APPENDIX F
Habitat Evaluation Procedure Model

This page left blank intentionally

TABLE OF CONTENTS

Table of Tables

Appendices

LOWER WILLAMETTE RIVER ECOSYSTEM RESTORATION PROJECT HABITAT EVALUATION MODEL

1. PURPOSE

The purpose of the Lower Willamette River Ecosystem Restoration Project habitat evaluation model is to evaluate the increase in ecological function and habitat benefits as a result of restoring aquatic, riparian, and floodplain habitats along the Lower Willamette River in Portland, Oregon. Specifically, the model and its components will address the extent to which habitat restoration will benefit multiple key fish and wildlife species. The model is comprised of multiple species Habitat Suitability Indices (HSIs) within the Habitat Evaluation Procedures (HEP) framework developed by the U.S. Fish and Wildlife Service (USFWS 1980a).

The habitat evaluation model is proposed for one-time use for the Lower Willamette River Ecosystem Restoration Study being conducted by the U.S. Army Corps of Engineers, Portland District and its cost-share partner, the City of Portland. HSIs for native salmonids (tributary model), native amphibians, and western pond turtles as described in this model have been approved for one-time use on this project. The Mainstem Salmonid HIS is a new model and is under review for certification. HSIs for beaver and wood duck used existing models but not all parameters were used. The HSI for the yellow warbler may be reviewed as an additional parameter was added to broaden its applicability to include additional neotropical migrants. Documentation of approval is provided in Appendix A.

This page left blank intentionally

2. BACKGROUND

This document summarizes the model used for estimating ecological function of the proposed alternatives of the Lower Willamette River Ecosystem Restoration Study (Study). This model was used to assess the existing and the with- and without-project future condition of riverine, riparian, and floodplain habitats and their relationships to fish and wildlife species production and survival. The intent of the model was to provide a set of quantitative tools for evaluating and comparing a broad set of potential ecological outputs associated with various alternatives.

In order to evaluate and compare restoration alternatives, it was necessary to assign a numeric value to the habitat benefits for each alternative. These habitat benefits, known as Habitat Unit (HU) outputs are derived through the use of the Habitat Evaluation Procedure (HEP). HEP provides a means for designing a mathematical model based on the habitat suitability of the proposed restored habitats for one or more species that represent those habitats. The output of the model provides a quantitative value (HUs) to be used for further evaluation and comparison of the proposed alternatives. This quantitative or numeric scoring method further facilitates comparisons of potential habitat impacts and benefits between alternatives through the use of the HUs in conducting an incremental cost and cost effectiveness analysis. Section 3 provides a description of the development and use of the HEP model.

2.1 Proposed Project

The study area includes the Lower Willamette River watershed between its confluence with the Columbia River at river mile (RM) 0 and Willamette Falls, located at RM 26.6. Several tributaries are found within the study area, two of which are included in this study. Those tributaries include Columbia Slough, which enters the Willamette River at RM 0.5, and Tryon Creek, which enters the river at RM 20.1.

The Lower Willamette River is a large, low-gradient river with average annualized daily discharge of 33,160 cfs. Habitat types present in the floodplain include bottomland riparian forest, scrub/shrub, ponded wetlands, and grassland. Columbia Slough is tied to the Willamette River hydrologically, but supports habitat types more typically associated with backwaters than with a high-discharge stream. Tryon Creek is a typical mid-gradient stream approximately 7 miles long, with an average annualized discharge of approximately 5 cfs. Tryon Creek supports the only potential spawning habitat in the study area.

Quality habitat for salmonids and other native fish species is limited in the Lower Willamette River and its tributaries. Key habitat types and features such as off-channel habitat, shallow water habitat, channel and bank complexity and large woody debris are insufficient to support the migratory and rearing life stages of the focal species. Spawning habitat for coho and steelhead exists in Tryon Creek and other tributaries to the Lower Willamette, but often times, as in Tryon Creek, access to this habitat is partially blocked by barriers. Rearing habitat is found in Columbia Slough and the mainstem Willamette River. Changed flow regimes and water temperature patterns have altered the availability and quality of off-channel habitat including backwater sloughs, floodplain ponds, and other slow-moving side-channel habitat. Overall, native species that are adapted to a fast moving river of cooler temperatures have declined in the warmer, slower moving river. Key factors adversely affecting natural riverine functions in the mainstem of the river are:

- **Altered Hydrology** The marked reduction in peak flows from upstream dams and other water uses has altered the timing, size, and frequency of runoff and flood events that are critical for maintaining healthy riparian, floodplain, in-channel, and off-channel habitats. Increases in base flows have also occurred.

- **Loss of Habitat Complexity** Dredging, channel straightening, and bank stabilization have all changed the main channel of the Willamette River from a multiple channel, structurally complex system dominated by shallow water areas to a deep, steep-banked channel with little diversity in structure or depth. Loss of channel complexity, woody material, and shallow water habitats adversely affect a wide range of fish and wildlife species. In many locations, invasive species have replaced diverse native plant communities, with a resulting decrease in ability to support a wide diversity of fish and wildlife species or species that are highly specialized.

- **Loss or Degradation of Off-channel Habitats** Extensive fill, development in the floodplain, and alterations in channel banks have destroyed or degraded floodplain and off-channel habitats by filling them or by reducing or eliminating the frequency with which floodplain habitats are inundated.

- **Reduction in Nutrients and Woody Material** As a result of the loss of riparian vegetation, stabilization of shorelines, and the development of the floodplain, the input of naturally derived nutrients and woody debris has been reduced. Reduced input of woody debris is detrimental to aquatic habitat quality as wood provides habitat diversity, cover, and sediment retention. There has also been a loss of nutrient input from salmonid carcasses, although this source of nutrient input would generally occur in the tributaries or higher in the Willamette River system where spawning grounds are found.

- **Degraded Water Quality** Water quality has been adversely affected by urbanization and agricultural land uses over the last 150 years. Industrial and non-industrial wastes, along with contaminants in agricultural and urban runoff have contributed to degraded water quality. Water temperatures have also increased due to impacts from major dams, reservoirs, and loss of riparian vegetation.

- **Contaminated Sediments** Portland Harbor was added to EPA's National Priorities List of contaminated sites in December 2000 because river sediments are contaminated with metals, pesticides, polychlorinated biphenyls (PCBs), and petroleum products. Ecosystem restoration work proposed under this study will be coordinated with the Portland Harbor superfund site and comply with USACE guidance for Civil Works projects with hazardous, toxic, and radioactive wastes (*e.g.*, ER 1165-2-132).

Tributaries to the Lower Willamette River also have contributing factors that affect the health of the mainstem river. Problems within tributaries include:

- Changes in bank gradient and channel substrate,
- Excessive sediment deposition,
- A lack of species and structural diversity within all habitat types in too narrow riparian corridors,
- Limited connection or linkage between riparian habitats and upland habitats,
- Disturbance due to the proximity of urban development, domestic animals, and recreational trails, and,
- Presence of fish barriers.

Several physical, hydraulic, and chemical parameters are considered necessary to establishing baseline habitat quality in the study area. These parameters include the following:

Tidal Influence: Tidal range in the Willamette mainstem and Columbia Slough typically is between 0-3 feet. Because the influence of tidal fluctuation varies depending on discharge from the Willamette River, the influence of tidal inundation on velocity and water surface elevation is difficult to predict in the absence of extensive hydraulic modeling. However, stage data developed by use of USGS gauges on the Willamette River indicate that the average water surface elevation under normal winter flows is between 9.7 and 9.9 ft NAVD for sites on the mainstem and Columbia Slough. There is no tidal influence on Tryon Creek upstream of the mouth of the creek.

Salinity: The confluence of the Willamette River and the Columbia River is located at Columbia RM 101, well upstream of the Columbia River estuarine mixing zone, the upstream extent of which occurs at about RM 30. Therefore, there are no saline or brackish waters found at any of the proposed restoration sites.

Velocity: Due to the lack of hydraulic modeling data in the lower mainstem, it is not possible to completely predict water velocity at edges or in side channels. The mainstem river in the study area, particularly in proximity to its confluence with the Columbia River, is low gradient and water velocities tend to be relatively low. In order to restore conditions found in historic side channels of the lower river, side channels in Kelley Point Park have been designed to have velocities of less than 1 foot/sec. Similar or lower velocities are expected in backwater sloughs and wetlands, such as those proposed for the BES Plant and Oaks Bottom/Sellwood Riverfront Park sites.

Dissolved Oxygen (DO): Aroner (2001) found DO levels between 6.0 and 14.3 mg/L in the mainstem Willamette River. Data regarding DO levels in Tryon Creek were not found, but it is assumed that DO levels in that water body are equal to or higher than those in the mainstem, as water is generally cooler and the streambed and instream structures offer more opportunities for oxygen to be mixed with flowing water than in the mainstem. Low DO (<4 mg/L) has occurred on past occasions in Columbia Slough, usually as a result of high input of de-icing materials from nearby Portland International Airport. Measures to contain de-icing materials have been put into place, and such events no longer occur. However, overall DO levels in Columbia Slough appear to be low, although current specific monitoring data for DO is not available.

Temperature: Water temperature is a concern in the project area and total maximum daily loads (TMDLs) are in place for temperature in the Willamette River mainstem, Columbia Slough, and Tryon Creek (ODEQ 2006). Numeric temperature criteria have been designated in Oregon that are specific to salmonids life stages. The mainstem Willamette is considered a migration corridor and has a 64.4°F seven-day moving average standard of daily maximum temperature for rearing and migration (ODEQ 2006). Water temperature in the mainstem Willamette River can reach upward of 73°F during the summer/fall low flow period (July-Sept.). However during the winter and spring, including the spring runoff when juvenile salmonids are out-migrating, temperatures rarely exceed 58°F (USGS 2014). On the other hand, temperatures in the tributaries are of concern year-round, and have a designated numeric temperature criteria for spawning and juvenile rearing of 55.4°F. Therefore summer/fall low temperatures can be limiting as high temperatures have been recorded in the Columbia Slough up to 73°F and 68°F in Tryon Creek.

This page left blank intentionally

3. HABITAT EVALUATION MODEL

The Habitat Evaluation Procedure (HEP) is a procedure developed by the U.S. Fish and Wildlife Service (1980a and 1980b) to facilitate the identification of effects of various types of actions on fish and wildlife habitat. The basic premise of HEP is that habitat quantity and quality can be numerically described. HEP can provide a comparison of habitat quality between different sites or between different times at one site (for example, pre-construction versus post-construction). A key assumption in HEP is that an individual species "prefers" (or survives/reproduces better) in habitats with certain physical characteristics that can be measured. For example, if yellow warblers typically nest in deciduous shrubs, then sites with greater deciduous shrub cover are more suitable for yellow warblers than sites which have little or no deciduous shrub cover.

A Habitat Suitability Index (HSI) is the typical format used in HEP which is a mathematical relationship between a physical, chemical, or biological habitat attribute and its suitability for a single species or assemblage of species. The Suitability Index (SI) is a unit less number between 0 and 1 that describes the requirements of a species for certain attributes such as cover, distance to foraging, water temperature, etc. A set of one or more Suitability Indices that represent key habitat requisites for the species during one or more life history stages are combined into an overall Habitat Suitability Index (HSI) by adding or multiplying the individual indices. The attributes are measured in the field and/or via GIS analysis and their corresponding index values are inserted into the model to produce a score that describes existing habitat suitability. The overall HSI value is also an index score between 0 and 1. This index value can be multiplied by the area of the site to yield HUs, or it can be used as an index score for a habitat quality comparison only.

A number of HSIs have been published for either individual species or guilds or other attributes, including those that may occur in Oregon (both native and non-native). Existing HSI models encourage model users to devise other models or make model alterations based on their knowledge of the species ecology. Alterations to the models should be fully documented (Raleigh et al 1986). HSIs can be created or modified using literature and other data. For example, local or draft models have been developed for native amphibians (WDFW 1997), and Western pond turtle (Tetra Tech 2012), and are based on the literature for the species.

The selection of species to include in this HEP model was based on several criteria. First and foremost, the species' geographic range must include the project vicinity. The species must also utilize the habitat type or types that are currently present, or are proposed for restoration. Species with existing HSI models are preferred. Utilizing previously developed and verified models provides a greater level of scoring certainty. Suitable HSI models must include habitat variables for which data collection is possible, given the availability of time and resources. Finally, variables must also show a change in score between the existing and proposed condition. If the project does not affect the SI score for a species, it will not be possible to quantify an effect. Habitat variables that do not meet the above requirements were omitted.

The existing models offer the user a maximum number of habitat variables for a species that can be used in assessing a variety of project impacts. Therefore, focusing on variables that respond to the action would provide a greater measure of the project effects and provide more meaningful scores. Any alterations to the existing models were made to ensure that the SIs utilized were identified as variables that would show a measurable response to project features. These variables were selected for each species based upon available, site-specific data and knowledge and understanding of habitat issues of the Lower Willamette ecosystem.

The individual SIs for various habitat parameters for each species are combined arithmetically to yield an overall index score for the species. In cases where existing species SIs were modified by eliminating parameters, the scores for the remaining variables were averaged to provide equal weight to each, yielding an overall average index score. Scores for each species can be used individually or combined to yield an overall index score for multiple species or species assemblages. In this case, the individual scores for each species or assemblage are averaged together to provide an overall HSI score. Averaging allows for equal weighting of the species or assemblages and ensures that no species is of greater importance, providing a multi-species approach to restoration. The overall HSI score is multiplied by the area of habitat that may be affected by a project. This final score yields HUs. HUs can be calculated separately for each species or for a combined score for multiple species. The future with- and without-project HUs are compared to determine the net difference (either positive or negative) between alternatives.

4. DESCRIPTION OF MODEL

As identified previously, the proposed habitat evaluation model is a combination of multiple individual species HSIs. The resultant indices were averaged or geometrically combined, and during the use of the model.

4.1 Description of Input Data

Input data for the model was collected specifically at the project alternative sites and by the use of aerial photographs or a GIS database for the project area. The input data required varies substantially from one HSI to another. Typical variables that were measured include percent canopy cover, diameter of trees, water depth, water velocity, number of pieces of downed wood, vegetation composition, etc. These measured variables were then assigned an SI value (unitless number from 0 to 1) based on the suitability curve or discreet suitability values or thresholds developed in the model.

Typically, input variables were measured at multiple locations on the project site and then averaged to yield an overall percent canopy cover or similar value. If the project site was comprised of several distinctly different vegetation communities, then variables were measured specifically for each community to yield multiple scores for the overall site.

Acreages for the model were developed by mapping the area at each site where restoration actions were both implementable and would have an effect on habitat quality. The acreage for with- and without-project conditions is the same to ensure an objective comparison of habitat values before and after implementation of restoration measures.

4.2 Description of Output Data

The output data from an HSI, one or several individual suitability indices, were entered into the HSI model equation to yield an overall habitat suitability index for the species. For example, yellow warbler model includes four variables: 1) V1, percent deciduous shrub crown cover; 2) V2, percent overall canopy cover; 3) V3, average height of deciduous shrub cover; and 4) V4, percent shrub canopy comprised of hydrophytic vegetation. The equation for combining these variables is an average as shown below, because none of the variables are limiting factors (such that a score of zero should render the habitat completely unsuitable for yellow warbler), and it appears that the variables are compensatory (such that while a low suitability score for one variable will reduce the overall habitat suitability, the other variables can somewhat compensate and still provide suitable habitat).

$$HSI = (V_1 + V_2 + V_3 + V_4) / 4$$

4.3 Capabilities and Limitations of the Model

A major assumption of HEP is that there is a linear relationship between the HSI and either carrying capacity for a species or an observed preference/requirement for a specific habitat feature. When developing specific HSI models, it is necessary to define varying qualities of habitat (i.e. optimum, good, fair, poor) based on observed relationships in the literature. For example, if the majority of observations of yellow warbler nests were in deciduous shrubs ranging from 1.5 to 4 meters, then deciduous shrubs of that height are assumed to provide optimal nesting habitat, and thus yield a high index score (in the range of 0.8 to 1.0). Shrubs of lesser height are assumed to be less suitable and yield lower index scores.

Specific limitations have been observed in the use of HEP and HSIs and include: 1) many of the developed models have not been tested sufficiently to match observed "preferred" habitats by the various species or to match species experts' knowledge of optimal habitat; 2) high values generated from the HSIs do not necessarily match observed higher species diversity or abundance than sites with lower values; 3) difficulty in collecting sufficient data to use the models (particularly when models have numerous variables); 4) use of one species model to represent suitability for wider guilds or assemblages may not accurately represent those other species; and 5) lack of variables that describe landscape scale effects on species diversity and abundance. (Barry, *et al*. 2006; O'Neil, *et al*. 1988; Wakeley 1988)

These limitations have been recognized in the development of this integrated model. Because it may be inaccurate to represent habitat suitability for large guilds or assemblages of species, multiple species were selected for the HEP portion of this model (and are described later) to encompass the habitat requirements for relatively small guilds or individual species of interest.

Another limitation in the use of ecological models is that other factors beyond the specific parameters evaluated in the models could have greater effects on species populations. Examples could be infectious diseases that could wipe out a localized population, climate change effects on temperatures and hydrology, and invasive species. These are important considerations for the success of any habitat restoration project and while not amenable to analysis in this proposed model, they should be considered by the project team during design development and implementation. Specifically:

- **Climate change** Although Earth's climate is clearly changing; insufficient data exists to accurately predict the effects this process will have on parameters that directly affect some of the species whose life stages were used to prepare this model. Increasing temperatures may cause warmer water temperatures, higher base flows in the winter and spring and lower base flows in the summer and fall, and less predictable tidal fluctuation, Although this same lack of data means that the effects of climate change cannot be measured in this HEP model, long-term monitoring and adaptive management strategies can be developed to measure these effects and respond to them effectively.

- **Invasive species:** One of the objectives of this study is to restore a viable native riparian and wetland plant community. This is to be accomplished by removing invasive species, revegetating with native species, and creating conditions under which native species are competitive with invasive species. Specific measures have been developed as part of this study to reduce the effects of invasive species, and although these effects may not be measurable in this model, effective control of invasive species will lead to more habitat complexity in riparian and wetland areas, thus increasing the value of these habitats for foraging and cover by juvenile salmonids and other species. Monitoring and adaptive management strategies for reestablishing native plant communities are outlined in Section 10 of the Feasibility Study.

This project is not intended to restore or manage habitat for a single species, nor is it intended to specifically increase the population of a single species. This project is intended to restore functioning habitat in the Lower Willamette River basin to support ecosystem function over time, rather than creating a specific static habitat type. The models have been modified or created to reflect local or regional data, as well as to simplify the models so that only the variables (and habitat types) likely to change as a result of the restoration project are included.

4.4 Model Development Process

All HSIs proposed for use in this model have been documented and reviewed. The amphibian model was developed by a multi-agency team based on regional literature and expert opinions. The Western pond turtle model was developed based on regional literature and reviewed and modified based on expert reviews. Testing and validation of the models is more limited. A recommendation for future use of these models is that the monitoring plan developed for this project should incorporate many of the parameters included in the HSI models to test and validate assumptions on habitat suitability. This monitoring data could inform future refinements or changes to the models and improve their predictive capability.

4.5 Identification of Formulas and Proof Computations are Done Correctly

All equations used in the HEP model are specifically stated and described below, as well as the Suitability Curves. Calculations are done in standard spreadsheet software (i.e. Microsoft Excel). The models are completely transparent and all assumptions can be verified.

4.6 Availability of Input Data

Input data used for this model was collected from on-site field surveys and from the use of aerial photography and GIS data.

4.7 Proposed HSI Models

Published HSIs for the following species or guilds were reviewed for potential inclusion in the HEP including: beaver *(Castor canadensis)*, yellow warbler *(Dendroica petechia)*, great blue heron *(Ardea herodias)*, downy woodpecker *(Picoides pubescens)*, red-winged blackbird *(Agelaius phoeniceus)*, wood duck *(Aix sponsa)*, osprey *(Pandion haliaetus)*, bald eagle *(Haliaeetus leucocephalus)*, black-capped chickadee *(Poecile atricapilla)*, native amphibians.

It is recommended that HSIs for several species be utilized to capture the range of benefits that could be provided by habitat restoration projects. The recommended HEP model includes the following species or guild: (1) Western pond turtle *(Clemmys marmorata)*; (2) beaver; (3) wood duck; (4) yellow warbler; (5) native amphibians (Northwestern salamander (*Ambystoma gracile*), long-toed salamander (*Ambystoma macrodactylum*), roughskin newt (*Taricha granulosa*), red-legged frog (*Rana aurora*), Oregon spotted frog (*Rana pretiosa*) and the Pacific treefrog (*Hyla regilla*) and (6) salmonids. As the life stage requirements for habitat differ between the mainstem Willamette River and the tributaries for salmonids, different models were selected for the tributaries and mainstem sites. For the tributaries, the salmonid model was based on both the spawning and rearing habitats of coho (*Oncorhynchus kisutch*) and Chinook. For the mainstem, the salmonid model was based on the habitat requirements of juvenile Chinook (*Oncorhynchus tshawytscha).*

The Western pond turtle is a species of concern in the study area and utilizes backwaters and ponds. The beaver is a mammal species dependent on native riparian species for food (cottonwood, willow, and alder). The wood duck is a cavity nesting waterfowl species that utilizes riparian areas for nesting. While the yellow warbler represents migratory neotropical birds that utilize riparian habitat for nesting, their foraging characteristics are sufficiently different that they are evaluated separately. The red-legged frog, Pacific treefrog, and rough-skinned newt are native amphibians that primarily represent aquatic amphibians utilizing riparian and wetland habitats. Chinook and coho are native salmonids that are listed as threatened under the federal Endangered Species Act and are currently present in the Lower Willamette basin.

Table 4.1 provides a list of the species or guilds recommended for the model along with the variables or attributes measured for the model associated with their preferred habitat.

Table 4.1. Recommended species for HEP model

Species/Guild Selected	Habitat Type Associated With	Variables/Attributes
Western pond turtle	Off-channel ponds, sloughs, and backwaters	Water depth, water temperature, percent cover, availability of nesting sites
Beaver	Riparian and floodplain vegetation communities (particularly cottonwood and willow)	Tree canopy closure, tree size class, shrub crown cover, height of shrub canopy, species composition
Wood duck	Riparian and floodplain vegetation communities and near shore aquatic habitats	Cover
Yellow warbler	Riparian and floodplain vegetation communities (particularly cottonwood and willow)	Deciduous shrub crown cover, canopy cover, height of shrub canopy, hydrophytic shrubs, velocity
Native amphibians (Northwestern salamander, long-toed salamander, red-legged frog, Pacific treefrog, Oregon spotted frog, roughskin newt)	Slow velocity stream reaches/alcoves, off-channel ponds, sloughs, and backwaters and other wetlands	Permanent water, water velocity, emergent and submergent vegetation, ground cover along water's edge, riparian zone width, water temperature, land use
Native salmonids (tributaries) (Chinook and coho)	Tributary spawning and rearing (pools, riffles, instream structure)	Maximum water temperature, percent pools, substrate, % pools and backwaters
Native salmonids (mainstem) (Chinook)	Mainstem out-migration and rearing (shallow water margins, floodplain side channels and backwaters)	Substrate, depth, and percent cover bank vegetation

Several of the existing HSI models do not appear appropriate to use in their current condition and the reasons for not selecting the species and models are briefly described in Table 4.2.

Table 4.2 Species not selected for HEP model

Species	Description of Variables	Reason for Not Selecting
Bald eagle	Size of waterbody for foraging; morphoedaphic index; distance from nest to foraging area	Model designed for breeding season at lacustrine habitats and based on volume of forage base. Not relevant to project area or proposed alternatives. Could have created new model for wintering habitat, but primarily based on availability of perching habitat and proximity to waterbodies, which will not change significantly as a result of proposed restoration measures.

Species	Description of Variables	Reason for Not Selecting
Black-capped chickadee	% Tree canopy closure, average height of trees, # of snags	Restoration of floodplain and riparian habitats will benefit these attributes and habitat requirements, but are not directly predictable from proposed changes.
Downy woodpecker	Basal area per hectare, # snags/ha	Will likely benefit from floodplain/riparian restoration, but attributes are not directly relevant.
Great blue heron	Distance between foraging areas and heronry sites, shallow clear water, distance from human activities	Attributes not likely to show a significant change from future without-project to future with-project condition.
Osprey	Obstructions over water, transparency, human activities	Attributes will not show a significant change.
Red-winged blackbird	Dominant emergent vegetation type, water present/absent, carp present/absent, larvae of odonates, patchiness of vegetation, layers of wetland vegetation	Will benefit from floodplain wetland restoration, but attributes not directly relevant.

4.7.1 Western Pond Turtle Life History and Habitat Requirements

The Western pond turtle (*Clemmys marmorata*) is found in the Pacific Northwest generally west of the Cascade Range from Puget Sound south to Baja California Norte. There are two subspecies: the northern subspecies occurs north of the American River in California (C. *marmorata marmorata*) and the southern subspecies occurs south of the American River (C. *marmorata pallida*). In Oregon, the species occurs in the western Cascades, the Willamette Valley, Coast Range, and Klamath Mountains and possibly east of the Cascades in the Deschutes and John Day drainages (likely from introductions, Holland, 1994).

Western pond turtles are in the family of Emydidae that includes many species of semi-aquatic pond and marsh turtles including slider turtles. Life history requirements of the turtles in this family have many similarities (Rosenberg et al. 2009). The model described herein was based on the slider turtle model developed by the U.S. Fish and Wildlife Service (Morreale and Gibbons 1986) with the addition of key parameters identified by regional Western pond turtle experts. Based on the co-occurrence of Western pond turtles and red eared sliders in most habitats in the Willamette Valley and similar life history uses of habitats, the parameters included in the model appear appropriate for Western pond turtle.

Western pond turtles are very wary and sensitive to human disturbance, particularly movements of pedestrians even as far as 100 meters away (Holland 1994). They forage in water and eat a wide variety of aquatic invertebrates, and terrestrial insects. Pond turtles likely eat small fish, crayfish and frogs as well, but much less frequently, and possibly only via scavenging. Scavenging of carrion may also be an important food source, particularly seasonally (early spring). Pond turtles typically overwinter in the northern part of the range from one to six months, but may frequently emerge on sunny days to bask. Overwintering can occur in mud on the bottom of ponds, under overhanging banks, or in forested areas under a thick layer of leaf litter. Pond turtles may also use terrestrial habitats if their aquatic habitat seasonally dries up (Rosenberg et al 2009). During the rest of the year, turtles generally occur in aquatic habitats, with a slow to moderate current. A significant amount of time is used for basking on rocks, logs or emergent vegetation.

Nesting can occur from late April through July. Nesting habitat is a key terrestrial component of Western pond turtle life history. Females excavate nests in sparsely vegetated areas with grass and/or forbs. It is typically on south-facing gentle slopes or other areas with good sun exposure and typically fairly compact dry soil with silt or clay, although sandy loam and gravel/cobble mixed with soil have also been used

(Rosenberg et al. 2009). Nesting habitat within approximately 200 meters to aquatic habitats may be preferred. The various studies cited in Rosenberg et al. (2009) generally found that solar exposure and warmer temperature soils were the most consistent trait. It appears that hatchlings remain in the nest over the winter and emerge the following spring.

Predation on eggs and hatchlings is typically very high by raccoons, fox, coyote, and skunks, as well as, domestic dogs. Small turtles may also fall prey to largemouth bass, bullfrogs, trout, other resident fish and waterfowl. Larger turtles typically do not have many predators, but may occasionally be taken by the mammals listed above, and also by bear, river otter, and humans. Minimizing habitat for bullfrogs and other non-native predators will benefit western pond turtles, although unfortunately the turtles typically prefer warm waters that bullfrogs also prefer. Some significant limiting factors to western pond turtle survival in the Willamette Valley appear to be: 1) predation of nests; 2) hatchling predation by bullfrogs; and 3) lack of nesting habitat (B. Castillo, ODFW, pers. comm.). Loss of aquatic habitat and road mortality are also major threats to this species (Rosenberg et al. 2009).

Table 4.3 shows the parameters used in the western pond turtle HSI, and describes the rationale behind their inclusion in this study.

Table 4.3 Western Pond Turtle Variables

Species	V	Variable	Used	Not Used	Rationale
Western Pond Turtle					This model was created specifically for this species native to the west coast states. The model was developed based on current literature and researchers including Rosenburg et al 2009, Morreale and Gibbons 1986, Holland 1994, and personal communication with former ODFW turtle expert, Bill Castillo. It is the same as the model approved for use on the Willamette Floodplain Restoration Project.
	V_1	Percent area with water depth preferred by adults	X		Identified as a limiting factor that could be measurably improved.
	V_2	Percent cover along water's edge	X		Identified as a limiting factor that could be measurably improved.
	V_3	Water temperature during low flows	X		Identified as a limiting factor that could be measurably improved.
	V_4	Percent area with water depth < 0.3 meters	X		Identified as a limiting factor that could be measurably improved.
	V_5	Availability of suitable nesting sites	X		Identified as a limiting factor that could be measurably improved.
$HSI_{W\ Pond\ Turtle} = (V_1 + V_2 + V_3 + V_4 + V_5) / 5$					

4.7.2 Beaver Life History and Habitat Requirements

Beaver are herbivorous aquatic mammals found throughout North America wherever suitable riparian and wetland habitats occur. Beaver were once so numerous (50-100 million) that most aquatic habitats in North America were shaped by beaver activity. The HSI model for beaver is described in Allen (1982) and habitat requirements for the winter food life stage, which is targeted for this project, are summarized below. The winter food life requisite was targeted for riverine and wetland cover types. The water life requisite was omitted due to lack of influence of change the project would have on these factors which, include percent stream gradient, aver water fluctuation on an annual basis. Beaver are generalized herbivores, but have strong preferences for specific plant species and size classes. Aspen, willow, cottonwood, and alder are the preferred species. Woody stems less than 10 centimeters in diameter near water are preferred and herbaceous vegetation and leaves are consumed during the summer. Aquatic vegetation is also utilized.

Table 4.4 shows the variables used in the beaver HSI, and describes the rationale behind their inclusion in this study.

Table 4.4 Beaver Variables

Species	V	Variable	Used	Not Used	Rationale
Beaver					**Same as Willamette Floodplain model**
	V_1	Percent tree canopy closure	X		Variable identified in the published HSI as a limiting factor for winter food life requisite for riverine and wetland cover types.
	V_2	Percent trees 1-6 inches dbh	X		Variable identified in the published HSI as a limiting factor for winter food life requisite for riverine and wetland cover types.
	V_3	Percent shrub crown cover <5m	X		Variable identified in the published HSI as a limiting factor for winter food life requisite for riverine and wetland cover types.
	V_4	Average height of shrub canopy	X		Variable identified in the published HSI as a limiting factor for winter food life requisite for riverine and wetland cover types.
	V_5	Species composition of woody vegetation (trees and/or shrubs)	X		Variable identified in the published HSI as a limiting factor for winter food life requisite for riverine and wetland cover types.
	V_6	Percent of lacustrine surface dominated by yellow and/or white water lily		X	Only relevant for lacustrine habitat, not riverine or wetland
	V_7	Percent stream gradient		X	Not relevant for winter food life requisite
	V_8	Average water fluctuation on annual basis		X	Not relevant for winter food life requisite
	V_9	Shoreline development factor		X	Only relevant for lacustrine habitat, not riverine or wetland
$HSI_{Beaver} = (V_1 + V_2 + V_3 + V_4 + V_5) / 5$					

4.7.3 Wood Duck Life History and Habitat Requirements

Wood duck range and life history are summarized in Sousa and Farmer (1983). Wood ducks inhabit creeks, rivers, floodplain lakes, swamps, and beaver ponds. A Pacific population breeds from British Columbia south to California and east to Montana of which, a majority winters in the Sacramento Valley. Wood ducks have been referred to as primarily herbivorous, although invertebrates also make up a part of their annual diet. Suitable cover for wood ducks may be provided by trees or shrubs overhanging water, flooded woody vegetation, or a combination of these two types. For nesting, wood ducks utilize bottomland hardwood forests with trees of sufficient size to contain usable cavities that are near water.

The habitat in the project area is suitable for winter habitat only and therefore that is the life requisite focused on for this project.

Table 4.5 shows the variables used in the wood duck HSI, and describes the rationale behind their inclusion in this study.

Table 4.5 Wood Duck Variables

Species	V	Variable	Used	Not Used	Rationale
Wood Duck – Winter Habitat Only					Same as Willamette Floodplain model
	V_1	Number of potentially suitable tree cavities / 0.4 ha (1.0 acre)		X	Not relevant for winter habitat
	V_2	Number of nest boxes / 0.4 ha (1.0 acre)		X	Not relevant for winter habitat
	V_3	Density of potential nest sites / 0.4 ha (1.0 acre) = $(0.18* V_1 + 0.95* V_2)$		X	Not relevant for winter habitat
	V_4	Percent of water surface covered by potential brood cover		X	Not relevant for winter habitat
	V_5	Percent of the water surface covered by potential winter cover	X		Appropriate for use since the model is prepared for winter habitat
$HSI_{Wood\ Duck} = V_1$					

4.7.4 Yellow Warbler Life History and Habitat Requirements

The yellow warbler was selected to represent neotropical migratory birds that may use the riparian habitat of the Willamette River. Yellow warblers are a breeding bird throughout the U.S. The existing model and habitat requirements are described in Schroeder (1982). The yellow warbler prefers riparian habitats composed of abundant, moderately tall, deciduous shrubs ranging in height from 1.5 to 4 meters. Shrub densities between 60 and 80% are considered optimal and coniferous areas are avoided. Greater than 90% of prey are insects and foraging takes place primarily on small limbs in deciduous foliage. Nests are generally located 0.9 to 2.4 meters above the ground in willows, alders, and other hydrophytic shrubs and trees, including box elders and cottonwoods. Male yellow warblers have greater mating success in shrubs less than 3 meters tall. The SIs used in the yellow warbler HSI include the three variables in the published model (Schroeder 1982) plus one additional variable utilized in the Willamette Floodplain model, to be consistent with that model as accepted by Eco-PCX.

Table 4.6 shows the variables used in the yellow warbler HSI, and describes the rationale behind their inclusion in this study.

Table 4.6 Yellow Warbler Variables

Species	V	Variable	Used	Not Used	Rationale
Yellow Warbler					**Same as Willamette Floodplain model**
	V_1	Percent deciduous shrub crown cover	X		Identified as a limiting factor that could be measurably improved.
	V_2	Percent overall canopy cover	X		Identified as a limiting factor that could be measurably improved.
	V_3	Average height of deciduous shrub canopy	X		Identified as a limiting factor that could be measurably improved.
	V_4	Percent of shrub canopy comprised of hydrophytic shrubs – Yellow Warbler	X		Identified as a limiting factor that could be measurably improved.
$HSI_{\text{Yellow Warbler}} = (V_1 + V_2 + V_3 + V_4) / 4$					

4.7.5 Native Amphibians Life History and Habitat Requirements

This HSI is a combination of the habitat requirements of both aquatic and terrestrial amphibians that commonly occur in Western Washington and Oregon including; Northwestern salamander (*Ambystoma gracile*), long-toed salamander (*Ambystoma macrodactylum*), roughskin newt (*Taricha granulosa*), red-legged frog (*Rana aurora*), Oregon spotted frog (*Rana pretiosa*) and the Pacific treefrog (*Hyla regilla*). The habitat requirements of these species in the HSI for native amphibians are summarized below (WDFW 1997). While these amphibian species included in the model are considered aquatic, they also use adjacent riparian areas extensively for wintering and feeding. Due to the multiple species included, additional parameters such as water depth requirements for breeding are not applicable across all species and have not been included.

Northwestern salamanders occur in western Oregon, Washington and British Columbia, and are considered to be aquatic salamanders that breed in ponds and stream backwaters. They live in moist forest or woodlands as juveniles and adults. They lay their eggs in moderately deep water (0.5-2 m) attached to small sticks or rigid stems. Larvae live in surface sediments or under debris or logs in their natal waterbodies.

Long-toed salamanders occur throughout much of Oregon, Washington and British Columbia, are also considered to be aquatic salamanders that breed in seasonal ponds, lake shores and slow-moving streams through wet meadows. They live in a variety of terrestrial habitats (grasslands, woodlands, disturbed areas) as juveniles and adults. They lay their eggs in shallow water (<0.5 m) attached to stems, leaves, or pebbles. Larvae live in surface sediments or under debris in shallow water.

Roughskin newts occur in most of Oregon, and are also considered to be aquatic salamanders, which utilize ponds and slow-moving streams for most of the year or year-round. They prefer forested or partially wooded habitats adjacent to ponds, lakes or sloughs, often where there is extensive aquatic vegetation. They lay their eggs in moderately deep water (0.5-2 m) in mid to late spring, attaching the eggs to stems or floating vegetation. Juveniles and adults live in and under rotting logs and forage in the ponds or moist forest floors.

Red-legged frogs occur on the west side of the Cascade crest in Oregon, Washington and British Columbia. They prefer moist coniferous or deciduous forest and forested wetland habitats. They breed in cool slow-moving waters such as shaded ponds and sloughs in winter to early spring. They lay their eggs in moderately deep water (0.5 - 2 m) and attach the eggs to submerged branches or aquatic vegetation. Juveniles and adults will live in emergent wetlands, logs, or brush adjacent to pond edges. During the rainy season, they move into forest habitats and live under logs and debris, foraging on the forest floor. A major limiting factor for native amphibian survival is lack of adjacent moist forest habitat (B. Castillo, ODFW, pers. comm.).

Oregon spotted frogs occur in British Columbia, western Washington and the Cascade Mountains of Washington and Oregon. Historically they were found in the Willamette Valley, but they appear to have been eliminated from this habitat (Leonard et al. 1993). Oregon spotted frogs are aquatic and require water for breeding, foraging and wintering habitats. They use seasonal waterbodies such as ponds or flooded sloughs/overflows that dry up by summer. However, connections to permanent water must be present to allow tadpoles to metamorphose. Juveniles and adults inhabit marshes, and marshy edges of ponds, streams and lakes with abundant vegetation.

Pacific treefrogs are the most common frog in the northwest and can live in a variety of habitats including marshes, wet meadows, forests and brushy disturbed areas. They breed in shallow water (<0.5 m) attaching their eggs to grasses or twigs. Adults live in wet meadows and riparian areas.

All native frogs have been reduced in part due to the presence of the non-native bullfrog. Bullfrogs often eat smaller frogs, and even small bullfrogs, turtles and fish. This habitat suitability index also incorporates a negative index for some habitat characteristics that are preferred by bullfrogs, such as water temperature, percent silt in the substrate, and permanently ponded deep water.

Table 4.7 shows the variables used in the native amphibian HSI, and describes the rationale behind their inclusion in this study.

Table 4.7 Native Amphibian Variables

Species	V	Variable	Used	Not Used	Rationale
Native Amphibians - New					This is the same model approved for use in the Willamette Floodplain study, except that this model does not use the 7th variable used in that model.
	V_1	Percent area with permanent water	X		Identified as a limiting factor that could be measurably improved.
	V_2	Percent area with emergent or submergent wetland/aquatic vegetation	X		Identified as a limiting factor that could be measurably improved.
	V_3	Percent ground cover along water's edge	X		Identified as a limiting factor that could be measurably improved.
	V_4	Width of riparian zone	X		Identified as a limiting factor that could be measurably improved.
	V_5	Maximum temperature during low flows	X		Identified as a limiting factor that could be measurably improved.
	V_6	Land use within 200 meters of wetland edge	X		Identified as a limiting factor that could be measurably improved.

Species	V	Variable	Used	Not Used	Rationale
	V_7	Water current in breeding areas during spring		X	Current was not identified as a limiting factor because the primary breeding habitat for amphibians would occur in backwater, off-channel areas where there is no current. Furthermore, measures recommended in this plan would not affect current at the scale of measurement recommended in the model.
$HSI_{Native\ Amphibians} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6) / 6$					

4.7.6 Native Salmonid Life History and Habitat Requirements

The purposes for creating two separate models for native salmonids are to account for differences in how habitats will be utilized by salmonids species at different life stages occurring in the project area and to estimate the effect that implementing specific restoration measures will have on the quality of habitat variables that most directly affect these life stages. The tributary model was formulated by modifying existing HSIs to primarily assess changes in habitat quality and quantity for spawning adults and juvenile salmonids utilizing their natal habitat. The mainstem model was developed to target out-migrating juvenile salmonids as they begin their egress into the estuary and eventually the ocean. The mainstem model utilized both existing HSIs and site specific data collected in the Lower Willamette River.

The following sections describe the development of each of the two models based on the specific life stage requirements for native salmonids that each model targets. Therefore, an overview of salmonids life history is presented along with the habitat features required to support them. The details of the proposed project are then described to link the restoration features with these habitat requirements. Finally, a discussion of each model's development and the rationale of parameters selected to best measure habitat response to the restoration measures is presented.

The restoration measures prescribed to each of the two stream types were selected to correspond to the life stages that utilize them. Measures targeted towards restoring aquatic and riparian habitat are as follows:

- Remove invasive species and minimize disturbance of native habitats.
- Revegetate riparian zones and wetlands with an appropriate mix of native species
- Restore hydrologic aspects of each site to encourage survival of appropriate plant communities
- Restore streambeds by placing large wood for habitat diversity
- Encourage or install communities of overhanging streamside vegetation to reduce solar gain, stabilize shorelines, and provide wildlife cover
- Remove barriers to fish access to spawning and rearing areas
- Slope steepened banks to a gentler angle to allow floodwaters to spread out and to provide shallow water habitat
- Remove revetments and fill, and use bioengineering methods for bank stabilization where possible, and
- Reconnect side channels and backwater wetlands to streams and rivers where possible.

4.7.6.1 Native Salmonids Tributary Model

HSI models have been published for native salmonids that correspond to the life stages that utilize the habitat found in the tributaries of the project area. These include HSIs developed for Chinook salmon (Allen and Hassler 1986, Beauchamp et al. 1983, Raleigh et al. 1986) and coho (McMahon 1983). The HSI curves for these two species were combined to assess tributary habitat conditions.

Chinook Salmon Life Stage Requirements and Utilization of the Tributaries in the Project Area
Spring and fall Chinook occur in the Willamette River, although the fall run is considered to be entirely derived from plantings of hatchery fish from 1964-1994 and Friesen et al. (2007) found that the majority of Chinook collected in the Lower Willamette are spring run. Spring Chinook enter the Willamette River from approximately April through early July and then migrate upstream to spawning grounds, spawning later in the year from August to October. Fall Chinook enter the Willamette River from August to October, spawning immediately from early September through early October. Fry emerge from the spawning grounds from January through April.

Spring Chinook are frequently stream-type, in that juveniles may rear in freshwater streams for up to a year or more before migrating to the ocean. Some spring Chinook and most fall Chinook are typically ocean-type, and only rear for 2-6 months in freshwater before migrating to the ocean. Some ocean-type Chinook migrate as fry to estuarine areas and rear for extended periods there.

In the tributaries of the project area, Chinook salmon use tributary stream habitat for spawning, egg incubation, and freshwater rearing. It is these habitat requirements that are targeted in the tributary model. Chinook salmon require clean, cool water and clean gravel to spawn. Females deposit their eggs in the gravel bottom in areas of relatively swift water. For maximum survival of eggs and larvae, water temperatures must range 43 and 57°F (Raleigh et al. 1986). Optimum rearing habitat for Chinook consists of pools and wetland areas with woody debris, boulders and/or overhanging vegetation for cover. Additionally, hard/rocky substrate is required for the production of algae and macroinvertebrates to provide food for rearing salmonids.

Coho Salmon Life Stage Requirements and Utilization of Tributaries in the Project Area
Adult coho enter the Willamette River from late August through early December, migrating into tributaries along the length of the River. Adult coho will often hold for extended periods in deep pools, where they are less vulnerable to predation, and periodically come out to capture prey in riffle areas. Spawning occurs typically from September through December. Fry emerge from the spawning grounds from late February through April. Coho fry and juveniles rear in their natal streams for one or two years typically, although even longer freshwater residence can occur. Fry typically congregate after emerging from the gravel and within a few days begin swimming along the bank margins, especially near overhanging vegetation. Coho will also typically settle on the bottom during darkness. Areas with a high percentage of margin habitat (narrow streams) and with woody debris and pools are the most productive for coho. Coho move into side channels and under debris for wintering. Most juvenile coho salmon outmigrate seaward as smolts in late spring (March through June), typically during their second year.

Similarly to Chinook, coho utilize tributary habitat found in the project area to complete their adult spawning, egg incubation and juvenile rearing phases. Also similarly to Chinook, coho require similar habitat features for these life stages. Adult coho salmon returning to spawn need adequate flows and water quality, and unimpeded passage to their natal grounds. They also need deep pools with vegetative cover and in-stream structures such as root wads for resting and shelter from predators. The timing of coho salmon spawning can also reflect water temperature changes in a particular river system.

Native Salmonids Tributary Habitat Suitability Model

In order to evaluate the extent to which habitat restoration measures will benefit native salmonids in tributaries to the Lower Willamette River, an HSI model was developed to specifically target the life histories of salmonids that utilize this habitat. The tributary model is comprised of modifications to the existing HSIs for Chinook (Raleigh et al. 1986) and coho salmon (McMahon 1983). Of the existing HSIs for Chinook, Raleigh et al. 1986 was selected for use in the tributary model as the juvenile rearing habitat represented is that of natal tributary streams found in the Project Area. The modifications of the HSIs were based upon localized response variables identified in available data and publications, as well as site specific observations. This modified model was previously approved by ECO-PCX for use by the Willamette Floodplain Ecosystem Restoration Project. It was subsequently assessed and determined that it is applicable to the Lower Willamette River Ecosystem Restoration Project.

The HSIs for both Chinook and coho salmon were modified in order to create the tributary model that includes a list of variables that show a response to the restoration action and that address factors or processes that are limited to the salmonids life histories that utilize this habitat type. As the life stages that are targeted in tributaries are present year round the model applies to year-round conditions.

Table 4.8 includes a list of the variables included in the original Chinook and coho salmon HSIs and the rationale for use or exclusion. Variables were omitted if they did not pertain to a limiting factor in the project area.

Table 4.8 Native Salmonids Tributary Variables

Species	V	Variable	Used	Not Used	Rationale
Native Salmonids					The salmonids tributary model uses an identical set of variables as those used in the Willamette Floodplain Restoration Project model. 3 variables from the existing Chinook model (Raleigh et al 1984) and one variable from the existing Coho model were used to prepare this model (McMahon 1983).
Chinook - Modified					
	V_1	Annual maximal or minimal pH		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_2	Maximum temperature	X		Identified as a limiting factor that could be measurably improved.
	V_3	Minimal dissolved oxygen		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_4	Percent pools during the low water period	X		Identified as a limiting factor that could be measurably improved.
	V_5	Pool class rating		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_6	Maximum temperature (embryo)		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_7	Maximum or minimum temperature (embryo)		X	Not identified as a limiting factor that could be measurably affected by the proposed project.

Species	V	Variable	Used	Not Used	Rationale
	V_8	Average substrate size (embryo)		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_9	Average velocity (embryo)		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{10}	% fines (embryo)		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{11}	Average base flow		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{12}	Average peak flow		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{13}	Substrate composition in riffle/run areas	X		Identified as a limiting factor that could be measurably improved.
	V_{14}	% riffle-run fines		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{15}	Nitrate-N concentration		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{16}	% cover		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{17}	Substrate cover		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
Coho - Modified					
	V_1	Maximum temperature – upstream migration		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_2	Minimum DO concentration – upstream migration		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_3	Maximum temperature – spawning to emergence of fry		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_4	Minimum DO concentration – spawning to emergence of fry		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_5	Substrate composition in riffle/run areas		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_6	Maximum temperature during rearing		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_7	Minimum DO concentration – rearing		X	Not identified as a limiting factor that could be measurably affected by the proposed project.

Species	V	Variable	Used	Not Used	Rationale
	V_8	% vegetative canopy cover		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_9	Vegetation index of riparian zone		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{10}	% pools		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{11}	% pools with canopy		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{12}	% instream and bank cover		X	Not identified as a limiting factor that could be measurably affected by the proposed project.
	V_{13}	% total area of quiet backwaters and deep pools	X		Identified as a limiting factor that could be measurably improved.
	V_{14}	Maximum temperature during rearing and out-migration of smolts		X	Not identified as a limiting factor, therefore no restoration measures were developed to address this variable.
	V_{15}	Minimum DO concentration during outmigration		X	Not identified as a limiting factor, therefore no restoration measures were developed to address this variable.
$HSI_{Salmonids\ Tributary} = (V_1 + V_2 + V_3 + V_4) / 4$					

4.7.6.2 Native Salmonids Mainstem Model

Existing HSIs for out-migrating juvenile Chinook were utilized in the development of a model to represent this life stage of native salmonids. These data along with site specific data were combined to create a model specific for use in evaluating the effects of this proposed Project on native juvenile salmonids migrating and rearing through the tidal estuarine habitat during their egress to the ocean.

Juvenile Chinook Salmon Life Stage Requirements and Utilization of the Mainstem Willamette

When juvenile Chinook salmon enter the mainstem Willamette River they begin their migration out to the ocean through the lower river's tidally influenced estuary. Outmigration typically occurs during the winter and spring, peaking between February and May (Friesen et al. 2007). The habitat conditions required for this life stage are unique and the process by which out-migrating juvenile salmonids take up residence in large, tidally influenced estuarine systems is more recently becoming understood. Recent studies such as Friesen et al. (2007) and Teel et al. (2009) provide a conceptual model of what are important habitat variables unique to this habitat type.

Juvenile salmonids have been found along channel margins during outmigration through the large rivers, where velocities are lower and cover is more abundant (Murphy et al. 1989 and Beechie et al. 2005). Additionally, outmigration studies have shown that juvenile Chinook are found off-channel floodplain habitats, particularly sloughs and channel edges, and off-channel terrace tributaries and tributary mouths (Murphy et al. 1989; Sommer et al. 2001, 2005; Brown 2002). However, Chinook were virtually absent from beaver ponds or off-channel sloughs. In these studies, velocities along banks in large rivers have been found to have mostly low velocities (<0.5 ft/s) (Beechie et al. 2005) and all backwater habitats had mean water velocity of <0.5 ft/s (Murphy et al. 1989 and Beechie et al. 2005). Therefore, juvenile Chinook are attracted to habitats that are by definition low in velocity. Additionally, numerous studies conclude that younger age classes of juvenile salmonids are highly associated with shallow, nearshore beach habitats with sandy substrate (e.g., Lister and Genoe 1970, Johnsen and Sims 1973, Dauble et al. 1989). Bank cover is also an important variable in out-migrating habitats and juvenile Chinook were found by Beechie et al. (2005) to be associated will all potential cover types present.

The simplification of freshwater and estuarine waterways in the Lower Columbia River Estuary (LCRE) has reduced the amount of estuarine habitat for out migrating juvenile salmonids (Bottom et al. 2005). Therefore, tidally influenced habitats, like those found in the Lower Willamette River, are in need of restoring in order to increase the amount of available rearing and holding habitat for out-migrating juvenile salmonids (Teel et al. 2009 and Roegner 2010). Roegener et al. (2010) studied numerous parameters on restored habitats in the LCRE, including fish use, sediment accretion, and vegetation elevation. It is recommended that similar parameters be built into monitoring the effectiveness of the restoration measures recommended in this plan, although the scope of this study does not allow those same parameters to be incorporated into this model for comparison between baseline and projected conditions.

In the project area, historically, many juvenile salmonids resided in the Willamette River for a period of months or up to a year or more. In the 1940s it was reported that large numbers of fry were present in the Willamette River from February through early April (NPCC 2004). Studies in the 1960s confirm the pattern of rearing in the mainstem of large rivers. Scale analyses of returning adults indicated that only 10 percent had entered the ocean as subyearlings, suggesting that a large proportion of the juveniles observed migrating downstream had overwintered in the mainstem Willamette or Columbia Rivers (NWPCC 2004). Some subyearlings have been observed in off-channel areas of the Willamette and the lower reaches of valley floor tributaries, and their movements may be timed to co-occur with (or may be triggered by) fall and early winter freshets, which flood habitat that would be unsuitable during summer because of high temperatures and low flow (NWPCC 2004). The channelization of the Willamette River has drastically reduced off-channel and other low velocity rearing habitats for juvenile Chinook (Kostow 1995).

Teel et al. (2009) recently identified that Willamette River spring-run Chinook salmon use the seasonal floodplains near the convergence of the Willamette and Columbia rivers. They also identified that that both spring and fall subyearling Chinook salmon from outside the Willamette River use these wetlands, and that some portion of Chinook salmon occupying lower Willamette River wetland habitats make extensive migrations down the Columbia River before entering the Willamette River.

A collaborative effort between the Oregon Department of Fish and Wildlife and City of Portland Bureau of Environmental Services monitored the biology, behavior, and habitat resources of juvenile salmonids in the lower Willamette River from May 2000 – July 2003 (Friesen 2005 and Friesen et al. 2007). The results of this study show that the lower Willamette is more than a simple migration corridor, and that juvenile Chinook salmon not only feed but apparently grow during their outmigrations.

During the three year study, density values of both hatchery and unmarked juvenile Chinook salmon generally increased beginning in November and declined to near zero by June. Habitat associations varied with collection methods. Radio-tagged Chinook salmon are not highly associated with nearshore areas; they were distributed evenly across the river channel regardless of year, time of day, origin, or area. Electrofishing found that catch per unit effort (CPUE) varied significantly among habitat types mainly due to low catches of fish at seawall habitats. In addition, electrofishing CPUE for juvenile salmonids in off-channel areas was not significantly greater than in main-channel areas. However, all off-channel types were clearly utilized.

Habitat use by juvenile Chinook as observed in the mainstem Willamette is described below. Habitats in the study area were categorized into six categories: beaches, alcove, riprap, seawall, rock outcrop and mixed. The majority of the riverbank habitat was classified as undeveloped ('natural') and beaches with sandy substrate were the most prevalent habitat type. Natural beaches appeared to be an important habitat for younger age classes of Chinook salmon. These habitat types are typical under natural conditions in the larger rivers of the Lower Columbia Estuary. In addition, beaches were not a preferred habitat of large predator fishes and therefore enhancements directed at creating beaches were recommended. Unaltered nearshore habitats (beaches) appear to be important to smaller fish as juvenile salmonids are generally associated with the upper portion of the water column. All off-channel habitats were utilized by juvenile salmonids as they are likely important for forage and refuge. Seawalls and riprapped sites on the other hand appeared to be under-utilized by juvenile Chinook. However, densities of large predators were constantly highest at sampling sited dominated by rocky habitats in the summer and autumn.

These studies indicate that juvenile Chinook primarily utilize nearshore shallow water beach habitat with sandy substrate and off-channel refuge habitats during their out-migration in through the estuarine mainstem Willamette River. It is therefore these habitats that are target for restoration in this portion of the project area. However, Friesen et al (2004) state that of the habitat parameters studied some relationships were confused and recommended a more rigorous statistical approach for future work and greater understanding of how juvenile out-migrating salmonids utilize habitat in the Lower Willamette River.

Chinook juveniles appear to prefer areas with slow to moderate velocities, < 30 cm/s (Healey 1991). Although velocities in side channels and off-channel areas that would be created as part of this project were not modeled, these areas were designed to have low velocities. Because they are located in tidal areas, velocities would be associated with filling and draining due to tidal cycles as well as increased or decreased water surface elevations due to fluctuating upstream discharge rates. Since velocities were assumed to be low in restored side channels and off-channel areas across all mainstem sites, velocity was not considered necessary in developing the mainstem model.

Native Salmonids Mainstem Habitat Suitability Model Development

The mainstem model is a new HSI developed for Chinook salmon to account for the unique habitat that exists in the mainstem of the tidally influenced Lower Willamette River and to evaluate the extent to which habitat restoration measures will benefit out-migrating juvenile salmonids. The mainstem model is developed from modifications of existing HSIs for Chinook salmon (Alan and Hassler 1986) and the site specific data collected in the study discussed above (Friesen et al. 2007). The modifications of the existing HSIs were based upon localized response variables identified in available data and publications, as well as site specific observations. The HSIs for Chinook in Alan and Hassler (1986) were selected for use in the mainstem model as the juvenile rearing habitat represented is that of tidal estuaries similar to those found in the project area.

The SIs for Chinook that were selected to include in the mainstem model include variables that may show a response to the restoration action and that address factors or processes that are limited to or preferred by juvenile salmonids utilizing this habitat type. The SIs target the habitat conditions that out-migrating juvenile Chinook would encounter in the study area, as indicative of a large tributary of the Lower Columbia River estuary.

In the Friesen et al. (2007) study, habitat parameters were measured to identify those contributing to habitat selection of juvenile Chinook salmon. In the spring, only bank vegetation showed a relationship with Chinook density. In the winter, sand substrate, shallow water, and moderate amounts of bank vegetation were associated with higher catches. Therefore, bank vegetation, substrate, and depth were the parameters selected to be the indicators of habitat quality for out-migrating juvenile salmonids in the estuarine mainstem of the Willamette River.

As peak out-migration for juvenile Chinook occurs between February and May, the features of the proposed projects were designed to be connected during this season. Additionally, the mainstem model addresses variables that are applicable during this season. For example, temperature and dissolved oxygen may be limiting in some locations in the project area during summer/fall low flow months but since they are within the optimum ranges during the out-migration period, they are not factors included in the model.

Table 4.9 includes a list of the variables included in the original Chinook salmon HSIs and the rationale for use or exclusion. Variables were omitted if they did not pertain to a limiting factor in the project area. Due to the number of variables associated with tidal habitats on large rivers such as the Willamette, more rigorous analysis of Willamette habitat relationships and hydraulic conditions is warranted.

Table 4.9 Native Salmonids Mainstem Variables

Species	V	Variable	Used	Not Used	Rationale
Native Salmonids					This model was created based on recent literature of Chinook use of mainstem Willamette River shallow water habitats -- based off of existing HSIs from Allen and Hassler 1986 and site specific data collected by Friesen et al 2004 and 2007.
Juvenile Chinook - Modified					
	V_1	Temperature (°C)		X	The optimal water temperature for outmigrating salmonids is 12-13°C (53-55°F) (Allen and Hasler 1986). Average temperature in the mainstem Willamette is 58.8°F during the outmigration period, which is within their tolerance range, therefore temperature was not identified as a limiting factor during the season of peak out-migration (February – May), for which the project is designed, and no restoration measures were developed to address this variable. Additionally, scale of the proposed project is too small to make a difference in temperature in the waterbodies in which the restoration sites occur.
	V_2	Salinity (ppt)		X	Lethal salinity level for juvenile salmonids is between 15-30 ppt (Allen and Hasler 1986). Study area is upstream of Columbia River estuarine mixing zone and saline conditions do not exist, therefore salinity was not included as an evaluation parameter.
	V_3	Dissolved Oxygen (mg/L)		X	The tolerance level for DO for juvenile salmonids is >4.5 mg/l (Allen and Hasler 1986). DO in mainstem is between 6.0-14.8 mg/l, therefore not identified as a limiting factor during the season of peak out-migration (February – May), for which the

					project is designed, and no restoration measures were developed to address this variable. Additionally, scale of the proposed project is too small to make a difference in DO in the waterbodies in which the restoration sites occur.
	V_4	Substrate	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V_5	Depth	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V_6	Water Velocity (ft/s)		X	Optimal water velocities for juvenile salmonids are between 0.06-0.24 m/sec. Side channels and backwaters by definition are low velocity habitats and have been designed for this project to have the geometry and other criteria specifically to ensure low velocities (< 30 cm/s). Developing velocity estimates at this stage of the study would require extensive hydraulic modeling of the lower Willamette River, beyond the scope of this study. Proposed side channels and backwaters do not currently exist, therefore there is no baseline to compare benefits.
Juvenile Chinook - New					
	V_1	Depth (<20m from shore)	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V_2	Substrate	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V_3	Percent cover bank vegetation	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
$HSI_{Salmonids\ Mainstem} = (V_1 + V_2 + V_3) / 3$					

Highlights of the selected model with the attributes measured for each species or species assemblage

HEP Model	
Western Pond Turtle	V_1 = Percent area with water depth preferred by adults V_2 = Percent cover along water's edge V_3 = Water temperature during low flows V_4 = Percent area with water depth less than 0.3 meters V_5 = Availability of suitable nesting sites $HSI_{W\ Pond\ Turtle} = (V_1 + V_2 + V_3 + V_4 + V_5) / 5$
Beaver	V_1 = Percent tree canopy closure V_2 = Percent of trees in 2.5 to 15.2 cm dbh size class V_3 = Percent shrub crown cover V_4 = Average height of shrub canopy V_5 = Species composition of woody vegetation $HSI_{Beaver} = (V_1 + V_2 + V_3 + V_4 + V_5) /5$
Wood Duck	V_1 = Percent of the water surface covered by potential brood cover $HSI_{Wood\ Duck} = V_1$
Yellow Warbler	V_1 = Percent deciduous shrub crown cover V_2 = Percent overall canopy cover V_3 = Average height of deciduous shrub canopy V_4 = Percent of shrub canopy comprised of hydrophytic shrubs $HSI_{Yellow\ Warbler} = (V_1 + V_2 + V_3 + V_4) / 4$
Native Amphibians	V_1 = Percent area with permanent water V_2 = Percent area with emergent or submergent wetland/aquatic vegetation V_3 = Percent ground cover along the water's edge V_4 = Width of riparian zone V_5 = Maximum temperature during low flows V_6 = Land use within 200 meters of the wetland edge $HSI_{Native\ Amphibians} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6) / 6$
Native Salmonids (Tributaries)	V_1 = Maximum water temperature during low flows V_2 = Percent pools during low water period V_3 = Instream cover (LWD) present V_4 = Predominant substrate size in riffle and run areas $HSI_{Salmonids\ Tributaries} = (V_1 + V_2 + V_3 + V_4) / 4$
Native Salmonids (Mainstem)	V_1 = Depth (<20m from shore) V_2 = Substrate V_3 = Percent cover bank vegetation $HSI_{Salmonids\ Mainstem} = (V_1 + V_2 + V_3) / 3$

4.8 Model Parameters

4.8.1 Western Pond Turtle

The HSI for western pond turtle is described in the following equation:

$$\mathbf{HSI_{WPondTurtle} = (V_1 + V_2 + V_3 + V_4 + V_5) /5}$$

V_1 = % Area with water depth preferred by adults (1-2 m) ***(Morreale and Gibbons 1986)***

% Area	SI
0	0
20	0.5
50	1.0
75	1.0
100	0.2

V_2 = % Cover along water's edge (Includes canopy, LWD, emergent wetland vegetation, etc. that either overhangs or is adjacent to the water within ordinary high water (OHW) marks) ***(Morreale and Gibbons 1986)***

% Cover	SI
0	0
25	0.2
50	0.5
75	1.0
100	1.0

V_3 = Water temperature during low flows (July-September) ***(Morreale and Gibbons 1986; Holland 1994)***

Temperature (C)	SI
5	0
10	0.2
15	0.6
20	1.0
25	1.0
30	0.6

V_4 = % Area with water depth less than 0.3 meters ***(Bill Castillo ODFW)***

% Area	SI
0	0.1
25	1.0
50	1.0
75	0.3
100	0

V_5 = Availability of suitable nesting sites (qualitative) ***(Bill Castillo ODFW)***

Availability	**SI**
None	0
Very few (1-2 in project area)	0.2
Sparse (3-4 in project area)	0.5
Moderate (5-7 in project area)	0.8
Abundant (>7 in project area)	1.0

4.8.2 Beaver

The HSI for beaver is described in the following equation:

$$HSI_{Beaver} = (V_1 + V_2 + V_3 + V_4 + V_5) /5$$

V_1 = Percent tree canopy closure (the percent of the ground surface shaded by a vertical projection of the canopies of woody vegetation ≥5.0 m (16.5 ft) in height) ***(Allen 1982)***

Percent canopy closure	**SI**
0	0
25	0.5
50	1.0
75	0.8
100	0.6

V_2 = Percent of trees in 2.5 to 15.2 cm (1 to 6 inches) dbh size class ***(Allen 1982)***

Percent of trees	**SI**
0	0.2
25	0.4
50	0.6
75	0.8
100	1.0

V_3 = Percent shrub crown cover (the percent of the ground surface shaded by a vertical projection of the canopies of woody vegetation < 5 m (16.5 ft) in height) ***(Allen 1982)***

Percent cover	**SI**
0	0
25	0.6
50	1.0
75	0.9
100	0.8

V_4 = Average height of shrub canopy *(Allen 1982)*

Average height (meters)	**SI**
0	0
1	0.3
2	1.0
3	1.0
4	1.0

V_5 = Species composition of woody vegetation (trees and/or shrubs) *(Allen 1982)*

Vegetation Class	**Description**	**SI**
A	Woody vegetation dominated (>50%) by one or more of the following species: aspen, willow, cottonwood, alder	1.0
B	Woody vegetation dominated by other deciduous species	0.6
C	Woody vegetation dominated by coniferous species	0.2

4.8.3 Wood Duck

The HSI Index for wood duck is described in the following equation:

$$HSI_{Wood\ Duck} = V_1$$

V_1 = Percent of the water surface covered by potential brood cover (shrub cover, overhanging tree crowns within 1 m (3.3 ft) of the water surface, woody downfall, and herbaceous) *(Sousa and Farmer 1983)*

Percent surface covered	**SI**
0	0
25	0.4
40	0.8
50-75	1.0
85	0.6
100	0

4.8.4 Yellow Warbler

The HSI for neotropical birds is described in the following equation:

$$HSI_{Yellow\ Warbler} = (V_1 + V_2 + V_3 + V_4) / 4$$

V_1 = % deciduous shrub cover *(Schroeder 1982)*

% Cover	SI
0	0
25	0.4
50	0.75
60	1.0
80	1.0
90	0.8
100	0.6

V_2 = % overall canopy cover *(Schroeder 1982)*

% Canopy Cover	SI
0-20	0
20-40	0.1
40-60	0.2
60-70	0.8
70-80	1.0
80-100	0.1

V_3 = Average height of deciduous shrub canopy height *(Schroeder 1982)*

Canopy Height (m)	SI
0	0
1	0.5
2+	1.0

V_4 = % canopy comprised of hydrophytic shrubs (Yellow Warbler) *(Schroeder 1982)*

% Hydrophytic Shrubs	SI
0	0.1
25	0.3
50	0.55
75	0.8
100	1.0

4.8.5 Native Amphibians

The HSI for native amphibians is described in the following equation:
$$HSI_{Native\ Amphibians} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6) / 6$$

V_1 = % Area with permanent water *(modified from WDFW 1997)*

% Area of Permanent Water	SI
0	0

10	0.6
25-40	1.0
>50	0.2

V_2 = % Area with emergent or submergent wetland/aquatic vegetation *(WDFW 1997)*.

% Area Wetland Vegetation*	**SI**
0	0
25	0.5
>50	1.0

**Areas dominated by reed canary grass and/or purple loosestrife cause HSI = 0.2.*

V_3 = % Ground cover along the water's edge, including debris, overhanging vegetation, undercut banks, etc. (width of area where overhanging vegetation is rooted) *(WDFW 1997)*

% Cover	**SI**
0	0
25	0.3
50	0.6
75	0.9
100	1.0

V_4 = Width of riparian zone *(WDFW 1997)*

Width (m)	**SI**
0	0
10	0.2
30	0.6
>60	1.0

V_5 = Maximum water temperature during low flows (late summer/early fall) *(modified from Graves and Anderson 1987*)

Temperature (°C)	**SI**
0	0.1
5	0.5
10	1.0
15	0.3
20	0

V_6 = Land use within 200 meters of the wetland edge *(WDFW 1997)*

Land Use	**SI**
Developed	0

Row Crops	0.1
Managed Pasture	0.5
Fallow Grass/herbs	0.7
Shrubs/trees	1.0

4.8.6 Salmonids Tributaries

The HSI for tributary salmonids is described in the following equation:

$\mathbf{SI_{Salmonids\ Tributaries} = (V_1 + V_2 + V_3 + V_4) /4}$

V_1 = Maximum water temperature during low flow (late summer/early fall) ***(Raleigh et al. 1986)***

Temperature (°C)	**SI**[1,2]
0	A = 0, B = 0**
5	A = 0.5, B = 0.3
10	A = 1.0, B = 0.9
15	A = 0.9, B = 1.0
20	A = 0.5, B = 0.9
25	A = 0, B = 0

[1]**A** = prespawning adults, **B** = juveniles
[2]Average the adult and juvenile values for V_1

V_2 = Percent pools during low water period ***(Raleigh, et al. 1986)***

Percent Pools	**SI**
0	0.2
25	0.6
50	1.0
75	0.9
100	0.2

V_3 = Instream cover (LWD) present ***(modified from McMahon 1983)***

Instream cover (% of surface area)	**SI**
0	0.1
10	0.2
20	0.4
30	0.8
40	1.0

V_4 = Predominant substrate size in riffle or run areas ***(Raleigh, et al. 1986)***

Class	**Description**	**SI**
A	Rubble or small boulders predominant; limited amounts of	1.0

	gravel, large boulders, or bedrock	
B	Rubble, gravel, boulders, and fines occur in approximately equal amounts or gravel is predominant	0.6
C	Fines, bedrock, or large boulders are predominant. Rubble and gravel are < 25%	0.3

4.8.7 Native Salmonids Mainstem

The HSI for mainstem salmonids is described in the following equation:

$HSI_{Salmonids\ Mainstem} = (V_1 + V_2 + V_3) / 3$

$V_1 =$ % Cover Bank Vegetation (Friesen *et al* 2004)

% Cover	SI
0-10	0
11-20	0.3
21-30	1
31-40	0.6
41-80	0.2
81-100	0.1

$V_2 =$ Depth (<20 m from the shore) (Friesen *et al*. 2004; Allen and Hassler 1986)

Depth (m)	SI
0.0 – 0.5	0.5
0.6 – 3.0	1.0
3.1 – 10	0.6
>10	0

$V_3 =$ Substrate (Friesen *et al*. 2004; Allen and Hassler 1986)

Substrate Type	SI
Bedrock	0.25
Riprap	0.35
Sand	1.0
Fines	0.45

4.9 HEP Results

The HSIs for each species or guild were calculated for each proposed project both for existing and future conditions. HSIs were calculated for future-without conditions at five years, ten years, and 25 years and future-with project conditions at five years, ten years, and 25 years. These HSI scores were then combined to produce a combined HSI score utilizing the following equations, one for tributary project sites and the other for mainstem project sites suitable for use in a cost effectiveness and incremental cost analysis (CE/ICA).

HSI Equation Tributaries	$HSI_{All} = (HSI_{WPondTurtle} + HSI_{Beaver} + HSI_{Wood\ Duck} + HSI_{Yellow\ Warbler} + HSI_{Native\ Amphibians} + HSI_{Salmonids\ Tributaries}) / 6$
HSI Equation Mainstem	$HSI_{All} = (HSI_{WPondTurtle} + HSI_{Beaver} + HSI_{Wood\ Duck} + HSI_{Yellow\ Warbler} + HSI_{Native\ Amphibians} + HSI_{Salmonids\ Mainstem}) / 6$

When scoring each variable for without and with project conditions the following assumptions were made:

Without Project Condition Assumptions
The assumptions used to score the baseline future conditions of the restoration sites at 5, 10 years and 25 years through 50 years are as follows:

- *Vegetation* The composition of the riparian community would remain similar to existing conditions. Although riparian zones are dynamic ecosystems, most areas surveyed either displayed stable, mature ecosystems (for example, sites along Tryon Creek) that are unlikely to change significantly over the projected time period without a significant event such as devastating wildfire, massive flood, or infestation by disease or pest, or are so constrained by revetments, development, and hardscape in the floodplain that the natural cycle of disturbance and regeneration no longer occurs.

- *Water Quality* Although localized water temperature decreases may occur as a result of increased canopy cover along some stretches of stream, overall water temperatures are expected to increase by up to 1 degree due to continued development and climate change effects. Other water quality parameters including turbidity, and pollution from stormwater and industrial outputs are expected to improve over time due to increased regulation of water resources and better management of stormwater.

- *Large Woody Debris* LWD accumulation would remain similar to existing conditions. Narrow riparian zones in most areas do not promote woody debris recruitment, and although some woody debris may accumulate over the projected time period, a net gain of LWD is not expected.

- *Percent Ground Cover at Water's Edge* The percentage of ground cover composed of materials such as logs and brush at the water's edge is not expected to have increased significantly.

- *Side Channels and Alcoves* Available off-channel habitat would remain the same as existing conditions or would decrease as streams further incised.

- *Fish Passage Barrier Removal* Fish passage would remain partially blocked at some locations.

With Project Condition Assumptions
The assumptions used to establish the future conditions of the restoration sites after implementation of restoration measures are as follows:

- *Revegetation* Five years after the project, a rapid increase in the number of small diameter trees, canopy cover and density, and understory shrub height over current conditions is expected. This increase is expected to continue for approximately 10 years, after which the rate of increase of these parameters would likely decrease. Twenty-five years after the project, deciduous trees would be mature and the deciduous tree canopy would be closed to the extent that it was going to close at that level of succession. Shrub canopy cover would decrease somewhat in response to the lower amount of sunlight coming through the upper canopy and shrub heights would decrease. Maximum cover over the stream and along the water's edge would be expected by this time. The increase in cover over the stream will produce a minimal reduction in the localized water temperature.

- *Water Temperature* Water temperature benefits are not expected to occur on the mainstem Willamette River as a result of this project, due to its limited size in comparison to the size of the waterbodies on which it occurs. Other water quality parameters including level of dissolved oxygen, turbidity, and pollution from stormwater and industrial outputs may be slightly improved on a site-specific scale by the proposed restoration measures, but these improvements are not expected to be measureable.

- *Large Woody Debris* Within one year following implementation of the project, complexity and instream cover is expected to increase substantially with the placement of LWD. Pools would scour in association with the wood and sediment and debris deposition would also occur, locally reducing channel incision and maintaining or improving connections to the floodplain. After 25 years with the project, additional instream cover would develop with the potential of additional debris collecting in the piles and further recruitment of gravels as pools developed. Recruitment of LWD would increase during this time period due to revegetation of the riparian zone during project construction. Instream cover would further increase.

- *Percentage of Ground Cover at Water's Edge* The percentage of ground cover would increase significantly in some areas immediately upon completion of the project due to placement of LWD and revegetation, and is expected to further increase as restored vegetation matures and fills in available spaces.

- *Side Channels and Alcoves* Immediately following implementation of the project, additional habitat would be created for fish rearing during high water events. Communities of hydrophytic plant species would be developing in these areas. Twenty-five years after the project, habitat would still be available for fish rearing during high-flow events. Further development of hydrophytic plant communities would be observed in these areas.

- *Fish Passage Barrier Removal* Immediately following implementation of the project, fish access would be restored to habitat upstream for both rearing and spawning. This fish passage barrier removal project on Tryon Creek was scored by assessing the existing conditions of the habitat upstream that would be made accessible to salmonids. Since the Tryon Creek/Highway 43 Culvert project is specifically a fish passage project, the only HSI that the project was evaluated for was tributary salmonids. It is not assumed that additional restoration of the habitat upstream would occur, therefore the project conditions remained constant over the 50 year projected lifecycle of the project.

For each group of species, a habitat suitability index (HSI) was derived (between 0 and 1). For this project, the index scores for each site were averaged. The overall resulting index score was multiplied by the acreage of potential alternative restoration plans to yield habitat units. HSIs were calculated for existing conditions, conditions at 5 years without the project, 10 years without the project, and at 25+ years without the project, at 5 years after restoration, 10 years after restoration, and at 25+ years after restoration. It was assumed that conditions found at these control points would reflect milestone changes in the habitat conditions as the site matures after the project is implemented. After 25 years, it was assumed that the characteristics of the site would reflect conditions expected in a maturing ecosystem that is beginning to realize the full benefits of vegetation plantings and temperature reduction. Fast-growing trees such as alders and willows are starting to mature by then, and conifers such as western red cedars and Douglas-firs are well established.

Existing Habitat at Project Sites

Kelley Point Park is a greenspace at the convergence of the Willamette and Columbia Rivers. Existing habitat features include riparian vegetation, a forested wetland, and the shorelines of the two rivers. The park has a high percent of forest cover, except where park grass, cleared areas, and banks of sand, gravel, and cobble slope down to the rivers. Existing and future with project conditions will provide the habitat for all species identified in the HEP model.

The BES Plant site is along the south bank of the Columbia Slough. Existing habitat features at the project site consist of narrow and mostly immature riparian zone on both banks, a depressional wetland swale, and the shoreline of the Columbia Slough. Existing and future with project conditions will provide the habitat for all species identified in the HEP model.

Kenton Cove lies on the north shore of the Columbia Slough. Existing habitat features include gently to moderately sloping banks covered with grasses or riparian forest that lead down to the backwater cove. Existing and future with project conditions will provide the habitat for all species identified in the HEP model.

The Oaks Crossing/Sellwood Riverfront Park site is on the north shore of the Willamette River. The project footprint is comprised mostly of forest cover with small patches of bare ground or grass/lawn. Existing and future with project conditions will provide the habitat for all species identified in the HEP model.

Existing habitat at the Tryon Creek Highway 43 Culvert project site is defined primarily by tributary stream habitat surrounded by a narrow mature riparian zone and a narrow floodplain with steep upland areas consisting of mature trees. Existing habitat conditions of newly accessible stream miles provide the with-project habitat conditions value for tributary fish species only. Therefore only the tributary model was used to score this project. Although there may be incidental benefits to other wildlife utilizing the improved passage at the culvert, these are not measurable with this model. As the habitat conditions of Tryon Creek vary along the length of the newly accessible area, the exiting habitat conditions were scored for three distinct reaches and summed together to provide total habitat units. Furthermore, as fish passage is blocked at this structure the habitat value upstream of the culvert is assumed to be zero for anadromous fish under current conditions.

Table 4.10 summarizes the scores under existing conditions and after restoration occurs. The highest possible index score is a 1.0 and indicates the best possible conditions for each group of species. Scores between 0.7 and 1.0 indicate good to excellent quality habitat. Sites scoring below 0.3 are not considered to have suitable habitat for the species selected.

Table 4.10 HSI Scores Under Existing Conditions and After Restoration and Acres at Each Site

Project Site	**Existing HSI**	**HSI After Restoration (25-50 years)**	**Acres**
Mainstem Willamette River			
Kelley Point Park	0.48	0.86	45.10
Cathedral Park	0.40	0.61	3.50
Saltzman Creek	0.37	0.69	2.00
Oaks Crossing/Sellwood Riverfront Park	0.44	0.73	10.44
Columbia Slough			
St. Johns Landfill Boat Ramp	0.29	0.54	3.10
BES Treatment Plant South	0.41	0.70	6.60
Kenton Cove	0.40	0.60	5.90
Tryon Creek			
Tryon Highway 43 Culvert			
Reach 1	0	0.93	13.00
Reach 2	0	0.65	24.10
Reach 3	0	0.63	11.90

Habitat units were determined by multiplying the combined HSI scores by the area of habitat that may be affected by each project. The area of habitat was determined by the project boundaries and area of influence around the project boundaries (i.e., area that would be shaded by riparian vegetation, area opened up by construction of tidal channels, or area around newly installed cover features where juvenile fish may venture to) or in the case where fish passage barriers were replaced, the area was determined by the amount of available habitat opened upstream from the barrier. Table 4.11 shows the results of the HU calculations at set control points selected for years 0, 5, 10, and 25 under both with and without project conditions. To calculate average annual habitat units (AAHUs), the HUs for both with and without-project conditions at each of the control points were entered into the USACE IWR Planning Suite Annualizer. The Annualizer then interpolated HU values for all 50 years of the project life based upon area under the curve calculations. These scores were then totaled and divided by 50 (for the total number of years) to achieve the AAHU score. The AAHU score was calculated for both with and without-project conditions from which a net AAHU score is determined to assess the net gain of the project. AAHU scores under with and without project conditions, as well as net gain, are shown in Table 4.12.

Table 4.11. HU calculations for each project site.

Project Site	**Habitat Units**						
	Existing	**Future Without Project**			**Future With Project**		
	Year 0	**Year 5**	**Year 10**	**Year 25**	**Year 5**	**Year 10**	**Year 25**
Kelley Point Park	21.65	23.00	22.55	22.55	36.08	37.88	38.79
Cathedral Park	1.40	1.37	1.37	1.37	2.07	2.21	2.14
Saltzman Creek	0.74	0.74	0.72	0.72	1.22	1.28	1.38
Oaks Crossing/Sellwood Riverfront	4.59	4.80	4.80	4.91	7.62	8.04	7.62
St. Johns Landfill Boat Ramp	0.90	0.90	0.93	0.93	1.46	1.71	1.67
BES Plant South	2.74	2.81	2.81	2.75	4.20	4.57	4.60
Kenton Cove	2.34	2.39	2.39	2.37	2.86	3.33	3.55
Tryon Highway 43 Culvert	0.00	0.00	0.00	0.00	39.65	39.65	39.65

Table 4.12 Average Annual Habitat Units (AAHUs) for each project site.

Project Site	**AAHUs**		
	Future W/o Project	**Future With Project**	**Net Gain**
Kenton Cove	2.37	3.37	1.00
Oaks Crossing/Sellwood Riverfront Park	4.86	7.55	2.69
BES Plant South	2.76	4.46	1.69
Kelley Point Park	22.55	37.48	14.93
Tryon Highway 43 Culvert	0.00	39.65	39.65
Saltzman Creek	0.72	1.31	0.589
Cathedral Park	1.3715	2.11	0.74
St. Johns Landfill Boat Ramp	0.9255	1.6185	0.693

Conclusions

Table 4.11 shows the increase in habitat value that would occur due to implementation of the proposed projects, and the data sheets in Appendix B show the increased habitat value on a per/species basis and at each site. These tables show that significant lift to the habitat of the indicator species would occur, indicating that the health of the watershed would be significantly improved if the project were implemented. Use of these scores to populate the cost effectiveness/incremental cost analysis model show that these projects are "best buy" plans, meaning that they are good plans that are worth implementing.

5. REFERENCES

Allen, A.W. 1982. Habitat suitability index models: Beaver. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.30. 20p.

Allen, M.A., and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) – Chinook salmon. U.S. Fish and Wildlife Service Biological Report 82(11.49). U.S. Army Corps of Engineers, TR EL-82-4.

Aroner, W.E. 2001. Willamette River Watershed Water Quality Status and Trends Report. Report to Portland Bureau of Environmental Services.

Beechie, T.J and M. Liermann, E.M. Beamer, R. Henderson. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Transactions of the American Fisheries Society 134:717-729.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptista, D. A. Jay, K. K. Jones, E. Casillas, and M. H. Schiewe. 2005. Salmon at river's end: the role of the estuary in the decline and recovery of Columbia River salmon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-68.

Brown, T. G. 2002. Floodplains, flooding and salmon rearing habitats in British Columbia: a review. Research document 2002/007, Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia, Canada.

Chapman, D.W., and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. In: T.G. Northcote (Ed.). Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries. Institute of Fisheries, University of British Columbia, Vancouver, BC.

Dauble, D.D., T.L. Page, and R.W. Hanf, Jr. 1989. Spatial distributions of juvenile salmonids in the Hanford Reach, Columbia River. Fishery Bulletin 87:775-790.

Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of Fisheries Resources Board of Canada. 29:91-100.

Friesen, T.A., and J.S. Vile, A.L. Pribyl. 2004. Migratory Behavior, Timing, Rearing, and Habitat Use of Juvenile Salmonids in the Lower Willamette River. Oregon Department of Fish and Wildlife Columbia River Investigations. Clackamas, Oregon.

Friesen, T.A. (Ed.) 2005. Biology, Behavior, and Resources of Resident and Anadromous Fish in the Lower Willamette River. Final Report of Research, 2000-2004. City of Portland Bureau of Environmental Services, Portland, Oregon.

Friesen, T.A., J.S. Vile, and A.L. Pribyl. 2007. Outmigration of juvenile Chinook salmon in the lower Willamette River, Oregon. Northwest Science. 81(3):173-190.

Healey, M. C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 311–394 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Holland, D.C. 1994. The Western Pond Turtle: Habitat and History. Oregon Department of Fish and Wildlife, prepared for U.S. DOE, Bonneville Power Administration. Project #: 92-068.

Johnsen, R.C., and C.W. Sims. 1973. Purse seining for juvenile salmon and trout in the Columbia River Estuary. Transactions of the American Fisheries Society. 102:341-345.

Kostow, K., ed. 1995. Biennial Report on the Status of Wild Fish in Oregon. Oregon Department of Fish & Wildlife.

Lister, D.B. and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of Chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada. 27:1215-1224.

McMahon, T.E. 1983. Habitat Suitability Index Models: Coho Salmon. Report FWS/OBS-82/10.49, Western Energy and Land Use Team, U.S. Fish & Wildlife Service, Washington, DC.

Morreale, S.J. & J.W. Gibbons. 1986. Habitat Suitability Index Models: Slider Turtle. Biological Report 82(10.125), National Ecology Center, U.S. Fish & Wildlife Service, Washington, DC.

Murphy, M.L., and J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (Oncorhynchus) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 46:1677-1685.

Northwest Power and Conservation Council (NPCC). 2004. Draft Willamette Subbasin Plan. Prepared for the Northwest Power and Conservation Council by the Willamette Restoration Initiative.

ODEQ. 2006. Willamette Basin TMDL Lower Willamette Subbasin. Oregon Department of Environmental Quality.

Raleigh, R.F., W.J. Miller & P.C. Nelson. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Chinook Salmon. Biological Report 82(10.122). National Ecology Center, U.S. Fish & Wildlife Service, Washington, DC.

Roegner, G.C., E.W. Dawley , M. Russell, A. Whiting & D.J. Teel (2010) Juvenile Salmonid Use of Reconnected Tidal Freshwater Wetlands in Grays River, Lower Columbia River Basin. Transactions of the American Fisheries Society. 139:4, 1211-1232.

Rosenberg, D., J. Gervais, D. Vesely, S. Barnes, L. Holts, R. Horn, R. Swift, L. Todd, and C. Yee. 2009. Conservation Assessment of the Western Pond Turtle in Oregon. Version 1.0. Sponsored by: Bureau of Land Management, U.S. Fish and Wildlife Service, U.S.D.A. Forest Service, Oregon Department of Fish and Widllife, City of Portland, Metro.

Schroeder, R.L. 1982. Habitat suitability index models: Yellow warbler. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.27. 7p.

Sommer, T. R., W. C. Harrell, and M. L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. North American Journal of Fisheries Management 25:1493–1504.

Sommer, T. R., M. L. Nobriga, W. C. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325–333.

Sousa, P.J. and A.H. Farmer. 1983. Habitat suitability index models: Wood duck. U.S. Department of the Interior, Fish and wildlife Service. FWS/OBS-82/10.43. 27pp.

Teel, D.J., and C. Baker, D.R. Kuligowski, T.A. Friesen, B. Shields. 2009. Genetic stock composition of subyearling Chinook salmon in seasonal floodplain wetlands of Lower Willamette River, Oregon. Transactions of the American Fisheries Society 138:211-217.

U.S. Fish and Wildlife Service (USFWS). 1980a. Habitat as a Basis for Environmental Assessment. 101 ESM. USDI Fish and Wildlife Service. Division of Ecological Services. Washington, D.C.

USFWS. 1980b. Habitat Evaluation Procedures (HEP). 102 ESM. USDI Fish and Wildlife Service. Division of Ecological Services. Washington, D.C.

USFWS. 1980c. Draft Review Copy Green Heron Habitat Suitability Index Model. U.S. Fish and Wildlife Service. Washington, D.C.

USGS. 2014. National Water Information System. Accessed from: http://nwis.waterdata.usgs.gov/nwis

Washington Department of Fish and Wildlife (WDFW). 1997. Draft Habitat Suitability Index Model: Pond Breeding Amphibian and Cover Model. Prepared for the U.S. Army Corps of Engineers, Columbia River Channel Deepening Project.

This page left blank intentionally

Appendix A - Model Certification Letters

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P AUG 15 2013

MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: April 12, 2013 ECO-PCX Recommendation for Approval for Single Use of the Oregon Chub, Native Salmon, American Kestrel, Native Amphibians, and Western Pond Turtle Habitat Suitability Index (HSI) Models in the Willamette Floodplain Restoration Study

1. These five HSI models originally were recommended for single use approval on one planning study but during the HQ model review period another team began developing another project study which sought to utilize the same set of HSI models to that study area being coincident with the original study request. These five models are usable and applicable to both of these studies.

2. July 2, 2013 HQUSACE approved these five HSI Models for single use approval on both the Willamette River Floodplain Restoration study and the Lower Willamette River Restoration Study. In application, these reports shall define parameters such as "narrow width", "significant presence", and "low flow period" to document assumptions used and ensure consistent application.

HARRY E. KITCH, P.E.
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

Encl

application.

HARRY E. KITCH, P.E.
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

Encl

Printed on Recycled Paper

REPLY TO ATTENTION OF:

DEPARTMENT OF THE ARMY MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS P.O. BOX 80 VICKSBURG, MISSISSIPPI 39181-0080

CEMVD-PD-N 14 April 2014

MEMORANDUM FOR CECW-NWD (Kopecky)

SUBJECT: Summary of Model Review Results and Recommendation for Approval for Single Use of the Out-Migrating Juvenile Chinook Salmon HSI Model in the Lower Willamette River Ecosystem Restoration Project

1. References:
   a. Engineering Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. February 2012

   c. Model Approval Plan, Juvenile Chinook Salmon HSI Model, dated 16 October 2013 (Encl 1)

   d. Final Model Documentation (Encl 2)

   e. Model Review Documentation (Encl 3)

2. The Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the Out-Migrating Juvenile Chinook Salmon HSI Model in accordance with references 1.a, 1.b and the Model Approval Plan (Encl 1). The ECO-PCX recommends single-use approval of the model in the Lower Willamette River Ecosystem Restoration Project. Please log in this recommendation with the Office of Water Project Review for consideration by the Model Certification Team.

3. There is a large amount of life history diversity within the Chinook salmon species. In the Willamette and Columbia River basins substantial variation exists based on time of freshwater entry, time of spawning, age and time of smolt migration, and length of freshwater residence. The Juvenile Chinook model was developed by the Portland District to evaluate the specific habitat requirements associated with active out-migrating juvenile salmon smolts within the lower Willamette's tidally influenced estuary.

The Columbia River/Lower Willamette estuary is critical habitat for all types (stream- and ocean-type) and populations of Chinook salmon because at some point all juveniles take up residence in the estuary (timing is dependent on population type and out-migration status). This out-migration habitat is critical to salmon life history for feeding, rearing, refuge, and salt-water acclimation. Generally, juvenile Chinook salmon utilize nearshore shallow water beach habitat within the mainstem Willamette and Columbia Rivers. The subject model included habitat parameters which contributed to habitat selection of juvenile Chinook salmon migrating and rearing through the tidally influenced habitats in the Lower Willamette River. Based on recent studies, bank vegetation, substrate, and depth were associated with higher densities of juvenile Chinook salmon among nearshore and backwaters habitat types. Therefore, these variables were the parameters selected to be indicators of habitat quality for out-migrating juvenile Chinook salmon in the estuarine mainstem of the lower Willamette River. The model follows the HEP methodology to document the quality (suitability

index score between 0.0 and 1.0) and quantity (area of restoration site) of available habitat for the selected species.

4. Review of the Juvenile Chinook Model was conducted by Fred Goetz (NWS). Fred is a SME in Pacific salmon ecology and familiar with the structure and function of estuarine habitat in the Lower Willamette River. The ECO-PCX managed the review to assess the technical quality, system quality, and usability of the models. The review results are in Enclosure 3.

There were 24 final comments (5 of high significance, 9 of medium significance, and 10 of low significance). The comments of high significance were related to the selection of variables used in the model, the objective of the model, and the spatial resolution/objective of the model. Medium significance comments generally focused on improvements to variable definitions, salmon life history refinements, application considerations, overall documentation structure, and a recommendation for future validation of the model. Finally, comments of low significance addressed the flow of the documentation and refinements to references cited. In response to the comments, the following modifications were made to the model:

- The documentation was revised to explicitly state the objective of the model. Due to the variation within salmon life-history components and the unique habitat requirements for each component, the intended use of the model was revised to more accurately reflect the system being represented. This included better definition of estuarine habitat, out-migration habitat requirements, life-history requirements, and temporal resolution of the model.
- Dissolved oxygen and velocity parameters were added to define the boundary conditions and applicability of the model.
- Spatial resolution was improved through improved definition of the objective of the model and the system being represented by the model.
- Definitions and descriptions were improved throughout the document to better understand the technical aspects of the model’s functionality, and justify the selection of model parameters and index scores.

All comments were addressed and incorporated to the satisfaction of the ECO-PCX and reviewer.

5. The Juvenile Chinook Model meets technical quality standards. The theoretical premise behind the model relates to a species' relationship to environmental factors/variables considered important and the range of conditions within which the species selects occupancy. The model provides reliable information on the known habitat requirements of juvenile Chinook salmon, provides an objective method of estimating how well specific habitat variables meet the habitat requirements, and provides a measurable basis for documenting project influences. The model is based on the current state of knowledge regarding the basic environmental conditions and resources required by juvenile Chinook salmon to survive and contribute to the population. The model is applicable to sites with water
velocities <30 cm/s and DO >4.5 mg/L, and during active out-migration time periods. The ATR team should be charged with evaluating the applicability of the model based on limitations and assumptions described in the model documentation. The model is in compliance with Corps policies and accepted procedures.

6. The model has sufficient system quality. The software platform (MS Excel 2007) is appropriate and available to all users. The component of the spreadsheet containing the Juvenile Chinook Model was reviewed and tested for computational correctness by the ECO-PCX. HSI values were calculated

2

CEMVD-PD-N
SUBJECT: Summary of Model Review Results and Recommendation for Approval for Single Use of the Out-Migrating Juvenile Chinook Salmon HSI Model in the Lower Willamette River Ecosystem Restoration Project

correctly. The PDT is proposing the use of additional models within the overall habitat evaluation procedure which requires some level of aggregation to obtain HUs. These methods and the method to produce AAHUs should be reviewed during ATR. As always when aggregating multiple species or community models, the PDT should conduct sensitivity analyses to better understand how individual variables, species or communities are affected by the alternatives.

7. The model has acceptable usability in that the scoring of variables, development of an overall score, and output interpretation is straightforward. The data required for input is readily available through a combination of information ascertained through field/site visits and/or elicitation of expert assistance from ecologists and biologists. The model is transparent and would allow for verification of calculations and outputs.

8. The ECO-PCX has reviewed the comments, District responses, and revisions to the model documentation and determined there are no unresolved or unaddressed issues which would prevent a recommendation for approval for single use.

9. In summary, the ECO-PCX finds the Out-Migrating Juvenile Chinook Salmon HSI model has sufficient technical quality, system quality, meets usability criteria, and complies with USACE policy. It is the recommendation of the ECO-PCX that the model be approved for single use in the Lower Willamette River Ecosystem Restoration Project. Please notify the ECO-PCX of the findings of the Model Certification Panel.

Enclosures (3)

Jodi Creswell
Operating Director, Ecosystem Restoration
Planning Center of Expertise

CF (with enclosures):
CECW-PC (Coleman, Matusiak, Trulick, Ware,
Bee) CECW-CP (Kitch, Hughes)
CECW-PB (Carlson)
CECW-NWD (Durham-Aguilera, McLean,
Kramer) CENWD-PDD (Combs, Fischer, Hudson,
Weiss)
CENWP-PM-E (Lightner,
Cisneros) CENWP-PM-F (Hicks,
Saldana)
CENWS-EN-ER (Gleason, Goetz,
Jackels) CENWS-PM-PL (Ringold)
CEMVD-PD-N (Wilbanks, Lachney,
Creswell) CEMVP-PD-P (Richards,
Stefanik)
CESAW-TSD-PL (Barnes)
CEERD-EE-W (Swannack, Reif)

3