Middle Green River
Levee Setback Feasibility Study

January 2013

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

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Cover photo by N. Ahrens (vicinity of Hamakami Reach Project Site).

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EXECUTIVE SUMMARY

The Middle Green River Setback Feasibility Study assesses and recommends for construction 10 high-value habitat restoration projects along the Middle Green River. These projects are intended to improve ecological functions beneficial to ESA-listed Chinook salmon and steelhead trout. The 10 projects analyzed in this study were prioritized from a list of 71 projects by using an assessment model to evaluate habitat benefit, cost, and land availability and then comparatively ranking projects against each other.

The Middle Green River contributes valuable ecosystem services to the metropolitan Puget Sound region including wild and hatchery salmon, food crops and livestock, drinking water, flood control, water quality treatment, and scenic and recreational activities. In 2000 and 2007 respectively, Green River fall Chinook salmon and steelhead trout were listed as "threatened" under the Endangered Species Act (ESA). Throughout the Middle Green River sub-basin, habitats for these species have been degraded as a result of dam operations to regulate flood flows, land use conversion, and river channelization. Despite these conditions, the Middle Green River is the primary spawning area for Chinook salmon, and is used extensively by juvenile Chinook and other salmonids for rearing.

The Middle Green River contains 17 training levees that were constructed to protect farmland from erosion due to lateral river channel migration. Many plans, including the Green-Duwamish River Ecosystem Restoration Feasibility Report (2000) and the Water Resource Inventory Area (WRIA) 9 Salmon Habitat Plan (2005) have proposed restoration projects to set back these levees from the river in order to increase the quantity and quality of habitat for ESA-listed species. These prior plans, however, generally lack sufficient detail to determine which projects should or can be implemented first. The purpose of this study is to screen and prioritize the top projects in order to move forward with their implementation. The assessment model results are summarized and ranked based on the overall feasibility score in Table 1.

Table 1. Project Ranking Based on Overall Feasibility.

Site Name/ Indicator	Habitat Assessment Score	Cost Assessment Score	Land Assessment Score	Overall Feasibility Score	Rank	Cost Assessment
Auburn Narrows	0.5	4	4	8.5	1	$437,213
Porter	2.0	1	4	7.0	2	$3,876,661
Flaming Geyser	0.8	3	2	5.8	3	$1,792,997
Hamakami	0.4	4	1	5.4	4	$213,451
Lones	2.0	2	1	5.0	5	$2,546,790
Neely	0.7	3	1	4.7	6	$529,217
Turley	1.6	2	1	4.6	7	$2,702,623
Ray Creek	0.5	4	0	4.5	8	$593,416
Hamakami Reach	3.2	1	0	4.2	9	$16,783,378
Horath	1.6	1	0	2.6	10	$7,478,446

All projects in this study are expected to provide significant habitat benefits, primarily by allowing the river to create and maintain riverine and floodplain processes that provide juvenile salmon rearing habitat. The Habitat Assessment represents the "ecological lift" or difference between existing and future (post-project) conditions. The Cost Assessment represents the size and scope of the project, with land acquisition and earthwork being the most expensive elements. The Land Assessment consists of analyzing land availability in terms of property owner interest in selling their property, as well as the agricultural impacts of the project. Because of this, Land Availability is the most sensitive and changeable factor in this feasibility assessment.

Overall Feasibility was determined by adding the Habitat, Cost, and Land Availability assessments to create an overall feasibility score that can be ranked. Implementing projects based on overall feasibility provides a multi-objective, balanced approach to project selection. All projects would have to undergo additional review to assess and mitigate impacts to adjacent properties and comply with federal, state and local codes and regulations. While some consideration has been given to flood, agriculture, and other floodplain land uses, further project development and discussion with stakeholders will be needed to ensure that project implementation adequately takes into account other land uses.

Cumulative Results

The cumulative habitat benefit from implementing the recommended projects, are estimated to be:

- **28 acres** of newly inundated channel area at 1,800 cubic feet per second (cfs) that would create riverine wetland and aquatic habitat
- **13 acres** of newly inundated channel and floodplain area at 8,800 cfs that would provide flood refuge habitat for salmonids
- **67,000** feet of additional wetted channel edge for juvenile salmonid rearing habitat
- **36 wood trapping sites**, potential logjam sites, enhanced wood retention and aquatic habitat
- **110 acres** for channel movement and the formation of diverse and productive habitat
- **7,000 feet** of erodible bank to provide native gravels and sediments for spawning and floodplain soils
- **70 acres** of floodplain forest that will be newly exposed to provide long-term supply of large wood to the channel
- **105 acres** of new plantings to provide riparian benefits
- **<1%** of agricultural land use within the Upper Green Agricultural Production District (APD) to be converted to fish habitat
- **$29,475,746 =** Total cost exclusive of Horath, which is part of Hamakami Reach.

I. PURPOSE

1. PURPOSE

The purpose of this feasibility study is to screen the top salmon habitat restoration projects and prioritize those projects for implementation in the Middle Green River Sub-Basin between RM 32 and 46. Since 2000, several reports have proposed habitat restoration projects for the Middle Green River but lack sufficient detail to determine which projects have the highest ecological value. Typically, these previously documented restoration concepts lack specific information on design, cost, land availability, and compliance with local codes and regulations.

This feasibility study provides a condensed list of high-value habitat restoration projects, supported by detailed conceptual designs and cost estimates. This study will assist land managers in planning for the eventual implementation and sequencing of these projects, as well as securing project funding.

1.1. Rationale

The Middle Green River has high ecological value because it is the primary spawning area for threatened Green River fall Chinook, and is used extensively by juvenile Chinook and other salmonids for rearing. However, according to the WRIA 9 Salmon Habitat Plan, habitat conditions in this reach have been impaired by training levee construction and land conversion, as well as flow modification for flood control (by Howard Hanson Dam). King County is committed to improving habitat productivity in the Middle Green River by constructing restoration projects that increase the quantity and quality of lateral (i.e., side channel, wetland) rearing habitat[1]. These projects involve removing and setting back levees, constructing engineered log structures, removing roads, installing livestock-exclusion fence, and re-vegetating riparian zones.

1.2. Study Goals

The goal of the Middle Green River Levee Setback Feasibility Study is to prioritize floodplain habitat restoration projects along the Middle Green River.

1.3. Study Objectives

The study objectives consisted of:

- screening projects identified in existing salmon habitat recovery plans;
- developing conceptual designs that have the potential to re-establish habitat-forming processes for ESA-listed Chinook and steelhead;
- applying an assessment model to measure three indicators of feasibility including habitat benefit, cost, and land availability; and
- analyzing results and prioritizing projects.

1.4. Study Setting

The Green/Duwamish River is located within Water Resource Inventory Area (WRIA) 9 and extends 93 miles from Stampede Pass in the Cascade Mountains to its mouth at Elliott Bay in Puget Sound (Fig 1). Land use is varied throughout the watershed and includes timber and agricultural production, as well as residential, commercial, and industrial development. Howard Hanson Dam (HHD), located at RM 64.5, is operated by the U.S. Army Corps of Engineers (USACOE) to limit downstream flooding. This study focused on a 14-mile segment of the Green River in unincorporated King County, from the outlet of the Green River Gorge (RM 46), to the Auburn city limits (RM 32). Although this report refers to the study area as the Middle Green River, please note that the Middle Green River subwatershed is considerably more extensive and extends upstream to HHD, encompassing upland drainages.

The Middle Green River contributes valuable ecosystem services to the metropolitan Puget Sound region including wild and hatchery salmon, food crops and livestock, drinking water, flood control, water quality treatment, scenic and recreational activities. The Middle Green is located within unincorporated King County, which regulates land use for agricultural, recreational, and natural resource purposes. Agricultural activities are supported within the APD, while open space and fish and wildlife habitats are supported by a variety of public lands, including the Green River Natural Area.

[1] Existing KC Policy R-648 requires that all such projects in APDs result in a "net benefit" for agriculture.

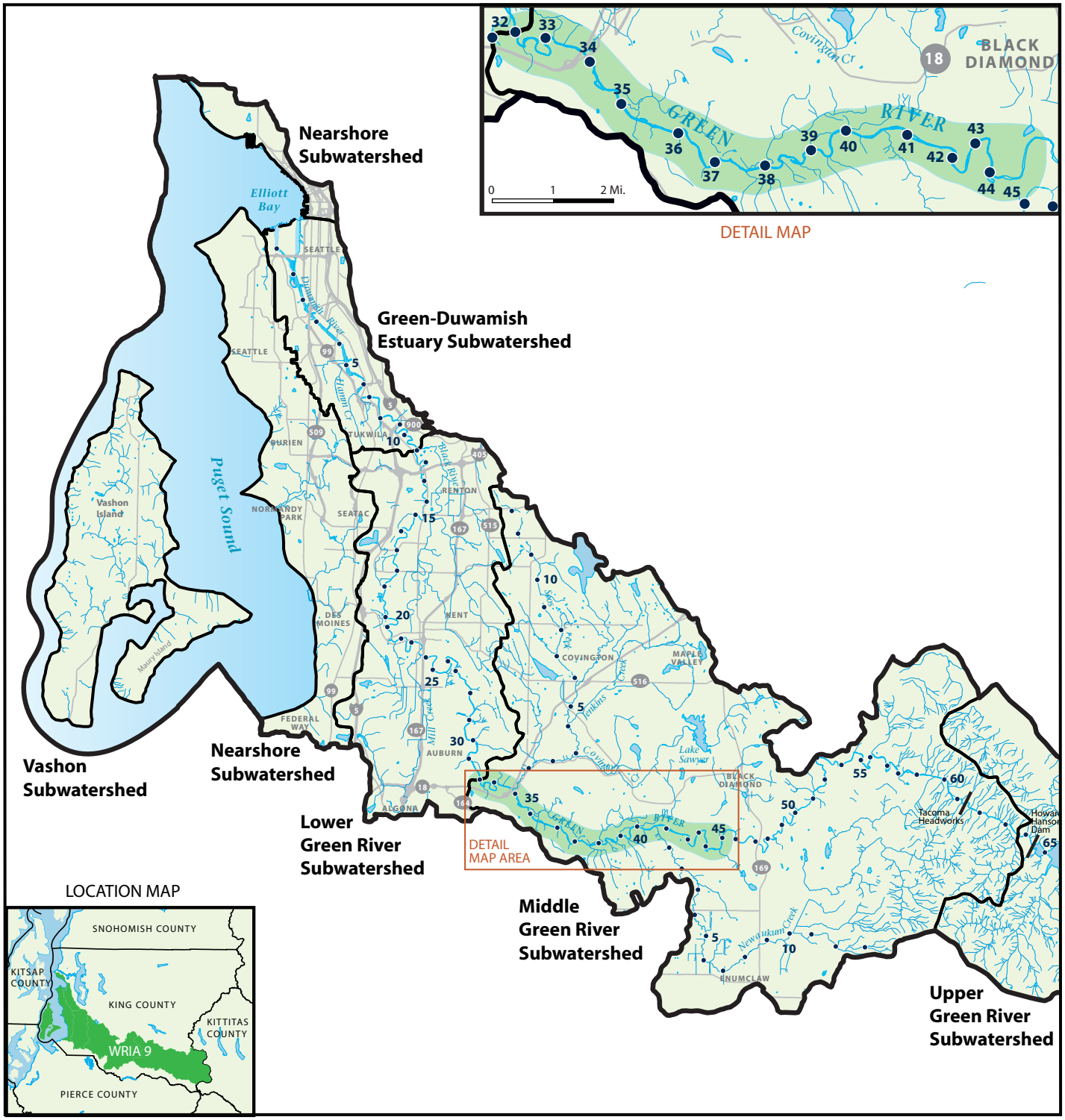

Figure 1

VICINITY MAP

Middle Green River Feasibility Report

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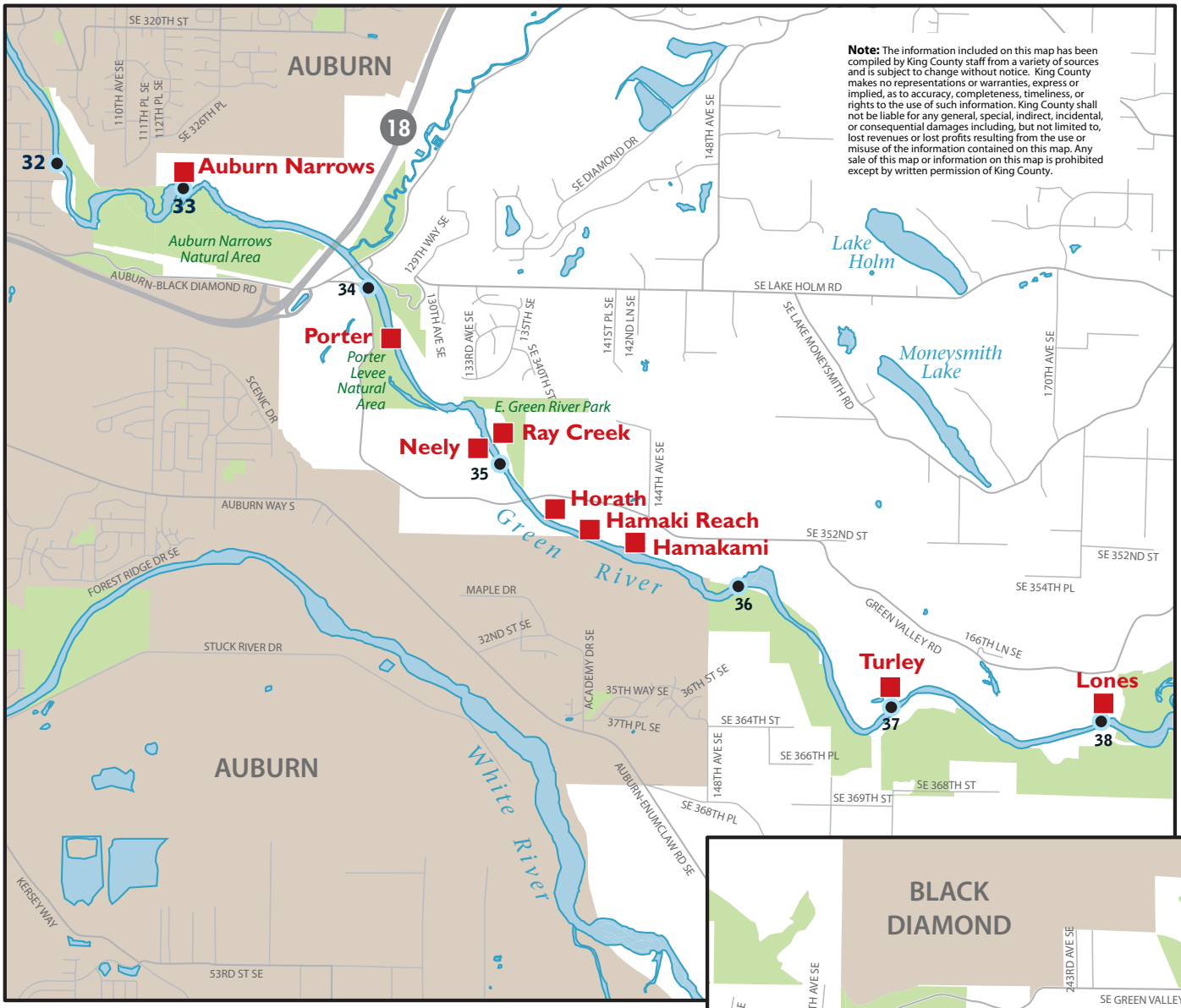
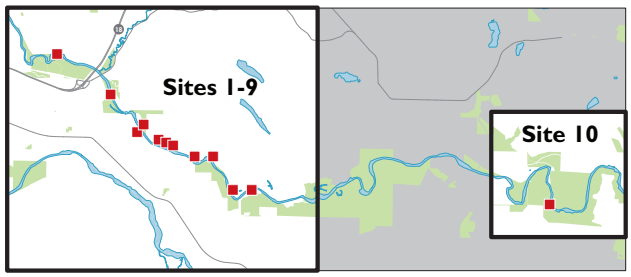


Sites 1-9 Map



Locator Map

Site 10 Map

Figure 2

PROJECT LOCATIONS

Middle Green River Feasibility Report

Project Location

40 River Mile (King Co. FHRS)

River/lake

Road

N

0 1/4 1/2

Mile

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Habitat productivity in the Middle Green River is sustained by flooding, channel migration, and logjam formation. Prior to human modification, the Middle Green River valley was a diverse floodplain system with greater numbers of logjams and more complex channel patterns.

Training levees have prevented river migration and habitat creation, while agricultural land conversion has removed floodplain vegetation. Infrastructure (roads and bridges) and residential development have also limited habitat restoration opportunities.

1.5. Flood and Erosion Control Context

Habitat conditions in the Middle Green River have been impaired by the construction of HHD (ca. 1961), which regulates floods and affects downstream flow regimes and habitat-forming processes. The Tacoma Headworks (ca. 1911) facilitates drinking water diversion for the City of Tacoma, which reduces flow levels in the river, and blocks fish passage, necessitating an on-site \'truck-and-haul' facility.

Another primary modification that impaired habitat occurred through the construction of training levees along the river downstream of the dam between RM 44 and 32. The training levees (also known as revetments) along the Middle Green River were primarily constructed to prevent lateral channel migration that prevents soil erosion; they do not prevent flooding. Flood control levees, which prevent flooding past the levee boundary, are uncommon on the Middle Green River.

Training levees are typically constructed by piling locally borrowed river gravel against an eroding bank or into a berm and then covering the berm with imported rip rap. The condition of the training levees varies; some are actively failing while others remain intact. Nine training levees were built by the Army Corps of Engineers in the 1950s; the remaining levees were constructed privately.

A total of 17 facilities are listed in the King County River and Floodplain Management Unit's facility inventory. King County has legal Right of Way access and maintenance easements for all of these facilities. Most of the restoration projects assessed in this study consist of removing the training levees and constructing setback structures.

Setback structures are designed to prevent lateral erosion and may be located some distance from the active channel. Setback structures can include training levees, buried revetments (rock-filled trenches that resist erosion); and engineered log jams (ELJs) or engineered log structures (ELSs) that are designed to limit erosion by redirecting erosive flows.

1.6. Salmon Recovery Plan History

King County previously participated in preparing the following plans and reports pertaining to the implementation of restoration projects in the Middle Green River. The restoration projects assessed in this Feasibility Study were previously identified in at least one of these reports:

- Water Resource Inventory Area (WRIA) 9 Salmon Habitat Plan (WRIA 9 2005)[2]
- Middle Green River Restoration Blueprint (MGRRB) (King County 2005)
- Green/Duwamish River Ecosystem Restoration Feasibility Report (ERP) (U.S. Army Corps of Engineers 2000)
- King County Flood Hazard Management Plan (2007)

The WRIA 9 Salmon Habitat Plan proposed two conservation hypotheses to guide project selection and design in the Middle Green River.

- MG-1: Protecting and creating/restoring habitat that provides refuge habitat (particularly side channels, off channels and tributary access), habitat complexity (particularly pools) for salmon over a range of flow conditions and at a variety of locations (for example, main stem channel edge, river bends and tributary mouths) will enhance habitat quantity and quality and lead to greater residence time, greater growth and higher survival of juvenile Chinook salmon.
- MG-2: Protecting and restoring natural sediment recruitment (particularly spawning gravels) by reconnecting sediment sources to the river will help maintain spawning, adult holding and juvenile rearing habitat of Chinook salmon.

In 2005, a science panel was convened to prioritize a large list of projects for WRIA 9, which included virtually all of the projects from the USACOE-sponsored Ecosystem Restoration Feasibility Report and the Middle Green River Blueprint.

The 2005 prioritization generated a large list of projects, which was included in the WRIA 9 Salmon

[2] The WRIA 9 plan draws from and expands on the projects identified in the Blueprint and the ERP and is used to guide habitat evaluations in this study.

Habitat Plan. However, in order to choose individual projects for implementation in each subwatershed (for example, create a three-year workplan), the list needed to be prioritized with finer resolution. In 2008, the WRIA 9 Implementation Technical Committee (ITC) condensed the list to the top five projects in each subwatershed, based on subjective perceptions of potential benefit, then ranked each of these by subwatershed using a new methodology that refined the 2005 criteria (Latterell 2008). This methodology prioritized projects that the ITC were confident would have a substantial, immediate and sustained benefit to juvenile Chinook salmon. Confidence in the outcome was based on the following factors: strength of the project strategy, alignment with the Plan and standards for ecological success.

The ITC recommended implementing watershed-wide polices to prevent further degradation, as a prerequisite for the success of restoration projects. Second, they recommended that the WRIA focus a majority of its restoration efforts on increasing capacity in the Lower Duwamish Transition Zone. Third, they recommended immediate focus on protecting high-quality habitats in the marine nearshore and freshwater through easements or acquisition. Restoring habitat and processes in the nearshore and freshwater was the fourth step in the watershed-wide sequence; this work was to commence immediately and continue for over a decade until complete.

This feasibility study identifies restoration alternatives with the best chance of improving salmonid refuge habitat and habitat complexity and ultimately survival rates. Restoration projects are expected to benefit the two most common life-history types: marine-direct fingerlings and estuarine-reared fry, each of which spend important time in the river before outmigrating. Projects could also benefit yearling life-history types, but this type is thought to be uncommon. Additionally, restoration in the Middle Green could potentially reduce density-dependent migration to the Lower Green and Duwamish estuary (Greene et al. 2005). If so, juvenile densities in the Transition Zone could be lessened and thereby reduce the habitat bottleneck in this area. Moreover, enhancing the refuge habitat in the Middle Green River Sub-Basin could reduce the number of fish washed downstream during floods.

1.7. Agricultural Context

The Middle Green River flows through the Upper Green River APD. There are 3,500 acres contained within the Upper Green River APD of which approximately 900 acres (26%) are enrolled in the King County Farmland Preservation Program (FPP). Agricultural land use accounts for 1,315 acres, or 37% of the land within the APD.

King County's five APDs have some of the best soil and growing conditions in King County and represent the last remaining areas of clustered farmland in the County. They were originally designated in the 1985 King County Comprehensive Plan. Following passage of the Washington State Growth Management Act, the APDs were designated as the County's resource lands of long-term commercial significance. Counties are required to protect and enhance their designated resource lands. King County has a strong policy on protecting APDs through a combination of Comprehensive Plan policies, land use and zoning regulations and the FPP. By preserving of agricultural land the APDs have also provided opportunities for salmon habitat restoration that might have otherwise been lost through urbanization.

The FPP was created through a $50 million bond issue approved by King County voters in 1979. Through the program, property owners can voluntarily sell the County the development rights to their property. Restrictive covenants placed on the property limit the amount of non-tillable surface that is permitted, do not allow the soil to be permanently disrupted for non-agricultural purposes and restrict activities that would make the property less suitable for agriculture. Actions that convert FPP property to non-agricultural use (i.e., aquatic habitat) require a determination of the condition of the property at the time the FPP easement was purchased. If portions of the FPP easement area include aquatic habitats that were not farmed at the time of acquisition, these areas could be restored to create habitat benefits. Removing land that was farmed at the time of entering the FPP has never been attempted and would, at a minimum, require a determination by the King County Council that the property no longer meets the objectives of the program. Additional restrictions and/or approvals may also be required and therefore consultation with the King County Prosecutors Office is strongly recommended early in project planning efforts.

Because of the importance of protecting agriculture and restoring salmon habitat, the implementation of habitat restoration projects within the APD is regulated by King County Code; specifically the Aquatic habitat restoration project approval – public

meeting 21A.24.381. This code is intended to minimize potential conflicts and achieve potential benefits associated with the simultaneous protection of agricultural productivity, flood control and the implementation of aquatic habitat projects. Proposed aquatic habitat restoration projects that are located on property situated within an APD must submit a project proposal to the Agriculture Procedures Committee (APC). The APC evaluates whether the project will reduce the ability to farm within the APD. Aquatic habitat restoration projects may include mitigation measures to reduce agricultural impacts.

2. METHODS

2. METHODS

Project feasibility was assessed using three indicators: habitat benefit, cost and land availability (Figure 3). Assessment workbooks can be found in Appendix B.

Habitat Benefit was assessed based on expected changes in factors that create and maintain refuge habitat and increase habitat complexity. Benefit that was calculated as "ecological lift" is the difference between existing and future conditions.

Cost estimates included land acquisition, planning, pre-design, final design, construction, maintenance, monitoring, and contingency. Mitigation for agricultural impacts was not factored into the project cost.

Land Availability was assessed based on: a) willingness of the land owner to sell or convey for the proposed project; b) whether the land contained FPP easements; and c) whether the project would maintain farmable area. Projects that generated FPP and agricultural land impacts were rated lower than projects that did not generate these impacts.

The final values that were calculated from assessments of these three indicators were standardized, added and then ranked. Project rankings represent a balance of significant habitat benefit, relative cost (as compared to the other 10 projects) and land availability based on landowner participation (sale of land or easements) and minimization of FPP and agricultural land impacts.

2.1. Project Eligibility

A total of 71 Middle Green River restoration projects identified in previously prepared studies were examined (Figure 4). The initial project list included:

- Five projects identified in the 1993 King County Flood Hazard Management Plan (1993)
- Nine projects identified in the Green/Duwamish River Ecosystem Restoration Feasibility Study (ERP) (2000)
- Nineteen projects identified in the Green/ Duwamish and Central Puget Sound Watershed Water Resource Inventory Area 9 (WRIA 9) Salmon Habitat Plan (WRIA 9 2005)
- Thirty-eight projects identified in the Middle Green River Restoration Blueprint (MGRRB) (2006).

Many projects were identified in multiple plans, so there were fewer than 71 unique projects. Project designs were not advanced for analysis unless they were also consistent with a process-based design approach and directly addressed WRIA 9 habitat goals.

Figure 3. Components of Feasibility Analysis

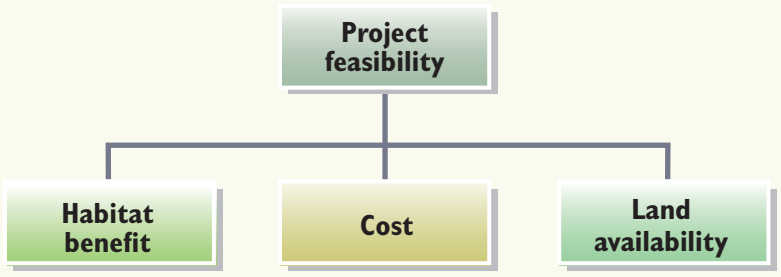


Figure 4. Project Selection Flow Chart

2.2. Conceptual Designs

Conceptual design development included analysis of multiple alternatives. Project design alternatives were established according to National Environmental Protection Act (NEPA) standards for alternatives analysis wherein Alternative 1 is the no-action, or existing conditions design alternative. Alternative 2 represents the conceptual design. While best available science and engineering practices were incorporated in this conceptual analysis, detailed engineering studies, hydraulic/hydrology analyses and structural and geotechnical evaluations will be needed in the future. Most of the design alternatives in this study consist of actions for modifying existing site conditions primarily to remove training levees and, where necessary, limit lateral erosion using setback structures that may include new training levees, buried revetments or ELSs. A smaller number of the projects focus solely on riparian vegetation and wood placement. Designs in this study do not call for building highly-engineered and static habitat features such as side channels or wetlands. Instead, a process-based design approach was used to guide design.

Process-based design provides a holistic approach to ecological restoration that defines success in terms of reestablishing normative rates and magnitudes of physical, chemical and biological processes that create and sustain river and floodplain ecosystems (Beechie, et al., 2010). These include processes such as erosion, sedimentation, large wood transport, storage and routing of water, plant growth and succession, inputs of nutrients and thermal energy and nutrient and food web cycling. Process-based design also recognizes demands for human goods and services, such as flood control, transportation and agriculture into restoration project planning activities. One of the principal benefits of the process-based approach is that it allows projects to physically and biologically adjust in response to external disturbances such as flooding, drought and climate change. This approach also minimizes the potential for post-construction corrective action and long-term maintenance.

Project designs recognized agricultural practices as constraints—especially potential impacts to FPP and agriculture. Because all of the training levees in the Middle Green were constructed over 50 years

ago, some are now showing evidence of erosion (for example, Lones and Turley). Consequently, the proposed projects have the potential to provide greater security for agriculture by constructing setback structures that provide a more durable boundary protection, while improving habitat conditions. Projects were not designed to provide any additional protection from flood inundation[3], nor are they intended to increase the extent of flood inundation outside the project site, though hydraulic analysis is warranted at a later stage of design[4].

This study also includes design alternatives that, where possible, are substantially consistent with ERP designs (see Section 2.1). The aim is to promote cooperative federal funding agreements with the USACOE, which may improve the chances of the project being funded in the future.

2.3. Indicator 1: Habitat Benefit

Habitat benefits to juvenile salmonids were determined by estimating the effect of each project on eight habitat metrics (Table 2, Figure 5) and their consistency with basic standards for successful restoration (Palmer et al. 2005). The rationale for the eight habitat metrics was that, in aggregate, the predicted change in these metrics would represent a project's potential for increasing salmonid refuge habitat over a range of flow conditions and for increasing habitat complexity.

Table 2. Habitat Lift Metrics

Metric	Description
1	Inundated area at 1,800 cfs
2	Inundated area at 8,800 cfs
3	Wetted edge length
4	Large wood trapping sites
5	Migration area
6	Erodible bank
7	Wood supply (Exposed forest)
8	Replanting Area

Refuge habitat was defined as slow water areas that offer shelter to juvenile salmonids that might otherwise be consumed by predators or displaced by high flows. Shelter from floods—termed "flow refuge"—may occur in many locations such as side channels[5], backwaters[6] and floodplains[7], channel edges[8] and logjams.

Habitat complexity is produced and sustained by physical processes. This study assessed each project's influence on four processes[9]:

1. channel migration
2. sediment storage and recruitment
3. wood storage and recruitment
4. forest establishment.

A project's effect on each process could not be simulated directly, so indicators of the potential for improvement in each process were used (Table 2). For example, channel migration potential was estimated from the area of unobstructed channel migration zone (within the mapped severe hazard channel migration zone or CMZ). The potential effect of a project on sediment storage and recruitment was estimated from the length of erodible bank – any bank lacking a training levee or other bank protection structure. A project's effect on the change in large wood recruitment potential was estimated from the area of existing forest exposed to channel migration. The project's effect on large wood storage potential was estimated from the number of

[3] For example, existing overflow and distributary channels will not be blocked.

[4] The Porter, Horath and Hamakami Reach sites are expected to see increases of 1-7 acres of inundation at 8,800 cfs, but these effects are predicted to occur inside the project boundaries. The local and upstream effects of each project on flood inundation will need to be evaluated in more detail (e.g., with hydraulic modeling).

[5] Either channelized flow of emergent hyporheic groundwater in flood channels, or channel units connected to mainstem at both ends but containing less than half the discharge.

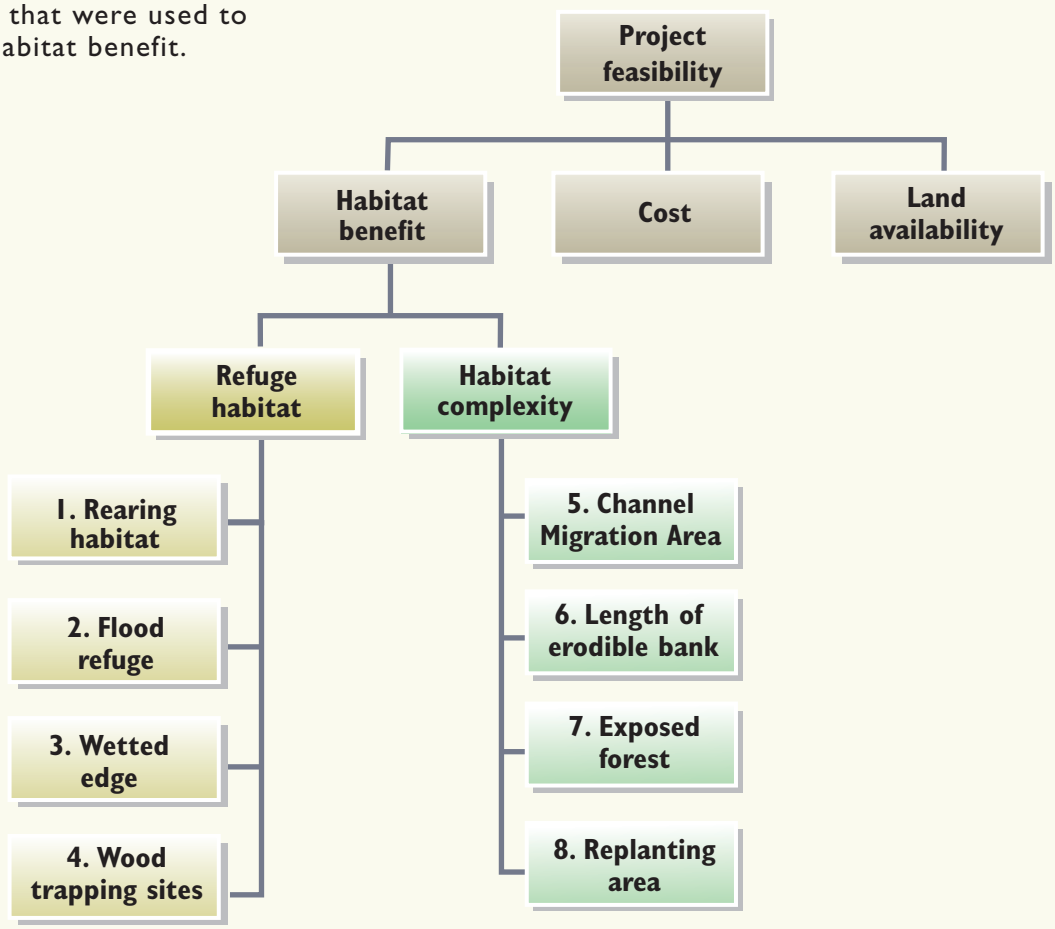
[6] Slow-water, partially enclosed channel unit along mainstem bank at the downstream end of a disconnected floodplain channel or secondary channel.

[7] Portion of the valley bottom area that is flooded at specified flows. A multi-elevation depositional feature formed by a combination of cut-and-fill alluviation, over bank deposits and logjam-forced aggradation of bedload into pseudo-terraces. May contain floodplain scour pools. Excludes unvegetated portions of active channel.

[8] Slow-water channel units located where the wetted channel meets either a deep, nearly vertical shore or a shallow, gently sloping shore.

[9] Flow variability is central in developing complex habitat, but cannot be altered by any projects in this study; it is driven by climatic variability and modified by Howard Hanson Dam (HHD). However, sufficient flow variability remains in the Middle Green to affect geomorphic change (Konrad et al. 2011).

Figure 5. Expanded view of metrics that were used to estimate habitat benefit.



places wood could likely be trapped by geomorphic features. The effect on forest establishment potential was based on the area of clearings that could be replanted with trees.

2.3.1. Ecological Lift

Each project was analyzed for its ability to generate "ecological lift," which is the difference between existing and future conditions (Table 3), where "future" means approximately 10 years after implementation. In this time, the river was expected to be reshaped by several moderate floods [for example, 1.5 year recurrence interval (RI)] and at least one large flood (five or 10 year RI).

The lift from an individual alternative was then divided by highest lift from any alternative for each indicator. This analysis yields values from 0-1.0 (or 0-100%) indicating the level of benefit of any single project alternative to the alternative that is expected to produce the largest change in the habitat metric in question. This value represents the level of habitat benefit expected to result from a given project, compared to the project with the greatest improvement in that metric. This value was multiplied by a constant (i.e., 4) to standardize the values for comparison with land assessment scores, which ranged from 0 to 4.

A weighted average score was calculated to integrate the ecological lift values, which range from 0 to 4, where 4.0 indicates the project is expected to deliver the greatest improvement, compared to all other projects (see Methods Section for details on calculations for relative ecological lift). Weighting factors were assigned to each of the habitat indicators, according to their perceived importance in the WRIA 9 Salmon Habitat Plan. Edge habitat was considered to be the most important, so it was assigned a weighting factor of three. Large wood (LW) trapping sites and the project checklist (compliance with standards) were assigned a weighting factor of one. All other indicators were assigned a weighting factor of two.

Table 3. Methods for Evaluating Project Benefits	
Step	**Method**
1	Measure habitat metrics under existing conditions.
2	Estimate habitat metrics under future conditions (10 years).
3	Compare existing to future conditions to estimate habitat 'lift'.
4	Calculate 'relative lift'. Divide lift from one alternative by highest lift from any alternative; yields values from 0-100% indicating level of benefit relative to the best alternative.
5	Score project with checklist standards.

It must be acknowledged that the predicted outcomes of each project in this study are imprecise, meaning there is substantial uncertainty in the estimated quantities of each metric under future conditions. Existing conditions can be mapped more precisely. Summaries of future conditions are reported with the same precision as existing conditions, for ease of comparison—but this does not mean future conditions can be predicted as precisely. The uncertainty of predicted responses is better reflected in estimates of habitat lift. These estimates are each rounded to a level that sets somewhat more reliable and realistic expectations (Table 4). In general, the reported precision of future conditions is one order of magnitude lower than that of existing conditions measurements. This means that the values for ecological lift in assessment tables will show a coarsened value for the difference between the current and future conditions. For example, if the existing and future conditions for Metric 3 are reported to the nearest 100 feet (high precision), the habitat lift for Metric 3 would be reported to the nearest 1,000 feet (low precision). One exception is the area for replanting (Metric 8); the precision of the existing and future conditions is the same because it is under direct control.

2.3.2. Assessment Units

Habitat metrics were measured within "assessment units" or the approximate area of channel and valley floor that could potentially be modified— directly or indirectly—by a project. The CMZ hazard maps were used to define the lateral boundaries of the assessment units; this is valid because the CMZ maps in this part of the Green River assumed existing facilities would not prevent channel migration over the very long-term. Upstream and downstream boundaries were set at approximately 3,300 feet beyond the project site in each direction. This value approximates the distance that full meander sequence (two adjacent bends) would be expected to occupy, given the post-HHD flow regime (e.g., see Konrad et al. 2011). Existing and future conditions were mapped entirely within the boundaries of the assessment unit; the same area was used for all the alternatives of a given project.

2.3.3. Metric 1: Inundated Area at 1,800 cfs

Inundated area at 1,800 cubic feet per second (cfs) is an indicator of rearing habitat availability, or refuge under rearing flows. Flows at this level are expected to inundate riverine wetlands and side channels. This flow level approximates the average daily discharge during the period of time juvenile Chinook are rearing in the river; February through June. If a project increases rearing habitat, juvenile salmonids could potentially grow faster and survive at higher rates because they can spend less energy finding food and can better avoid competition and predation. Flows at this level are also expected to inundate most riverine wetlands and side channels[10].

Existing inundated area was estimated by simulating water surface elevations at 1,800 cfs with a Hydrologic Engineering Centers River Analysis System (HEC-RAS) model applied to a Lidar-based model of ground surfaces. Flow elevations from HEC-RAS cross sections were converted to a Triangulated Irregular Network (TIN) GIS raster layer. The TIN was used to create a 3D polygon boundary for each assessment unit. The flow elevation TIN was copied into the resulting shape and clipped to the assessment unit. The clipped TIN was converted to a raster to create a simulated water surface grid, which was subtracted from the digital ground surface model to create a difference grid. The difference grid indicated the approximate depth of the water above the ground; all values over zero are under water. A binary grid was created to identify all inundated grid cells. The grid was converted to polygons and the inundated area was calculated for the assessment unit.

Future conditions were estimated by revising the inundated area polygons to show new (additional) inundated areas that are likely to occur as the result of training levee modification and associated geomorphic change (for example, channel migration,

[10] A flow duration analysis performed for the Auburn Narrows Habitat Restoration Project (King County 2004) identified 1,820 cfs as having the highest probability of inundating lateral habitats (at least during Feb. 1 through May 31). The results indicated that discharge exceeded 1,820 cfs for 14 consecutive days in 60% of the years. This discharge also approximates the historical daily mean flows and the ordinary high water mark (OHWM) in the Green River.

Table 4. Approximate precision of existing conditions measurements, by metric, compared to the reported precision for potential ecological lift generated by projects.

Metric	Description	Approx. precision: existing conditions	Approx. precision: ecological "lift" estimate
1	Inundated area at 1,800 cfs	0.1 acre	1.0 acre
2	Inundated area at 8,800 cfs	0.1 acre	1.0 acre
3	Wetted edge length	100 feet	1,000 feet
4	LW trapping sites	1 site	1 site
5	Migration area	1 acre	10 acres
6	Erodible bank	100 feet	1,000 feet
7	Wood supply (Exposed forest)	1 acre	10 acres
8	Replanting area	1 acre	1 acre

bed aggradation, avulsions). Unless an avulsion was expected, it was assumed that the existing inundated areas would persist. For example, future conditions maps include low-lying areas behind facilities that were previously disconnected from the main channel. The estimated quantity of inundated area under future conditions was rounded to the nearest acre (in summary tables) to reflect the uncertainty in the value (Table 4).

2.3.4. Metric 2: Inundated Area at 8800 cfs

The inundated area at 8,800 cfs is an indicator of flood refuge habitat. It corresponds with the approximate flow level that is effective at causing measurable channel changes in the period after HHD was installed (Konrad et al. 2011). The use of this metric assumes that inundated area at 8,800 cfs is positively related to the quantity of slow-velocity (<45 cm per second) flood refuge habitat (after Beechie et al. 2005). If so, maximizing area at 8,800 cfs could potentially give juvenile Chinook more opportunities to avoid displacement and injury during floods and survive at a higher rate.

Existing and future conditions were estimated the same way as in Metric 1.

2.3.5. Metric 3: Wetted Edge Length

Wetted edge length (of the channel) is an indicator of refuge habitat availability. Wetted edges are shallower and, at a given discharge, should have lower velocity flow than the mainstem. The length of the wetted channel edge is expected to correlate with slow-velocity habitat area under rearing flows. If so, projects that increase wetted edge length could support faster growth and higher survival in juvenile salmonids because fish need to spend less energy foraging and avoiding competition and predation.

Existing wetted edge length was measured by tracing the lateral boundaries of the polygon representing inundated area at 1,800 cfs with a polyline in ArcMap, including the margins of mid-channel islands. The wetted edge maps excluded locations where the channel margin runs along rock-armored facilities and inundated areas that were not connected at 1,800 cfs. Future wetted edge length was estimated in the same way, but instead following the boundaries of the revised inundation map for 1,800 cfs.

2.3.6. Metric 4: Large Wood Trapping Sites

Large wood trapping sites are indicative of refuge habitat availability and habitat complexity. Wood trapping locations include the upstream ends of bars, side channel entrances, outer meander bends and ELSs. The number of logjams is expected to increase with the number of wood trapping sites. Logjams create flow refuge habitat by dissipating stream energy and creating low-velocity areas in their lee and in pools scoured by higher flows. Logjams create habitat complexity by protecting banks, blocking side channels, deflecting flows, raising water levels and causing erosion and deposition.

Existing wood trapping locations were mapped from aerial photos (orthophotos, regardless of whether there was wood present at the time of the photo.

To estimate future conditions, new trapping sites were added at the upstream ends of bars, side channel entrances, outer meander bends and ELSs, according to the new channel configuration and ELJ locations.

2.3.7. Metric 5: Area for Channel Migration

The area available for channel migration is an indicator of habitat complexity. Meandering[11], avulsion[12] and widening[13] is expected to create and maintain complex morphology in the streambed and floodplain and promote hydraulic diversity.

Existing area for channel migration—over many decades into the future—was estimated by mapping the portions of each assessment unit that was within the CMZ but lacked training levees and revetments. The CMZ was mapped assuming existing facilities would fail but major public infrastructure (roads, bridges) would be protected. For this analysis, we considered the anticipated function of this facility and projected the likely long-term channel migration. This was accomplished by reducing the area of the CMZ inside the assessment unit to reflect the direct and indirect effects of training levees and bridge abutments on channel movement as well as the underlying topography. This required professional judgement about where the river could likely or plausibly move. To estimate future conditions, the existing polygon was expanded to include portions of the channel migration zone that would be exposed by the removal of a revetment. The predicted outcome is one of many possible results, and not the only successful outcome.

2.3.8. Metric 6: Length of Erodible Bank

The length of an erodible (unarmored) bank is an indicator of habitat complexity. Reducing bank strength and exposing floodplains and terraces to new erosion should promote sediment recruitment and storage. The quantity of recruitment and storage should correlate with the length of erodible bank. Increases in sediment recruitment and storage should enhance habitat complexity by triggering channel widening, bar formation and wood retention.

Existing erodible bank length was mapped with a polyline file representing right and left banks of the river at 1,800 cfs. Lines were drawn along all unarmored banks in the assessment unit. If there was a facility behind the bank within a distance equal to one channel width, it was considered to be an erosion-resistant bank and that bank was not mapped as "erodible." If the facility was over one channel width away, it was considered to be an erodible bank.

To estimate future conditions, the updated wetted edge line was revised to indicate portions of training levees that would be either removed or destabilized (for example, by removal of face rock).

2.3.9. Metric 7: Existing Wood Supply (Exposed Forest)

The area of existing forest within the area exposed to channel migration is an indicator of habitat complexity because it influences the potential for local wood recruitment. Projects can promote wood recruitment by exposing existing forests to bank erosion; the amount of wood recruitment and storage should increase with the area of existing forests exposed to channel migration. Increased wood retention is expected to increase habitat complexity by increasing logjam frequency and function.

Existing conditions were measured by mapping the forested area inside the portion of the assessment unit that was exposed to channel migration. Existing forests were digitized as polygons from 2009 orthophotos (at 1:1,000 scale). The resulting area was less than or equal to the unobstructed channel migration zone area. The unobstructed CMZ polygon(s) was selected in ArcMap and the Intersect tool was used to measure the area of existing forest that was within that polygon.

To estimate future conditions, the existing conditions map was revised to include additional forested areas that would be vulnerable to channel migration in the future, including newly exposed forest areas that may be eroded between year 1 and year 10.

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[11] Erosion on the outside of a river bank in a somewhat orderly and repeated pattern of curves (Lorang and Hauer 2005). Channel width often remains relatively constant. It may result in the loop cutoffs, producing backwaters and oxbows. Point bars form on inside bends and support woody vegetation.

[12] Large-scale relocations into new or abandoned channels, resulting in a new main channel or a secondary flowpath (Lorang and Hauer 2005). Often coupled with widening. Can result from headcutting in a secondary channel that proceeds until it captures the main channel. Tends to produce lateral and mid-channel bars, backwaters and side channels.

[13] Occurs where bank erosion and bar deposition dominate—often where the local sediment supply increases relative to the river's transport capacity. Bar formation and bank erosion is coupled; the bar forces the river into the opposite bank, the channel widens and becomes more sinuous. Bars grow and the channel widens until small-scale avulsions form additional channels and promote stability. This results in pools, scour holes and riffles, backwaters and ponds. Colonization by vegetation and logjam formation,traps more sediment and builds landforms with mature trees (Lorang and Hauer 2005).

2.3.10. Metric 8: Replanting Area

The area available for replanting is an indicator of habitat complexity. Projects can either (1) replant vegetation in cleared areas; or (2) allow the channel migration to replace cleared areas with natural vegetated landforms; the replacement of native forests is directly related to the change in cleared areas. Promoting native forests will enhance habitat complexity by dissipating stream energy (in the floodplain), promoting soil formation and retention and contributing large wood over the long term. Conversion of cleared areas to forest should correlate, over the long term, with increased logjam frequency in the channel. Increases in logjam frequency and function may correlate with faster growth and higher survival in juvenile salmonids because fish need to spend less energy foraging, searching for profitable habitats and avoiding competition and predation.

To estimate future conditions, maps were made to indicate areas that could be replanted with native trees by year 10.

2.3.11. Compliance with Standards for Ecological Success

After quantifying expected habitat changes, each project alternative was evaluated with a checklist that tested for compliance with four standards for ecologically successful restoration (Palmer et al. 2005). A project could earn a single point for each standard met, so four points were possible. A point was awarded if the team could answer "yes" to each set of questions, with confidence.

Standard 1: A dynamic ecological endpoint – a guiding image is identified beforehand and is used to guide the restoration.

- Will the project move the river toward the least degraded and most dynamic state possible, as opposed to a single, fixed endpoint or unchanging condition?
- Is the design informed by reference sites or historical conditions, where possible?
- Are goals achievable in spite of ongoing environmental impact of local or upstream origin?

Standard 2. Ecological condition of the river will be measurably enhanced.

- Is the amount of refuge habitat and habitat complexity expected to show measurable change?
- Are natural processes expected to sustain and enhance the new habitat over time?

Standard 3. The river ecosystem will be more self-sustaining than prior to the restoration.

- Is the site expected to recover from floods with minimal maintenance?

Standard 4. Implementing the restoration does not inflict irreparable harm; though short-term impacts may occur.

- Does the project minimize damage to existing and functioning habitat?
- Will impacted vegetation—and other existing habitat—be restored or replaced?

2.4. Indicator 2: Cost

The project cost assessments are based on estimates to acquire property, design and permit, construct, maintain and monitor projects (Figure 6). These estimates are based on best available actual costs from recent projects.

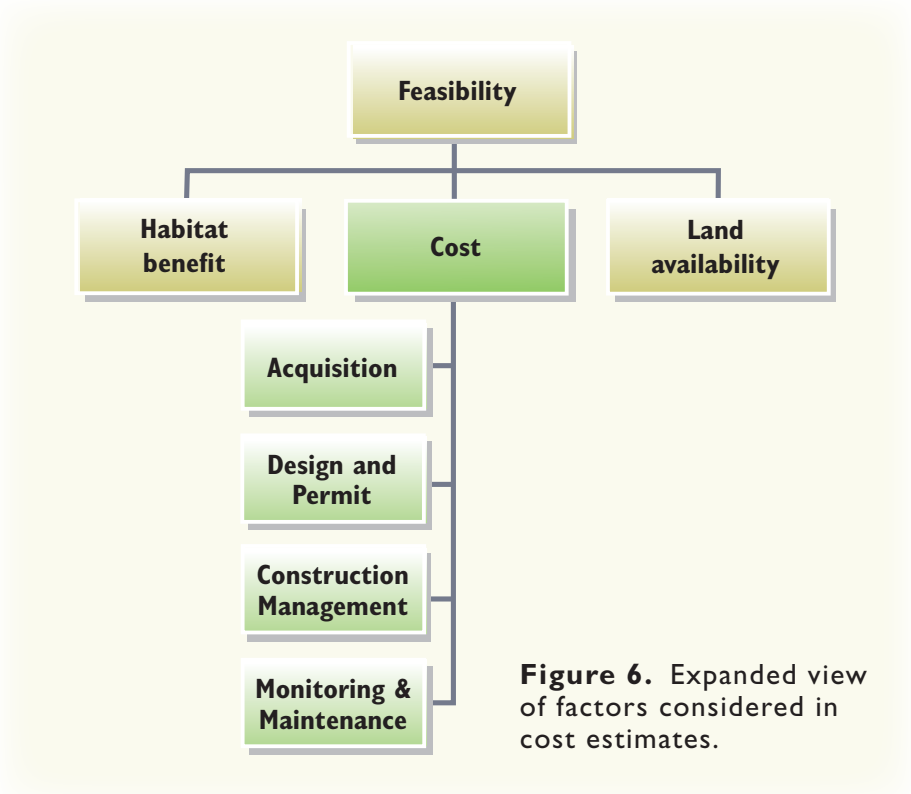


Figure 6. Expanded view of factors considered in cost estimates.

2.4.1 Cost Calculation Methods

The cost assessment sheet, the detailed cost sheets for each project site and the formulas used to calculate total cost are listed in Appendix A. Costs were calculated as follows:

The Total Cost (Ctotal) = Cc + Ca + Cd + Cmi + Cmaint + Cmon

Cc = Construction Costs:

- Construction unit costs are based on the estimates per previous projects such as Tolt, Cedar Rapids, Belmondo and current projects such as Carlson Upper.
- Quantity take-offs are based on ground elevations taken from existing Lidar surveys along the Middle Green River Reach.
- Quantities used in calculations included reuse of existing material.
- A contingency factor of 40% was added to construction and planting cost estimates due to unknown site conditions, regulatory requirements and engineering and construction requirements. Contingency used in determining total costs is applied to the sum of tax (8.6%) and construction costs.
- All unit costs have been adjusted to represent 2011 values.
- Construction cost includes floodplain or riparian planting costs.

Ca = Acquisition Costs = Cav * Pa * Cfm + Cpf

- Cav = Total Assessed Value (KC Assessor)
- Pa = % of site for acquisition
- Cfm = Fair Market factor (+15%)
- Cpf = Purchasing Fees = Title report, Appraisal and Phase 1 Environmental Site Assessment (ESA)* # of parcels to purchase ($25,000 per parcel).

Cd = Design, Permitting and Outreach Costs:

- Cd = Total construction Cost (Cc) * 25% (for projects less than $1 million) ***or***
- Total construction Cost (Cc) * 40% (for projects greater than $1 million).

Cmi = Construction Monitoring and Inspection Costs:

- Cmi = Total construction Cost(Cc) * 15%.

Cmaint = Maintenance Costs:

- Cmaint = Ranges from $5,000 to $50,000 depending primarily on project scope.

Cmon = Monitoring Costs :

- Cmon = Planning level cost estimates based on level of monitoring intensity.

2.5. Indicator 3: Land Availability

Project feasibility is dependent on access to land needed to construct a project. Access consists of the ability to acquire land from a property owner and usability of the land per zoning, title or other conditions that could add challenges to using the land for restoration purpose (Figure 7). Land availability was assessed by evaluating landowner support, FPP easement status and agricultural impacts in three assessment questions.

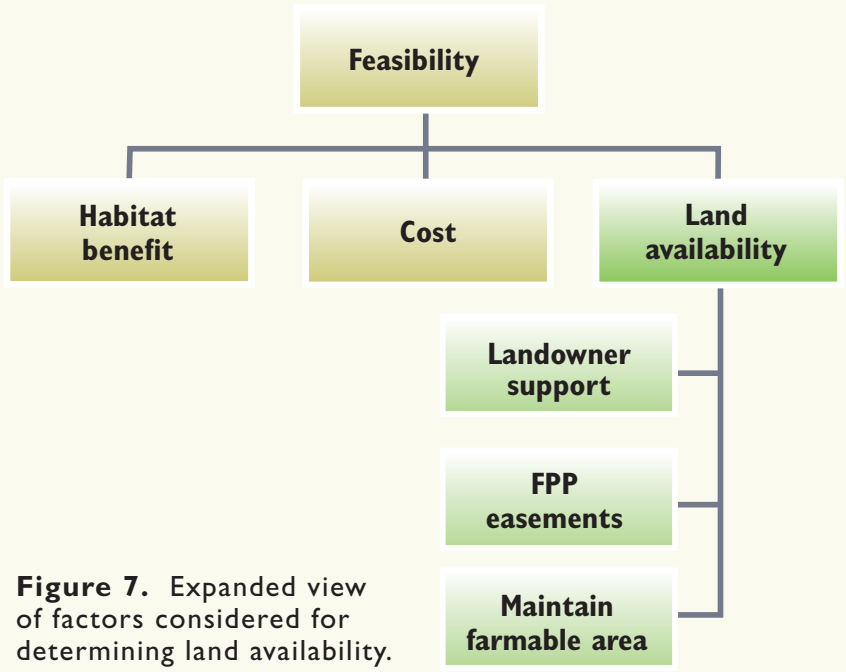


Figure 7. Expanded view of factors considered for determining land availability.

2.5.1. Landowner Support

Landowners were contacted by phone and in person to determine receptivity to potential projects. Drawings of project designs were shown to property owners and they were asked if they were receptive to potentially selling property to construct the proposed project.

Question 1: Are the property owners receptive to selling property to construct the proposed project?

- Sites where the answer to question is "Yes" were given a "4".
- Sites where the answer to question is "No" were given a "0".
- Sites where the answer to question is "Mostly" 2 points were added to the existing score.
- Sites where the answer to question is "Some" 1 point was added to the existing score.
- Scores do not reflect input from the Agricultural Commission or adjacent property owners.

2.5.2. FPP Easements

Owners of properties in the King County Farmland Preservation Program (FPP) voluntarily sold the development rights to their property and allowed restrictive covenants to be placed on it that limit the property's use and development. The covenants restrict the use of the property in several ways that affect the use of the land for habitat restoration: land use is restricted to agriculture or open space, 95% of the property is kept open and available for cultivation, and activities that would impair the agricultural capability of the property are restricted.

Question 2: Does the site include FPP easements?

- Sites where the answer to question is "No" were given a 4.
- Sites where the answer to question is "Yes" were given a 1.

2.5.3. Maintain Farmable Area

All of the projects examined in the study are located within the Upper Green APD with the exception of Auburn Narrows and Flaming Geyser. In some cases proposed projects involve the construction of setback structures on/or adjacent to farmland. These actions could—in the short-term—remove agricultural land from production, but in the long-term the new setback structures could reduce risks of channel migration or reduce the frequency or depth of flood inundation on the land, thereby increasing the security of long-term agricultural production.

Question 3: Can the existing critical habitats be reconnected to the active channel without reducing more than 5% of the farmable area?

- Sites where the answer to question is "Yes" were given a 4
- Sites where the answer to question is "No" were given a 0
- Sites where the answer to question is "Mostly" 2 points were added to the existing score
- Sites where the answer to question is "Some" 1 point was added to the existing score.

2.6. Overall Feasibility Analysis

An overall feasibility score was generated for each project by normalizing the scores for each of the three assessment areas and adding them together. Accordingly, the top-ranked projects were those with the highest combined scores.

Assessments of habitat benefit, cost and land availability generated summary tables for:

- habitat benefit
- cost
- land availability and agriculture
- cumulative ecological benefit.

3. RESULTS

Results of applying the multi-objective assessment methodology to 10 conceptual restoration designs.

Site 1: Auburn Narrows

Figure 8. Auburn Narrows site photos

Site Description

The Auburn Narrows project site is located on the left (south) bank of the Middle Green River between RM 33.8 and RM 31.7 (Figure 9). It is a 50.9-acre King County Natural Area that is split into two physiographic halves. It is located outside of the Upper Green APD. The 26.1-acre northern half of the site consists of a 100-year floodplain adjacent and parallel to the river, hereafter referred to as the floodplain. The 24.8-acre southern half of the property consists of a flat terrace approximately 4 to 6 feet higher in elevation than the floodplain, hereafter referred to as the low terrace.

Existing Conditions

In the 1960s a 2,500 linear foot (lf) training levee was constructed along the edge of the Green River on the Auburn Narrows site. In 1971, King County purchased the property, and in 1994 approximately 1,400 linear feet of the top four feet of the training levee was removed, leaving the buried toe of the training levee. In 2005, the County sold Tacoma Public Utilities (TPU) an easement across the eastern half of the property so that TPU could construct a wetland mitigation project in association with the construction of an off-site pipeline. Subsequently, TPU constructed a 5.5 acre wetland on the eastern half of the floodplain and planted 25.5 acres of upland in the low terrace. In the floodplain on the western half of the property, King County constructed a 950 linear-foot side channel and planted a 5.5 acre riparian zone with native trees and shrubs in 2005. In 2007 a 300-foot training levee was removed near the river and a 50-foot section of inlet was constructed to connect the river to the side channel. Between 2002 and 2011, over 25,000 trees and shrubs were planted in the low terrace west of the TPU terrace planting area.

The Auburn Narrows assessment unit contains 39 acres of inundated area at 1,800 cubic feet per second (cfs) and 103.5 acres at 8,800 cfs. The wetted edge was 34,100 feet and there are 20 wood trapping sites. Of the 163 acres currently exposed to channel migration in the assessment unit, 129 acres are forested and could supply wood to the river. Erodible banks measure 17,700 feet.

Habitat-forming processes are now limited primarily by constraints on channel migration imposed by the Highway 18 Bridge, and the remnants of the training levee. The gravel road between the wetland creation area and the side channel area impairs the flow of floodwaters across the floodplain and reduces the potential of this area to adjust to floods and form aquatic habitat features. The potential for channel migration has been reduced but not eliminated. Landslides or log jams could initiate channel migration and some bend migration could occur at the downstream end of the existing facility.

Conceptual Project Design

This design alternative consists of removing 75 linear feet of buried revetment located under the access road, and the removal of 775 feet of toe rock from the training levee modified in 1994 (Figure 10). A setback structure is not believed necessary because the channel is constrained by the Highway 18 Bridge. The buried revetment was installed to protect the side channel from potentially head-cutting through the TPU wetland mitigation site and leading to a potential avulsion of the Green River. The TPU easement area is underlain by bentonite clay, which was tilled into the soil. This ensures that the conditions support the created wetland area and satisfy compensatory wetland mitigation requirements.

Indicator 1: Habitat Benefit Assessment

This project is not expected to expose significant additional areas to channel migration. The wetted channel is assumed to join a portion of the wetland and the side channel at 1,800 cfs (Table 6). If so, the effective wetted edge length could increase by 3,000 feet, because the wetland edge would then be counted as usable fish habitat. Removing the rock toe along the left bank may allow the river to make vertical adjustments of the bed and some minor adjustment of the left bank, increasing erodible bank length by approximately 1,000 feet. The project involves approximately 10 acres of shrub underplanting, which has ecological value, but is not considered equivalent to replacing a cleared area with trees. So this value is not shown in the table. This project would meet all four standards for ecological success Table 7).

Indicator 2: Cost Assessment

The construction cost estimate for Auburn Narrows includes planting 10 acres of open space and the removal of rock revetment and existing utilities. The actual quantity of rock revetment is unknown and is based on approximate dimensions. A contingency of 40% is used to account for the uncertainty of construction costs.

Table 5. Auburn Narrows Design Details

Category	Detail	Units	Value
Planning context	WRIA 9 plan project number	None	0
	ERP project number	None	0
	Project alternative	N/A	2
Existing conditions	Area of project site	Acres	51
	Length of existing training levee (toe rock only)	Linear feet	1,300
Proposed actions	Levee to be removed	Linear feet	0
	Rock revetment to be removed	Linear feet	775
	Planting area	Acres	10
Affected properties	Total parcels	Number	1
	King County parcels or easements	Number	1
	Private Property Interests to Acquire (TPU Easement)	Number	1

Table 6. Auburn Narrows Habitat Benefit

Metric	Factor	Units	Alt 1	Alt 2	Alt 2-Alt 1	Ecological Lift*
1	Inundated area at 1800 cfs	Acres	39.0	39.0	0	0
2	Inundated area at 8800 cfs	Acres	103.5	103.5	0	0
3	Wetted edge length	Feet	34,100	36,700	2,600	3,000
4	Large wood trapping sites	Number	20	20	0	0
5	Channel migration area	Acres	163	163	0	0
6	Length of erodible bank	Feet	17,700	18,600	900	1,000
7	Wood supply (exposed forest)	Acres	129	129	0	0
8	Replanting area	Acres	0	0	0	0

*Rounded to reflect uncertainty in outcomes

Table 7. Auburn Narrows Standards Checklist

Standard	Description	Score Alt 2	Compliance
1	Dynamic ecological endpoint	1	complies with standards
2	Measurably enhanced	1	complies with standards
3	More self-sustaining	1	complies with standards
4	No irreparable harm	1	complies with standards

Table 8. Estimated Project Costs	
Type of Cost	**Totals**
Acquisition	$0
Design, Permitting and Outreach	$95,242
Construction	$238,105
Construction Management and Inspection	$35,716
Maintenance	$24,000
Monitoring	$10,000
Total Project Cost	**$437,213**

Indicator 3: Land Availability Assessment

This parcel is owned by King County, however Tacoma Public Utilities owns an easement across the eastern half of the parcel to allow for the construction of a wetland mitigation project that is subject to Section 404 permit requirements until 2014.

The Auburn Narrows project scores high for land availability because it is a King County-owned ecological land. The management goals for ecological lands are to conserve and enhance ecological value and to accommodate passive recreational use that does not harm the ecological resources on the site. Ecological sites are used by visitors for low-impact activities such as walking, nature observation, or fishing.

Construction to remove the revetment rock toe and the grade-control rock buried in the construction access road would require due consideration of the Tacoma Public Utilities easement terms and conditions. TPU's Section 404 permit requires monitoring through 2014. After the permit conditions and wetland performance standards have been satisfied the permit will be closed. Thereafter, any site modifications that could lead to lateral channel migration and changes to the TPU mitigation wetlands would not submit TPU to Section 404 mitigation performance standards. Presumably, once the mitigation requirements have been satisfied, TPU should be amenable to eliminating the buried road revetment and the training levee toe rock. The proposed construction activities will require a review of the legal easement to the eastern part of the property that is owned by TPU in order to determine if agreements with TPU are required for the proposed modifications.

Table 9. Auburn Narrows Land Availability Assessment		
Question	**Description**	**Result**
1	Receptive landowners?	Yes
2	Does site include FPP easements?	No
3	Does Project Maintain FPP Farmable Area?	Yes

Future Design Analysis

The proposed project has the potential to increase wetted edge length and increase connectivity between the mainstem, wetlands, and the side channel. Headcutting from the downstream end of the construction side channel could migrate across the access road once the buried revetment is removed. This could lead to channel braiding and migration, creating a mosaic of aquatic habitats. This could lead to changes in passive recreational activities that occur on the site, including fishing and bird watching.

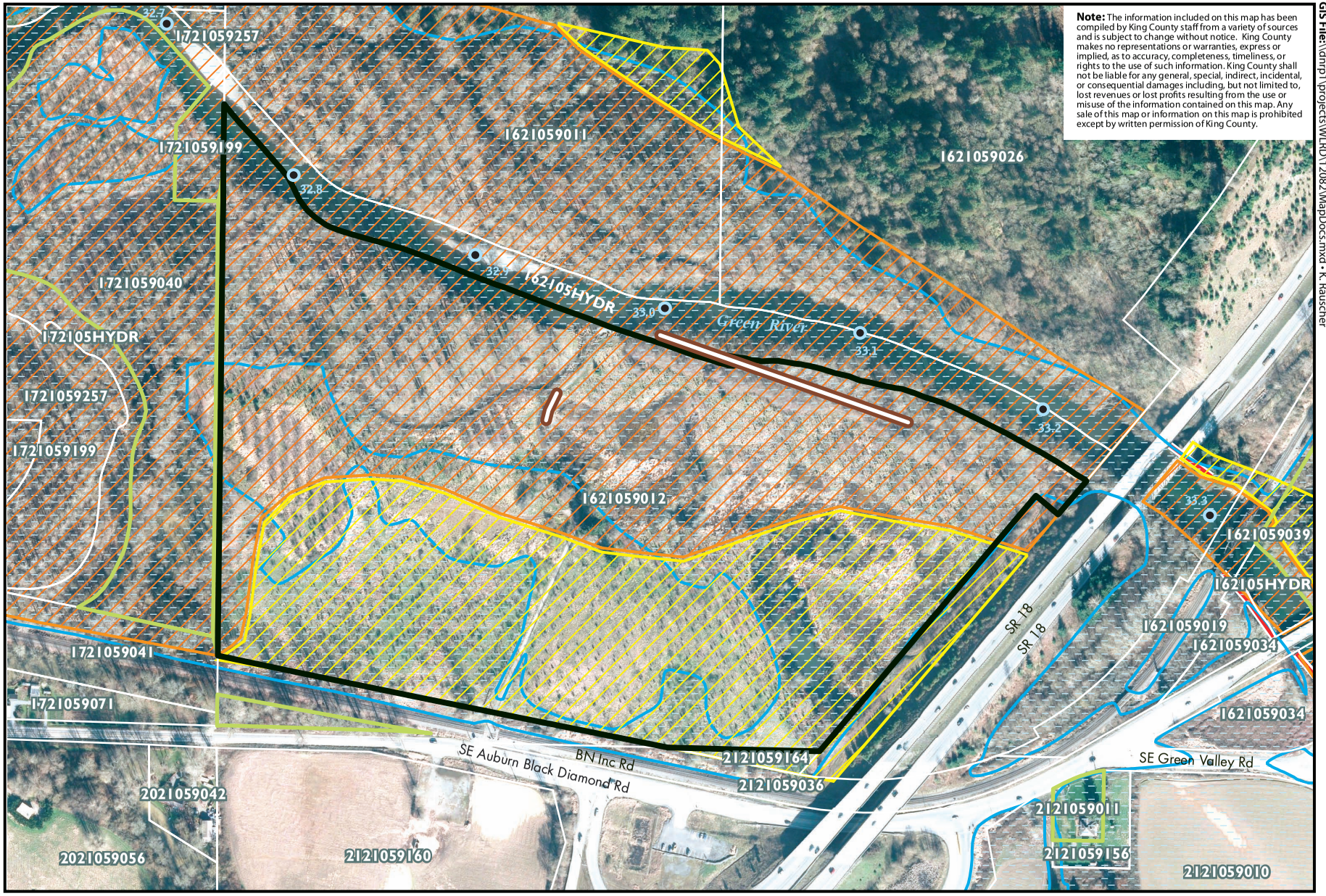


Figure 9

AUBURN NARROWS

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Remnant Structure (Toe Rock)
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

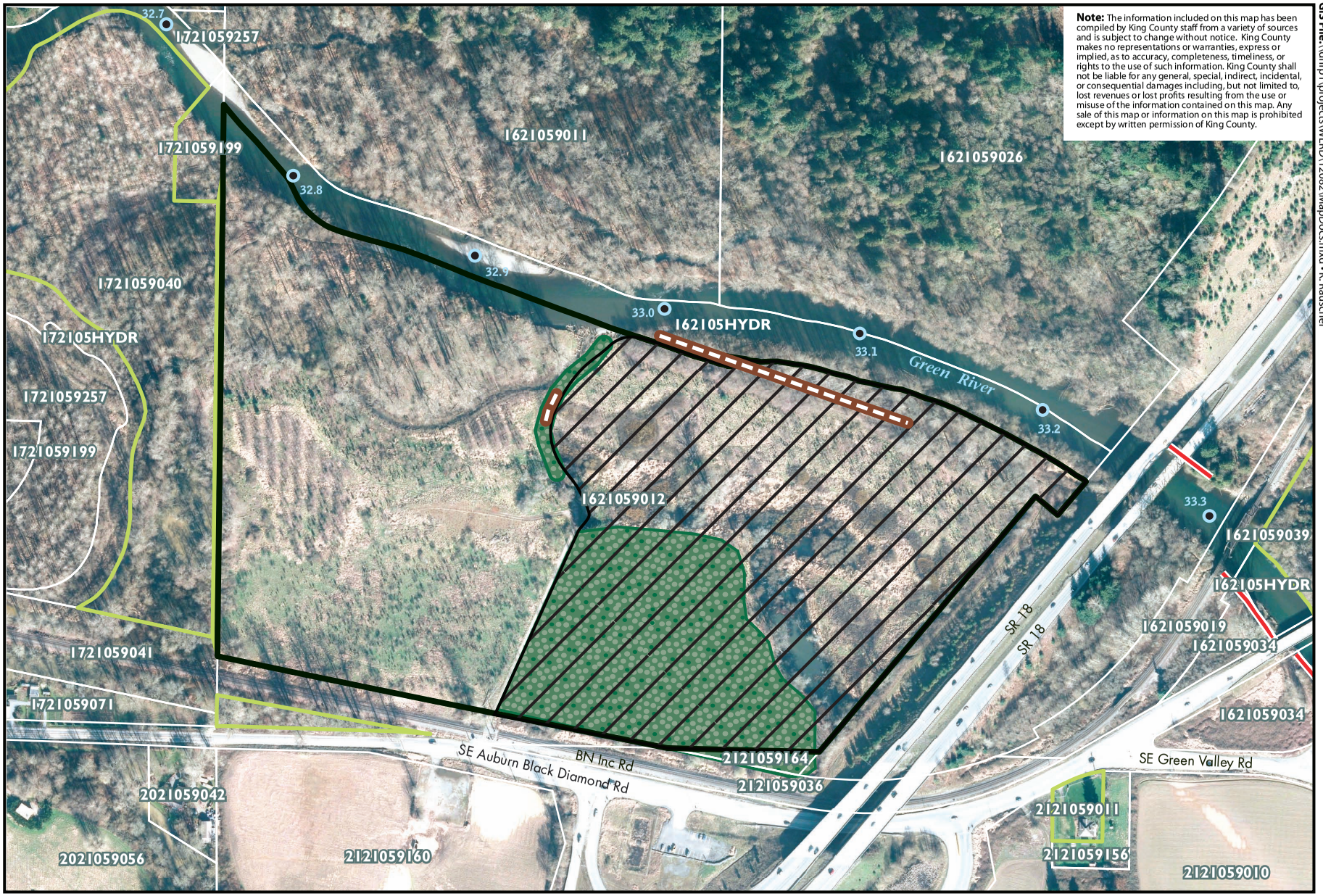
N

0 200 400

Feet

King County

Department of Natural Resources and Parks
Water and Land Resources Division



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GIS File: \\dnrp1\projects\WLRD\12082\MapDocs.mxd • K. Rauscher

Figure 10

AUBURN NARROWS

Alternative 2

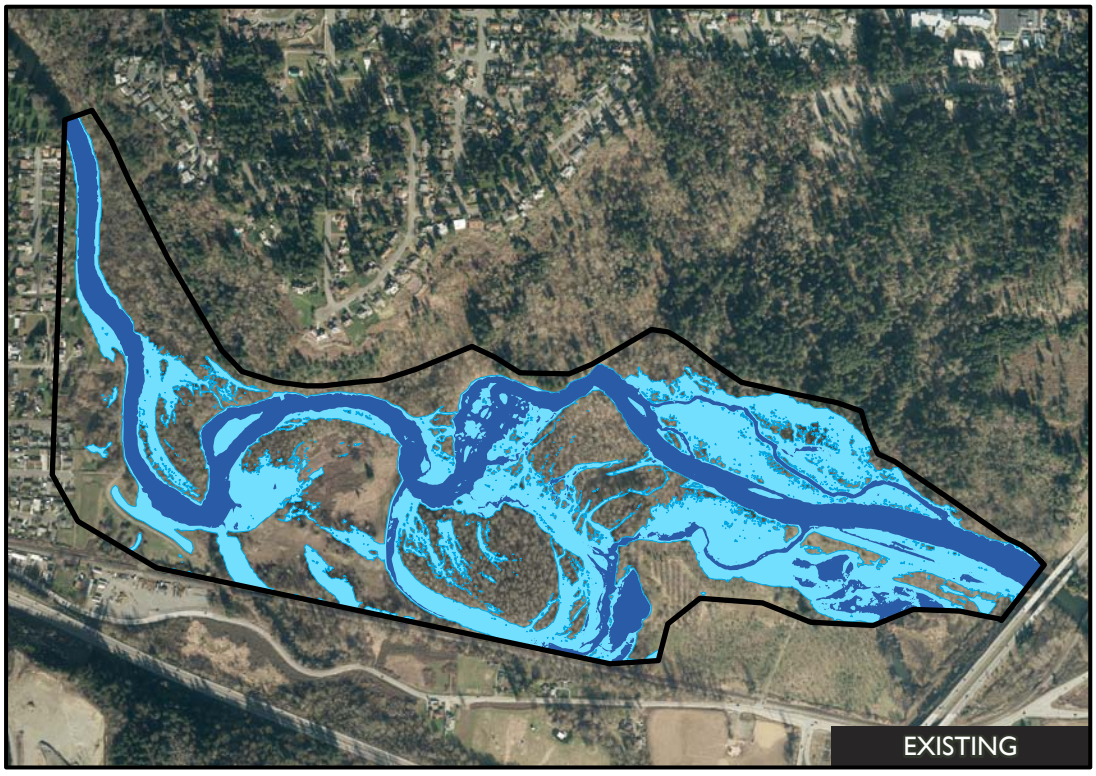
- Project Area Boundary
- Existing Levee
- Structure to Be Removed
- TPU Easement
- Replanting Area
- King County Owned Parcel
- 1... Parcel Boundary & No.
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

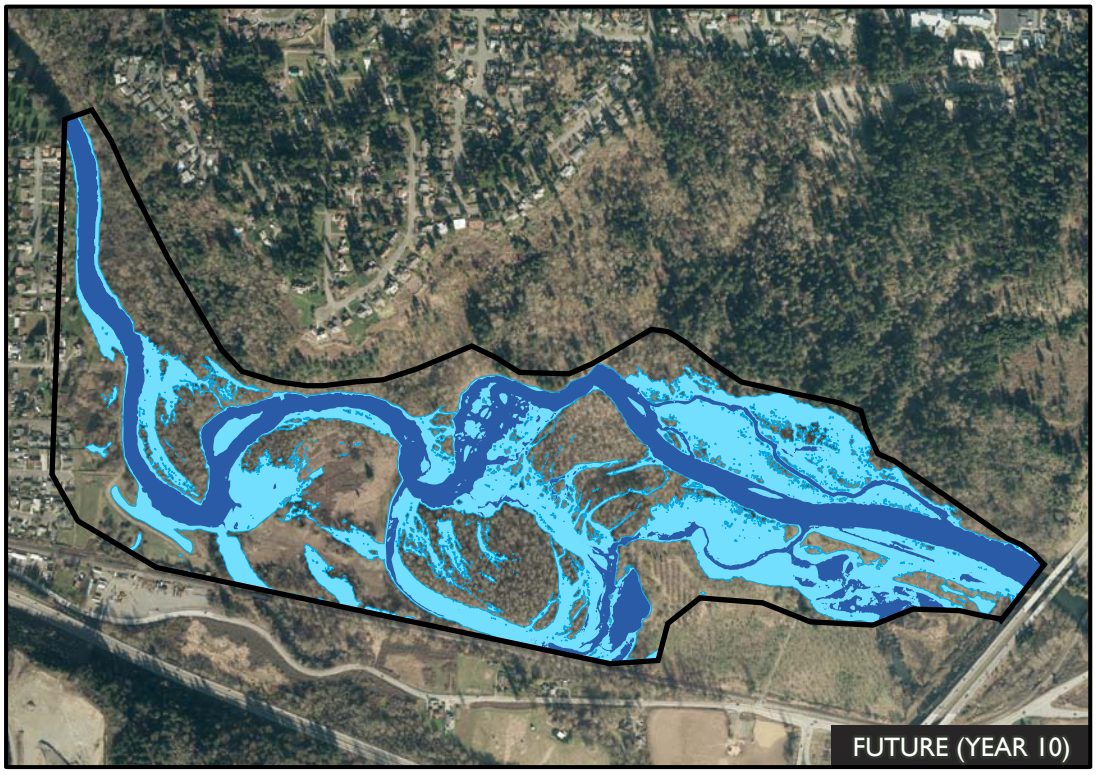
N

0 200 400
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure 11. Auburn Narrows maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.





Assessment Unit Boundary

Inundated Area 1800 cfs

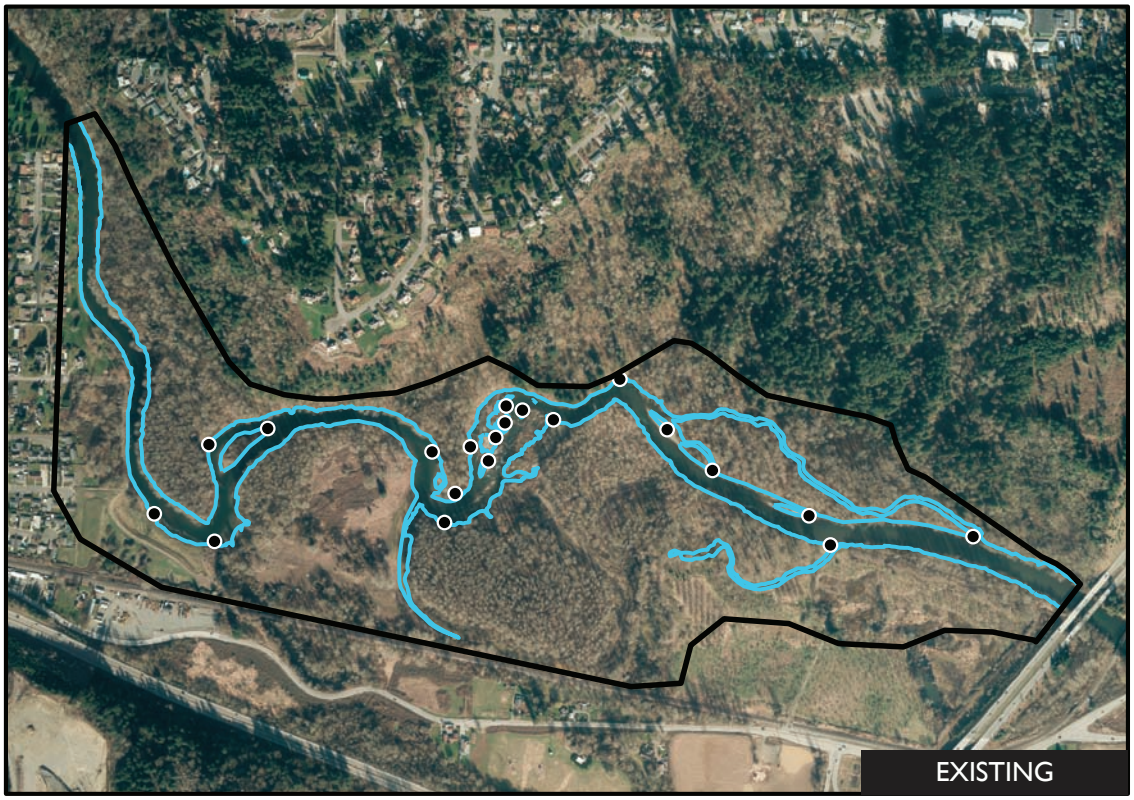
Inundated Area 8800 cfs

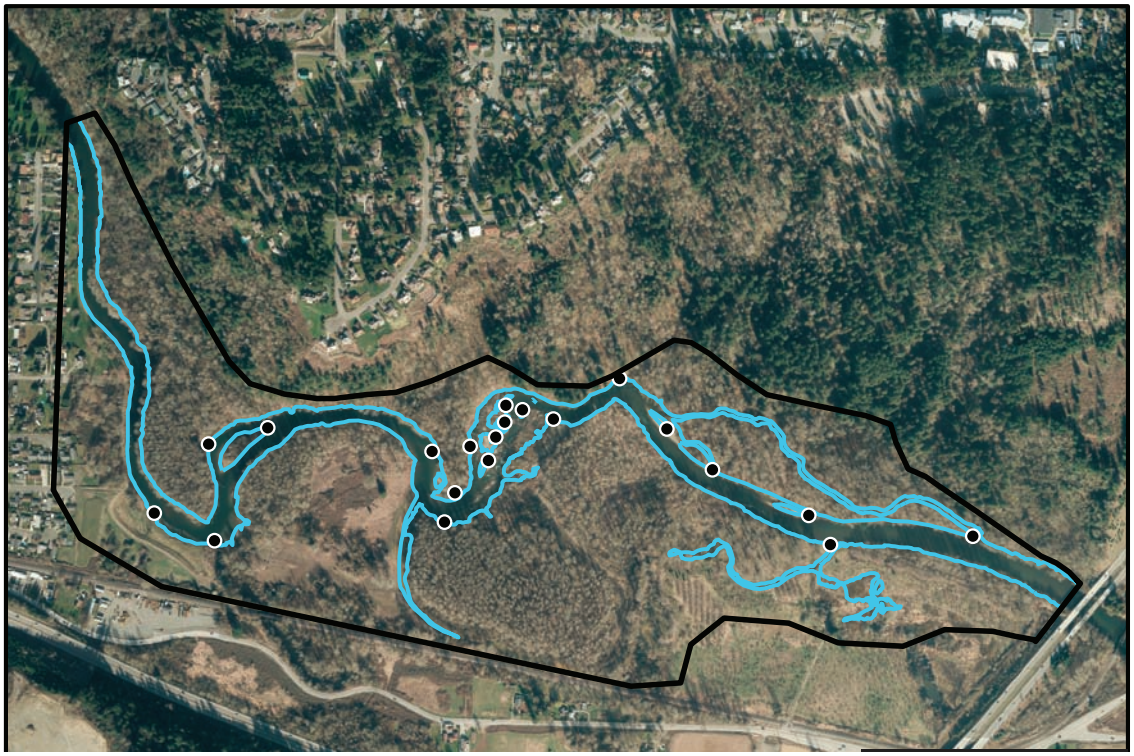
N

0 1,000

Feet

Figure 12. Auburn Narrows maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.





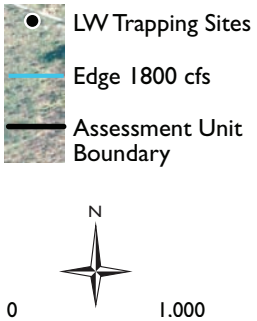


Figure 13. Auburn Narrows maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.

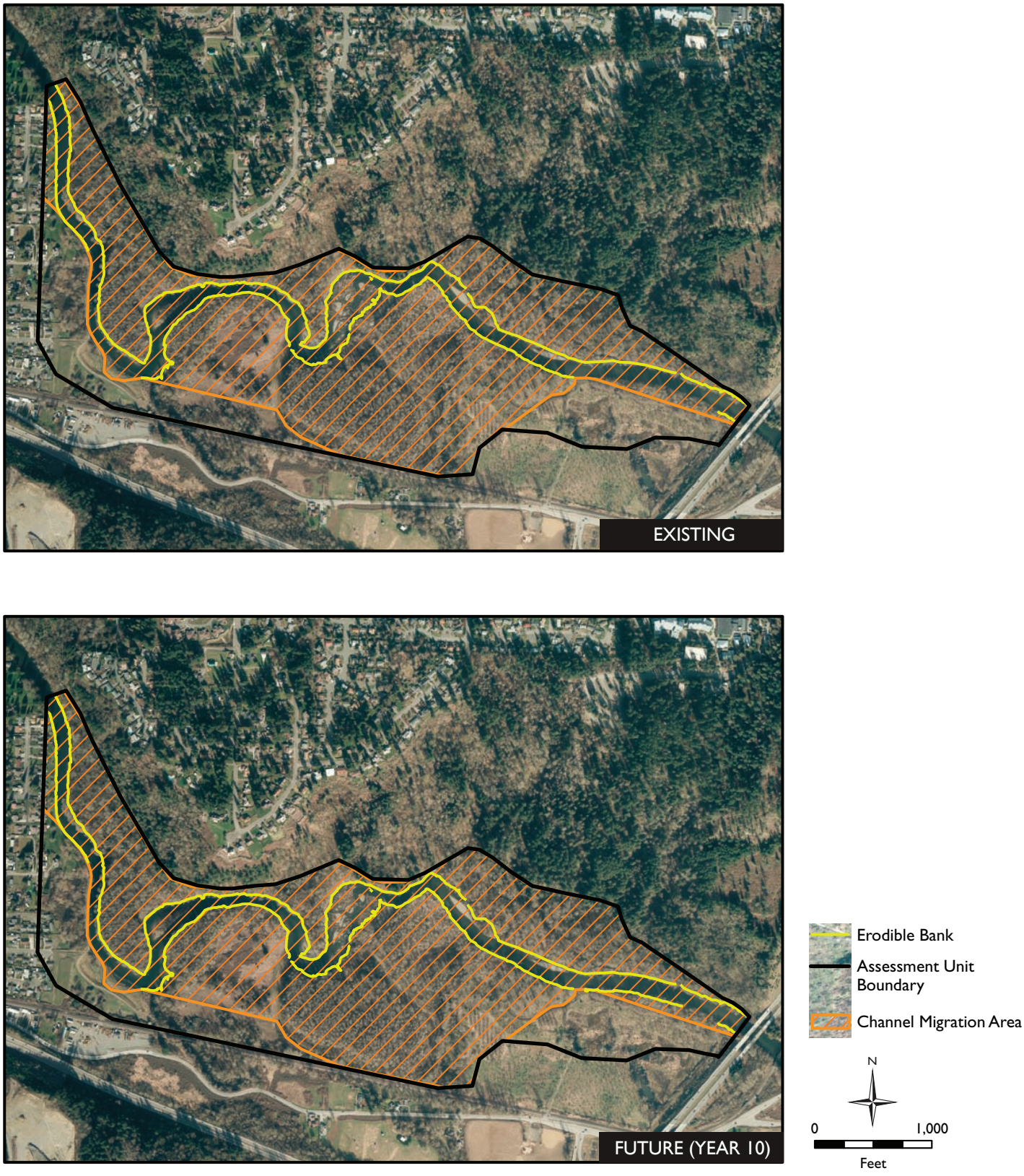
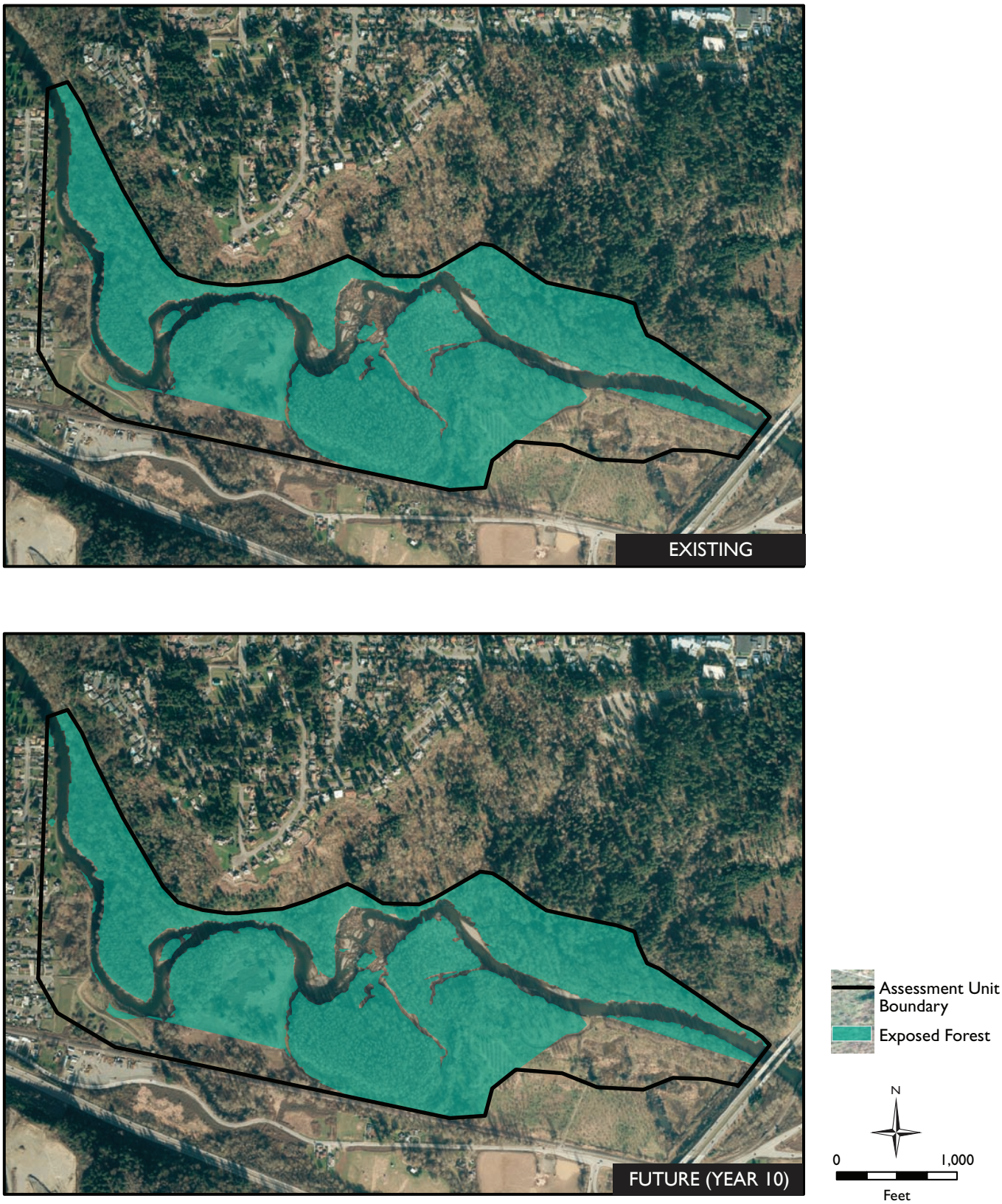


Figure 14. Auburn Narrows maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration.



Site 2: Porter

Figure 15. Porter site photos

Site Description

The 38-acre Porter project site is located on the left bank of the Middle Green River between RM 33.5 and RM 34.1 within Section 21, Township 21 N and Range 5E (Figure 16). Porter is located within the Upper Green APD. In 1961, King County acquired an easement on the property to facilitate access to construct and maintain a flood protection project (King County 2004). The Porter training levee was subsequently constructed to prevent channel migration. King County purchased the Porter site in 1998; it is currently managed as the Porter Levee Natural Area. Deed restrictions associated with the acquisition require that the property be used in perpetuity for habitat purposes. An existing 1,700-foot training levee is located adjacent to the Green River on the property. This training levee is constructed of native alluvium faced with angular rock. A portion of the former river channel (1.7 acres) is located behind the training levee, which forms an oxbow pond.

Existing Conditions

The river is prevented from migrating across the floodplain at the Porter site by the rock revetment on the left bank. An oxbow pond, which was once the river mainstem, was formed by the construction of the training levee. Connectivity between the mainstem and the oxbow pond was improved in 1999 by the excavation of an inlet and outlet in the training levee. Fish may enter the oxbow pond behind the training levee by swimming through the inlet or outlet, but access is limited during low flow periods. The inlet and outlet are less than 13 feet wide and at high flow, mainstem water velocities at both locations are rapid. The high velocities may prevent fish from locating the inlet or outlet and reaching the refuge area during flood flows.

Habitat conditions throughout the natural area are nearly static. The mainstem channel is relatively uniform. The Porter assessment unit contains 42.7 acres of inundated area at 1,800 cfs and 171.5 acres at 8,800 cfs. Wetted edge measures 36,200 feet and there are six wood trapping sites. Of the 57 acres that are currently exposed to channel migration in the assessment unit, 35 acres are currently forested and could supply wood to the river. Erodible banks measure 9,700 feet. Previous restoration projects at Porter also included re-vegetating pasture areas between 2001 and 2006.

Conceptual Project Design

This design is an updated version of the Green-Duwamish River ERP Alternative 3, which was the preferred design alternative for Porter (Figure 17). This design consists of removing 1,700 linear feet of the existing training levee, including its toe. A 2,000-linear foot rock setback structure would be constructed along the toe of the Green Valley Road. This new setback structure might include some flood control functions insofar as it is designed to prevent flooding of the road. Depending on the results of more detailed hydraulic analysis, the setback structure construction might require improvements to Green Valley Road. A 400-foot rock training levee would be constructed at the southeast corner of the property.

Indicator 1: Habitat Benefit Assessment

This project is expected to promote river migration toward the left bank and the formation of a point bar on the right bank. The point bar would likely contain a network of backwaters. The streambed in the project site is expected to aggrade, thereby increasing water surface elevations in the mainstem channel and the backwater along the Mosby farm road, which runs east-west along the southern property boundary. These two project effects— increased lateral erosion and streambed aggradation—may increase the inundated area in the assessment unit by roughly 7 acres at 1,800 cfs and by 3 acres at 8,800 cfs. A rise in the water surface elevation could also promote the extension and enlargement of some of the backwater areas on both sides of the river. As a result of backwater expansion and habitat features in the new point bar, the wetted edge length could increase by 10,000 feet. An additional four wood trapping sites are expected to form at the entrance of new side channel connections and on the new point bar. This project is eventually expected to expose an additional 30 acres of floodplain to erosion by the river and an additional 1,000 feet of the left bank would be erodible. The project could potentially give the river access to an additional 20 acres of existing forest capable of supplying wood for the river. Though the site has been planted before, some clearings remain; up to 8 acres could be planted with woody plants in the floodplain of the Porter site. A fraction of this area has already been planted with live stakes.

Table 10. Design Details for Porter

Category	Detail	Units	Value
Planning Context	WRIA 9 Plan Project Number	None	MG-17
	ERP Project Number	None	25
	Project Alternative	N/A	3
Existing Conditions	Area of Project Site	Acres	50.4
	Length of Existing Levee	Linear Feet	1,700
Proposed Actions	Levee to be Removed	Linear Feet	1,700
	Rock Revetment to be Removed	Linear Feet	1,700
	New Setback Levee to Construct	Linear Feet	1,845
	New Rock Revetment Structure to Construct	Linear Feet	2,000
	Planting Area	Acres	8
	Water Diversion	Each	1
	Land Removed from Agricultural Use	Acres	0
Affected Properties	Total Parcels	Number	2
	King County Parcels or Easements	Number	2
	Private Property Interests to Purchase	Number	0

Table 11. Habitat Benefit for Porter

Metric	Factor	Units	Alt 1	Alt 2	Alt 2 - Alt 1	Ecological Lift*
1	Inundated Area at 1800 cfs	Acres	42.7	49.9	7.2	7
2	Inundated Area at 8800 cfs	Acres	171.5	174.8	3.3	3
3	Wetted Edge Length	Feet	36,200	45,700	9,500	10,000
4	Large Wood Trapping Sites	Number	6	10	4	4
5	Channel Migration Area	Acres	57	82	25	30
6	Length of Erodible Bank	Feet	9,700	10,800	1,100	1,000
7	Wood Supply (Exposed Forest)	Acres	35	52	16	20
8	Replanting Area	Acres	0	8	8	8

**Rounded to reflect uncertainty in outcomes*

Indicator 2: Cost Assessment

The construction costs for Porter include training levee and rock removal, installation of the setback boundary protection, 8 acres of planting and water diversion that is required to maintain water quality during construction. The cost estimate included mass balance calculations that took into account material that would be hauled off site, imported for new construction and re-use of salvageable material. There would be cost savings if the training levee prism material is left in place and only the rock is removed. This would allow the river to erode away the training levee material and essentially achieve the same work as hauling away the material. Also included are costs associated with a removal and re-installation of approximately 400 feet of the Porter Levee at the upstream end. This element is included to match the ERP but may not be necessary. The design, permitting and outreach are estimated at 25% of construction total cost.

Indicator 3: Land Availability Assessment

Porter scores high for land availability because it is a King County-owned ecological land.

Future Design Analysis

The proposed project has the potential to both benefit and impact adjacent agricultural practices. Additional hydraulic analysis will be performed during preliminary design. The proposed setback structure has the potential to increase the frequency and duration of inundation and saturation of land directly adjacent to Green Valley Road. An analysis of the effects of the project on Green Valley Road and adjacent properties will be performed as part of detailed design development.

Table 12. Porter Standards Checklist

Standard	Description	Score Alt 3	Compliance
1	Dynamic Ecological Endpoint	0.33	Use of rock bank is not moving river to least degraded state possible, nor informed by reference sites.
2	Measurably Enhanced	1	Complies with standards
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

Table 13. Estimated Project Costs for Porter Alternative 3

Type of Cost	Total
Acquisition	$0
Design, Permitting and Outreach	$649,689
Construction	$2,598,758
Construction Management and Inspection	$389,814
Maintenance	$38,400
Monitoring	$200,000
Total Project Cost	**$3,876,661**

Table 14. Land Availability Assessment for Porter Alternative 2

Question	Description	Result
1	Receptive landowners?	Yes
2	Does site include FPP easements?	No
3	Does project maintain farmable area?	Yes

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VC File: wlrbafs1.dnrp.kingcounty.lcl/vc/cart/finished/workgroups/wlr/ecological services unit/1208_2670L_MGRF_Porter3EC.ai • L. Preston, DNRPIT GIS, Visual Comm. & Web Unit

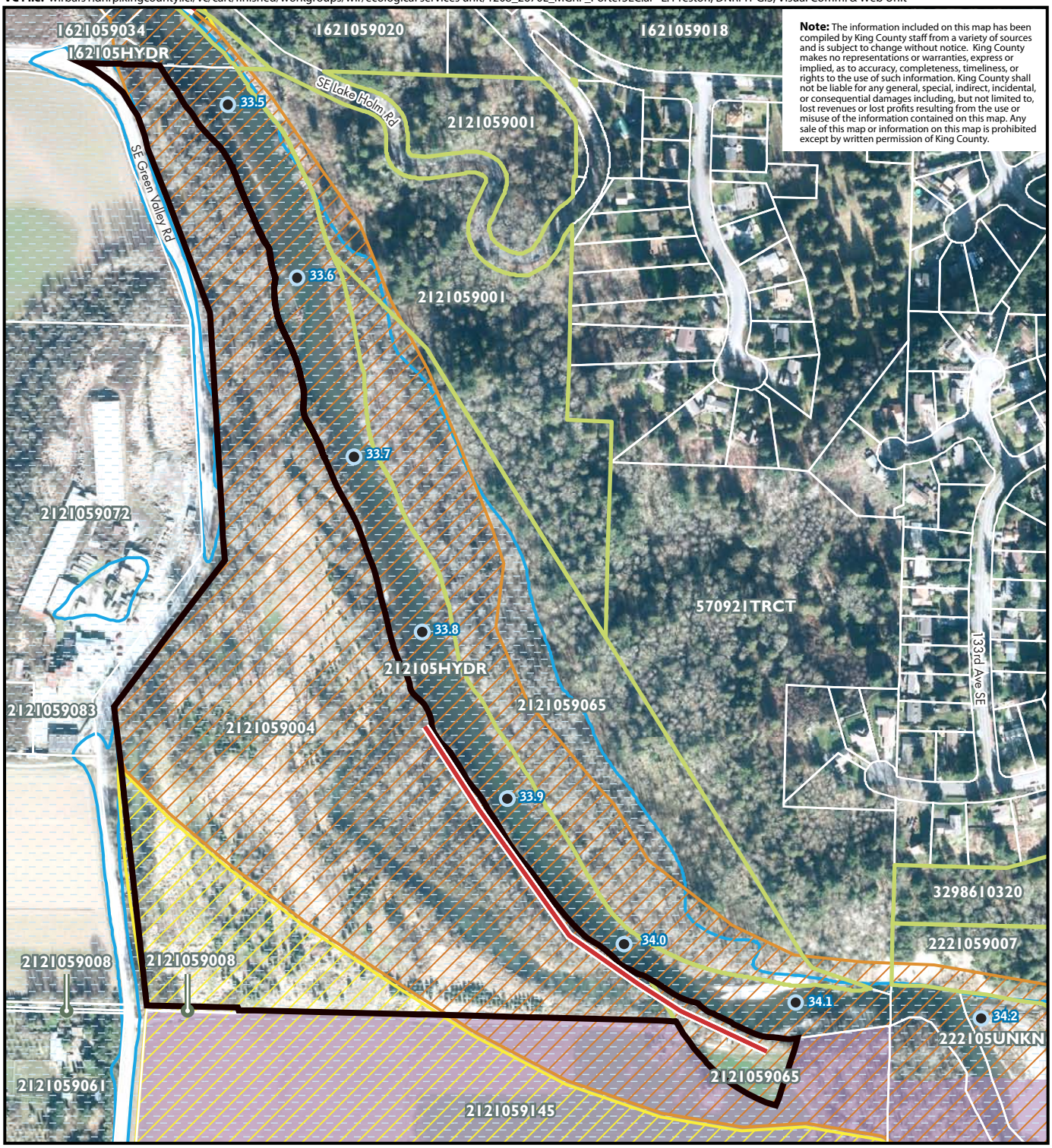

Figure 16

PORTER

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

N

0 200 400
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

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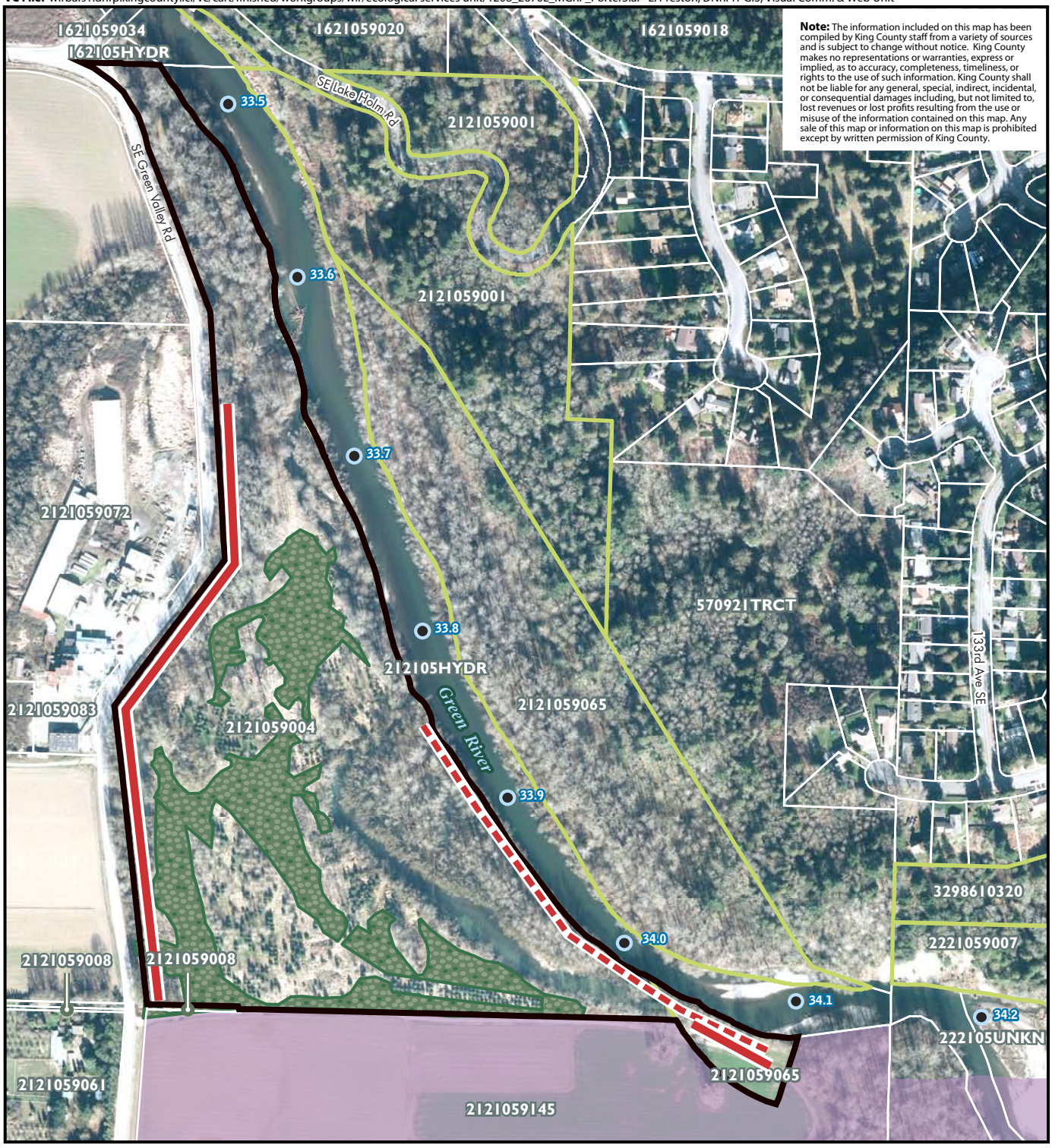
VC File: wlrbafs1.dnrp.kingcounty.lcl/vc/cart/finished/workgroups/wlr/ecological services unit/1208_2670L_MGRF_Porter3.ai • L. Preston, DNRPIT GIS, Visual Comm. & Web Unit



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N

0 200 400
Feet

Figure 17
PORTER
Alternative 2

- Project Area Boundary
- Existing Levee
- New Setback Structure
- Levee to Be Removed
- Replanting Area
- King County Owned Parcel
- Parcel Boundary & No.
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

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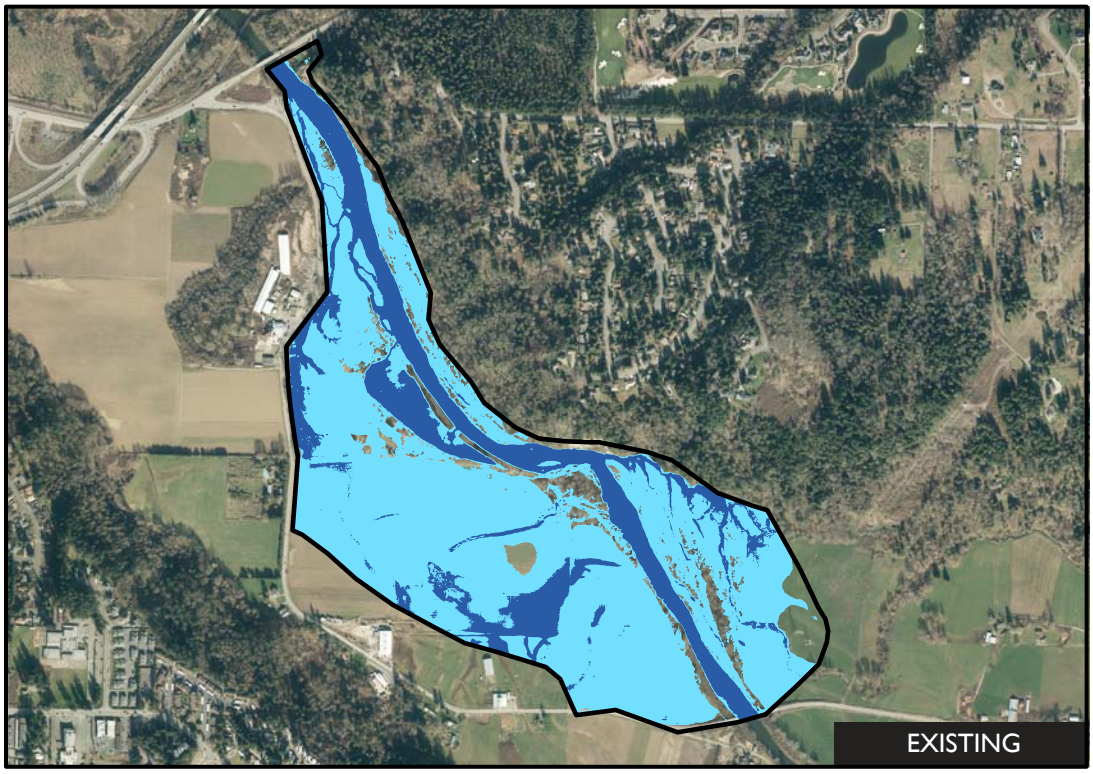
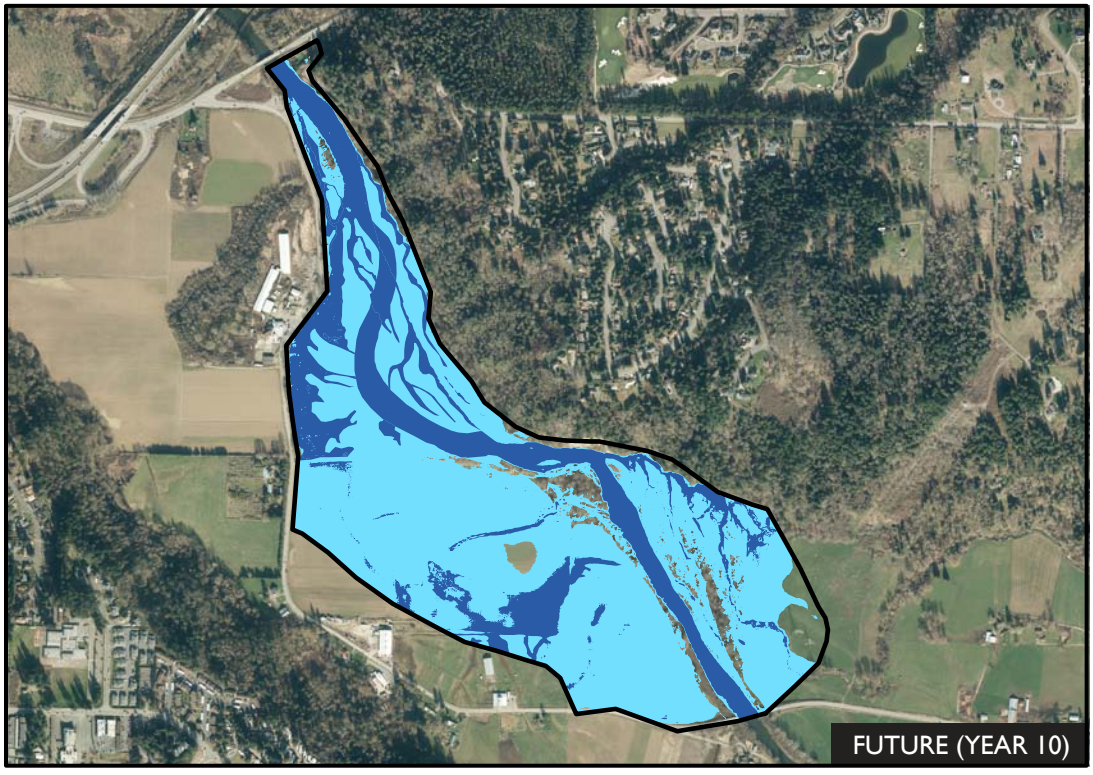
Figure 18. Porter maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.





Assessment Unit Boundary

Inundated Area 1800 cfs

Inundated Area 8800 cfs

N

0 1,000

Feet

Figure 19. Porter maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.

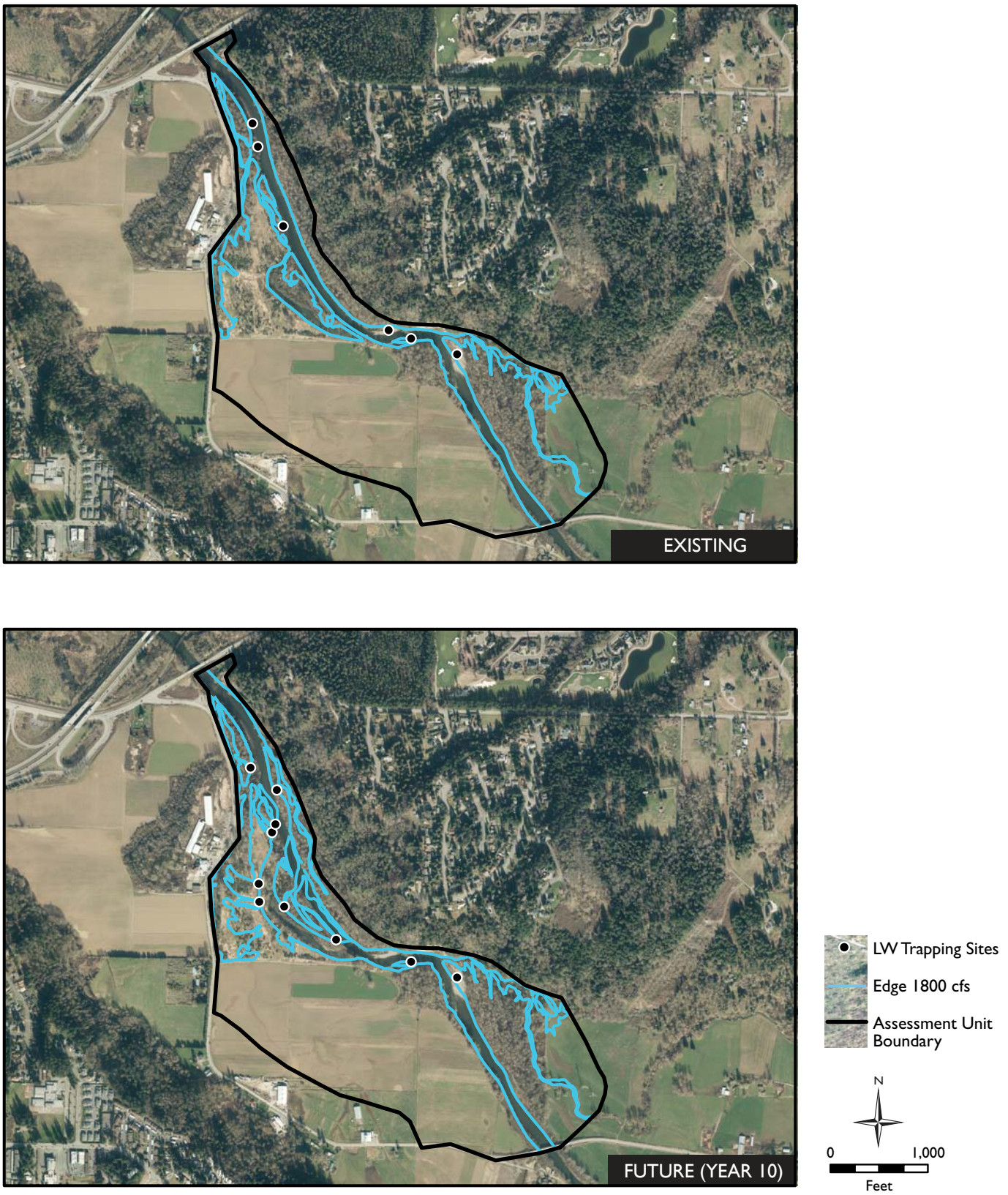


Figure 20. Porter maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.

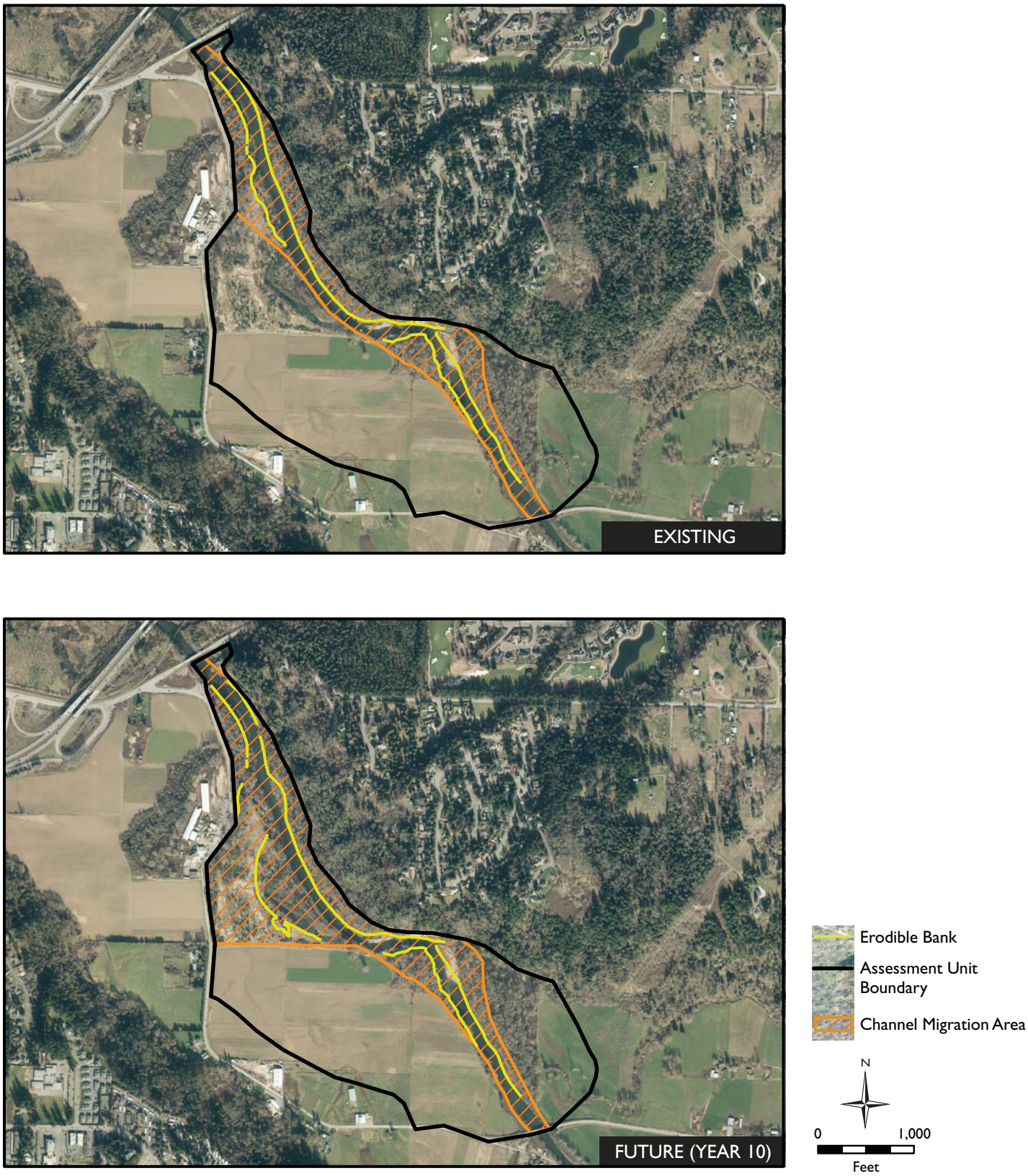
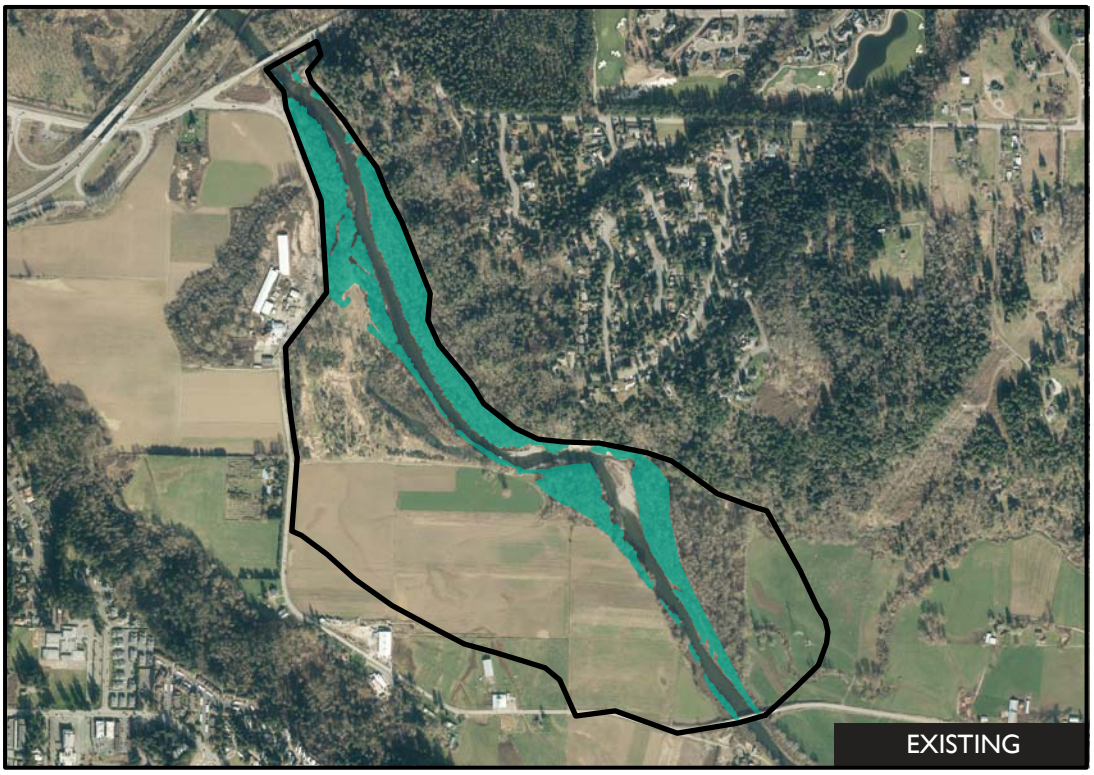
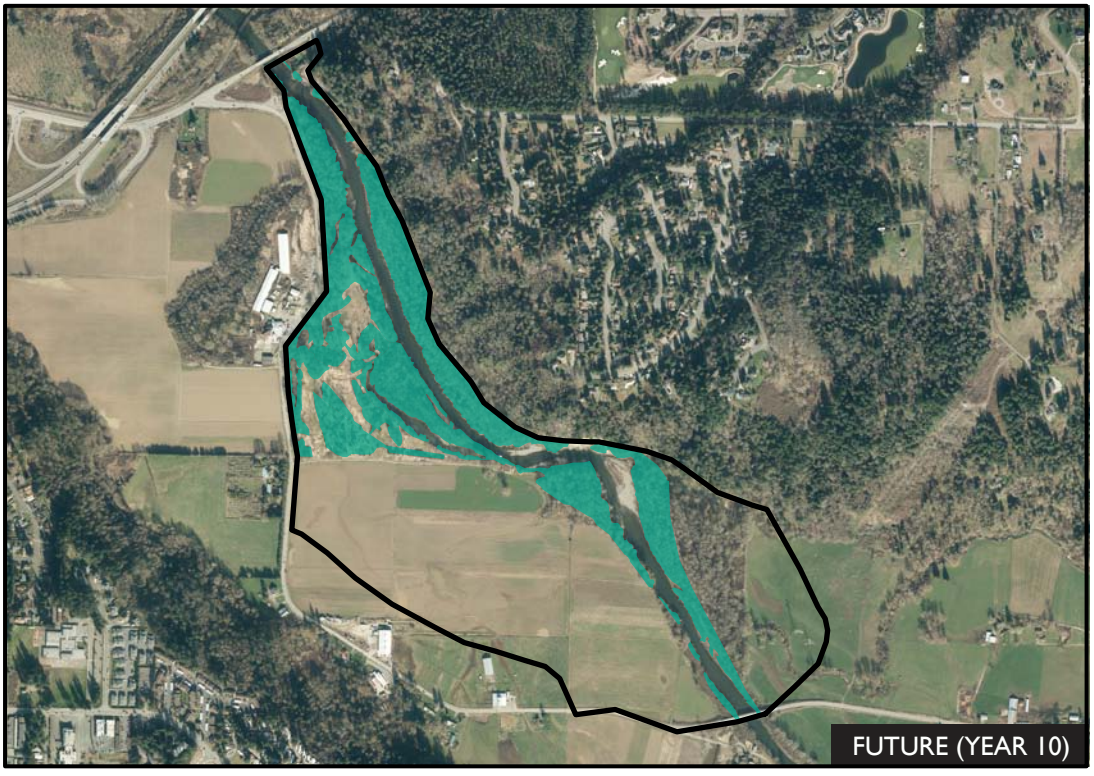
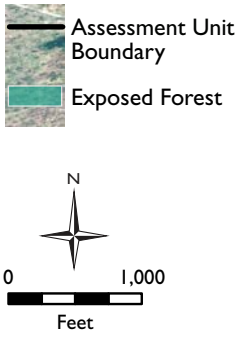


Figure 21. Porter maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration and replanting areas.







Site 3: Ray Creek

Site Description

The Ray Creek project site is located on the right bank of the Middle Green River near RM 35 (Figure 23). Ray Creek is a wall-based tributary to the Middle Green River (WRIA 09.0098) that occupies a former Green River side channel on private property. Ray Creek is located within the south half of Section 22 and 23, Township 21, Range 5 East.

Figure 22. Ray Creek site photos.

Existing Conditions

Habitat conditions in Ray Creek are primarily limited by the lack of a functional riparian forest, a scarce supply of instream wood, livestock access to the stream and encroachment by reed canarygrass and other invasive plants. Some trees exist near the stream, but the riparian forest has mostly been cleared and replaced with pasture grasses. The stream is significantly exposed to the sun throughout the day.

Habitat indicators used for the other riverine projects in the study were not applicable to Ray Creek because most of the project area is within a floodplain tributary.

Conceptual Project Design

This design consists of installing 11,400 linear feet of livestock exclusion fence and planting 8 acres of riparian buffer along Ray Creek (Figure 24). The fence would be set 25 feet from the edge of the stream. This project is designed to benefit salmonids primarily by providing juvenile salmon with improved riparian habitat in a floodplain tributary.

Indicator 1: Habitat Benefit Assessment

The primary habitat benefit of this project would be the creation of an additional 8 acres of riparian and floodplain planting, which would provide shade for the stream, future wood deposits to the channel and eventually the Green River, and wildlife habitat.

Table 15. Design Details for Ray Creek

Category	Detail	Units	Value
Planning Context	WRIA 9 Plan Project Number	None	MG-16
	ERP Project Number	None	27
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	40.2
Proposed Actions	Fencing to Construct	Linear Feet	11,400
	Planting Area	Acres	8
	Land Removed from Agricultural Use	Acres	0[1]
Affected Properties	Total Parcels	Number	12
	King County Parcels or Easements	Number	1
	Private Property Interests to Purchase	Number	11

Table 16. Habitat Benefit for Ray Creek

Metric	Factor	Units	Alt 1	Alt 2	Alt 2 - Alt1	Ecological Lift*
1	Inundated Area at 1800 cfs	Acres	n/a			0
2	Inundated Area at 8800 cfs	Acres	n/a			0
3	Wetted Edge Length	Feet	n/a			0
4	Large wood trapping sites	Number	n/a			0
5	Channel Migration Area	Acres	n/a			0
6	Length of Erodible Bank	Feet	n/a			0
7	Wood Supply (Exposed forest)	Acres	n/a			0
8	Replanting Area	Acres	0	8	8	8

*Rounded to reflect uncertainty in outcomes

Table 17. Ray Creek Standards Checklist

Standard	Description	Score Alt 2	Sources of Non-Compliance
1	Dynamic Ecological Endpoint	0.67	Does not move river toward least degraded or most dynamic possible.
2	Measurably Enhanced	0.67	May not measurably change amount of refuge habitat and habitat complexity in the mainstem of the Green River.
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

Indicator 2: Cost Assessment

The construction costs for Ray Creek is associated with planting and fencing along the riparian buffer.

Table 18. Estimated Project Costs for Ray Creek

Type of Cost	Total
Acquisition	$0
Design, Permitting and Outreach	$136,778
Construction	$341,946
Construction Management and Inspection	$51,292
Maintenance	$38,400
Monitoring	$25,000
Total Project Cost	**$593,416**

Indicator 3: Land Availability Assessment

Easements or acquisition would be required for 15.7 acres on 11 privately owned parcels. One parcel is owned by King County.

The project site is used as pasture for a diary calf farm. None of the parcels are part of the FPP. The property owner is not interested in the proposed project because it will require him to maintain additional fence.

Table 19. Land Availability Assessment for Ray Creek

Question	Description	Result
1	Receptive landowners?	No
2	Does site include FPP easements?	No
3	Does project maintain farmable area?	Yes

Future Design Analysis

As previously noted, the property owned is not interested in the proposed project because the additional fencing along Ray Creek will require additional maintenance. This issue could be addressed, perhaps by leasing and maintaining the fence until the buffer is established.

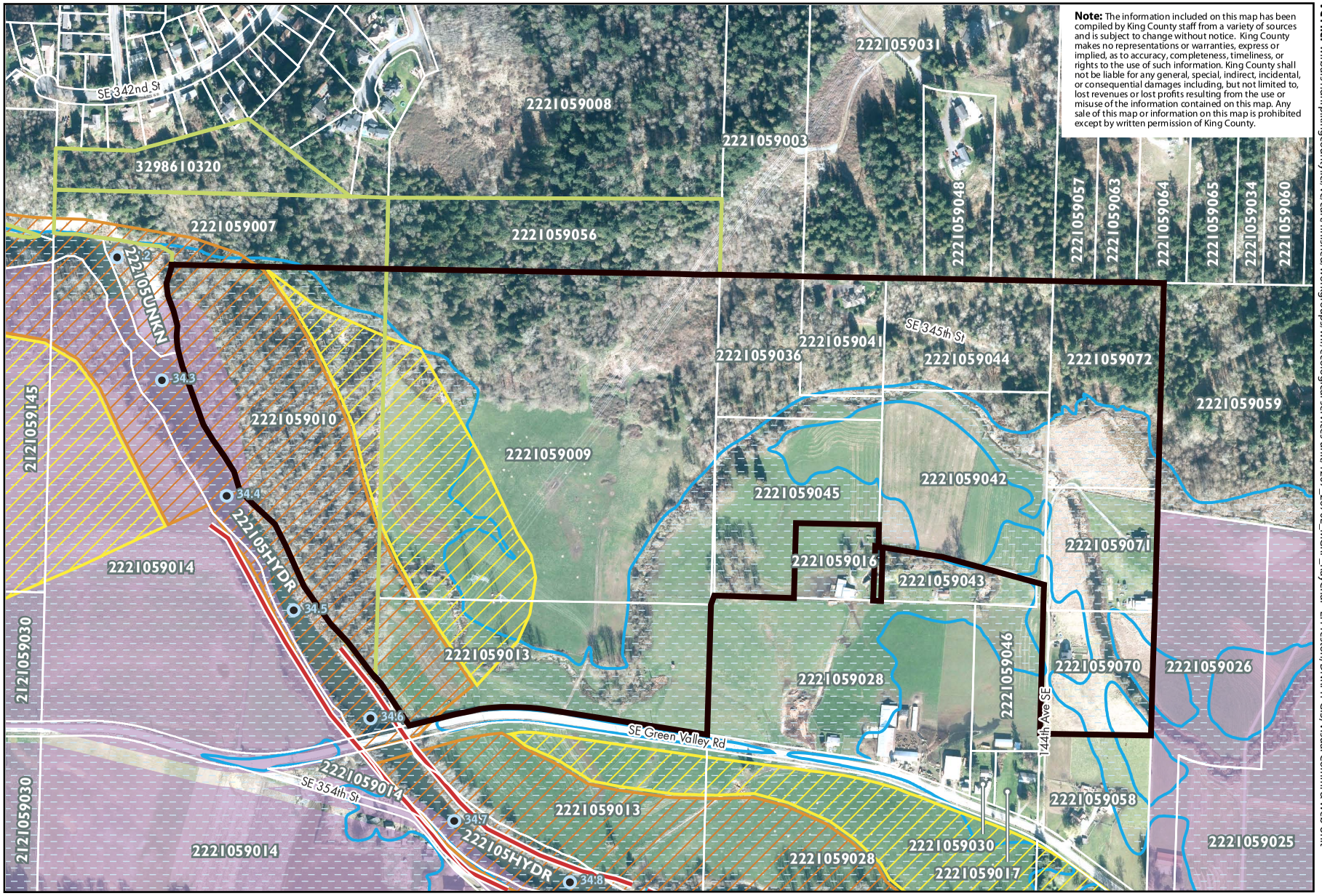


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Figure 23

RAY CREEK

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

N

0 250 500

Feet

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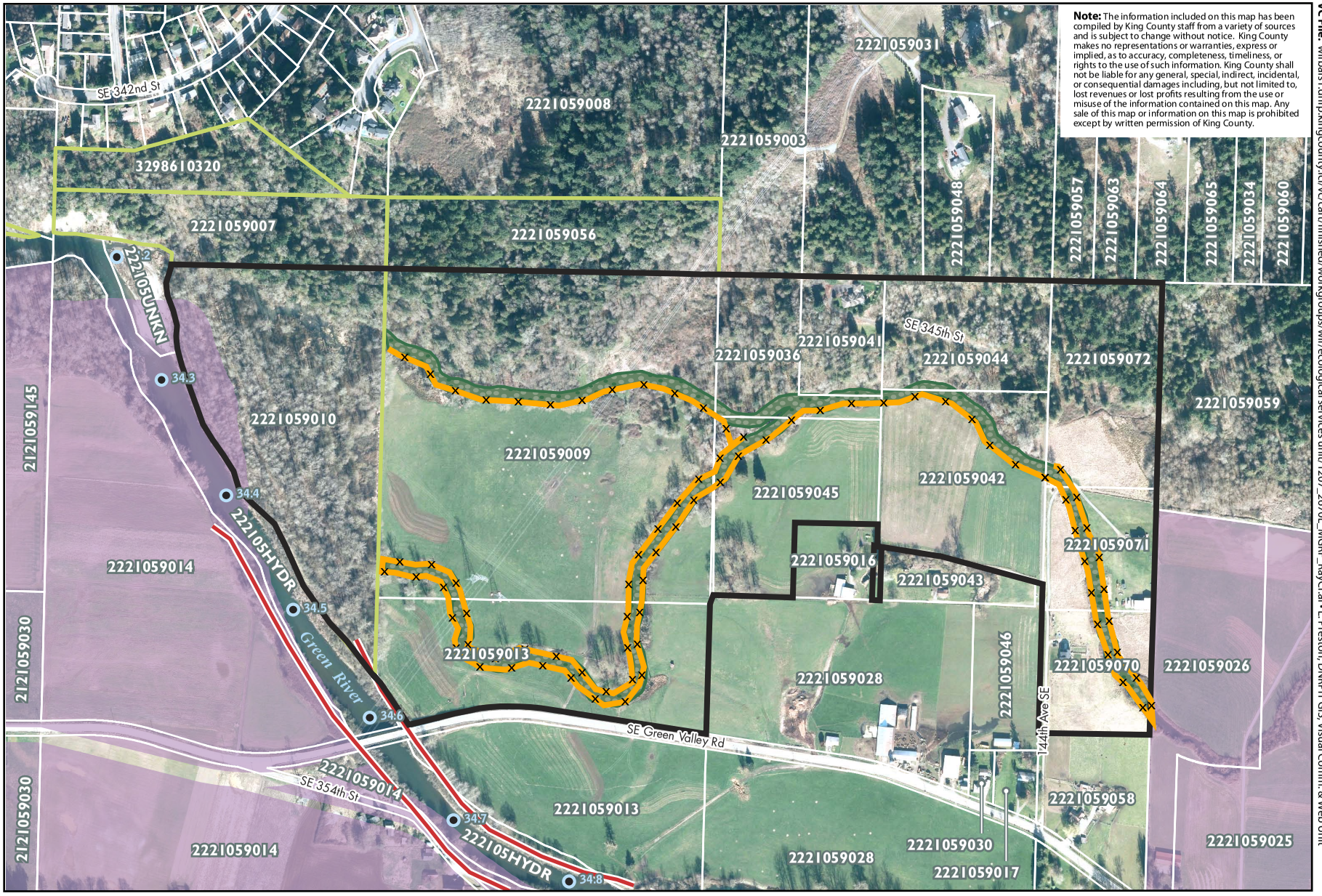

Figure 24

RAY CREEK

Alternative 2

Project Area Boundary
Existing Levee
Fencing
Replanting Area

King County Owned Parcel
Parcel Boundary & No.
Farmland Preservation Program Properties

N
0 250 500
Feet

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Site 4: Neely

Figure 25. Neely site photo

Site Description

The Neely project site is located on the left bank of the Middle Green River between RM 35.5-35.7, Northeast Section 27, Township 21, Range 52, immediately north of Neely Bridge (Figure 26). The Neely site is located within the Upper Green APD and consists of one privately owned parcel that is enrolled in the FPP. King County owns a flood control easement along the training levee that allows access for maintenance and inspection.

Existing Conditions

Habitat conditions at Neely are primarily constrained by training levees, which prevent channel migration and inhibit the formation of logjams. The channel is uniform with few off-channel areas for juvenile rearing. Near the downstream end of the assessment unit, the river has the potential to migrate laterally into the forested floodplain, but is unlikely to do so because the confinement imposed by the Neely bridge facility on the right bank keeps the channel in a relatively stable position.

The Neely assessment unit contains 15.3 acres of inundated area at 1,800 cfs and 72.5 acres at 8,800 cfs (Table 21). Wetted edge measures 14,800 feet, and there are two wood trapping sites. An estimated 21.5 acres are exposed to channel migration, of which 12 acres are forested and could eventually supply wood to the river. Erodible banks measure 3,800 feet.

Conceptual Project Design

This design consists of adding two ELJs to the left bank of the Neely site to promote lateral migration towards the right bank and Ray Creek (Figure 27). The purpose of these ELJs would be to promote the gradual development of a channel meander in an otherwise straight reach, as has been documented in more natural settings. The existing training levees would be left intact. The training levee on the right bank only extends approximately 450 feet downstream from Neely Bridge, and it is not expected to prevent the river from adjusting to the presence of ELJs.

Table 20. Neely Design Details

Category	Detail	Units	Value
Planning Context	WRIA 9 Plan Project Number	None	MG-15
	ERP Project Number	None	
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	59.2
	Length of Existing Levee	Linear feet	1,905
Proposed Actions	New Engineered Log Deflection Structures to Construct (ELJ)	Each	2
	Water Diversion	Each	1
	Land Removed from Agricultural Use	Acres	0
Affected Properties	Total Parcels	Number	1
	King County Parcels or Easements	Number	1
	Private Property Interests to Purchase	Number	0

Indicator 1: Habitat Benefit Assessment

This project is intended to cause the river channel to migrate toward the right bank and create a bar with backwaters and side channels behind the engineered logjam (Figure 28). This is a plausible but uncertain outcome. The resulting mainstem would be more sinuous and flows would potentially split into low-lying relic channels within the forested floodplain on the right bank. The channel response could increase inundated area by 1.0 acres at 1,800 cfs and 0.2 acres at 8,800 cfs. The added sinuosity and connections to abandoned channels on the right bank could increase edge habitat by 6,000 feet (Figure 29). Four additional wood trapping sites could form; one at the upstream ELJ, another near the apex of the point bar, and one at each of the side channel inlets on the right bank, across from the logjams. The ELJs may succeed in overcoming the indirect constraints on channel movement from Neely Bridge and effectively expand the area exposed to channel migration by four acres, which is currently forested (Figure 30). This would likely recruit some wood to jams that might form at the side channel inlets on the right bank.

Indicator 2: Cost Assessment

The construction cost is for the installation of two ELJs.

Table 23. Estimated Project Costs for Neely

Type of Cost	Total
Acquisition	$0
Design, Permitting and Outreach	$127,540
Construction	$318,850
Construction Management and Inspection	$47,827
Maintenance	$5,000
Monitoring	$30,000
Total Project Cost	**$529,217**

Table 21. Neely Habitat Benefit

Metric	Factor	Units	Alt 1	Alt 2	Alt 2 - Alt 1	Ecological Lift*
1	Inundated Area at 1800 cfs	Acres	15.3	16.3	1.0	1
2	Inundated Area at 8800 cfs	Acres	72.5	72.7	0.2	0
3	Wetted Edge Length	Feet	14,835	20,700	5,900	6,000
4	Large Wood Trapping Sites	Number	2	6	4	4
5	Channel Migration Area	Acres	21	25	3.5	0
6	Length of Erodible Bank	Feet	3,800	3,900	100	0
7	Wood Supply (Exposed forest)	Acres	12	16	3.4	0
8	Replanting Area	Acres	0	0	0	0

*Rounded to reflect uncertainty in outcomes

Table 22. Neely Standards Checklist

Standard	Description	Score Alt 2	Compliance
1	Dynamic Ecological Endpoint	0.67	Not moving toward least degraded and most dynamic possible.
2	Measurably Enhanced	1	Complies with standards
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

Indicator 3: Land Availability Assessment

The Neely site is privately owned and enrolled in FPP. King County owns a flood control easement across the site. Construction of the ELJs may require obtaining temporary construction easements. The existing property owner had concerns that the proposed project would negatively affect the flood control functions of the existing training levee.

Table 24. Land Availability Assessment for Neely

Question	Description	Result
1	Receptive landowners?	Some
2	Does site include FPP easements?	Yes
3	Does project maintain farmable area?	Yes

Future Design Analysis

Further design development should include additional hydraulic analysis to evaluate how the proposed project would affect existing flooding, transportation, agriculture and recreational safety. Any ELJs would have to address recreational boater safety as well.

There is some potential for modifying a portion of the existing bank protection underneath the Neely Bridge. This option was not explored in the study because it was deemed that there were insufficient benefits to justify the potential costs and complications.

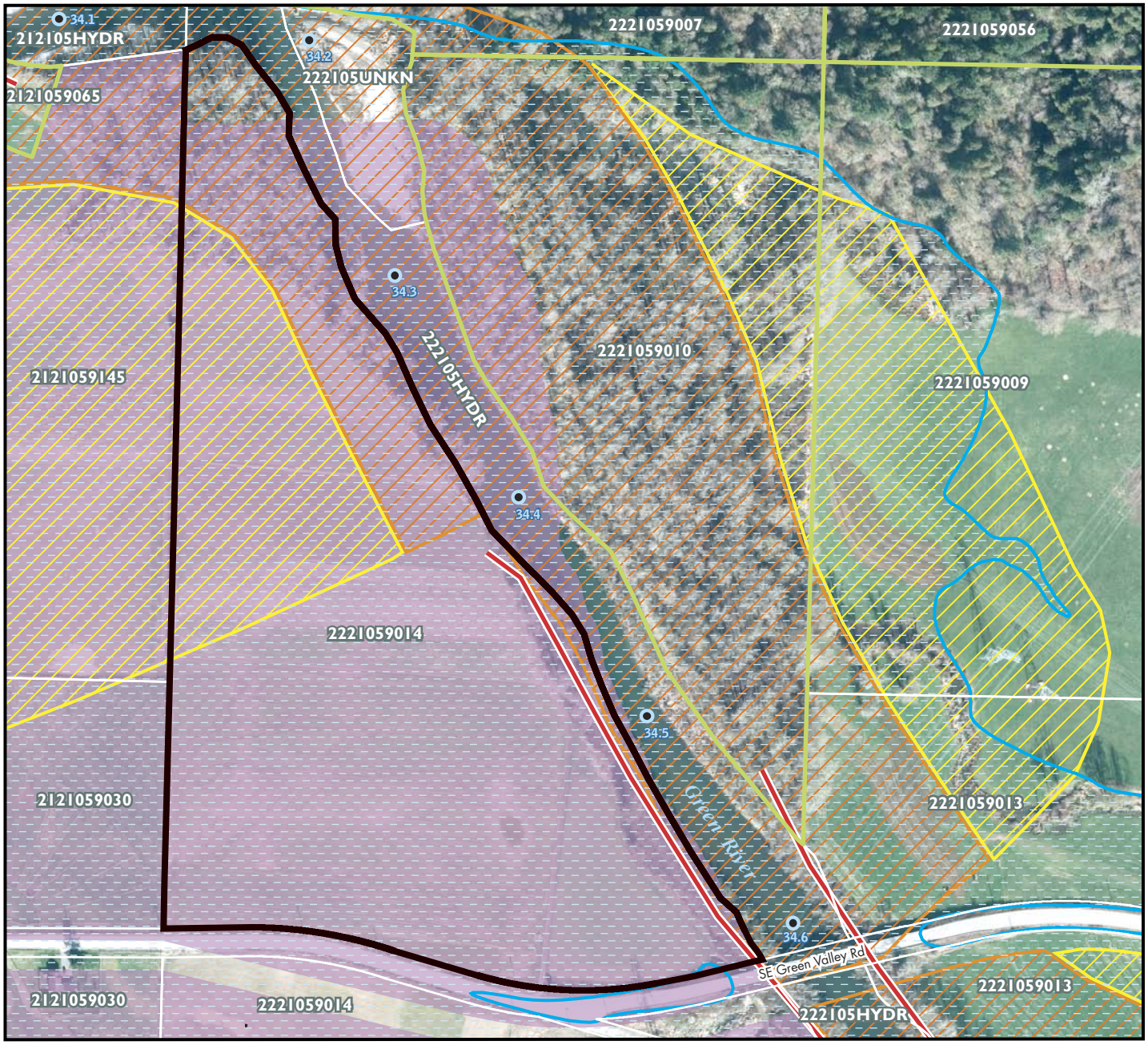

Figure 26

NEELY

Alternative 1 (Existing Conditions)

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

- Project Area Boundary
- River Facilities
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

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Feet

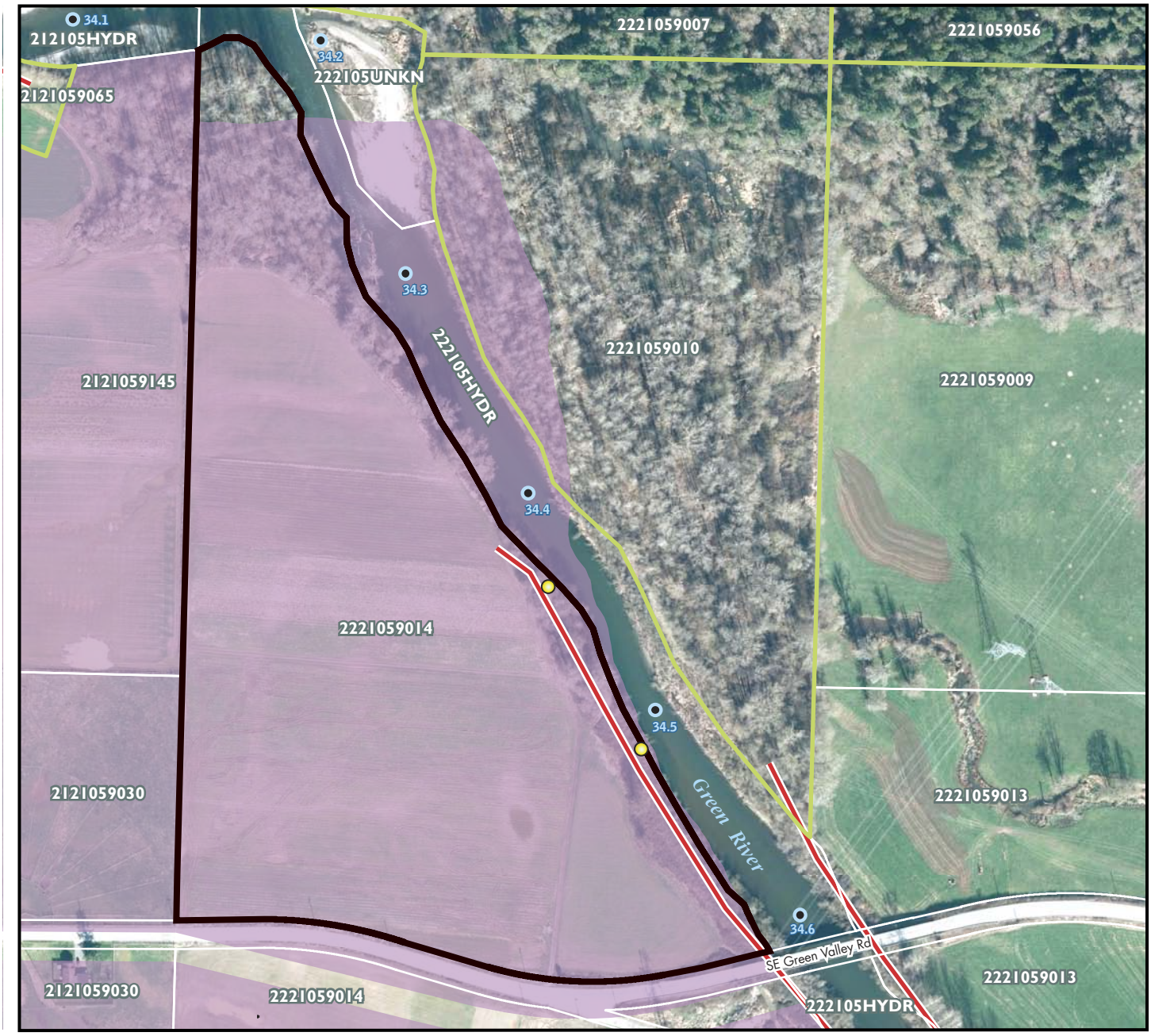

Figure 27

NEELY

Alternative 2

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

- Engineered Log Structure
- Project Area Boundary
- River Facilities
- King County Owned Parcel
- Parcel Boundary & No.
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

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N

0 100 200 300
Feet

Figure 28. Neely maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.

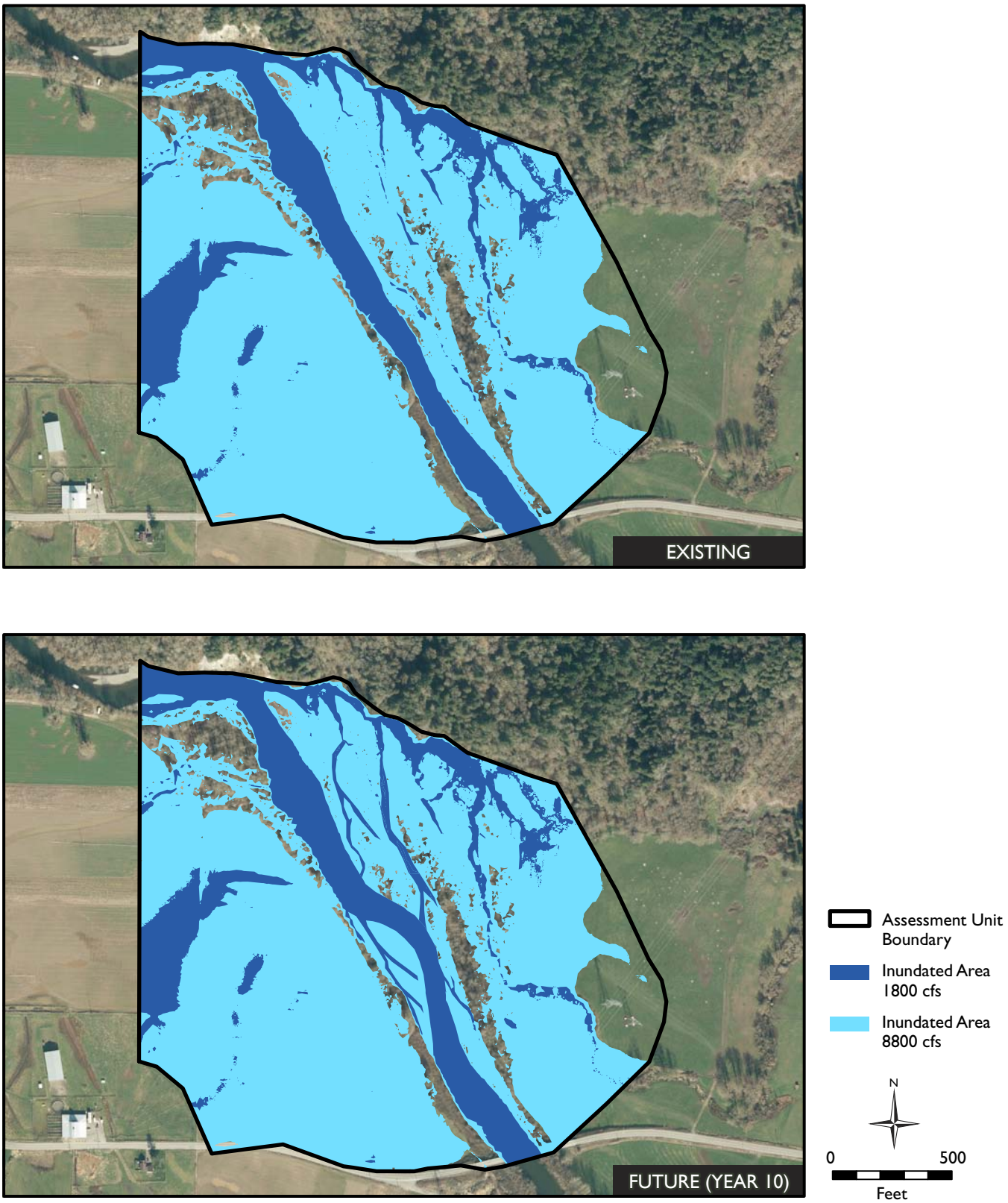


Figure 29. Neely maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.

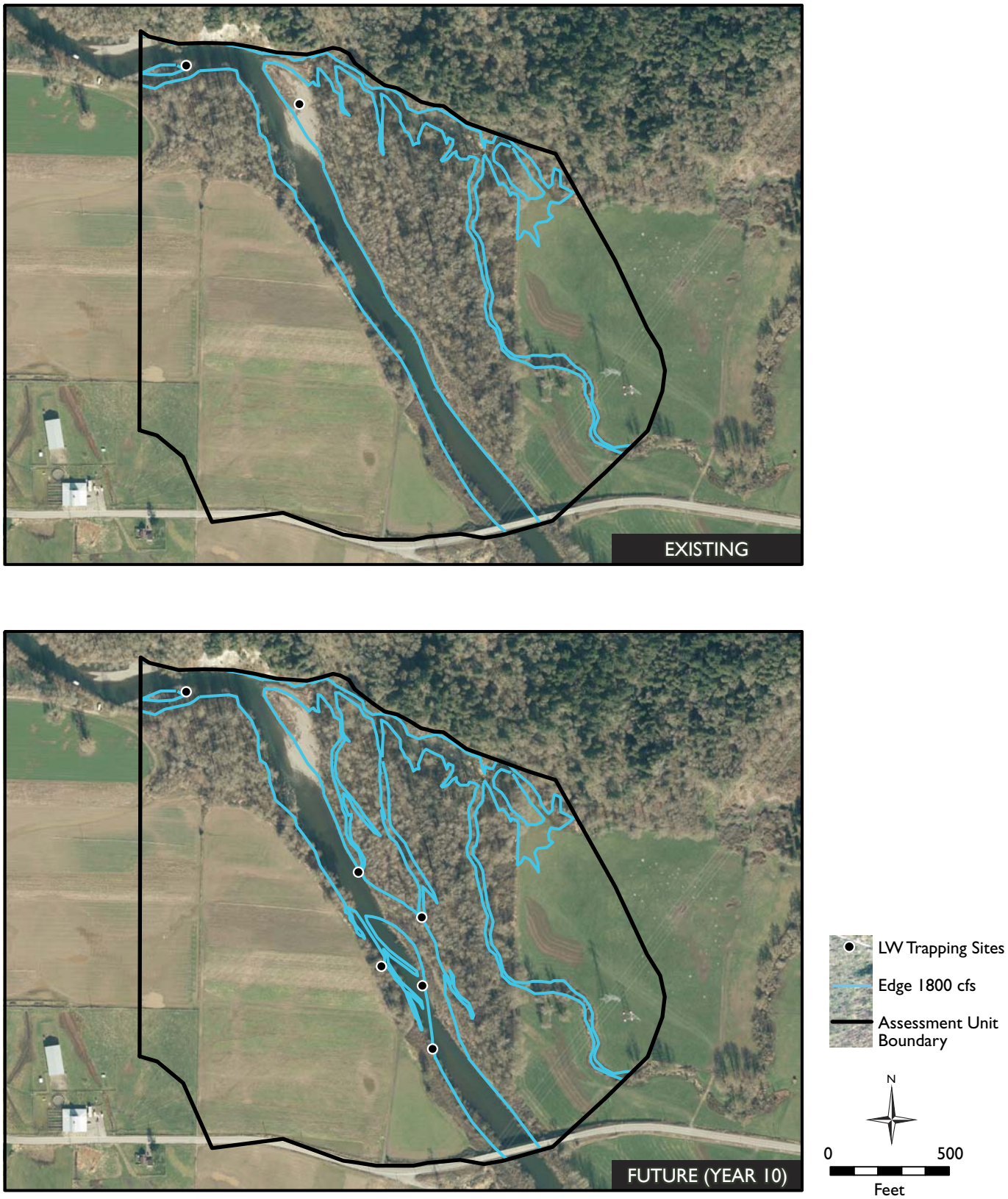


Figure 30. Neely maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.

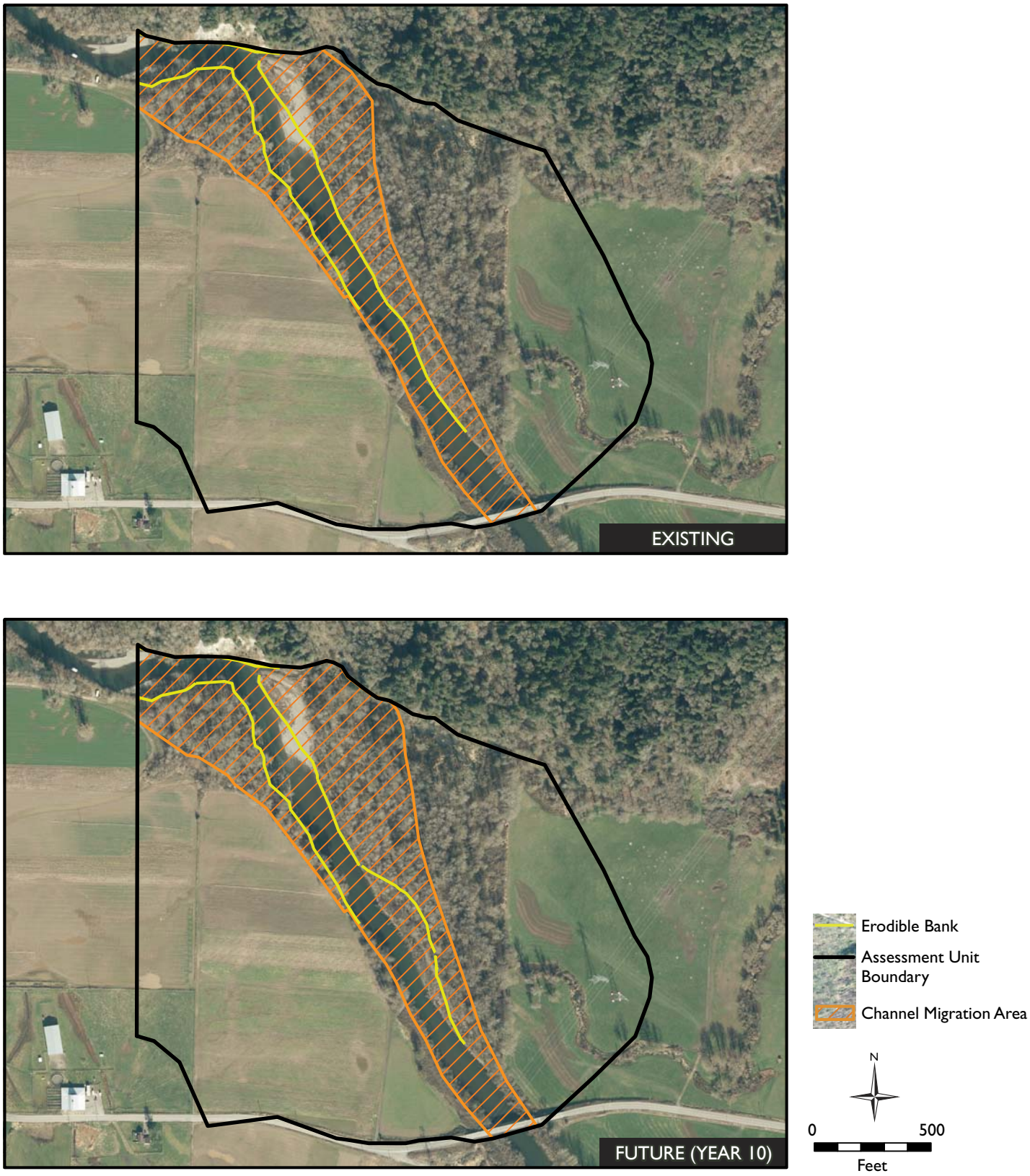
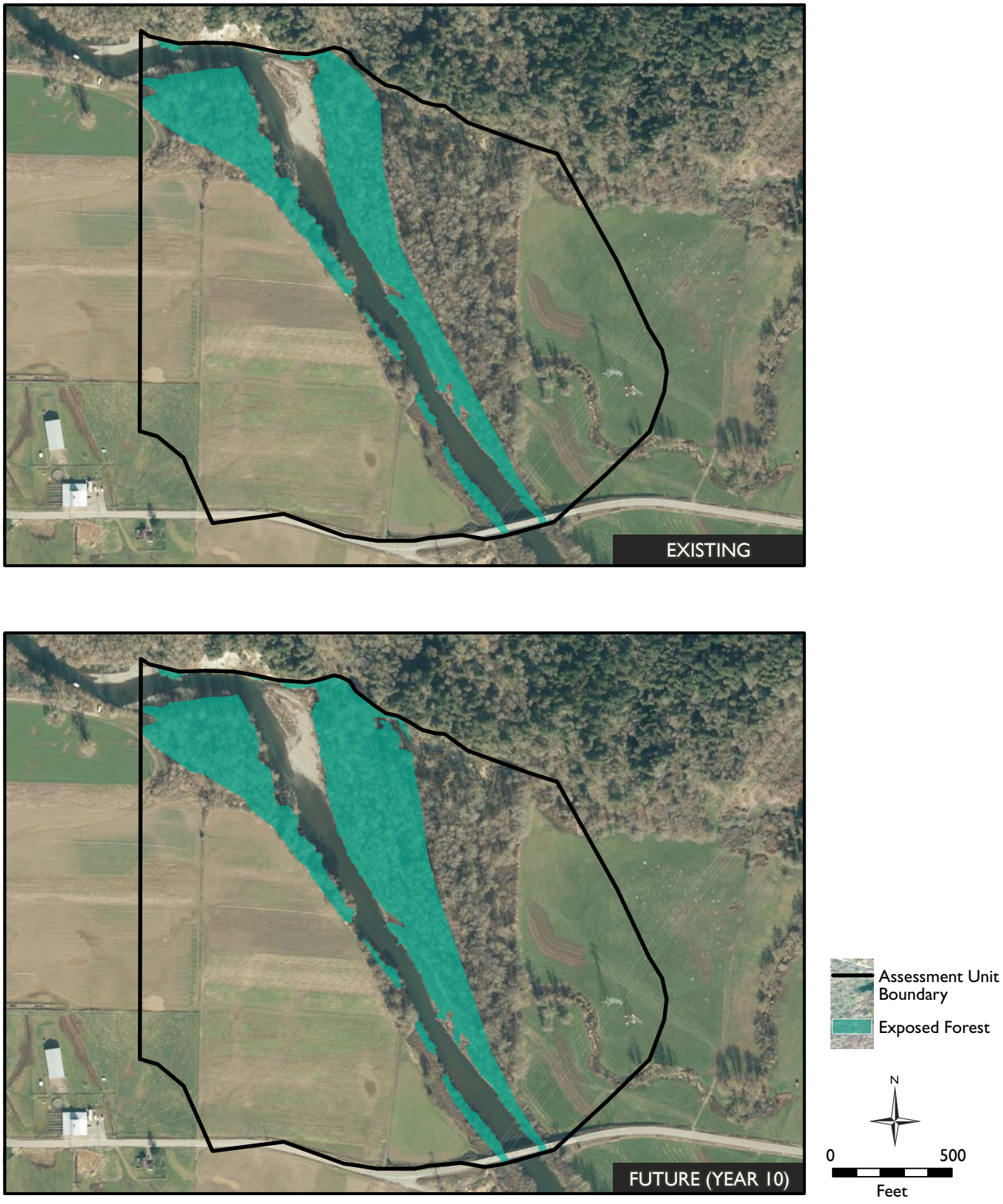


Figure 31. Neely maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration.



Site 5: Horath

Site Description

The Horath site is located on the right bank at RM 35.3, Southwest Section 22, Township 21 North, Range 5 East (Figure 33). It is located east of the Neely Bridge. The site consists of a low terrace with an oxbow pond formed by a training levee. Most of the site is grazed cattle pasture with some riparian vegetation along the banks of the training levee. King County owns a flood control easement along the training levee that allows access for maintenance and inspection.

Existing Conditions

Habitat conditions at the Horath site are impaired by training levees on both banks of the river and by extensive riparian clearing. This reach was once far more complex than it is today; it historically contained multiple channels with forested islands. The mainstem channel contains little or no large wood and it lacks off-channel habitat, with the exception of one large oxbow pond on the right bank, behind the revetment. Similar to Porter, this feature was once an historic mainstem channel that was isolated by the placement of the training levee. This feature intercepts groundwater and connects the mainstem through a notch between the revetments. It holds open water year-round and is accessible to fish at most springtime flows.

The Horath assessment unit contains 24.2 acres of inundated area at 1,800 cfs and 108 acres at 8,800 cfs. Wetted edge measures 21,800 feet and there are eight wood trapping sites. An estimated 86 acres are currently exposed to channel migration. Virtually all of this area exists in the portion of the assessment unit upstream from the facilities. Forests cover 44 acres of this area and could supply wood to the river. Erodible banks measure 7,600 feet.

Conceptual Project Design

This design consists of removing the existing training levee and constructing a setback structure approximately 100 feet west of and parallel to Green Valley Road (Figure 34). The existing pasture would be planted with riparian and floodplain vegetation to create a riparian buffer prior to the removal of the existing training levee. The downstream end of the new setback structure would be tapered to protect Neely Bridge.

Figure 32. Horath site photos

Indicator 1: Habitat Benefit Assessment

Removal of the training levee would allow the river to form a pronounced meander bend on the right bank, potentially facilitating the abandonment of the current mainstem channel in the lower part of the site (Table 26). If this scenario took place, it is assumed that the original mainstem channel would persist, along with multiple backwater or side-channel features, fed by a combination of surface flow and groundwater (Figure 35). As the channel moves right and widens, the bed would be expected to aggrade and raise water surface elevations so that more existing low elevation areas would be inundated at 1,800 cfs. The combined effect would be to increase the inundated area by 1 acre at 1,800 cfs and at 8,800 cfs. An additional 3,000 feet of wetted edge habitat could form; virtually all of this would occur in the original, abandoned channel (Figure 36). Up to seven trapping sites could form on newly-created bars, outer meander bends and side-channel entrances (Figure 37). The area

exposed to channel migration would increase by 30 acres and the length of erodible bank would be lifted by approximately 2,000 feet. An estimated 10 acres of existing forest occurs in the newly-exposed floodplain. The area outside of the active channel migration would require 28.7 acres of revegetation.

Indicator 2: Cost Assessment

The construction costs for Horath include training levee and rock removal, installation of a launchable rock revetment for setback boundary protection, 29 acres of planting, and water diversion that is required to maintain water quality during construction. The

Table 25. Design Details for Horath

Category	Detail	Units	Value
Planning context	WRIA 9 Plan Project Number	None	MG-14
	ERP Project Number	None	0
	Project Alternative	N/A	2
Existing conditions	Area of Project Site	Acres	58.7
	Length of Existing Levee	Linear feet	2,671
Proposed actions	Levee to be Removed	Linear feet	1,813
	Rock Revetment to be Removed	Linear feet	1,813
	New Setback Levee to Construct	Linear feet	2,751
	New Rock Revetment Structure to Construct	Linear feet	2,751
	Planting Area	Acres	29
	Water Diversion	Each	1
	Land removed from Agricultural Use	Acres	21.7
Affected properties	Total Parcels	Number	5
	King County Parcels or Easements	Number	1
	Private Property Interests to Purchase	Number	4

Table 26. Habitat Benefit for Horath

Metric	Factor	Units	Alt 1	Alt 2	Alt 2 - Alt 1	Ecological Lift*
1	Inundated Area at 1800 cfs	Acres	24.2	25.2	1.0	1
2	Inundated Area at 8800 cfs	Acres	108.1	108.9	0.8	1
3	Wetted Edge Length	Feet	21,800	24,900	3,100	3,000
4	Large Wood Trapping Sites	Number	8	15	7	7
5	Channel Migration Area	Acres	86	117	30.7	30
6	Length of Erodible Bank	Feet	7,600	9,400	1,800	2,000
7	Wood Supply (Exposed Forest)	Acres	44	53	8.9	10
8	Replanting Area	Acres	107	0	28.7	29

*Rounded to reflect uncertainty in outcomes.

Table 27. Horath Standards Checklist

Standard	Description	Score Alt 2	Compliance
1	Dynamic Ecological Endpoint	1	Complies with standards
2	Measurably Enhanced	1	Complies with standards
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

cost estimate includes mass balance calculations that take into account material that would be hauled off site or imported for new construction, and re-use of salvageable material. A cost saving measure not included in this estimate could be to leave the training levee prism material and only remove rock. This may require additional costs for a few ELJs to promote channel migration. The setback boundary protection does not require a setback structure due to higher bank elevation but the costs could go higher if wood elements are included. The project includes land acquisition costs. The design, permitting and outreach cost is estimated at 25% of construction total cost.

Table 28. Estimated Project Costs for Horath

Type of Cost	Total
Acquisition	$1,011,400
Design, Permitting and Outreach	$1,112,115
Construction	$4,448,426
Construction Management and Inspection	$667,269
Maintenance	$139,200
Monitoring	$100,000
Total Project Cost	**$7,478,446**

Indicator 3: Land Availability Assessment

This project site is privately owned and the project will require acquisition of one parcel and partial acquisition of another. King County owns one parcel within the project area, which could be the nucleus for a lot line adjustment encompassing the purchased land. The property is not FPP, but within the APD.

The property owner is not interested in removing the training levee or selling property adjacent to the Green River or Ray Creek. The property owner said that he would want more than the fair market value of the property to sell it. The project would remove 29 acres from farming land use.

Table 29. Land Availability Assessment for Horath

Question	Description	Result
1	Receptive landowners?	No
2	Does site include FPP easements?	No
3	Does project maintain farmable area?	No

Future Design Analysis

Further design development should include additional hydrologic analysis to evaluate how the proposed project would affect existing flooding, transportation, agriculture and recreational safety. The proposed project has the potential to impact adjacent agricultural practices and to increase the frequency and duration of inundation and saturation of land directly adjacent to Green Valley Road.

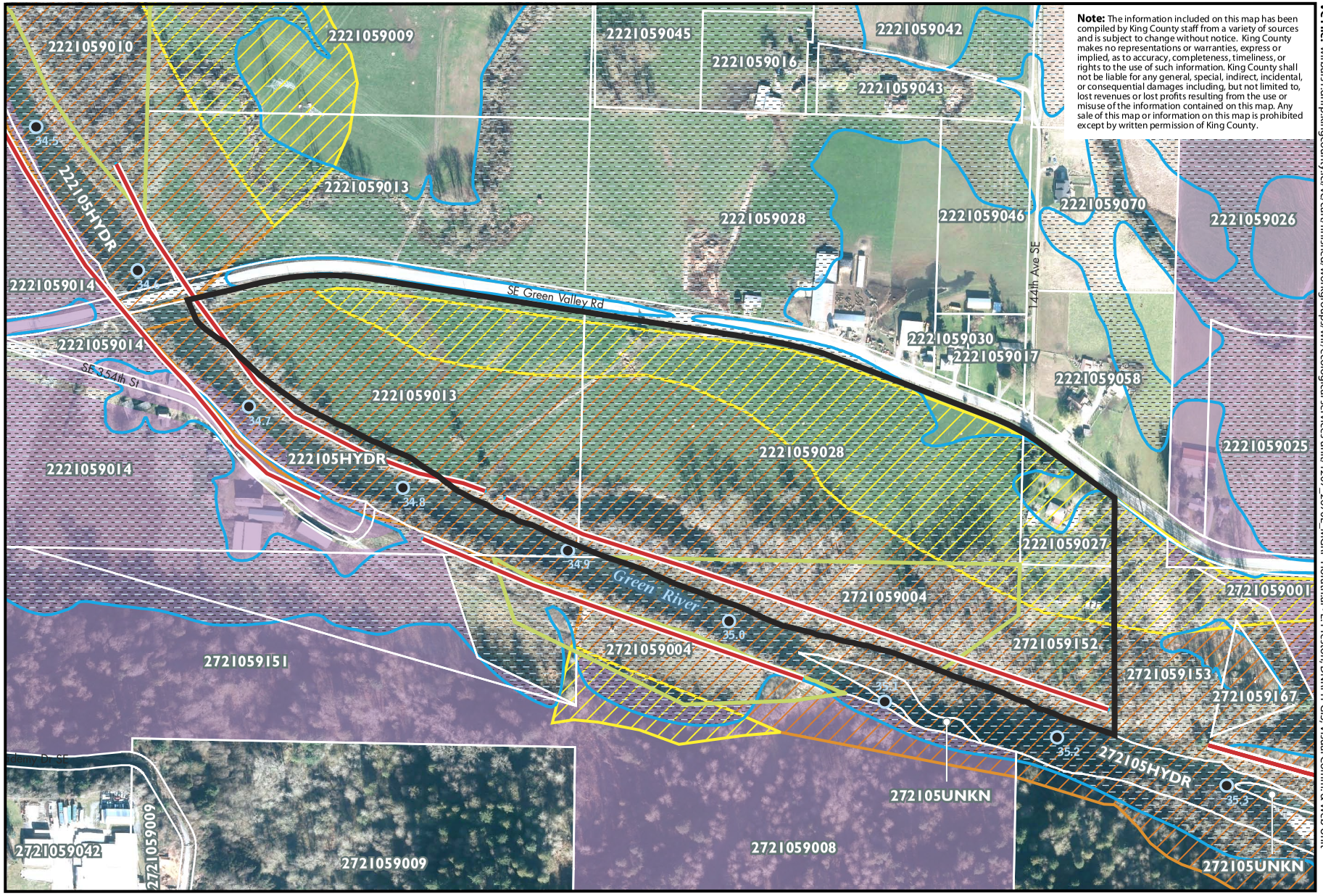


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Figure 33

HORATH

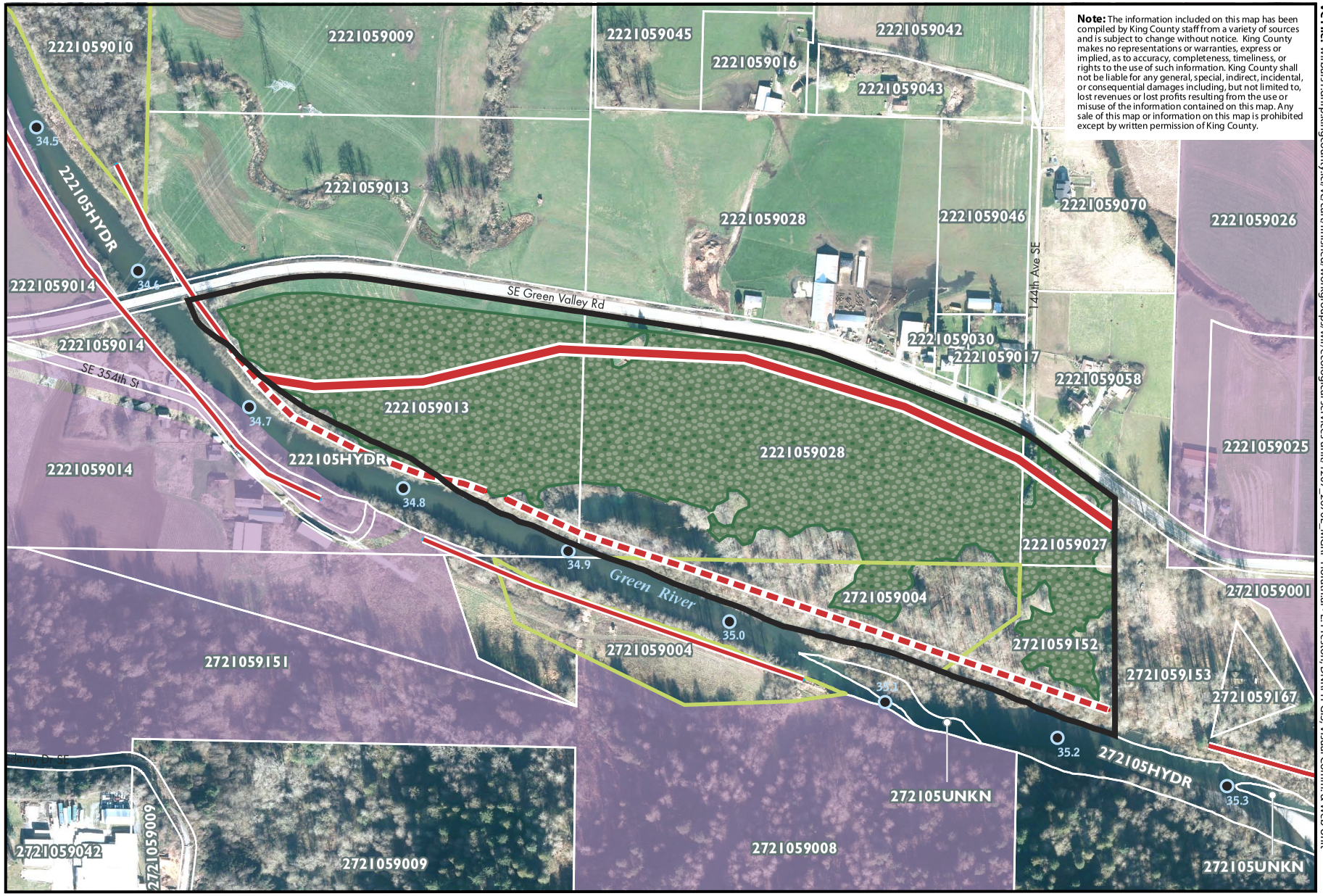
Alt. 1: Existing Conditions

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 33.2 River Mile (King Co. FHRS)
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- 100 Year Floodplain
- Farmland Preservation Program Properties

N

0 250 500
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division



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Project Area Boundary
Existing Levee
New Setback Structure
Levee to Be Removed
Replanting Area

King County Owned Parcel
Parcel Boundary & No.
Farmland Preservation Program Properties
33.2 River Mile (King Co. FHRS)

N
0 250 500
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure 34

HORATH

Alternative 2

Figure 35. Horath maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.

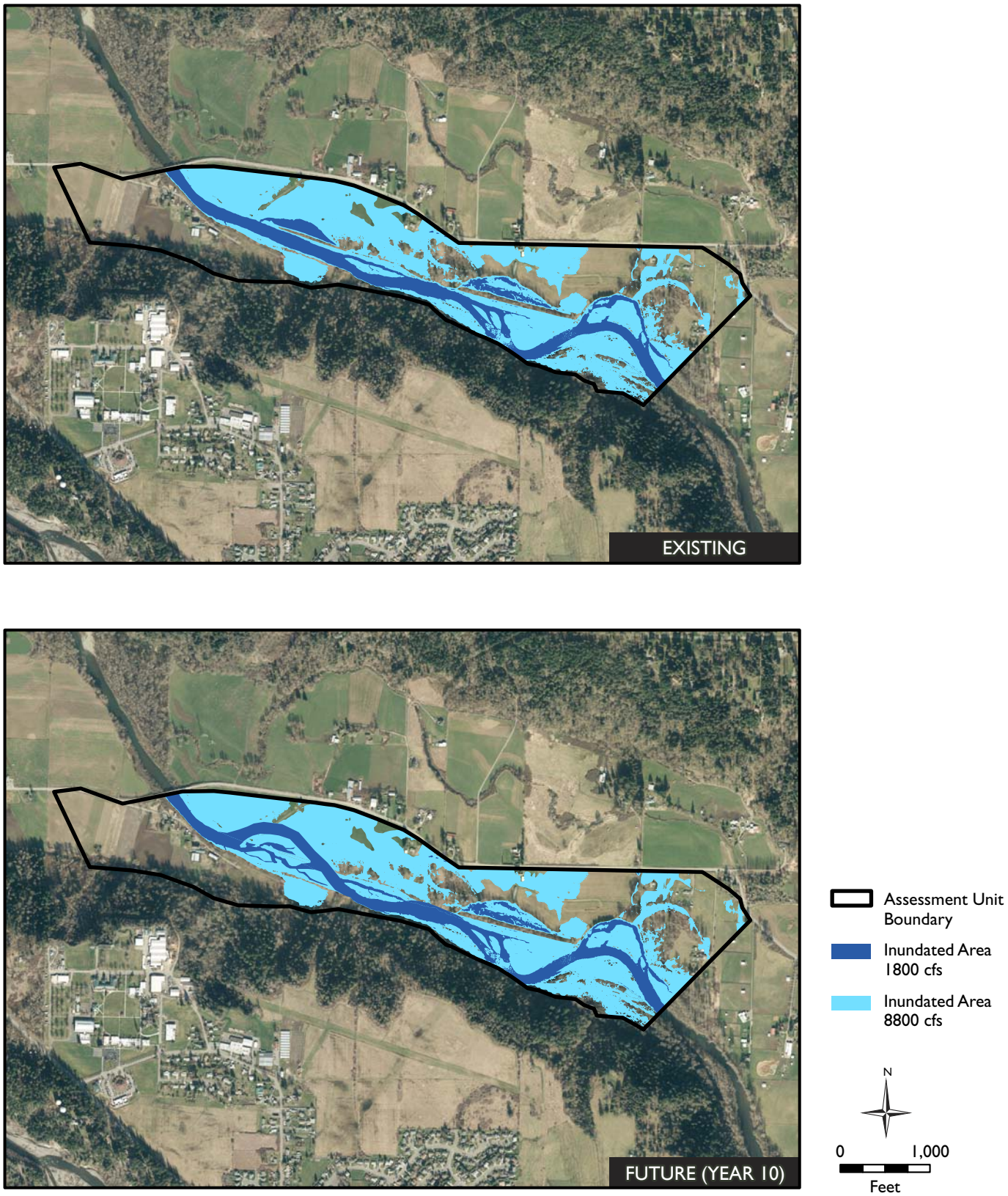
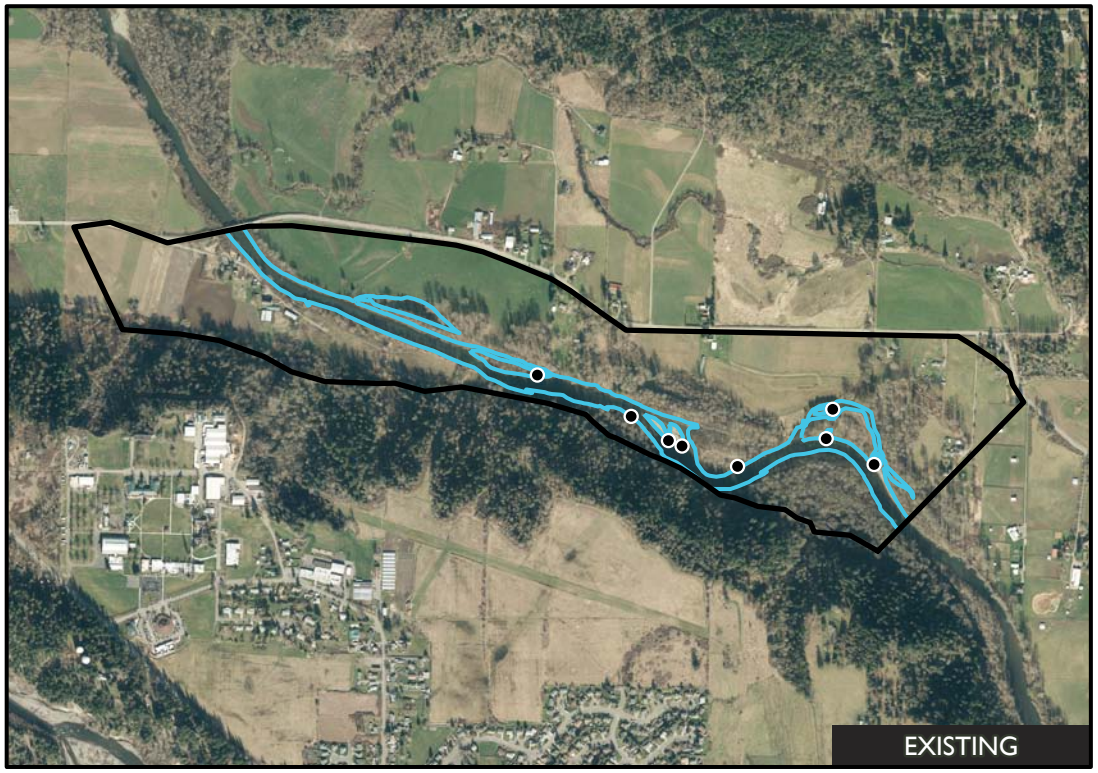
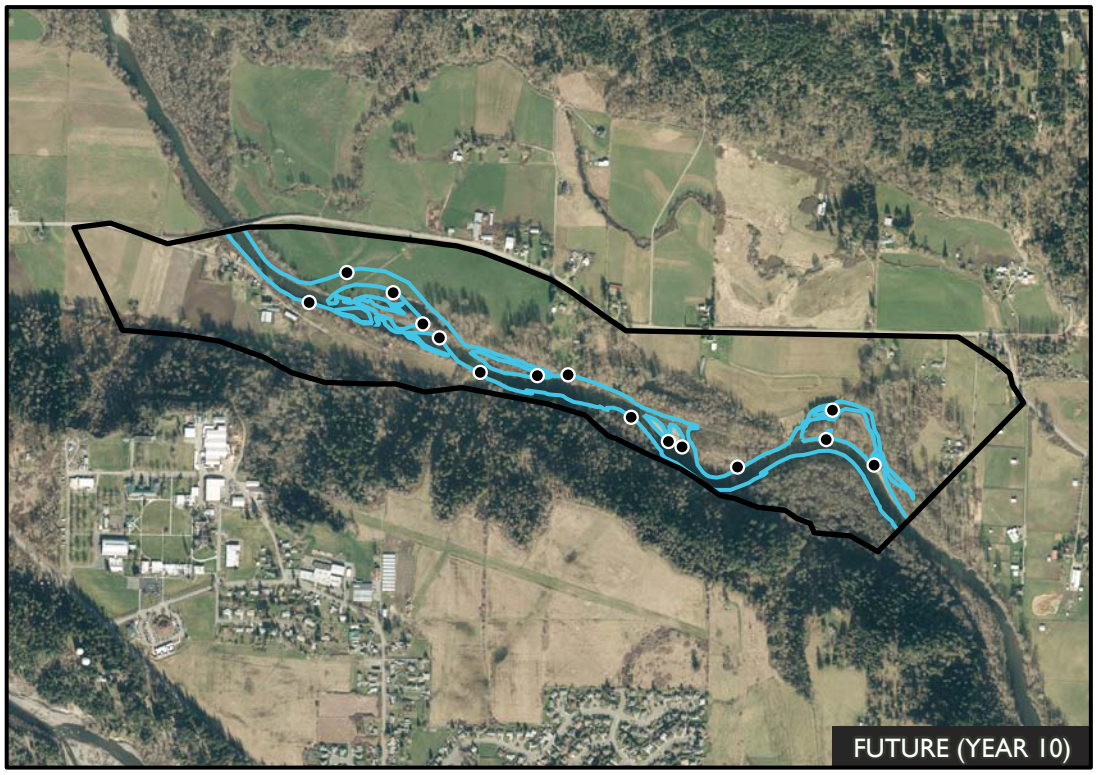


Figure 36. Horath maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.





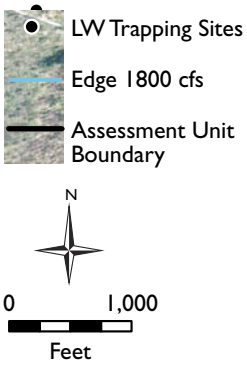
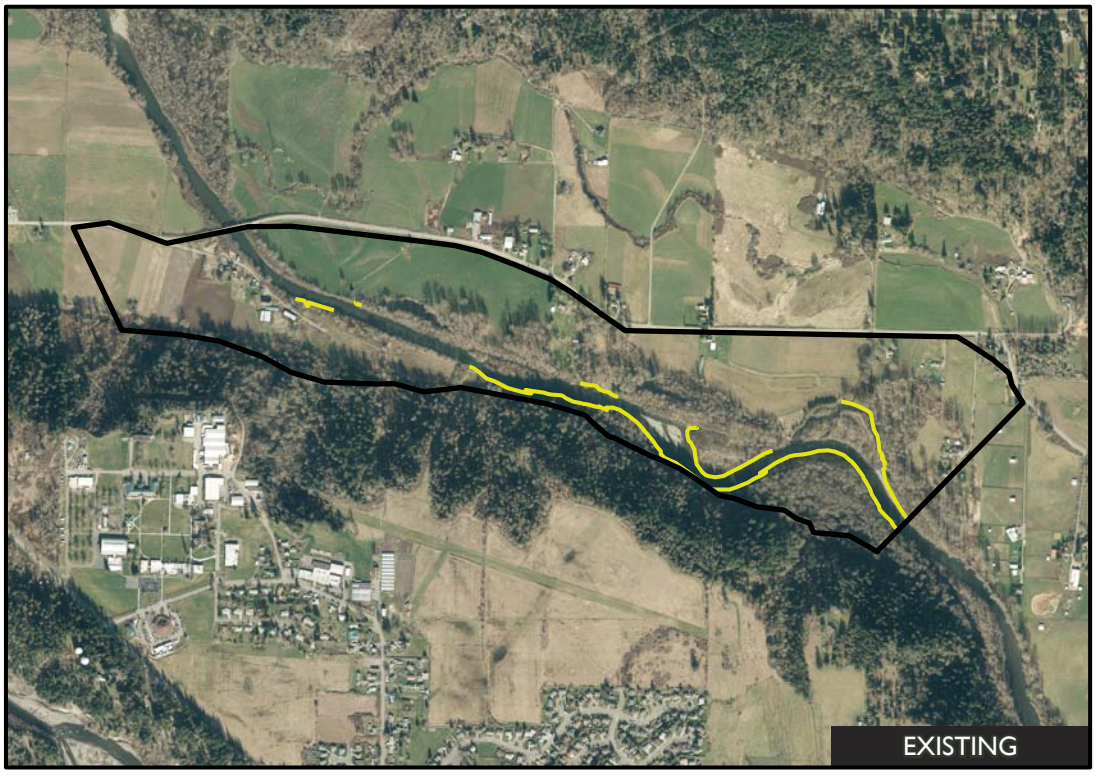
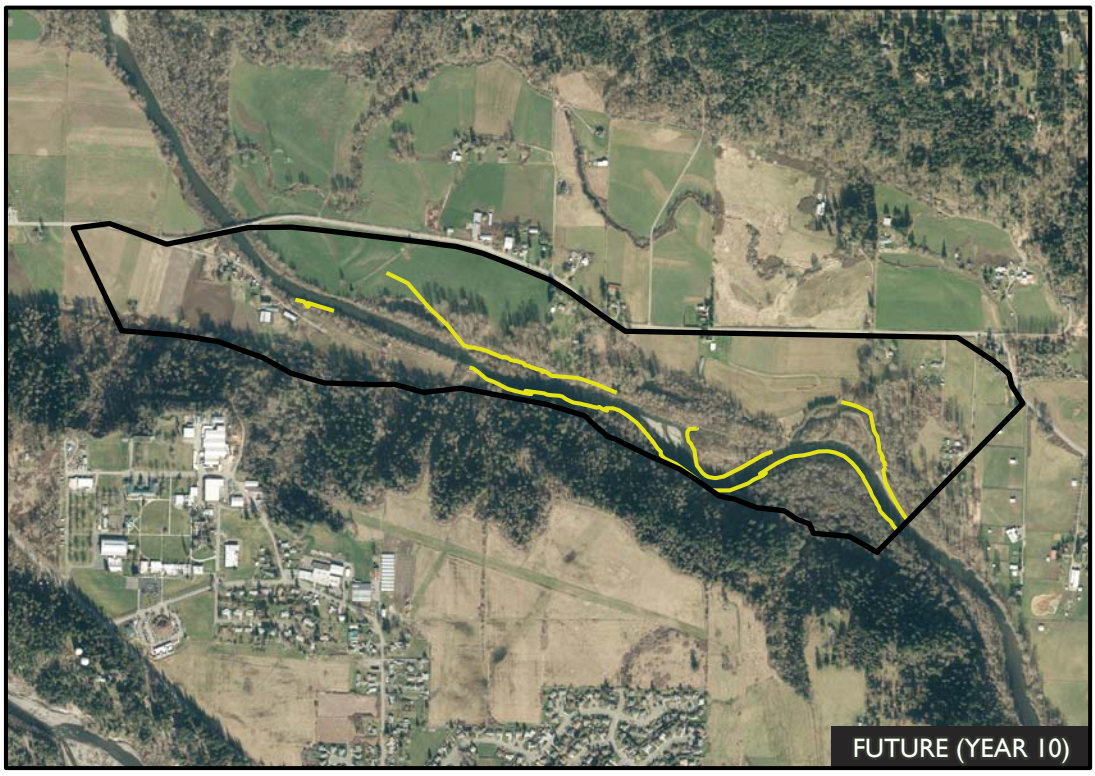
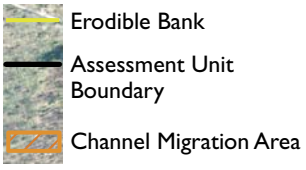


Figure 37. Horath maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.







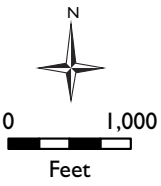
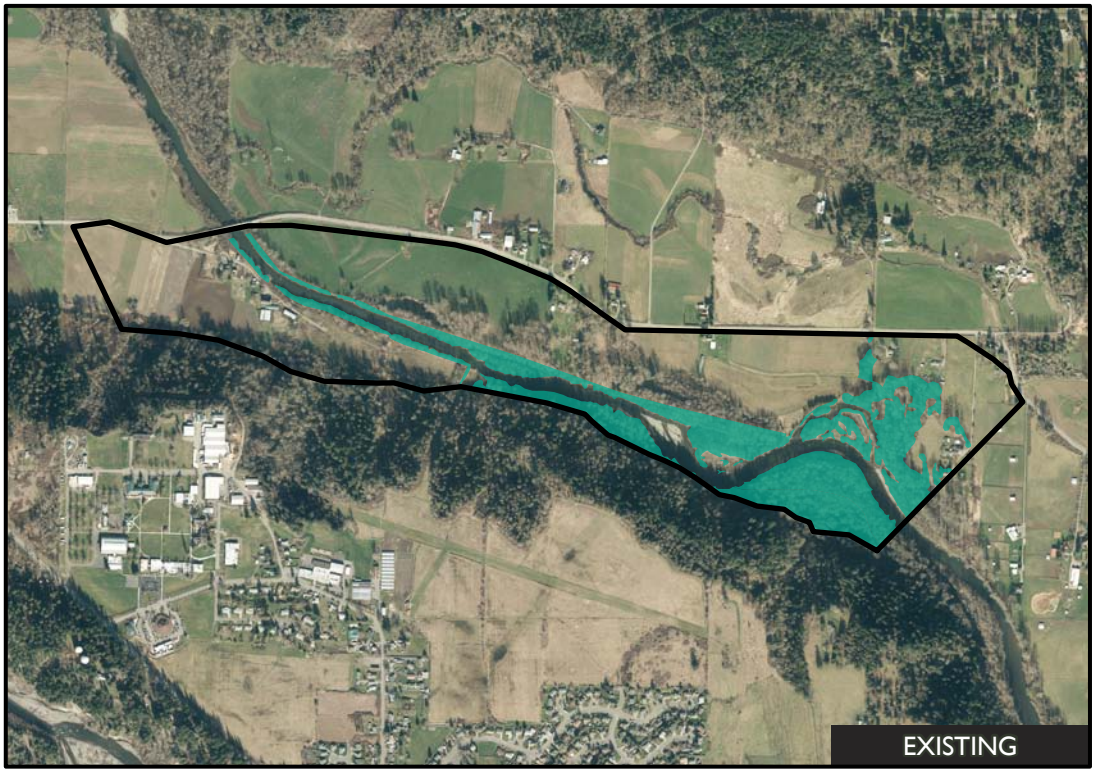
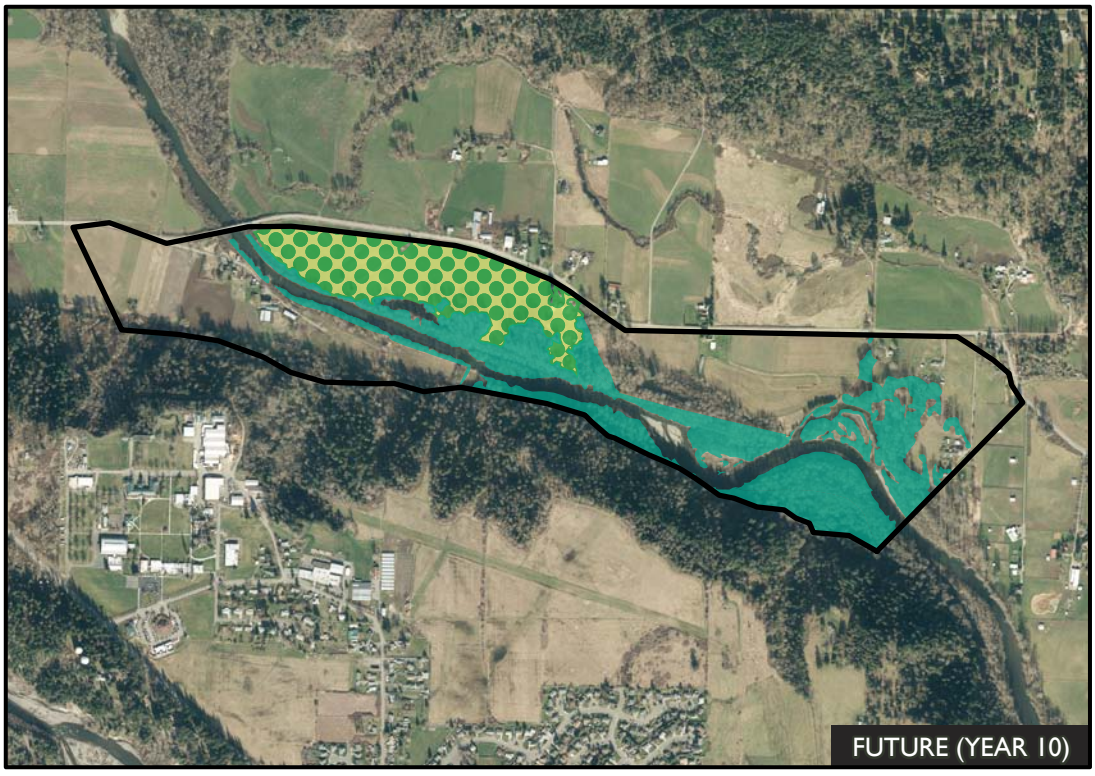


Figure 38. Horath maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration and replanting areas.





Site 6: Hamakami Reach

Figure 39. Hamakami Reach site photos

Site Description

The Hamakami Reach Project is located in the same place as the Horath and Hamakami sites; ; the "Reach" project is based on combining these two separate projects into one large project. This project site is located on the right bank at RM 35 and 36, Northwest Section 26, Township 21 and Range 5E. King County owns a flood control easement along the training levee that allows access for maintenance and inspection (Figure 40).

Existing Conditions

The Hamakami Reach contains a mixture of livestock pasture and relatively high-habitat functioning areas. The left bank is largely ecologically intact; it remains in native forest and does not contain a training levee facility. The river can migrate freely across the left bank, up to the valley wall. Native floodplain vegetation and off-channel areas exist in this area. Further upstream, bars and backwaters are present. On the right bank, river migration is impaired by a training levee, behind which is located an oxbow pond. Just upstream from this training levee is the site of a bioengineered riverbank stabilization project installed in 1999. At this location, the river splits and contains high-quality salmonid habitat, although the bank stabilization project purposefully constrained channel migration on the right bank. Further upstream, the right bank is mostly cleared and is used for agriculture.

The Hamakami Reach assessment unit contains 30.6 acres of inundated area at 1,800 cfs and 133.8 acres at 8,800 cfs (Table 31). Wetted edge measures 29,900 feet, and there are 10 wood trapping sites. An estimated 142 acres are currently exposed to channel migration within the assessment unit – virtually all of this area occurs upstream of the facilities being considered for removal. Of this amount, 59 acres are currently forested and could supply wood to the river. Erodible banks measure 11,400 feet.

Conceptual Project Design

This design would extend the setback structure proposed for Horath further east to form a 4,300 linear foot setback structure (Figure 41). Significant efforts would have to be made to improve land availability for the Hamakami Reach project. This would probably involve working closely with the local landowners to acquire lands and easements within the project area. One possible strategy would be to secure access and plant the site with native trees, and then allow them to grow for a decade or more. Meanwhile, future funding could be secured to eventually remove the existing bank protections. Another option would be to build this project in

phases, where Phase 1 could implement the portion similar to the Horath project, and then the upstream portion could be completed second, as funding was available and constraints were addressed.

Indicator 1: Habitat Benefit Assessment

This project would significantly increase channel complexity and provide ecological benefits over a large area. The channel could potentially split immediately downstream of the existing bank stabilization project. If so, the channel would likely migrate through the right bank, leaving backwaters along the inside bends of the resulting meanders (Figure 42). Two or three large meanders could form in the currently straight channel. Inundated area is estimated to increase by 4 acres at 1,800 cfs and by 7 acres at 8,800 cfs, as the river moves the right bank, creating new channels or low-lying floodplain. If new channels develop, abundant backwater and side channel features in both the new channels and relic channel would likely develop; the wetted edge length could potentially increase by 15,000 feet (Figure 43). Extensive bar formation and channel splitting could create approximately 10 wood trapping locations. Constructing a setback structure would expand the area vulnerable to channel migration by 40 acres and increase erodible bank length by 4,000 feet (Figure 44). Thirty-two acres of the site are available for floodplain re-vegetation. An additional 20 acres of existing forest would be exposed to the channel to supply wood to the river (Figure 45).

Table 30. Design Details for Hamakami Reach

Category	Detail	Units	Value
Planning Context	WRIA 9 Plan Project Number	None	MG-12
	ERP Project Number	None	28
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	105.5
	Length of Existing Levee	Linear feet	1,380
Proposed Actions	Levee to be Removed	Linear feet	4,064
	Rock Revetment to be Removed	Linear feet	4,064
	New Setback Levee to Construct	Linear feet	4,653
	New Rock Revetment Structure to Construct	Linear feet	4,653
	Planting Area	Acres	32
	Water Diversion	Each	1
	Land Removed from Agricultural Use	Acres	23.5[2]
Affected Properties	Total Parcels	Number	9
	King County Parcels or Easements	Number	1
	Private Property Interests to Purchase	Number	8

Table 31. Habitat Benefit for Hamakami Reach

Metric	Factor	Units	Alt 1	Alt 2	Alt 2 - Alt 1	Ecological Lift*
1	Inundated Area at 1800 cfs	acres	30.6	34.3	3.8	4
2	Inundated Area at 8800 cfs	acres	133.8	141.2	7.3	7
3	Wetted Edge Length	Feet	29,900	45,000	15,100	15,000
4	Large Wood Trapping Sites	Number	10	20	10	10
5	Channel Migration Area	Acres	142	184	41.6	40
6	Length of Erodible Bank	Feet	11,400	15,300	3,900	4,000
7	Wood Supply (Exposed forest)	Acres	59	74	15.9	20
8	Replanting Area	Acres	156	0	31.9	32

*Rounded to reflect uncertainty in outcomes

Table 32. Hamakami Reach Standards Checklist			
Std.	**Description**	**Score Alt 2**	**Compliance**
1	Dynamic Ecological Endpoint	1	Complies with standards
2	Measurably Enhanced	1	Complies with standards
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

Indicator 2: Cost Assessment

The construction costs for Hamikami Reach include training levee and rock removal, installation of a launchable rock revetment for setback boundary protection, 32 acres of planting, and water diversion that is required to maintain water quality during construction. The cost estimate includes mass balance calculations that took into account material that would be hauled off site or imported for new construction, and re-use of salvageable material. A cost saving measure not included in this estimate could be to leave the training levee prism material and only remove rock. This may require addition of a few ELJs to promote channel migration. The setback boundary protection does not require a setback structure due to higher bank elevation but the costs could go higher if wood elements are included. The project includes land acquisition costs. The design, permitting and outreach are estimated at 25% of construction total cost.

Table 33. Estimated Project Costs for Hamakami Reach	
Type of Cost	**Total**
Acquisition	$2,296,805
Design, Permitting and Outreach	$2,523,890
Construction	$10,159,266
Construction Management and Inspection	$1,523,890
Maintenance	$153,600
Monitoring	$110,000
Total Project Cost	**$16,783,378**

Indicator 3: Land Availability Assessment

This project design would require the acquisition of eight properties. Some property owners expressed an interest in potentially selling their properties. Other property owners were conditionally interested; in other words,if their neighbor sold, they would consider it. One landowner was not interested in considering a potential sale under any conditions.

Table 34. Land Availability Assessment for Hamakami Reach		
Question	**Description**	**Result**
1	Receptive landowners?	No
2	Does site include FPP easements?	Yes
3	Does project maintain farmable area?	No

Future Design Analysis

Further design development should include additional hydrologic analysis to evaluate how the proposed project would affect existing flooding, transportation, agriculture and recreational safety. The proposed project has the potential to both benefit and impact adjacent agricultural practices and to increase the frequency and duration of inundation and saturation of land directly adjacent to Green Valley Road. Any ELJs would have to address recreational boater safety. A new setback structure may be required along the edge of Green Valley Road to protect it from lateral erosion. The Hamakami Reach includes FPP properties. The project would affect 40 acres of land and result in a loss of 23.5 acres of agricultural land (pasture). Future design analyses will also need to consider project effects on or constraints posed by a natural gas pipeline that runs across the eastern portion of the project area.

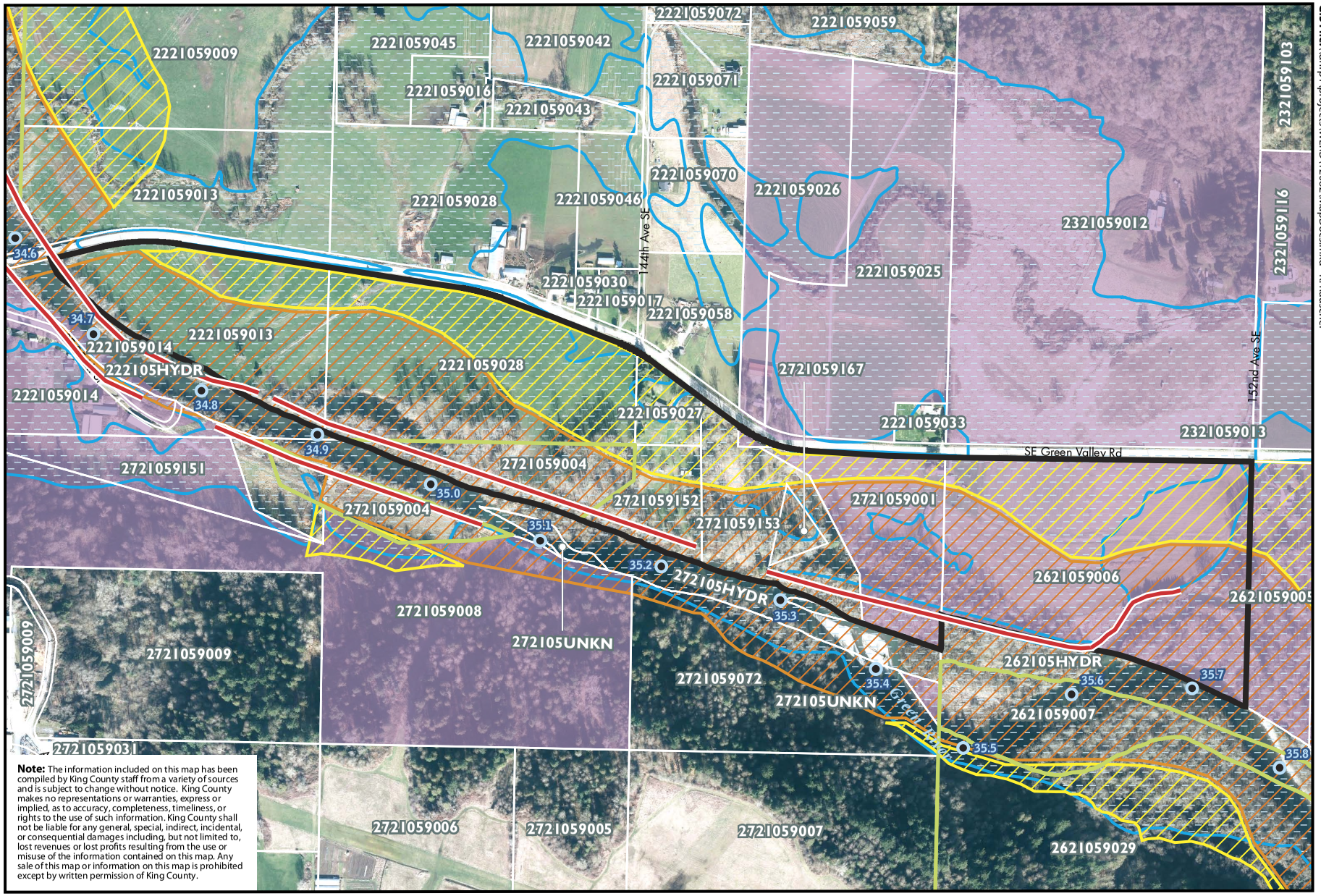


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Figure 40

HAMAKAMI REACH

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- River Mile (King Co. FHRS)

N

0 250 500
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

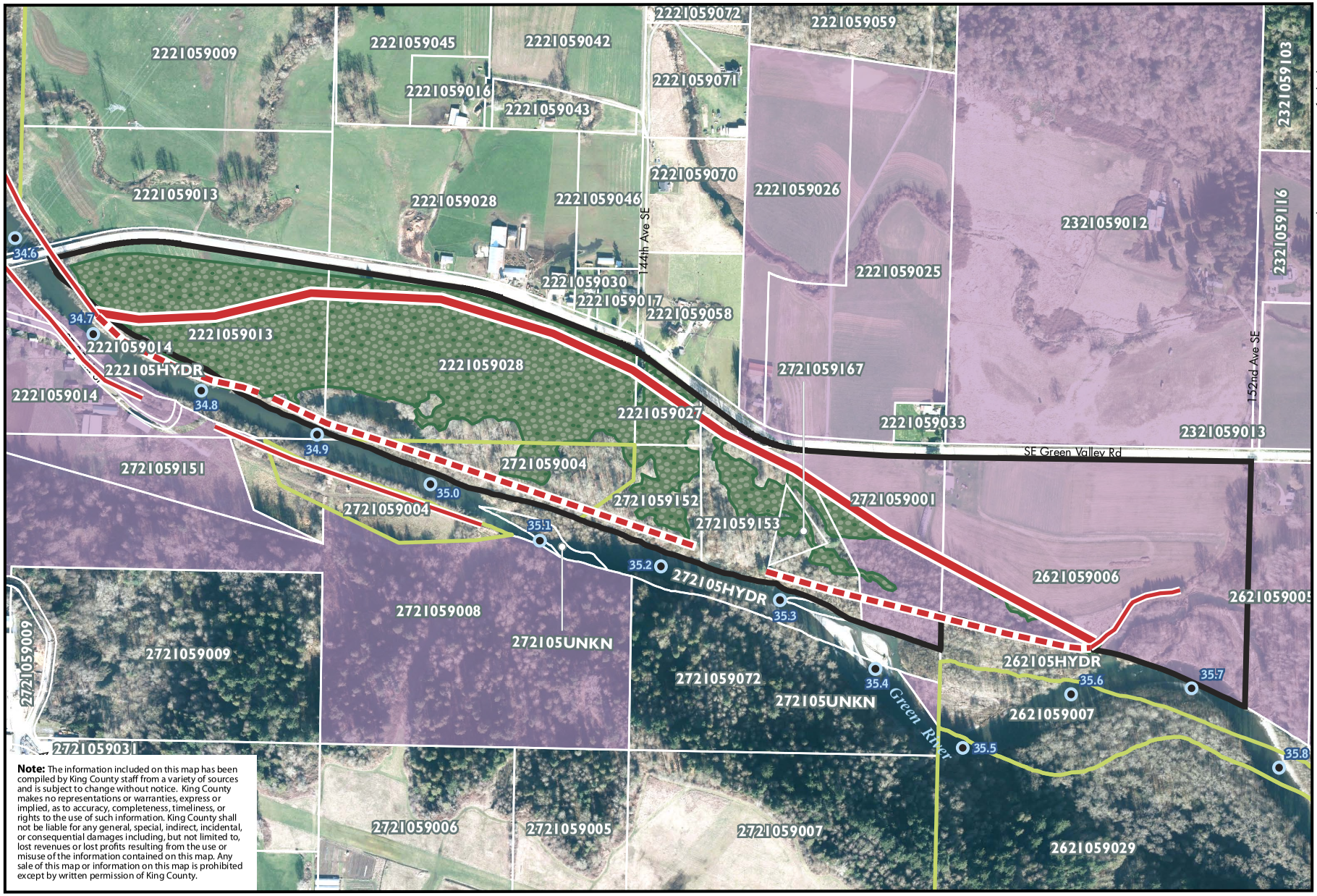

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Figure 41

HAMAKAMI REACH

Alternative 2

- Project Area Boundary
- Existing Levee
- New Setback Structure
- Levee to Be Removed
- Replanting Area
- King County Owned Parcel
- Parcel Boundary & No.
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

N

0 250 500
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure 42. Hamakami Reach maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.

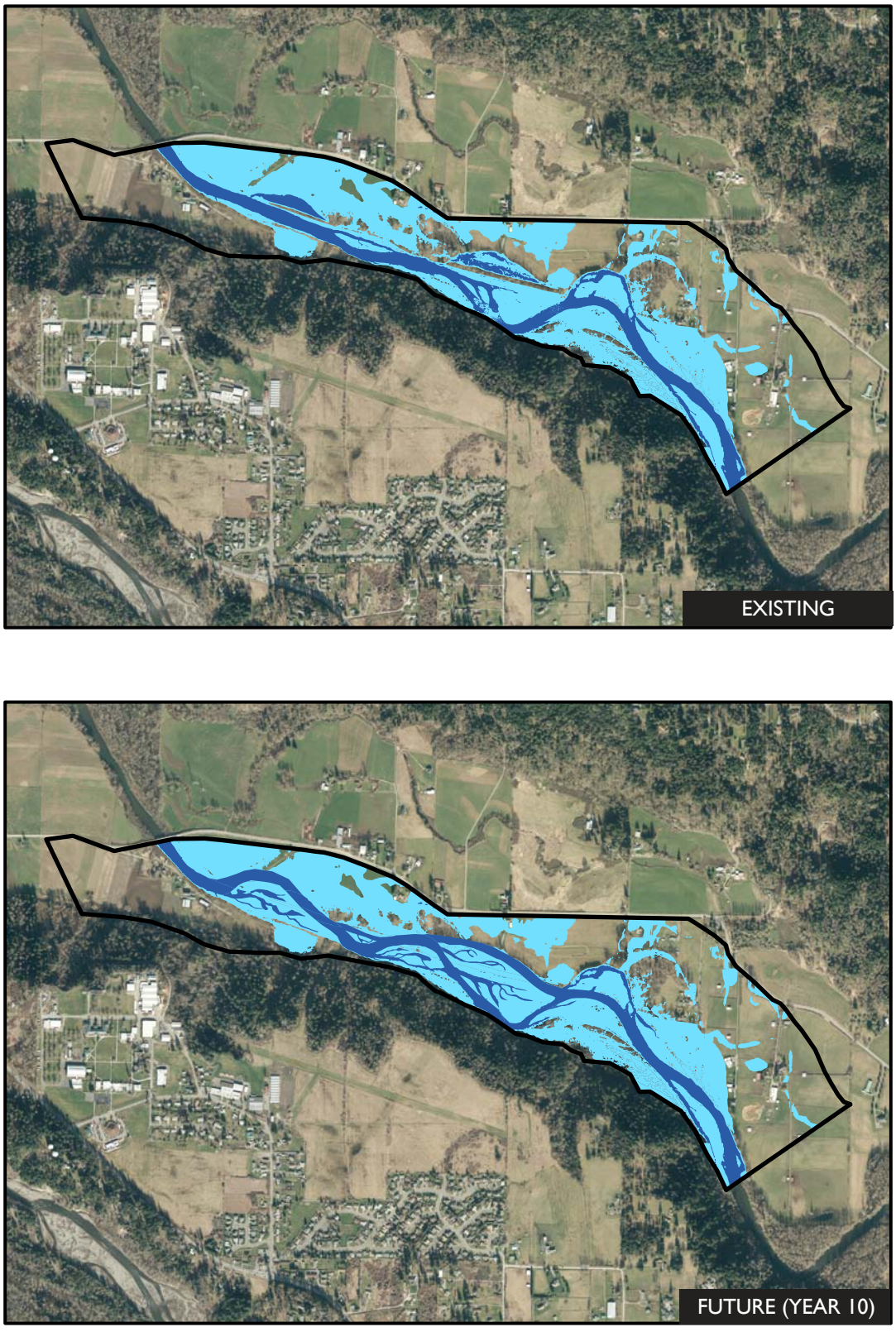


Figure 43. Hamakami Reach maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.

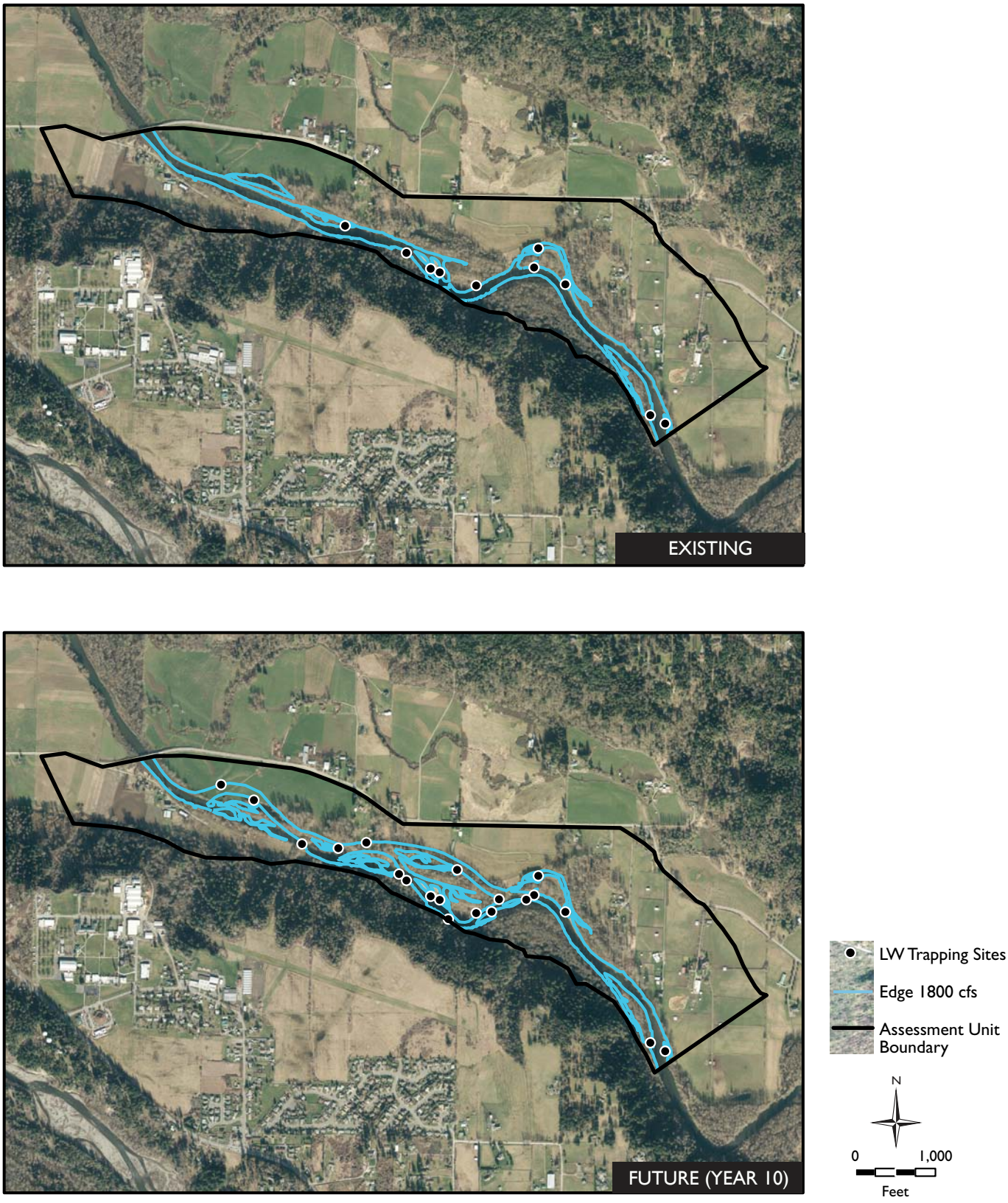
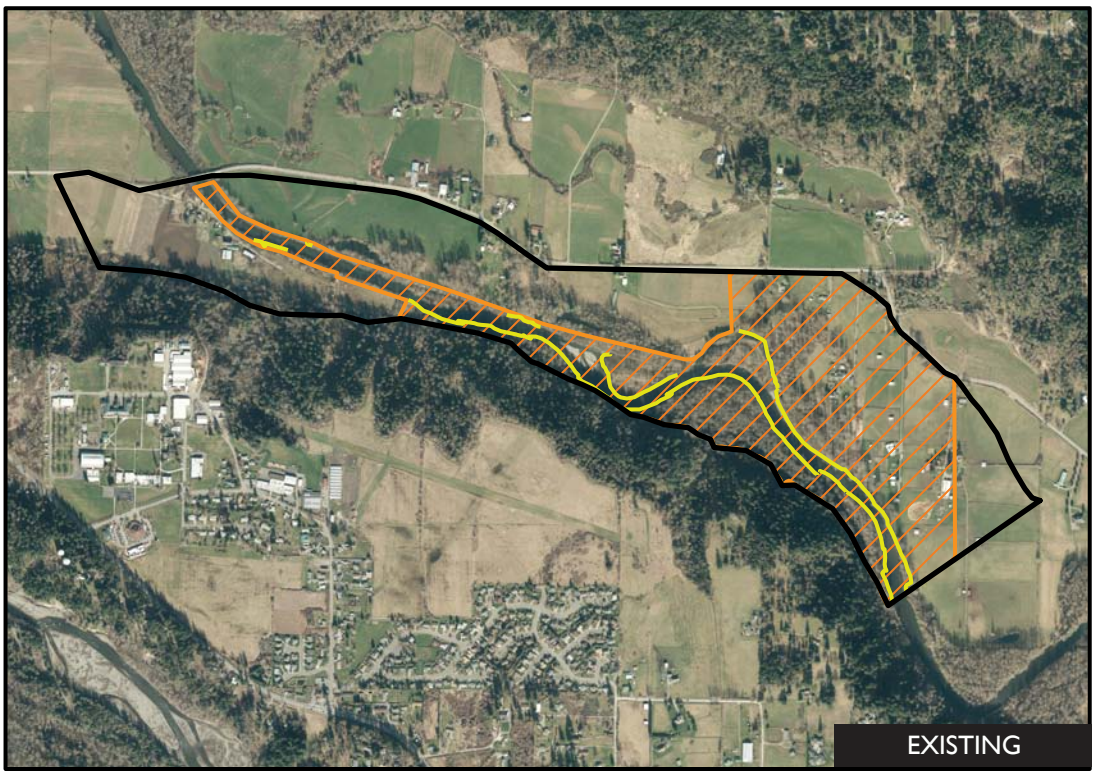
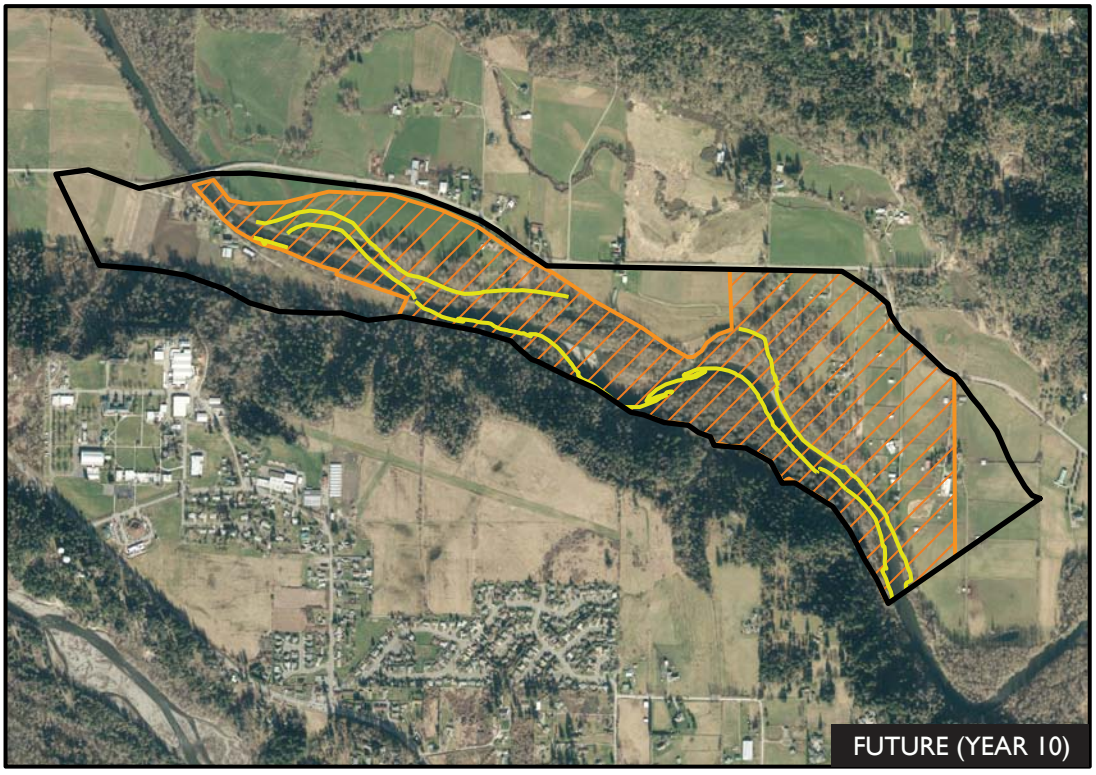


Figure 44. Hamakami Reach maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.



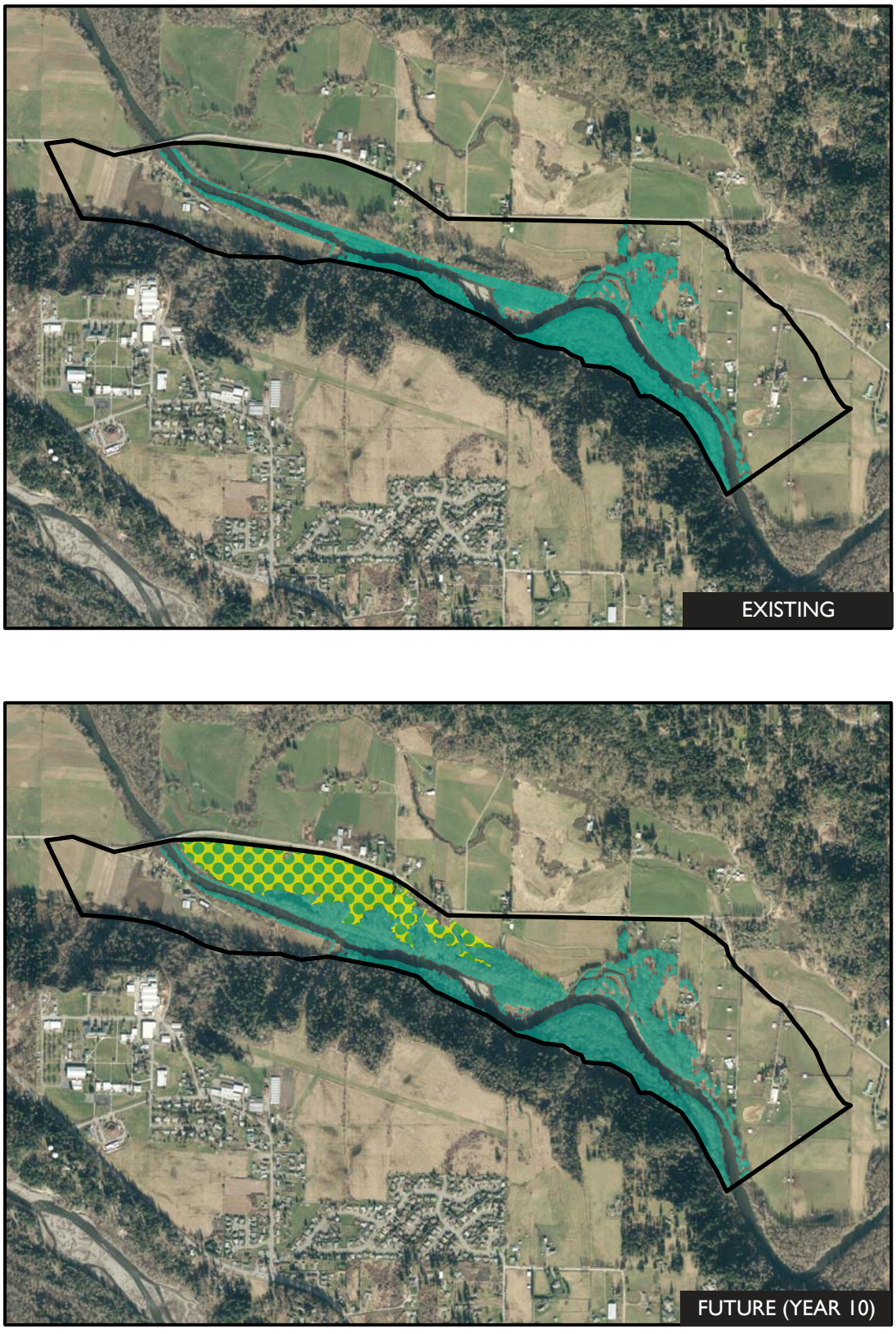


Erodible Bank
Assessment Unit Boundary
Channel Migration Area

N

0 1,000
Feet

Figure 45. Hamakami Reach maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration and replanting areas.



Site 7: Hamakami

Figure 46. Hamakami site photos

Site Description

The Hamakami site is located on the right bank of the Middle Green at RM 35.6 Northwest Section 26, Township 21, Range 5 East (Figure 47). The training levee forms a oxbow pond and protects adjacent farmland, to some degree. King County owns a flood control easement along the training levee that allows access for maintenance and monitoring.

Existing Conditions

Habitat at the Hamakami site is primarily constrained by a rock training levee, which limits juvenile fish access to the oxbow pond during typical river flows. Fine sediment deposition has created a berm at the outlet of the oxbow behind the revetment. This oxbow could provide high-quality rearing habitat for juvenile salmonids, but access is limited to high flow periods.

The Hamakami assessment unit is currently disconnected from the mainstem at 1,800 cfs, though it contains 5.3 acres of connected, inundated area at 8,800 cfs. Other habitat indicators are not applicable to this project because the project does affect them.

Conceptual Project Design

This design consists of lowering the outlet channel at the north end of the training levee to improve the flow connection between the main channel and the wetland slough located behind the training levee (Figure 48).

Table 35. Design Details for Hamakami

Category	Detail	Units	Value
Planning Context	WRIA 9 Plan Project Number	None	MG-13
	ERP Project Number	None	28
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	6.3
	Length of Existing Levee	Linear Feet	1342
Proposed Actions	Excavation	Square Feet	2400
	Land Removed from Agricultural Use	Acres	0
Affected Properties	Total Parcels	Number	2
	King County Parcels or Easements	Number	0
	Private Property Interests to Purchase	Number	0

Indicator 1: Habitat Benefit Assessment

The primary habitat benefit from this project would be re-establishing a flow connection and fish-passage between the oxbow pond and the mainstem at 1,800 cfs. This would increase the inundated area available to juvenile fish by 2 acres. The existing oxbow pond has abundant wood and is encircled by mature vegetation. No other habitat changes are anticipated from this project. The accessible wetted edge would increase by 4,000 feet.

Table 36. Habitat Benefit for Hamakami

Metric	Factor	Units	Alt 1	Alt 2	Alt 2 - Alt 1	Ecological Lift*
1	Inundated Area at 1800 cfs	Acres	0	1.9	1.9	2
2	Inundated Area at 8800 cfs	Acres	5.3	5.3	0	0
3	Wetted Edge Length	Feet	0	3,800	3,800	4,000
4	Large Wood Trapping Sites	Number	n/a			
5	Channel Migration Area	Acres	n/a			
6	Length of Erodible Bank	Feet	n/a			
7	Wood Supply (Exposed forest)	Acres	n/a			
8	Replanting Area	Acres	n/a			

*Rounded to reflect uncertainty in outcomes

Table 37. Hamakami Standards Checklist

Standard	Description	Score Alt 2	Compliance
1	Dynamic Ecological Endpoint	1	Complies with standards
2	Measurably Enhanced	0.67	Natural Processes not Expected to Sustain and Enhance the New Habitat.
3	More Self-Sustaining	0	Site not expected to recover on its own without maintenance at the inlet, at least over the long-term. Unclear as to whether maintenance will be needed in 10 years.
4	No Irreparable Harm	1	Complies with standards

Indicator 2: Cost Assessment

The construction cost for the Hamakami project is associated with the excavation of floodplain material to make a connection with the oxbow. This action would require land acquisition costs.

Table 38. Estimated Project Costs for Hamakami

Type of Cost	Total
Acquisition	$142,655
Design, Permitting and Outreach	$15,173
Construction	$37,933
Construction Management and Inspection	$5,690
Maintenance	$5,000
Monitoring	$7,000
Total Project Cost	**$213,451**

Indicator 3: Land Availability Assessment

King County owns a flood easement to the training levee. A temporary construction easement (TCE) might be required to perform the necessary work. The property owner indicated he was somewhat receptive to the project but concerned about impacts from increasing flow into the oxbow pond.

Further consideration should be given to the option of increasing the channel dimensions in order to permit increased frequency of flows at lower stage elevations. This may be possible to build with hand crews or a small track hoe within the terms of the exiting flood control easement.

Table 39. Land Availability Assessment for Hamakami		
Question	**Description**	**Result**
1	Receptive landowners?	Some
2	Does Site include FPP Easements?	Yes
3	Does project maintain farmable area?	Yes

Future Design Analysis

Further design development should include additional hydraulic analysis to evaluate potential changes to the frequency and extent of inundation of the oxbow pond and surrounding area.

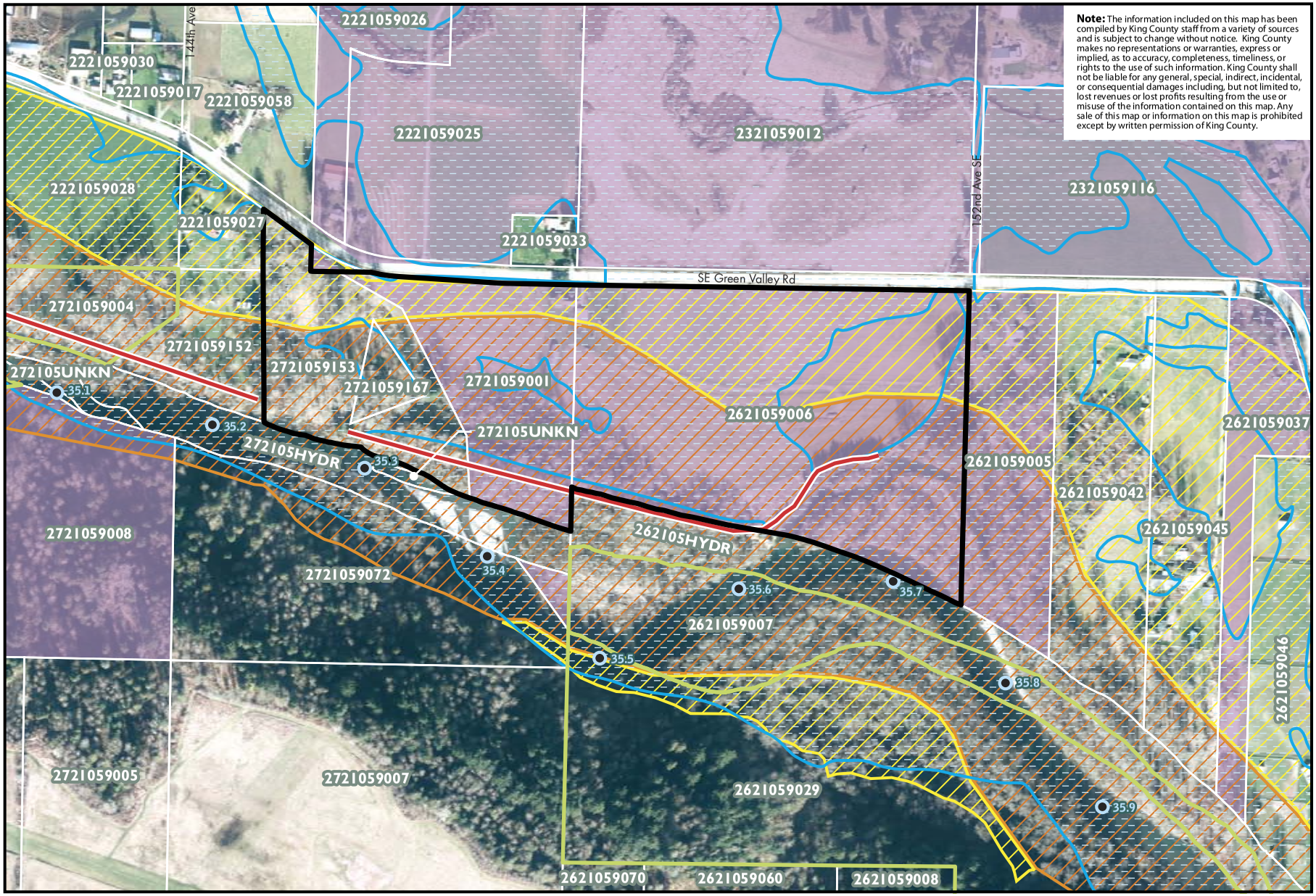


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Figure 47

HAMAKAMI

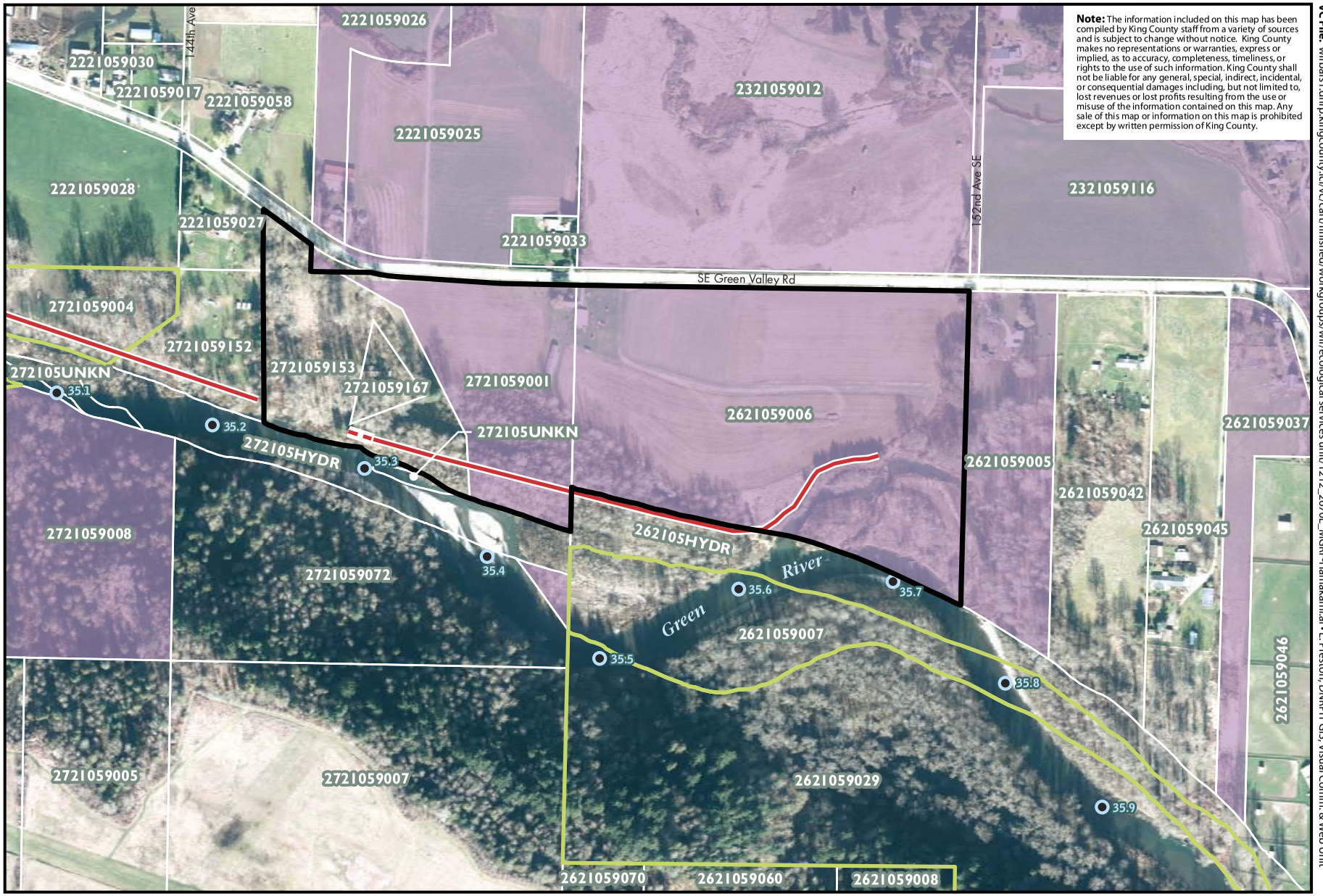
Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

N

0 250 500
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division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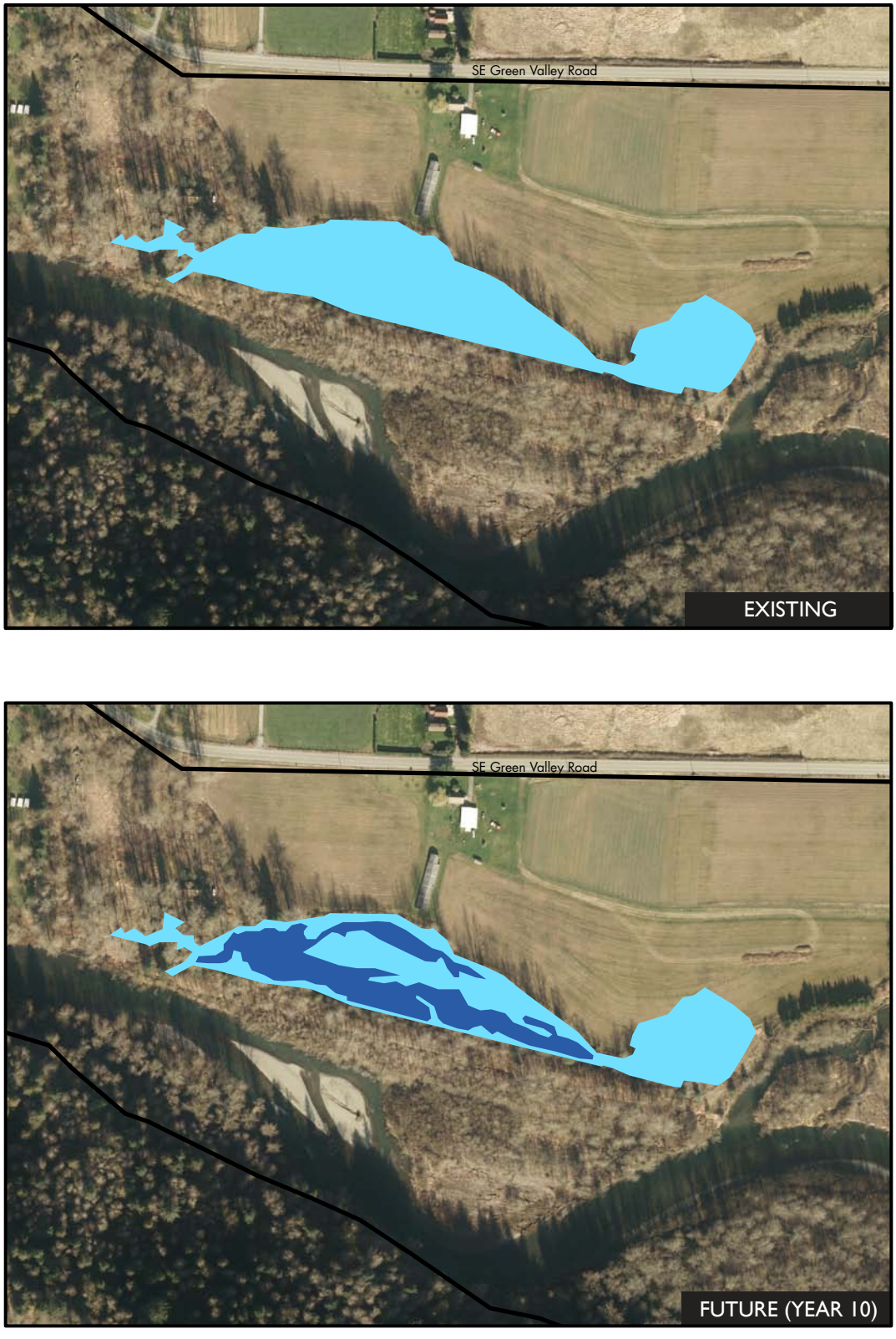
2221059026
2221059030
144th Ave
2221059017
2221059058
2321059012
2221059025
2221059028
152nd Ave SE
2321059116
2221059027
2221059033
SE Green Valley Rd
2721059004
2721059152
272105UNKN
35.1
2721059153
2721059167
2721059001
2621059006
272105UNKN
35.2
272105HYDR
35.3
2621059037
2621059005
2621059042
2721059008
262105HYDR
2621059045
35.4
2721059072
River
35.6
35.7
Green
2621059007
35.5
35.8
2621059046
2721059005
2721059007
2621059029
35.9
2621059070
2621059060
2621059008
Figure 48
HAMAKAMI
Alternative 2
Project Area Boundary
Levee to Be Removed
Existing Levee
King County Owned Parcel
Parcel Boundary & No.
Farmland Preservation Program Properties
33.2
River Mile (King Co. FHRS)
N
0
250
500
Feet
King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure 49. Hamakami maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.



Site 8: Turley

Figure 50. Turley site photos

Site Description

The Turley site sits on the right bank of a large meander bend at RM 37, Southeast Section 26, Township 21 North, Range 5 East (Fig 51). The Turley site contains two training levee that were constructed at different times by the USACOE. An oxbow pond lies behind the levee; however, access to the side channel appears to be limited to higher flows.

Existing Conditions

Habitat conditions at Turley are constrained by two rock levees on and behind the right bank of the river. One training levee is adjacent to the channel. The other lies 450-500 feet north of the existing channel bank; it is at least 1,000 feet long and resembles a berm. It currently bisects the slough on the north side of the river. The left bank has no facilities and is unconfined, except where the river meets the valley wall. Areas along the left bank support an extensive network of side channels. The right bank revetment guards an oxbow pond, which is an historic channel that remains connected to subsurface and flood flows—but that does not appear to be connected to surface flows during the spring rearing window.

The Turley assessment unit contains 37.0 acres of inundated area at 1,800 cfs and 161.0 acres at 8,800 cfs (Table 41). Wetted edge measures 29,000 feet and there are two wood trapping sites. An estimated 154 acres are currently exposed to channel migration; 93 acres in this area are currently forested and could supply wood to the river. Erodible banks measure 14,300 feet.

Conceptual Project Design

This design consists of removing the existing training levee and constructing a setback structure along the edge of the oxbow pond (Figure 52).

Indicator 1: Habitat Benefit Assessment

This project would allow the river to migrate into the right bank, forming a point bar with backwaters or side channels developing in the existing river location. An additional two acres of inundated area (at 1,800 cfs) could result as the channel adds sinuosity and length (Figure 53). The project would have little, if any, effect on the inundated area at 8,800 cfs. The channel would likely reconnect with the oxbow pond north of the river, improving access and rearing opportunities for juvenile fish. A surface-water connection to this area may already exist, but could not be verified. Reconnecting the river to the pond would increase the wetted edge length by 11,000 feet (by making accessible at a broader range of flows) (Figure 54). This project potentially exposes an additional 30 acres of floodplain to channel migration (Figure 55). The formation of a point bar and new inlets could create six new wood trapping sites. The length of erodible bank would be increased by 1,000 feet. The site could support 9 acres of plantings. The project could expose an additional 20 acres of existing forest to the river to supply wood to the channel (Figure 56).

Table 40. Design Details for Turley			
Category	**Detail**	**Units**	**Value**
Planning Context	WRIA 9 Plan Project Number	None	MG-11
	ERP Project Number	None	29
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	52
	Length of Existing Levee	Linear feet	1,630
Proposed Actions	Levee to be Removed	Linear feet	1,630
	New Setback Levee to Construct	Linear feet	2,372
	Fencing to Construct	Linear feet	10
	Planting Area	Acres	9
	Land Removed from Agricultural Use	Acres	7.9
Affected Properties	Total Parcels	Number	2
	King County Parcels or Easements	Number	0
	Private Property Interests to Purchase	Number	2

Table 41. Habitat Benefit for Turley						
Metric	**Factor**	**Units**	**Alt 1**	**Alt 2**	**Alt 2 - Alt 1**	**Ecological Lift***
1	Inundated Area at 1800 cfs	Acres	37.0	39.2	2.2	2
2	Inundated Area at 8800 cfs	Acres	161.0	161.1	0.1	0
3	Wetted Edge Length	Feet	29,000	39,900	10,900	11,000
4	Large Wood Trapping Sites	Number	2	8	6	6
5	Channel Migration Area	Acres	154	180	25.9	30
6	Length of Erodible Bank	Feet	14,300	15,100	800	1,000
7	Wood Supply (Exposed forest)	Acres	93	109	15.9	20
8	Replanting Area	Acres	147	138	9.3	9

*Rounded to reflect uncertainty in outcomes

Table 42. Turley Standards Checklist			
Standard	**Description**	**Score Alt 2**	**Compliance**
1	Dynamic Ecological Endpoint	0.67	Not moving river toward least degraded, most dynamic state possible.
2	Measurably Enhanced	1	Complies with standards
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

Indicator 2: Cost Assessment

The construction costs for Turley include rock removal, installation of a launchable rock revetment for setback boundary protection, 9 acres of planting, and water diversion that is required to maintain water quality during construction. The cost estimate includes mass balance calculations that took into account material that would be hauled off site or imported for new construction and re-use of salvageable material. This estimate does not include removal of training levee prism material. The setback boundary protection does not require a setback structure due to higher bank elevation but the costs could go higher if wood elements are included. The project includes land acquisition costs. The design, permitting and outreach are estimated at 25% of construction total cost.

Table 43. Estimated Project Costs for Turley

Type of Cost	Total
Acquisition	$75,000
Design, Permitting and Outreach	$453,468
Construction	$1,813,874
Construction Management and Inspection	$272,081
Maintenance	$43,200
Monitoring	$45,000
Total Project Cost	**$2,702, 623**

Indicator 3: Land Availability Assessment

This project would require the acquisition of three privately owned parcels that are enrolled in FPP. Affected property owners have indicated that they are somewhat interested in the proposed project with a willingness to sell. Both property owners indicated that the restrictions of the FPP covenant presented economic challenges to them, because it requires that they demonstrate that they are selling agricultural commodities; for example timber, hay, vegetables.

Table 44. Land Availability Assessment for Turley

Question	Description	Result
1	Receptive landowners?	Some
2	Does site include FPP easements?	Yes
3	Does project maintain farmable area?	Yes

Future Design Analysis

Further design development should include additional hydrologic analysis to evaluate how the proposed project would affect existing flooding and agriculture. The proposed project has the potential to both benefit and impact adjacent agricultural practices and to increase the frequency and duration of inundation and saturation of agricultural land.

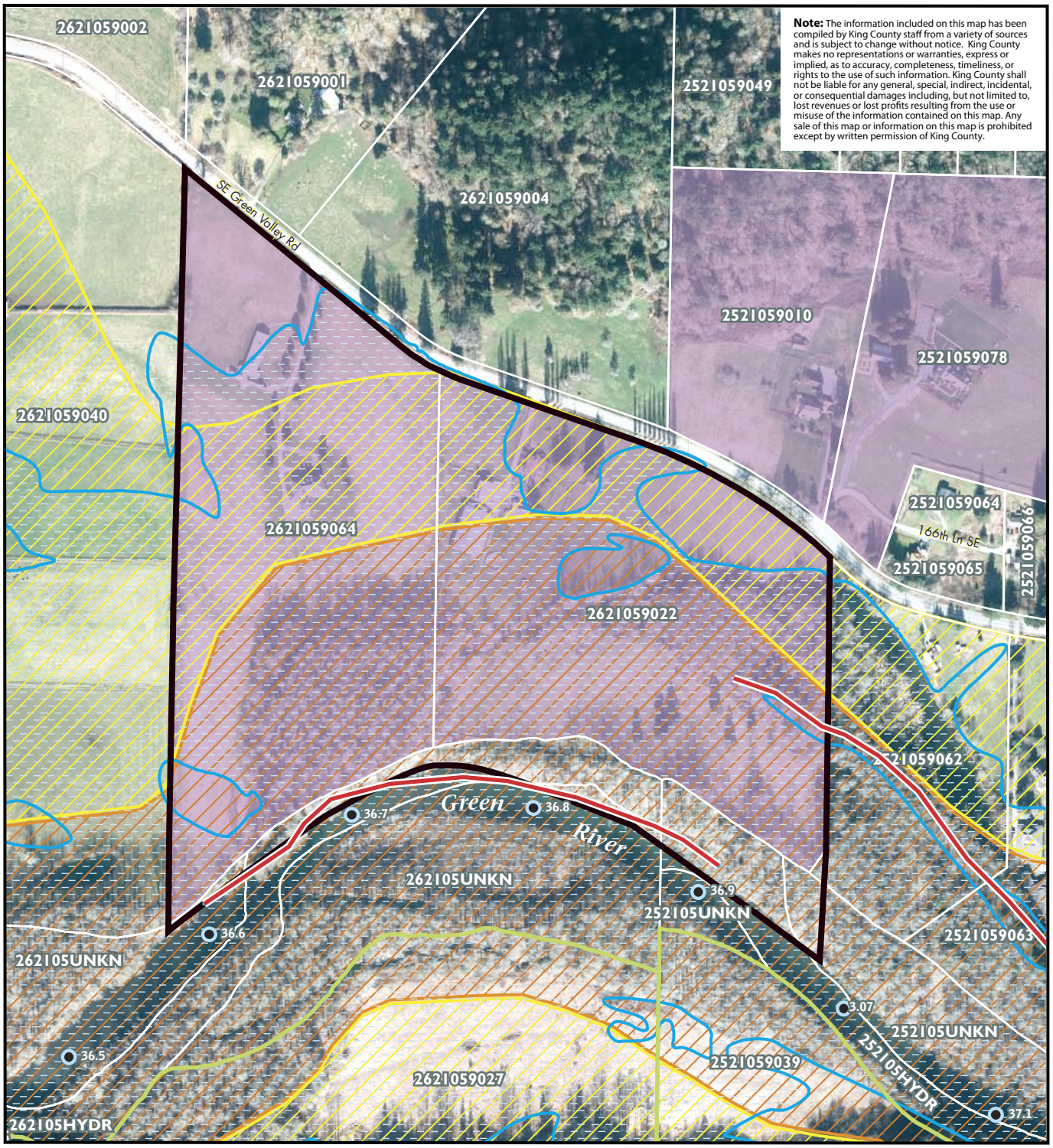


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Figure 51

TURLEY

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- Parcel Boundary & No.
- King County Owned Parcel
- Farmland Preservation Program Properties
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- 100 Year Floodplain
- 33.2 River Mile (King Co. FHRS)

N

0 100 200 300
Feet

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

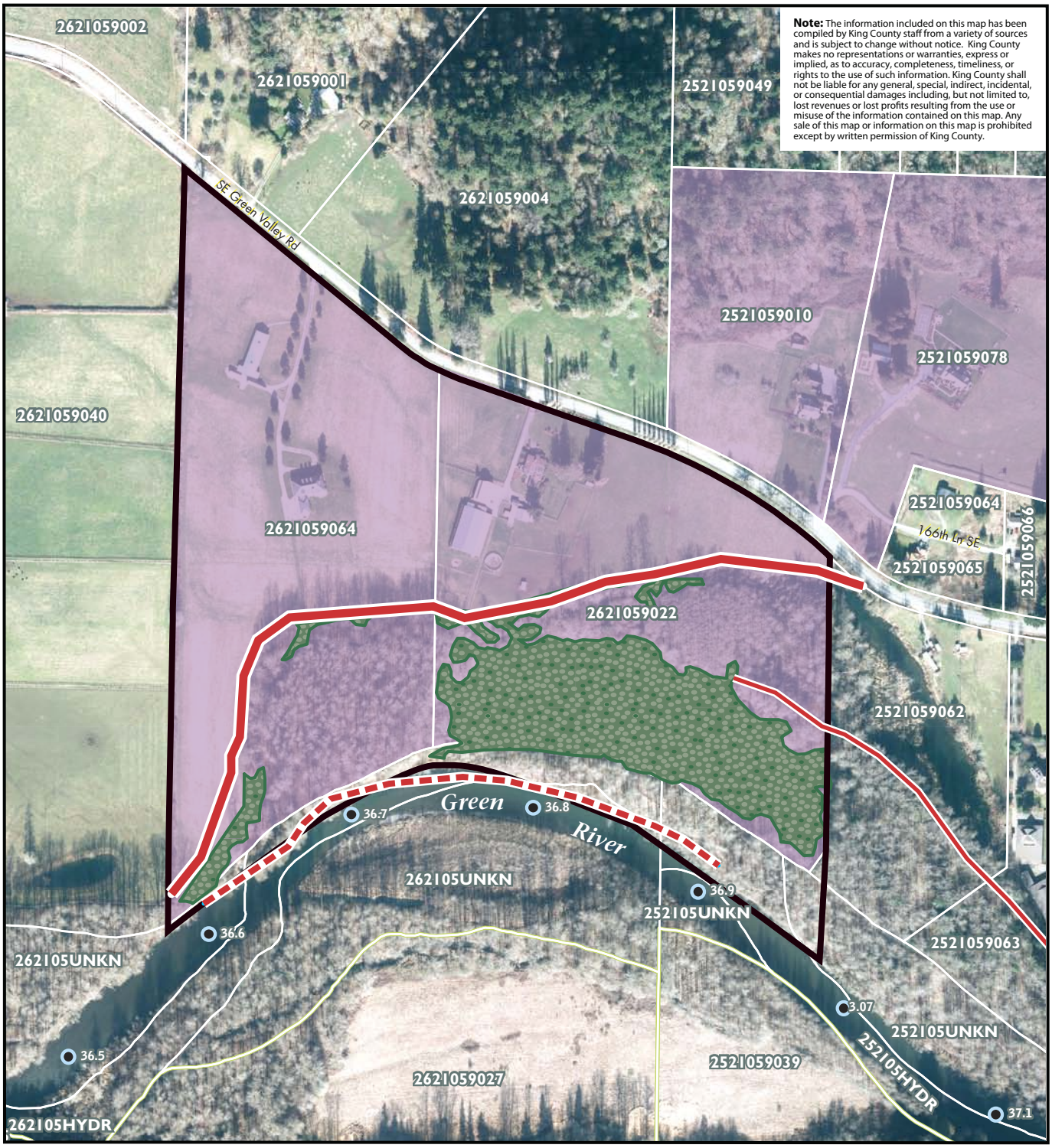

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Figure 52

TURLEY

Alternative 2

- Project Area Boundary
- Levee to Be Removed
- Existing Levee
- New Setback Structure
- Replanting Area
- King County Owned Parcel
- Parcel Boundary & No.
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

N

0 100 200 300
Feet

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

Figure 53. Turley maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.

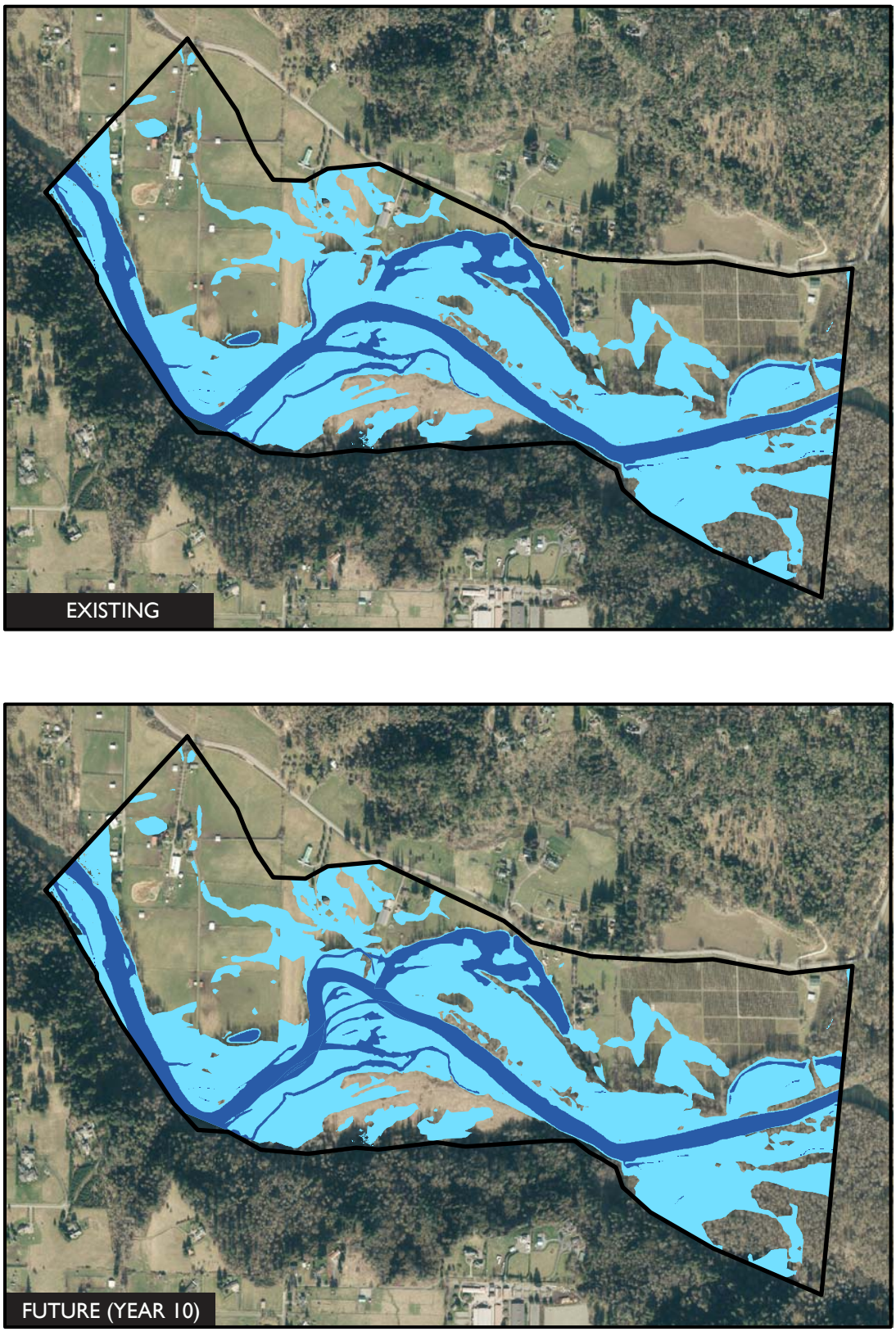
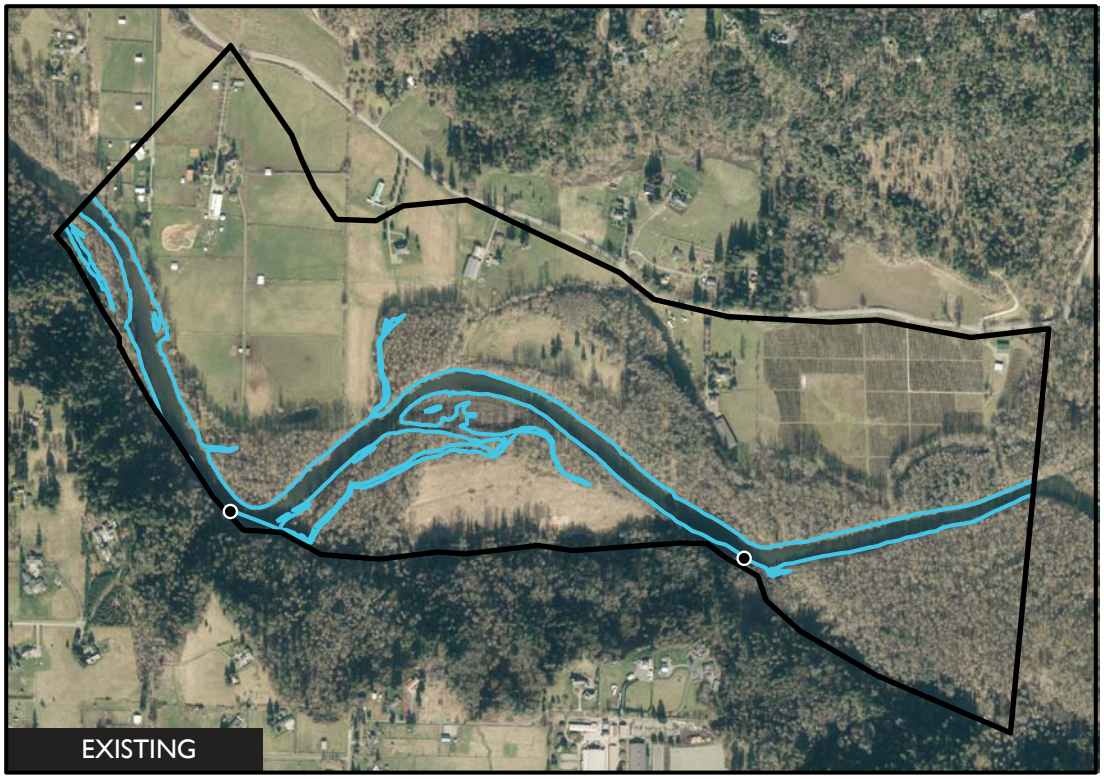


Figure 54. Turley maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.



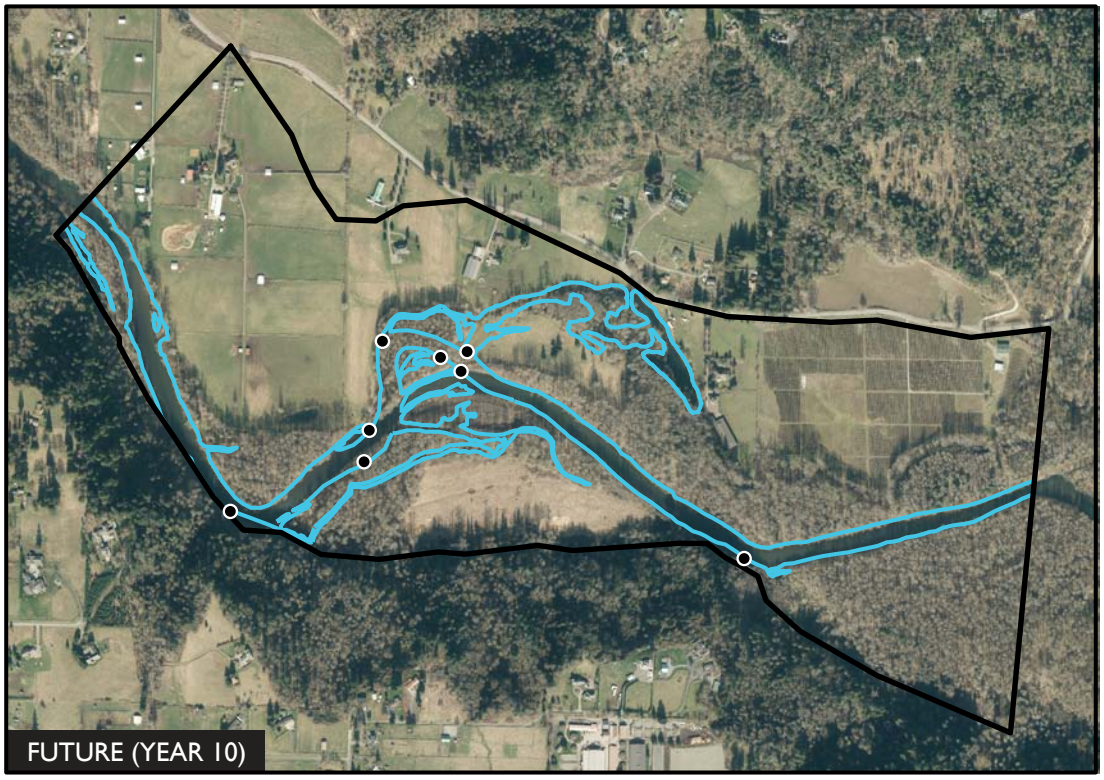


Figure 55. Turley maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.

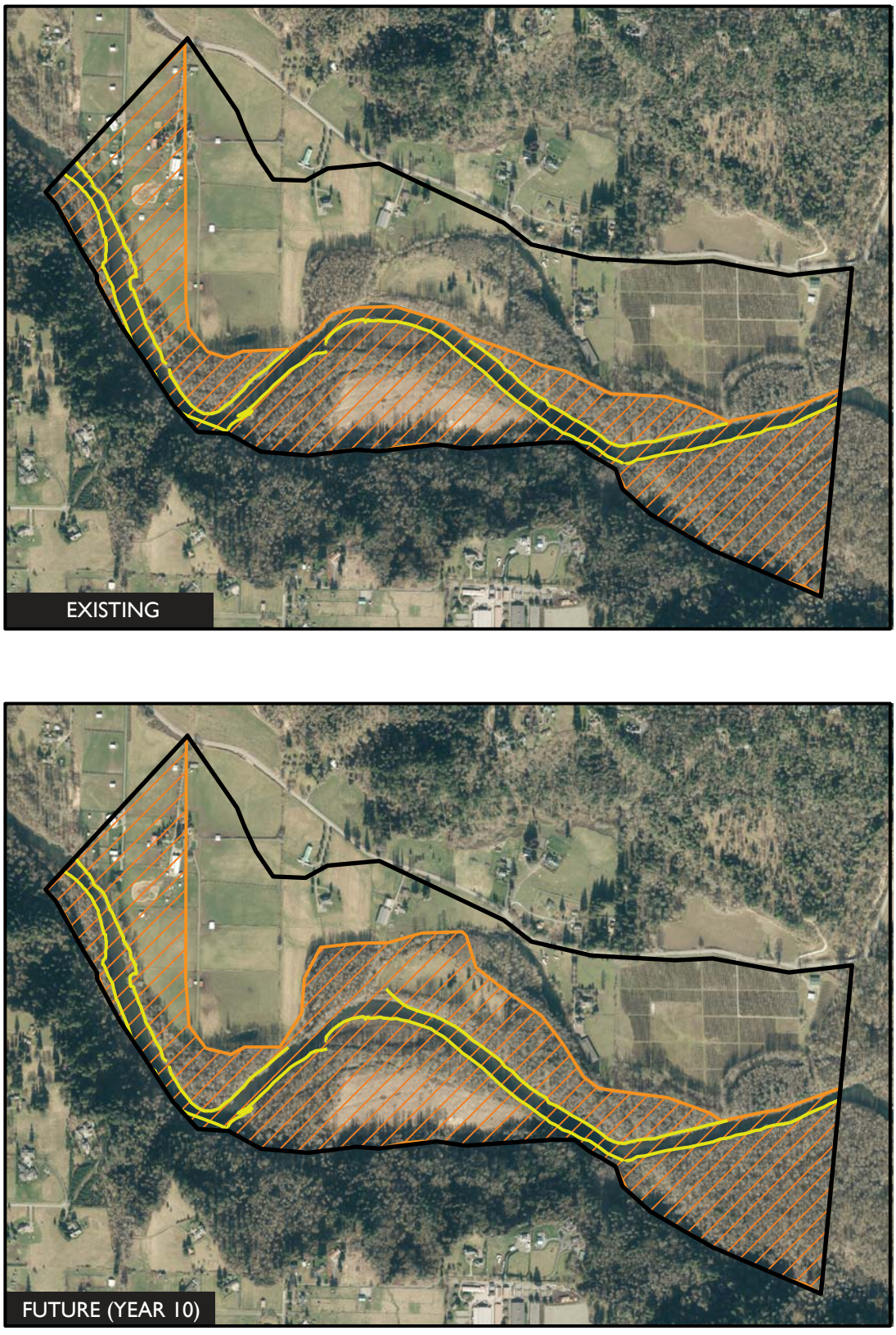
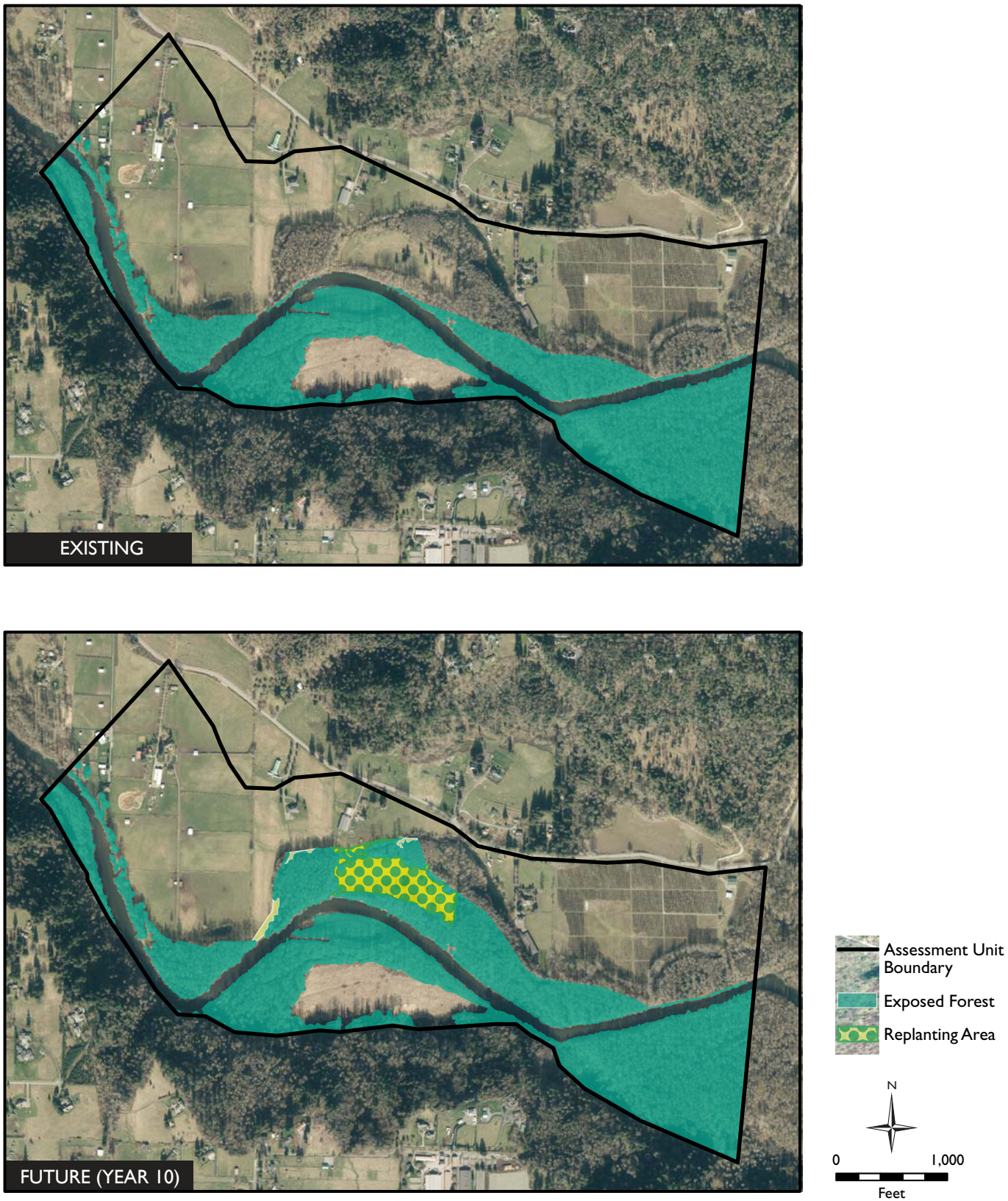


Figure 56. Turley maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration and replanting areas.



Site 9: Lones

Figure 57. Lones Site Photos

Site Description

The Lones Levee site is on the right bank at RM 37.5, Southeast Section 25, Township 21 North, Range 5 East (Figure 58). The training levee prevents the river from migrating through the 37-acre site, which contains a series of abandoned channels that are seasonally impounded and that support two forested wetlands. The 1,482 linear foot training levee is eroding and a portion of the revetment face has been eroded by the river (Figure 57), exposing a core of gravel.

Existing Conditions

Habitat conditions in the Lones assessment unit are the least degraded of all the assessment units in this study, particularly at the upstream end, where the river exhibits a high degree of physical complexity and lateral channel migration. The upstream part of the unit contains an actively migrating channel with numerous logjams, a side channel, springbrooks (one-way channels fed by upwellings), and backwaters; as well as extensive floodplain forests. Lones Levee prevents the channel from migrating toward the left bank. It appears to also prevent the river from aggrading at that location, which would allow it to avulse into historic channels behind the left bank.

The Lones assessment unit contains 49.2 acres of inundated area at 1,800 cfs and 210.5 acres at 8,800 cfs(Table 46). Wetted edge measures 45,300 feet and there are 17 wood trapping sites. An estimated 373 acres are currently exposed to channel migration; 225 acres in this area are currently forested and could supply wood to the river. Erodible banks measure 18,400 feet.

Conceptual Project Design

This design consists of removing 1,482 feet of rock revetment to destabilize the existing training levee (Figure 59). Contruction includes 1,188 linear feet of rock revetment along the edge of the upper terrace to create a non-deformable boundary, and building two ELJs downstream to intercept the channel as the straight channel begins to meander. An 800 LF alternate setback structure would provide additional channel migration area. This design would require further analysis to ensure consistency with King County codes and regulations.

Table 45. Design Details for Lones			
Category	**Detail**	**Units**	**Value**
Planning Context	WRIA 9 Plan Project Number	None	MG-9
	ERP Project Number	None	30
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	0
	Length of Existing Levee	Linear Feet	1,482
Proposed Actions	Rock Revetment to be Removed	Linear Feet	1,482
	New Rock Revetment Structure to Construct	Linear Feet	1,188
	New Engineered Log Deflection Structures to Construct (ELJ)	Each	2
	Water Diversion	Each	1
	Land Removed from Agricultural Use	Acres	0
Affected Properties	Total Parcels	Number	2
	King County Parcels or Easements	Number	1
	Private Property Interests to Purchase	Number	2

Indicator 1: Habitat Benefit Assessment

Table 46. Habitat Benefit for Lones						
Objective	**Factor**	**Units**	**Alt 1**	**Alt 2**	**Alt 2 - Alt 1**	**Ecological Lift***
1	Inundated Area at 1800 cfs	Acres	49.2	60.7	**11.5**	12
2	Inundated Area at 8800 cfs	Acres	210.5	212.6	**2.1**	2
3	Wetted Edge Length	Feet	45,300	63,000	**17,700**	18,000
4	Large Wood Trapping Sites	Number	17	29	**12**	12
5	Channel Migration Area	Acres	373	381	**8.7**	10
6	Length of Erodible Bank	Feet	18,400	18,300	**-100**	0
7	Existing Wood Supply	Acres	225	232	**7**	10
8	Area for Replanting	Acres	179	179	**0**	0

*Rounded to reflect uncertainty in outcomes

Table 47. Lones Standards Checklist			
Standard	**Description**	**Score Alt 2**	**Compliance**
1	Dynamic Ecological Endpoint	1	Complies with standards
2	Measurably Enhanced	1	Complies with standards
3	More Self-Sustaining	1	Complies with standards
4	No Irreparable Harm	1	Complies with standards

Indicator 2: Cost Assessment

The construction costs for Lones includes rock removal, installation of a rock revetment for setback boundary protection, 2 ELJs, and water diversion that is required to maintain water quality during construction. The cost estimate includes re-use of rock and does not include importing rock. This estimate does not include removal of training levee prism material. The setback structure could consist of a buried revetment due to higher bank elevation; however, construction costs could go higher if wood elements are included. The project includes land acquisition costs.

Table 48. Estimated Project Costs for Lones

Type of Cost	Total
Acquisition	$130,294
Design, Permitting and Outreach	$394,910
Construction	$1,579,640
Construction Management and Inspection	$236,946
Maintenance	$50,000
Monitoring	$200,000
Total Project Cost	**$2,546,790**

Indicator 3: Land Availability Assessment

Three private parcels and one King County-owned parcel are associated with this project. In addition to a River Protection Easement established in 1959 and FPP covenants and restrictions in the late 90s, a conservation easement (Recording # 20000425001324) was purchased by King County Water and Land Resources Division on April 25, 2000 for the purpose of setting back and/or abandoning the training levee and allowing lateral channel migration to reoccupy the abandoned side channel and wetlands. The current property owner (who acquired the property after the easement was purchased) would like King County to repair and maintain the existing training levee facility and has opposed the construction of a buried setback revetment.

Table 49. Land availability assessment for Lones

Question	Description	Result
1	Receptive landowners?	Some
2	Does site include FPP easements?	Yes
3	Does project maintain farmable area?	Yes

Future Design Analysis

Further design development should include additional hydrologic analysis to evaluate how the proposed project would affect existing flooding and agriculture. The proposed project has the potential to both benefit and impact adjacent agricultural practices and to increase the frequency and duration of inundation and saturation of agricultural land. The FPP status of the project area properties requires that any setback structure project protect existing agricultural activities.

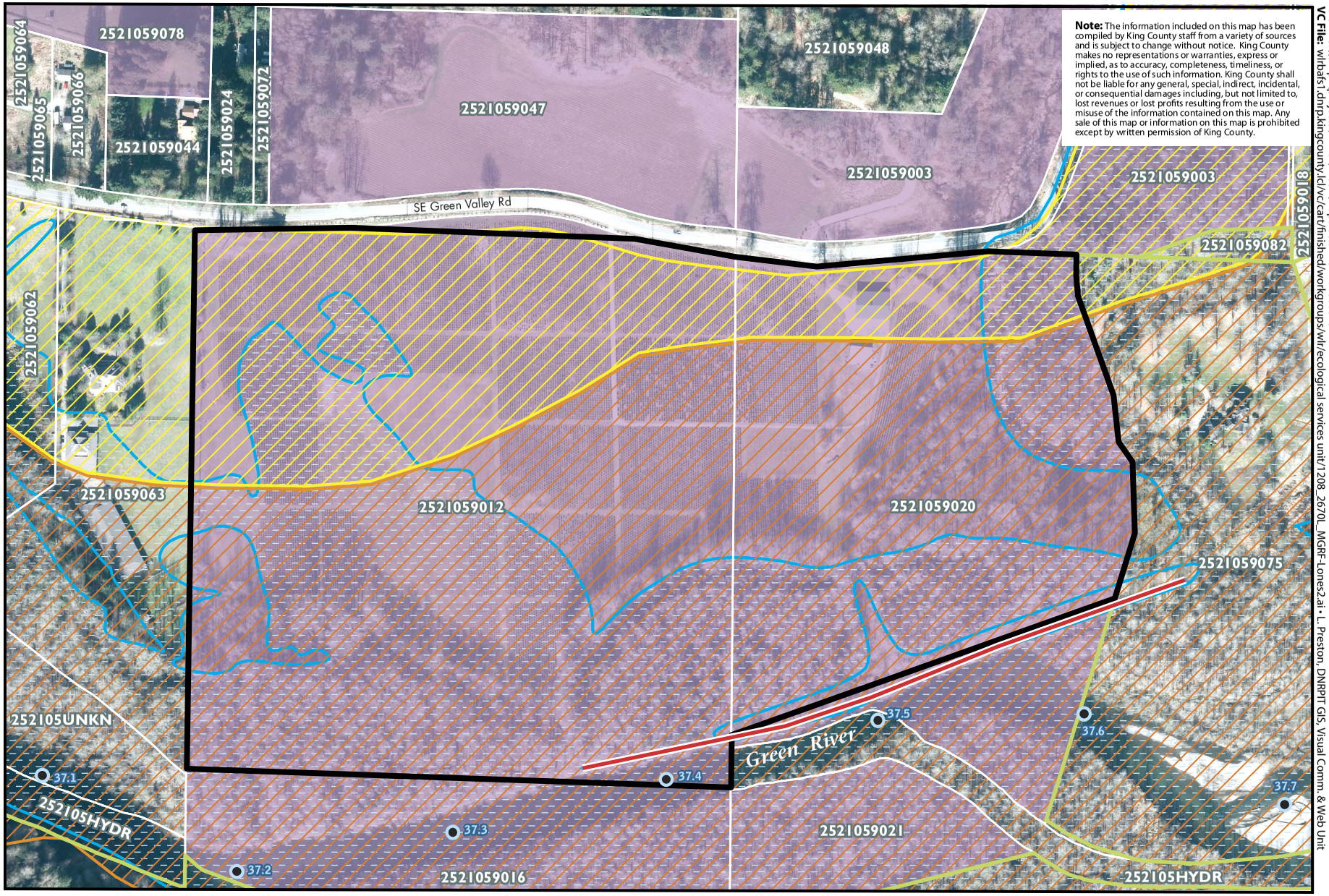


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Figure 58

LONES

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- Farmland Preservation Program Properties
- 33.2 River Mile (King Co. FHRS)

N

0 100 200 300
Feet

King County
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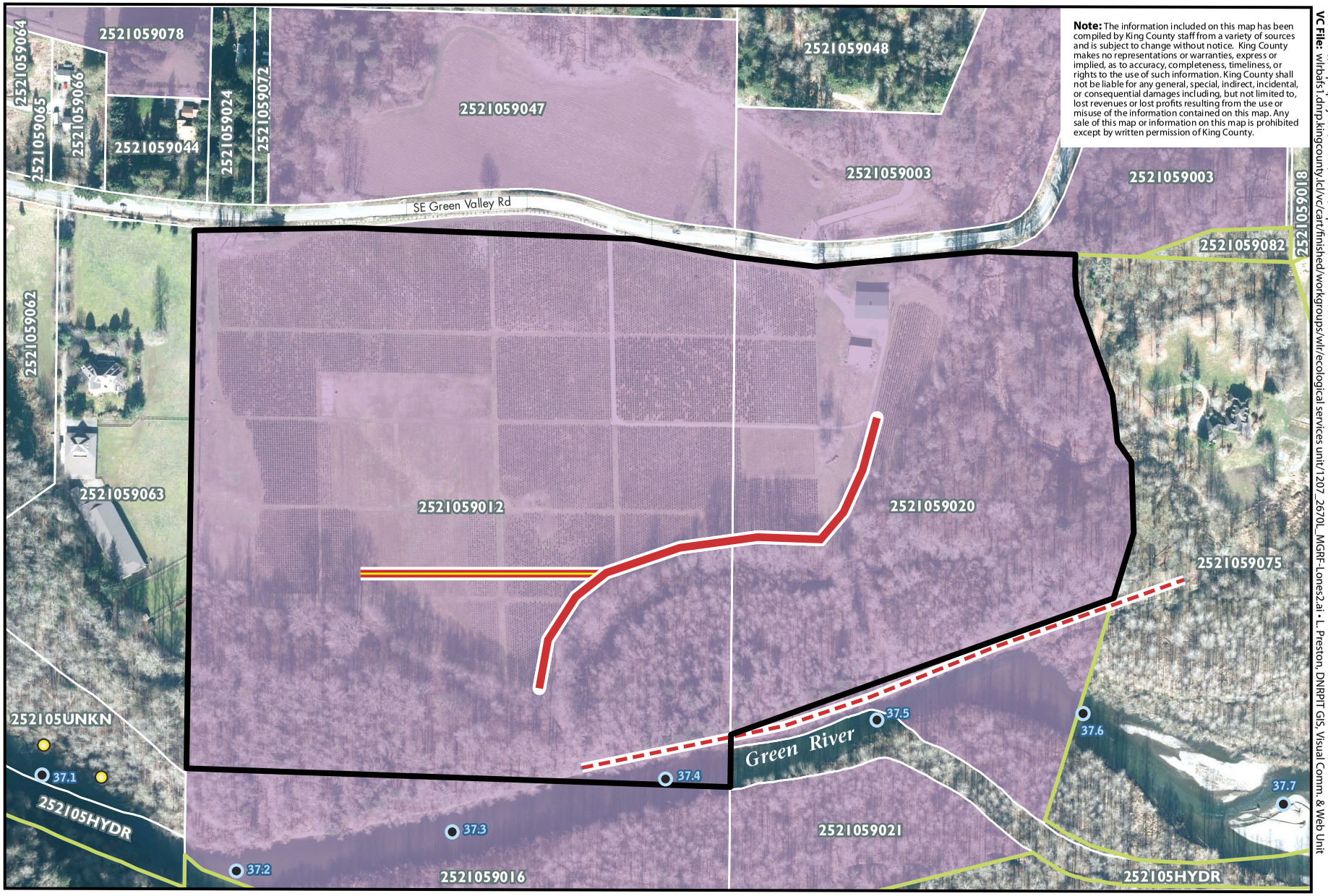


Figure 59

LONES

Alternative 2

Engineered Log Structure
Project Area Boundary
New Setback Structure
Alternate Setback Structure
Levee to Be Removed
King County Owned Parcel
Parcel Boundary & No.
Farmland Preservation Program Properties
33.2 River Mile (King Co. FHRS)

N
0 100 200 300
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure 60. Lones maps comparing existing and future (year 10) conditions for inundated area at 1,800 cfs and 8,800 cfs.

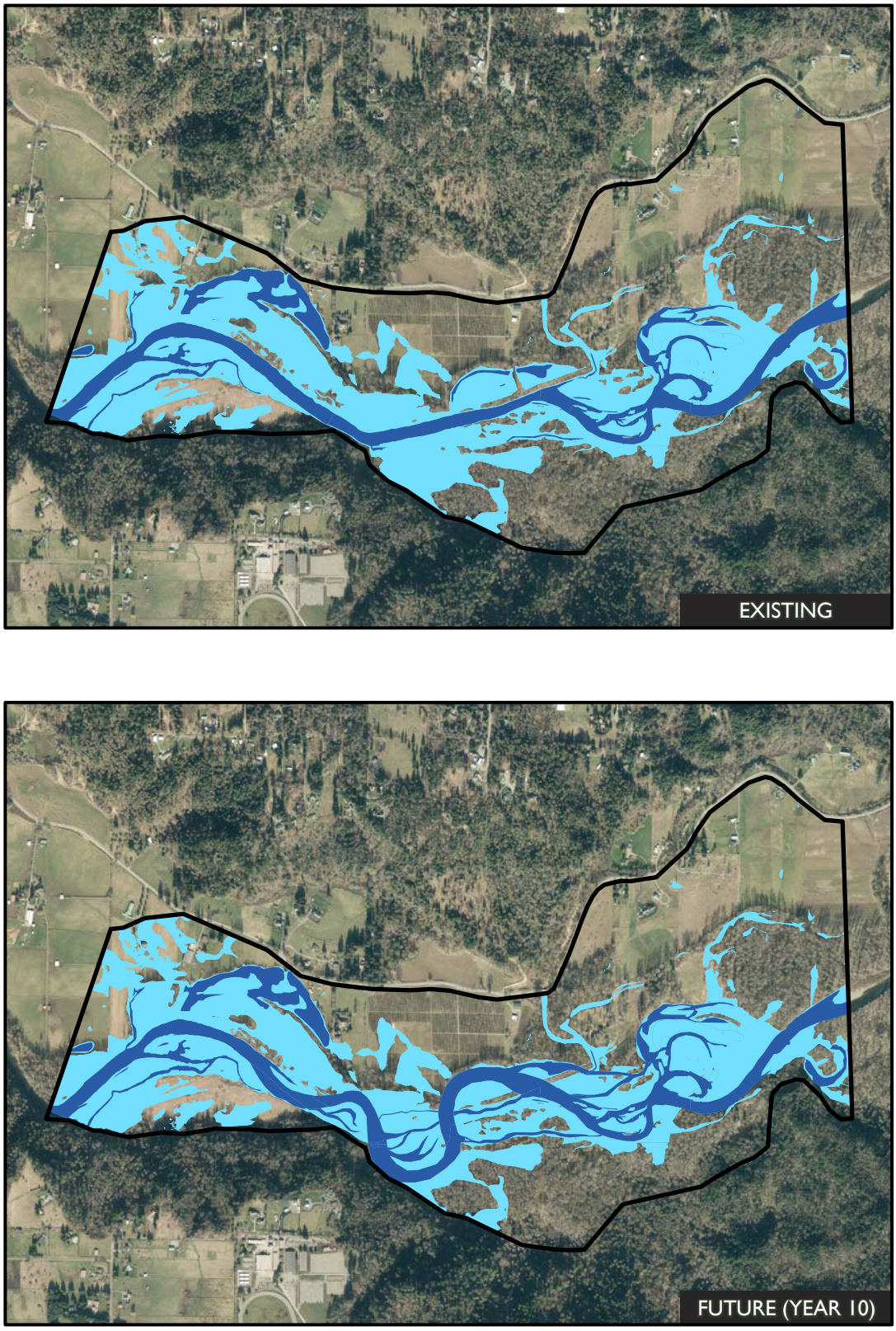


Figure 61. Lones maps comparing existing and future (year 10) conditions for wetted edge length at 1,800 cfs and large wood trapping sites.

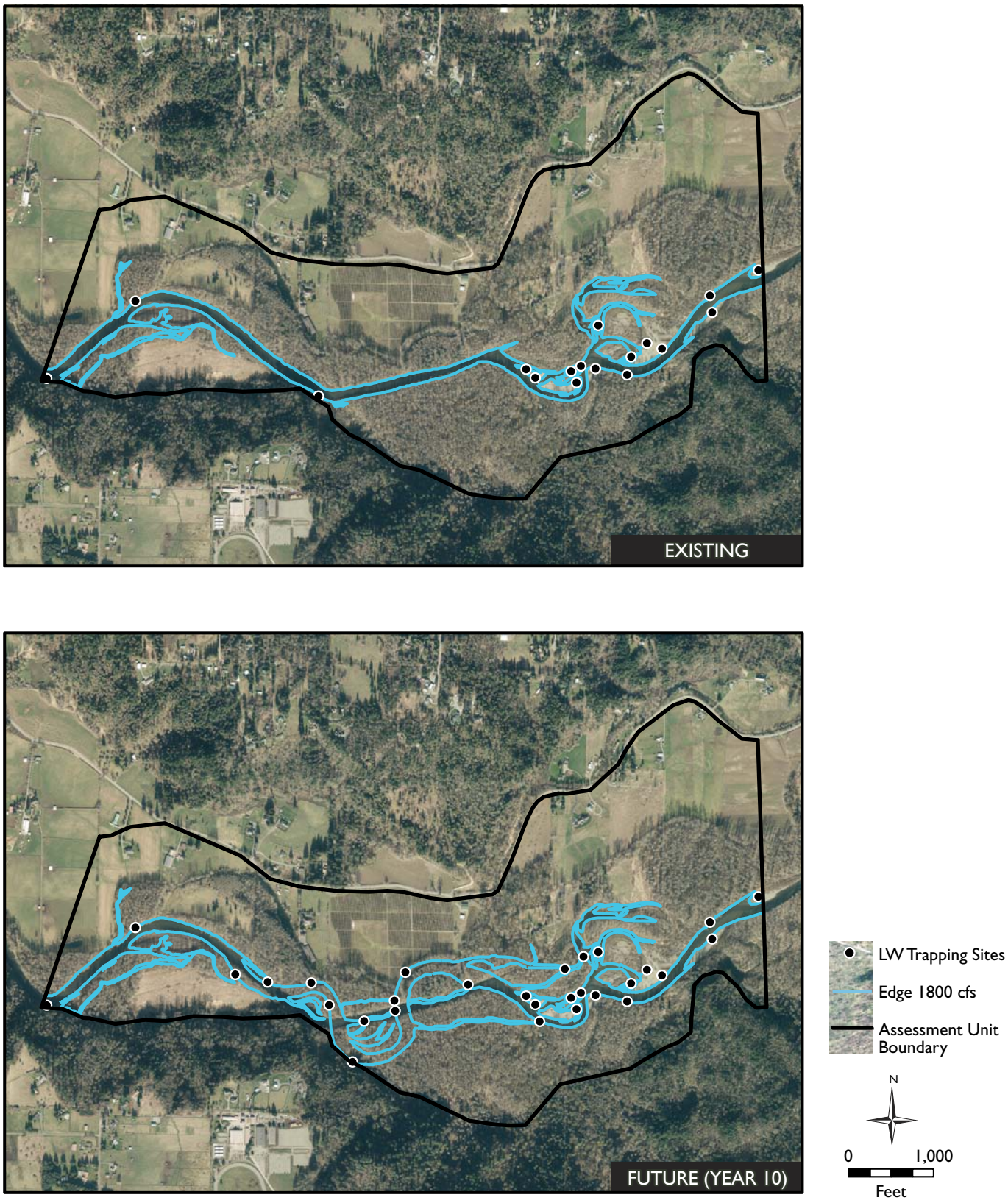


Figure 62. Lones maps comparing existing and future (year 10) conditions for erodible bank length at 1,800 cfs and channel migration area.

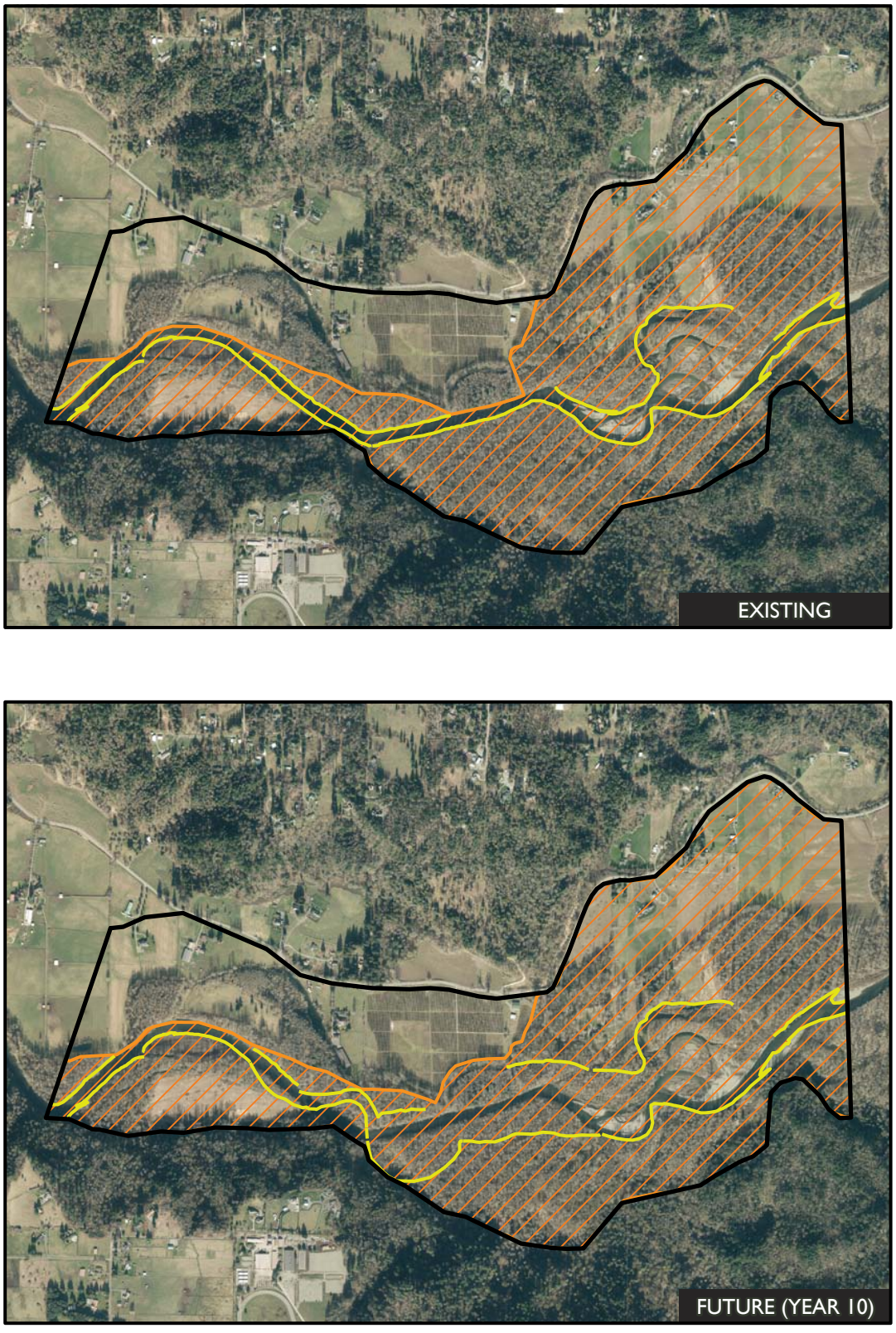
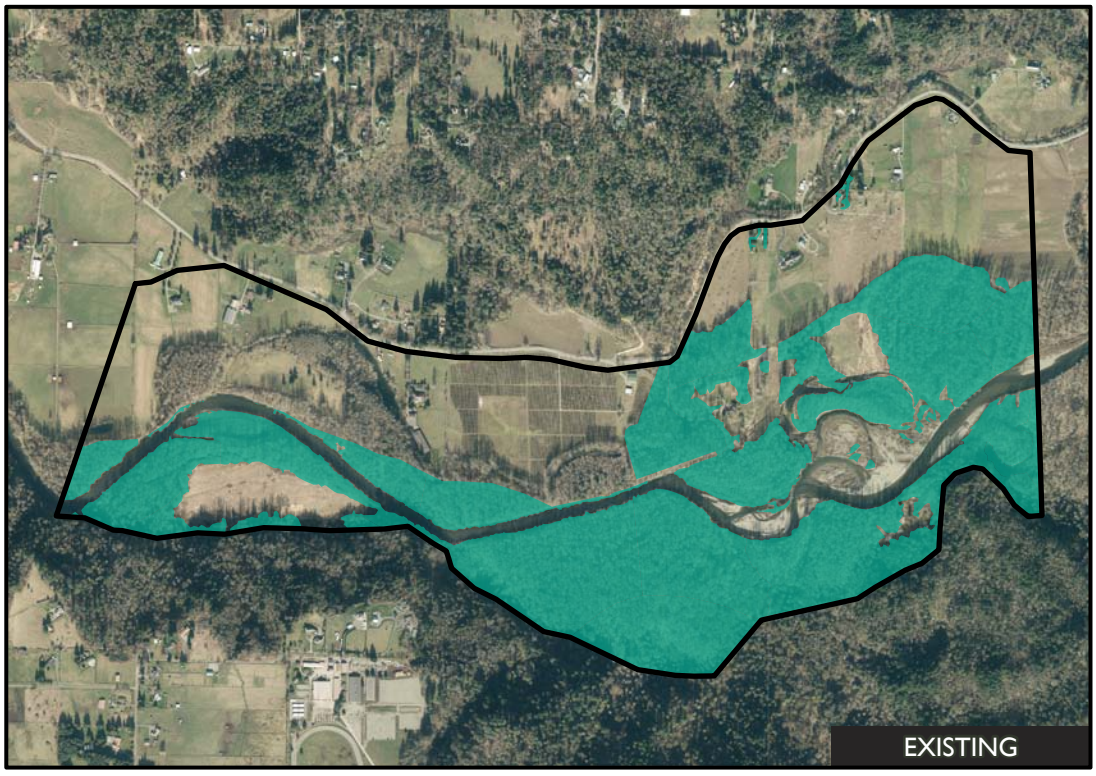
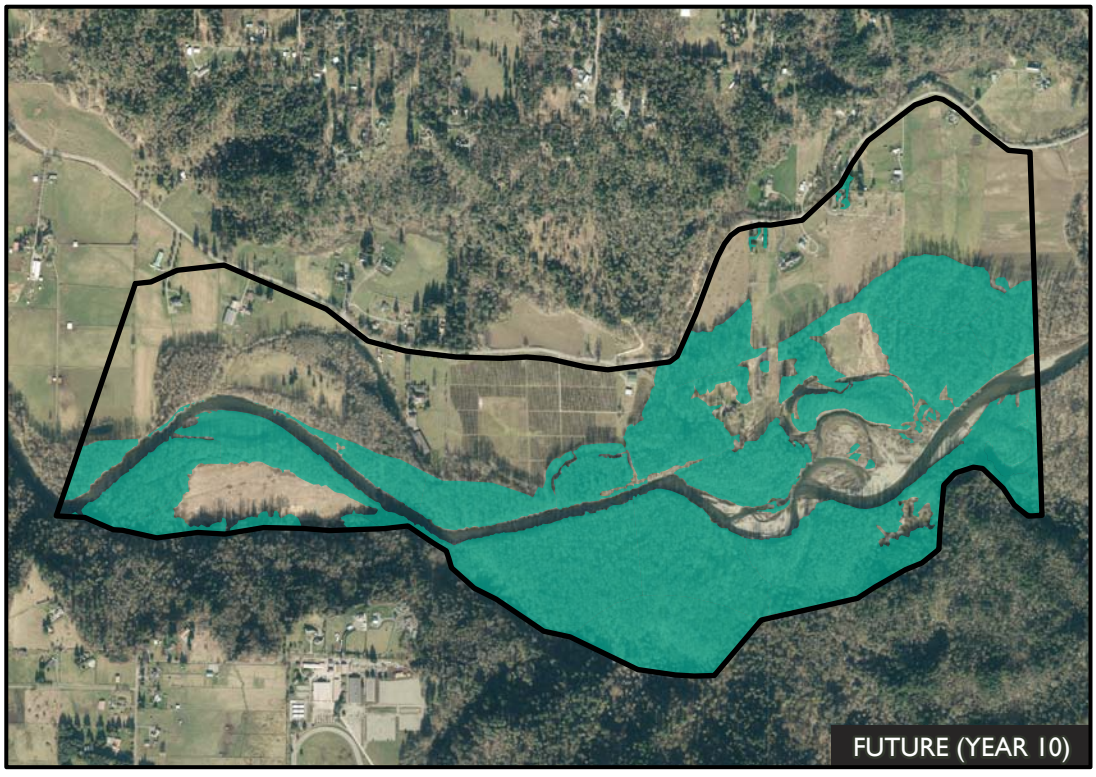
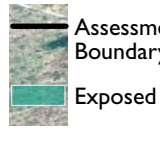
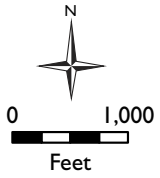


Figure 63. Lones maps comparing existing and future (year 10) conditions for areas of existing forest exposed to channel migration.









Site 10: Flaming Geyser

Figure 64. Flaming Geyser Site Photos

Site Description

Flaming Geyser is located on the left bank at RM 44, Southeast Section 30, Township 21 North, Range 6 East (Figure 66). This site is a collection of lands owned by King County and the State of Washington that are managed for outdoor recreation and natural resource protection.

Existing Conditions

Habitat conditions in the Flaming Geyser assessment unit have been degraded by the historic clearing of the riparian forest, which was followed by livestock grazing. Once livestock was removed from the assessment unit, invasive weeds like blackberry and Scotch broom became established on the site.

The Flaming Geyser assessment unit contains 88.7 acres of forest in the area exposed to channel migration, though the channel is relatively stable in this location (Table 51). Clearings occupy 36.9 acres; all of which could be replanted.

A side channel exists on the site, crossing through the floodplain on the right bank more or less parallel with the river (Figure 65). Another side channel, on the left bank of the river is approximately 9 acres in size and is frequently isolated from the river due to a small culvert and beaver dams. This area could be opened up, as was recommended in the Flaming Geyser Feasibility Study (Landau, 2006). Both side channels contain abundant pools, riffles and logjams.

Conceptual Project Design

This project consists of planting 37 acres of land with native riparian vegetation (Figure 67).

Figure 65. Existing Side Channel at Flaming Geyser Project Site

Indicator 1: Habitat Benefit Assessment

The primary habitat benefit from this project would be the revegetation of 37 acres of riparian forest. The river channel at this location is relatively stable and the mainstem is unlikely to re-occupy the side channel soon, so the plantings would not contribute substantial instream wood to the river in the near-term. However, replacing the blackberry-dominated fields of this old farmstead with native trees and shrubs could greatly enhance wildlife habitat for a myriad of species that would benefit from increased foraging, nesting, cover and migration opportunities.

Indicator 2: Cost Assessment

The construction cost for Flaming Geyser is associated with only planting in the floodplain. The design, permitting and outreach costs, and construction management and inspection should be considerably lower than estimated, which is based on a percentage of construction cost.

Table 50. Design Details for Flaming Geyser 2

Category	Detail	Units	Value
Planning Context	WRIA 9 Plan Project Number	None	MG-3, MG-4
	ERP Project Number	None	35
	Project Alternative	N/A	2
Existing Conditions	Area of Project Site	Acres	37
	Length of Existing Levee	Linear feet	0
Proposed Actions	Planting Area	Acres	37
	Land Removed from Agricultural Use	Acres	0
Affected Properties	Total Parcels	Number	1
	King County Parcels or Easements	Number	0
	Private Property Interests to Purchase	Number	1

Table 51. Habitat Benefit for Flaming Geyser

Metric	Factor	Units	Alt 1	Alt 2	Ecological Lift*
1	Inundated Area at 1800 cfs	Acres	n/a		
2	Inundated Area at 8800 cfs	Acres	n/a		
3	Wetted Edge Length	Feet	n/a		
4	Large Wood Trapping Sites	Number	n/a		
5	Channel Migration Area	Acres	n/a		
6	Length of Erodible Bank	Feet	n/a		
7	Wood Supply (Exposed forest)	Acres	n/a		
8	Replanting Area	Acres	0	36.9	36.9

*Rounded to reflect uncertainty in outcomes

Table 52. Flaming Geyser Standards Checklist

Standard	Description	Score Alt 2	Compliance
1	Dynamic ecological endpoint	1	Complies with standards
2	Measurably enhanced	1	Complies with standards
3	More self-sustaining	1	Complies with standards
4	No irreparable harm	1	Complies with standards

Table 53. Estimated Project Costs for Flaming Geyser	
Type of Cost	**Total**
Acquisition	$0
Design, Permitting and Outreach	$280,514
Construction	$1,122,055
Construction Management and Inspection	$63,116
Maintenance	$177,120
Monitoring	$45,000
Total Project Cost	**$1,792,997**

Indicator 3: Land Availability Assessment

The property assessed is owned by the Washington State Department of Parks and Recreation (WA Parks); a small portion of the assessment area is owned by King County. Additional outreach effort would be required to encourage WA Parks participate in project development. For the purposes of this study it was assumed that the property owner was somewhat amenable to the revegetation of the native buffer.

Table 54. Land Availability Assessment for Flaming Geyser		
Question	**Description**	**Result**
1	Receptive landowners?	Some
2	Does site include FPP easements?	No
3	Does project maintain farmable area?	Yes

Future Design Analysis

The potential may exist to plant a nearly 1-mile section of the left bank opposite and downstream from the proposed project site with natives plants and trees. This area is managed by WA Parks, but is currently not adequately vegetated to provide riparian functions and habitat value. Planting this area will likely be difficult owing to conflicts between recreational use of the area (for example, remote control airplane flying) and threatened species habitat provision.

An open water area exists nearby that is thought to be isolated from the river by a culvert and beaver dams. Some have proposed to enlarge the culvert under the road to increase connectivity of this feature. This option was not explored as part of this study, in part, because the work would be done outside the scope of the ERP concepts, and secondly, because it was not related to a levee setback or ERP project.

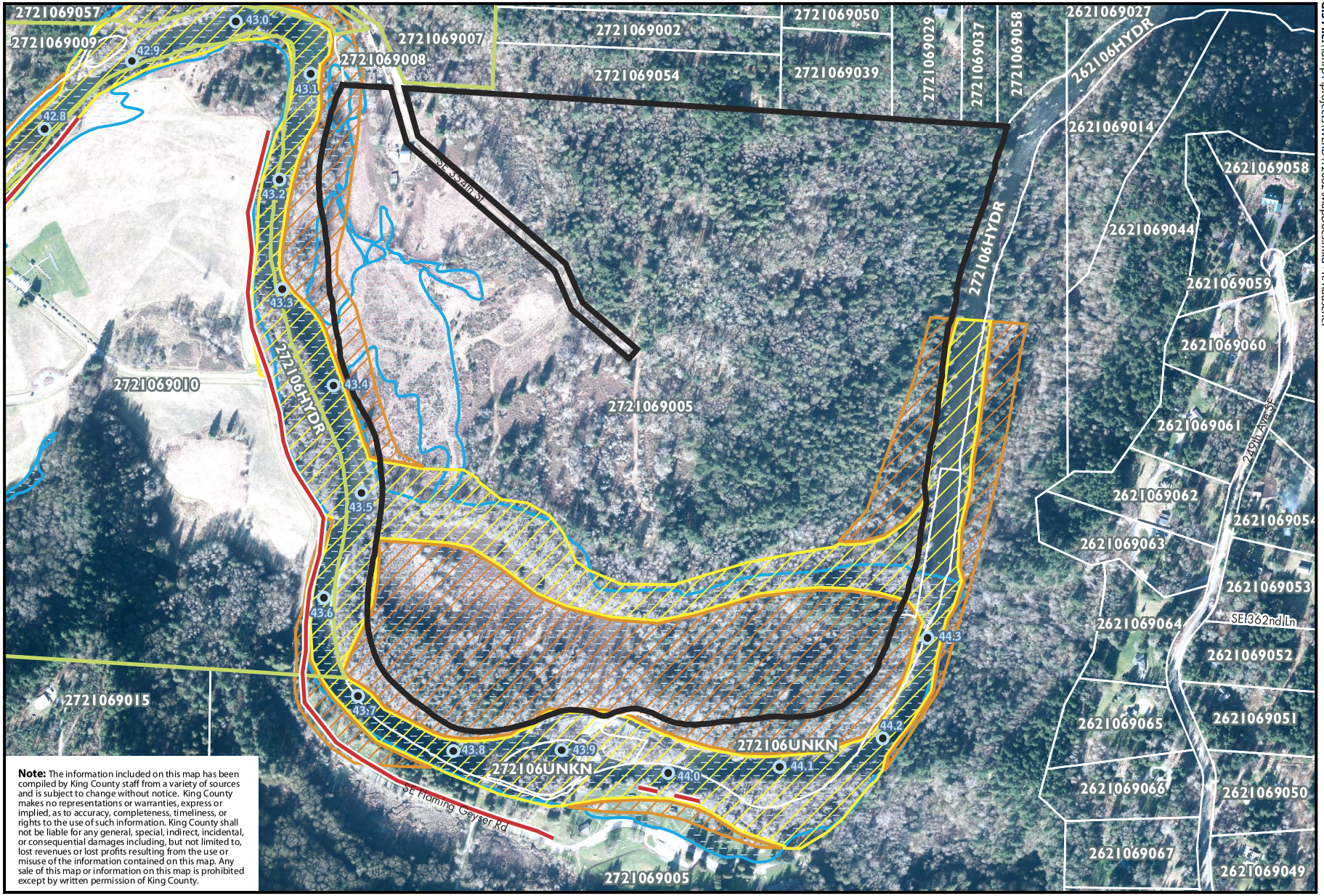


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Figure 66

FLAMING GEYSER

Alternative 1 (Existing Conditions)

- Project Area Boundary
- Existing Levee
- King County Owned Parcel
- Parcel Boundary & No.
- 100 Year Floodplain
- Moderate Channel Migration Zone
- Severe Channel Migration Zone
- 33.2 River Mile (King Co. FHRS)

N

0 500

Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

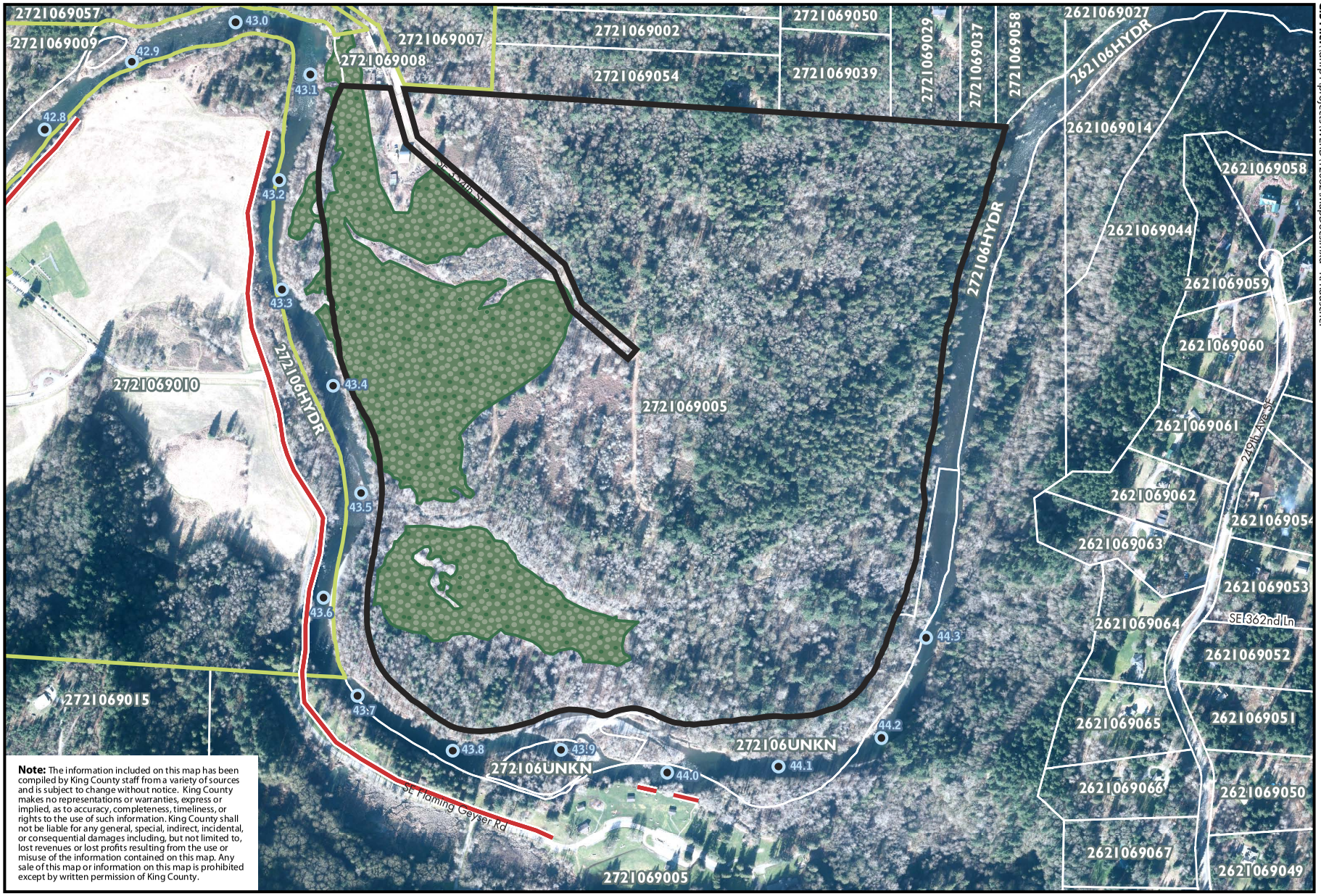

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Figure 67

FLAMING GEYSER

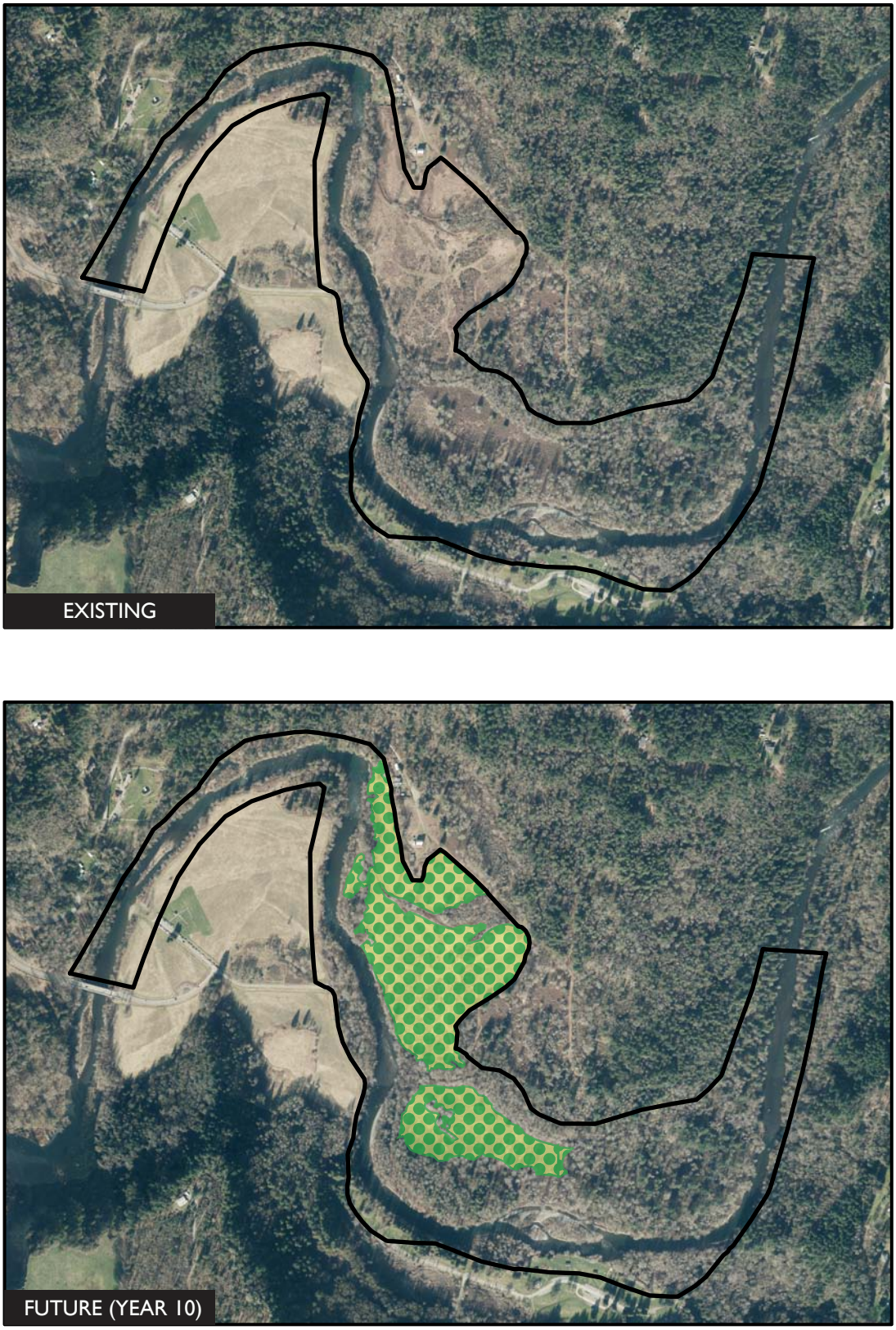
Alternative 2

Project Area Boundary
Existing Levee
Replanting Area
King County Owned Parcel
Parcel Boundary & No.
33.2 River Mile (King Co. FHRS)

N
0 500
Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure 68. Flaming Geyser maps comparing existing and future (year 10) conditions for planting areas.



4. SUMMARY

4. SUMMARY

This study identified and assessed 10 habitat restoration project sites in the Middle Green River where opportunities exist to improve ecological functions to benefit ESA-listed Chinook salmon and steelhead, along with other aquatic and terrestrial wildlife. The assessment model results are summarized and ranked based on the overall feasibility score (Table 55).

Projects evaluated in this study ranged widely in scope, cost and benefit (Figure 69). In general, the relative habitat benefit expected from projects was correlated with the cost of the project. Project cost was generally linked to the size and scope of the project. Not surprisingly, larger projects cost more and provide greater benefits. The land assessment was the most sensitive factor in this feasibility assessment model since it is based on changeable variables including property owner willingness to sell and the agricultural impacts (or benefits) of the project.

4.1 Habitat Benefit

Projects varied widely in their capacity to deliver specific habitat benefits (Table 56). Lones is expected to create the most rearing habitat refuge at 1,800 cfs, but Hamakami Reach could generate the most flood refuge at higher flows. These two projects are expected to generate the highest levels of edge habitat and trapping sites for large wood.

Four projects expose the most floodplain to channel migration: Hamakami Reach, Porter, Horath and Turley. Hamakami Reach would generate the largest increase in erodible bank length, to supply wood and sediment to the river. Five projects (Hamakami Reach, Porter, Horath, Turley and Auburn Narrows) are expected to expose 10 acres or more of forested floodplain, which can support natural wood recruitment and logjam formation. These five projects all involve setting back training levees. Flaming Geyser, Horath, Hamakami Reach and Ray Creek offer the best opportunities for extensive revegetation.

The Hamakami Reach project is expected to provide the greatest ecological lift, but land availability is low and the cost is high. Porter ranks second for ecological lift and scores high for land availability, meaning it could be implemented expeditiously. Lones is nearly tied with Porter for ecological lift, but land availability is moderate. Turley scores slightly lower for ecological lift and has moderate land availability, as well. Horath is expected to provide comparable ecological lift to Turley, but is currently unavailable, primarily due to land availability issues, and is significantly more costly. Auburn Narrows ranks relatively low in terms of ecological lift, but is a worthwhile, inexpensive project that could be implemented easily. Combining projects, such as Lones and Turley could create almost as much ecological lift as the Hamakami Reach project.

Table 55. Project Rankings Based on Overall Feasibility

Site Name Indicator	Habitat Assessment Score	Cost Assessment Score	Land Assessment Score	Overall Feasibility Score	Rank	Cost Assessment
Auburn Narrows	0.5	4	4	8.5	**1**	$437,213
Porter	2.0	1	4	7.0	**2**	$3,876,661
Flaming Geyser	0.8	3	2	5.8	**3**	$1,792,997
Hamakami	0.4	4	1	5.4	**4**	$213,451
Lones	2.0	2	1	5.0	**5**	$2,546,790
Neely	0.7	3	1	4.7	**6**	$529,217
Turley	1.6	2	1	4.6	**7**	$2,702,623
Ray Creek	0.5	4	0	4.5	**8**	$593,416
Hamakami Reach	3.2	1	0	4.2	**9**	$16,783,378
Horath	1.6	1	0	2.6	**10**	$7,478,446
					Total Cost:	**$29,475,746***

*Total cost exclusive of Horath.

Figure 69. Relative Habitat Benefit (Ecological Lift), Cost, Land Availability

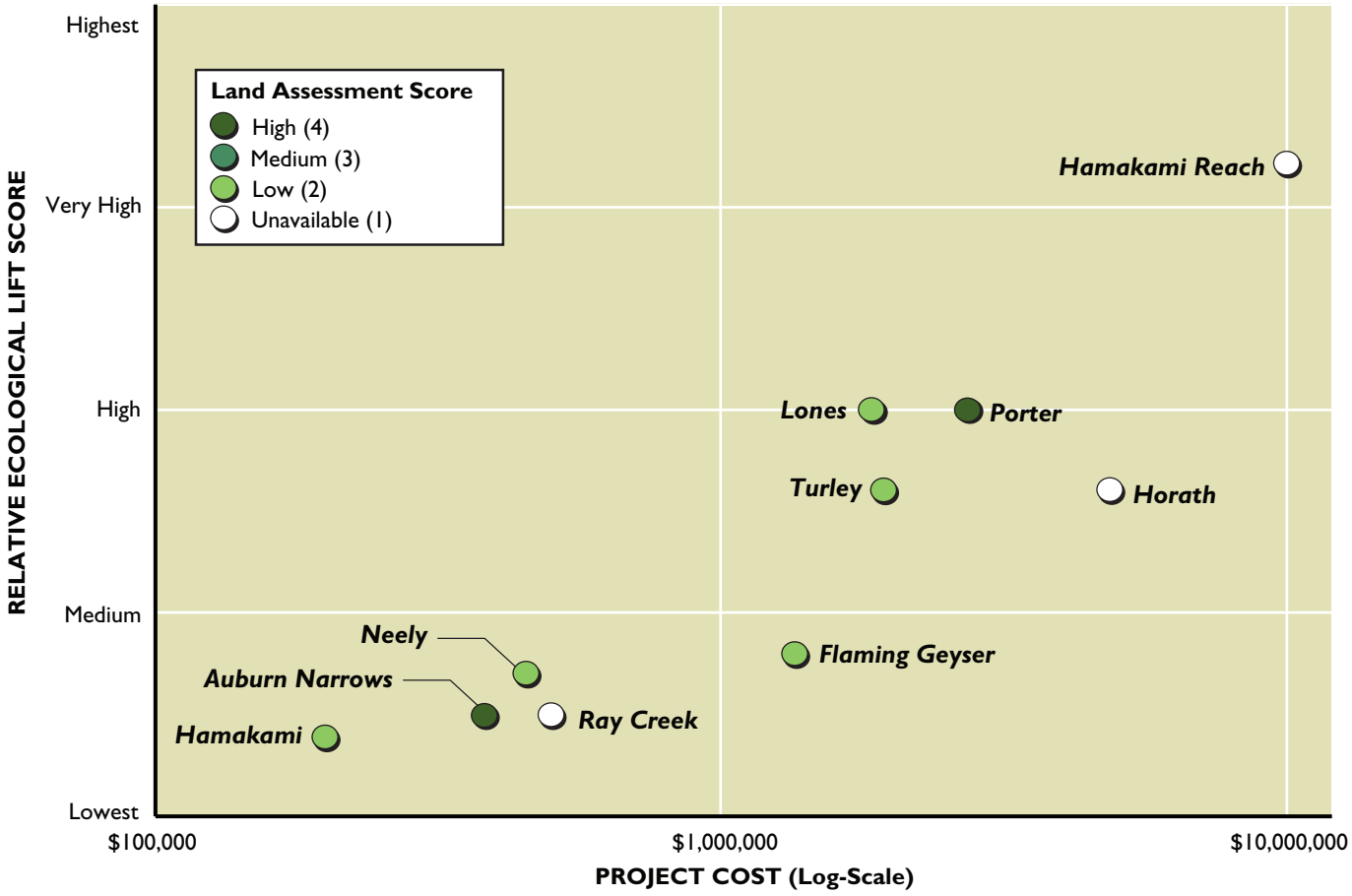


Table 56. Summary of Habitat Benefits or Ecological Lift Anticipated from Each Project

Site Name	Flow Refuge–1800cfs (acres)	Flow Refuge–8800cfs (acres)	Edge (feet)	Trapping Sites (count)	Migration Area (acres)	Erodible Bank (feet)	Wood Supply (acres)	Reforest (acres)	Weighted Average Score (4 possible)	Based on Wt. Avg. Score
Hamakami Reach	4	7	15,000	10	40	4,000	20	32	3.2	1
Porter	7	3	10,000	5	25	1,000	20	8	2.1	2
Lones	12	2	18,000	12	10	0	10	0	2.0	3
Horath	1	1	3,000	7	30	2,000	10	29	1.6	4
Turley	2	0	11,000	6	30	1,000	20	9	1.6	4
Flaming Geyser	0	0	0	0	0	0	0	37	0.8	5
Neely	1	0	6,000	4	0	0	0	0	0.7	6
Auburn Narrows	0	0	3,000	0	0	1,000	0	0	0.5	7
Ray Creek	0	0	0	0	0	0	0	19	0.5	7
Hamakami	2	0	4,000	0	0	0	0	0	0.4	8

4.11 Cost

The total cost of implementing the projects in this report could exceed $29 million. Construction costs represent the majority of the expense, followed by acquisition and design, permitting and outreach.

Table 57. Estimated cumulative project costs for implementing recommended Middle Green River projects and percent of total cost by project sites.

Type of Cost	Total	Percent of Total
Acquisition	$3,656,154	12%
Design, Permitting and Outreach	$5,183,799	20%
Construction	$22,680,920	77%
Construction Management and Inspection	$3,402,138	12%
Maintenance	$628,820	2%
Monitoring	$772,000	3%

4.12 Land Availability and Agriculture

Seven potential restoration projects are located within the Upper Green APD on private agricultural land: Neely, Ray Creek, Horath, Hamakami, Hamakami Reach, Turley and Lones. Training levees were previously constructed on these properties to protect agricultural land from lateral channel migration and erosion. These properties abut or include potential lateral habitats including side-channels, wetlands, or oxbow ponds formed by the construction of training levees. The removal and/or setting back of the training levees as assessed in this feasibility study could increase risk of erosion to some agricultural land within the APD, although the conceptual designs developed for this study include setback structures to mitigate these risks. Some FPP and agricultural properties are already at risk of erosion due to the deteriorating condition of some of the training levees. Setting back these training levees would improve habitat conditions, while providing long-term protection to some properties.

If all seven of these projects were implemented, 79 acres, (approximately 2% of the farmable acreage in the APD) would be removed from production. Of this acreage, 34 are currently enrolled in the FPP. Constructing habitat restoration projects on these APD properties would require some form of mitigation consistent with King County codes and ordinances to provide a net benefit to agriculture.

4.2 Cumulative Ecological Lift

The cumulative habitat benefit from implementing all recommended projects identified in Table 55 would be substantial, primarily affecting the number of large wood trapping sites, wetted edge length and riparian forest extent (Table 58). Inundated area at 1,800 cfs could increase by 28 acres (some portion of which would become riverine wetland), and by an additional 13 acres at 8,800 cfs. Roughly 67,000 feet of new edge habitat could form. An additional 36 wood trapping sites could form, contributing to greater numbers of logjams, enhanced wood retention and associated aquatic habitat. The river channel could migrate an additional 110 acres, creating diverse and productive habitat in the process. The river would also be able to access native gravels and sediments from local sources, as the length of erodible bank could increase by nearly 7,000 feet. Seventy acres of existing floodplain forest would be reconnected to the channel to supply large wood and enhance habitat complexity over the long-term. The riparian forests of the Middle Green River could be expanded by roughly 105 acres through planting efforts in existing clearings.

Table 58. Cumulative habitat benefits from implementing recommended Middle Green River projects.

Metric	Factor	Units	Ecological Lift
1	Inundated Area at 1,800 cfs	Acres	28
2	Inundated Area at 8,800 cfs	Acres	13
3	Wetted Edge Length	Feet	67,000
4	Large Wood Trapping Sites	Number	36
5	Channel Migration Area	Acres	110
6	Length of Erodible Bank	Feet	7,000
7	Wood Supply	Acres	70
8	Area for Replanting	Acres	105

5. RECOMMENDATIONS

5. RECOMMENDATIONS

The Middle Green River Levee Setback Feasibility Study provides the following recommendations:

- From a habitat perspective, all projects recommended in this feasibility study should be implemented. However, we recommend prioritizing and implementing projects based on the integrated assessment in which Habitat, Cost and Land Availability assessments are combined to create an overall feasibility score and then ranked. Implementing projects based on the overall feasibility provides a multi-objective, balanced approach to project selection. All projects would have to undergo additional review to assess and mitigate impacts to adjacent properties and comply with federal, state and local codes and regulations.
- The WRIA 9 ITC should provide additional guidance to King County regarding optimizing the sequencing of Middle Green River restoration work.
- Because of the overlapping interests of performing aquatic habitat restoration and preserving agricultural productivity within APDs, stakeholders should have an opportunity to provide input as to the overall approach and prioritization of projects.
- Each of the projects in the APD will need to be evaluated during formal design for compatibility with land use policies and regulations. A process to facilitate discourse among King County staff and other entities related to this effort should be initiated in order to achieve consistency with policies and regulations related to implementing restoration projects in the APD.
- Many revegetation opportunities exist in the Middle Green River but were not evaluated in this study. However, it is recommended that a conceptual design for a comprehensive, large-scale revegetation effort to expand and connect the forested areas within the Middle Green Natural Area and other public lands such as Flaming Geyser be completed.
- Landowner outreach should be an active and integral part of the design development process.
- The criteria used to evaluate benefits in this study are different from those used in the 2008 Middle Green subwatershed prioritization because more detail was available for each project site and the design concepts were more complete. The results of the 2008 effort should be updated to align with the results of this feasibility study because this analysis is based on a better understanding of the project concepts, benefits and limitations.

5.1. Limitations of this Study

This study does not include site-specific information based on detailed analysis of potential impacts (for example, drainage improvement or reduction) to agricultural properties. Nor does this study determine the consistency of these projects with the aquatic habitat restoration or other relevant codes, Comprehensive Plan language, ordinances, or other permit-related requirements. These efforts will take place as projects move forward with the acquisition, design and permitting processes and would have to be successfully achieved prior to constructing projects. Future design issues will need to be addressed and in most cases, further geomorphic and hydraulic analyses (for example, modeling) will be required.

While some of the projects exemplified in this study may ultimately remove agricultural land from production, benefits to agriculture would likely be provided in a number of ways. Setting back and reconstructing old and/or failing levees would provide greater erosion protection to a significant number of acres in the APD. Drainage improvement and soil top-dressing are other measures that could be used to mitigate for the reduction farmable area. Other benefits to agricultural production may be provided by these projects on a site-specific, project-level basis.

There is substantial uncertainty related to the estimated costs and quantities of habitat under future conditions, and land availability is subject to change over time. This uncertainty should be recognized in project selection, planning and design.

Estimates of ecological lift are plausible, but can only be determined with a small degree of accuracy and precision – particularly for the large setback structure projects. Numerous simplifying assumptions must be made, and predicted outcomes are based on many subjective judgments that could differ between qualified observers. Greater accuracy and precision will likely be achieved through further study in the design phase of each project. The lift caused by planting projects is relatively accurate and precise,

by comparison. In spite of limited precision and accuracy, the predicted future outcomes from each project are thought to be plausible, if not likely. In that case, the estimates are sufficient for the purpose of choosing between projects and ranking them for implementation. Estimates of lift are representative, in the sense that each project location was analyzed with site-specific data and observations, not simply from a generalized formula or from literature referencing other locales. The estimates will be revised with future studies, but they are much more authoritative than what existed prior to this study, allowing for more informed decision-making on the basis of expected project outcomes.

Land availability was assessed by presenting project design figures to property owners and asking them if they would sell easements or property. Responses are sufficient for the purpose of choosing between projects; however, property owner attitudes towards projects are subject to change over time in response to variables such as economic externalities (land values, commodity prices), personal situations (employment, retirement), FPP and current use taxation status, and offering price. Where multiple acquisitions are necessary, some property owners indicated that they might sell if their neighbors were also participating. The property owners that were not professional farmers were generally more interested in selling than farmers.

The project cost assessments provide planning-level estimates for design, permitting, construction, maintenance and monitoring. The construction cost estimates included in this report were done at a planning level. The values in the costs were based on the best information available at this preliminary stage and could be subject to considerable change including changes in scope, regulatory requirements and/or unknown site constraints. The unit costs were based on previous projects, Washington State Department of Transportation unit bid analysis and best professional judgement.

Due to the many unknowns at this stage of a feasibility study, a contingency of 40% was applied to the sum of tax and construction total for each project. Contingency for projects at this stage could range up to 150% in some instances. Some examples of unknowns are:

- Design elements could change considerably thereby affecting quantities and costs.
- Unit costs may change year to year due to inflation and the economy.
- Discovery of previously unidentified site constraints such as contaminated soils or historic or cultural resources.
- There is variability in construction management, design, permitting, outreach, monitoring and land costs.
- Costs associated with protecting surrounding infrastructure will be better known as the design progresses..
- Variability in bid amounts for projects implemented using private contractors.
- Changes in regulatory standards or policy requirements affecting the properties.
- Scope changes necessary to comply with agricultural protection requirements outlined in KCC 21A.24.381
- Unexpected delays resulting from permitting, property acquisition or resolving conflicting policy requirements. Costs increase as a result of schedule delays.

APPENDICES

Cost Estimate 1: Auburn Narrows Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Auburn Narrows, Alternative 2

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
1	**Mobilize for construction**	1	LS	$13,290.00		$13,290.00		Assume to be 10% of all construction costs except pile installation.
2	**Clearing and grubbing**	1.0	LS	$2,000.00		$2,000.00	KC to provided updated cost/1 exc, 1opp, 1 utility for 4 days.	Includes areas for roads and structures.
3	**Stabilized construction entrance (4 - 8" rock)**	53	TN	$17.00		$906.67	Cost from KC equipment and production rates calculator.	15' x 50' x 1' dims (+25% for longer drives, and roadway connection).
4	**Erosion control**	**1**	**LS**	**$4,524.04**		**$4,524.04**		
	A. Hog fuel for access corridors and staging	250	CY	$16.50	$4,125.00			
	B. Wattles	200	LF	$2.00	$399.04			
	C. High visibility construction fencing	0	LF	$0.98	$0.00			
10	**Auburn narrows levee**					**$22,740.74**		
	Revetment material removal and haul away	830	TN	$25.00	$20,740.74		Cost to excavate and haul away	700' length
	Access road revetment removal and haul away	80	TN	$25.00	$2,000.00		Cost to excavate and haul away	75' length
13	**Plantings**					**$100,000.00**		
	Plantings	10	Acres	$10,000	$100,000.00			
16	**Other**					**$15,000.00**		
	Decommision of water well	1	LS	$5,000.00	$5,000.00			
	Decommision of power lines	1	LS	$10,000.00	$10,000.00			
TOTALS	Construction cost					$159,615.45		
	Tax(8.6%)					$13,733,46		8.6% King County rate(Auburn)
	Contingency (50% of sum of construction cost and tax)					$86,712.46		50% contingency due to unknowns
	TOTAL CONSTRUCTION COSTS					**$260,137.37**		

Cost Estimate 2: Porter Levee Alternative 2								
King County - Natural Resources and Parks - Ecological Restoration and Engineering Services **Preliminary Construction Cost Estimate – Porter Levee Removal, Alternative 3**								
Item No.	**Item Description**	**Qty**	**Unit**	**Unit Price**	**Cost**	**Total Price**	**Comments**	**Assumptions**
2	**Clearing and grubbing**	1.0	LS	$30,000.00		**$30,000.00**		Includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	53	TN	$25.00		**$1,333.33**	Cost from KC equipment and production rates calculator.	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
4	**Erosion control**	1	LS	$25,422.80		**$25,422.80**		
	A. Hog fuel for access corridors and staging	1300	CY	$16.50	$21,450.00		8" Thick blanket on access corridors and staging areas	
	B. Wattles	1500	LF	$2.00	$2,992.80		KC price plus $20/install for 25'compost sock	
	C. High visibility construction fencing	1000	LF	$0.98	$980.00		For discretionary use. Cost from KC's Materials and production rates calculator plus $0.5/lnft for install	
5	**Boundary protection**					**$618,597.95**		
	Setback revetment along gv road rip rap installation	18,336	TN	$12.26	$224,796.39			15' high revetment at 2:1 slope, 4' thick and 25% added rock
	Setback levee along g v road installation	0	TN	$6.00	$0.00			Levee Prism only
	Upstream end setback revetment rip rap installation	1,988	TN	$12.26	$24,368.17			15' high revetment at 2:1 slope, 4' thick and 25% added rock
	Upstream end setback levee installation	5,215	TN	$6.00	$31,288.89			
	Total revetment rip rap import	9,598	TN	$35.23	$338,144.50		Based on Tolt Bid Amounts	
	Total levee fill import	0	TN	$25.00	$0.00		Based on Tolt Bid Amounts	
	Engineered log structures type 1	0	LF	$812.50	$0.00		Cost per herrera cost estimate for carlson upper 30%	
6	**Large ELJ structure construction**					**$0.00**		
9	**Log roughening**					**$0.00**		

Cost Estimate 2: Porter Levee Alternative 2, Continued

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Porter Levee Removal, Alternative 3

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
10	**Levee/rock removal, reuse, import or haul away**					**$638,515.22**		
	Total levee material removed	43,168	TN					Total volume per lidar elevations
	Total levee material reused	5,215	TN	$8.00	$41,718.52		Based on Tolt bid amounts	Cost of removal and haul to setback levee location
	Total levee material hauled away	37,953	TN	$12.26	$465,306.05		Based on Tolt bid amounts	Assuming no levee material left behind
	Total rip rap and toe rock removal reused	10,725	TN	$12.26	$131,490.66		Based on Tolt bid amounts	Cost of removal and haul to setback levee location
	Total rip rap and toe rock removal hauled away	0	TN	$25.00	$0.00		Based on Tolt bid amounts	
13	**Plantings**					**$160,000.00**		
	Plantings	8	Acre	$20,000.00	$160,000.00			
15	**Water management**					**$75,000.00**		
	Thalweg diversion bulkbags	1	LS	$75,000.00	$75,000.00			
16	**Water pump relocation**					**$5,000.00**		
	Remove existing water pump and reconnect at hard point upstream	1	LS	$5,000.00	$5,000.00			
TOTALS	Construction cost					$1,709,259.30		
	Tax (8.6%)					$146,996.30		8.6% King County rate (Auburn)
	Contingency (40% of the sum of construction cost and tax)					$742,502.24		40% contingency due to unknowns
	TOTAL CONSTRUCTION COSTS					**$2,598,757.85**		

Cost Estimate 3: Ray Creek Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Ray Creek

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
1	**Mobilize for construction**	1	LS	$18,100.00		$18,100.00		Assume to be 10% of all construction costs except pile installation
2	**Clearing and grubbing**	1.0	LS	$10,000.00		$10,000.00	KC to provided updated cost/ 1 exc, 1opp, 1 utility for 4 days	Includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	0	TN	$17.00		$0.00	Cost from KC equipment and production rates calculator	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
4	**Erosion control**	1	LS	$0.00		$0.00		
	A. Hog fuel for access corridors and staging		CY	$16.50	$0.00			
	B. Wattles		LF	$2.00	$0.00			
	C. High visibility construction fencing		LF	$0.98	$0.00			
13	**Plantings**					$160,000.00		
	Plantings	8	Acre	$20,000.00	$160,000.00			
16	**Other**					$34,445.00		
	Fence installation	13,782	LF	$2.50	$28,445.00			SHRP fencing costs
	Other							
TOTALS	Construction cost					$224,905.00		
	Tax (8.6%)					$19,341.83		8.6% King County rate (Auburn)
	Contingency (40% of the sum of construction cost and tax)					$97,698.73		40% contingency due to unknowns
	TOTAL CONSTRUCTION COSTS					**$341,945.56**		

Cost Estimate: 4: Neely Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Neely Levee, Alternative 2

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
2	**Clearing and grubbing**	1.0	LS	$10,000.00		$10,000.00	KC to provided updated cost/ 1 exc, 1opp, 1 utility for 4 days	includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	53	TN	$17.00		$906.67	Cost from KC equipment and production rates calculator.	15' X 50' x 1' dims (+25% for longer drives, and roadway connection)
4	**Erosion control**	1	LS	$9,737.60		$9,737.60		
	A. Hog fuel for access corridors and staging	500	CY	$16.50	$8,250.00			
	B. Wattles	500	LF	$2.00	$997.60			
	C. High visibility construction fencing	500	LF	$0.98	$490.00			
6	**Large ELJ structure construction**					$150,000.00		
	Large ELJ structure construction	2	LS	$75,000.00	$150,000.00			
	Other locations		LS	$75,000.00	$0.00			
	Total ELJ ballasting required(unit in tons)	2	LS	0.00	0.00			
15	**Water management**					$20,000.00		
	Thalweg diversion bulkbags	1	LS	$20,000.00	$20,000.00			
TOTALS	Construction cost					$209,714.27		
	Tax (8.6%)					$18,035.43		8.6% King County rate (Auburn)
	Contingency (40% of the sum of construction cost and tax)					$91,099.88		40% contingency due to unknowns
	TOTAL CONSTRUCTION COST					**$318,849.57**		

Cost Estimate: 5: Horath Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Horath Reach

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
1	**Mobilize for construction**	1	LS	$224,490.00		**$224,490.00**		Assume to be 10% of all construction costs except pile installation
2	**Clearing and grubbing**	1.0	LS	$10,000.00		**$10,000.00**	KC to provided updated cost/ 1 exc, 1opp, 1 utility for 4 days	Includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	53	TN	$17.00		**$906.67**	Cost from KC equipment and production rates calculator.	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
4	**Erosion control**	1	LS	$24,425.20		**$24,425.20**		
	A. Hog fuel for access corridors and staging	1,300	CY	$16.50	$21,450.00			
	B. Wattles	1,000	LF	$2.00	$1,995.20			
	C. High visibility construction fencing	1,000	LF	$0.98	$980.00			
5	**New levee**					**$1,314,436.61**		
	Rip rap rock needed	36,453	TN		$0.00			Assuming 4' thick with 25% increase for toe rock
	Levee material imported and installed	0	TN	$25.00	$0.00		Horath and Kaech setback levee not needed due to high bank at setback	
	Rip rap imported and installed	23,000	TN	$35.23	$810,277.04			Cost of import and installation
	Rip rap installation of reused rock	8,973	TN	$12.26	$110,012.83			Cost of installation of rock that is being reused
	Excavation for rock revetment	22,783	CY	$17.30	$394,146.73		Based on Tolt #s	Excavated for rock placement and hauled away-added 25% to volume of rock

Cost Estimate 5: Horath Alternative 2, Continued

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Horath Reach

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
10	**Levee material removal**					**$655,091.14**		
	Levee material removed	31,586	TN					
	Levee material reused	0	TN	$8.00	$0.00			Assume all material unsuitable for reuse
	Levee material hauled away	31,586	TN	$12.26	$387,250.35			Cost of removal and haul away
	Rip rap removed	13,453	TN					
	Rip rap reused	8,973	TN	$12.26	$110,012.83		Assume 2/3 of removed rock is reusable	Cost of removing and hauling to setback
	Rip rap hauled away	4,480	TN	$35.23	$157,827.95		Assume 1/3 of removed rock is not usable	Cost of removal and haul away
13	**Plantings**					**$580,000.00**		
	Plantings by acreage	29	Acre	$20,000.00	$580,000.00			
15	**Water management**					**$75,000.00**		
	Thalweg diversion bulkbags	1	LS	$75,000.00	$75,000.00			
TOTALS	Construction cost					$2,925,849.62		
	Tax (8.6%)					$251,623.07		8.6% King County rate (Auburn)
	Contingency(40% of the sum of construction cost and tax)					$1,270,989.07		30% contingency due to unknowns
	TOTAL CONSTRUCTION COST					**$4,448,461.76**		

Cost Estimate 6: Hamakami Reach Alternative 2, Continued

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Hamikami Reach (Hamikami, Horath and Kaech), Alternative 2

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
10	**Levee material removal**					**$1,886,019.31**		
	Levee material removed	96,711	TN					
	Levee material reused	0	TN	$8.00	$0.00			Assume all material unsuitable for reuse
	Levee material hauled away	96,711	TN	$12.26	$1,185,678.22			Cost of removal and haul away
	Rip rap removed	35,177	TN					
	Rip rap reused	23,463	TN	$12.26	$287,657.86		Assume 2/3 of removed rock is reusable	Cost of removing and hauling to setback
	Rip rap hauled away	11,714	TN	$35.23	$412,683.23		Assume 1/3 of removed rock is not usable	Cost of removal and haul away
13	**Plantings**					**$640,000.00**		
	Plantings by acreage	32	ACRE	$20,000.00	$640,000.00			
15	**Water management**					**$75,000.00**		
	Thalweg diversion bulkbags	1	LS	$75,000.00	$75,000.00			
TOTALS	Construction cost					$6,681,969.43		
	Tax (8.6%)					$574,649.37		8.6% King County rate (Auburn)
	Contingency(40% of the sum of construction cost and tax)					$2,902,647.52		30% contingency due to unknowns
	TOTAL CONSTRUCTION COST					**$10,159,266.33**		

Cost Estimate 7: Hamakami Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Hamikami, Alternative 2

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
1	**Mobilize for construction**	1	LS	$2,270.00		**$2,270.00**		Assume to be 10% of all construction costs except pile installation
2	**Clearing and grubbing**	0.3	LS	$10,000.00		**$2,500.00**	KC to provided updated cost/ 1 exc, 1opp, 1 utility for 4 days	Includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	53	TN	$17.00		**$906.67**	Cost from KC equipment and production rates calculator.	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
4	**Erosion control**	1	LS	$3,895.04		**$3,895.04**		
	A. Hog fuel for access corridors and staging	200	CY	$16.50	$3,300.00			
	B. Wattles	200	LF	$2.00	$399.04			
	C. High visibility construction fencing	200	LF	$0.98	$196.00			
16	**Other**					**$15,377.78**		
	Channel excavation	889	CY	$17.30	$15,377.78			
TOTALS	Construction cost					**$24,949.48**		
	Tax (8.6%)					**$2,145.66**		8.6% King County rate (Auburn)
	Contingency (40% of the sum of construction cost and tax)					**$10,838.06**		30% contingency due to unknowns
	TOTAL CONSTRUCTION COST					**$37,933.20**		

Cost Estimate 8: Turley Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Turley, Alternative 2

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
1	**Mobilize for construction**	1	LS	$97,960.00		**$97,960.00**		Assume to be 10% of all construction costs except pile installation
2	**Clearing and grubbing**	1.0	LS	$10,000.00		**$10,000.00**	KC to provided updated cost/ 1 exc, 1 opp, 1 utility for 4 days	Includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	53	TN	$17.00		**$906.67**	Cost from KC equipment and production rates calculator.	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
4	**Erosion control**	1	LS	$24,425.20		**$24,425.20**		
	A. Hog fuel for access corridors and staging	1,300	CY	$16.50	$21,450.00			
	B. Wattles	1,000	LF	$2.00	$1,995.20			
	C. High visibility construction fencing	1,000	LF	$0.98	$980.00			
5	**New levee or revetment**					**$587,827.45**		
	Rip rap rock needed	18,859	TN		$0.00			Assuming 4' thick with 25% increase for toe rock
	Levee material imported and installed	0	TN	$25.00	$0.00			
	Rip rap imported and installed	8,491	TN	$35.23	$299,141.29		Based on Tolt #s	Cost of import and installation
	Rip rap installation of reused rock	6,915	TN	$12.26	$84,778.62		Based on Tolt #s	Cost of installation of rock that is being reused
	Excavation for rock revetment	11,787	CY	$17.30	$203,907.54		Based on Tolt #s	Excavated for rock placement and hauled away-added 25% to volume of rock

Cost Estimate 8: Turley Alternative 2, Continued

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Turley, Alternative 2, Continued

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
10	**Levee material removal**					**$206,404.77**		
	Levee material removed	0	TN					
	Levee material reused	0	TN	$8.00	$0.00			Assume all material unsuitable for reuse
	Levee material hauled away	0	TN	$12.26	$0.00			Cost of removal and haul away
	Rip rap removed	10,367	TN					
	Rip rap reused	6,915	TN	$12.26	$84,778.62		Assume 2/3 of removed rock is reusable	Cost of removing and hauling to setback
	Rip rap hauled away	3,452	TN	$35.23	$121,626.14		Assume 1/3 of removed rock is not usable	Cost of removal and haul away
13	**Plantings**					**$180,000.00**		
	Plantings by acreage	9	Acre	$20,000.00	$180,000.00			
15	**Water management**					**$75,000.00**		
	Thalweg diversion bulkbags	1	LS	$75,000.00	$75,000.00			
TOTALS	Construction cost					$1,193,024.09		
	Tax (8.6%)					$102,600.07		8.6% King County rate (Auburn)
	Contingency (40% of the sum of construction cost and tax)					$518,249.66		30% Contingency due to unknowns
	TOTAL CONSTRUCTION COST					**$1,813,873.83**		

Cost Estimate 9: Lones Alternative 2

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Lones Levee

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
2	Clearing and grubbing	1.0	LS	$6,173.44		$6,173.44	KC to provided updated cost/ 1 exc, 1opp, 1 utility for 4 days	Includes areas for roads and structures
3	Stabilized construction entrance (4 - 8" rock)	53	TN	$17.00		$906.67	Cost from KC equipment and production rates calculator	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
4	Erosion control	1	LS	$49,263.56		$49,263.56		
	A. Hog fuel for access corridors and staging	1,300	CY	$16.50	$21,450.00		8" thick blanket on access corridors and staging areas	
	B. Wattles	3,425	LF	$2.00	$6,833.56		KC price plus $20/install for 25' compost sock	
	C. High visibility construction fencing	1,000	LF	$0.98	$980.00		For discretionary use. Cost from KC's materials and production rates calculator plus $0.5/lnft for install.	
	D. Access road across burns creek	200	LF	$100.00	$20,000.00		Culvert, fill, quarry spalls, maintenance	Reuse levee material as fill
5	Along FPP boundary					$518,700.00		
	Rock revetment along FPP boundary	1,482	LF	$350.00	$518,700.00		Cost from Chinook Bend estimates	Salvaged+import rip rap
	ELS structures along FPP boundary		LF	$505.30	$0.00			
	Downstream deflection structures		LF	$350.00	$0.00			
6	Large ELJ structure construction					$150,000.00		
	large ELJ structure construction	2	LS	$75,000.00	$150,000.00		Based on Tolt bid amounts	
	Total ELJ ballasting required (unit in tons)	2	TN					Not cost item-used for estimating surplus or import requirements

Cost Estimate 9: Lones Alternative 2, Continued

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Lones Levee

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
9	**Log roughening**					**$0.00**		
	Log roughening	0	Each	$10,000.00	$0.00		Cost from Tolt Levee removal (bidding avg)	
10	**Lones Levee**					**$144,459.58**		
	Levee material removal	0	TN	$12.26	$0.00		Cost from Tolt Levee Removal (bidding avg)	Haul away
	Rip rap and toe rock removal and reuse	11,783	TN	$12.26	$144,459.58		Cost from Tolt Levee Removal (bidding avg)	Reuse
12	**On site materials re-used (savings or cost)**							
	As large ELJ ballasting	0	TN					Rip rap needed in ELJ ballasting
	As new revetment rip/ rap and toe rock	0	TN					Rip rap needed for new revetments
	Total rip rap surplus (i.e. levee rocks from site minus needed)	11,783	TN		$0.00			Rip rap hauled away
	Total rip rap import (i.e. needed minus levee rocks from site)	0	TN		$0.00			Rip rap import-for revetment & ELJ
15	**Water management**					**$75,000.00**		
	Thalweg diversion bulkbags	1	LS	$75,000.00	$75,000.00			
TOTALS	Construction cost					$1,038,963.25		
	Tax (8.6%)					$89,350.84		8.6% King County rate (Auburn)
	Contingency(40% of the sum of construction cost and tax)					$451,325.63		30% contingency due to unknowns
	TOTAL CONSTRUCTION COST					**$1,579,639.72**		

Cost Estimate 10: Flaming Geyser Alternative 4

King County - Natural Resources and Parks - Ecological Restoration and Engineering Services
Preliminary Construction Cost Estimate – Flaming Geyser

Item No.	Item Description	Qty	Unit	Unit Price	Cost	Total Price	Comments	Assumptions
2	**Clearing and grubbing**		LS	$10,000.00		**$0.00**	KC to provided updated cost/ 1 exc, 1opp, 1 utility for 4 days	Includes areas for roads and structures
3	**Stabilized construction entrance (4 - 8" rock)**	0	TN	$17.00		**$0.00**	Cost from KC equipment and production rates calculator	15' x 50' x 1' dims (+25% for longer drives, and roadway connection)
13	**Plantings**					**$276,750.00**		
	Plantings	37	Acre	$20,000.00	$738,000.00			
TOTALS	Construction cost					$739,000.00		
	Tax (8.6%)					$63,408.00		8.6% King County rate (Auburn)
	Contingency (40% of the sum of construction cost and tax)					$320,587.2		30% contingency due to unknowns
	TOTAL CONSTRUCTION COST							

Land Assessment Worksheet

Site Name	Site No.	Design Alternative	(Question 1) Receptive Landowners	(Question 2) Does site include FPP easements?	(Question 3) Does the Project Maintain Farmable Area?	Objective Score	Land Availability Score
Auburn Narrows	1	2	Yes	No	Yes	4	4
Porter	2	3	Yes	No	Yes	4	4
Ray Creek	3	2	No	No	Yes	0	0
Neely	4	2	Some	Yes	Yes	1	1
Horath	5	2	No	No	No	-1	0
Hamakami Reach	6	2	No	Yes	No	-2	0
Hamakami	7	2	Some	Yes	Yes	1	1
Turley	8	2	Some	Yes	Yes	1	1
Lones	9	2	Some	Yes	Yes	1	1
Flaming Geyser	10	4	Some	No	Yes	2	2

Cost Assessment Worksheet

Site Name	Site No.	Design Alternative	Total Construction Cost (Cc)	Total Acquisition Cost (Ca)	Total Design, Permitting & Outreach Cost (Cd)	Total Construction Monitoring & Inspection Cost (Cmi)	Total Maintenance Cost (Cmaint)	Total Monitoring Cost (Cmon)	Total Cost (Ctotal)
Auburn Narrows	1	2	$260,137	$0	$104,055	$39,021	$24,000	$10,000	$437,213
Porter	2	3	$2,598,758	$0	$649,689	$389,814	$38,400	$200,000	$3,876,661
Ray Creek	3	2	$341,946	$0	$136,778	$51,292	$38,400	$25,000	$593,416
Neely	4	2	$318,850	$0	$127,540	$47,827	$5,000	$30,000	$529,217
Horath	5	2	$4,448,462	$1,011,400	$1,112,115	$667,269	$139,200	$100,000	$7,478,446
Hamakami Reach	6	2	$10,159,266	$2,296,805	$2,539,817	$1,523,890	$153,600	$110,000	$16,783,378
Hamakami	7	2	$37,933	$142,655	$15,173	$5,690	$5,000	$7,000	$213,451
Turley	8	2	$1,813,874	$75,000	$453,468	$272,081	$43,200	$45,000	$2,702,623
Lones	9	2	$1,579,640	$130,294	$394,910	$236,946	$5,000	$200,000	$2,546,790
Flaming Geyser	10	4	$1,122,055	$0	$280,514	$168,308	$177,120	$45,000	$1,792,997

Habitat Assessment - Existing Conditions

Site Name	Site Number	Design Alternative	Rivermile	Riverbank	Existing @ 1800 cfs (acres)	Existing @ 8800 cfs (acres)	Existing Wetted edge	Existing Trapping sites	Existing unobstructed CMZ area (acres)	Existing erodible bank (feet)	Existing forest area in unobstructed CMZ area	Existing cleared area (acres)
Auburn Narrows	1	2	33.0	left	38.95020661	103.5262397	34,118	20	163.3962121	17,727	129.4230257	12.05769054
Porter	2	3	33.8	left	42.7	171.5	36,177	6	56.7	9,690	35.4	102.0
Ray Creek	3	2	34.2	right	0	0	0	0	0.0	0	6.8	15.7
Neely	4	2	34.4	left	15.3	72.5	14,835	2	21.5	3,838	12.3	46.9
Horath	5	2	34.8	right	24.2	108.1	21,772	8	86.0	7,610	44.0	106.7
Hamakami Reach	6	2	36.0	right	30.6	133.8	29,850	10	141.9	11,392	58.5	155.9
Hamakami	7	2	36.0	right	0	5.3	0	0	0.0	0	0	0.0
Turley	8	2	37.0	right	37.05	161.0	29,069	2	154.4	14,313	93.3	147.2
Lones	9	2	37.3	right	49.2	210.5	45,305	17	373.2	18,368	224.7	178.8
Flaming Geyser	10	2	44.0	right	0	0	0	0	0.0	0	88.7	36.9

Habitat Assessment - Future Conditions

Site Name	Future wetted area@ 1800 cfs (acres)	Future wetted area at 8800 cfs (acres)	Future wetted edge (feet)	Future trapping sites (no.)	Future unobstructed CMZ area (acres)	Future erodible bank (feet)	Future forest area in unobstructed CMZ (acres)	Future cleared area (acres)
Auburn Narrows	39.00381084	103.5262397	36,655	20	163.4	18,644	129.4	12.05769054
Porter	49.9	174.8	45,750	10	81.7	10,800	51.5	94
Ray Creek	0	0	0	0	0.0	0	6.8	0
Neely	16.3	72.7	20,666	6	25.0	3,867	15.7	46.9
Horath	25.2	108.9	24,923	15	116.7	9,444	52.9	78.0
Hamakami Reach	34.3	141.2	45,009	20	183.5	15,312	74.4	124.00
Hamakami	1.9	5.3	3,840	0	0.0	0	0	0
Turley	39.2	161.1	39,945	8	180.3	15,119	109.2	137.9
Lones	60.7	212.6	62,970	29	381.4	18,293	231.6	178.8
Flaming Geyser	0	0	0	0	0.0		88.7	0.0

Habitat Assessment - Relative Ecological Lift

Site Name	Relative score for wetted area at 1800 cfs	Relative score for wetted area at 8800 cfs	Relative sccore for wetted edge at 1800 cfs	Relative score for trapping sites	Relative score for erodible bank	Relative score for forest area in unobsstructed CMZ area	Relative score for revegetated area
Auburn Narrows	0.018585326	0.0	0.57446929	0	0.935714286	-0.00571536	0.0
Porter	2.5	1.8	2.2	1.3	1.1	4.0	0.9
Ray Creek	0.0	0.0	0.0	0.0	0.0	0.0	2.1
Neely	0.3	0.1	1.3	1.3	0.0	0.8	0.0
Horath	0.3	0.4	0.7	2.3	1.9	2.2	3.1
Hamakami Reach	1.3	4.0	3.4	3.3	4.0	3.9	3.5
Hamakami	0.7	0.0	0.9	0.0	0.0	0.0	0.0
Turley	0.8	0.1	2.5	2.0	0.8	3.9	1.0
Lones	4.0	1.2	4.0	4.0	-0.1	1.7	0.0
Flaming Geyser	0.0	0.0	0.0	0.0	0.0	0.0	4.0

Habitat Assessment - Total Ecological Lift

Site Name	Total Lift @ 1800 cfs (acres)	Total Lift @ 8800 cfs (acres)	Total Lift in wetted edge	Total Lift in trapping sites	Total Lift in unobstructed CMZ area	Lift in erodible bank (feet)	Total Lift in forest area in unobstructed CMZ	Total Lift in revegetated area
Auburn Narrows	0.053604224	0.0	2,537	0	0.003787879	917	-0.023025712	0
Porter	7.2	3.3	9,573	4	25.0	1,110	16.1	8.0
Ray Creek	0.0	0.0	0	0	0.0	0	0.0	8.0
Neely	1.0	0.2	5,831	4	3.5	29	3.4	0.0
Horath	1.0	0.8	3,151	7	30.7	1,834	8.9	28.7
Hamakami Reach	3.8	7.3	15,159	10	41.6	3,920	15.9	31.9
Hamakami	1.9	0.0	3,840	0	0.0	0	0.0	0.0
Turley	2.2	0.1	10,876	6	25.9	806	15.9	9.3
Lones	11.5	2.1	17,665	12	8.1	-75	7.0	0.0
Flaming Geyser	0.0	0.0	0	0	0.0	0	0.0	36.9

Habitat Assessment - Compliance with Standards for Ecological Success

Site Name	Is the project intended to move the river towards the least degraded and most dynamic state possible ?	Is the design informed by reference sites or historical conditions, if possible?	Are goals achievable in spite of ongoing local and watershed stressors?	Is the amount of refuge habitat and habitat complexity expected to show measurable change?	Are natural processes expected to sustain and enhance the new habitat over time?	Have expectations about how and when the indicators will respond been stated as explicitly as possible?	Is the site expected to recover from floods on its own – with minimal maintenance?	Does the project minimize damage to functioning site-appropriate habitat?	Will impacted vegetation – and other existing habitat– be restored or replaced?	Checklist Score	Weighted average score (out of 4)
Auburn Narrows	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	4.0	0.5
Porter	No	No	Yes	Yes	Yes	Yes	Yes	No	No	2.3	2.0
Ray Creek	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	3.3	0.5
Neely	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	3.7	0.8
Horath	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	4.0	1.6
Hamakami Reach	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	4.0	3.4
Hamakami	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	2.7	0.4
Turley	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	3.7	1.8
Lones	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	4.0	2.2
Flaming Geyser	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	4.0	0.8

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