Paleoliquefaction Study of the Willamette River Valley, Portland to Corvallis, Oregon
FINAL REPORT

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Element II (Research on Earthquake Occurrence and Effects)
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ABSTRACT

In 2002 we surveyed several tributary rivers to the Willamette as well as a segment of the Willamette itself between miles 151 and 76 (Fig 1). We found five sites with earthquake-induced paleoliquefaction on the Calapooia River which confirms the work of Thurber and Obermeier (1996, unpublished manuscript). We did not find liquefaction features west of the Willamette River owing to generally near surface bedrock. We also found no paleoliquefaction sites in the Willamette River banks owing to extensive rip-rapping of the areas most likelyto host paleoliquefaction features. Because of budget and time constraints we were unable to survey areas outside those shown in figure 1.

The limited nature of preexisting work in the Willamette system and sparse age constraints on liquefaction in that area makes regional correlation of liquefaction features and magnitude estimation of earthquakes problematic. Many kilometers of rivers and creeks remain to be searched and are likely to yield valuable new information. Dating of additional paleoliquefaction features will help to further constrain the number and timing of prehistoric events in the Willamette Valley. This is critical for determining whether the prehistoric liquefaction features formed as the result of one or more Holocene earthquakes. Therefore, it is important to inventory the areas already searched, conduct reconnaissance along rivers that have never been searched, and to study earthquake induced soft-sediment structures in these areas in detail. Further mapping of the areal extent and severity of liquefaction will help to define the source areas and to estimate the magnitudes of prehistoric earthquakes. This is the approach collaborators and I have used successfully in other regions and will take in broadening this study.

We now have strong evidence of paleoliquefaction in the Willamette River valley. The Nisqually earth-quake of February 28, 2001 (Mw = 6.8) produced strong ground shaking over a wide area and caused significant damage in parts of northwestern Washington (Wang and others, 2001). This subduction zone earthquake produced widespread liquefaction in parts of Olympia and South Seattle well inland of the coastal region where deformation from large subduction zone earthquakes is well documented (Atwater, 1987, 1992, 1994, 1995). Large earthquakes in the coastal region as well as those similar to the Nisqually event could easily leave a more extensive record of liquefaction in the Willamette Valley than we have found to date.

INTRODUCTION

Studies of earthquake hazard in the Pacific Northwest have concentrated largely on earthquakes generated within the Cascadiasubduction zone (e.g. Atwater, 1987, 1992, 1994, 1995; Heaton and Hartzel, 1987, Nelson

and Personius, 1996, Nelson *et. al.*, 1996, Atwater and Hemphill-Haley, 1997,). These studies largely focus on documenting evidence for past great subduction zone earthquakes and determining the potential for great earthquakes in the future. Most paleoseismology work has been done along coastal portions of several river valleys in Washington, the central Oregon coast, and along islands in the Columbia River (Atwater, 1994, Obermeier and Dickinson, 1997, Dickinson and Obermeier, 1998). Some research has been done in inland areas such as the Willamette Valley (Thurber and Obermeier, 1996, Maden, written communication, 1999). The proposed project area lies within the Willamette Valley in western Oregon between Corvallis and Portland. Although most of the earthquake hazard of this region is considered to come from subduction zone events along coastal Oregon and Washington, there remains much to be learned about the earthquake potential from the paleoliquefaction history of this inland region.

For a given earthquake moment magnitude **M**, liquefaction-related ground failures occur within a certain epicentral and fault distance (Ambraseys, 1988). In addition, the severity of liquefaction tends to decrease with epicentral distance (Youd et al., 1989). Therefore, the distribution of liquefaction features can be used to estimate the location and magnitude of paleoearthquakes (Obermeier, 1996). We propose to apply methods of paleoseismic research that have been very successful in the central and eastern United States to the Willamette Valley (McCalpin, 1996). This consists of using the methods of Obermeier (Obermeier *et.a*l., 1991a, b) in surveying rivers and creeks for evidence of paleoliquefaction features, and Sims (Sims, 1973, 1975, 1978; Sims and Garvin, 1995, 1998) and Tuttle (Tuttle and Schweig, 1995, 1996, Tuttle et.al, 1997, 1999, Tuttle 1999) in the detailed study and interpretation of earthquake-induced liquefaction structures in sediments.

Given the tectonic setting of the Willamette Valley one might expect the seismic hazard to be significant. However, modern seismicity in the area is sparse with only 2 earthquakes of crustal origin recorded since 1975 (Fig. 1). In addition, the historic seismicity record is short (about 25 years), making it difficult to assess the hazard. Paleoliquefaction, the study of fault rupture and ground shaking as preserved in the geologic record, offers a time window of thousands of years that is well-suited for estimating the long-term strain accumulation and release in this region. Paleoliquefaction studies have successfully identified large Holocene earthquakes preserved in the geologic record in regions, such as the Wabash valley of Indiana and Illinois (Obermeier, and others, 1991a) that had experienced only moderate earthquakes during the historic and modern periods. Paleoliquefaction studies have also greatly extended the record of seismicity in the New Madrid Seismic Zone (Tuttle and Schweig, 1995, 1996, 2000; Tuttle and others, 1999, 2000).

Thurber and Obermeier (1996) were the first to conduct a search for liquefaction features along two tributaries of the Willamette, the Calapooia and Luckiamute rivers and reconnoitered the Long Tom River and both Mudd Creeks south of Corvallis (Fig. 2). During that search, they found evidence for at least two earthquakes during the late Pleistocene. All of the evidence came from the Calipooia River where 16 liquefaction-induced features occur at seven sites along the lower 14 km section of the river. Maximum dike width is 10 cm, and height was up to 5 m. Twenty-two km of the Luckiamute River was also searched; however, limited bank exposures at that time revealed deformation features at only one site. They attributed the small dikes to late Pleistocene events based on correlations of deposits seen in the river banks of the Calapooia and the Luckiamute. They interpreted the dikes source as the silty sand Diamond Hill Member of the late Pleistocene Rowland Formation. The sand dikes cut through the post-Diamond Hill paleosol into the overlying late-Pleistocene Missoula flood deposits (Irish Bend Member of the Willamette Formation, circa 13- ka). These units are commonly exposed along the Calapooia, but younger [Holocene?] fluvial deposits are more widely exposed. Thurber and Obermeier (1996) interpreted the liquefaction to have occurred in at least two seismic events. The older event is represented by two dikes at one site that terminate between rhythmites of the Irish Bend Member. The younger event is indicated by a silt dike that cross-cuts one of the sand dikes, reintrudes another sand dike and is truncated by Holocene fluvial deposits that unconformably lie above strata they interpreted as Irish Bend Member. However, these two liquefaction events could well be developed from a single earthquake and aftershock sequence similar to

that described by Sims and Garvin (1995, 1998) following the 1989 Loma Prieta earthquake. Clearly, better age control is needed to estimate timing of the events.

Thurber and Obermeier (1996) estimated that liquefaction features along the Calpooia River formed as a result of a Mw 5.5 to 6.0 earthquake based on the empirical threshold of liquefaction for earthquakes worldwide. They interpreted the relatively uniform small size and distribution pattern of the liquefaction effects, across 8 km, to indicate formation on the periphery of strong shaking from larger events. (a core region of widest dikes would be expected from a local tectonic source). The limited number of liquefaction events over an unknown time span was considered to be the result of local intracrustal seismicity rather than multiple great subduction earthquakes (Thurber and Obermeier, 1996).

In June 2000, we (Sims and Tuttle) conducted a reconnaissance of the Willamette and its tributaries from just south of Corvallis to just north of Salem to determine the likelihood of finding adequate exposures for paleoliquefaction studies. Our survey was limited to near road exposures and road crossings of the Willamette, Calapooia, Luckiamute, Mudd, Marys, North and South Yamhill rivers, and Muddy Creek. We found that the banks are well exposed and that there are extensive Holocene terrace deposits in most places inset into the Pleistocene fluvial and flood deposits.

Thurber and Obermeier's finding of a few liquefaction features in the Willamette Valley and Portland areas are the result of reconnaissance studies in individual areas and not a complete integrated assessment of the river system as a whole. The limited area surveyed by them in the Willamette Valley does not allow for a high level of confidence in determining if the features result from large subduction events or local intracrustal events. The age of the structures is somewhat in doubt as few radiocarbon dates are available for the host deposits and Thurber and Obermeier (1996) do not report any radiocarbon dates as part of their study. They also do not mention any evidence for liquefaction in post Pleistocene deposits of which there are many in the banks of the Willamette River and its tributaries. Thus, with incomplete coverage and lack of dating of paleoliquefaction features, the question of source zones is moot. Earthquake source determination can only be addressed with broader coverage of liquefaction features and better age data to constrain timing of events and to allow regional correlations of liquefaction features. In addition, we need a more complete picture of the size distribution of similar-aged features for the purposes of evaluating the magnitudes of prehistoric earthquakes.

The February 28, 2001 Nisqually earthquake produced strong ground shaking over a wide area and caused damage in the Olympia, Seattle, and Tacoma areas of Washington. Liquefaction was widespread in parts of Olympia and South Seattle. The relatively long duration of the event and the relatively low cyclic resistance of some of the fills and Holocene deposits in the area are likely causes for the significant liquefaction and ground failure observed for this event (Wang and others, 2001). Responses to similar earthquakes affecting the region of the Willamette River system region could easily have produced widespread liquefaction in the past.

RESULTS

We completed detailed reconnaissance by canoe and raft totaling 135 km on the, Calapooia, Luckiamute, Willamette, and South Fork Santiam rivers. We also conducted auto reconnaissance along about 40 km of the North Fork Santiam River, and the South Yamhill River from near Amity to its mouth.

The surveys were conducted when the water level was low and cutbanks best exposed. We used handheld GPS (Global Positioning System) to locate relevant features and marked them on topographic base maps. Liquefaction features are described in terms of their size (width of dikes, and lateral extent and thickness of sand blows and sills), orientation, sedimentary structures, cross-cutting relations, soil development, and stratigraphic context.

Calapooia River: We surveyed the lower 32 km of the Calapooia River from the confluence of Butte Creek to the mouth at Albany. The Calapooia above the confluence with Butte Creek becomes too shallow

for canoe, and its banks are low and heavily vegetated. We found exposures containing sand dikes along the Calapooia (Table 1). We also discovered Native American presence occupation sites at CR-2 and 11, which contained ancient firepits with abundant charcoal. In general, the stratigraphic section is well exposed along the Calapooia. We measured several sections that have datable material that will allow us to place the sand dikes in context.

Charcoal and wood are common in most stratigraphic sections we examined. Table 1 gives a summary of radiocarbon ages for dated samples. The full list of radiocarbon samples collected is given in Appendix B.

Table 1. Summary of Radiocarbon samples and dates related to paleoliquefaction features. Many more samples are on hand but funds are lacking to date them.

Location	No. of Dikes	Events	Radiocarbon Samples	Radiocarbon Dates
CR-3	1	1	none	NA
CR-7	1	1	maximum age	Not dated
CR-8	4	1?	none	NA
CR-10	2	2	minimum age	4360±40 BP (detrital charcoal)
CR-13	1	1	maximum age	680±40 (detrital charcoal)

Luckiamute River: We completed a detailed survey of the lower 25 km of the Luckiamute river from about 2.5 km above Helmick State Park to its mouth by canoe. We also conducted a road survey above Helmick State Park to the town of Pedee. Above Helmick State Park the banks of the Luckiamute River are gently sloped, commonly <2 m high, and heavily vegetated. Outcrops of bedrock occur in the upper 5-6 km of the Luckiamute and at Pedee the river bed is completely bedrock.

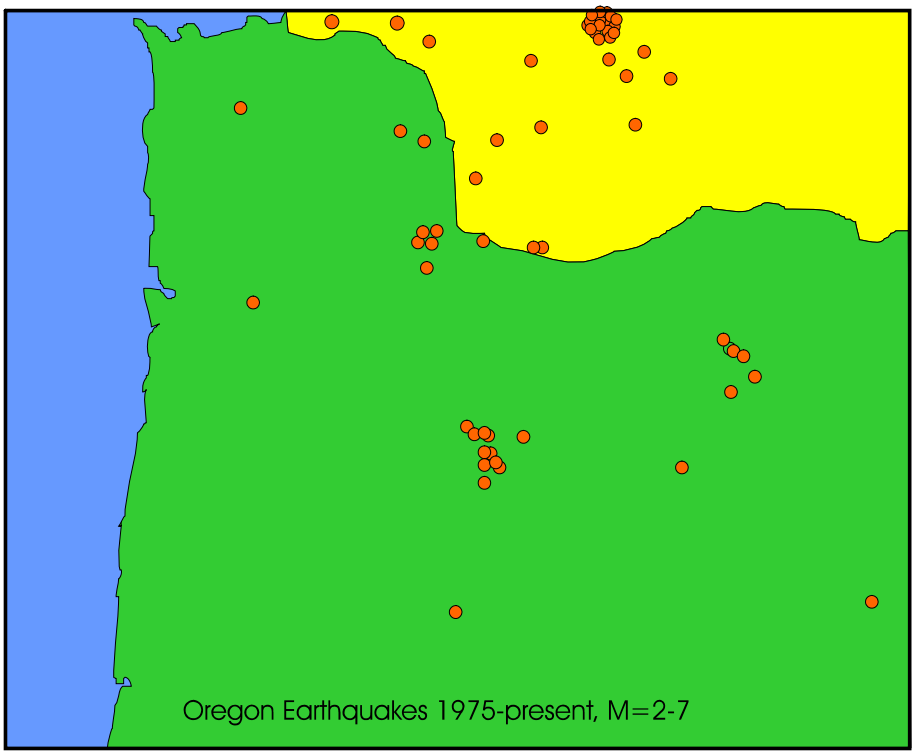
Sand dikes were reported by Thurber and Obermeier (1996) In our detailed survey area we found no sand dikes. Outcrops are generally good but there are numerous exposures of bedrock that make the occurrence of sand dikes unlikely.

Willamette River: We completed a detailed survey of the section of the Willamette River between river mile 151 and 122. In the upper part of this stretch exposures are excellent and of three types. The most abundant type of exposure is low banks of well exposed cobble gravel overlain by soil. The second most common type of exposure is well-exposed high banks of Missoula Flood deposits, and older Pleistocene deposits (O'Connor and others, 2001). The third type of sediment most often seen below Corvallis is various types of bedrock overlain by Missoula flood deposits and younger overbank deposits. From a few kilometers above Corvallis and downstream rip-rapping of cutbanks to control bank erosion is common. This obscures most of the likely areas of natural exposure. We found no sand dikes in the exposures along the Willamette River.

South Fork Santiam River: We completed detailed canoe reconnaissance of 30 km along the South Fork Santiam River from Lebanon, OR to the confluence with the North Fork Santiam River. Exposures are primarily limited to low banks containing cobble to boulder gravel ovelain by thin silt deposits. Above Lebanon bedrock outcrops are common. Both of these factors severely limit the possibility of sand dikes being formed or exposed.

North Fork Santiam River: I conducted an auto reconnaissance of the North Fork Santiam River. From the several bridge crossings and easily reachable banks, we characterize the North Fork Santiam River similar to the South Fork Santiam.

South Yamhill River: We conducted an auto reconnaissance of the South Yamhill River from just west of Amity to near the mouth and noted a number of promising outcrops. Time did not permit exploring these further.



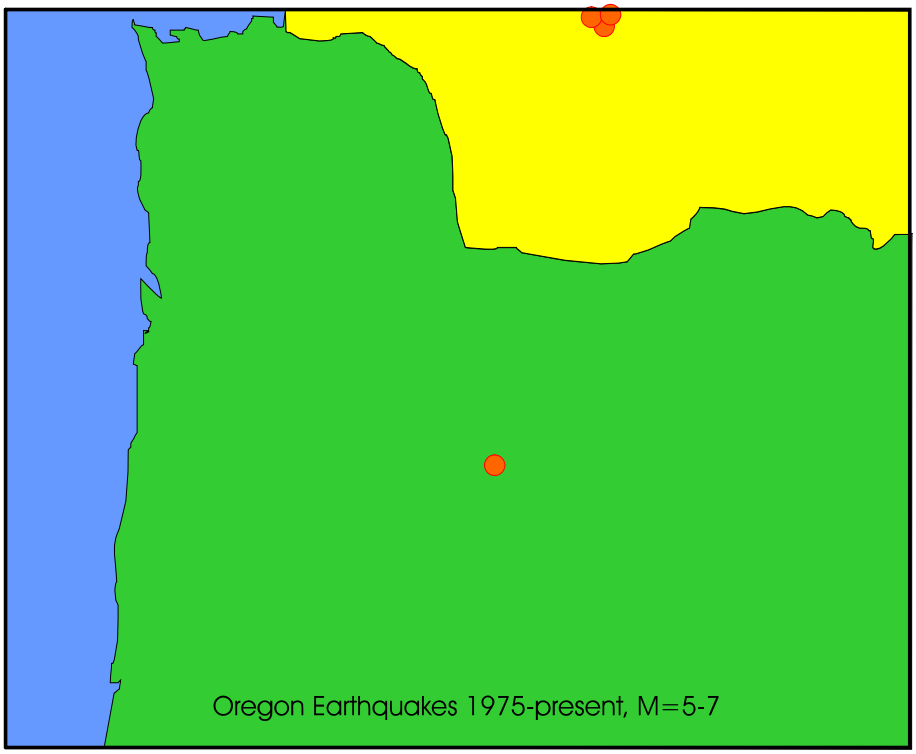


Figure 1. Instrumentally recorded seismicity in western Oregon 1975-present.

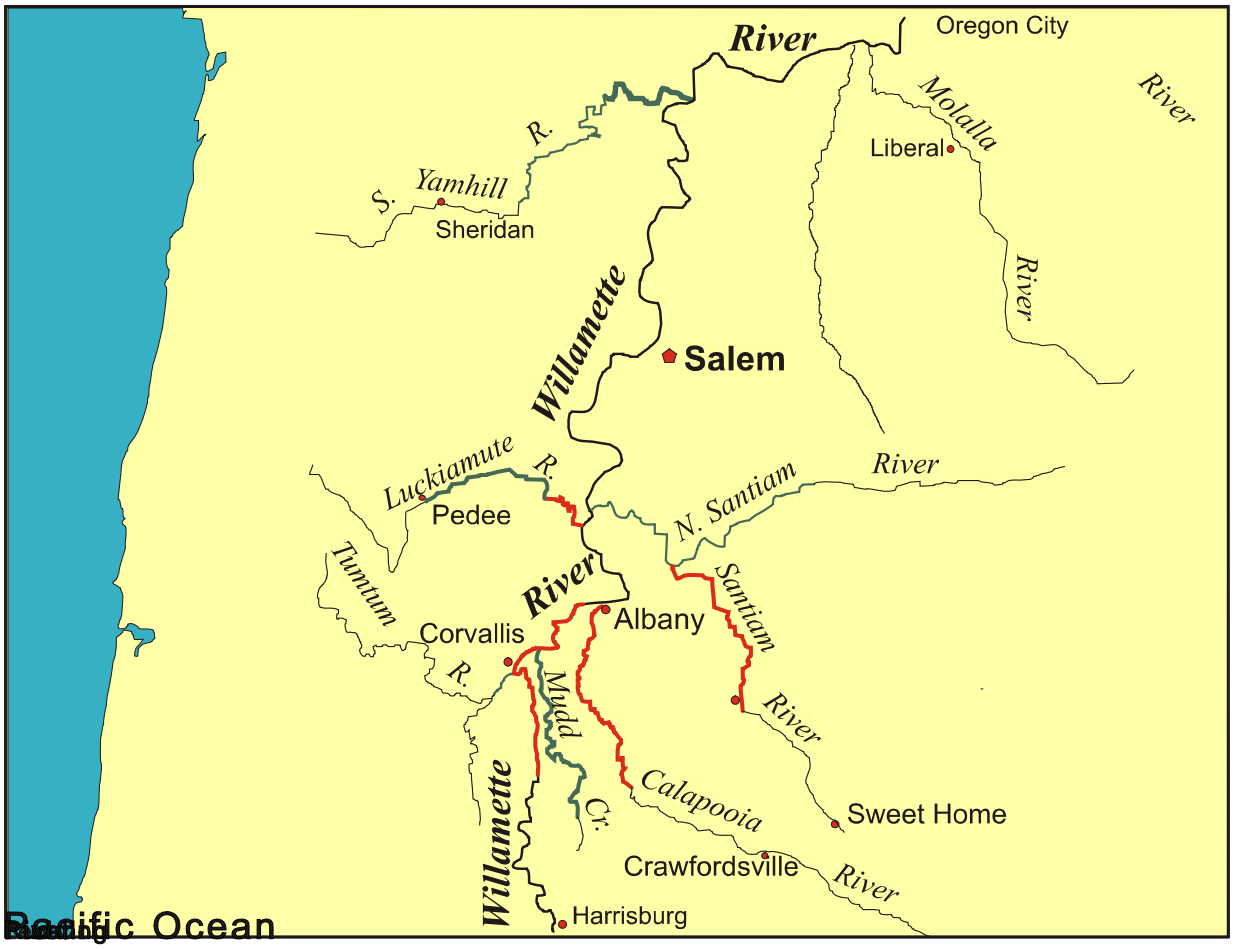


Figure 2. Willamette Valley rivers. River reaches surveyed by canoe shown in red, reconnaissance by car and foot shown in green.

SUMMARY

Systematic searches for liquefaction features were conducted along the Willamette River between miles 151, south of Corvallis, and mile 122, south of Albany, the lower part of the Calapooia River to mile 4 at Albany, the South Santiam River from at Lebanon, OR to its confluence with the North Santiam River near Jefferson, OR, the Luckiamute River to near Pedee, and Muddy Creek (Fig. 1). The searches were conducted by inflatable raft, canoe, and by foot where necessary. We conducted the searches when the water level was low and cutbanks are best exposed. We examined the cut-bank exposures, during reconnaissance, for the presence of liquefaction features and other deformation related to earthquakes. The locations of relevant features were measured and described in terms of their size (width of dikes, and lateral extent and thickness of sand blows and sills), orientation, sedimentary structures, cross-cutting relations, soil development, and stratigraphic context (See Appendix A).

As demonstrated by the recent Nisqually earthquake in Washington, large to very large earthquake centered in western Oregon today would have a major impact on urban areas including Portland, Salem, Corvallis and Eugene/Springfield. Buildings, bridges, lifelines, and essential facilities may be at considerable risk. However, the seismic hazard, though considered great, is poorly understood because there are large uncertainties pertaining to the timing, sources, and magnitudes of large prehistoric earthquakes in this

region. This project demonstrates the feasibility of determining up to 400+ years of paleoseismic history for the Willamette Valley and will help to reduce some of these uncertainties. Our findings will have an immediate impact on the National Seismic Hazard Maps, perhaps the most visible product of the USGS Earthquake Hazard Reduction Program, which will be prominent contributors to the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings.

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Appendix A

Appendix contains Field data sheets with stratigraphic sections

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-1** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): **44°32.062'** Longitude (degrees): **123°8.720'**

Geographic Location: **near Tangent, OR**

Owner or Tenant /Address of Property:

Access: Marker:

Geological setting:

Archeological context:

Exposure Length(m): **30m** Exposure Height(m): **4** Exposure Quality: **Good**

Number of observed dikes: **0**

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, and truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **J. Sims** Name:

Affiliation: Date: 8/21/2002

Site Designation (name and number): **CR-1**

Samples collected (see diagram): Artifacts Soil

Wood **CR-1-W1** Charcoal Flotation

Photographs (roll and date): **Digital OR-2,3**

Diagram:

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-2** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): **44°32.336'** Longitude (degrees): **123°9.038'**

UTM: **4931752** **10T0488020**

Geographic Location: **near Tangent, OR**

Owner or Tenant /Address of Property:

Access: Marker:

Geological setting:

Archeological context:

Exposure Length(m): **20m** Exposure Height(m): **4** Exposure Quality: **Good**

Number of observed dikes: **0**

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, and truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: 8/21/2002

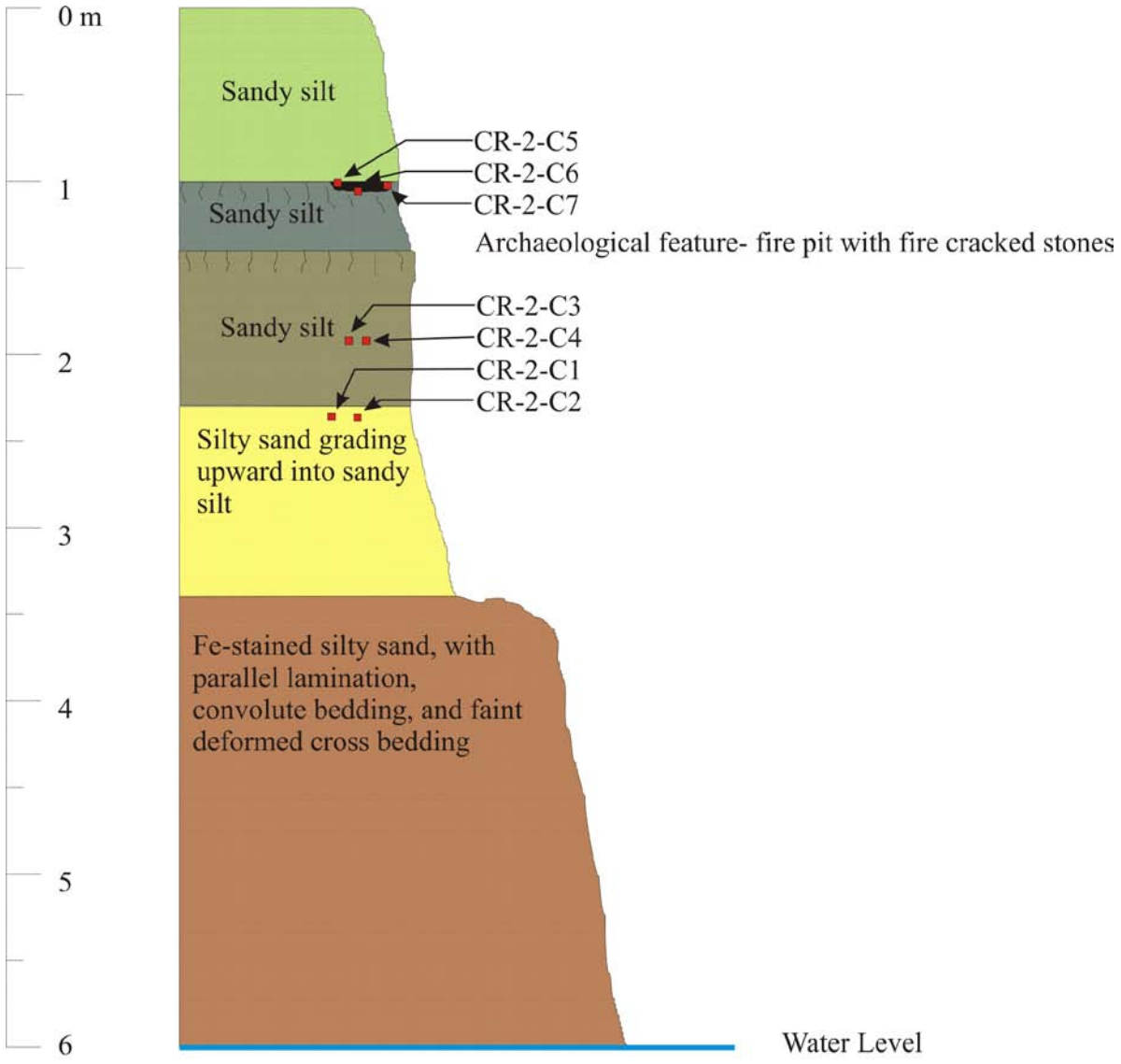
Site Designation (name and number): **CR-2**

Samples collected (see diagram): Artifacts Soil

Wood Charcoal **CR-2-C1, CR-2-C2 CR-2-C3, CR -2-C4** Flotation

Photographs (roll and date): **Digital OR-4**

Diagram:



Calipooia River Site CR-2

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-3** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): **44°32.533'** Longitude (degrees): **123°9.213'**

UTM: **4932134** **10T0487796**

Geographic Location: **near Tangent, OR**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **12m** Exposure Height(m): **6** Exposure Quality: **Good**

Number of observed dikes: **1**

Distance between dikes (m): **NA**

Widths of dikes (cm): **1-3 cm**

Strikes and dips of dikes (degrees): **N32°E 83°W**

Cross-cutting relations of dikes: **NA**

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):
Truncated by modern cultural deposits (trash pit) which include porcelain plates, metal scrap to about 2 m below the surface

Thickness and length of blows/sills: **No sand blow or sills**

Dike, sill, and blow material (grain-size, clasts): **Fine sand fining upward to coarse silt**

Sedimentary structures (flow lamination, vertical/horizontal bedding): **Flow lamination in dikes**

Soil development or chemical weathering: **Host is sand, fine to silty with Mn-stained pebbles and cobbles, discontinuously Fe-cemented**

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

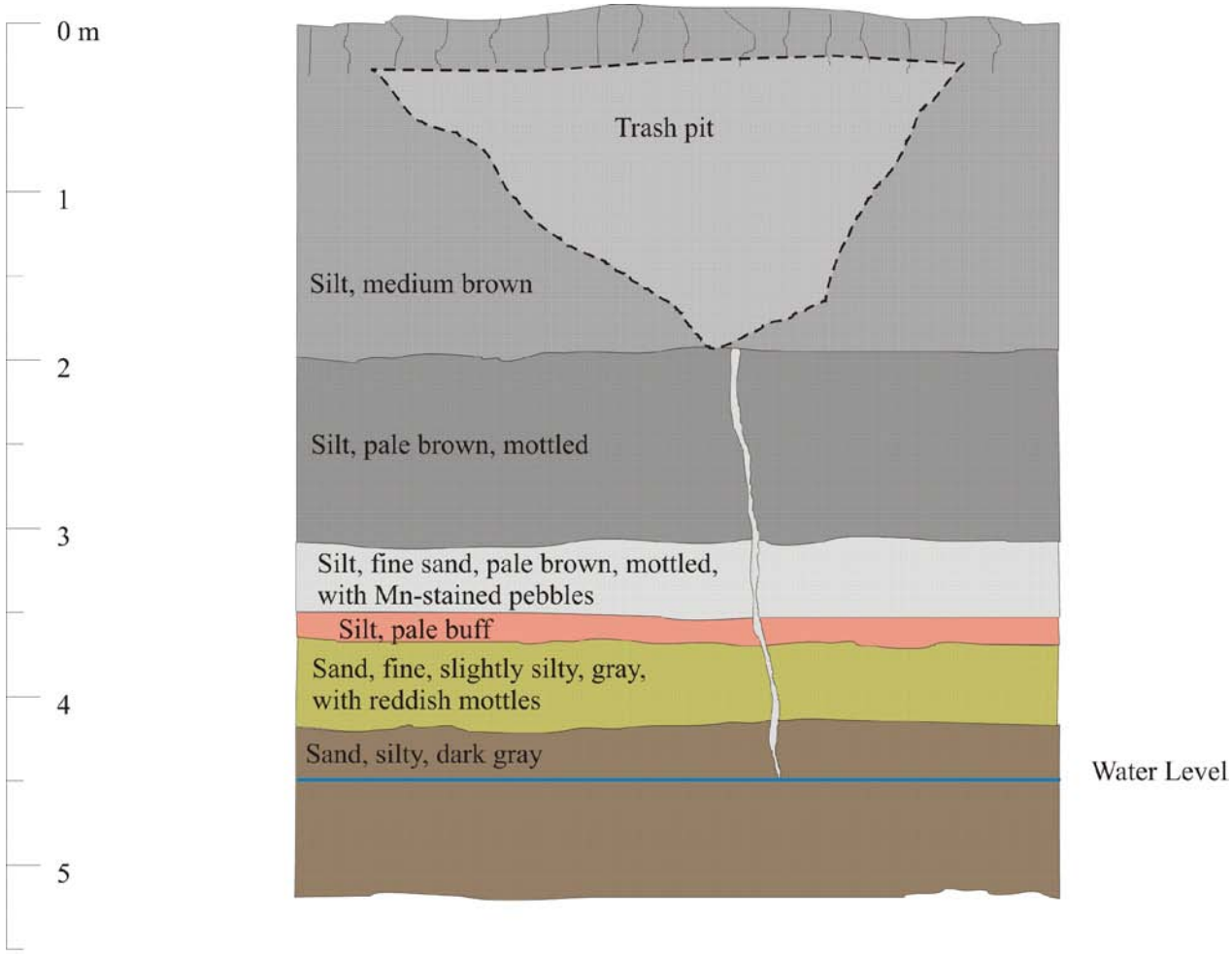
Site Designation (name and number): **CR-3**

Samples collected (see diagram): Artifacts Soil

Wood Charcoal Flotation

Photographs (roll and date): **Digital OR-4**

Diagram:



Notes: All bedding planes transitional. Top of gravel bed determined by soil probe

Calipooia River Site CR-3

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-4** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): **44°32.715'** Longitude (degrees): **123°9.072'**

UTM: **4932433** **10T0487989**

Geographic Location: **near Tangent, OR**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **15m** Exposure Height(m): **5** Exposure Quality: **Fair**

Number of observed dikes:

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, and truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

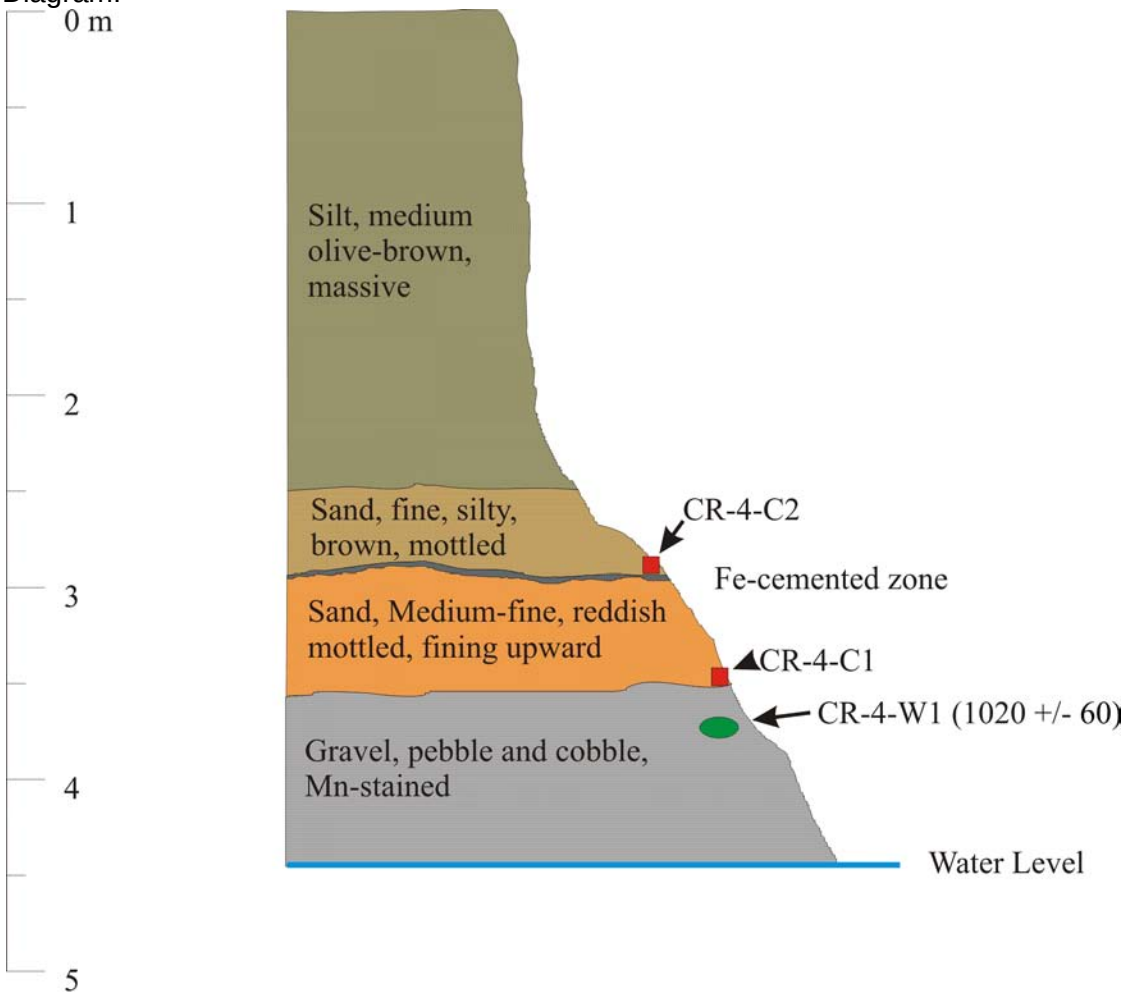
Affiliation: Date: **8/21/2002**

Site Designation (name and number): **CR-4**

Samples collected (see diagram):	Artifacts	Soil
Wood **CR-4-W1**	Charcoal **CR-4-C1, CR-4-C2**	Flotation

Photographs (roll and date): **Digital OR-5**

Diagram:



Calipooia River Site CR-4

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-5** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): **Missing** Longitude (degrees): **Missing**

UTM: **Missing**

Geographic Location: **near Tangent, OR**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting: **Abundant Mn-stained cobble gravel, cemented by Fe**

Archeological context:

Exposure Length(m): **15m** Exposure Height(m): **5** Exposure Quality: **Fair**

Number of observed dikes:

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

Site Designation (name and number): **CR-5**

Samples collected (see diagram):	Artifacts	Soil
Wood	Charcoal	Flotation

Photographs (roll and date):

Diagram:

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-6** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): Longitude (degrees):

UTM: **4933438** **10T0488269**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting: **Lacustrine(?) Silt with abundant wood fragments, leaf fragments, discontinuous parallel lamination in medium sand with silt laminae**

Archeological context:

Exposure Length(m): **10m** Exposure Height(m): **3** Exposure Quality: **Good**

Number of observed dikes: **None**

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, and truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

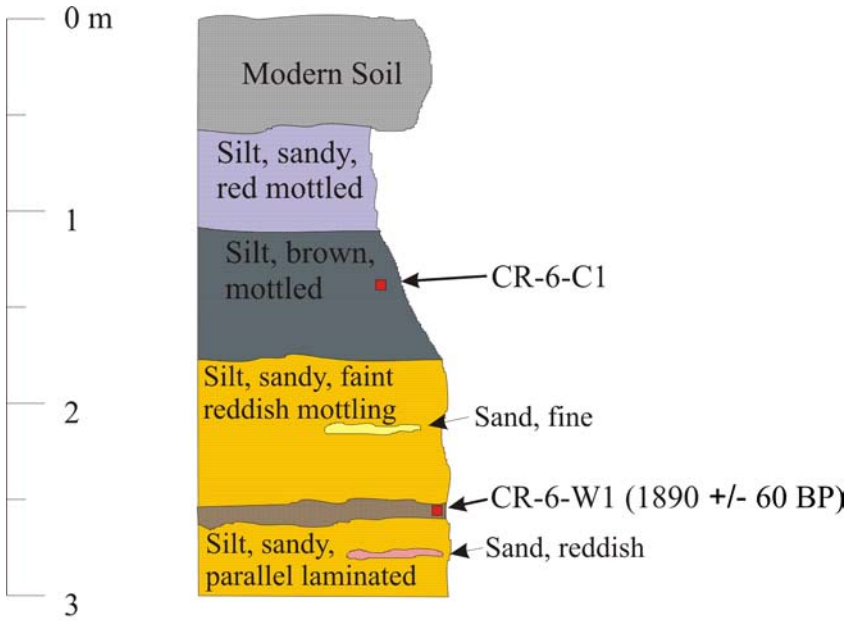
Site Designation (name and number): **CR-6**

Samples collected (see diagram): Artifacts Soil

Wood **CR-6-W1**, **CR-6-W2** Charcoal Flotation

Photographs (roll and date): **Digital OR-7**

Diagram:



Calipooia River Site CR-6

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-7** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): Longitude (degrees):

UTM: **4934300** **10T0488110**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker: **South of Highway 34 Bridge**

Geological setting:

Archeological context:

Exposure Length(m): **25m** Exposure Height(m): **4** Exposure Quality: **Excellent**

Number of observed dikes: **1**

Distance between dikes (m): **NA**

Widths of dikes (cm): **2-7 cm**

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes: **NA**

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m): **See diagram**

Thickness and length of blows/sills: **See diagram**

Dike, sill, and blow material (grain-size, clasts): **Fine sand fining upward to coarse silt**

Sedimentary structures (flow lamination, vertical/horizontal bedding): **None visible**

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

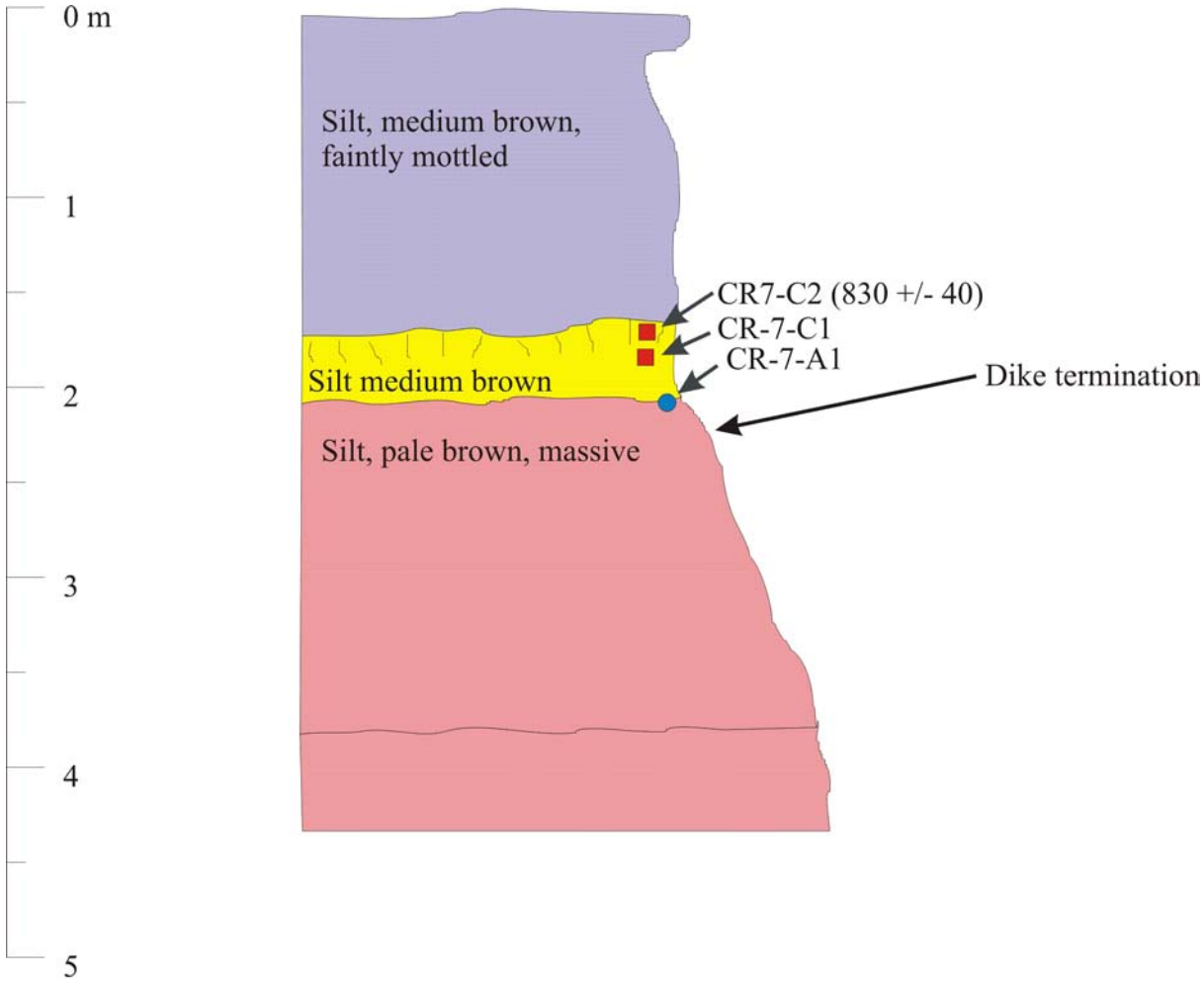
Site Designation (name and number): **CR-7**

Samples collected (see diagram): Artifacts **CR-7-A1** Soil

Wood Charcoal **CR-7-C1**, **CR-7-C2** Flotation **CR-7-P1, CR-7-P2**

Photographs (roll and date): **Digital OR-6, 7, 8, 9**

Diagram:



Calipooia River Site CR-7

Information Supplied By: Name

Affiliation: Date: 8/21/2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-8** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): Longitude (degrees):
UTM: **4935371** **10T0488543**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting: **Willamette Silt (?) Overlain by poorly bedded sand and silt 1.45 m from water line to top of paleosol perhaps developed in Willamette Silt (?)**

Archeological context:

Exposure Length(m): **40m** Exposure Height(m): **5.3** Exposure Quality: **Excellent**

Number of observed dikes: **4 upstream dikes=a, b Downstream dikes=c, d**

Distance between dikes (m): **a-b=2.5 m; b-c=23.5 m; c-d=13 m**

Widths of dikes (cm): **a-generally 4 cm but up to 11 cm; b-generally 2 cm near base narrowing gradually to termination; c-1.5-7 cm; d-5-7 cm**

Strikes and dips of dikes (degrees): **a-not measured unable to access; b-N21°E 85°NW c-N13°W87°Wd-N4°W vertical**

Cross-cutting relations of dikes: **NA**

Termination of dikes (blow, sill, **pinch**, truncation) and depth below surface (m):**a-unable to access, b-terminates 85 cm below surface only a few mm wide, crack extends 4 mm into base of soil, c-4 mm root grows into top of dike, d-1.8 m above water line**

Thickness and length of blows/sills: **NA**

Dike, sill, and blow material (grain-size, clasts): **A-sand, fine to medium, silty, some Fe-staining; B-silt, coarse, gray; C-Sand, fine to medium, Fe-stainedthickest in cut-banks, thins toward river; D-silt**

Sedimentary structures (flow lamination, vertical/horizontal bedding): **None visible**

Soil development or chemical weathering: **Soil at top of cutbank is 88 cm thick; nice ped development, fairly clay rich; 10 cm thick Fe-stained horizon, base of which is 25 cm above base of soil**

Information Supplied By: **Sims/Tuttle** Name:

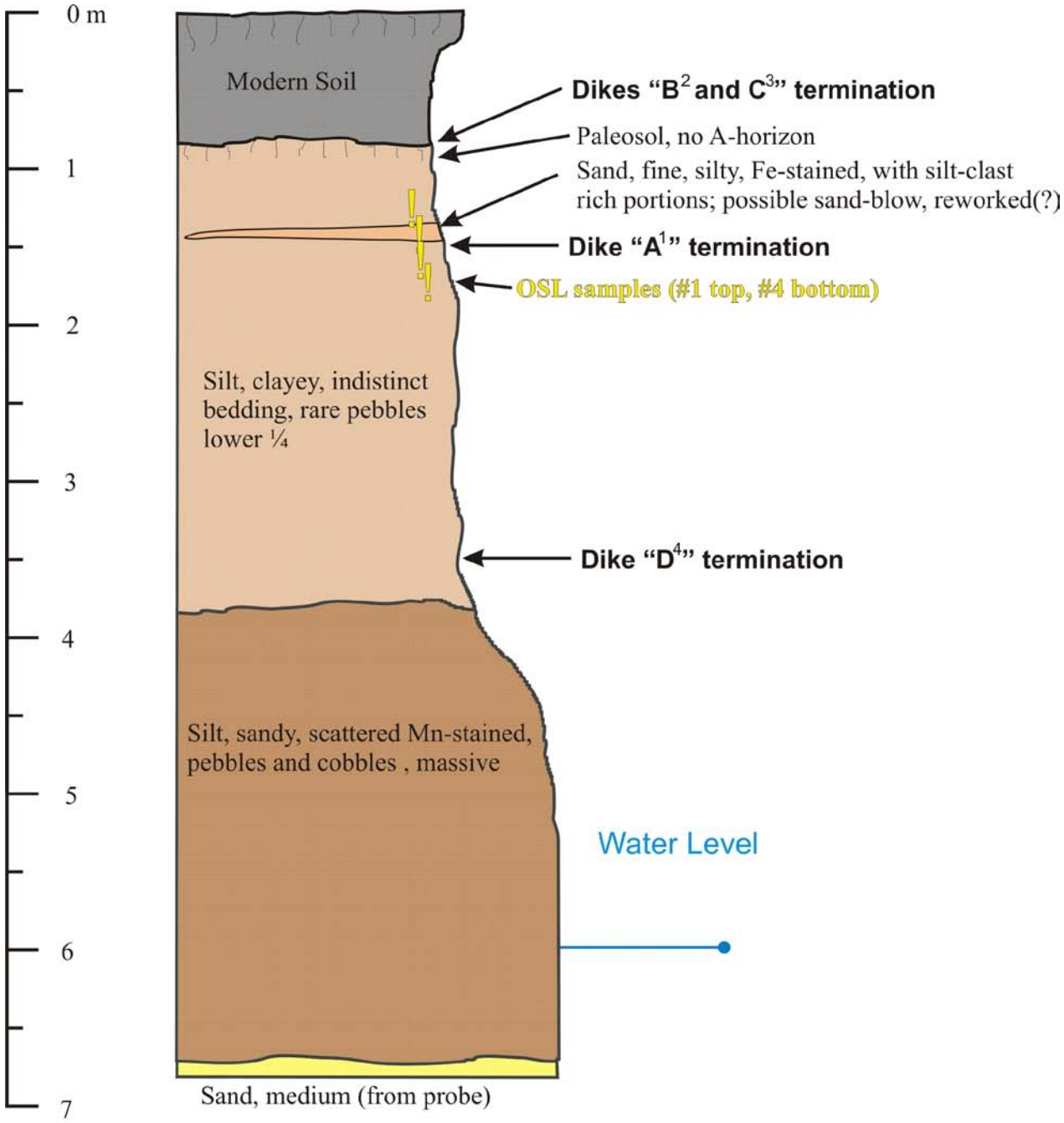
Affiliation: Date: **8/21/2002**

Site Designation (name and number): **CR-8**

Samples collected (see diagram): Artifacts **none** Soil

Wood **none** Charcoal **none** Flotation

Photographs (roll and date):Digital OR-10
Diagram:



[1] Dike A consists of: Sand, silty, fine to medium grained, some Fe-stain; extends -4mm into soil

[2] Dike B consists of: Silt, gray, fine to medium grained; extends 4mm into soil

[3] Dike C consists of: Sand, silty, fine grained, Fe-stained

[4] Dike D consists of: Silt, gray, fine to medium grained

Calipooia River, Site CR-8

Information Supplied By: Name

Affiliation: Date: 2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-9** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): Longitude (degrees):

UTM: **4935271** **10T0488839**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **100m** Exposure Height(m): **5** Exposure Quality: **Excellent**

Number of observed dikes:

Distance between dikes (m):

Widths of dikes (cm): **a-generally 4 cm but up to 11 cm; b-generally 2 cm near base narrowing gradually to termination; c-1.5-7 cm; d-5-7 cm**

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes: **NA**

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding): **None visible**

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

Site Designation (name and number): **CR-9**

Samples collected (see diagram): Artifacts **none** Soil

Wood **none** Charcoal **none** Flotation

Photographs (roll and date): **Digital OR-104 Beginning of series**
-103 Beginning of continuous section
-102 Another of beginning of series
-101 Another of beginning of continuous section
-100 Channel cut and lacustrine deposit
-099 Lacustrine deposit and another channel
-098 "folding"?
-097 More section, nothing out of the ordinary
-096 ditto
-095 End of series

Diagram:

Information Supplied By: Name

Affiliation: Date: 2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-10** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): Longitude (degrees):

UTM: **4936574** **10T0488899**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **150m** Exposure Height(m): **5** Exposure Quality: **Excellent**

Number of observed dikes: **2**

Distance between dikes (m): **NA**

Widths of dikes (cm): **4 mm but up to 1 cm in lower 2.5 m, 1-1.6 cm , 2.8 cm @ 1m above paleosol. Bifurcates about 25 cm below carbonate horizon**

Strikes and dips of dikes (degrees): **younger dike N 55°E 87°NW in lower 1.8 m above water line to top of paleosol to N25°E 85°NW (upper part**). **Small silt dike=N26°W 89°SW**

Cross-cutting relations of dikes: **Silt dike cut by sand dike**

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m): **Below modern soil in carbonate horizon at base, cross cutting dike traced to within 10 cm (vertical) of contact with channel fill. Older dike terminates about 50 cm above paleosol. (See diagram)**

Thickness and length of blows/sills: **None**

Dike, sill, and blow material (grain-size, clasts): **Sand, fine, silty in NW striking dike. Silt in SW striking dike**

Sedimentary structures (flow lamination, vertical/horizontal bedding): **None visible**

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

Site Designation (name and number): **CR-10**

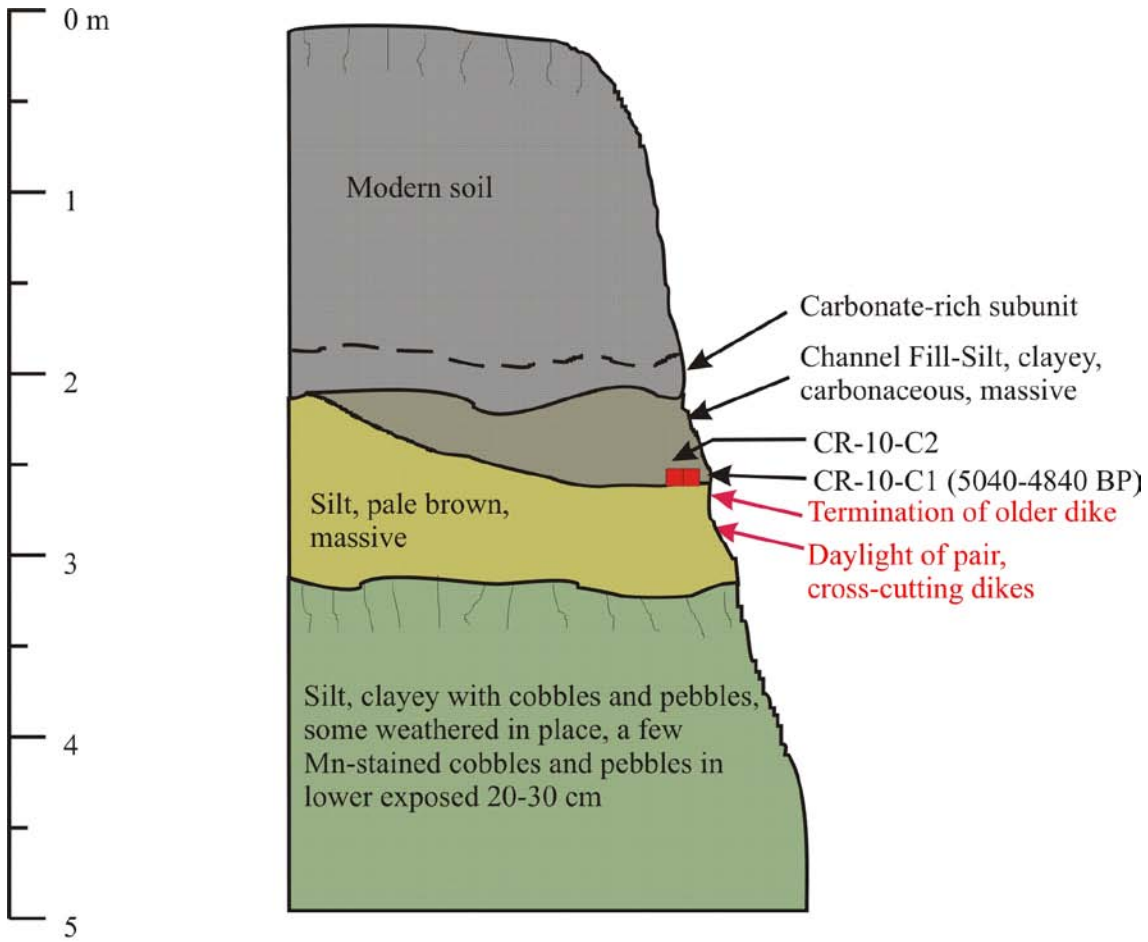
Samples collected (see diagram): Artifacts **none** Soil

Wood **none** Charcoal **CR-10-C1** Flotation
CR-10-C2

C1 and C2 are near the base of the channel fill and postdate the two generations of dikes. The channel fill cuts out pale brown silt to 52 cm above the paleosol, and contains 1-4 cm diameter calcareous nodules.

Photographs (roll and date): **35 mm=5 photos, digital=1**

Diagram:



Notes: Two dikes present a 0.4-1 cm-wide silt dike cut by a 1-1.6 cm-wide silty fine-sand dike

Calipooia River Site CR-10

Information Supplied By: Name

Affiliation: Date: 2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-11** USGS 7.5 Minute Quad: **Riverside**

Latitude (degrees): Longitude (degrees):

UTM: **4939187** **10T0490014**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context: **Native American fire pit with fire-cracked rocks, hammer stone? In surface collection**

Exposure Length(m): **10m** Exposure Height(m): **5** Exposure Quality: **good**

Number of observed dikes:

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: **8/21/2002**

Site Designation (name and number): **CR-11**

Samples collected (see diagram): Artifacts **none** Soil

Wood **none** Charcoal Flotation

Photographs (roll and date):**None**

Diagram: **None**

Information Supplied By: Name

Affiliation: Date: 2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-12** USGS 7.5 Minute Quad: **Tangent**

Latitude (degrees): Longitude (degrees):

UTM: **4927912** **10T0491357**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **100m** Exposure Height(m): **5** Exposure Quality: **Excellent**

Number of observed dikes: **Feature had appearance of dike but ion examination turned out to be a man made ditch**

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees):

Cross-cutting relations of dikes:

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date:

Site Designation (name and number): **CR-12**

Samples collected (see diagram): Artifacts Soil

Wood **none** Charcoal Flotation

Photographs (roll and date):**None**

Diagram: **None**

Information Supplied By: Name

Affiliation: Date: 2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **CR-13** USGS 7.5 Minute Quad: **Tangent**

Latitude (degrees): Longitude (degrees):

UTM: **missing**

Geographic Location: **Calapooia River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **25m** Exposure Height(m): **6** Exposure Quality: **Good**

Number of observed dikes: **1**

Distance between dikes (m):

Widths of dikes (cm): Pinches and swells, at widest is 1.5 cm mostly 4 mm

Strikes and dips of dikes (degrees): N45°E, vertical

Cross-cutting relations of dikes: **NA**

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):**becomes discontinuous about 1 m above water**

Thickness and length of blows/sills: **NA**

Dike, sill, and blow material (grain-size, clasts): **sandy to 26 cm above water but with pods of silt**

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: 8/24/02

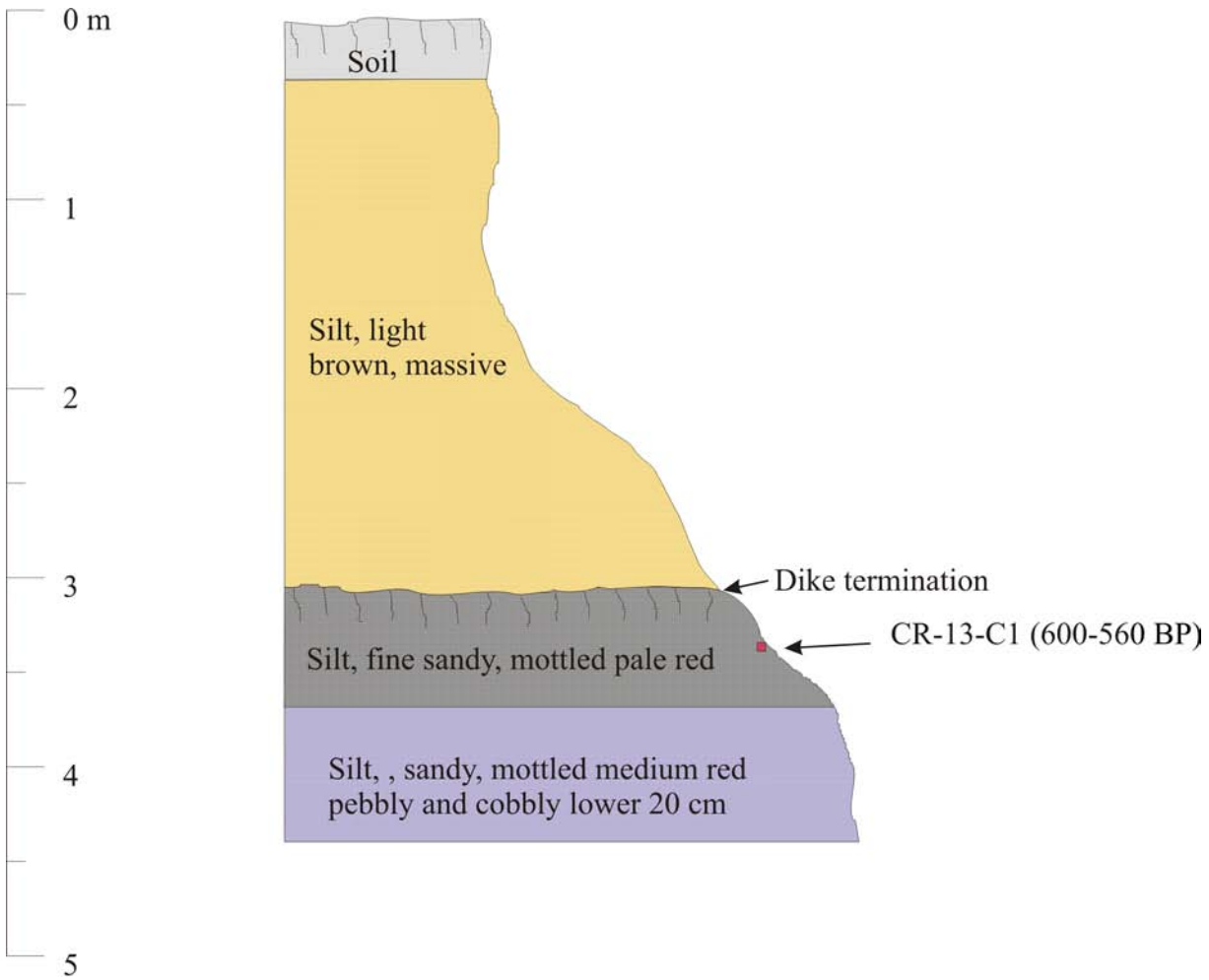
Site Designation (name and number): **CR-13**

Samples collected (see diagram): Artifacts Soil

Wood **none** Charcoal **CR-13-C1** Flotation

Photographs (roll and date):

Diagram:



Calipooia River Site CR-14

Information Supplied By: Name

Affiliation: Date: 2002

Site Description for Paleoliquefaction Study

Site Designation (name and number): **LR-1** USGS 7.5 Minute Quad: **Monmouth**

Latitude (degrees): Longitude (degrees):

UTM: **4958664** **10T0482144**

Geographic Location: **Luckiamute River**

Owner or Tenant /Address of Property:

Access: **Canoe** Marker:

Geological setting:

Archeological context:

Exposure Length(m): **20m** Exposure Height(m): **6**.5 Exposure Quality: **Fair**

Number of observed dikes:

Distance between dikes (m):

Widths of dikes (cm):

Strikes and dips of dikes (degrees): N45°E, vertical

Cross-cutting relations of dikes: **NA**

Termination of dikes (blow, sill, pinch, truncation) and depth below surface (m):

Thickness and length of blows/sills:

Dike, sill, and blow material (grain-size, clasts):

Sedimentary structures (flow lamination, vertical/horizontal bedding):

Soil development or chemical weathering:

Information Supplied By: **Sims/Tuttle** Name:

Affiliation: Date: 8/24/02

Site Designation (name and number): **CR-13**

Samples collected (see diagram): Artifacts Soil

Wood **LR-1-W1** Charcoal Flotation

Sample taken from orange weathered silt which is underlain by or ange mottled pebbly sand. The sample is from the silt at the contact with the subjacent gravely sand. We sampled the outermost rings of the log that was about 1 m long and lay about 60-70 cm above the water line

Photographs (roll and date):

Diagram:

Information Supplied By: Name

Affiliation: Date: 2002

Appendix B

Radiocarbon Samples						
		Sample Type				
Site	Sample #	Charcoal	Wood	Artifact	Pollen	Remarks
CR-1	w1		x			
CR-2	c1	a, lg[1]				single angular piece 1x1cm, 2.3 m below surf, and 1.3 m below fire pit
	c2	sa, med				single piece 10x5mm, from upper mottled silt, ~2.3m below surface, and 1.3 m below fire pit
	c3	a, lg				2m below surface mottled silt, ~1m below fire pit
	c4	sa, lg				2m below surface, from mottled silt, ~1m below fire pit
	c5	a, sm				from fire pit /w cracked and fired rock 1m below surface in mottled silt
	c6	a, sm				from fire pit /w cracked and fired rock 1m below surface in mottled silt
	c7	a, sm				from fire pit /w cracked and fired rock 1m below surface in mottled silt
CR-3	none					DIKE, ***No datable material present***
CR-4	c1					from Fe stained sand 1 m above water level
	c2	a, lg				1.6 m above water level, from mottled silty sand
	w1					outer few cm of tree trunk 90 cm above water level
CR-5	none					DIKE, ***No datable material present***
CR-6	c1	sa, sm				from mottled silt 40 cm above lacustrine
	w1		X			wood, twigs and leaves, 40-45 cm above water level
	w2		x			from top of lacustrine, 1.2 m above water level
CR-7	c1	a, sm				1.8 m below surface,

[1]Notations on angularity and size of charcoal fragments as follow: angularity a=angular, sa=subangular, sr=subrounded, r=rounded. Size sm=small (<1-2 mm), med=medium (~2-5 mm), lg=large (~5-10 mm), huge=>10 mm

	c2	a, lg				62 cm above dike
	c3	sa, sm				lower archeological pit, at dike term level
	p1				x	upper archeological pit, 40 cm above dike term,
	p2				x	lower archeological pit
	a1			x		
CR-8	none					Four dikes, ***No datable material present***
CR-9	c1					in lacustrine at ct with overlying mottled silt. in Stratigraphic Reference Section
CR-10	c1	a, huge				2cm above base of channel fill, POSTDATES 2 DIKES
	c2	a, med				3 cm above base of channel fill
CR-11	c1					in archaeological feature resembling a fire pit with fire cracked rocks
	c2					in archaeological feature resembling a fire pit with fire cracked rocks
	c3					in archaeological feature resembling a fire pit with fire cracked rocks
	c4					in archaeological feature resembling a fire pit with fire cracked rocks
	a1			x		hammer stone?, ***No datable material present***
CR-12	none					thought to be dike, but is filled in trench
CR-13	c1	a, sm				34 cm below top of small dike, in host
	w1			x		26 cm below top of dike, in host
LR-1	w1			x		Outermost rings from horizontal log in mottled silt at ct with cobble sand