Geologic Resources Inventory Scoping Summary
Fort Vancouver National Historic Site, Washington and Oregon

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The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a Geologic Resources Inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

The National Park Service held a GRI scoping meeting for Fort Vancouver National Historic Site (FOVA) on Friday, October 16, 2009 at the FOVA Pearson Headquarters Building. After an introduction to Fort Vancouver National Historic Site by Bob Cromwell (FOVA, Historical Archaeologist), meeting Facilitator Bruce Heise of the Geologic Resources Division (NPS GRD) gave an overview of the Geologic Resources Inventory program. GIS Facilitator Greg Mack from the Pacific West Regional Office (NPS PWRO) presented an overview of GIS and led the discussion of map coverage. Jim O'Connor, hydrologist with the United States Geological Survey (USGS), presented an overview of the Portland Basin and regional geology. Geologic features, processes, and issues were discussed briefly in the meeting and more extensively during a field trip led by Bob Cromwell to historic Fort Vancouver and the McLoughlin House unit in Oregon City.

Participants at the meeting included NPS staff from the park, Geologic Resources Division, and the Pacific West Regional Office and cooperators James O'Connor (USGS) and Colorado State University (CSU) (see table 2). This scoping summary highlights the GRI scoping meeting for FOCA including the geologic setting, the plan for providing a digital geologic map, a discussion of geologic resource management issues, a description of significant geologic features and processes, and a record of meeting participants.

Park Setting

The fort and village of Fort Vancouver National Historic Site lie on a floodplain terrace on the northern bank of the Columbia River within the city of Vancouver, Washington. Authorized as a national monument in 1948 and changed to a national historic site in 1961, Fort Vancouver National Historic Site commemorates the Hudson's Bay Company's fur trading operations. Under the leadership of John McLoughlin, Fort Vancouver became the center of political, cultural, commercial, and manufacturing activities in the Pacific Northwest from 1825 to 1849. Located on the banks of the Columbia River, Fort Vancouver National Historic Site joins together a national park, a premier archaeological site, the region's first military post, an international fur trade emporium, one of the oldest operating airfields, the first national historic site west of the Mississippi River, and a waterfront trail and environmental center on the banks of the Columbia River.

In 2003, the McLoughlin House, located approximately 30 km (20 mi) south in Oregon City, Oregon, became a unit of Fort Vancouver National Historic Site. The unit lies near the confluence of the Willamette and Clackamas rivers and contains the McLoughlin House, the graves of Dr. and Mrs. John McLoughlin, and the home of Dr. Forbes Barclay, a Hudson's Bay Company associate, physician, and early Oregon City civic leader.

Brief History of Fort Vancouver National Historic Site (Bob Cromwell)

Fort Vancouver National Historic Site was founded to commemorate Hudson's Bay Company (HBC), the oldest commercial operation in North America. In 1824, George Simpson, governor of the Hudson's Bay Company's Northern Department, arrived at Fort George (originally named Fort Astoria when owned by the American Fur Company) with Dr. John McLoughlin, the company's Chief Factor for the planned new post. McLoughlin selected Fort Vancouver at an opening in the forests about 160 km (100 mi) from the mouth of the Columbia River. The gently sloping banks and river terraces offered easy access to the river, pasture for livestock, and rich soil for agriculture. By March, 1825, McLoughlin had constructed a 4-m- (13-ft) high stockade and two warehouses for merchandise inside the walls. McLoughlin remained at the fort from its establishment until his retirement from the HBC in 1846, and his governing policies had a direct impact on the eventual Euro-American settlement of the region and the establishment of the state of Oregon.

Every major "first" in industry in the Pacific Northwest occurred at Fort Vancouver. For example, the first apple orchards were planted in 1826. The Pacific Northwest commercial salmon fishing industry received its start at Fort Vancouver as did the first water-powered lumber mill. The fort can be compared to a "gated community," with socio-economic and racial segregation between the fort (where the more prosperous Clerks of Scottish descent resided), and the Employee Village 0.40 km (0.25 mi) to the west, where the very diverse community of HBC employees lived. Fort Vancouver became the largest store along the Oregon Trail. In 1842 to 1843, Oregon Trail pioneers began arriving at Fort Vancouver. Due to John McLoughlin's generosity and the supplies at Fort Vancouver, the pioneers managed to survive and prosper in their first 3 years in Oregon Territory.

Fort Vancouver was also home to the most diverse ethnic community in North America at that time. In 1840, the village's population ranged from 600 to 1,000 people at a time when 120 people lived in San Francisco and Portland did not exist. HBC Governor, George Simpson, called Fort Vancouver, "the prettiest congregation of nations." The congregation consisted of Scots, Englishmen, Americans, Russians, Irish, French, Hawaiians, French-Canadians, Portuguese, and 26 recognized American Indian tribes, including Chinookian-speaking peoples that had been living along the Columbia River for thousands of years. Industry centered around a pond, approximately 4.5 m (15 ft) deep, near the banks of the river. That pond became the first municipal landfill in the Pacific Northwest, collecting refuse from the 1850s to 1904.

By 1849, over 10,000 Americans had homesteaded in the Willamette Valley. The U.S. Army arrived to protect these settlers and built Vancouver Barracks, the oldest Army post in the Pacific Northwest. The fort was used in various campaigns including the 1872 to 1873 Modoc war and the 1877 Nez Pierce war. In 1860, the Hudson's Bay Company relinquished Fort Vancouver to the U.S. Army and moved its operation north of the U.S.-Canadian border. The remnants of the fort burned in a mysterious fire in 1866.

Fort Vancouver Barracks was rebuilt and remained in active service well into the twentieth century. The post expanded during WWI and served as a base for the 5th Infantry Brigade from 1936 to 1938. The final use for Vancouver Barracks came in World War II when the post became a staging area for the Seattle Port of Embarkation. The post was closed in 1946, but was reopened as an Army Reserve Training Center in 1948 and remains so to this day.

Because of its national significance, Congress designated the site of the HBC Fort Vancouver as a National Monument on June 19, 1948. In 1961, its size was expanded and the site was renamed Fort Vancouver National Historic Site. In 2011, the National Park Service will acquire 31 structures totaling over 19,000 sq m (200,000 sq ft) when the U.S. Army relinquishes the Vancouver Barracks to Fort Vancouver National Historic Site.

When Chief Factor, John McLoughlin retired from the HBC in 1846, he built a house near Willamette Falls, along the banks of the Willamette River, in Oregon City, Oregon. Now known as the "Father of Oregon," McLoughlin became an American citizen and the first mayor of Oregon City. He died in 1857, and his family gave up ownership of the house in the 1870s. The house slowly fell into disrepair, and by 1909 it stood in the way of development and was threatened with demolition. Members of the local community rallied to save the house, forming the McLoughlin Memorial Association, and managed to purchase and move the house to its current location on the first terrace above the river on land donated by McLoughlin to the City of Oregon City for use as a park. The historical importance of the house and McLoughlin was reinforced in 1941 when the house and park were designated as the McLoughlin House National Historic Site, the first National Historic Site west of the Mississippi. The McLoughlin House, and the adjacent Barclay House (built and owned by HBC Doctor Forbes Barclay) were purchased by the NPS in 2003, and are now the McLoughlin House Unit of Fort Vancouver National Historic Site.

Overview of the Portland Basin and Regional Geology (Jim O'Connor)

Vancouver, Washington, Portland, Oregon, and Oregon City, Oregon lie within the Portland Basin, one of several depressions that collectively constitute the Puget-Willamette forearc of the Cascadia subduction system. Bisected by the Columbia River, the Portland Basin occupies a globally exceptional geologic setting wherein a continental-scale river flows through a basin developed within a tectonically-active, convergent-margin (Evarts et al. 2009). Tectonic, volcanic, and glacial events dominate basin sedimentation and record a unique blend of aggradation and incision in response to voluminous flood basalts, continental and locally derived sediment and volcanic debris, and catastrophic flood deposits.

In general, southern Oregon is composed of both hard and relatively soft rock units. Tectonic activity deforms the softer units. Overall north-south margin-parallel compression pushes the Oregon Cascades against metamorphic and other hard rocks to the north, causing the Oregon micro-plate to rotate clockwise. The pole of rotation sits at Lewiston, Oregon.

The rhomboid-shaped Portland Basin began forming roughly 20 million years ago (mya). Oblique convergence of the Pacific Plate beneath the North American Plate, coupled with clockwise rotation, caused the Portland Hills to thrust and fold upward into an anticline (convex fold) and the

adjacent Portland Basin to bow downward into a syncline (concave fold). Tectonic deformation and associated seismic activity continues today. Although movement along the offshore Columbia River Subduction Fault (CRSF) would be felt, tsunamis would not impact the Fort Vancouver area. Liquefaction features in the region, however, record previous CRSF activity. The base of today's subsiding Portland Basin lies about 460 m (1,500 ft) below current sea level.

Uplift during the Paleogene (65.5 to 23.03 mya) deformed submerged forearc strata into the present emergent Coast Range. A broad Columbia River valley transected the Cascade Range and allowed flood-basalt flows of the Columbia River Basalt Group (CRBG) to pour into northwestern Oregon approximately 16 to 15 mya. In the last half of the Miocene (about 14 to 5 mya), the Columbia River transported as much as 200 m (660 ft) of fine-grained fluvial and lacustrine sediments of the lower Sandy River Mudstone into the subsiding Portland Basin and deposited the sediment over the CRGB. In the southernmost part of the basin, a thick, northward-sloping volcaniclastic apron developed from debris flows and related fluvial deposits fed by northern Oregon Cascade volcanoes (Rhododendron Formation).

Near the end of the Miocene (5.332 mya), a narrow paleocanyon that had cut into Grand Ronde Basalt flows of the CRBG filled with over 200 m (660 ft) of coarse-grained sandstone and conglomerate of the lower Troutdale Formation. Entering the eastern Portland Basin north of the modern Columbia River, the paleochannel fanned out to the west, building a broad plain that buried the lower Sandy River Mudstone with over 70 m (230 ft) of gravel.

The Columbia River renewed its incision through thick Troutdale Formation gravel and entered the still-subsiding Portland Basin through a canyon south of the present Columbia River Gorge. As the river reverted to a low-gradient, near-sea level stream, fine-grained sediments of the upper Sandy River Mudstone were deposited above the Troutdale conglomerate. About 3.5 mya, voluminous lava flows erupted in the Cascade Range and generated large quantities of hyaloclastite (hydrated tuff-like breccia rich in black volcanic glass), which built a large fan where the river entered the Portland Basin. The hyaloclastite and lava flows filled the Columbia River canyon within the western Cascade Range, diverting the river to the north where Quaternary incision formed the present western Columbia River Gorge.

The present landscape of the Portland Basin owes its origin to volcanism and the indirect effects of Quaternary glaciation. Isolated hills and hill clusters scattered throughout the Portland Basin form the Boring Volcanic Field. Cored by cinder cones and associated lava flows, small shield volcanoes, and lava cones, the hills, some as much as 200 m (600 ft) high, record volcanic activity primarily younger than 1.8 mya (Evarts et al. 2009).

Broad terraces bordering the present Columbia River contain poorly sorted sand and gravel deposited prior to the Missoula Flood event and may represent voluminous outwash from times of advanced alpine glaciations. These older gravel deposits contain granitic rocks (and associated radon) from the Rocky Mountains that were used in the construction of the officers' housing at Fort Vancouver. Officers Row became known as Radon Ridge because of the associated radon gases.

When glacial Lake Missoula failed in the late Pleistocene, the cataclysmic Missoula Floods jetted floodwater through the Columbia River Gorge and into the Portland Basin at 97-113 km/hr (60-70

m/hr), carving channels and depositing extensive gravel sheets. The floodwaters were 120 m (400 ft) high and back flooded the Willamette River 160 km (100 mi) to Eugene. Sand and gravel were deposited 210 m (700 ft) above sea level at the time. Boulders (bedload clasts) in the colossal gravel bars in the eastern Portland Basin attain diameters exceeding 5 m (16 ft). Up to 70 m of festoon-bedded boulder sand and gravel formed bars in the lee of protruding uplands. Throughout the rest of the Portland Basin, Missoula Floods spread a thin skiff of silt, sand, and gravel above the older Columbia River terrace deposits.

The older flood deposits and Missoula Flood gravels influenced the location the Hudson's Bay Company. McLaughlin built the fort on terrace gravels to be out of the range of flooding. Likewise, farming operations were constructed on gravel terraces while pastures remained in the floodplain. Until twentieth-century construction of dams and floodplain levees, overbank deposits and bar accretion periodically supplied the floodplain with sediment and nutrients. Today, both Missoula Flood and older gravel deposits may influence utilities and infrastructure.

Since the last glacial period, sea level has been rising. As sea level rises, the Columbia River backfills (aggrades) with sediment. Aggradation has not kept pace with sea level rise, so no delta has formed at the mouth of the Columbia. Deposition of material transported by the river occurs approximately 320-480 km (200-300 mi) upstream from the Columbia's mouth. Aggradation occurs on the tributary rivers, as well. Younger fluvial deposits of clay and silt overlie Missoula Flood gravels. Fort Vancouver National Historic Site straddles Holocene backfill deposits and Missoula Flood deposits, but the contact between the two remains nebulous. In general, the Quaternary stratigraphy beneath the fort consists of:

- Holocene fluvial deposits
- Missoula Flood gravels
- Older flood terrace gravels

The fluvial history of the Columbia River may provide interpretive opportunities at Fort Vancouver National Historic Site, such as the incorporation in the Ice Age Floods National Geologic Trail.

In 1841, the Wilkes expedition entered the Columbia River and their ship, the Peacock, floundered on a gravel bar in the river. James Dwight Dana swam ashore, reached Fort Vancouver, and became the first geologist to set foot in the Pacific Northwest. Dana, who later became famous in geological circles, documented the processes of natural levee formation and the process of groundwater flooding in the floodplain behind the levees.

Most of the upland surfaces are blanketed by eolian silt (Portland Hills Silt). Paleosols in the Portland Hills Silt indicate episodic deposition of silt followed by periods of relative stability in which soils developed.

Throughout the Quaternary and especially in the late Holocene, Cascade Range volcanism has left its mark on the present topography. Lahars and large quantities of volcaniclastic sand and gravel have been funneled through the Sandy River at the eastern margin of the Portland Basin. About 1,500 years ago, eruptions of Mount Hood sent at least three lahars down the Sandy River to the Columbia. Snowmelt and rain-on-snow flooding has generated many large flood events. The largest historic flood on the Columbia River occurred in June, 1894 when snowmelt produced a flood discharge of 34,000 m^3/s (1.2 million ft^3/s). When Mount St. Helens erupted, approximately 34

million m^3 (1,200 million ft^3) of sediment emptied into the Columbia River near Longview, Washington.

Volcanic cones, channel deposits, flood gravels, terraces, gravel pits, and other geomorphic features may be mapped in remarkable detail with LIDAR (Light Detection and Ranging) remote sensing. In 2006, the USGS acquired LIDAR for the Columbia River floodplain to 30 m (100 ft) above sea level. The Oregon Department of Geology and Mineral Industries (DOGAMI) acquired LIDAR for the southern part of the Portland Basin. Clark County also acquired LIDAR, but their data remains difficult to obtain.

Geologic Mapping for Fort Vancouver National Historic Site

During the scoping meeting, GIS Facilitator Greg Mack (NPS PWRO) showed some of the main features of the GRI Program's digital geologic maps, which reproduce all aspects of paper maps, including all features, notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRI Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRI Program and allows for rigorous quality control. Staff members digitize maps or convert existing digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in personal MS Access geodatabase and shapefile formats, an ESRI ArcMap map document with feature class symbology, feature class layer files, FGDC-compliant metadata, and a help file in Adobe PDF format. The help file captures available ancillary map data including unit descriptions, source citations, ancillary map graphics, correlation of map units, cross sections, and geologic report. The help file can be accessed directly from the map document or using MS Windows Explorer. Final data products are posted at http://science.nature.nps.gov/nrdata/. The data model is available at http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm.

When possible, the GRI Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands (fig. 1). Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps (table 1) for the digital geologic data or develop a plan to obtain new mapping, if necessary.

Jim O'Connor (USGS) is starting a "Holocene Floodplain Corridor" project that will map the surficial geology within the floodplain. Working with graduate students and funded by a source external to the USGS, Jim expects to release the map late in the summer of 2010. At a minimum, the map will include the historic floodplain of Fort Vancouver. If some funds could be provided to include the officers' quarters on the terrace, the map would include all of the Fort Vancouver area. Participants agreed that this would be the best option and there are FY 2010 GRI funds budgeted to support this effort. Heise and O'Connor will work together on implementing the mapping.

The McLoughlin House unit is located to the south of Fort Vancouver in the Oregon City quadrangle. This park unit lies outside of the scope for the new mapping by Jim O'Connor and is

not covered. A DOGAMI published map by I. Madin (2007) covers the McLoughlin House quadrangle and will be used for bedrock geology and landslides for this park unit.

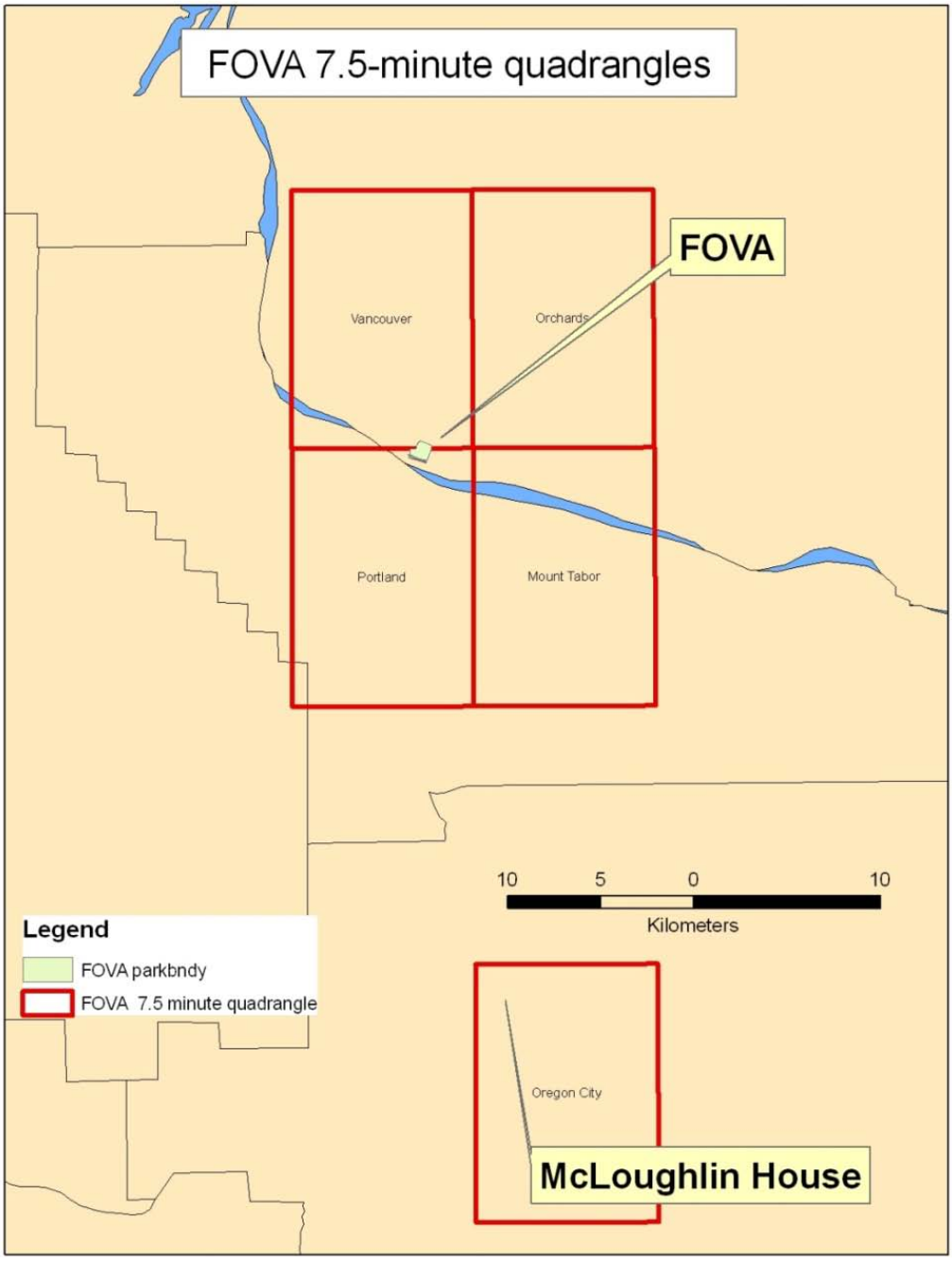

Figure 1. Quadrangles of interest for Fort Vancouver National Historic Site, Washington and Oregon.

Table 1. GRI Mapping Plan for Fort Vancouver National Historic Site

Covered Quadrangles	GMAP[1]	Citation	Scale	Format	Assessment	GRI Action
Portland	2533	Beeson, M. H., T. L. Tolan, and I. P. Madin. 1991. *Geologic map of the Portland quadrangle, Multnomah and Washington Counties, Oregon and Clark County, Washington*. Scale 1:24,000. Geological Map Series GMS-75. Portland, OR: Oregon Department of Geology and Mineral Industries.	1:24,000	Digital	Good reference	.
Vancouver		Evarts, R. C., and J. E. O'Connor. 2009 in press. *Geologic map of the Vancouver quadrangle, Washington and Oregon*. Scale 1:24,000. Open-File Reports. Reston, VA: U.S. Geological Survey.	1:24,000	Digital	Publication in 2009 is optimistic.	
Orchards		Evarts, R. C., and J. E. O'Connor. In preparation. *Geologic map of the Orchards 7.5' quadrangle, Washington*. Scale 1:24,000. Open-File Reports. Reston, VA: U.S. Geological Survey.	1:24,000	Digital	That the map is "in preparation" is probably optimistic.	
Oregon City	75201	Madin, I. P. 2007. *Geologic map of the Oregon City quadrangle, Clackamas County, Oregon.* Scale 1:24,000. Geological Map Series GMS-119. Portland, OR: Oregon Department of Geology and Mineral Industries.	1:24,000	Digital	Good reference	
Portland and Mount Tabor (in part)	35676	Madin, I. P. 1990. *Earthquake-hazard geology maps of Portland metro area.* Scale 1;24,000. Open File Report O-92-2. Portland, OR: Oregon Department of Geology and Mineral Industries.	1:24,000	Digital	Good reference. Includes Mount Tabor.	
Vancouver, Orchards		Phillips, W. M. 1987. Geologic map of the Vancouver quadrangle, Washing. Scale 1:100,000. Open File Report 87-10. Seattle, WA: Washington Division of Geology and Earth Resources. (30'x60' quadrangle)	1:100,000	Digital	Good compilation map using 1957 and 1963 data from D. E. Trimble. See Ray Wells for updates.	
Oregon City		Landslide maps may be available from Oregon State University				

[1]GMAP numbers are unique identification codes used in the GRI database.

Geologic Resource Management Issues

The principal geologic resource management issues discussed during the scoping session and on the subsequent field trip included seismic activity, volcanic eruptions, radon contamination, fluvial issues, and possibly an unstable bluff at the McLoughlin House.

Fort Vancouver Unit

Seismic

Deformation responsible for creating the Portland Basin slowly continues today. Although no large historic earthquakes have been recorded in the region, the Fort Vancouver National Historic Site is located in an area capable of producing magnitude 6-7 earthquakes. Earthquakes associated with the CRSF may produce liquefaction effects in which deposits of sand and silt along the Columbia and Willamette river banks may suddenly transition from a solid state to a liquefied state. Because the fort and officers quarters were constructed on terrace gravels away from the banks of the Columbia, liquefaction effects may be minimal at Fort Vancouver National Historic Site.

Volcanic Activity

Although a slim risk, volcanic activity poses a potential hazard to the park. Rocky Butte erupted approximately 130,000 years ago. Volcanic Mount Tabor lies within Portland's city limits. However, younger volcanic activity primarily occurs east towards the Cascade Range.

Fluvial

Historic Fort Vancouver never flooded. However, in 1948, flooding inundated the runway and terrace. Flooding also occurred during a winter flood in 1996. The floodplain behind the natural levee may flood via groundwater seepage. The terrace and flood deposits are well-drained and pose a minimal risk of failure. Boulders and cobbles deposited by Missoula Floods, however, may interfere with construction and infrastructure maintenance.

Radon

As previously mentioned, older terrace gravels used in the construction of the officers quarters contain radon. Radon gas causes lung cancer and occurs as a natural by-product of the radioactive decay of Uranium. While any exposure to radon presents some risk for lung cancer, the US Environmental Protection Agency has set an action level of 4 picocuries per liter (pCi/L). Corrective measures to reduce exposure to radon gas should be implemented at radon levels at or above 4 pCi/L. With Radon Act 51, Congress established the natural outdoor level of radon gas (0.4 pCi/L) as the target radon level for indoor radon levels (http://www.radon.com/radon/radon_levels.html, accessed November 2009).

McLoughlin House Unit

The principal geologic issue for the McLoughlin House unit is potential cliff collapse and landsliding. Both McLoughlin House and Barclay House rest on a bluff of dense basalt. A safety fence borders the abrupt edge of the bluff. Singer Creek once flowed through the property near the present location of the McLoughlin House. Although rerouted to the south of the unit, Singer Creek's old channel may be an historic zone of weakness.

Stratigraphy at Oregon City primarily consists of sediments, slippery soils, and relatively flat basalt flows. Silts and sands represent slackwater deposits left behind by the Missoula Floods that may landslide into any river or stream that cuts into them.

During the field trip, evidence for recent mass wasting was lacking. There were no groundwater seeps, cracks in the road, fractures in the bedrock, or offsets along curbs or sidewalks. Large, fist-size roots anchored the cliff, and the tree trunks did not indicate any downslope creep. Nevertheless,

the concave topography of the bluff behind the McLoughlin House may be the result of slumping or collapse associated with Singer Creek's previous channel. Slumping also may have occurred due the exceptional amount of rain that led to the 1996 flood event. John Salisbury, an interpretive ranger at the McLoughlin House, remembers the road below the cliff covered by landslide deposits. The old city land plat displayed in the McLoughlin House shows that the original channel began four blocks east of the McLoughlin House and flowed through the property. In addition, a pond had formed on the terrace. Resting a few feet from the edge of the bluff, the Barclay House may be more threatened by cliff collapse than the McLoughlin House. The park may wish to have Deanna Greco (NPS GRD) evaluate the site.

Other

Climate Change
As sea level rises, river and groundwater levels will also change. However, the potential influence on Fort Vancouver National Historic Site will probably be minimal. The fort is currently 5.5 m (18 ft) above mean sea level and the McLoughlin House rests on a cliff above the Willamette River.

Disturbed Lands
Abandoned quarries in the area serve as water supplies for the city.

Mineral Exploration
Neither mineral exploration and development nor oil and gas exploration and development exists in the immediate area.

Features and Processes

The scoping session for FOVA provided the opportunity to develop the following list of geologic features and processes, which will be further addressed in the final GRI report.

Aeolian (windblown)

- Strong easterly winds blowing through the Columbia Gorge formed east-to-west trending sand dunes north of the park from Missoula Flood deposits.

Fluvial

- Terrace gravels. The historic fort is located above range of flooding.
- Nexus of fine-grained Holocene deposits of clay and silt (youngest), Missouri Flood gravels and boulders, and older flood gravels.
- Flood deposits resulting from glacial Lake Missoula outbursts offer a great interpretive theme, which the park may wish to exploit.
- Willamette Falls in the Willamette River once consisted of a 12 to 15 m (40 to 50 ft) drop and was known as "Niagara West." The McLoughlin House was originally built along the east bank of the river adjacent to the falls.

Hillslope

- Possible mass wasting processes associated with McLoughlin House unit (see Geologic Resource Management Issues section).

- Windblown silt mantles the highly dissected, steep hills of basalt west of Portland, which can be seen from both units. The silt may slide when wet.

Glacial and Periglacial

- Glacial Lake Missoula outburst floods created unusual glacial features in the Columbia River valley. Missoula Floods shaped the landscape of the Portland Basin, but they supplied only a small fraction of total sediments.
- Older gravel deposits may be related to regional glacial episodes and present a complicated history. Alpine glaciers flowed down the Lewis River off Mt. Adams and other Cascade mountains to the north, forming large outwash terraces that may have blocked the Columbia River. Older terraces in the park may have been formed from these glacial deposits.

Lacustrine (Lake)

- The pond that existed when the Hudson's Bay Company built Fort Vancouver became a landfill and is now a wealth of archeological artifacts.
- Holocene floodplain ponds still exist in places.
- Ponds east of Pearson Field were backfilled in the 1950s.
- Historic maps contain backwater sloughs and ponds.
- Vancouver Lake is now artificially controlled.

Coastal – Columbia River Shoreline

- Nearest coastal sediments in the Columbia River bedload are 48 km (30 mi) downstream from Vancouver.
- Tidal influence reaches Bonneville Dam.
- Tidal range at FOVA is 0.6-0.9 m (2-3 ft).
- Current reversal extends up to Longview, Washington, but does not extend to Portland. No marine salinity to the Columbia River at Portland.

Paleontology (from Fay et al. 2009)

- FOVA does not maintain paleontological collections, but paleontological specimens occur within the extensive archaeology collection.
- Bones, shells, and teeth were used to craft artifacts and ornaments.
- Ground coral, primarily of the genus *Porites*, was used to manufacture mortar for the Powder Magazine's foundation.

Age Dates

- Radio carbon age dates collected from archaeological sites in the floodplain indicate a Holocene age of less than 3,000 years old.
- Mudflows occurred 1,500 and 200 years ago.
- A landslide dam formed in 1450 A.D. A breach in the dam some time before 1480 A.D. caused a debris flow.
- Archaeological evidence documents an 1894 flood event.

Other

- No geothermal features in the immediate area.

- No permafrost features.
- No caves or karst.
- No marine (submerged) resources.
- No type sections.

Field Trip of Historic Fort Vancouver and the McLoughlin House Unit (Bob Cromwell)

Stop 1: Parking lot by the Pearson Headquarters Building

- Missoula Flood sand and gravel to the north; Holocene gravels toward the river.

Stop 2: View of historic Fort Vancouver from the Land Bridge

- Pond (wetland) plants are growing in the location of the historic pond at the north end of the Land Bridge.
- View of the floodplain (Pearson airfield) and terraces (officers quarters).
- Stockade of Fort Vancouver erected on a terrace below the officers quarters.

Stop 3: Willamette Falls Overlook

- Prior to development, the falls consisted of a 12 to 15 m (40 to 50 ft) drop.
- Willamette Falls is considered to be an important American Indian site.
- Willamette Falls known as "Niagara West."
- Cataract plummets over just one basalt flow and is the result of a fault that cuts through the Portland Hills structure.
- Hudson's Bay Company built a mill at the falls in 1842.
- First long distance electrical transport from the falls to Portland.
- Today, paper mills lie abandoned.
- Columbia River Basalt Group (CRBG) basalt exposed in the road cut across the road from the overlook. CRBG underlies Portland Hills.
- Graffiti at the falls dates from 1841 when Joe Meeks carved his name into the basalt.
- Mount Hood erupted in 1860, a few years before the Corps of Discovery entered the territory, and increased the sediment load in the local rivers. Lewis and Clark named the Sandy River because of the abundant sediment load and quicksand, which made crossing the river difficult.

Stop 4: McLoughlin House unit (McLoughlin House and Barclay House), Oregon City, Oregon

- Houses rest on Singer Hill adjacent to a 4.5 to 6 m (15 to 20 ft) cliff of basalt (see Geologic Resource Management Issues section). The Barclay House is located a few feet from the bluff's edge but away from Singer Creek's previous channel. The McLoughlin House, moved to its current location in 1909, is farther away from the cliff edge, but lies over the historic channel of Singer Creek.
- Indications of bluff stability: well-established vegetation (vines, trees), no groundwater seeps, no obvious cracks in roadway, no debris at base of cliff, dense basalt lacking vertical fractures, no movement on window frames suggesting settling.

- Indications of bluff instability: historical accounts of previous landslides (John Salisbury), original location of Singer Creek.
- An old, stone retaining wall borders the bluff.
- Singer Creek has been rerouted to the south of the property and constrained within a man-made channel and waterfalls.
- The Singer grist mill was originally located behind the house and grave site.
- Limestone headstones of the McLoughlins are set in a slab of granite. The limestone was part of the Catholic Church, and the headstones were moved to the present site in the 1960s.
- Oregon City has been an active community since McLoughlin's time.

References

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