River Island
Conceptual Design Report

SUBMITTED TO
Metro

OCTOBER 2014

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Metro
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1. Introduction

1.1 BACKGROUND

This conceptual design report describes restoration opportunities for the River Island site on the Clackamas River. This work is being conducted by Metro as part of their Natural Areas Program. The goal of this effort is to support functioning riparian ecosystems and fish and wildlife populations. The design opportunities described here are informed by evaluating historical and current site conditions and through an extensive outreach effort with technical experts and the public. Opportunities presented here will be evaluated by project partners and compared with project goals and objectives. Opportunities will be prioritized, with work likely occurring in multiple future phases.

1.2 PROJECT AREA

River Island Natural Area is located near Barton County Park at approximately river mile (RM) 15 on the Clackamas River, a tributary to the Willamette River. The Clackamas River supplies drinking water to over 200,000 people and supports significant runs of federal and state listed fish species, including Chinook salmon, Coho salmon, steelhead, cutthroat trout, bull trout and Pacific lamprey. River Island's abundant native habitats – which include oak savannah, riparian forests and upland forests – support diverse wildlife populations including anadromous salmonids, migrating birds, and native turtles.

In 1996, a major flood event altered River Island, cutting off a meander bend and occupying an active gravel mine which was previously protected by a levee. The cutoff reduced stream length by approximately 3,600 feet and eroded 1,380,000 cubic yards of gravel from the area. Metro acquired a majority of the site in 1999 and currently owns 234 acres at River Island.

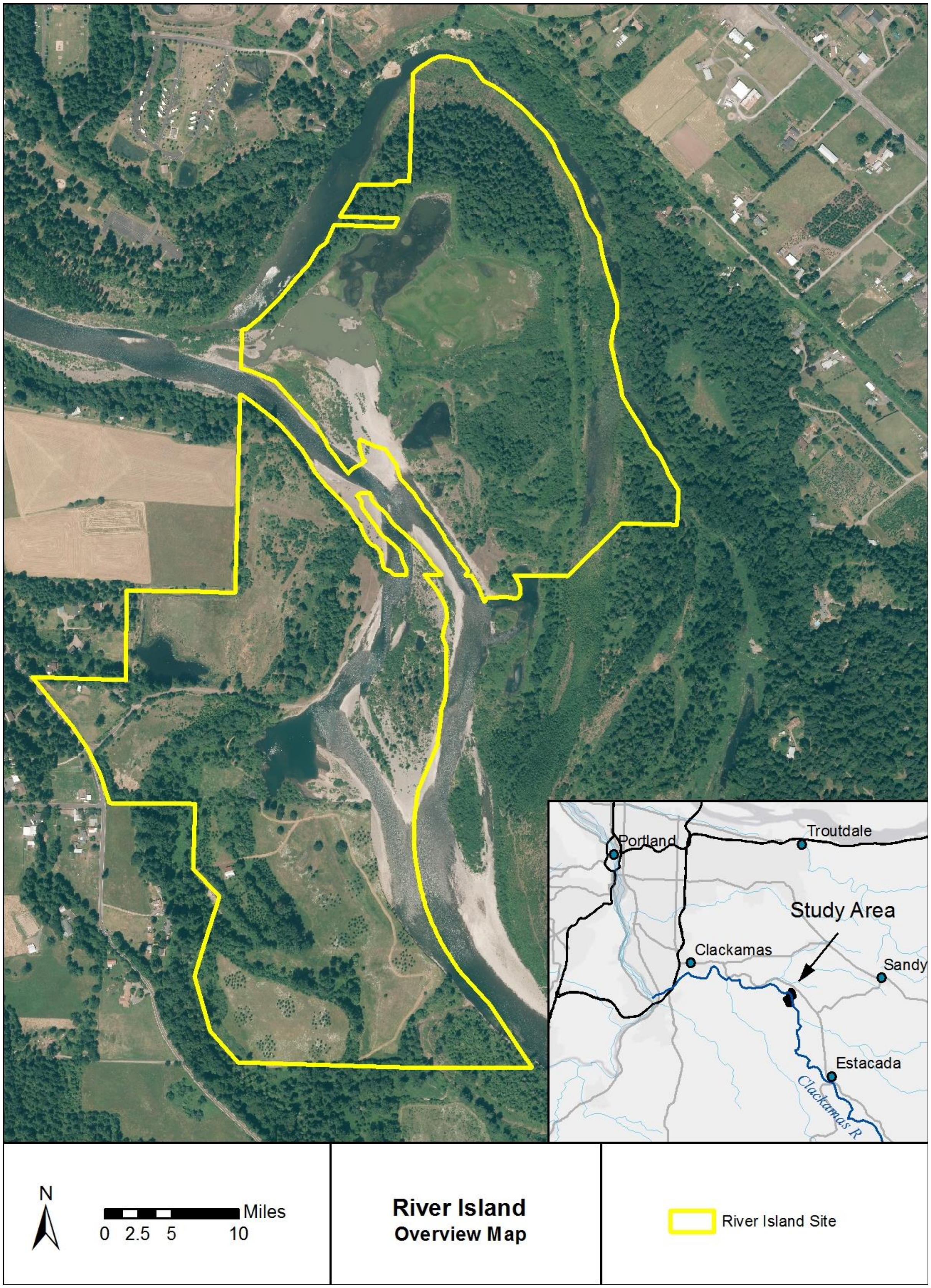

Figure 1. Overview map for the River Island project on the Clackamas River.

1.3 FRAMEWORK AND GOALS

1.3.1 Limiting Factors at the River Island Natural Area

The River Island Natural Area includes a variety of landscape factors which limit the quality and quantity of fish and wildlife habitat, as well as water quality. Previous studies, as well as this investigation, have identified the following limiting factors to ecosystem and species function:

- Remaining road infrastructure and associated debris along left bank
- Soil compaction and remnant mining materials from gravel operations
- Altered sediment transport regimes as a result of rapid channel migration and upstream dams
- Altered channel geometry due to levees and capture of gravel ponds leading to reduced floodplain and off-channel habitat connectivity
- Elevated water temperatures in captured gravel quarry ponds and Goose Creek
- Opportunistic, aggressive plant species which limit natural succession of riparian and floodplain forests (e.g. Japanese Knotweed, Himalayan blackberry, reed canary grass)
- Lack of large wood sources and recruitment leading to simplified mainstem, off-channel, and floodplain habitat

1.3.2 Metro's Restoration Rationale

The River Island Natural Area is located on Oregon's Clackamas River, a large watershed with current and historically important salmon runs and ecologically diverse habitats. The Clackamas also currently serves as a drinking water source for almost 200,000 people. The Natural Area has been degraded by rapid channel avulsion through an active gravel mining operation in 1996, as well as continuing basin-scale impacts from current and historical land uses. Metro and a number of other groups have identified the lower Clackamas in general, and River Island in particular, as priority restoration areas (e.g., ODFW 2010). Restoration at the River Island site was considered by Metro and project partners in 1997 (immediately post avulsion) and again in 2002. However, the then recent significant disturbance to an already dynamic site, and restoration funding sources that were then tied to specific performance criteria made restoration at that time unfeasible.

Today, restoration at River Island offers the opportunity to improve the site's stream, floodplain, and upland habitat to benefit fish, wildlife and water quality. No action has been the status quo since 1996, almost 20 years later Metro has stated the following reasons for re-considering taking action at River Island:

- This section of river has long been considered to have the ability to regain historical function on its own. However the timeframe for these changes may take decades or more and it is possible that the river will achieve an alternative state of equilibrium that would not maximize habitat.

- Numerous opportunities exist to enhance and restore habitat for state and federally listed threatened and endangered species including essential habitat for ESA listed salmonids (ODFW 2010).
- Because of the river's proximity to the Portland Metro Area it is an accessible resource to the public for fishing and recreation.
- With the passing of the natural areas and parks levy in 2013, Metro is able to use dedicated funding to restore lands acquired with the 1995 and 2006 natural area bond measures and put the site on a positive trajectory.

1.3.3 River Island Site Conservation Plan

Metro has developed a site conservation plan for the River Island Natural Area to describe a course of action that will protect and enhance the area as an environmental and recreational resource for Clackamas County and the Portland metropolitan region (Metro 2014). This document outlines Metro's primary goal for the River Island Natural Area: *to protect the site's rare and unique plants, fish and wildlife habitats, as a historical remnant of the Willamette Valley Oregon and provide an ecological showcase of native habitats and wildlife*. The area will be maintained and enhanced, to the extent possible, in a manner that is faithful to its pre-disturbance condition.

To achieve this goal, the conservation plan establishes a series of priority objectives, including:

- Restore and maintain high-quality habitat including Oregon white oak savanna, upland forests, riparian forests, and aquatic habitats
- Provide opportunities for research and education to local schools
- Develop appropriate funding strategies to implement strategic restoration improvement projects

1.3.4 Project Goals

Informed by previous analyses and the stakeholder (public, technical review committee) outreach efforts, the intent of this assessment is to identify project opportunities that promote the restoration and maintenance of the above listed conservation targets as well as overall stream function.

Channel Process and Function

- Strategically implement restoration actions in areas where existing processes are insufficient to create or maintain highly functioning habitats. Perform actions that will enhance habitat features in a way that will be geomorphically sustainable given the current and reasonably foreseeable sediment, landuse, large wood and recreational regimes.
- Restore perennial hydrologic connectivity to tributary habitats. Restoring these connections will support native fish use of additional habitats as well as reducing local water temperatures.

- Increase the frequency and magnitude of floodplain inundation during annual high flow periods. Floodplain inundation supports riparian forest health, fish and wildlife habitat and flood storage.

Riparian Forests

- Protect and restore natural riparian and floodplain vegetation communities along the mainstem and floodplain areas to historical density, structure, and species composition. Native riparian forests improve water quality, provide channel margin complexity, support nutrient exchange processes, provide a source for future large wood recruitment and provide essential habitat for migratory birds and other wildlife.

Native Fish Habitat

- Increase off-channel habitat quantity, diversity, and complexity for native salmonids over a range of flows by enhancing existing floodplain habitats and reconnecting off-channel and tributary habitats. These areas will provide velocity refuge during high flow periods and provide access to spawning and rearing habitat during critical low flow periods.

Native Turtle Habitat

- Preserve and enhance selected areas where native turtle use has been identified post-avulsion, including foraging, nesting and basking areas. Create and expand suitable nesting areas and upland overwintering habitats where feasible. Preservation and enhancement of existing turtle habitats will provide isolated slow-water areas for foraging, south-facing basking logs, and bare ground nesting areas for turtle species.

This restoration feasibility effort is specifically focused on the riverine and floodplain areas. Consequently, Oregon white oak savanna and upland forests are not explicitly addressed. Upon selection of potential project concepts, project objectives will be developed in subsequent design phases.

1.3.5 Other Considerations

Several potential constraints and considerations could influence project designs. These will be addressed throughout the design process in coordination with appropriate stakeholders. Initial considerations include:

- Recreational use, including boater safety
- Phasing and timelines of work implementation
- Funding windows
- Potential project partnerships
- Land ownership
- Cultural and historical sites

2. Site Analysis

The River Island Natural Area was assessed for potential restoration of riparian forest, salmonid habitat and native turtle habitat. Current fish habitat quality and use, turtle habitat quality and use, geomorphology, hydrology, hydraulics, vegetation, soils, and human alterations were all identified from existing data and from data collected as part of the design process.

2.1 DATA COLLECTION EFFORTS

Conceptual restoration alternatives have been developed based on site visits, topographic survey, LiDAR analysis, geomorphic analysis, and hydraulic modeling. The data collection efforts, including a description of existing data used for the analysis, are described below.

2.1.1 Existing Data

LiDAR

Light Detection and Ranging (LiDAR) data are available for this area. Data were collected by Watershed Sciences in 2007. The data were used for geomorphic analysis and to supplement the topographic survey data collected at the site. The LiDAR data were also used to analyze vegetation conditions using a comparison between the bare earth data and the highest hit (first return) data to analyze canopy height and density of vegetation on the site (completed by Metro staff).

Aerial Photography

Aerial photography was acquired for years including 1938, 1950, 1956, 1959, 1965, 1970, 1976, 1981, 1986, 1989, 1996, 1997, 1999, 2006, 2008, 2010 and 2012. The aerial photo record was used to evaluate trends in channel dynamics and planform. In addition to photography, geo-rectified maps published in 1855, 1908, and 1916 by the General Land Office were used to determine the earliest recorded condition of the river planform. Aerial photographs of the site can be found in Appendix A.

Hydrologic Data

Streamflow was determined from the Clackamas River gage at Estacada, OR (USGS gage #14210000), located approximately 10 miles upstream of River Island Natural Area. Low-flow calculations were completed for the site and an estimate was made to account for the input of Eagle Creek, a major tributary to the Clackamas which enters the mainstem between the Estacada gage and the study site. In addition, monitoring of main channel Clackamas River and Goose Creek will be initiated following high spring flows at the site via placement of three surface water sampling stations. These will provide additional information on site hydrology to support design.

Fish Use Data

Fish use data has been compiled by a variety of sources for the Clackamas River. In particular, an effort by Portland General Electric (PGE) describes historical and current fish runs in good detail (Taylor 1999). Site walks with the technical review committee provided additional information regarding fish use within the River Island Natural Area. Existing and potential fish use data will continue to inform the design process.

Turtle Presence Data

Reference data from the Oregon Native Turtle Working Group and input from Oregon Wildlife Institute Conservation Planning documents have been reviewed, including ODFW’s draft *Best Management Practices for Turtles in Oregon* (2014). Site walks with the technical review committee provided additional information regarding turtle use within the River Island Natural Area. These resources have and will continue to inform the design process and construction practices.

Human Land Use

Historical and present-day use of the River Island Natural Area was researched and summarized by Historical Research Associates (2014) in a Cultural Resources Study. The report includes descriptions of native peoples’ use, Euro American history and mining history at the site.

2.1.2 Data Collection

Site visits were conducted on multiple dates in 2013 and 2014 for site reconnaissance, collection of topographic data, and installation of gaging stations.

Site Reconnaissance

Initial site reconnaissance occurred in November 2013. This included repeat site walks utilizing aerial photography and LiDAR. General notes on existing form and process were taken and compared to observations and data collected by Inter-Fluve from 2002 through 2006 as part of previous restoration opportunities analyses.

Topographic Survey

Topographic surveys were conducted in December 2013. The surveys collected bathymetry data of the mainstem Clackamas and backwater areas, as well as detailed topographic data of the floodplain. The mainstem and backwater bathymetry was collected using a HydroLite singlebeam echosounder (Seafloor) mounted on a jet boat. The floodplain topography was collected with survey grade GPS and total station equipment. Data from the surveys was used for: 1) refinement of existing LiDAR data and provision of bathymetric data to support existing LiDAR ground surface data, 2) channel and floodplain cross-sections for hydraulic modeling of current and proposed restoration alternatives, and 3) creation of a grading plan and calculation of excavation quantities for off-channel creation alternatives.

Water Level and Temperature Monitoring

Water surface elevation monitors were deployed at the project site in summer of 2014. It is anticipated that additional mainstem monitoring stations, which will require an excavator for installation, will be deployed during subsequent design phases. Monitoring stations utilize HOBO U20 water level data loggers and will be placed in the same locations as the deployments in 2005. These loggers will be used to monitor water levels via a pressure transducer. An additional station will be deployed to collect atmospheric pressure, which is necessary for data processing in order to obtain accurate water level readings. These stations are intended to provide accurate water surface data for the reach. The U20 loggers also record water temperature, which will be useful for assessing temperature conditions as it relates to aquatic habitat quality.

Turtle Presence

Turtle presence and use surveys are currently (as of summer/fall 2014) being performed for the lower Clackamas River by the Oregon Wildlife Institute. These surveys will evaluate areas of turtle use and types of use within these areas.

2.2 FISH HABITAT AND USE

The Clackamas River fish runs are widely celebrated for their importance both historically and today. Significant fish harvest and other human use of the basin over the past 150 years has reduced the salmon runs, however the basin is still a significant producer of anadromous salmonids. Anadromous fish populations in the Clackamas basin include spring and fall Chinook salmon, Coho salmon, winter steelhead, summer steelhead (non-native), migratory cutthroat trout and Pacific lamprey (Taylor 1999, Runyon and Salminen 2005).

Several of the anadromous fish populations are listed by federal or state agencies as threatened or endangered. Table 1 lists some of the species present and their respective status under the state of Oregon and federal Endangered Species Act and the Oregon sensitive species list.

Table 1. Selected Clackamas River fish populations and their respective state and federal status (Runyon and Salminen 2005, ODFW 2012, ODFW 2008).

Common Name (Population Segment)	**Scientific Name**	**Life-History Forms**	**Federal / State Endangered Species Status**
Chinook Salmon (L. Columbia R.)	*Oncorhynchus tschawytscha*	Anadromous (fall and spring runs)	Threatened / Critical
Coho Salmon (L. Columbia R.)	*Oncorhynchus kisutch*	Anadromous	Threatened / Endangered
Steelhead / Rainbow Trout (L. Columbia River)	*Oncorhynchus mykiss*	Anadromous (winter steelhead), resident (rainbow)	Threatened / Critical (Steelhead)
Cutthroat Trout (L. Columbia R.)	*Oncorhynchus clarki*	Anadromous, fluvial, adfluvial, resident	Proposed / Vulnerable (Anadromous Form)
Bull Trout	*Salvelinus confluentus*	Fluvial, resident	Threatened / Critical
Pacific Lamprey	*Lampetra tridentanta*	Anadromous	No status / Vulnerable

Other resident native fish that occur in the Clackamas River include cutthroat trout, rainbow trout and bull trout. Bull trout, once thought to be eliminated from the basin were reintroduced beginning in 2011 and were observed spawning in the Clackamas in both 2011 and 2012 (Allen and Koski 2013). Other resident fish potentially occurring in the project area include sculpin, longnose dace, speckled dace, shiners, brook lamprey, suckers and northern pike minnow.

Different fish species utilize riverine habitats differently and at different times of year. The salmonids tend to require cool water, deeper pools for holding and rearing and gravels for spawning. Cover provided by large wood in the river or overhanging vegetation is important as well. Access to off-channel or backwater habitats can benefit various salmonid species. Fish use timing is illustrated in Figure 2.

Habitat Within Ponds

Fish use of the former gravel pits varies based on the time of the year. During high-flow events the ponds likely provide velocity refuge to salmonids as well as valuable rearing habitat. Higher water temperatures in the ponds during summer months may increase salmonid mortality through entrapment in areas with intolerably high temperatures or predation. Fish netting conducted by Wampler et al (2006) suggested limited salmonid use of the pools in the spring.

The captured gravel pits, which are now functioning as off-channel ponds, have been identified as a possible source of increased water temperatures. Within the ponds, average summer water temperatures in 2000 and 2001 were reported as 0.32 C to 2.76 C higher than the adjacent mainstem; pond temperatures were more variable throughout the summer than the mainstem (Wampler et al 2006). The ponds do not seem to be a major temperature source to the mainstem, however. In 2000 and 2001 summer mainstem water temperatures were 0.32 C and 0.36 C higher downstream of the ponds relative to upstream.

While a variety of salmonid species were caught in the ponds between March and June 2002 at flows between 2,401 and 4,816 cfs, researchers suggest that these species will likely leave the area during the summer when temperatures exceed 70 F. Entrapment within the ponds is also a concern. At lower water levels, the ponds become disconnected from the mainstem, preventing passage out of the area. Fish species tolerant of warm water were present within the ponds including native large-scale sucker, native northern pike minnow, carp and the non-native brown bullhead. Predation by some of these species on salmonids is likely to occur, particularly in summer (Wampler et al 2006).

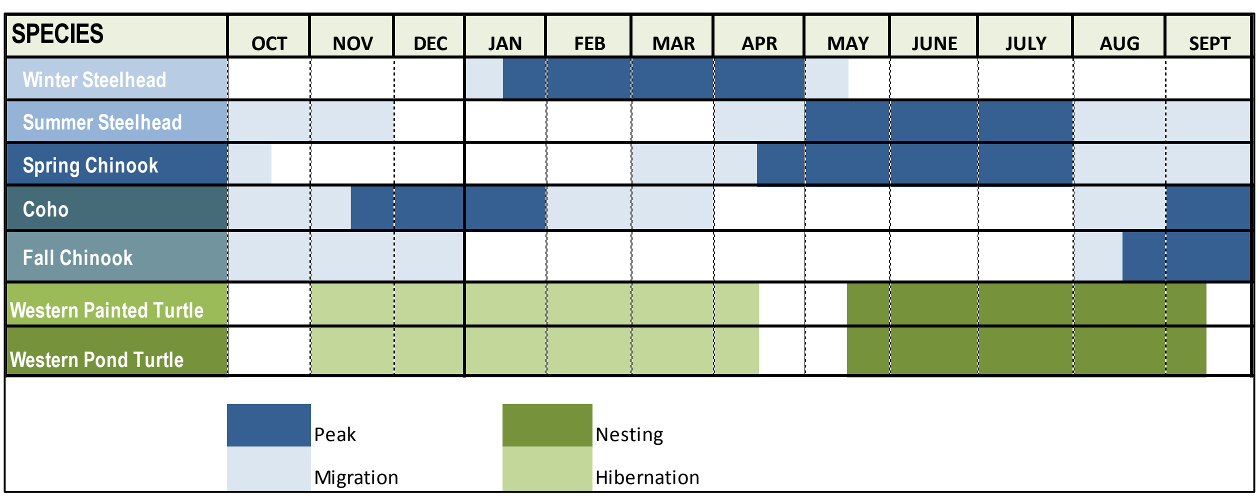

Figure 2. Habitat use of the Clackamas River by selected salmonid and turtle species (adapted from ODFW 2014 and PGE 2011).

2.3 TURTLE HABITAT AND USE

Turtles have been noted at five primary locations within the River Island study area. Historically, Oregon's two native turtle species, the western painted turtle (*Chrysemys picta bellii*) and the western (Pacific) pond turtle (*Actinemys marmorata*), were found throughout north-central and north-eastern portions of the Columbia River Basin, and in the northern portion of the Willamette River Basin. Presently, populations are substantially lower due to habitat reduction, degradation, fragmentation, road mortality, and the introduction of non-native invasive plants and animal species. Urbanization within the Portland metro area is one of the main factors causing habitat loss and turtle population declines. Both the western painted turtle and the western pond turtle are listed as "critical" on Oregon's State Sensitive Species List. The U.S. Fish and Wildlife Service (USFWS) lists the western pond turtle as a "species of concern" and both turtle species are classified as "sensitive species" by the USFS and BLM in Oregon.

Both species require permanent and seasonal water bodies that are slow moving and have a variety of water temperatures and depths, but maintain at least a four to six foot depth year-round. These conditions allow for overwintering in muddy substrates, provide vegetated refugia, and areas for foraging. Young turtles prefer low-flow, warm and shallow water conditions that are relatively protected from predators. Exposed logs of varying sizes placed within a water body – structures that are further from the shoreline and south-facing aspect are preferentially used – allow turtles to bask in the sunlight. Additionally, aquatic vegetation or smaller debris piles within or near the shoreline of a water body, can act as refugia from predators (ODFW 2014).

Key terrestrial habitats that have varying levels of vegetation and tree canopy cover are used primarily for nesting. The western pond turtle needs both aquatic and terrestrial habitats. They utilize land for nesting, overwintering, dispersal, and basking. Nesting activity peaks during June and July, in sites that are sparsely vegetated and have minimal tree cover. Nesting sites are typically in dry, well-drained soils within 100 meters (325 feet) of an occupied water body, in areas with sparse vegetation and often have a southern exposure. Eggs typically hatch in September and October. Most hatchlings overwinter in the nest and migrate to a water body the following spring (ODFW 2014).

Available terrestrial and aquatic overwintering habitats are utilized by both the western pond and western painted turtles. Soft, muddy substrate that allows a turtle to burrow into it and remain hidden from predators is required for aquatic overwintering of western painted turtles. In land overwintering sites, turtles have been noted in forested sites above flood stages near Oregon white oak where there is a deep layer of duff, moss or leaf litter (Kutschera, 2010).

Turtles are known to utilize the property, and, at the time of this writing Oregon Wildlife Institute is currently collecting data on turtle presence and use. Once available, this information will be incorporated into the design process. The project opportunities discussed in this report are based upon previous visual surveys by Metro staff. These visual surveys indicate that the turtles utilize the northeast corner of the gravel quarry and the alcove area along the river's left bank for basking (

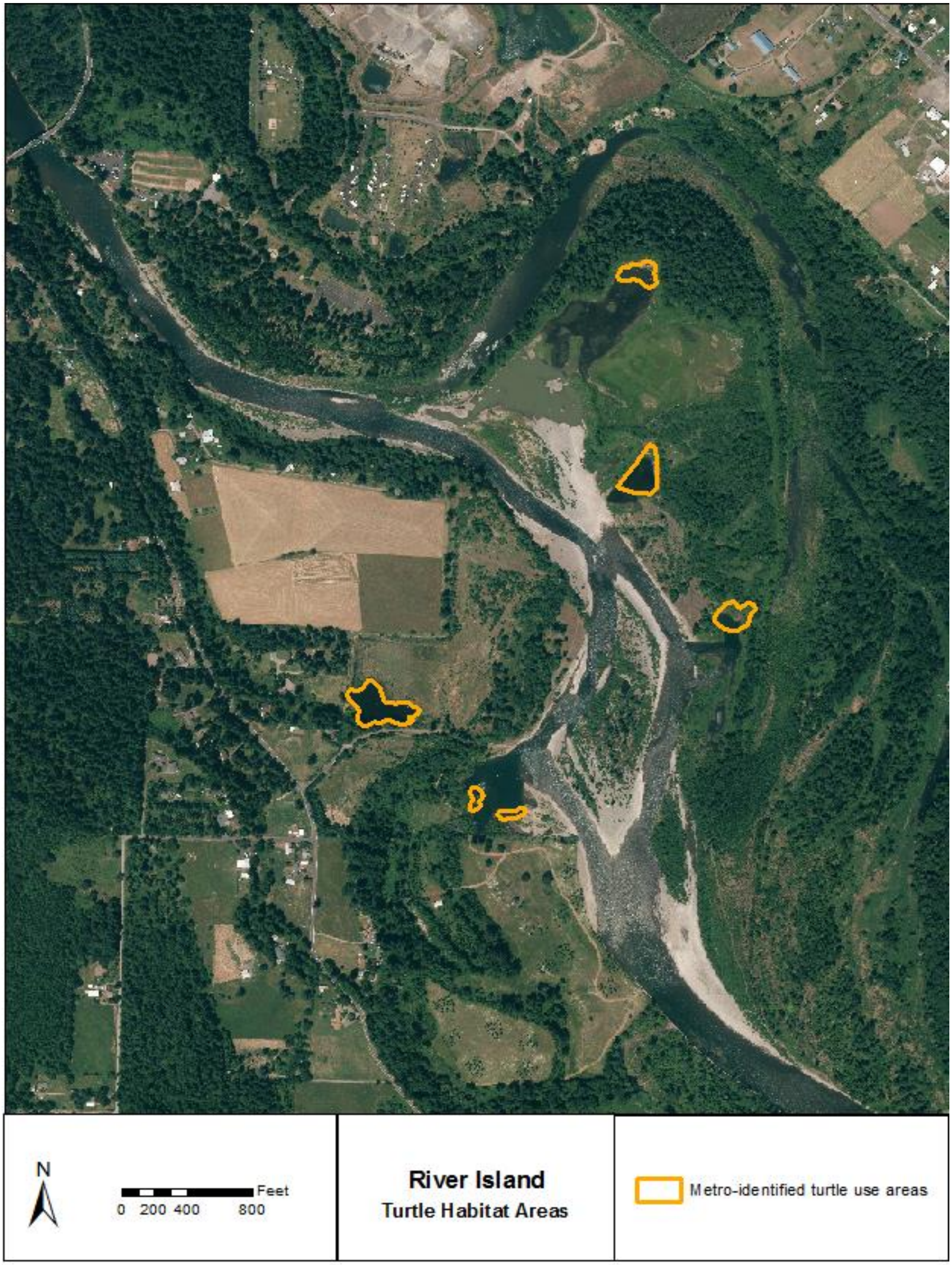

Figure 3). Known nesting areas were not available.

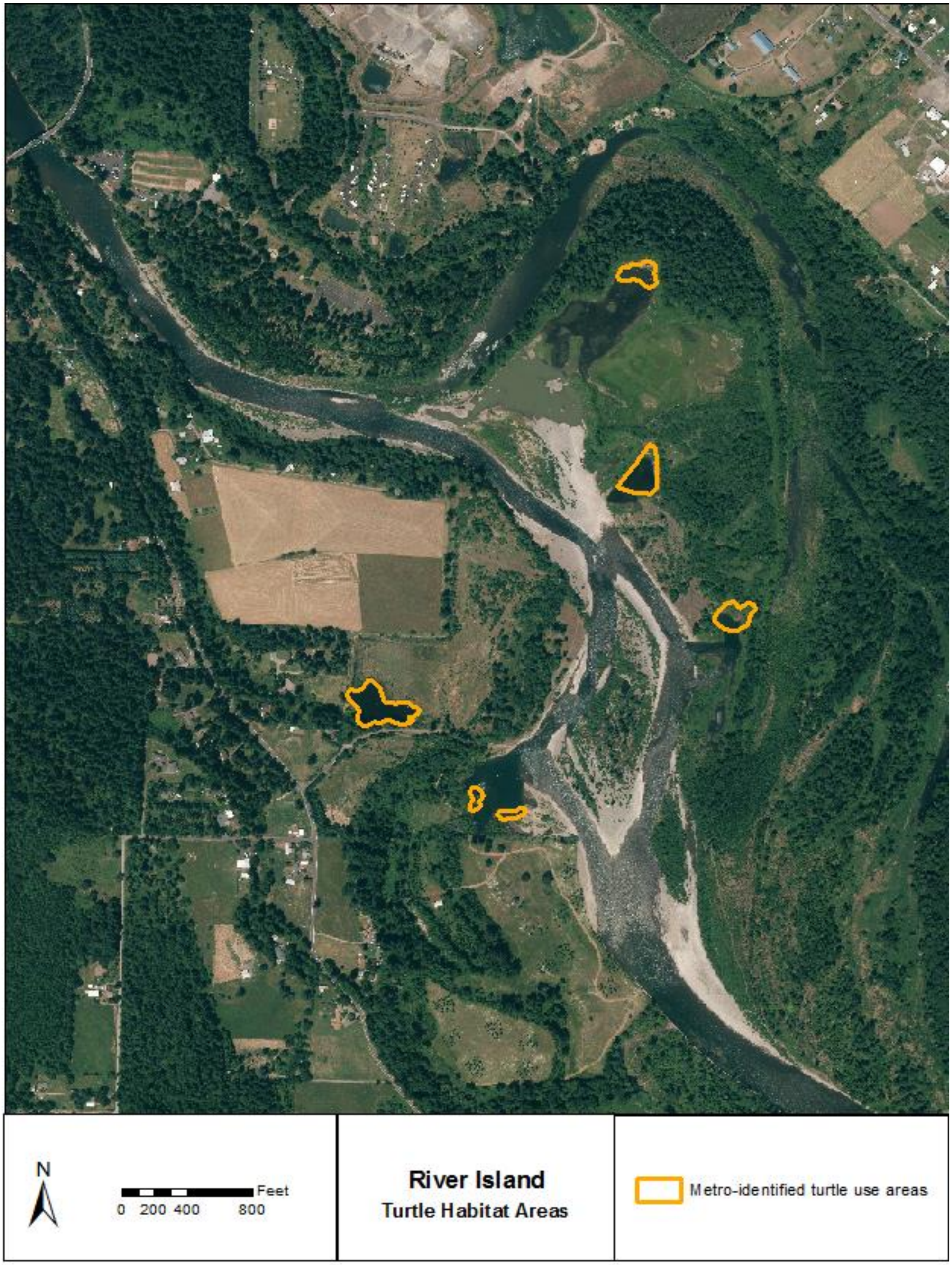

Figure 3. Areas of known turtle use at the River Island Natural Area based upon preliminary Metro visual surveys.

2.4 GEOMORPHOLOGY

2.4.1 Geomorphic Setting

In the vicinity of the River Island Natural Area, the Clackamas River and its modern floodplain occupy a partially-confined alluvial valley. The geology of the lower Clackamas River watershed is characterized by volcanic and sedimentary formations that flowed between the Cascade Mountains and the Portland Basin. Four major geologic units in the area of the River Island Natural Area include two volcanic units (the Sardine – aka the Rhododendron Formation, and the Boring Lava flows); and two sedimentary units (Troutdale Formation, Sandy River Mudstone and Alluvial deposits).

The Sardine Formation consists primarily of volcanic mudflow breccia that originated from the western Cascade Range in the late Miocene. Continental sedimentary rocks including the Troutdale Formation and Sandy River Mudstone were deposited in the early Pliocene as a result of stream flow from the western flank of the Cascade Range, filling basins in the Willamette Valley lowlands. Boring Lava are basaltic flows which erupted intermittently from vents throughout the region in the late Pliocene and Pleistocene. The Boring lava flows created cinder cones, shield volcanoes and lava plateaus throughout the Portland Basin. Finally, erosion and deposition continued as a result of streams transporting material off the Cascade Range and formed the Alluvial deposits present at the River Island Natural Area. Some of the deposited alluvium in the area originates from Pleistocene glacial outflow deposits and some is more recent Holocene deposits (Trimble 1963, WPN 2002).

2.4.2 Channel Process and Planform

The Clackamas River Watershed is located in the Willamette Valley physiographic province, a broad alluvial plain that spans the lowlands between the Coast Range and Cascade Mountains. The watershed is a complex network of underlying lithology types formed by water, volcanic inputs, and continental uplift. Over time, the Clackamas River has incised down through Pleistocene-aged and Estacada Formation Gravels.

Although there is little direct evidence of channel conditions prior to the mid-1900s, field observations, high resolution LiDAR, General Land Office maps, and underlying geology can provide some theories on channel form. During the Pleistocene era, an era defined by a cooler climate and much higher precipitation volumes, the channel form was likely created by high volume flooding and sediment inputs. Large boulders and cobbles located on abandoned floodplain surfaces (e.g. Estacada surface) indicate that historically the channel moved much larger volumes of water and sediment. As the channel has adjusted to drier and warmer contemporary climactic regimes, the channel no longer had the volumes of water necessary to fill its channel and span the valley floor. Over time, the now “underfit” Clackamas River incised into historical floodplain surfaces leaving behind abandoned floodplain surfaces and terrace deposits which serve as contemporary controls on lateral channel migration. Limits on lateral and vertical migration within the study reach are also imposed by Sandy River Mudstone, a thinly layered combination of claystone, siltstone, and sandstone within minor inter-layering of pebbly conglomerate, fine-grained tuff, and lignite (Trimble 1963, Evarts 2013).

Today, the River Island reach of the Clackamas River can be described as a moderate gradient (0.4%) semi-confined channel. Typical channel planform in the study area is a single-threaded channel, with point and mid-channel gravel bars. The channel exhibits primarily riffle-pool morphology, with occasional glides. Substrate ranges from boulders to silts, but is predominately gravels and cobbles. Currently, large off-channel "ponds" are located where the gravel mine pits once existed. These ponds are filled with six inches to two feet of silt deposits. See Appendix A for the General Land Office map and historical aerial photographs of the River Island Natural Area.

2.4.3 Meander Migration Analysis

Background and Methodology

The avulsion in the River Island reach of the Clackamas River during the 1996 floods set in motion a series of planform adjustments as the river began the process of equilibration to its new alignment. Migration analysis was performed on four meanders using established methodology (Transportation Research Board, 2004), with a goal of understanding both the trajectory of planform adjustments since the 1996 flood and identifying potential future trends. Bend radius was measured by drawing the best fit circle to the outside channel margin of each bend, using banklines digitized from georeferenced photos from the following years (1996, 1997, 1999, 2006, 2008, 2010 and 2012). Movement of the centroids of these circles is used to measure extension and translation of meander bends, while change in radius measures bend expansion.

Results and General Trends

While the analysis is helpful in identifying general trends, several factors make this site very dynamic and preclude a rigorous quantitative interpretation of the results to predict future trends. The presence of geologic controls (mainly deposits of Sandy River Mudstone) which are much less erodible than alluvial material can abruptly alter the alignment of the river or change the rate of meander migration. The presence of large sediment sinks (captured gravel pits), as well as reduced sediment input due to the River Mill Dam upstream, alter the timescales at which the river can build new bars and move laterally within the floodplain.

Meander 1 – This meander migrated quickly into the alluvial material and soil of the left bank, at a rate of ~ 135 feet/year in the first 3 years following the avulsion. As this meander progressed toward the captured gravel pit to the west of the main channel, the main flow path of the river shifted into a new alignment. The downstream edge of this meander continued to move through the downstream edge of the bank from 1999 to 2010, greatly expanding the radius of curvature of the bend. Overall, this meander has migrated ~40 feet per year to the west since the 1996 avulsion. A GPS ground survey of the bank in January of 2014 confirms continued movement to west. Given the lack of obvious geologic or vegetative controls in this area, the meander will likely continue to progress to the west. While larger alluvial material from this bank has likely been deposited directly downstream in new bars observed within the study area, bar formation may be slowed by the capture of alluvial material in the pond directly upstream.

Meanders 2 and 3 – Meander 2 migrated eastward into right bank alluvial deposits at a rate of ~ 90 feet/year from 1996 to 1999, but migration slowed greatly as the river occupied its new flow path to the west. Conversely, meander 3 did not fully develop until the flow path on river left became the primary path. This meander has translated north 215 feet and expanded its radius since 1999. Heavily vegetated berms that previously divided the various gravel pits armor the right bank in certain locations along Meander 2, which may contribute to the lack of migration.

Meander 4 – This meander has remained essentially stable over the study period. At higher flows, the river's energy is split between the main flow path and the flow path to the northeast (into the north most pond). The material on the outside of the bed is erodible, but the lack of energy at higher flows limits the ability of the river to expand in this direction. If meander 3 continues to migrate northward, it may converge with Meander 4. Continued deposition on the point bar on the inside of Meander 3 could direct more flow into the current high flow channel to the north.

Sources and Sinks of Sediment – The bank being eroded by Meander 1 is a major local source of sediment. New bars formed immediately downstream of this area may be made up of material from this bank. The presence of large sediment sinks in the system limits the ability of the river to move laterally. Sediment that would be used to form bars and push the river laterally instead falls to the bottom of previously excavated areas. Additionally, headcut migration has occurred in this reach (Wampler et. al 2006), further limiting the ability of the river to occupy previous floodplain surfaces. It is likely that this reach will remain dynamic in the short to medium term as it continues to equilibrate to its current sediment/energy balance.

Future Trends **–** Large outcrops of Sandy River Mudstone on river left will likely impede channel migration in this direction much beyond the extent of the most upstream pond on the left bank. A large bend has existed in this reach since at least 1855 (Figure 4). However, the current channel is adjusting to a new equilibrium, and significant filling of the sinks caused by the removal of alluvial material will be required for the channel to build bars and move laterally. Locally, the most active source of alluvial material is the eroding bank at Meander 1. Redistribution of this material will be an important element of driving future planform changes in this reach.

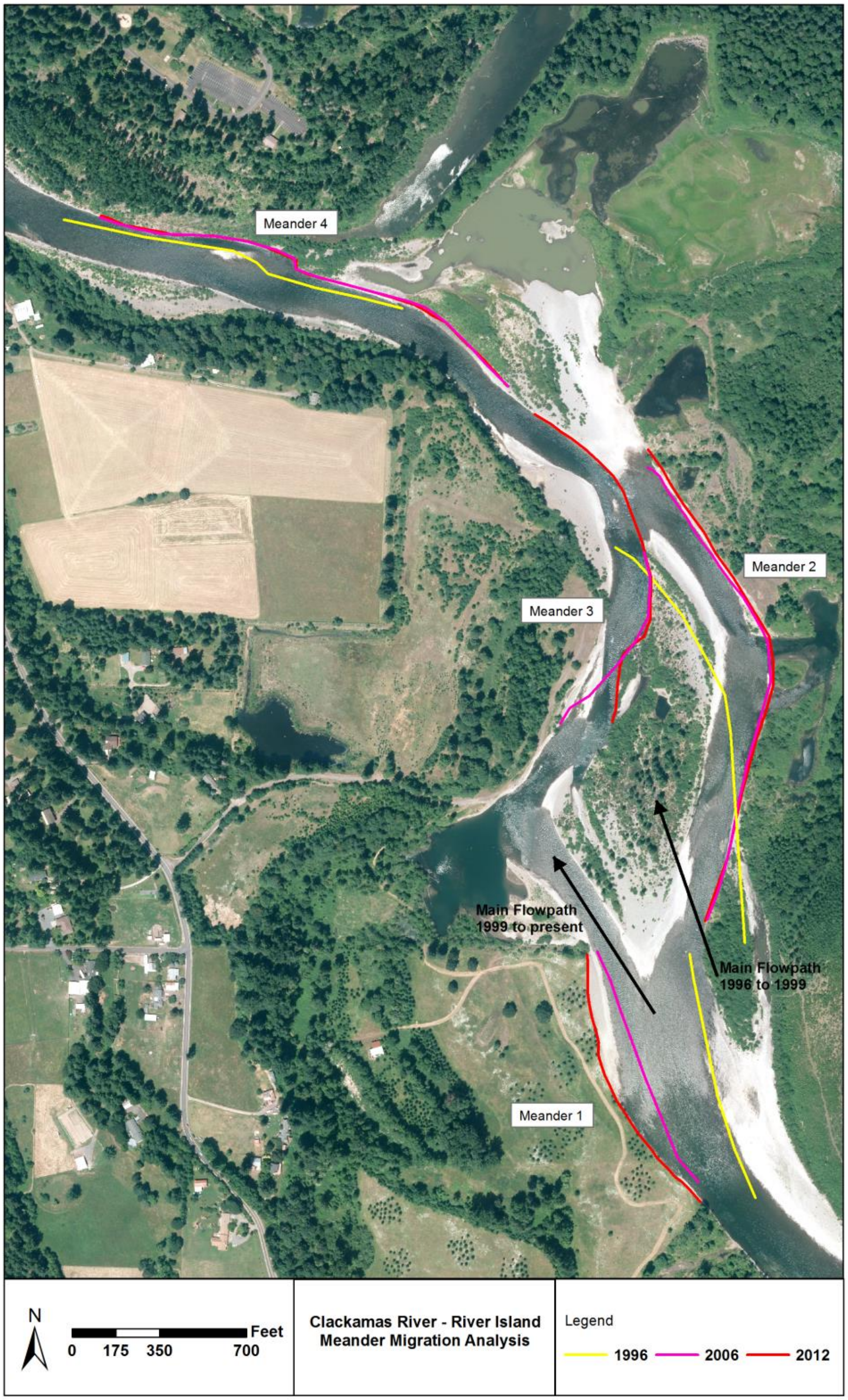

Figure 4. Meander migration analysis. Digitized banklines from 1996, 2006 and 2012 are depicted.

2.5 HYDROLOGY

The Clackamas River is a large tributary of the Willamette River. The River Island Natural Area is located at approximately RM 15 on the Clackamas. The contributing watershed area is approximately 785 square miles and originates in the high cascades, and meanders north and westward until its confluence with the Willamette River.

The watershed receives precipitation as rain and snow primarily between fall and spring. The headwaters of the Clackamas, between Mt. Hood and Mt. Jefferson, receive approximately 130 inches of precipitation and the lower basin receives approximately 61 inches of precipitation. Rain and snow that falls and infiltrates in the upper watershed is slowly released throughout the year as cool groundwater and flows in the lower basin are supported during the dry summer months (Taylor 1999). High flows occur as a result of storms, spring snowmelt and occasional rain-on-snow events.

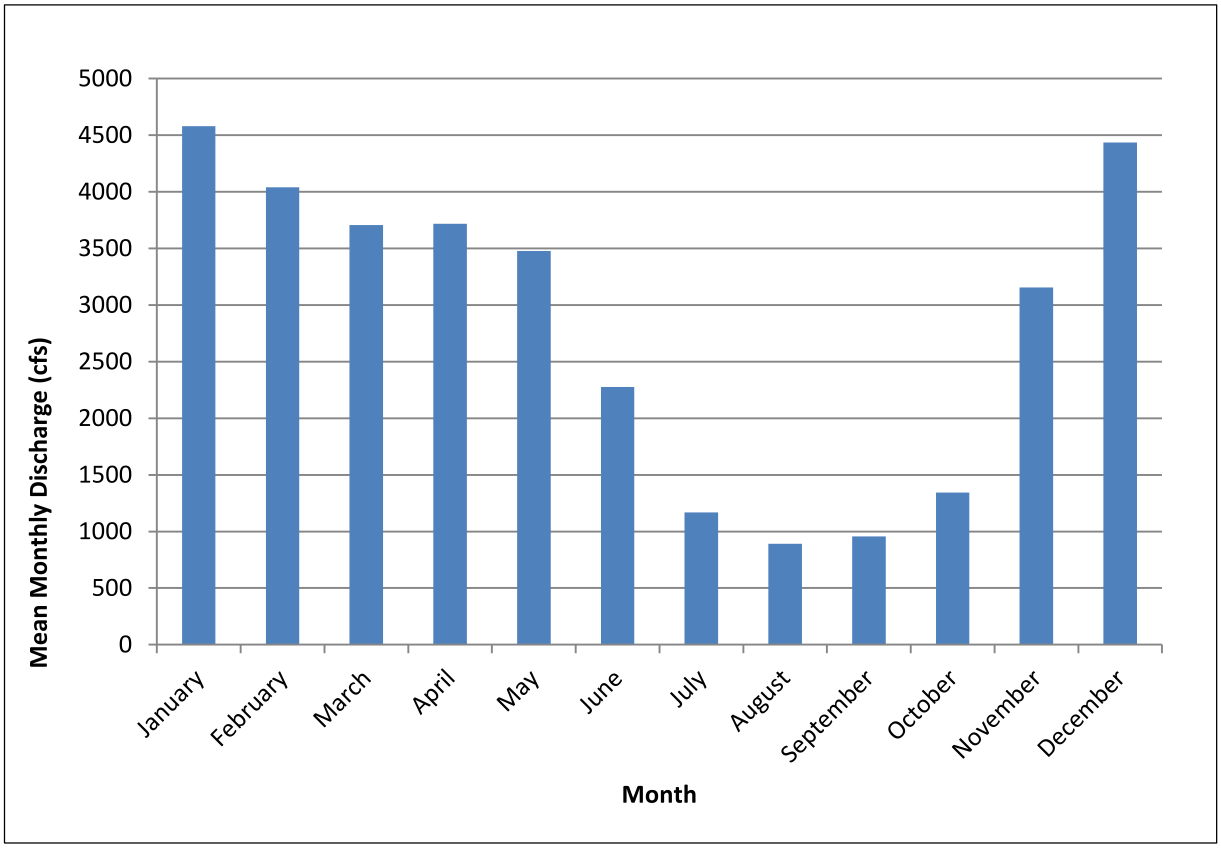

Figure 5. Mean monthly discharge from 1959-2013 at the USGS Clackamas River gage at Estacada, OR (USGS gage #14210000).

Major tributaries to the Clackamas River include Clear Creek, Deep Creek, Eagle Creek, North Fork Clackamas, South Fork Clackamas, Fish Creek, Roaring River, Oak Grove Fork and Collawash River.

2.5.1 Beaver Use

Use of the Goose Creek area by beavers was observed during field surveys. Beavers are a natural component of the Pacific Northwest landscape and historically have been present in the area

(Andonaegui 2001). On rivers like the Clackamas, which experiences high spring runoff, beaver structures are often blown out and are thus a transitory and dynamic component of the landscape. The longevity of any given beaver dam depends on its size and the local hydraulic forces that would result in dam failure. Dams formed in relatively quiescent settings such as backwater areas may be long-lived.

A recent literature review of beaver impact on fish (Kemp et al. 2012) notes that there is no consensus on whether beaver impact is, on the whole, positive or negative, though benefits to fisheries and habitat heterogeneity typically outweigh the costs. Beaver dams have been cited to have a beneficial effect on river systems and consequently salmonid use by increasing habitat complexity, increasing overwintering habitat and/or high flow refuge, and increasing food sources in the form of invertebrate production. Further, beavers offer a host of other wildlife and ecosystem benefits including temporary water storage and water filtration. Potential negative impacts of beaver dams have been noted to include reduced fish movements past dams, siltation of spawning habitat, and low oxygen levels in ponds.

2.5.2 Low Flow Hydrology

In order to support components of design, a low flow hydrologic analysis was conducted. Low flow conditions often have an important influence on fish use of off-channel habitats, stream temperatures, persistence of riparian vegetation, and beaver dynamics. Due to the off-channel habitat features that are intended to convey surface flow throughout the year in this project, the low-flow conditions are particularly important to design the appropriate elevation of these features. For this analysis, the minimum seven-day moving average flow that occurs once every 2 years (7Q2) and once every 10 years (7Q10) was calculated. This was performed by conducting a low-flow frequency analysis using data from the Clackamas River near Estacada, OR gage (USGS gage #14210000). Only gage data from 1959 to current was used for this analysis, though the record begins in 1908, due to the dam becoming operational in 1958. A noteworthy tributary, Eagle Creek, enters the Clackamas River between this gage and the study area. Eagle Creek contributes an estimated 12% of flow at the study area, therefore the 7-day moving average flows based on the USGS gage data were adjusted to account for this 12% increase. All further calculations are based on these adjusted, estimated values for flow at the study area.

The 7-day low flow was then calculated for each climatic year, defined as April 1 to March 31. This was only performed where there was a complete record of flows for the climatic year, or it was clear that the available data captured the lowest flow period during the year. There were 58 years of available low flow data. The data were then subjected to a log-normal, low flow frequency analysis. The ranked data are included in Table 2 and the results of the frequency analysis, including the 7Q2 and 7Q10 statistics, are included in Table 3

Table 2. Ranked list of low flows over the 58-year period of available data.

Rank	**Climatic Year (Apr 1 - Mar 31)**	**Minimum 7-day moving average flow (cfs)**
1	1965	638
2	1979	657
3	1992	665
4	1994	672
5	1964	679
6	1987	684
7	2001	696
8	1962	713
9	1977	720
10	1980	729
11	1967	735
12	1978	736
13	1991	748
14	1988	755
15	1988	755
16	1988	755
17	1966	768
18	1990	772
19	1963	782
20	1989	784
21	1993	785
22	1981	785
23	2005	787
24	1986	791
25	1970	812
26	1973	814
27	2003	817
28	2004	822
29	2007	823
30	1968	837
31	1998	845
32	1959	848
33	1985	850
34	1995	863
35	2006	864
36	1982	890
37	1983	893
38	2002	893
39	1961	901
40	2013	904
41	1976	915
42	2009	926
43	1960	939
44	1960	939
45	2000	942
46	2010	942
47	1996	942
48	2012	960
49	1969	975
50	1971	991
51	1972	1003
52	1975	1026
53	2011	1051
54	1997	1060
55	2008	1063
56	1974	1077
57	1984	1079
58	1999	1098

Table 3. Results of the low-flow frequency analysis. Flows are expressed as 'non-exceedence' flows, which means that the lowest flow in a given year (7-day average), on average, would be expected to drop below the non-exceedence value once during the given recurrence interval. For example, on average, once every 10 years, the lowest 7-day moving average flow would be expected to drop below 699 cfs.

Low Flow Recurrence Interval (years)	Non-exceedence flow (cfs)	Statistic
1.01	1171	
2	840	7Q2
5	745	
10	699	7Q10
25	654	
50	626	
100	602	

2.6 HYDRAULICS

2.6.1 Methods

A conceptual-level hydraulic model was built to inform the feasibility of floodplain reconnection and restoration efforts. It was built to evaluate flood-level inundations on a relative scale, and provide information on which areas in the study reach receive floodplain inundation. At this juncture, this model is only intended to be used for restoration feasibility. Depending upon opportunity area(s) selected for further development and construction, appropriate modeling methodologies will be evaluated and more detailed cross-sections may be added.

Existing channel and floodplain hydraulics were simulated using the U.S. Army Corps of Engineers Hydraulic Engineering Center River Analysis System (HEC-RAS 4.1.0; USACE 2010). HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The program is one-dimensional, meaning that there is no direct modeling of the hydraulic effect of lateral cross section shape changes, bends, and other two- and three-dimensional aspects of flow. The hydraulic model calculates channel and floodplain water surface elevations, velocities, depths, and shear stresses (among other metrics) for various input flows.

The model geometry was developed using topographic and bathymetry data obtained through surveys completed in December 2013. Survey data was supplemented with LiDAR data (Watershed Sciences 2007) in select locations, including those locations that span private (non-Metro) property. The existing conditions model geometry includes seventeen cross sections spaced over the project reach on the mainstem Clackamas River (Figure 6). Cross sections extend through the right bank floodplain to the right valley wall terrace toe. The 1.01-, 5-, 10-, 25-, 50-, and 100-year recurrence interval floods were modeled and calibrated to surveyed water surface elevations. The downstream-most cross-section was tied into the FEMA floodway for Clackamas County, allowing for use of the boundary conditions from the FEMA model. Future efforts will likely involve model calibration to deployed HOBO water loggers and finer-scale manning's roughness mapping.

Table 4. Flood frequency data used in the hydraulic model based on hydrologic analyses described above. Discharge units at each reach are cubic feet per second.

Flood Recurrence Interval	Calculated Discharge at River Island (cfs)
2	32,281
5	47,934
10	57,832
25	67,323
50	78,144
100	86,160

Roughness coefficients (Manning's n values) applied at each model cross section were estimated from field observations, aerial photography and published methods (Arcement & Schneider 1989). These are summarized in Table 5.

Table 5. Initial Roughness coefficients used in the existing conditions model

Description	Manning's n values
Channel	0.038
Floodplain	0.06

Following initial development of the model, flows were calibrated to surveyed water surface elevations. Water surface elevations were surveyed on four different dates (12/04/13, 12/05/13, 01/31/14, and 02/18/14), and the date and time (closest 15-minute interval) of surveyed water surface elevation shots was recorded. The model was then calibrated by adjusting roughness values (Manning's n) in the channel until survey data was matched. It is expected that during additional design-level topographic survey, low flow water surface elevations will be surveyed to allow for low flow calibration of the model. Results from on-site gaging stations will also be used to further calibrate the model in support of design of the selected alternative.

Flood Inundation Analysis

Flood inundation was modeled using HEC-RAS Mapper. HEC-RAS Mapper allows for visualization of floodplain inundation by overlaying HEC-RAS modeling outputs on digital terrain models. As previously described, digital terrain models were created by topographic and bathymetric surveys, combined with LiDAR in select locations. Georeferenced hydraulic modeling outputs are then displayed in ArcGIS.

2.6.2 Results

Floodplain Inundation

Inundation analysis results are presented in a map at the end of this section (

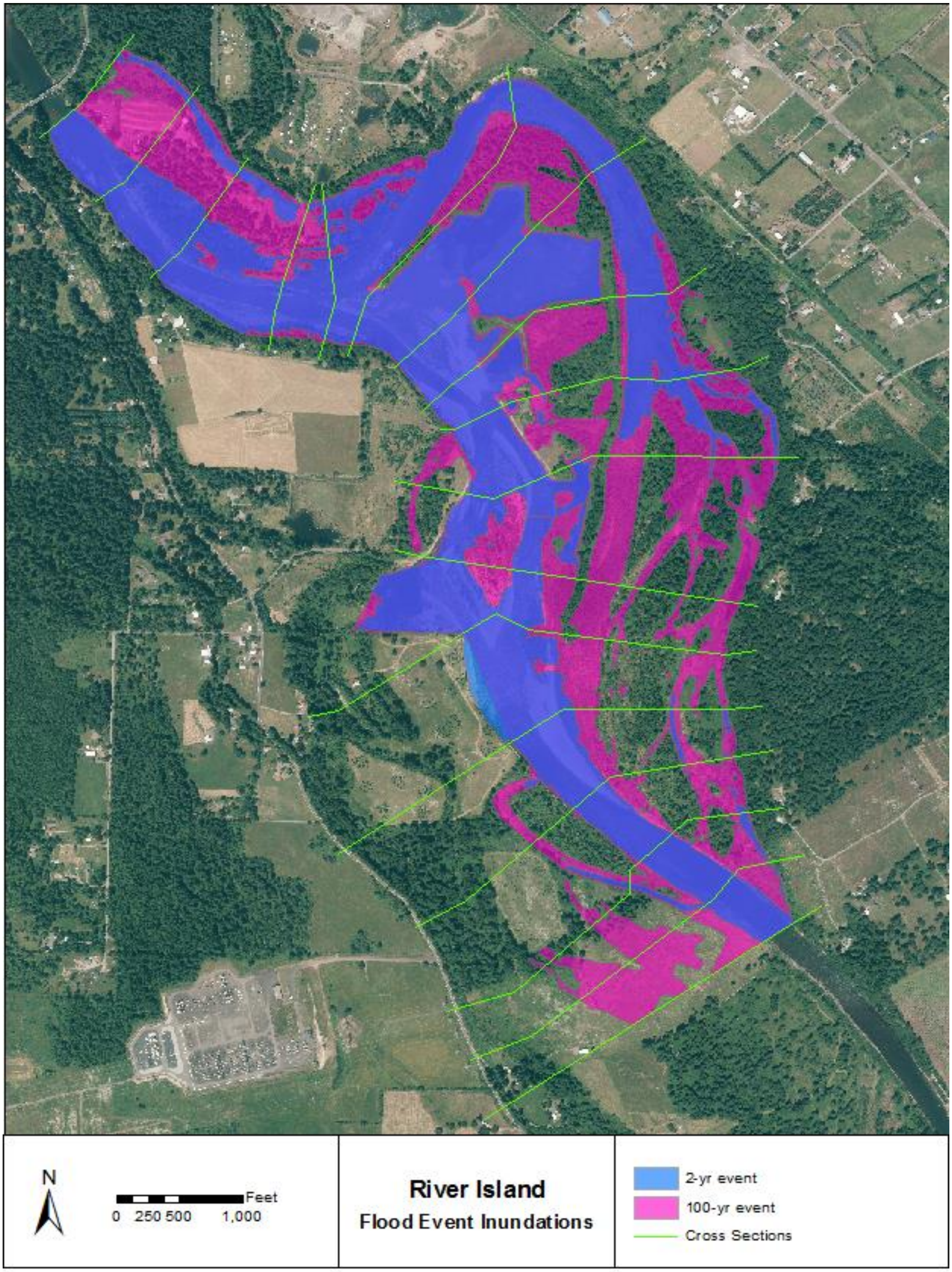

Figure 7). Much of the floodplain remains dry at the 100-year event. Throughout the project reach, limited activation is seen of side-channels and floodplain surfaces until the Q10. The pre-1996 channel backwaters at the Q2, and becomes fully active as a flow-through channel near the Q50.

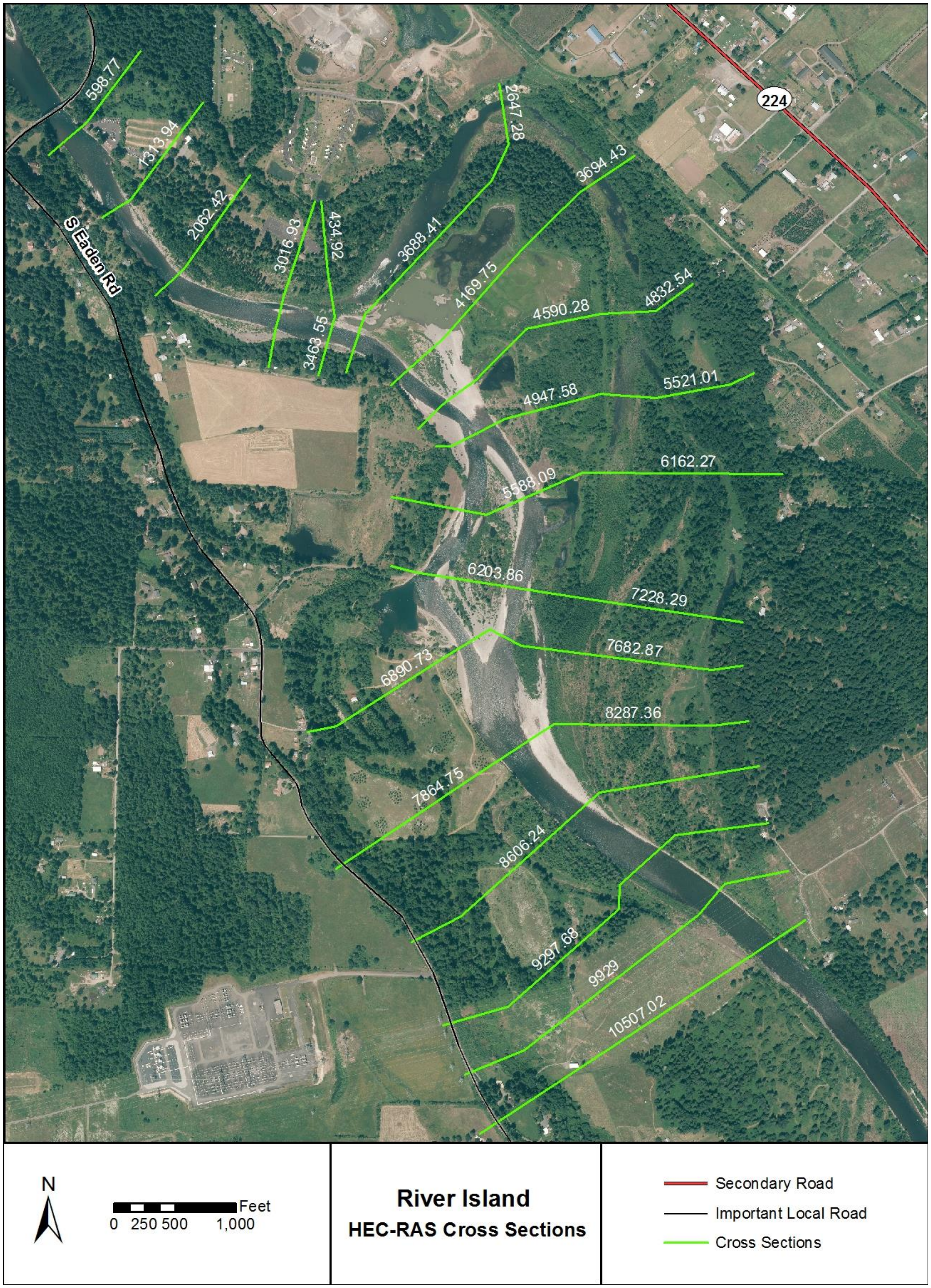

Figure 6. Conceptual-level HEC-RAS cross-sections for the River Island project area on the Clackamas River.

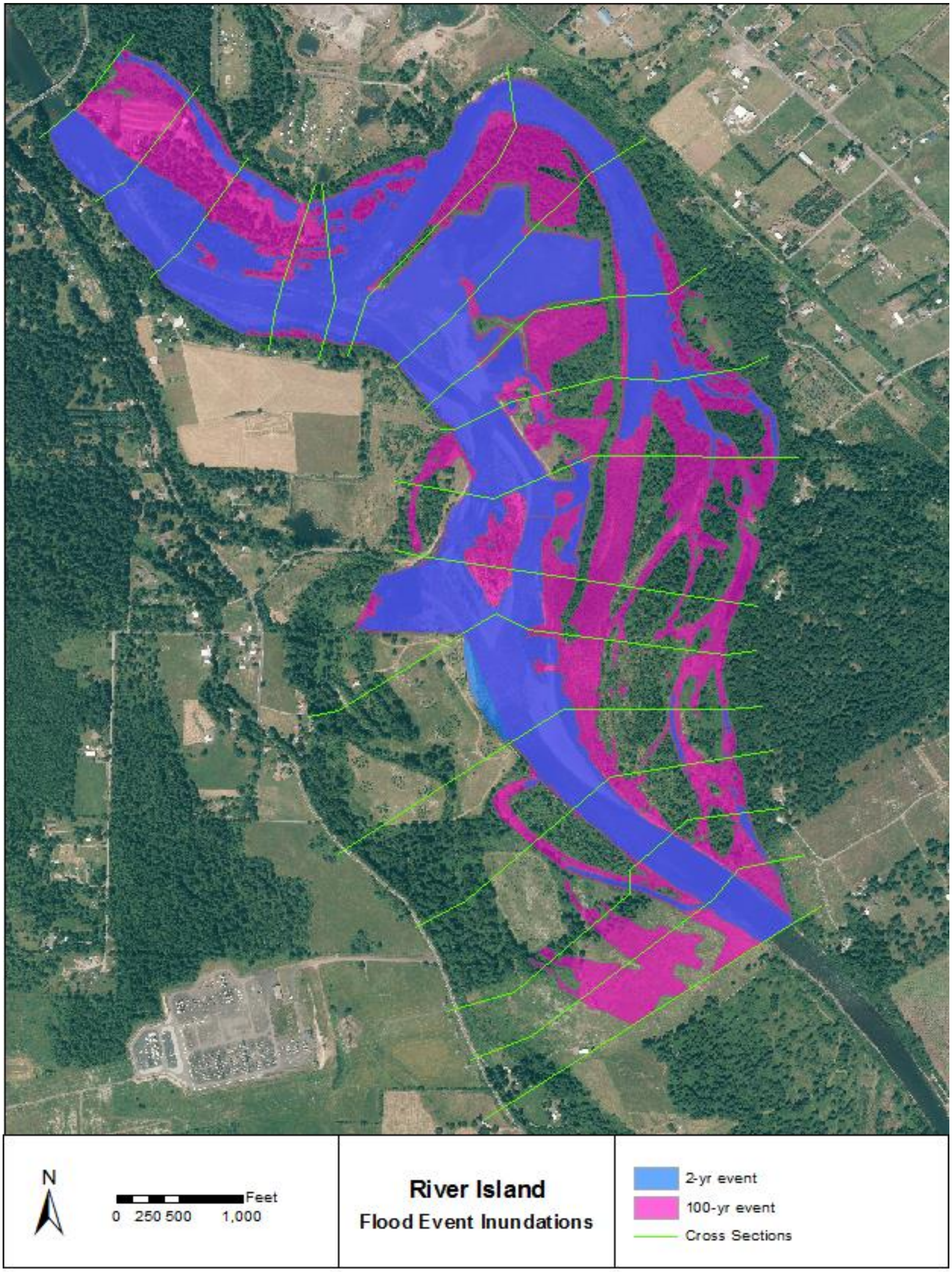

Figure 7. Inundation events for the River Island project area on the Clackamas River.

2.7 VEGETATION

Three major vegetation communities (based on Metro's habitat mapping criteria) are present at the River Island Natural Area: oak savanna, riparian forest and upland conifer-hardwood forest (Figure 8). All three types are assumed to have been historically present although they have been impacted by human development and changes in hydrology over time. River Island Natural Area includes 29 acres of Oregon white oak savanna habitat located on the river left terrace. This is a conservation priority habitat type within the Oregon Conservation Strategy and the Regional Conservation Strategy for the Greater Portland-Vancouver Metropolitan Area. Large open grown Oregon white oak trees can be seen in this area along with patches of young pine and Oregon white oak plantings. Riparian forest is present over approximately 139 acres at River Island along the lower floodplain terraces. Some variations of canopy structure in this habitat type include cottonwood, red alder/western red cedar and red alder/Douglas fir community types. Most areas of riparian forest within the site are severely altered due to past mining operations at the site. Upland forest with a mix of conifer and deciduous vegetation occupies 51 acres at River Island with trees ranging in age from 2 to 100+ years. Some variations of canopy structure in this habitat type include Grand fir/big leaf maple, Douglas fir/big leaf maple/red alder and big leaf maple/Douglas fir community types.

Height of vegetation estimated from LiDAR first return results was provided by Metro (Figure 8). These data provide information on the heights, densities, and probable species of vegetation at the site. This information is used in combination with other data sources to determine the spatial location of restoration project features including side-channels, backwater channels, large wood placements, and access roads.

Figure 8. LiDAR-derived vegetation canopy height (based off of 2007 LiDAR).

2.8 SOILS

The properties of soils found within a watershed influence to a large extent the movement of water through and within the soil layers. Information on soils in the soil survey of the Clackamas area (NRCS, 1985; 1998) is published by the USDA Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service) (Figure 9). Descriptions and percent coverage of the River Island Natural Area are located in Table 6.

Table 6. Descriptions of soil group properties

Map Unit Name	Description	Area (acres)	Percent of study area
Camas gravelly sandy loam	This very deep, excessively drained soil formed in mixed sandy and gravelly alluvium. Soils are on floodplains. Slopes are 0 to 5 percent.	45.70	19.49
Cloquato silt loam	This very deep, well-drained soil formed in mixed alluvium.	5.28	2.25
Newberg loam	This deep, somewhat excessively drained soil is on floodplains. It formed in mixed alluvium. Slope is 0 to 3 percent.	42.75	18.23
Pits	Remnant gravel pits.	34.63	14.77
Riverwash	Barren alluvial areas, typically coarse textured.	4.92	2.10
Wapato silty clay loam	This very deep, poorly drained soil formed in loamy mixed alluvium. Soil is on floodplains. Slopes are 0 to 3 percent.	9.76	4.16
Water	Open or flowing water	70.84	30.21
Woodburn silt loam	This deep, moderately well drained soil is on broad valley terraces it is formed in stratified glaciolacustrine deposits. Slopes 3 to 8 percent.	8.35	3.56
Xerochrepts and Haploxerolls, very steep	This map unit is on terrace escarpments. Slope is 20 to 60 percent.	12.24	5.22

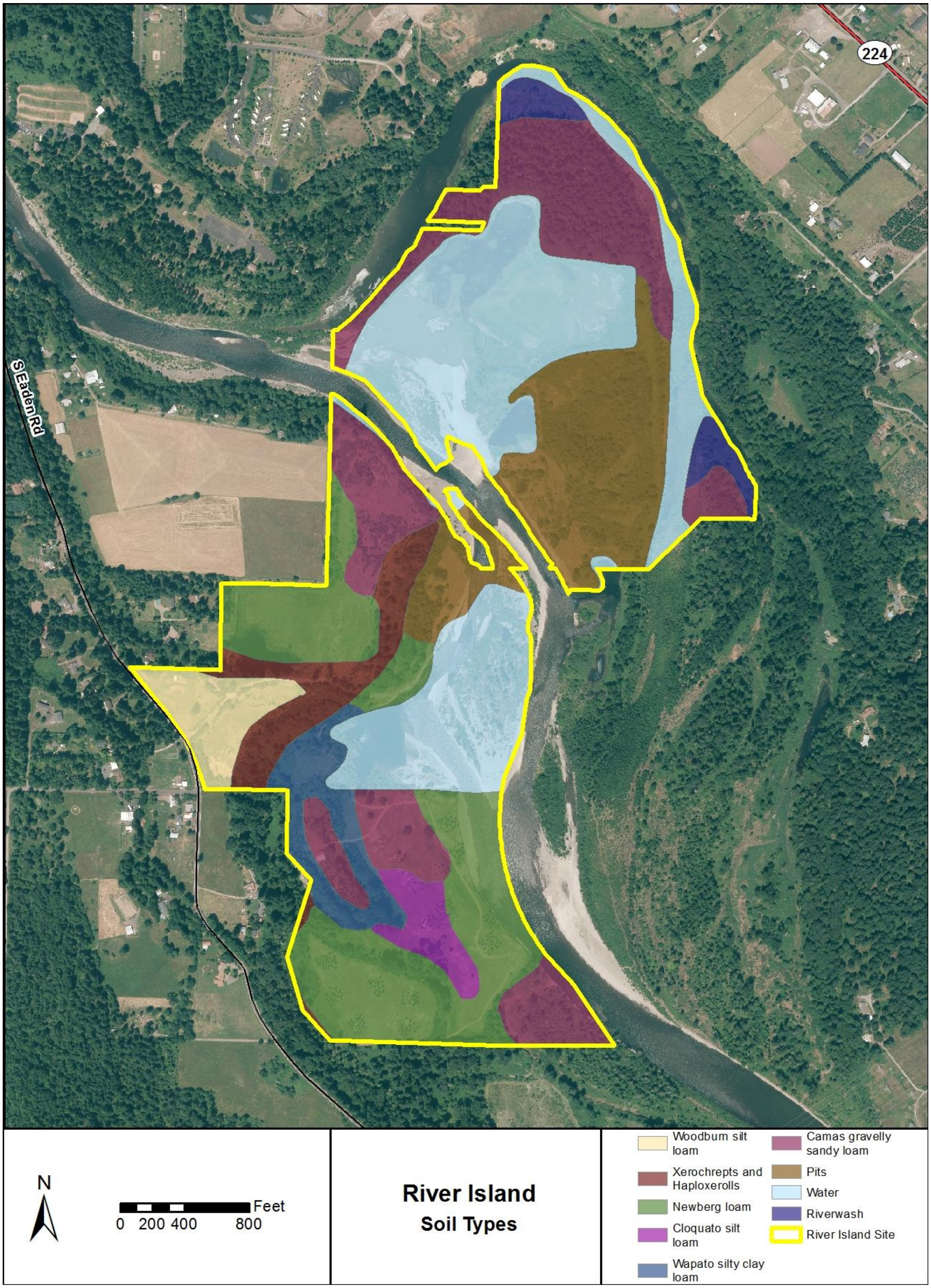

Figure 9. Surface soils map for the River Island project area along the Clackamas River.

2.9 HUMAN LAND USE AND DISTURBANCE

As reported by the Historical Research Associates report (2014) the Clackamas River Basin has been used by people for thousands of years. Willamette Falls located on the Willamette River approximately 16 miles west of the River Island Natural Area, has been, and continues to be a regionally significant landmark. The falls are a natural waterfall which was a traditional gathering point for Native Americans as well as an area of abundant fish harvest. The River Island Natural Area is reported to be within the traditional territory of the Clackamas, a Chinookan-speaking tribe who lived on the Willamette River near Willamette Falls, along the Clackamas River, and on nearby tributary streams.

French and English fur traders began to explore the area in the early 1800s bringing diseases which decimated tribes in the Pacific Northwest. Oregon City was founded in 1829 at Willamette Falls to take advantage of the water power to run a lumber mill. In the late 1830's settlers began to arrive in the area on what later was known as the Oregon Trail. With the development of the railroad, the pace and scope of human settlement and uses of the Lower Clackamas basin quickly accelerated - and included commodity extraction, farming, timber harvest, and human settlement.

Human use of the upland areas near the River Island Natural Area included transportation, commodity extraction and human settlement. Transportation corridors included the Barlow Road, located south of the site and a rail line built in 1903-1904 by the Portland Water and Light Railroad, called the Boring-Estacada Rail Line or the Springwater Line. The rail line ceased operation in the early 1930s when the trestle at Deep Creek burned. The remnants of this rail line are visible today. Commodity extraction included logging, grazing, mining, dams and fish hatcheries. Much of the logging is assumed to have occurred to clear land for mining and farming operations. Human settlement in the River Island area likely occurred in the mid-1800s. Settlement included building homes and other buildings as well as farming the upland and floodplain terraces in the area. Today, rural residential development surrounds the River Island Natural Area.

Mining

Previous gravel mining operations at the River Island project area continues to impact the nature of the Clackamas River and surrounding area today. Mining operations began at River Island in 1963 and over 200 acres of material was processed at an on-site plant. Between 1967 and 1971 a dike was constructed along the river left side of the main channel to prevent flow into the floodplain and the mining site. From the 1970's through the mid 1990's mining continued along with reclamation activities. In 1996 a catastrophic flood caused the Clackamas to avulse, flowing through the gravel mining operation and flooding mine pits. Reclamation and cleanup activities continued until 1999 when Parker-Northwest Paving began the process of donating and selling the property to Metro (Historical Research Associates, 2014).

Recreation

Recreation throughout the lower Clackamas River continues to impact the River Island Natural area. While there are many responsible users of the river, proximity to a major metropolitan region results in extensive numbers of tubers and floaters utilizing the area's river banks for camping and meals, often leaving behind trash (OPB 2013). During a 2008 survey more than 400 people per hour were tallied leaving Barton Park floating to Carver on warm summer days. The majority of river users were riding on non-maneuverable crafts (i.e. pool toys, tubes) and many of were carrying alcohol (OPB 2013). While the McIver to Barton Park reach is somewhat less popular for tubers, this reach is still a very high traffic area.

2.10 SAFETY CONSIDERATIONS

A number of potential safety concerns have been and will continue to be considered as part of project design. These considerations primarily apply to the use of large wood, which can pose a potential risk to recreational river users.

The restoration alternatives include placing wood structures (i.e. engineered log jams) along the mainstem and as cover wood within existing or created off-channel habitats. The structures on the mainstem would be designed to provide habitat function while minimizing risk to river recreationists, and would be anchored as required to achieve stability at the design flow (Metro defined as Q100). A number of safety guidelines are available, primarily from the State of Washington, and were reviewed and considered during design, including:

- Washington State Department of Transportation. August 9, 2010. Project Delivery Memo #10-01, Geomorphic/Safety Guidance for the use of Large Woody Materials for Mitigation Applications in Bridge Scour Projects.
- Skellenger & Bender Attorneys. 2007. Understanding the Legal Risks Associated with Design and Construction of Engineered Logjams. Written by Beth Andrus & James Gessford, P.E.
- River Safety Council. Proposed Safety Guidelines for the Construction and Placement of Large Woody Debris (LWD) Affecting Streams used for Recreation in Washington State.
- American Whitewater. Integrating Recreational Boating Considerations into Stream Channel Modification & Design Projects.

In general, these guidelines are aligned with the standard approach taken by Inter-Fluve in design and placement of large wood. A number of considerations were included in the design to minimize risk consistent with the guidelines:

- This portion of the Clackamas is heavily utilized by casual recreational river users such as those people inner-tube floating, fishing, rafting, and swimming. Children are common user-group members and personal floatation devices (PFDs) are commonly not worn.
- As a design standard, all mainstem wood placements should have sufficient line of sight and navigable escape routes to be easily avoided by unskilled river users.
- Mainstem structures would be configured to shed objects floating along the river and thus minimize risk to recreationists. The optimal configuration for safety will be site dependent, but will commonly depend on flow orientation to the bank, bank height, depth of log submersion, line of sight, near bank velocity, near bank shear stress, and near bank depth.
- Mainstem structures will be designed for stability at the 100-yr flood with consideration given to buoyancy, depth of burial, cabling, and ballasting.
- Safety signage warning river users of the presence of log structures may be a viable component of safety measures given the traffic and skill level of many river users. This is consistent with

recommendations by Andrus & Gessford (Skellenger & Bender, 2007); the River Safety Council; and the Washington State Department of Transportation.

Ballasting Large Wood

It should be noted that there is an ongoing regional debate, particularly in the State of Washington, regarding the personal injury and property damage liability associated with large woody material (LWM)-based enhancement work. Recent legislation in the State of Washington (House Bill 1194) sets legal requirements for stability of LWM on non-federal lands. The actual means and frequency of implementation of this legislation is, however, still evolving.

Meanwhile, resource agencies are moving towards substantially limiting the construction methods available to ballast LWM in enhancement projects. For example, the BPA HIP III handbook (2014) articulates the controls set by recent programmatic ESA consultation in the Columbia Basin. This consultation dramatically affects the means of ballasting LWM available through backfill applications and 'ferrous' methods (e.g. cabling and rebar).

The importance of ballasting LWM in certain settings is due to the physical reality that wood weighs less than water (typically 50% to 60% less), and when submerged will float and redistribute. In many settings, this may not cause substantial concern, either because the location is remote, or the fate of the redistributed LWM can be assessed with certainty and cleared from the potential to cause harm. Tactical placement methods in smaller stream systems can also limit the movement of non-ballasted LWM.

This does become particularly important however, when it is desired to realize all of the myriad benefits associated with LWM enhancement in settings where interaction with infrastructure or other resources of value is possible. Because in some systems the size of LWM that would be found as 'self-stabilizing' is simply not available for installation or is impractical to manipulate (i.e., very large and long logs, old growth logs), ballasting methods are commonly applied to emulate the stability characteristics of the larger materials.

Therefore, the current scenario which integrates the increased scrutiny and accountability for LWM stability on behalf of the public, with the increased scrutiny of ballasting methods on the part of the resource agencies, results in possible conflicts that the proponents of each LWM enhancement project must collectively navigate. In some cases, it may be required to modify the LWM enhancement approach to be more conservative, with the LWM less exposed to fluvial forces, and by default, less available for interaction with the stream channel and the target species.

3. Restoration Opportunities

Large planning opportunity areas were identified at River Island by Metro and project partners. Treatment options were then evaluated for specific stream and floodplain restoration opportunities. Proposed options, identified in section 3.3, were identified as the most feasible based on design criteria and current conditions. Treatment options may be selected individually or as a group. Additionally, it may be effective to phase work over multiple years, where after an initial phase of restoration work Metro and project partners can evaluate whether additional opportunities or maintenance treatments may be needed.

3.1 DESIGN CRITERIA (DRAFT)

Conceptual designs were developed with consideration of the restoration objectives and with constraints (Section 1.3), regulations, safety, and feasibility in mind. Draft design criteria have been developed to guide the design process and to ensure that project objectives are achieved and project constraints are understood and explicitly addressed. Draft design criteria are provided below within five sections: Geomorphic, Habitat, Engineering, Safety, and Feasibility. These design criteria will be revised and made to be more quantifiable once an opportunity area is selected.

3.1.1 Geomorphology

- Design projects that will enhance habitat features in a way that will be geomorphically sustainable given the current and reasonably foreseeable sediment, landuse, large wood and recreational regime, considering geomorphic parameters such as:
    - Avulsion potential
    - Changes in planform and cross-sectional geometry
    - Consider nearby infrastructure (e.g., Barton Park)
    - Preserve quantity of existing functional habitat
    - Consider and acknowledge the potential for beaver activity
    - Projected changes in hydrology (e.g. increasing intensity of storm events)
- Design projects that promote structure and complexity
    - Utilize and promote geomorphic function to sustain habitat features
    - Mimic natural large wood recruitment and retention processes to increase cover and roughness

3.1.2 Habitat

- Design projects to enhance ESA-listed salmonid populations:
    - Creation of off-channel habitat
    - Placement of large woody material
- Design projects to restore in-channel geomorphic processes and resulting habitat:
    - Pool scour
    - Capture and retention of spawning gravels
    - Large wood recruitment and retention
    - Floodplain inundation
- Design projects to provide immediate and direct benefits to target fish and turtle species:
    - Cover

  - Channel complexity
  - Velocity refuge
  - Increased food sources
  - Nesting grounds
  - Basking logs

3.1.3 Engineering

- Design resilient project geometry that:
  - Maintains sediment transport continuity (e.g. through side-channels)
  - Achieves desired levels of lateral channel stability (TBD)
  - Achieves desired levels of vertical channel stability (TBD)
  - Maximizes surface water connectivity
- Design flow for large wood stability (Metro defined as Q100)
- Design flow for off-channel habitat function and stability (Metro defined as Q100)
- Document current base flow conditions and be able to demonstrate no adverse impacts to adjacent land owners

3.1.4 Safety

- Design projects which take recreational use and safety into account, including:
  - Appropriate visibility
  - Appropriate amount of channel encroachment by wood structures

3.1.5 Feasibility/Construction

- Minimize impacts to target species during the construction process
- Minimize impacts to intact habitat
- Minimize noise, dust, and traffic disturbances to neighboring property owners
- Utilize onsite resources where feasible (e.g. trees, boulders)
- Consider proximity to access routes and utilize existing access where possible
- Consider impacts to residential wells during dewatering
- Consider phased construction, if relevant

3.2 DEVELOPMENT OF CONCEPTUAL RESTORATION TREATMENT OPTIONS

The River Island Site was broken into four different planning areas on Metro property. Planning areas were divided based on geomorphic feature classification and proximity for construction feasibility.

Development of restoration opportunities was driven by the above listed design criteria, outreach to the public and a technical review committee, as well as regional and local restoration objectives. These opportunities were formulated within the framework of known existing constraints and reasonably foreseeable projected changes to the site (e.g. meander migration analyses). Each restoration alternative will be completed in tandem with riparian revegetation to promote the long-term recovery of the riparian community and large wood delivery processes. During the conceptual phase, proposed alignment, habitat type, and channel complexity were the primary design elements considered. Specific assumptions were made regarding channel dimensions, large wood sizes, and access; these are described below. Depending upon selection of a preferred alternative(s), proposed conditions will be modeled as part of subsequent design efforts. Modeling will assess feasibility related to sediment transport, habitat accessibility, ballast requirements, and vertical and lateral channel dynamics.

3.3 DESCRIPTION OF CONCEPTUAL RESTORATION TREATMENT OPTIONS

A total of four restoration planning areas were identified and evaluated (Figure 10). Although these actions are framed as separate areas, they are not necessarily mutually exclusive, and combinations of the restoration treatments could be constructed at the site. Treatments were developed based on site investigations and analyses conducted as part of this effort, discussions with project stakeholders, and with reference to previous studies that included restoration recommendations for the area. In addition, an engineer's opinion of probable cost is included for each alternative. These costs are intended to provide planning-level cost opinions to gauge the effort and scope of each project. These costs will change in subsequent design phases, and scale or number of design elements may be added or subtracted to meet funding amounts and funding windows. The treatments are listed below and discussed in greater detail in the sections that follow. A summary of this information is presented in Table 7.

The four opportunity areas are:

- Shoe Island Opportunity Area
- Goose Creek Opportunity Area
- River Island North Opportunity Area
- River Island South Opportunity Area

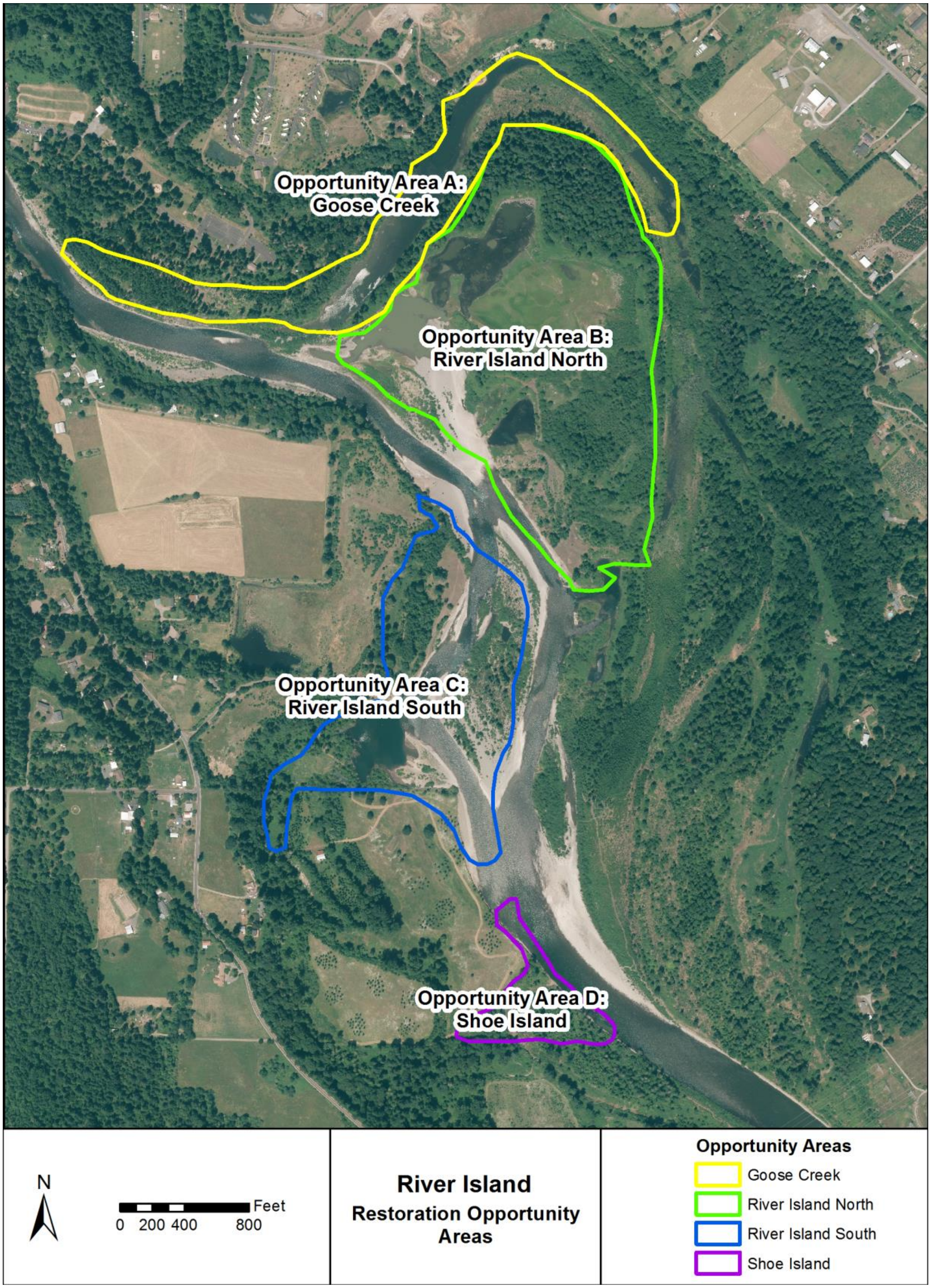

Figure 10. River Island Opportunity Areas for Restoration Options

3.3.1 Shoe Island Opportunity Area

Existing Conditions

In the early to mid-1900s Shoe Island was a forested island along the mainstem of the Clackamas River. Through at least 1938, approximately one-third of the mainstem's flow occupied the side channel that split to river left around this island. As the mainstem migrated towards the left valley toe, the island eroded away and the channel evolved towards a more single-threaded condition. This led to an associated decreasing percentage of the river's flow occupying the side channel. This trend continued until the avulsion in 1996, and until this time the side channel remained active at all flows, including low flows. Following the avulsion and subsequent incision processes, the side channel has progressively become less active. Currently, the channel does not function as a flow-through side channel until the 10-year flood event and functions at a backwater at regular high flow (e.g. Q1).

Figure 11. Downstream extent of Shoe Island at confluence with Clackamas River mainstem in background (facing downstream, December 2014)

Proposed Enhancements

The Shoe Island habitat concept would enhance the existing channel at the downstream (northern) end of Shoe Island. Potential work includes enhancing the existing channel from the outlet upstream 650 feet to the Metro property line. The outlet location is on the outside of a bend in a deep pool; the gravel bar on the inside of the bend promotes higher velocities on the outside of the bend here, each indicating this area is at lower risks for infill from deposition. Select excavation would be used to achieve inundation and connection to the mainstem at lower flow levels. Wood placements would occur throughout the backwater area to provide cover and complexity, while a large wood jam is proposed for the downstream side of the backwater's outlet. A flow-through side channel would be an additional option pending conversations with neighboring Bonneville Power Administration and private landowners.

Anticipated benefits

The addition of a backwater alcove complex would increase habitat quantity and diversity within the project reach. Specifically, this alternative would provide velocity refuge and create rearing and holding areas for ESA-listed Chinook salmon, steelhead trout, and Coho salmon. Though the backwater area is already connected annually, excavation of this area would provide low-flow rearing habitat that fluctuates with river levels. Large wood additions and logjams would provide cover and rearing habitat at a variety of river stages for juvenile salmonids.

Design considerations/potential constraints

Backwater habitats are naturally low-energy areas that are subject to sediment deposition. Sediment deposition can affect the quantity of habitat and possibly fish passage into the area. Placement of a log jam at the confluence of Shoe Island with the Clackamas River will help maintain scour and connectivity, but monitoring and potential future maintenance to address sediment deposition may be necessary. The location of this backwater on the outside of a bend, in a deep pool, and across from a gravel bar indicate deposition is less likely here than in other potential backwater areas. Further, the sediment supply-limited nature of the lower Clackamas (below the dams) further reduces the likelihood of sediment deposition within and near the backwater (or side channel) outlet. Analysis of deposition risk will be an important future design consideration. Continued lateral migration of the mainstem here towards the left bank is an additional important design consideration. Subsequent design phases should not impede future meander migration but account for it by creating habitats that can deform and adjust to changing river conditions and allow the river to develop fresh and new habitats over time.

A consideration that affects feasibility is whether an onsite fill area for excavated side channel alluvium can be found and permitted. Off-site haul of excavated alluvium would greatly increase project costs. Spoils need to be placed outside the 100-year floodplain. The total area excavated for the backwater alcove may be increased or decreased depending on desired quantity of habitat weighed against the costs of excavation. This will be determined during later design phases in consultation with Metro and project partners.

Projected cost

It is estimated that backwater construction at Shoe Island will cost approximately $402,500. A flow-through side channel alternative would cost more than this alternative.

3.3.2 Goose Creek Opportunity Area

Existing Conditions

Prior to the 1996 avulsion, Goose Creek entered the mainstem Clackamas River approximately 4,000 feet upstream of Barton Park. Following the avulsion, Goose Creek now runs within the abandoned pre-1996 mainstem Clackamas River channel. This has created a channel geometry that is substantially "over-fit" for the volume of water running through the channel (i.e. the channel size is much too large for Goose Creek's hydrologic and sediment regimes). This, combined with mainstem incision and deposition by the Clackamas at the confluence, has created a ponded condition in Goose Creek (Figure 12) where summer water temperatures are elevated well beyond temperatures which juvenile salmon can survive. Further, the outlet of Goose Creek is now perched and is disconnected at low to moderate annual river flows.

Figure 12. Downstream impounded portion of Goose Creek (cross sectional view facing left bank (levee), April 2014)

Proposed Enhancements

Restoration opportunities within the Goose Creek treatment area would reduce the channel size (width) along over 3,000 linear feet of Goose Creek (in the former Clackamas channel) to reduce water surface, improve riparian shading and decrease water temperatures to levels suitable for juvenile salmon and steelhead rearing. This alternative would re-direct the outlet of Goose Creek through existing high flow channels along the right bank. A roughened channel would be constructed that drops grade more gradually over the length of the new alignment. As this grade is re-adjusted, it is anticipated that bed elevation of Goose Creek will drop. This will help reduce channel width and move the Goose Creek channel towards a dimension commensurate with its hydrology. It is anticipated that the pre-1996 Clackamas River bed will then form a floodplain surface for Goose Creek. Some bedform manipulation and re-grading will likely be required, most notably in areas that were previously pools on the Clackamas River. The specific planform presented in the conceptual design planset may be adjusted during later stages of design depending upon model results and further analysis. Cross-section dimensions would vary along the length of the channel. Lateral scour pools would be added along the outside of meander bends. Large wood placements would consist of accumulations/jams of approximately three to seven pieces per structure to provide cover and complexity within pools and in other locations throughout the channel. Depending upon desired future conditions, there are opportunities to create wetlands and riparian forest throughout the former Clackamas River mainstem.

Anticipated benefits

Adjusting Goose Creek geometry would be expected to support riparian, wetland, and instream process and function. Reconnection, large wood habitat enhancements and temperature reductions following the work will improve the area for juvenile salmonid rearing. The proposed more gradual drop in grade would allow fish passage over a range of flows, with the potential to re-open passage at all but extreme low flows. Over time, spawning activity might be possible within the lower segments of Goose Creek near the Clackamas River.

Design considerations/potential constraints

There are multiple design considerations that will need to be addressed in subsequent design phases. Many of these considerations are dependent upon design criteria, which in subsequent phases will be established and agreed upon by Metro and project partners.

Of particular interest to design is lateral migration within the project reach, particularly the apex of the bend near the right bank gravel pond. As discussed in Section 2.4.3, the bend near the Goose Creek outlet is migrating in a north, northeasterly direction. As this migration continues, especially if the levee is removed, this puts the outlet of Goose Creek in the path of the projected migration trend of the Clackamas River. Consequently, it is anticipated that the mainstem of the Clackamas will recapture a portion of its historical planform (the proposed area where the resized Goose Creek's outlet will be). The timeline of this migration depends on a number of factors (e.g. future flood events, bank structure, and sediment deposition). Future design efforts should consider at what elevations the recapturing of this outlet is likely to occur. Based on this range of elevations, Goose Creek's re-designed profile should account for this potential capture and still allow fish-passage when it is re-captured by the migrating Clackamas River.

Currently, Goose Creek's restored outlet displayed on the concept-level design runs across a portion of Barton Park. This alignment or other alternative alignments will require conversations with and approval by Clackamas County. Additionally, construction access will depend upon an agreement with Clackamas County and, depending on the desired access route, discussions with the owners of the two private parcels between the park and Metro's property.

Projected cost

Based on the alignment displayed in the draft plansets, it is estimated that the proposed Goose Creek restoration option will cost approximately $1,736,500.

3.3.3 River Island North Opportunity Area

Existing Conditions

The River Island North area is currently characterized by a large abandoned gravel pit that is connected to the mainstem Clackamas River (Figure 13). The majority of the ponds are habitat for warm-water predatory fish species (e.g. carp, northern pike minnow), though the northern most margin of the ponds provides valuable basking habitat for native turtles. Because the channel and the right bank gravel pond are connected, the channel geometry is currently oversized and prevents sediment from transporting downstream and the meander from migrating. Currently the Clackamas is rebuilding its floodplain and bank to fill the void in material created by mining operations. Presumably, over time, sediment deposition will again disconnect the mainstem of the Clackamas River and the settling ponds, subsequent to which the mainstem will reinitiate its projected north, north-easterly migration trend. As this migration initiates, the river will likely remove re-established floodplain and bank as transport conditions begin to exceed the present depositional conditions. This pattern would likely continue over the course of many years and high flow events, and the channel would then presumably recapture portions of the gravel ponds until the bend fully matures and another avulsion takes place. This area also includes a number of levees and compacted soils that are remnant surfaces and substrates from the gravel mining operation.

Figure 13. River Island North area (photo taken from upstream extent of ponds, facing downstream (July 2014)).

Proposed Enhancements

Opportunities within this treatment area included re-grading of the floodplain to create a contemporary floodplain surface. Selected floodplain elevations could increase incrementally as you move away from the channel to mimic a successional floodplain forest (e.g. emergent terrace, riparian forest terrace, mixed conifer terrace). Ponds and wetlands could also be created in the new floodplain area. The extent and balance of each habitat type will depend upon material available and desired habitat types and quantities of Metro and project partners.

Efforts here would include reclaiming the right bank of the Clackamas River and separating it from the ponded areas. Early analyses suggest that material from along the left bank of the northern most portion of the pre-1996 Clackamas River planform (a historical gravel bar) would be appropriate to form the new Clackamas River right bank. If the right bank was reconstructed, buried log jams could be utilized to slow migration rate. Created floodplain behind the log jams would be planted with willows, cottonwood and red alder providing a large wood source for the Clackamas when the river migrates into the area in the following decades.

Anticipated benefits

Benefits associated with this opportunity include the re-establishment of floodplain connectivity at more regular return interval flows. Reconnecting the Clackamas with its floodplain will provide space for flood waters to dissipate and infiltrate, habitat for fish and wildlife, retention of nutrients, and filtration of fine sediments within the project area. This would also involve reclamation of soils compacted by the mining operation, which are hindering localized natural erosion processes and preventing re-generation of native floodplain species.

Design considerations/potential constraints

The total area for each habitat type (e.g. turtle ponds, riparian forest, mixed conifer forest) may be increased or decreased depending on desired quantity of habitat weighed against the availability of onsite material. A design consideration that affects feasibility is whether there is sufficient onsite fill to create the desired habitat types/quantities. Purchase and hauling of off-site excavated alluvium will greatly increase project costs. This would be determined during later design phases in consultation with Metro and project partners. Additional design considerations include determination of the presence of wetlands in the project area, and potential permitting and mitigation requirements associated with filling these areas.

Projected cost

It is projected that a full re-grade of and large wood placements throughout the right bank floodplain will cost approximately $5,163,500. Conversations with Metro and subsequent design phases may alter the pace/scope of re-grading efforts.

3.3.4 River Island South Opportunity Area

Existing Conditions

The left bank has two opportunity areas. The first is the a reclamation of a high flow side channel including removal of remnant asphalt and concrete material. The second is an upstream disconnected wetland alcove (See Conceptual Designs planset). Downstream of the alcove is a historical high-flow channel that is currently disconnected at the upstream end by an eroding access road (Figure 14). The alcove is created by hillslope seeps and tributaries that follow the valley-left terrace toe, and likely gains the majority of its water through subsurface flow from the Clackamas River (Figure 15). The alcove is currently disconnected by an access road and a plugged culvert.

Figure 14. Eroded access road along the Clackamas River left bank in River Island South (facing the left bank, April 2014).

Figure 15. Alcove Disconnected in River Island South (facing valley toe, April 2014)

Proposed Enhancements

Restoration opportunities here include decommissioning and/or realignment of the access road and the removal of a culvert, as well as the placement of large wood for cover within the alcove. Along the left bank, there are several opportunities to remove cement and asphalt remnants of the former mining operation, as well as decommissioning this access road. In the absence of this road, conceptual-level modeling efforts indicate this channel would be connected at the 10-year recurrence interval event. In the alcove area, it is proposed that the culvert be removed to reconnect the alcove at a range of flows throughout the year. The design re-connection flow would be determined in subsequent phases, where the area and duration of availability of habitat inundated will be weighed against the increasing costs of excavation.

Anticipated benefits

Along the left bank, general cleanup of the upstream high flow area will remove localized impacts of gravel operation remnants and re-open the high flow channel at the 10-year recurrence interval. Similar to the Shoe Island area, the reconnection of a backwater alcove complex would increase habitat quantity and diversity within the project reach. Specifically, this option would provide velocity refuge and create rearing and holding areas for ESA-listed Chinook salmon, steelhead trout, and Coho salmon. Reconnection of this area would provide low-flow rearing habitat that fluctuates with river levels. Large wood additions are intended to restore channel structure and form by adding channel margin complexity and creating cover and holding pockets for fish.

Design considerations/potential constraints

Along the left bank, a primary design concern is the orientation of the mainstem's main flow path towards the inlet of the channel. While this high-flow channel is elevated above the mainstem, the possibility for avulsion should be considered. Further, this area may be prone to landslides and regular sloughing of the surface has been observed towards the downstream end of this high flow channel. Once specific project objectives are determined, it should be considered whether or not slides would prevent the achievement of these goals.

One of the primary design considerations related to re-connection of the alcove area is the need for access along the existing road. Currently this is an unimproved access road, but future access needs should be examined prior to decommissioning of the road. Additional design considerations should include determining areas for realignment of the access road, connecting to the southeast portion of River Island Natural Area for the purpose of placement of large wood material during construction.

Projected cost

It is estimated that the reclamation of the left bank would cost $287,500. The removal of the culvert (with no additional regrading beyond the culvert removal) and additions of large wood in the alcove opportunity area are projected to cost approximately $149,500.

4. Opportunity Area Selection

To be completed in collaboration with Metro and Technical Review Committee. Restoration options will be evaluated with respect to how well they achieve the design criteria and informed by input from the stakeholder outreach process (Technical Review Committee and public outreach efforts). Table 7 offers a summary and comparison of the initial conceptual design options identified in each of the four opportunity areas. Based on this evaluation, a preferred option or set of options will be selected and taken forward to the draft and final design phases.

Table 7. Summary of conceptual design opportunities for each of the four opportunities areas.

Alternative	Highlights	Benefits	Limitations	Level of Effort
Shoe Island Opportunity Area	▪ Enhance 650 ft of existing channel ▪ Excavation of side channel to achieve inundation/connection to mainstem ▪ Wood placements throughout backwater ▪ Large wood jam at downstream side of backwater outlet ▪ Optional flow-through side channel	▪ Increase habitat quantity ▪ Provide low-flow rearing habitat for juvenile salmonids that fluctuates with river levels ▪ Large wood and logjams provide cover ▪ Provide velocity refuge (holding areas) for salmonids	▪ Possible sedimentation risk ▪ Future mainstem lateral migration ▪ Onsite fill/spoils area preferable	Low to Moderate
Goose Creek Opportunity Area	▪ Reduce the channel width of Goose Creek ▪ Remove gravel bar at the outlet of Goose Creek ▪ Some bedform manipulation and re-grading of channel ▪ Riparian restoration	▪ Reconnect Goose Creek to mainstem Clackamas River ▪ Large wood and logjams provide cover, diverse habitat ▪ Reduce water temperatures	▪ Mainstem Clackamas River channel migration patterns	High
River Island North Opportunity Area	▪ Regrade pond and floodplain areas to re-create historical channel geometry ▪ Bury logjams on right bank of Clackamas River to slow migration rate ▪ Plant cottonwoods in floodplain for future LWD recruitment	▪ Re-establishment of floodplain connectivity at more regular return intervals ▪ Floodplain provides space for floodwaters to dissipate/infiltrate ▪ Nutrient retention in floodplain sediment depositions ▪ Provide floodplain habitat for fish and wildlife ▪ Reclaim compacted soils to allow for more natural erosion processes and re-generation of native floodplain species	▪ Large amounts of onsite fill will be required to create desired habitats ▪ Determination of any wetlands may cause design limitations ▪ Potential issues with permitting or mitigation requirements for filling these areas	High to Very High
River Island South Opportunity Area (Alcove and Left Bank Areas)	▪ Remove cement and asphalt remnants of mining operations ▪ Large wood placement within wetland and adjacent mainstem alcove ▪ Decommission or realign access road to maximize habitat restoration opportunity ▪ Remove plugged culvert	▪ Remove localized impacts of gravel operations ▪ Increase habitat quantity ▪ Provide low-flow rearing habitat for juvenile salmonids that fluctuates with river levels ▪ Provide cover and restore channel complexity and form ▪ Provide velocity refuge (holding areas) for salmonids	▪ Risk of mainstem avulsion through side channel ▪ Possible landslides/sloughing ▪ Possible future need of the unimproved access road	Low to Moderate

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Appendix A – Historical Aerial Photographs

This appendix presents images of River Island from 1938 to 1999, as well as an 1855 General Land Office (GLO) map.

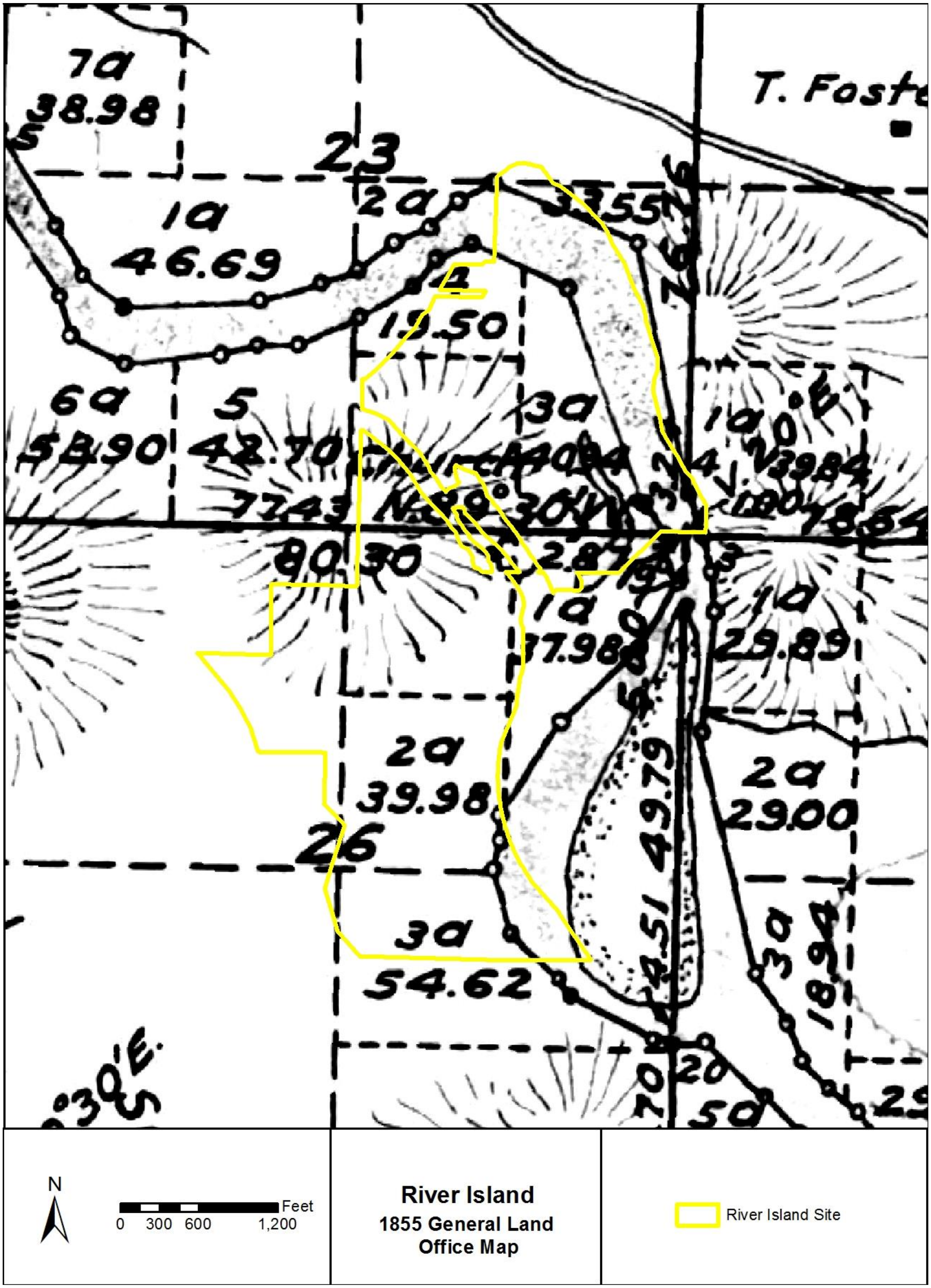

Figure 1. General Land Office map from 1855.

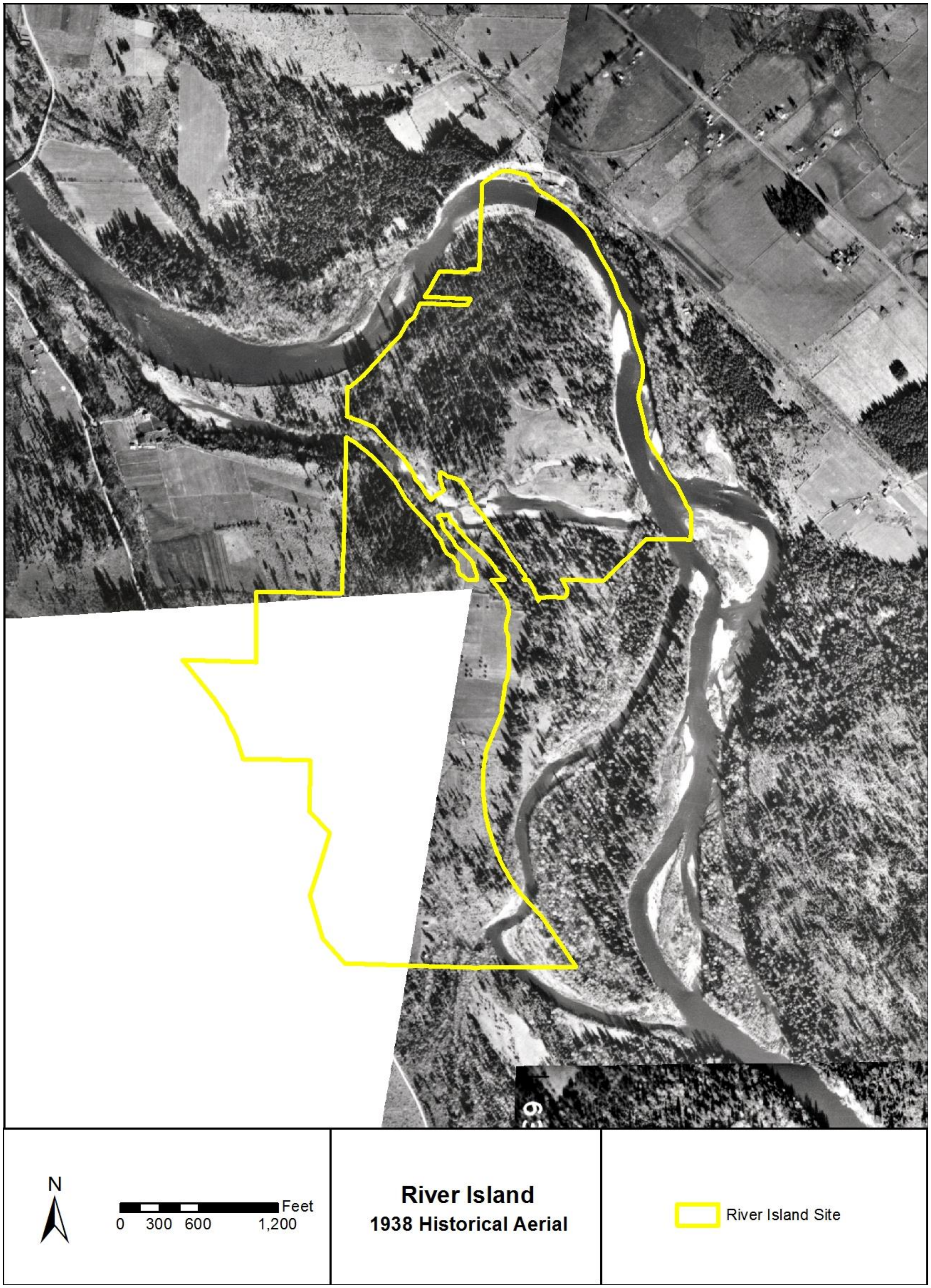

Figure 2. Historical image from 1938.

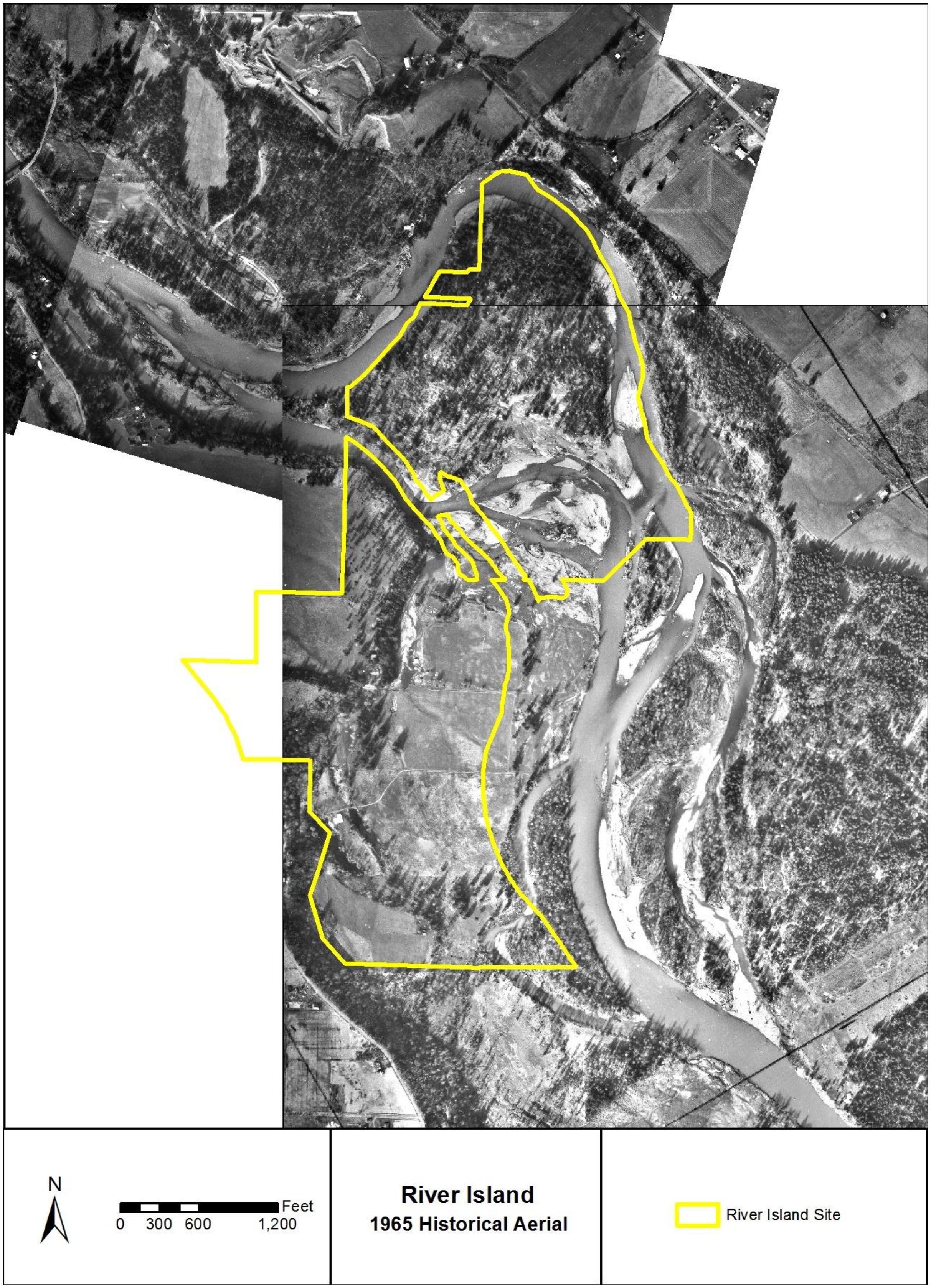

Figure 3. Historical aerial image from 1965.

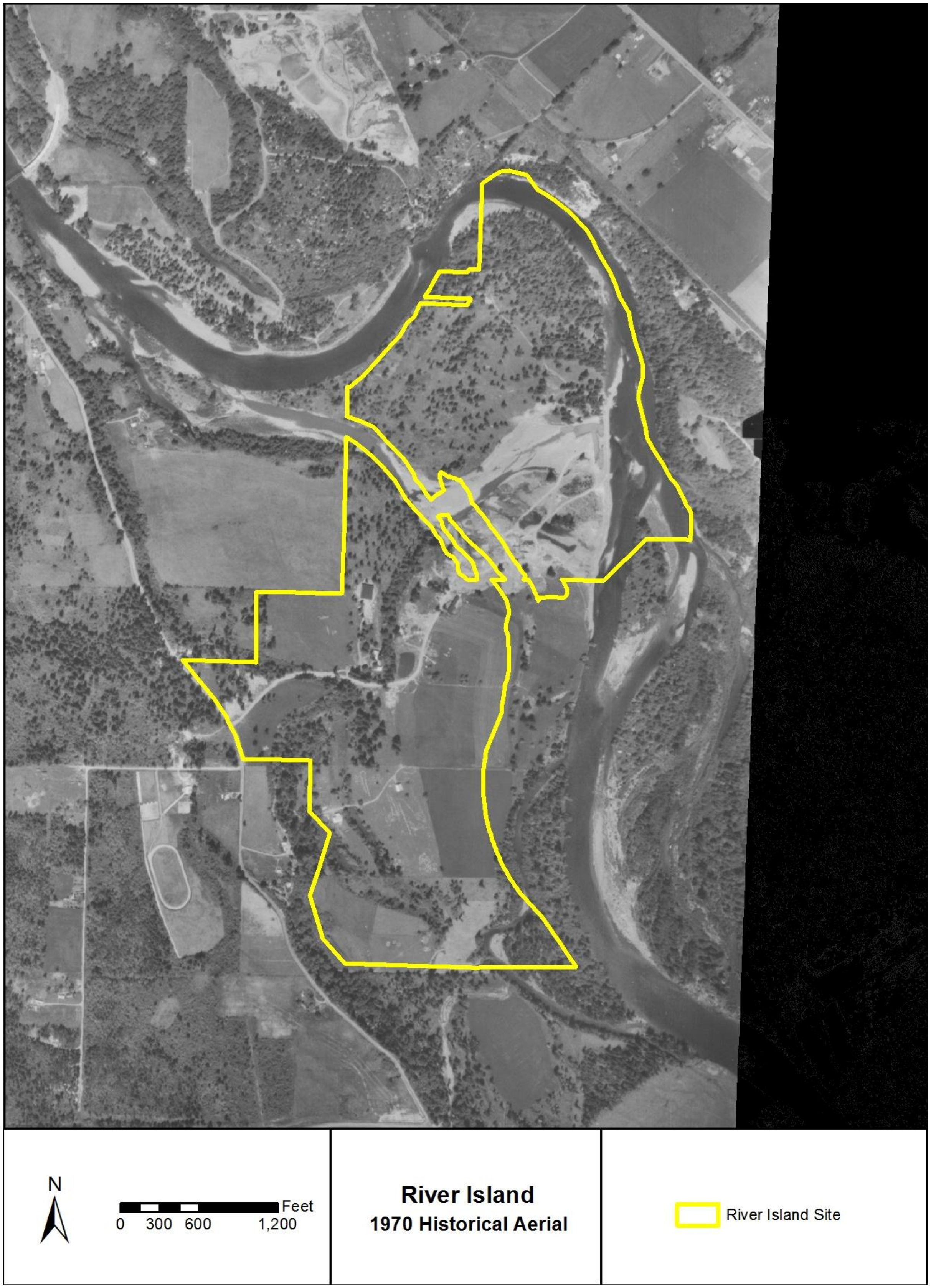

Figure 4. Historical aerial image from 1970.

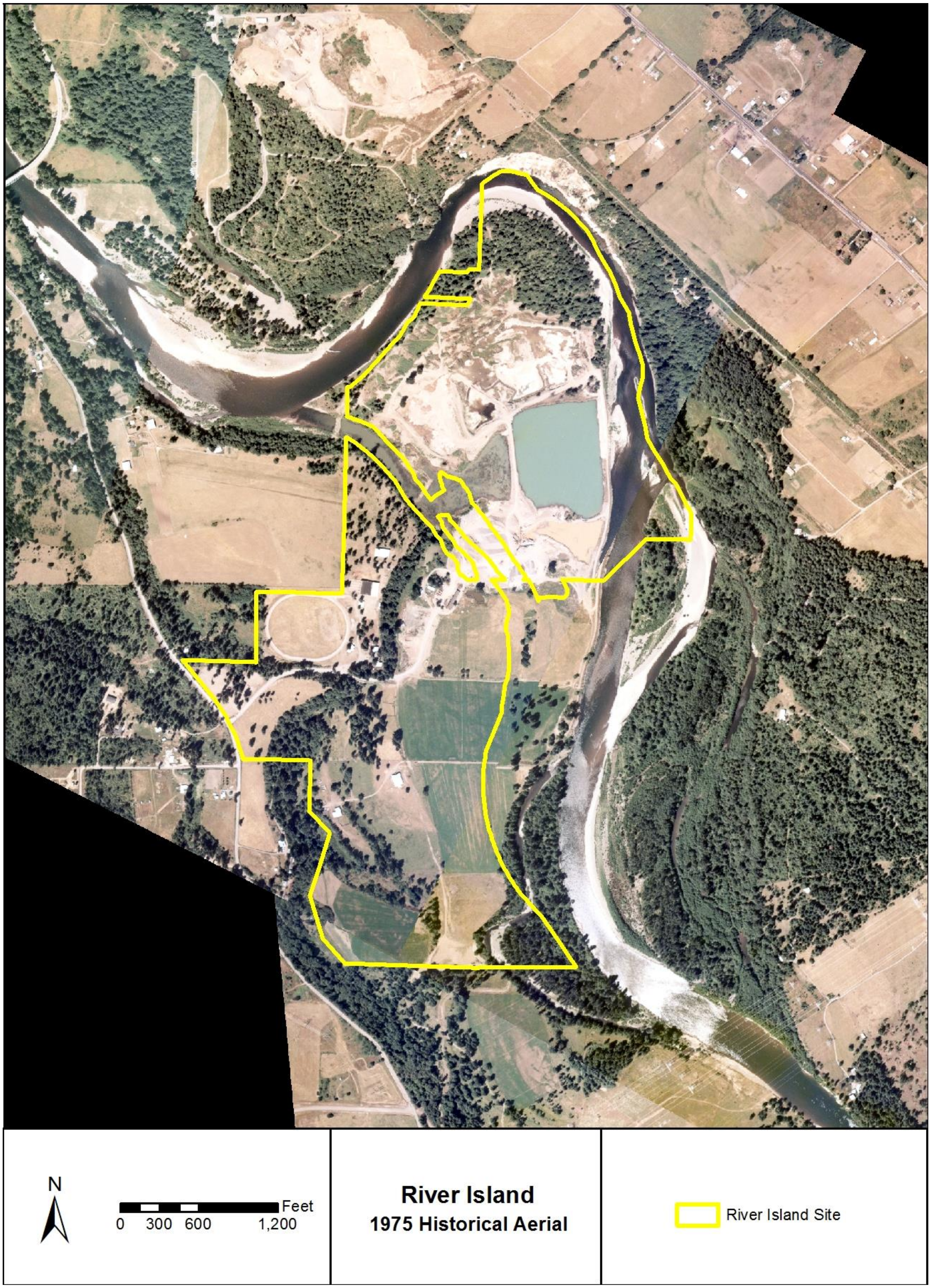

Figure 5. Historical aerial image from 1975.

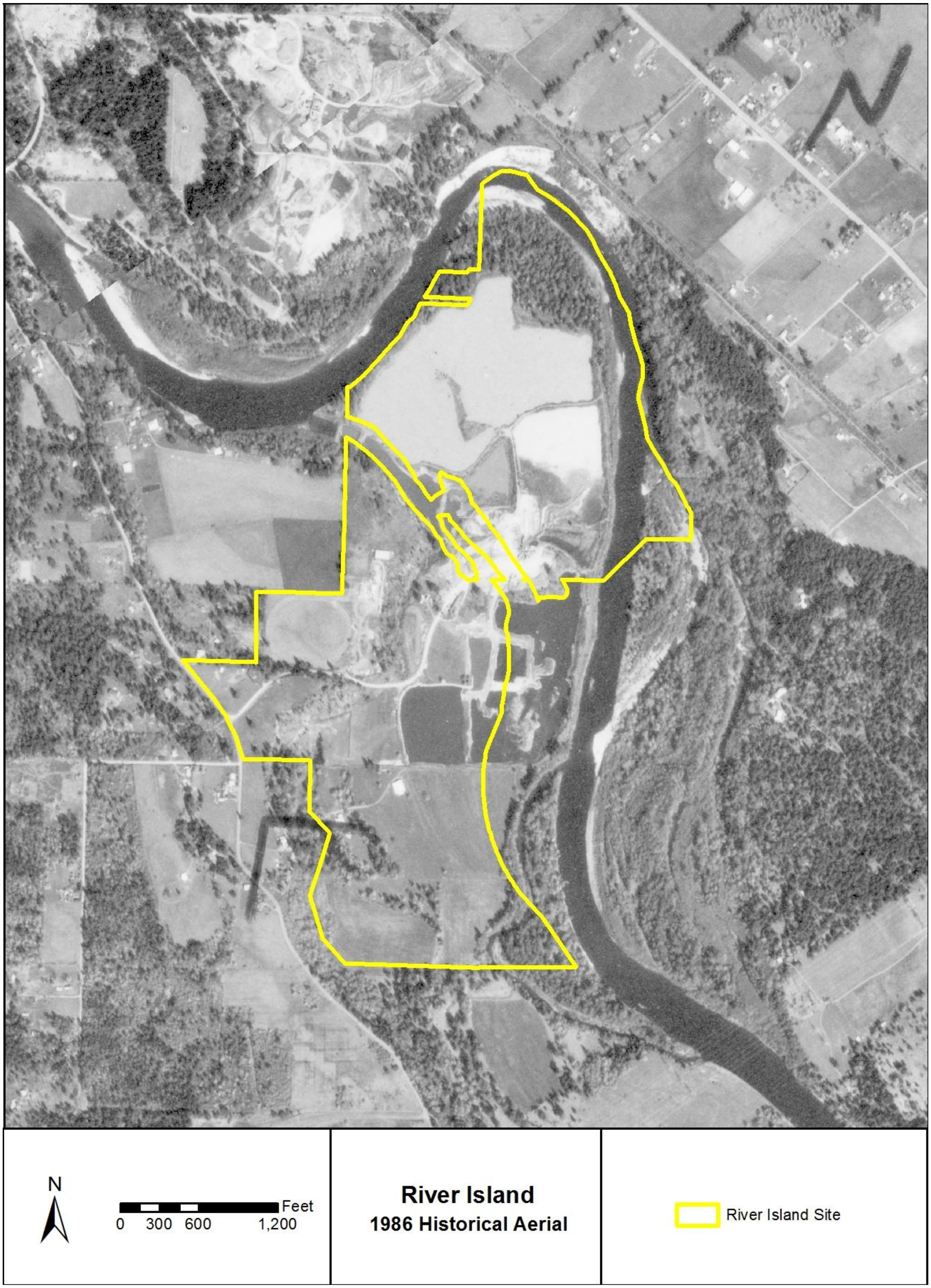

Figure 6. Historical aerial image from 1986.

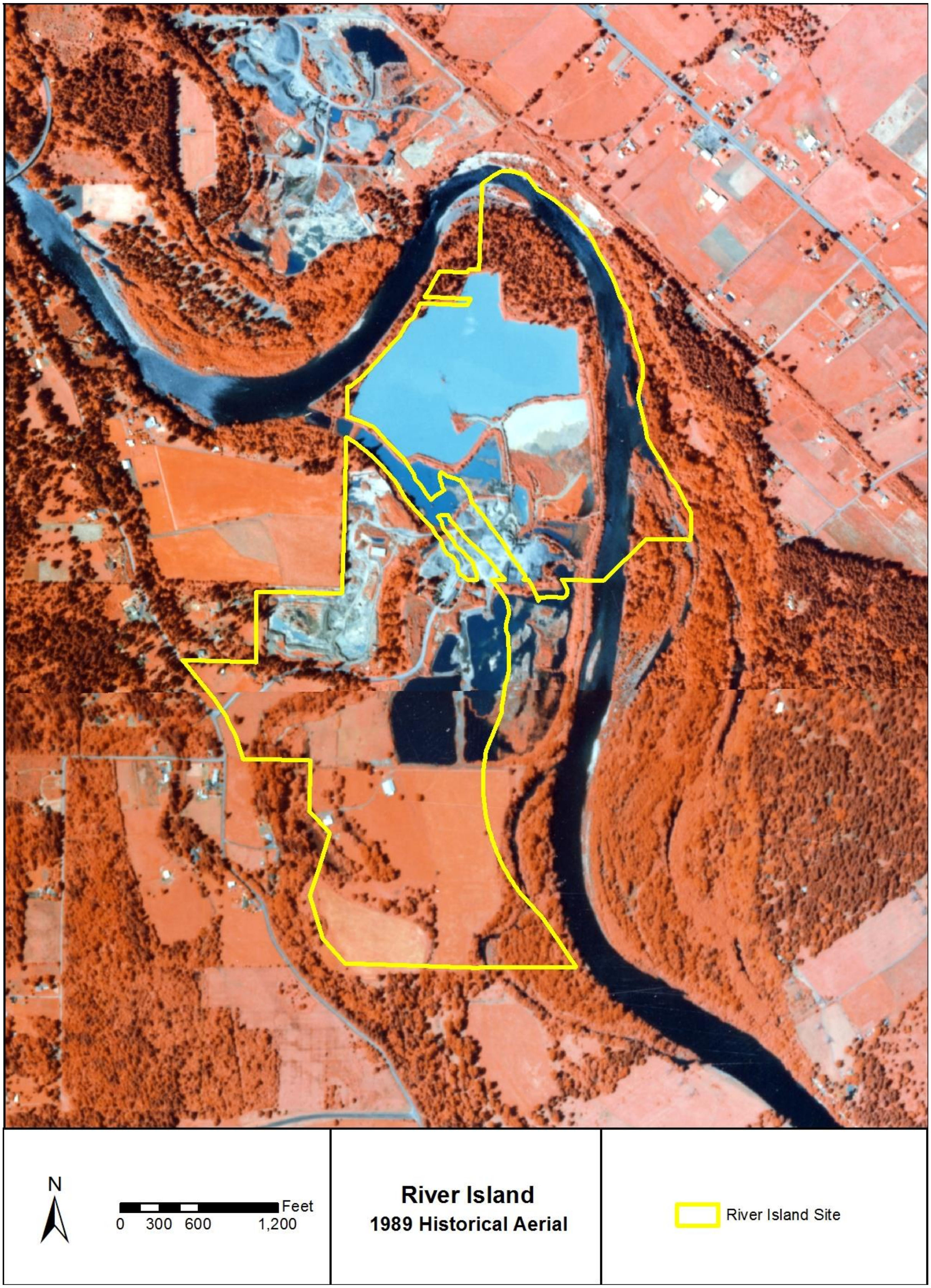

Figure 7. Historical aerial image from 1989.

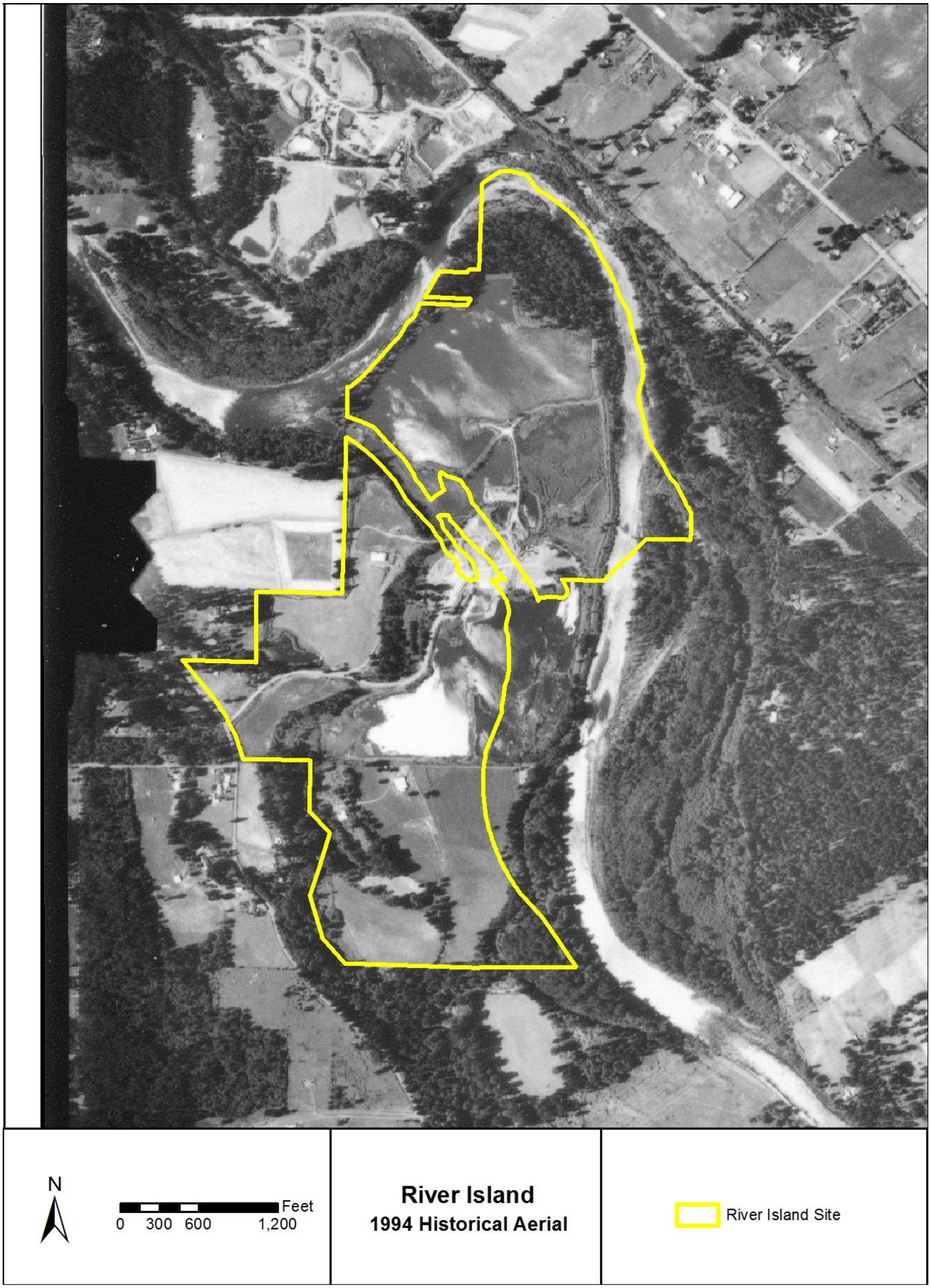

Figure 8. Historical aerial image from 1994 (pre-avulsion).

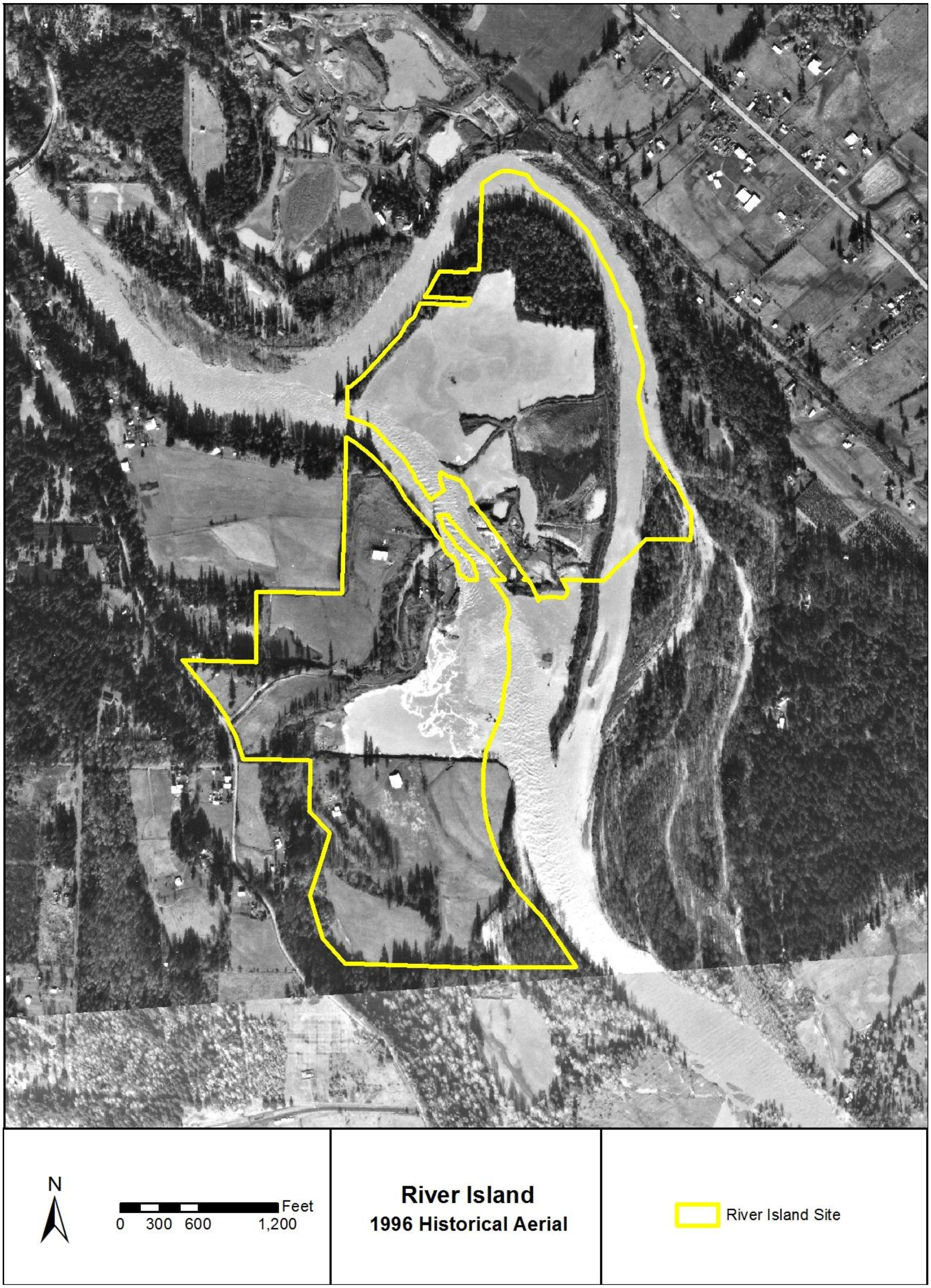

Figure 9. Historical aerial image from 1996 (post-avulsion).

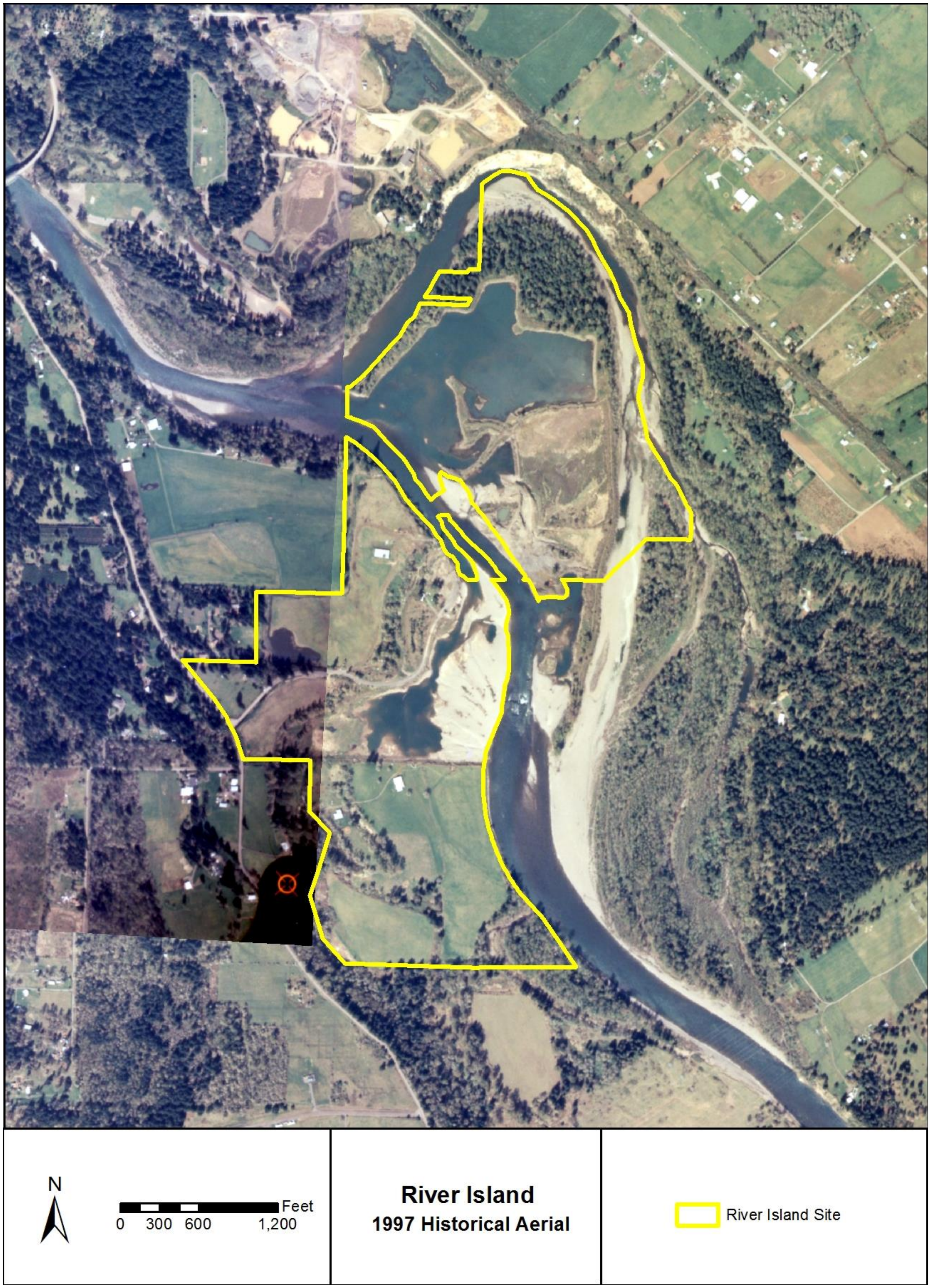

Figure 10. Historical aerial image from 1997.

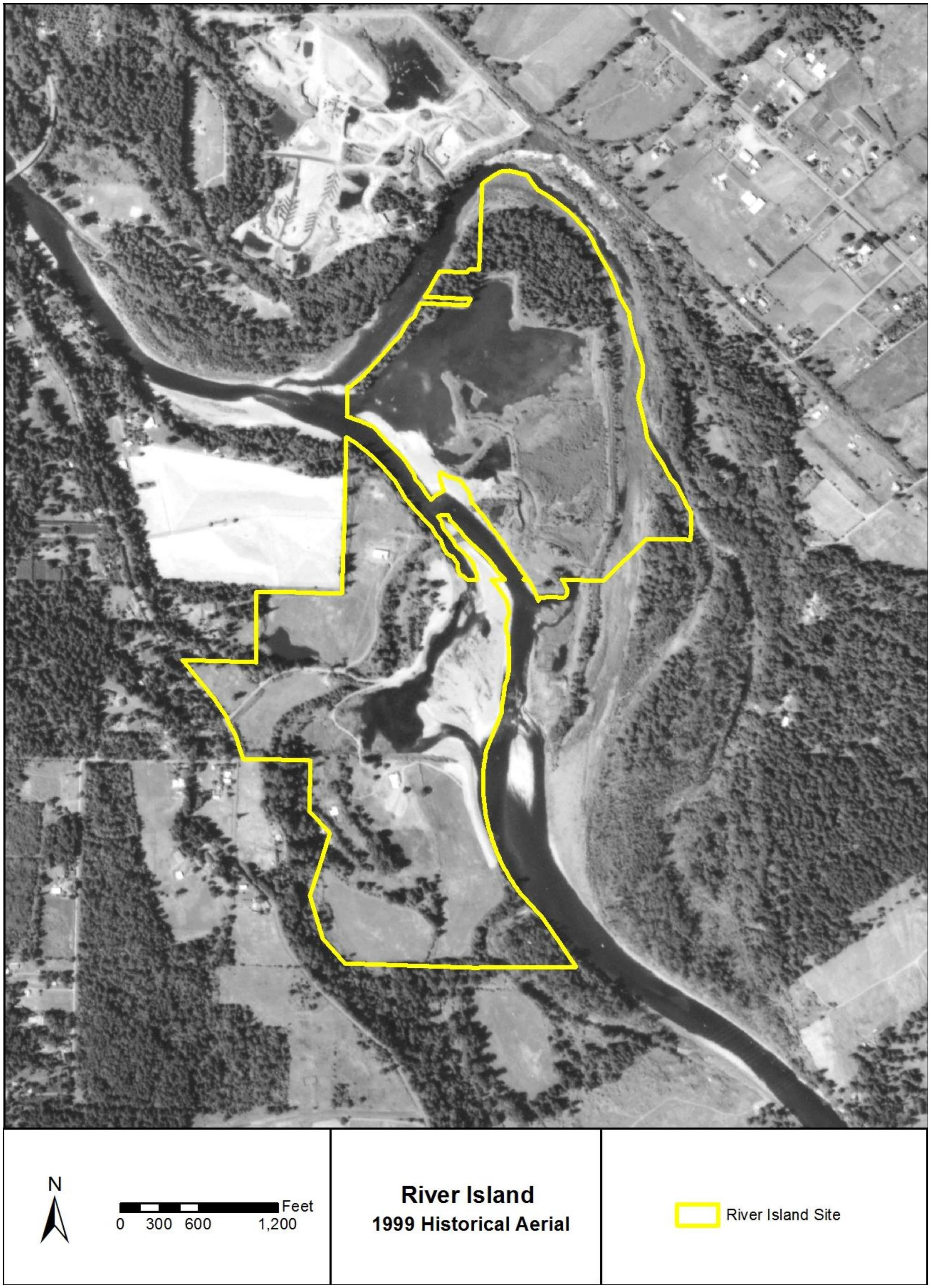

Figure 11. Historical aerial image from 1999.