waterways. Beneficial microhabitats develop for arthropods, small mammals, reptiles and amphibians.

c. Discourage off-trail pedestrian use to avoid disturbances to natural environments.

Recommended tree, shrub and forb species list for Site 1 woodlands. Once established over-seed with native grasses.

TREES/SHRUBS

Arbutus menziesii	Pacific madrone
Crataegus douglasii	Black hawthorn
Quercus garryana	Oregon white oak
Cornus nuttallii	Pacific Dogwood
Amelanchier alnifolia	Western serviceberry
Arctostaphylos uva-ursi	Kinnikinnick
Mahonia aquifolium	Tall Oregon grape
Ceanothus sanguineus	Red-stem ceanothus
Holodiscus discolor	Oceanspray
Philadelphus lewisii	Mock orange
Physocarpus capitatus	Pacific ninebark
Ribes sanguineum	Red-flowered currant
Rosa gymnocarpa	Bald-hip rose
Rubus ursinus	Trailing blackberry
Symphoricarpos albus	Snowberry

FORBS

Achillea millefolium	Common yarrow
Allium amplectons	Slimleaf onion
Anaphalis margaritacea	Pearly everlasting
Aquilegia formosa	Red columbine
Aster halii	Hall's aster
Brodiaea hyacinthine	Hyacinth brodiaea

Camassia leichtlinii	Leichtlin's camas
Camassia quamash	Common camas
Delphinium menziesii	Menzie's larkspur
Dodecotheon hendersonii	Shooting Star
Eriophyllum lanatum	Wooly sunflower
Erythronium oregonum	White fawn lily
Frageria vesca	Woods strawberry
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Geum macrophyllum	Largeleaf avens
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Solidago canadensis	Canada goldenrod
Tellima grandiflora	Fringecup
Thalictrum occidentale	Western meadowrue
Tolmeia menziesii	Piggyback plant
Viola adunca	Early-blue violet
Wyethia angustifolia	Narrow-leaf wyethia

8.4 Partnerships and Discussion

Creating and developing partnerships can be very rewarding and can produce excellent results while saving the city money. Initially, there will be costs to the city in order to implement the proposed shrubs plantings and soil/root protection tools, however those costs could be offset in lower maintenance costs for mowing and leaf blowing/removal. Funding for plants and labor may be pursued through grants from the Marion County SWCD, OWEB grant, Oregon Department of Fish & Wildlife, Oregon Habitat Joint Venture, Willamette Wildlife Mitigation Program and NRCS. We suggest installing shrubs in dense clusters at a rate of 1,800 per acre (4' X 3' spacing). Once installed, the shrubs will need minimal maintenance or upkeep.

Planted areas can provide excellent opportunities to monitor wildlife, insects and small mammals, and can utilized as environmental education labs for local schoolchildren.

8.5 Other Important Flora and Fauna

Mistletoe

The species of mistletoe (*Phoradendron villosum*) is of particular concern for wildlife. As a hemiparasitic epiphyte, this mistletoe taps its host tree for water and nutrients but is also able to photosynthesize some energy for itself. As mistletoe grows and thickens, it creates round masses often referred to as "witches' broom". A variety of birds nest in witches' brooms, including house wrens, chickadee and mourning doves. Additionally, 43% of spotted owl (*Strix occidentalis*) nests and 64% of Cooper's hawk (*Accipiter cooperii*) nests have been found to be associated with mistletoe species in Oregon. Birds such as American robins (*Turdus migratorius*), western bluebirds (*Sialia mexicana*), and Townsend's solitaire (*Myadestes townsendi*) are thought to feed on mistletoe berries.

In the past it has been a common arboricultural practice to prune out mistletoe in individual trees. Silvicultural tactics may recommend removal of "brooms" for economic concerns related to forestry wood products. At Bush's Pasture Park we recommend that mistletoe is retained to the extent possible. Here, it should be treated as a valuable resource and integral for wildlife in the park woodlands.

Birds

Birds such as acorn woodpecker (*Melanerpes formicivorus*) are bio-indicators of healthy Oak savanna ecosystems in the Willamette Valley, and are important to the spread and germination of Oregon White Oaks acorns. Acorn woodpeckers depend of the presence of standing dead trees (snags) and aerial deadwood for storing food and reproduction. During our visits to the park for this report we found that much of the aerial deadwood of the Oak woodlands has been removed from trees, and snags have been removed from the site even in low human use areas. Perhaps consequently, we found no evidence of acorn woodpecker activity. Not all areas of the park will lend themselves to retaining snags and aerial deadwood, however many will.

We recommend identifying suitable areas of acorn woodpecker habitat and managing those areas to maximize their habitat potential. Ideally, such areas should have a high density of large Oak trees, as these sorts of groves will have greater acorn yields and more potential for creating the large aerial deadwood on which the birds depend. Consideration for this habitat enhancement is recommended, as it will set the stage wildlife regardless if Acorn woodpeckers are present or not at this time.

Aside from the acorn woodpecker, aerial deadwood is an important resource for the entire woodland food chain by providing a food source for boring insects, which in turn are a food source for many species of birds. Leaving aerial deadwood in place can also aid the development of tree cavities, which are an important resource for many species of wildlife. Birds such as black-capped chickadee (*Poecile atricapillus*), white-breasted nuthatch (*Sitta carolinensis*), western screech owl (*Megascops kennicottii*) and violet-green swallow (*Tachycineta thalassina*) use tree cavities as a place for reproduction. Bird boxes can serve as a habitat replacement for some cavity dwelling species but should be considered as short-term band-aid solution and inferior to naturally occurring cavities.

Wildlife and its benefits to the community should be considered as an important resource of this park, and we recommend that wildlife habitat creation and retention be considered a priority in the park's management policies.

9. CONCLUSION

Although we have chosen to create separate sections to this report to discuss soils, site usage, Armillaria and wildlife habitat potential, the astute reader will notice that while these issues are separated, recommendations for improvement often overlap. This is not an accident. The main threats to the health of the Oaks at Bush's Pasture Park come from damage done to the soil by human activities. The ways these threats are presented to arborists and land managers often come in different forms; Armillaria infection, poor growth rates, loss of associated species, premature loss of old trees and lack of vigor in the face of common tree diseases. Though these symptoms may seem disparate, they are all related to poor soil conditions and therefore measures to improve the soil can ameliorate many of these symptoms at the same time.

In considering potential management measures to improve conditions in the Oak woodlands, we have tried to prioritize measures consistent with the Oak woodland's location within a heavily used city park. We have tried to provide recommendations which can be implemented without curtailing the public's use or enjoyment of this public space.

9.1 We recommend the following steps to improve conditions for Oregon White Oaks at Bush's Pasture Park:

1. Reduce or cease irrigation within the Oak woodlands to the extent possible. Reduction or elimination of irrigation should be implemented slowly over many years and combined with soil water-holding capacity improvements (such as items 2-4 below.) It is also recommended to limit irrigation prior to the Salem Art Fair to reduce soil compaction susceptibility in all Oak woodland areas affected by the event.
2. Retain leaf debris within the Oak woodlands to the extent possible. Decomposing leaf litter improves biological activity in the soil, lessens compaction and adds micronutrients to the soil.
3. Mulch compacted areas to the extent possible with high quality wood chips. High impact areas such as vehicle corridors and heavy pedestrian traffic zones should be mulched to lessen compaction of the soil. Mulch depth should be 2-4" and mulch should never touch the buttresses of any trees. Plywood or ground protection mats can serve as a temporary barrier to reduce compaction from pedestrian and light vehicle traffic during park events.
4. Mulch critical root zones and plant native understory plants to the extent possible. This will deter pedestrian and vehicular traffic in these vital zones, build the soil biological activity and facilitate the retention of leaf debris.
5. Create policies and enforcement mechanisms to control soil compacting activities. Not all soil compacting activities can or should be eliminated, so planning for these activities and mitigating their impact is essential. Vehicle traffic should be confined to paved or mulched corridors, and heavy pedestrian traffic events (such as that for the Salem Art Fair) should be held in areas where the soil has been protected from compaction through mulch or pavement. It is advised to consult with an arborist before and during any construction that impacts tree roots. Plans involving the use of heavy machinery within the Oak woodlands should be heavily scrutinized to determine their necessity, and what can be done to mitigate their impacts. Having an enforcement mechanism is a must; if there are no consequences for ignoring such rules, that is what we can expect people to do.
6. Retain dead wood in the trees and on the ground to the extent possible. Fallen dead wood is a resource that cycles nutrients, offers habitat for terrestrial species and can be used as physical barriers discourage human encroachment. Deadwood and dead trees may easily be retained in low to moderate use areas, and in high use areas with some planning and maintenance.
7. Identify suitable areas to replace turf with well-defined zones of native understory plants around the driplines of mature Oregon White Oaks. These zones can improve soil conditions for the Oaks, allow the growth of understory plants and improve wildlife habitat value of the park.

9.2 Further Investigations

We recommend the City of Salem and/or Mission Street Parks Conservancy plan for a comprehensive tree inventory in the coming years. Previous works by ODF/FEMA could be used as a starting point or the inventory could start from scratch. Either way, this sort of data recording the location, size and condition of trees in the park is vital to create a baseline to monitor the health of the Oak groves over time. This data also aids in monitoring stand composition and informing replacement planting. We recommend incorporating a type 1 tree risk assessment report into this inventory since an inventory involves visiting and checking the condition of each tree. Type 1 tree risk assessment is a cursory check and documentation of the trees likelihood for failure, and is meant to help park managers stay ahead of predictable tree failures and prioritize risk mitigation activities such as tree pruning, bracing and removal.

10. ASSUMPTIONS AND LIMITING CONDITIONS

1. Consultant assumes that any legal description provided to Consultant is correct and that title to property is good and marketable. Consultant assumes no responsibility for legal matters. Consultant assumes all property appraised or evaluated is free and clear and is under responsible ownership and competent management.

2. Consultant assumes that the property and its use do not violate applicable codes, ordinances, statutes or regulations.

3. Although Consultant has taken care to obtain all information from reliable sources and to verify the data insofar as possible, Consultant does not guarantee and is not responsible for the accuracy of information provided by others.

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7. This report and any values expressed herein represent the opinion of the Consultant, and the Consultant's fee is in no way contingent upon the reporting of a specific value, a stipulated result, the occurrence of a subsequent event or upon any finding to be reported.

8. Sketches, drawings and photographs in this report, being intended as visual aids, are not necessarily to scale and should not be construed as engineering or architectural reports or surveys. The reproduction of any information generated by architects, engineers or other consultants and any sketches, drawings or photographs is for the express purpose of coordination and ease of reference only. Inclusion of such information on any drawings or other documents does not constitute a representation by Consultant as to the sufficiency or accuracy of the information.

9. Unless otherwise agreed, (1) information contained in this report covers only the items examined and reflects the condition of those items at the time of inspection; and (2) the inspection is limited to visual examination of accessible items without dissection, excavation, probing, climbing, or coring. Consultant makes no warranty or guarantee, express or implied that the problems or deficiencies of the plans or property in question may not arise in the future.

10. Loss or alteration of any part of this Agreement invalidates the entire report.

Respectfully submitted,

Brian French

Will Koomjian

Matt Stine

10. APPENDIX

Photographs

Photo 1

Photo 2

Photo 3


Photo 4


Photo 5


Photo 6


Photo 7
30/NOV/2018


Photo 8


Photo 9
30/NOV/2018


Photo 10
CASE


Photo 11


Photo 12


Photo 13

Document 1.

Proposal for Services at Bush Park

Prepared by Brian French (Arboriculture International LLC, CCB #205536) and Will Koomjian (Emergent Tree Works LLC, CCB# 203904)

Scope:

Proposal and estimate for consultation services at Bush Park in Salem, Oregon, prepared for Mission Street Parks Conservancy and submitted on Sept 13, 2018. Parameters of proposed services are based on discussions and site visit with Michael Slater, Ellen Stevens and others on Aug 15, 2018.

Services:

The creation of a narrative report detailing current general condition of trees and groves at Bush Park. The report will consider current (and when relevant historical) soil conditions, site usage, stand age and composition, *Armillaria mellea* presence and wildlife habitat potential. The aim will be to provide a general, non-specific guide to the current issues affecting tree and stand health in the park, and to provide general and (where deemed worthwhile) specific recommendations to improve tree and grove health and growing conditions. Numerous photographs will be incorporated into the report to provide examples and aid explanation of the findings. Special emphasis will be placed on:

1. **Soil conditions**. Because of the high use characteristics of many parts of Bush Park, soil compaction and composition is a major concern. The arborists will identify approximately 8 sites at the park to do soil analysis on. Analysis at these sites will include visual assessment, soil penetrometer testing and laboratory soil analysis. The results will inform the arborists' assessment of current soil conditions for the major groves at the park, and used to recommend future actions to improve conditions.

2. **Site usag**e. Human uses of Bush Park can and do have major impacts on tree health and longevity. Working with the Conservancy and City of Salem parks personnel the arborists will attempt to understand what human activities are affecting tree and grove health at the park. More emphasis will be placed on ongoing activities vs. one time events; e.g. regular vehicle traffic vs. historical construction damage.

3. **Stand age and composition**. The arborists will look at data from the Conservancy's tree inventory works and provide a narrative guide to the current stand composition, and make recommendations to improve future stand composition.

4. **Armillaria**. *Armillaria mellea* is a root decaying fungus that represents a major threat of many species of trees, particularly Oregon White Oak (*Quercus garryana*) trees. The arborists will examine sites where ArMe has been identified, assess general severity, and make recommendations for environmental mitigation options. This work ideally should take place in the fall, to coincide with maximum mushroom presence.

5. **Wildlife habitat potential**. The arborists will make general assessments about the current wildlife habitat potential with special emphasis on arboreal (above 2m) conditions. Recommendations will be made for improving these conditions.

Disclaimers:

This report will rely on a tree inventory being undertaken by the Conservancy, and will rely on the numbering scheme of that inventory which is carried over from previous FEMA/City of Salem inventory works. The report will not be considered any form of tree risk assessment. If the arborists note serious hazards during site visits they will notify appropriate authorities, but this should not be considered a comprehensive or even cursory tree risk assessment. The report will be narrative in format, and focus on general conditions; specific tree conditions will only be noted at the arborists' discretion.

While some testing will take place as part of the assessment works (notably soil testing) the report should be considered a work of opinion. Direct test results will be made available to the Conservancy.

Document 2. Soil Analysis Data

Emergent Tree Works LLC
P. O. Box 14929

Portland OR 97293

Waypoint ANALYTICAL

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Project : Bush's Pasture Park - Salem, OR

Report No : **19-035-0008**
Purchase Order :
Date Recd : 02/04/2019
Date Printed : 02/15/2019
Page : 1 of 1

COMPREHENSIVE SOIL ANALYSIS

Sample Description - Sample ID	Half Sat % / TEC	pH / Qual Lime	ECe dS/m	NO_3-N ppm	NH_4-N ppm	PO_4-P ppm	K ppm	Ca ppm	Mg ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	Organic % dry wt.	Lab No.
				Sufficiency Factors											
Site 1	34	5.2	0.5	33.8	11.3	3.80	119.2	2067	428.4	1.76	6.36	11.0	304	7.73	01435
	139	None		0.7		0.1	0.6	0.9	1.3	0.9	0.9	0.7	4.3		
Site 2	29	5.5	0.2	1.9	9.9	8.00	51.1	695.9	200.7	1.18	2.03	9.51	181	3.70	01436
	52	None		0.2		0.2	0.4	0.8	1.5	1.7	0.8	1.6	7.0		
Site 3	29	5.4	0.4	17.8	36.3	15.0	224.2	1642	280.9	1.32	5.66	7.62	149	5.48	01437
	111	None		0.9		0.4	1.5	0.9	1.1	0.9	1.0	0.6	2.7		
Site 4	24	4.9	0.1	1.2	8.8	22.0	138.1	295.1	118.2	1.15	2.07	14.0	200	3.25	01438
	28	None		0.2		0.8	1.4	0.5	1.5	3.0	1.4	4.3	13.6		

Saturation Extract Values						SAR	Gravel %		Percent of Sample Passing 2 mm Screen					USDA Soil Classification	Lab No.
									Sand						
Ca meq/L	Mg meq/L	Na meq/L	K meq/L	B ppm	SO_4 meq/L		Coarse 5 - 12	Fine 2 - 5	Very Coarse 1 - 2	Coarse 0.5 - 1	Med. to Very Fine 0.05 - 0.5	Silt .002-.05	Clay 0-.002		
2.6	1.5	0.9	0.8	0.10	0.5	0.6	2.9	2.7	3.4	4.0	13.9	38.0	40.6	Clay	01435
0.6	0.3	0.4	0.3	0.04	0.4	0.6	0.8	0.2	0.4	1.0	13.9	54.0	30.6	Silty Clay Loam	01436
1.9	0.9	0.5	0.5	0.06	0.4	0.4	0.1	1.2	1.8	2.8	12.7	52.0	30.6	Silty Clay Loam	01437
0.4	0.3	0.3	0.2	0.05	0.3	0.5	0.1	0.4	1.4	1.8	6.1	58.0	32.6	Silty Clay Loam	01438

Sufficiency factor (1.0=sufficient for average crop) below each nutrient value. N factor based on 200 ppm constant feed. SAR = Sodium adsorption ratio. Half Saturation %=approx field moisture capacity. Nitrogen(N), Potassium(K), Calcium(Ca) and Magnesium(Mg) by sodium chloride extraction. Phosphorus(P) by sodium bicarbonate extraction. Copper(Cu), Zinc(Zn), Manganese(Mn) & Iron(Fe) by DTPA extraction. Sat. ext. method for salinity (ECe as dS/m),Boron (B), Sulfate(SO_4), Sodium(Na). Gravel fraction expressed as percent by weight of oven-dried sample passing a 12mm(1/2 inch) sieve. Particle sizes in millimeters. Organic percentage determined by Walkley-Black or Loss on Ignition.

* LOW , SUFFICIENT , HIGH

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Project : Bush's Pasture Park - Salem, OR

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COMPREHENSIVE SOIL ANALYSIS

Sample Description - Sample ID	Half Sat % / TEC	pH / Qual Lime	ECe dS/m	NO_3-N ppm	NH_4-N ppm	PO_4-P ppm	K ppm	Ca ppm	Mg ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	Organic % dry wt.	Lab No.
				Sufficiency Factors											
Site 5	32	5.9	0.3	12	16	56	426	366	155	1.13	3.36	7.89	210	7.71	01488
	41	None		0.4		1.5	3.3	0.5	1.4	2.1	1.7	1.8	10.5		
Site 6	25	5.2	0.2	4	15	43	352	210	130	0.833	2.77	5.77	159	5.37	01489
	29	None		0.4		1.4	3.6	0.4	1.6	2.1	1.9	1.8	10.8		
Site 7	28	5.6	0.9	66	13	25	400	621	209	0.522	5.41	6.85	76.6	11.7	01490
	54	None		1.4		0.7	3.0	0.7	1.6	0.7	2.0	1.1	2.9		
Site 8	31	6.0	0.6	31	16	29	523	630	191	0.465	2.80	5.21	37.8	11.4	01491
	57	None		0.8		0.8	3.6	0.6	1.3	0.6	1.0	0.8	1.4		

Saturation Extract Values						SAR	Gravel %		Percent of Sample Passing 2 mm Screen					USDA Soil Classification	Lab No.
									Sand						
Ca meq/L	Mg meq/L	Na meq/L	K meq/L	B ppm	SO_4 meq/L		Coarse 5 - 12	Fine 2 - 5	Very Coarse 1 - 2	Coarse 0.5 - 1	Med. to Very Fine 0.05 - 0.5	Silt .002-.05	Clay 0-.002		
1.9	0.6	0.3	0.6	0.13	0.4	0.3	0.7	1.5	1.6	2.8	14.3	50.9	30.3	Silty Clay Loam	01488
2.3	0.8	0.2	0.6	0.10	0.4	0.2	0.2	0.3	6.4	4.8	7.5	54.9	26.3	Silt Loam	01489
5.0	1.8	0.5	1.0	0.12	0.4	0.3	4.6	3.0	7.2	13.0	28.5	26.9	24.3	Sandy Clay Loam	01490
3.9	1.2	0.3	1.3	0.08	0.4	0.2	2.4	2.5	3.4	8.2	35.1	28.9	24.3	Loam	01491

Sufficiency factor (1.0=sufficient for average crop) below each nutrient value. N factor based on 200 ppm constant feed. SAR = Sodium adsorption ratio. Half Saturation %=approx field moisture capacity. Nitrogen(N), Potassium(K), Calcium(Ca) and Magnesium(Mg) by sodium chloride extraction. Phosphorus(P) by sodium bicarbonate extraction. Copper(Cu), Zinc(Zn), Manganese(Mn) & Iron(Fe) by DTPA extraction. Sat. ext. method for salinity (ECe as dS/m),Boron (B), Sulfate(SO_4), Sodium(Na). Gravel fraction expressed as percent by weight of oven-dried sample passing a 12mm(1/2 inch) sieve. Particle sizes in millimeters. Organic percentage determined by Walkley-Black or Loss on Ignition.

* LOW , SUFFICIENT , HIGH

Document 3. Reference Letter for City Council Meeting 2016

FOR CITY COUNCIL MEETING OF: January 25, 2016
AGENDA ITEM NO.: 6(e)

TO: MAYOR AND CITY COUNCIL

THROUGH: STEVE POWERS, CITY MANAGER

FROM: PETER FERNANDEZ, P.E., PUBLIC WORKS DIRECTOR

SUBJECT: IMPACTS TO OAK TREES IN BUSH'S PASTURE PARK

ISSUE:

Response to Council question regarding the causes of damage to the Oregon white oaks in Bush's Pasture Park and possible impact of crowds associated with Salem Art Fair and Festival.

RECOMMENDATION:

Information only.

SUMMARY AND BACKGROUND:

At the City Council meeting on December 7, 2015, Councilor Andersen noted that a large Oregon white oak had recently fallen in Bush's Pasture Park in the area where the annual Salem Art Fair and Festival is held. His question, generally, was what causes oak trees to weaken and topple in Bush's Pasture Park?

In summary, there are two main factors occurring in Bush's Pasture Park that can weaken the oak trees:

1. High Soil Moisture Content. Oregon white oaks are susceptible to root rot, which occurs when a naturally occurring fungus is activated by moist conditions in the soil during the summer. To reduce this impact, the City irrigates only sparingly, sufficient to maintain the turf. Limiting irrigation also reduces the propensity of soil to be compacted by users at the park.

2. Soil Compaction. Compact soils can weaken trees by reducing the ability of the roots to access water and air. To address soil compaction in Bush's Pasture Park, the City limits use of motor vehicles, has provided paved and bark pathways for foot traffic, and has incorporated soil aeration into its park maintenance practices.

Specific to the Salem Art Fair and Festival, staff works with the Art Association to place activities in a manner that minimizes adverse impacts related to compaction as much as practicable, concentrating booths away from denser stands of oaks, and maximizing use of paved pathways. Additionally, because the fair occurs during the summer months when the soil is dry, compaction is less of a concern as compared to compaction that can occur from other users in the fall, winter, and spring when the soil can be moist and is more easily compacted by foot traffic and other park activities.

Document 3. Reference Letter for City Council Meeting 2016

Additional information regarding history and characteristics of Bush's Pasture Park and Oregon White Oaks is provided below.

FACTS AND FINDINGS:

Overview of Bush's Pasture Park

Bush's Pasture Park covers approximately ninety acres and can be divided into three distinct areas: Upper Bush, Lower Bush, and the Historic Area. These three areas reflect different uses of the park. Uses in Upper Bush include picnics, playground, soapbox derby, walking and running, and the yearly Salem Art Fair and Festival. The fair draws more than 30,000 visitors over three days and takes place under the cover of the extensive native white oak grove. Lower Bush includes a ball field, a large turf area for drop-in use, a playground, a picnic facility, a large oak grove, and Pringle Creek along the east boundary. The third area is the historic area and encompasses the Bush House, Art Barn, conservatory, rose garden, orchard, and garden.

History

In the 1840s, this site was used for agriculture with crops in the Lower Bush area, cattle grazing under the oaks in Upper Bush, and small gardens and orchard around the Bush House. The City began to develop the area as a park beginning in the mid-1950s with the installation of playgrounds, irrigation systems, and lawns. Years later, the City discovered that regular summer irrigation within the oak savanna was detrimental to the trees and took corrective action by reducing the frequency and amount of water to prevent further damage.

In 1953, the Salem Art Association began conducting the Salem Art Fair and Festival at Bush's Pasture Park. During the first few years, the fair was held around the Bush House; even the clotheslines were used to hang and display art. By 1976, the fair had grown to more than 450 artists and been moved to the area it now occupies along the north-south paved path and under the oaks of Upper Bush. Recent fairs have drawn over 30,000 visitors over the three-day period.

Oaks, Root Rot, and Bush's Pasture Park

The largest and most numerous trees in the park are Oregon white oak (*Quercus garryana*). These trees are native to the area and were growing here long before Salem was settled. Some of the oaks in the park are more than 300 years old, while the smaller oaks were naturally regenerated or were planted over the last few decades. The native oak is a superb tree for our unique climate and local soils. It thrives in cool wet winters and does well during hot dry summers.

"Root rot" (*Armillaria mellea*) is the Oregon white oak's primary weakness. The disease is most often caused when a mature oak comes under irrigation. This fungus lives in all soils, but is not active when the ground is cold in winter or dry during summer. However, summer irrigation or significant late spring/early summer rains can activate the fungus, which will invade the roots of the oak. The fungus slowly moves through the roots and will continue even when summer irrigation is discontinued. There is no cure or remedy

Document 3. Reference Letter for City Council Meeting 2016

to stop the fungal growth once it has established itself in the tree. At some point, enough of the root strength will be compromised and the tree will fail.

There are signs City staff look for to determine if a tree is infected with *Armillaria*, such as the appearance of honey fungus at the base of the tree or on the ground near the tree. However, these indicators are not always present. In Oregon white oaks, there may be very few readily apparent signs of fungus; limb dieback and reduced growth associated with the fungus infected trees may be mistaken as symptoms of old age in a tree.

<u>Soil Types within the Park</u>
Three soil types dominate the park. The Upper Bush and Historic Area is Willamette silt loam, while part of Lower Bush is comprised of Clackamas gravelly loam covering the stadium and open field, and the oak grove to the east sits on Salem gravelly silt loam.

The Willamette silt loam has good drainage and allows for deep rooting plants such as the Oregon white oak. The Clackamas gravelly loam has poor drainage and not generally suited for deep-rooted plants, while the neighboring Salem gravelly silt loam provides good drainage and suited for deep-rooted plants. The large trees in the park are growing on the soils best suited for deep rooted, tall growing trees, while the stadium and ball fields are on the soils that best support their use.

The two soil types that support the major stands of oak trees within Bush's Pasture Park have a minimal amount of clay and are therefore less subject to compaction. Salem's dry summers coupled with minimal irrigation help further resist compaction. While the turf within the oak grove in Upper Bush is not lush, there is also a lack of large bare spots that would indicate severe soil compaction.

<u>Art Fair</u>
Much of the ambiance of the Salem Art Fair and Festival is the setting – in the shade and among the majestic Oregon white oaks. With more than 30,000 visitors to the fair each year, it is inevitable that this use can compact the soil, which in turn has a detrimental effect on the oaks. Working with City staff, Art Fair organizers strive to minimize the event's impacts on the park by aligning the layout to make use of the paved path for the heaviest traffic, and by clustering the vendor's booths away from the denser stands of oaks.

A more significant source of soil impact is motorized vehicles, which drive and park on the turf beneath the trees to service the vendor booths before, during, and after the event. City staff and Art Association officials work together to reduce this problem. It is helpful the Art Fair is held in July. This is when the soils are driest and most resistant to compaction.

<u>Soil Compaction Issues</u>
The Upper Bush area of the park attracts many picnickers and other active users with its abundance of tables, access to playgrounds, open fields, and restrooms. However, it is the shade from the many towering oaks that draw many park users. While the Salem Art Fair and Festival draws people in July when the ground is dry, many picnickers

Document 3. Reference Letter for City Council Meeting 2016

come out during the first warm days of spring when the ground moisture level is often still high. Park users can often be seen lined up waiting for picnic tables to open and they may spend a half day with friends and family. These spring days are when the soil is still soft from the winter's rains and more vulnerable to compaction.

Another source of soil compaction is the cross-country runs through the park, which occur year-round. The most critical time that the soil is most vulnerable is during the winter rains. The ground is saturated and soils are readily compacted during this time.

The compaction of soil around an oak will not cause root rot, but over time can reduce vigor of the tree, lessening its ability to resist fungal infection.

To reduce the impact of soil compaction in Bush's Pasture Park, the City has been aerating the soils.

Robert D. Chandler, PhD, PE
Assistant Public Works Director

JP/G:\Group\director\Judy\Council 2016\Jan 25\Bushs Pasture Art Fair Impacts_RDCv2(RS).docx
Ward 2
January 12, 2016

Document 4. Penetrometer Readings

Site 1	PSI	Inch Depth
	290	10
	300	10
	300	10
	300	10
	300	10
	300	10
	200	6
	180	4
	180	6
	160	4
	160	3
	160	4
	180	8
	220	10
	260	10

Site 2	PSI	Inch Depth
	300	10
	220	10
	300	10
	300	10
	300	10
	300	10
	220	10
	300	10
	300	10
	240	10
	300	10
	250	10
	300	10
	280	10
	280	10

Site 3	PSI	Inch Depth
	200	10
	220	10
	300	10
	180	10
	180	10
	300	10
	280	10
	200	10
	300	10
	280	10
	300	10
	250	10
	250	10
	300	10
	300	10

Site 4	PSI	Inch Depth
	300	10
	300	10
	300	10
	300	10
	300	10
	300	10
	300	10
	300	10
	280	10
	300	10
	300	10
	300	10
	300	10
	280	10
	220	10

Site 5	PSI	Inch Depth
	90	10
	50	10
	60	10
	60	10
	80	10
	40	10
	40	10
	60	10
	60	10
	60	10
	90	10
	90	10
	180	10
	120	10
	60	10

Site 6	PSI	Inch Depth
	280	10
	200	10
	180	10
	160	10
	160	10
	120	10
	100	10
	120	10
	160	10
	160	10
	200	10
	200	10
	200	10
	160	10
	120	10

Site 7	PSI	Inch Depth
	160	3
	160	3
	N/A	-
	150	3
	N/A	-
	140	3
	140	6
	120	3
	N/A	-
	180	3
	180	3
	N/A	-
	180	4
	120	3
	180	3

Site 8	PSI	Inch Depth
	140	3
	160	3
	140	3
	140	3
	140	3
	140	3
	120	3
	120	3
	120	3
	120	3
	120	3
	160	3
	160	3
	180	3
	120	3

Document 5. Height and Diameter Measurements of Site 8 and Site 4

Site 8, average height (47 feet), average diameter (11.5 inches), 89 trees

	Ht.'	DBH"		Ht.'	DBH"		Ht.'	DBH"		Ht.'	DBH"		Ht.'	DBH"
1.	49	12	21.	61	17	41.	48	11	61.	54	10	81.	48	12
2.	48	11	22.	54	18	42.	62	15	62.	52	8	82.	52	11
3.	42	9	23.	48	14	43.	57	18	63.	51	9	83.	41	9
4.	48	16	24.	52	11	44.	47	8	64.	46	7	84.	43	9
5.	46	15	25.	20	10	45.	42	12	65.	60	10	85.	54	16
6.	44	16	26.	62	14	46.	43	10	66.	54	12	86.	49	16
7.	50	12	27.	64	17	47.	42	7	67.	53	10	87.	58	12
8.	54	11	28.	33	9	48.	52	12	68.	55	11	88.	52	11
9.	41	9	29.	53	12	49.	63	13	69.	19	6	89.	54	17
10.	50	12	30.	32	8	50.	31	6	70.	49	14			
11.	54	11	31.	54	13	51.	47	9	71.	57	14			
12.	41	9	32.	37	9	52.	57	15	72.	52	14			
13.	50	12	33.	48	13	53.	52	9	73.	53	13			
14.	54	11	34.	59	12	54.	47	8	74.	49	10			
15.	41	9	35.	44	11	55.	32	7	75.	45	8			
16.	50	15	36.	53	14	56.	55	9	76.	55	17			
17.	52	15	37.	51	12	57.	51	10	77.	57	13			
18.	39	14	38.	44	9	58.	45	9	78.	15	6			
19.	39	16	39.	46	9	59.	60	16	79	35	10			
20.	42	10	40.	46	8	60.	52	9	80.	44	11			

Site 4, average height (68 feet), average diameter (19 inches), 25 trees

	Ht.'	DBH"		Ht.'	DBH"
1.	61	15	21.	69	18
2.	67	22	22.	64	15
3.	64	16	23.	70	13
4.	76	34	24.	67	18
5.	69	19	25.	71	18
6.	51	16			
7.	63	17			
8.	66	20			
9.	60	24			
10.	66	19			
11.	74	21			
12.	79	26			
13.	78	21			
14.	71	16			
15.	69	21			
16.	64	12			
17.	63	14			
18.	73	18			
19.	63	18			
20.	75	24			

Document 6. Soil Conditions Summary Table

Site #	pH	Grove Characteristics	Penetrometer Analysis	Soil Composition	Est. Infiltration rate (in./hr.)	Soil Chemistry (N-P-K and micronutrients)	Major Concerns
1	**5.9**	Several very large, old Oaks in isolated grove. Saplings recently planted around periphery. Turf understory.	Dense surface soil. Inconsistent and occasionally shallow layer above gravelly subsoil. Average resistance 233psi.	Organic content 7.7% 13% coarse sand and gravel 14% fine sand 38% silt 41% clay	0.13	Low optimum N, low P-K. Micronutrients sufficient.	Irrigation is the major tree health concern. Shallow soil depth likely mitigates some irrigation impacts.
2	**5.5**	Grove of mostly large, mature Oaks. Well-spaced with turf understory. Visual indicators of soil compaction and heavy impact. Bare soil in several places.	Very dense soil, deeper than 10”. Average resistance 279psi.	Organic content 3.7% 2.4% coarse sand and gravel 14% fine sand 54% silt 31% clay	0.19	Low N-P, optimum K. Micronutrients sufficient.	Soil appears majorly compacted from human activity and this is likely impacting tree health. Consider protection as well as soil building measures to improve soil porosity.
3	**5.4**	Grove of mostly large, mature Oaks. Similar to sites 2 and 4 with less indication of compaction and human impact. Turf understory.	Dense soil, deeper than 10”. Average resistance 256psi.	Organic content 5.5% 5.9% coarse sand and gravel 13% fine sand 52% silt 31% clay	0.19	Low optimum N, low P, optimum K. Low Manganese, other micronutrients sufficient.	Less concern of compaction than sites 2 and 4. Poor drainage is a concern; soil building measures can help alleviate.
4	**4.9**	Grove of mostly large, mature Oaks. Similar to sites 2 with many visual indicators of compaction. Turf understory.	Very dense soil, deeper than 10”. Average resistance 292psi.	Organic content 3.3% 3.7% coarse sand and gravel 6% fine sand 58% silt 33% clay	0.18	Low N, low optimum P, optimum K. Calcium low, micronutrients sufficient.	Soil appears majorly compacted from human activity and this is likely impacting tree health. Consider protection as well as soil building measures to improve soil porosity.
5	**5.9**	Grove of mostly large, mature Oaks on slope with Rhododendron garden understory. Heavy use of mulch Oregon Ash seedlings noted. Heavy irrigation in summer.	Very loose surface soil (decomposed mulch,) deeper than 10”. Average resistance 76psi	Organic content 7.7% 6.6% coarse sand and gravel 14% fine sand 51% silt 30% clay	0.19	Low N, optimum P-K. Calcium low, micronutrients sufficient.	Previous root failures of Oaks here likely caused by irrigation. Oregon Ash seedlings indicate overly wet conditions for Oaks.
6	**5.2**	Grove of mostly large, mature Oaks on slope with established understory of native plants. Visual indicators of undisturbed, uncompacted soil.	Dense soil, relatively undisturbed, deeper than 10”. Average resistance 168psi.	Organic content 5.4% 11.7% coarse sand and gravel 8% fine sand 55% silt 26% clay	0.20	Low N, optimum P-K Calcium low, micronutrients sufficient.	This is a site with dense clay soil which is uncompacted by human activity.
7	**5.6**	Grove of mostly smaller Oaks and Douglas-firs on riparian floodplain with turf understory.	Sandy, shallow surface soil above gravelly subsoil. Average resistance 155psi.	Organic content 11.7% 27.8% coarse sand and gravel 29% fine sand 27% silt 24% clay	0.27	Optimum N, low optimum P, optimum K Calcium low, micronutrients sufficient	Shallow soil which has poor water retention characteristics. Soil building measures will improve Oak health and maximize habitat potential.
8	**6.0**	Grove of mostly smaller Oaks with Douglas-firs present in some parts of grove. On riparian floodplain but on level ground above site 7. Primarily Camas understory.	Sandy, shallow surface soil above gravelly subsoil. Average resistance 139psi.	Organic content 11.4% 16.5% coarse sand and gravel 35% fine sand 29% silt 24% clay	0.32	Low optimum N-P, optimum K. Calcium and copper low, micronutrients sufficient.	Shallow soil which has poor water retention characteristics. Protect established Camas understory from human impacts.

Document 7. Open-grown mature Oaks (vehicle disturbance) Map

Document 8. Conifer groves Map

Document 9. Closed-canopy, even-aged Oak woodlands Map

Document 10. Southwest Quadrant of the Park (Sites 2 and 4) Map

Document 11. Site 1 Oak grove and other isolated groves Map