APPENDIX A: HABITAT VALUATION METHODOLOGY

RIVER PLAN / NORTH REACH
HABITAT VALUATION METHODOLOGY

TECHNICAL REPORT

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Prepared for:
City of Portland Bureau of Planning and Sustainability

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1. Introduction

A habitat valuation methodology has been developed for use by the City of Portland's River Plan for the North Reach in-lieu fee and for a future mitigation bank. The goals of the habitat valuation are to 1) develop a method that is based on the best available science, user-friendly and transparent; 2) meet the mitigation criteria of regulating agencies such as the Department of State Lands and the US Army Corps of Engineers; 3) provide an assessment process ensure no net loss of natural resource function in the North Reach of the Willamette River through development impacts that cannot be otherwise avoided or minimized, and 4) utilize a system that is compatible with the Portland Harbor Natural Resources Damages settlements.

A method that combines functional based suitability indices (SI) and the Habitat Equivalency Analysis (HEA) model developed by the National Oceanic and Atmospheric Administration (NOAA 1995) was selected. This Functional HEA will be used to determine the amount of debits at the impact sites and credits at restored sites. This method, described in further detail below, will be utilized for the valuation of all habitat types found at each mitigation site before and after restoration and at each affected site before and after the site is developed. Therefore, this method will provide the means for a quantitative determination of ecological lift as a result of implementing restoration measures.

2. Habitat Valuation Methodology

2.1 Ecosystem Functions

The habitats along the lower Willamette River through Portland provide a number of important ecological functions. While there is a large amount of literature that identifies and estimates ecological functions, there is not a consistent framework that organizes, lists, and describes all the functions provided by an ecosystem. In order to ensure that the habitat valuation method is accounting for major ecological functions in the lower river, a draft framework and list of functions was developed. For this effort, categories of ecological functions were slightly modified from the categories used in Karr and Yoder (2004). The specific ecological functions within these categories were identified by reviewing, condensing and organizing several key documents on watershed and ecological function, including: the Federal Interagency Stream Restoration Working Group (FISRWG 1998) Stream Corridor Restoration: Principles, Processes, and Practices; the National Marine Fisheries Service (NMFS 1996) Making ESA determinations of effect for individual or grouped actions at the watershed scale; and City of Portland (2001, 2005, 2009a) Healthy Portland Streams, Framework for the Integrated Management of Watershed Health, and Portland Watershed Management Plan Measures. The organization and list of functions are depicted in Figure 1.

Ecological Functions

Energy & Nutrient Cycling

Insolation/thermal inputs

Food Web
- primary production
- secondary production
- feeding
- respiration
- decomposition

Organic inputs

Sediment production, transport & storage

Nutrient cycling

Hydrology

Groundwater recharge & storage

Base flow

Peak flow/flooding

Flood storage & attenuation

River/floodplain interaction

Physical Structure/Habitat

Structural complexity

Habitat connectivity

Channel composition & dynamics

Refugia

Water Quality

Temperature

Sediment/Turbidity

Oxygen production

Contaminant fate & transport

Biological Populations & Their Interactions

Reproduction (spawning, nesting)

Growth

Survival

Competition

Predation/Parasitism

Figure 1. Ecological functions that the habitat valuation methodology seeks to track and protect.

The challenge in using these ecological functions directly as measures of habitat value is that many functions are very difficult to measure directly: ecological functions may be measured through research, but the complexity of measuring highly dynamic ecological processes is often more than can be addressed in ongoing monitoring programs or as a component of development review. As a consequence, most monitoring and assessment programs rely on ecological indicators that serve as surrogates of ecological functions. Ecological indicators often focus on structural and compositional components of the ecosystem, rather than directly on processes or functions (Mulder, et al 1999). This is often a matter of practicality rather than importance: measuring primary production may require sophisticated methods of experimental study such as carbon (^{14}C) tracing, but estimating standing stock of algae or trees and shrubs is more straightforward, for example, and it is easier to measure the width, vegetative composition and connectivity of a riparian area than to measure the myriad complex functions that the riparian area provides, such as maintaining water quality, providing microclimates, supplying organic inputs into the food web, supplying wood and other functions related to habitat maintenance, channel dynamics and stream morphology.

2.2 Habitat Typing

The first step in valuing habitats along the Lower Willamette River involves delineating habitat types at each project site into six classifications including Riverine, Riparian, Stream, Wetlands, Grasslands and Upland habitats.

Habitat types are defined as follows:

> ***Riverine -*** Riverine habitat is the portion of the Willamette River bank between ordinary high water (OHW) and 20 feet below ordinary low water (OLW) NAVD88. OHW in the North Reach of the Willamette River is 20 feet NAVD88 based on OHW references of 14.7 feet to 15.2 feet Columbia River Datum (CRD) according to USACE (1991), and a conversion of + 5.03 feet between CRD and NAVD88.
>
> ***Riparian -*** Riparian habitat includes the region of the river bank between OHW and the 100-year flood elevation of approximately 32 feet NAVD88. This elevation was confirmed by observation of riparian species on the banks of the Willamette River.
>
> ***Upland Forest -*** Upland forest includes the region of the river bank above the riparian zone, from elevation 32 feet NAVD88 to the project boundary or property boundary that is dominated by forested vegetation.
>
> ***Stream -*** Stream habitat includes tributary streams to the North Reach of the Willamette River and includes instream and bank habitats.
>
> ***Wetland -*** Wetland habitat includes, by definition, those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

2.3 Suitability Indices

This habitat valuation method takes a functional approach by addressing measurable variables that indicate the ability of the ecosystem to function properly. Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem. Ecosystem functions evaluated for this habitat valuation method include those defined by the City of Portland's Natural Resource Inventory (2009b) and Framework for Integrated Management and Watershed Health (2005) and include the flow of energy and materials, hydrology, physical habitat, water quality, and biological interactions. These functions are further broken down in detail and are matched with variables to be measured as indicators of these functions.

The following section presents the ecosystem functions for each habitat type along with the variables that are matched with these functions. The variables are broken down as a suitability index between a value of 0 and 1, with zero being the least valuable condition and one providing the most valuable or optimum condition. These variables are to be measured either through GIS or aerial mapping analyses or through observations in the field at each site. The average of the variables provides the model for which each habitat type is valued at a specific site.

The suitability indices provide a means for designing a mathematical model based on ecosystem functionality of the project site. The output of the model provides a quantitative value to be used for further evaluation in the HEA model and comparison of the action impacts.

3. Riverine Habitat

Ecosystem functions that are addressed in the riverine habitats of the Lower Willamette River include the flow of energy and materials, hydrology, physical habitat, water quality, and biological interactions. Often times, one variable will indicate the status of more than one ecosystem function. To highlight this complexity, Table 1 matches the functions that each variable is measuring. A description of each habitat variable is then described below.

Table 1. Riverine Habitat Valuation Variables and Corresponding Functions.

	Flow of Energy & Materials					Hydrology					Physical Habitat				Water Quality				Biological Interactions			
	Insolation/thermal inputs	Food Web	Organic inputs	Sediment production, transport & storage	Nutrient cycling	Groundwater recharge & storage	Base flow	Peak flow/flooding	Flood storage & attenuation	River/floodplain interaction	Structural complexity	Habitat connectivity	Habitat composition & dynamics	Refugia	Temperature	Sediment/Turbidity	Oxygen production	Contaminant fate & transport	Reproduction (spawning, nesting, etc.)	Growth & Survival	Competition	Predation/Parasitism
Floodplain Access			X	X	X	X		X	X	X	X	X	X	X		X				X		
Percent Cover Shoreline Vegetation	X	X	X		X						X	X	X	X	X							X
Shoreline Vegetation Type	X	X	X		X						X	X	X	X	X							
Proportion of Natural Shoreline	X	X	X	X	X	X	X			X	X	X	X	X	X	X				X		
Shallow Water Habitat Depth (<20m from shore)														X						X		X
Proportion of Shallow Water <10 feet in Depth														X						X		X
Slope of Active Channel Margin														X						X		X
Substrate		X	X	X	X								X	X	X	X		X		X		
Large Wood Debris Volume			X					X			X	X	X	X						X		X
Off-Channel Habitat		X	X	X	X	X			X	X	X	X	X	X		X				X		
Substrate Depth		X	X	X	X																	

Riverine Variables

3.1 Floodplain Access

A river's ability to access its floodplain is important in absorbing flow energy during high flow events. Floodplain access contributes to channel diversity by creating variable velocities both within and outside the river channel (COTE 2010). Floodplain access is defined as the potential of a river or stream to access its floodplain. Floodplain access is calculated by dividing OHW by wetted width. Larger floodplain access scores indicate a greater potential interaction between the river and its floodplain.

Table 2. V_1 = Floodplain Access (COTE 2010)

Floodplain Access (Ordinary High Water/Wetted Width)	Suitability Index Value
< 1.0	0
1.0 – 1.5	0.3
1.5 – 2.0	0.6
2.0 – 2.5	0.8
> 2.5	1.0

3.2 Percent Cover Shoreline Vegetation

Shoreline vegetation is the herbaceous or woody plants that grow and hang over riverbanks above or into the water surface. Vegetation on the shoreline stabilizes the banks and provides cover and refugia habitat for species utilizing the shoreline. Percent cover of shoreline vegetation is defined as the percent of the total shoreline area that is covered by vegetation.

Figure 2. V_2 = Percent Cover Shoreline Vegetation - (COTE 2010)

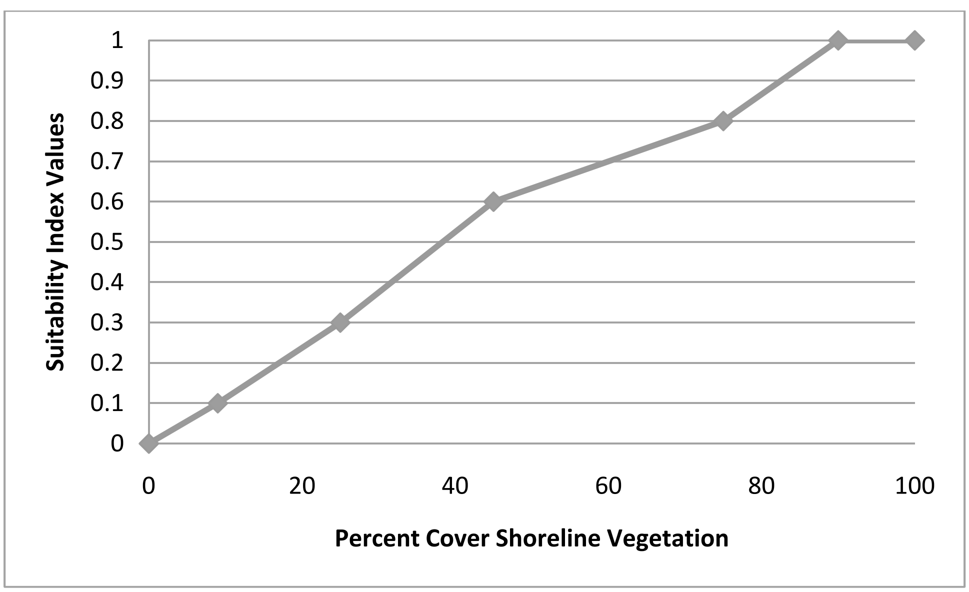


Table 3. V_2 = Percent Cover Shoreline Vegetation (Friesen, et al. 2004 and COTE 2010)

% Cover	Suitability Index Value
<10	0.1
10 - 30	0.3
30 - 60	0.6
60 - 90	0.8
>90	1.0

3.3 Shoreline Vegetation Type

The type of vegetation growing on the shoreline is calculated by the percent area covered and multiplied by the suitability index (SI) score for each category and added together. A more natural condition and species composition will score the highest. Native trees, shrubs, and ground cover provides water quality benefits to adjacent water bodies by filtering water that moves across this area. This vegetation also contributes terrestrial input to the aquatic system through wind-throw of terrestrial insects, leaves, woody debris and other sources of organic material. Shoreline vegetation also provides important habitat for terrestrial and avian species that depend on the aquatic environment (City of Seattle 2006).

Table 4. V_3 = Shoreline Vegetation Type (City of Seattle 2006 and PHNRTC 2009)

Type	Suitability Index Value
Mature Native Vegetation	1.0
Native Shrubs	0.7
Non-native Shrubs	0.5
Grass/Landscape	0.2
Invasive Species	0.1
Vegetated Riprap	0.05
Unvegetated/Paved/Buildings/Riprap	0

3.4 Proportion of Natural Shoreline

This variable is measured as the proportion of natural shoreline that is unarmored. Bank armoring causes increased shoreline erosion and a reduction of fish and wildlife habitat. Natural shorelines that are not altered by human structures such as bulkheads, riprap, etc. provide the optimal shoreline conditions for juvenile salmon. Shoreline armoring inhibits the natural shoreline processes, such as erosion and sloughing, blocking necessary sediment recruitment to create and maintain shallow littoral habitat. Additionally, shoreline armoring removes any heterogeneity at the shoreline, which is important for refuge (City of Seattle 2006).

Figure 3. V4 = Proportion of Natural Shoreline (Unarmored) (City of Seattle 2006)

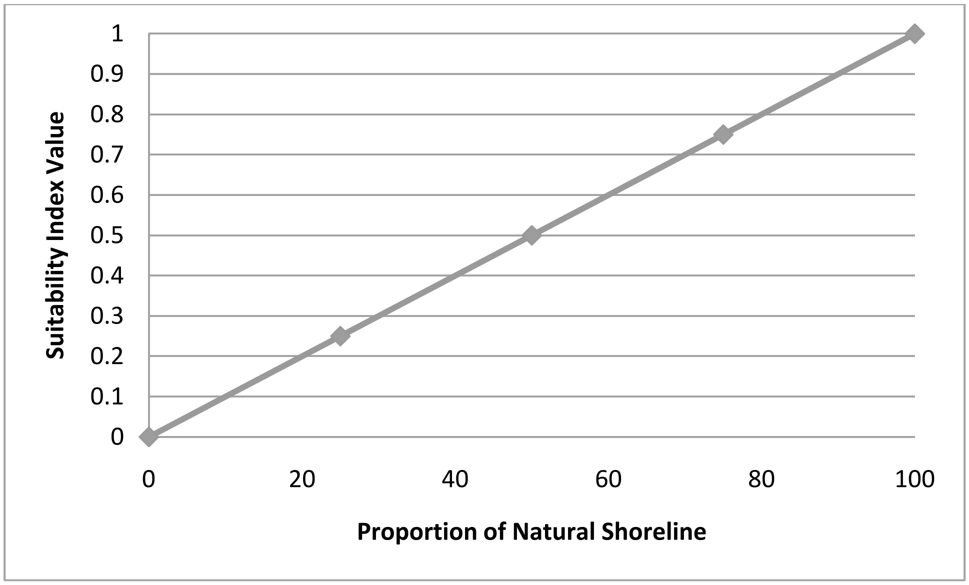


Table 5. V_4 = Proportion of Natural Shoreline (Unarmored) (City of Seattle 2006)

Percent	Suitability Index Value
0	0
25	0.25
50	0.5
75	0.75
100	1.0

3.5 Proportion of Shallow Water Habitat

The proportion of shallow water habitat is defined as the percentage of the disturbance area that is less than 20 feet deep. Shallow water habitat along shorelines provide important habitat to juvenile Chinook and other aquatic species by providing refuge from larger predators.

Figure 4. V_5 = Proportion of Shallow Water (City of Seattle 2006)

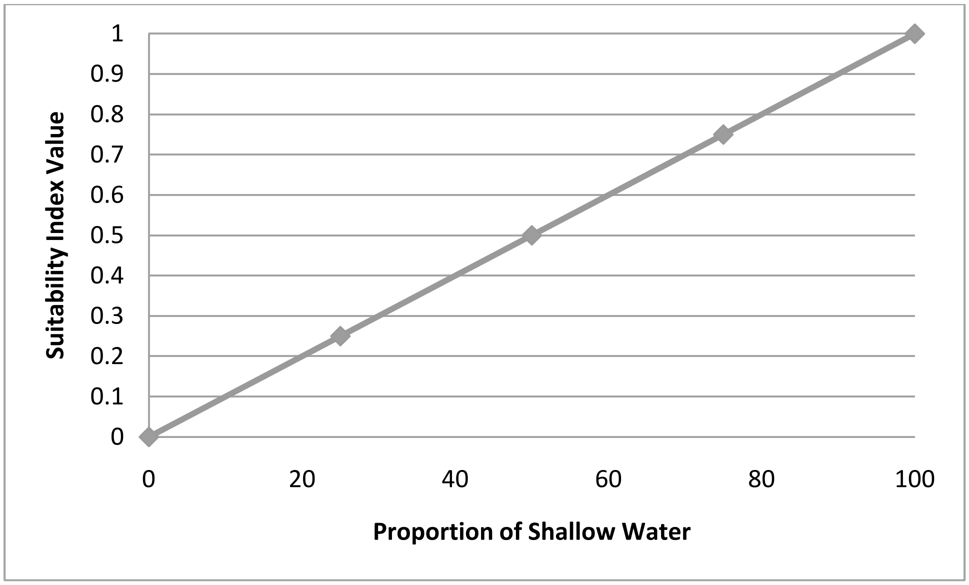


Table 6. V_5 = Proportion of Shallow Water (City of Seattle 2006)

Percent	Suitability Index Value
0	0
25	0.25
50	0.5
75	0.75
100	1.0

3.6 Shallow Water Habitat

The proportion of shallow water habitat found in depth categories that are scored based on juvenile salmonid preferences. This is calculated by summing the percent of each category multiplied by the (SI) score. Although shallow water habitat is defined as littoral areas less than 20 feet in depth, there is higher value in the depths that are less than 10 feet as shallower depths provide better refuge from large predators. Shallow water habitat greater than 10 feet, provides habitat for benthic organisms that are an important source of food for salmonids (City of Seattle 2006).

Table 7. V_6 = Shallow Water Habitat Depth (<20 m from the shore) (Friesen, et al. 2004; Allen and Hassler 1986)

Depth (m)	Suitability Index Value
0.0 – 0.5	0.5
0.6 – 3.0	1.0
3.1 – 10	0.6
>10	0

3.7 Slope of Active Channel Margin

The slope of the channel bank is commonly referred to as the channel sideslope. Sideslopes are calculated as vertical distance (rise) divided by horizontal distance (run). However, sideslopes are typically called out as a ratio of horizontal distance to vertical distance, such as 7 feet horizontal to 1 foot vertical (7H:1V, or 7:1). This convention is followed in the table below. This variable calculates the sideslope for shallow water habitat below ordinary low water. Shallow sideslopes generally correlate with improved bank stability.

Table 8. V_7 = Slope of Active Channel Margin (PHNRTC 2009)

Slope (H:V)	Suitability Index Value
< 7:1	1.0
7:1 – 5:1	0.7
5:1 –3:1	0.2
> 3:1	0

3.8 Substrate

This variable is defined as the proportion of substrate type located below Ordinary Low Water. This is calculated by summing the percent area of each category multiplied by the suitability index (SI) score. Substrate provides habitat structure for aquatic species. Species will perform normal behavioral and life history functions under preferred habitat conditions and will avoid non-preferred conditions.

Table 9. V_8 = Substrate (Friesen, et al. 2004; Allen and Hassler 1986)

Substrate Type	Suitability Index Value
Bedrock/armoring	0.25
Riprap	0.35
Gravel/Cobble/Sand	1.0
Fines	0.45

3.9 Large Wood

Large wood are either natural or cut, with some part of the piece within the active channel of the river. The minimum size for counting a piece of large wood is 6 inches in diameter by 10 feet in length. Large wood debris is measured as the volume of large wood below OHW per unit area. Large wood provide cover and refugia for aquatic species and structure for physical and biogeochemical processes.

Table 10. V_9 = Large stream Large Wood Debris Volume (ft3/ft2) (COTE 2010)

Volume (ft3/ft2)	Suitability Index Value
0	0
0.02 – 0.061	0.5
0.062 – 0.110	0.6
0.111 – 0.202	0.7
0.203 – 0.452	0.8
>0.452	0.9

3.10 Number of Pilings/Dolphins

The greater number of pilings and groups of pilings (dolphins) the greater the disturbance to important habitat in the shallow water near-shore area of the river. Predators have been found to utilize in-water structure and low velocity areas creating by pilings (USACE 2010).

Table 11. V_{10} = Number of Pilings/Dolphins

Number of Piles or Dolphins per 100 Linear Feet of Shoreline	Suitability Index Value
None	1.0
Less than 4 single piles and/or 2 dolphins	0.6
More than 4 piles and/or 2 dolphins	0.2

3.11 Proportion of Shallow Water Habitat Covered by Overwater Structure

Shading or changes in the lighting regime can cause changes in fish behavior and predator-prey interactions. As lighting decreases, predation on juvenile salmonids by piscivorous fishes increases.

Table 12. V_{11} = Proportion of Shallow Water Habitat Covered by Overwater Structure

Proportion	Suitability Index Value
0%	1.0
1-10%	0.5
11 – 25%	0.4
25 – 50%	0.2
<50%	0

3.12 Best Management and Green Design/Construction Practices

This variable is scored though a separate checklist that will give credit for the use of various types of best management practices or green/sustainable business practices that are intended to minimize the impact of the development. These may include such things as using a minimum of piles to reduce driving impacts, using transparent grate material on overwater structures in order to reduce the amount of shading, etc.

Table 13. V_{12} = Best Management and Green Design/Construction Practices

Score (%)	SI
0-25	0
25-50	0.2
50-75	0.5
75-100	1.0

Special Case Variables

When the following cases are present at the site, additional variables will be added to the riverine equation.

3.13 Off-Channel Habitat

If off-channel habitat is present, altered or created, the following variable will be measured to identify the off-channel habitat type and condition.

Table 14. V_{13} = Off Channel Habitat (PHNRTC 2009)

Off-channel Habitat Type	Suitability Index Value
Cold water tributary	1.0
Warm water tributary	0.9
Side channel	1.0
Alcove or slough with tributary	1.0
Alcove or slough without tributary	0.8
Embayment (cove) with tributary	1.0
Embayment (cove) without tributary	0.8

3.14 Substrate Depth

If the riverbed substrate is supplemented due to the project design, the depth of the altered substrate is measured. The greater the depth of the substrate fill, the greater probablity of its proper function and sustainability.

Table 15. V_{14} = Substrate Depth

Depth (inches)	Suitability Index Value
0”	0
1 – 12”	0.2
12 – 18”	1.0

Table 16. Riverine Model Equation

Riverine Model	
	V_1 = Floodplain Access V_2 = Percent Cover Shoreline Vegetation V_3 = Shoreline Vegetation Type V_4 = Proportion of Natural Shoreline V_5 = Proportion of Shallow Water V_6 = Shallow Water Habitat Depth (<20m from shore) V_7 = Slope of Active Channel Margin V_8 = Substrate V_9 = Large Wood V_{10} = Number of Pilings/Dolphins V_{11} = Proportion of Habitat Covered by Overwater Structure V_{12} = Best Management and Green Design/Construction Practices *V_{13}= Off-Channel Habitat* *V_{14} = Substrate Depth*
SI Equation Riverine	$SI_{Riverine} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 + V_9 + V_{10} + V_{11} + V_{12}) / 12$

SI Equation with Special Case Variables:

SIRiverine = (V1 + V2 + V3 + V4 + V5 + V6 + V7 + V8 + V9 + V10+ V11 + V12 + V13 + V14) / 14

4. Riparian Habitat

Ecosystem functions and the associated variables that are addressed in the riparian habitats of the Lower Willamette River are highlighted in Table 17. A description of each habitat variable is then described below.

Table 17. Riparian Habitat Valuation Variables and Corresponding Functions.

	Flow of Energy & Materials					Hydrology					Physical Habitat				Water Quality				Biological Interactions			
	Insolation/thermal inputs	Food Web	Organic inputs	Sediment production, transport & storage	Nutrient cycling	Groundwater recharge & storage	Base flow	Peak flow/flooding	Flood storage & attenuation	River/floodplain interaction	Structural complexity	Habitat connectivity	Habitat composition & dynamics	Refugia	Temperature	Sediment/Turbidity	Oxygen production	Contaminant fate & transport	Reproduction (spawning, nesting, etc.)	Growth & Survival	Competition	Predation/Parasitism
Percent Impervious Surface	X			X		X	X	X		X					X	X		X		X		
Land Use within 200 meters of the Waterbody Edge				X	X				X	X								X				
Percent Area with Emergent and/or Submergent Wetland/Aquatic												X		X					X	X		
Percent Cover Along Water's Edge												X		X					X	X		
Down Wood												X		X					X	X		
Percent of Trees in the 1 – 6 inch (2.5 to 15.2 cm) DBH Size Class												X		X					X	X		
Percent Shrub Crown Cover												X		X					X	X		
Average Height of Shrub Canopy												X		X					X	X		

Percent of Shrub Canopy Comprised of Hydrophytic Shrubs												X		X					X	X		
Width of Vegetated Riparian Zone	X	X	X	X	X					X	X	X	X	X	X	X		X	X	X		
Percent Tree Canopy Cover	X	X	X		X						X	X	X	X	X							
Species Composition of Woody Vegetation		X	X									X	X						X	X		

Riparian Variables

4.1 Land Use within 200 meters of the Waterbody Edge

This variable describes the land uses adjacent and within 200 meters of the water's edge. Developed or managed land uses score lower than natural areas with native vegetation.

Table 18. V_1 = Land use within 200 meters of the Waterbody Edge (WDFW 1997)

Land Use	Suitability Index Value
Impervious	0
Managed Impervious	0.1
Grass/herbs	0.7
Shrubs/trees	1.0

4.2 Percentage Area with Emergent and/or Submergent Wetland/Aquatic Vegetation

This variable is measured as the percent area that is covered by aquatic vegetation along the wetted edge of the waterbody. Wetland and aquatic vegetation provide unique habitat features and indicate a functioning riparian zone.

Figure 5. V_2 = Percent Area with Emergent and/or Submergent Aquatic Vegetation (WDFW 1997)

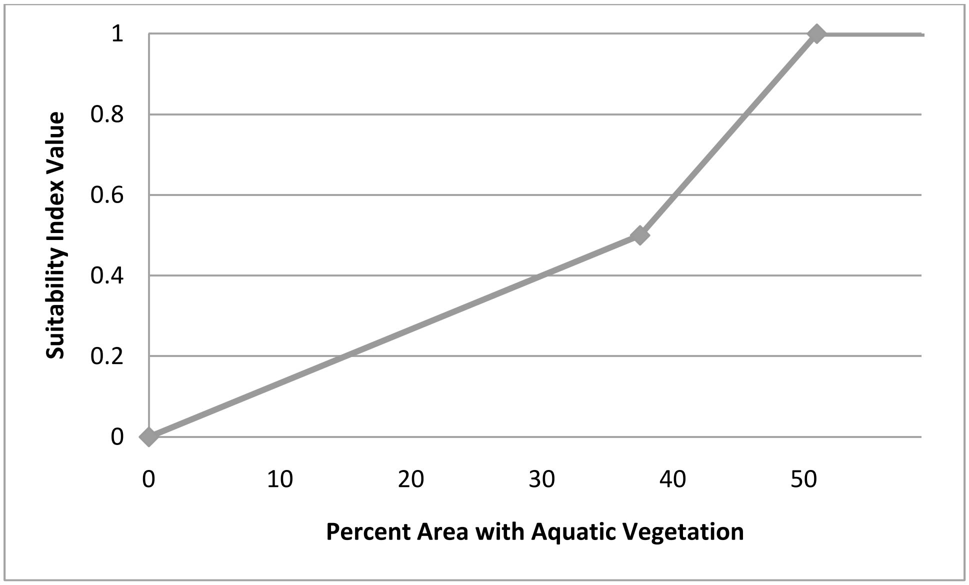


Table 19. V_2 = Percent Area with Emergent and/or Submergent Aquatic Vegetation (WDFW 1997)

% Area Aquatic Vegetation*	Suitability Index Value
0 - 25	0
25 - 50	0.5
>50	1.0

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

4.3 Percent Cover Along Water's Edge

Percent cover along the water's edge is defined as the proportion of canopy cover, emergent vegetation, wood debris, etc. that cover the wetted edge of the waterbody. Vegetation on the shoreline stabilizes the banks and over hanging vegetation and woody debris provide cover and refugia habitat for species utilizing the shoreline.

Figure 6. V_3 = Percent Cover Along Water's Edge (Morreale & Gibbons 1986 and Sousa & Farmer 1983 and WDFW 1997)

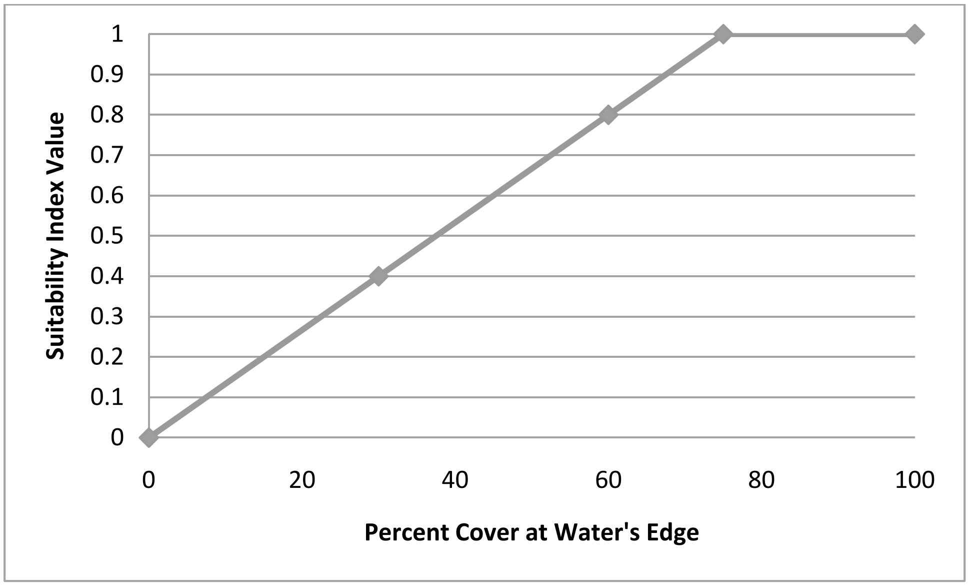


Table 20. V_3 = Percent Cover Along Water's Edge (Morreale & Gibbons 1986 and Sousa & Farmer 1983 and WDFW 1997)

% Cover	Suitability Index Value
0	0
30	0.4
60	0.8
75 - 100	1.0

4.4 Down Wood

Down wood includes downed logs, branches, and root wads in non-aquatic map units. Down wood does not refer to large wood (in-water), which is accounted for in the stream and riverine models. Down wood must be a minimum of 2 inches in diameter and 6 feet in length (COTE 2010). Down wood is measured by the number of pieces present per acre.

Table 21. V_4 = Down Wood (COTE 2010)

Number of Pieces	SI
None	0
1 - 3	0.2
4 - 7	0.4
8 - 12	0.6
13 - 20	0.8
> 20	1.0

Vegetation and Plant Communities

The following six variables measure various features of the vegetation composition and plant communities that comprise the riparian zone. Healthy plant communities serve many important ecosystem functions including providing habitat for native wildlife and plants, enhancing air and water quality by trapping airborne particulates and filtering sediments and pollutants from runoff before they enter streams, stabilize banks and hillside slopes and dissipate erosive forces, and provide scenic, recreational and educational values (City of Portland 2005).

4.5 Percent Trees in the 1 to 6 inches (2.5 to 15.2 cm) DBH Size Class

Proportion of trees that are between 1 to 6 inches diameter at breast height (DBH) relative to other tree size classes.

Figure 7. V_5 = Percent Trees in the 1 to 6 inches (2.5 to 15.2 cm) DBH Size Class (Allen 1982)

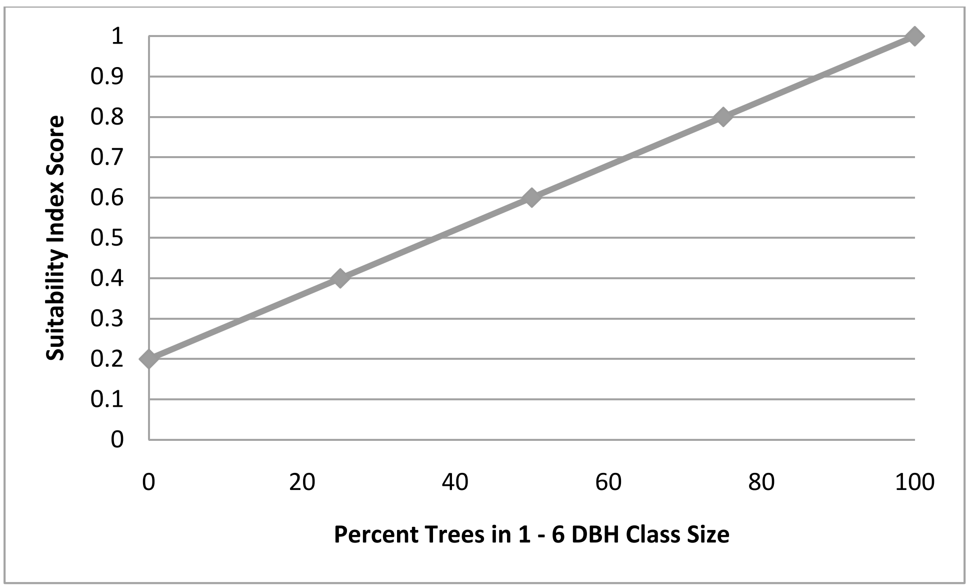


Table 22. V_5 = Percent Trees in the 1 to 6 inches (2.5 to 15.2 cm) DBH Size Class (Allen 1982)

Percent of Trees	Suitability Index Value
0	0.2
25	0.4
50	0.6
75	0.8
100	1.0

4.6 Percent Shrub Crown Cover

The percent shrub crown cover is defined as the percent of the ground surface shaded by a vertical projection of the canopies of woody vegetation < 5 m (16.5 ft) in height.

Figure 8. V_6 = Percent Shrub Crown Cover (Allen 1982 and Schroeder 1982)

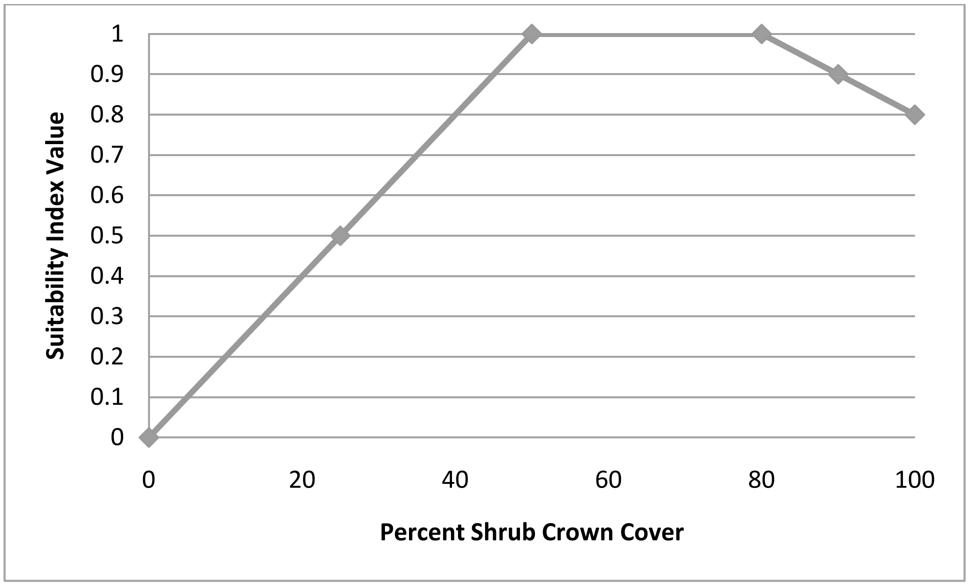


Table 23. V_6 = Percent Shrub Crown Cover (Allen 1982 and Schroeder 1982)

Percent Cover	Suitability Index Value
0	0
1 - 25	0.5
25 -50	0.75
50 - 80	1.0
80 - 90	0.9
90 - 100	0.8

4.7 Average Height of the Shrub Canopy

The average height of the shrub canopy is defined as the average height of woody vegetation < 5 m (16.5 ft) in height.

Figure 9. V_7 = Average Height of Shrub Canopy (Allen 1982 and Schroeder 1982)

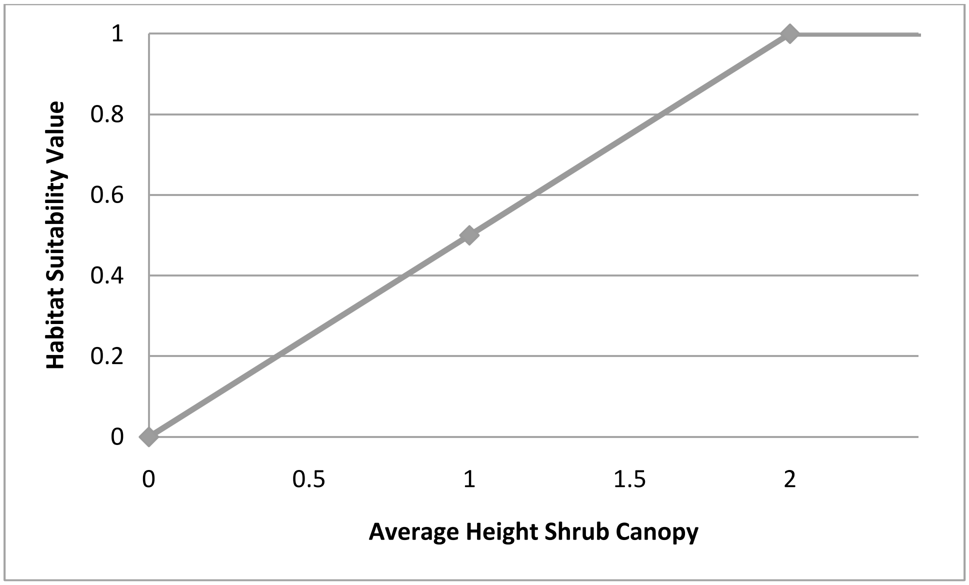


Table 24. V_7 = Average Height of Shrub Canopy (Allen 1982 and Schroeder 1982)

Average height (meters)	Suitability Index Value
0	0
1	0.5
2	1.0
>2	1.0

4.8 Percent Canopy Comprised of Hydrophytic Shrubs

The percent canopy comprised of hydorphytic shrubs is defined as the proportion of woody vegetation < 5 m (16.5 ft) in height that is hydrophytic. Hydrophytic plants are those that have adapted to living in or on aquatic environments.

Figure 10. V_8 = Percent Canopy Comprised of Hydrophytic Shrubs (Schroeder 1982)

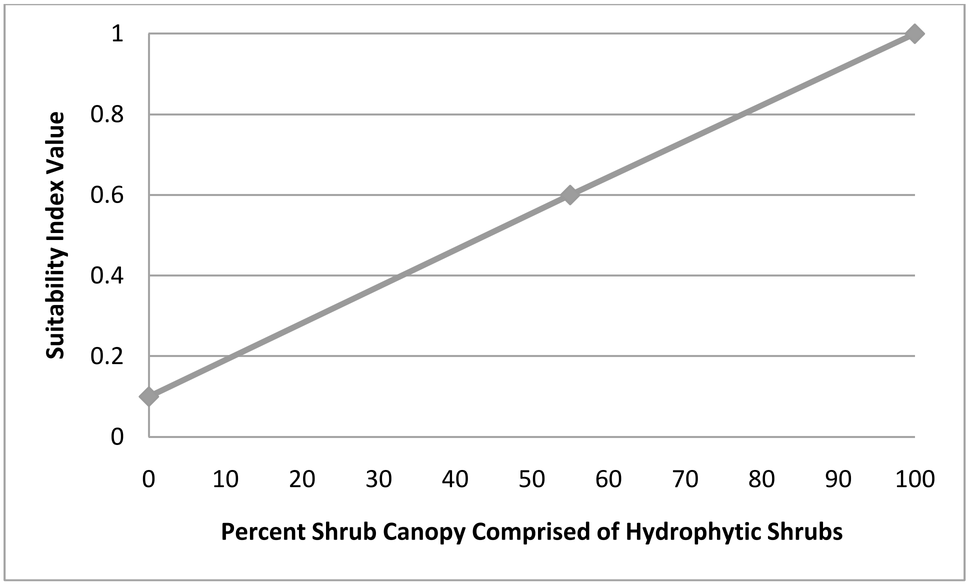


Table 25. V_8 = Percent Canopy Comprised of Hydrophytic Shrubs (Schroeder 1982)

% Hydrophytic Shrubs	Suitability Index Value
0	0.1
55	0.6
100	1.0

4.9 Width of Vegetated Riparian Zone

This variable is defined as the width of vegetation extending from the OHW. As riparian width increases so do ecosystem functions provided by the riparian zone including moderation of temperatures, sediment and runoff filtration, water quality protection, and provide fish and wildlife habitat structure and organic matter such as insects and large wood for the aquatic food web (City of Portland 2005).

Table 26. V_9 = Width of Vegetated Riparian Zone (WDFW 1997)

Width (m)	Suitability Index Value
0 – 10	0
10 – 30	0.2
30 - 60	0.6
>60	1.0

4.10 Percent Tree Canopy Closure

Percent tree canopy closure is defined as 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.

Figure 11. V_{10} = Percent Tree Canopy Closure (Allen 1982) (USFWS 1980)

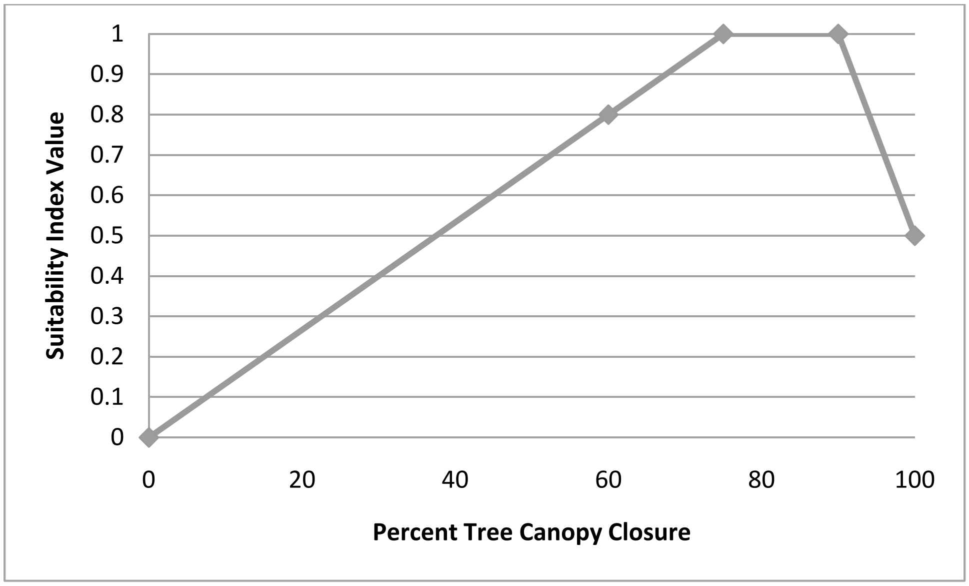


Table 27. V_{10} = Percent Tree Canopy Closure (Allen 1982) (USFWS 1980)

Percent Canopy Closure	Suitability Index Value
0	0
60	0.8
75 -90	1.0
100	0.5

4.11 Species Composition of Riparian Woody Vegetation

This variable categorizes the species composition of woody vegetation found in the riparian zone.

Table 28. V_{11} = Species Composition of Riparian 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

Table 29. Riparian Model Equation

Riparian Model	
	V_1 = Land Use within 200 meters of the Waterbody Edge V_2= Percent Area with Emergent and/or Submergent Wetland/Aquatic Vegetation V_3 = Percent Cover Along Water's Edge V_4 = Down Wood V_5 = Percent of Trees in the 1 – 6 inch (2.5 to 15.2 cm) DBH Size Class V_6 = Percent Shrub Crown Cover V_7 = Average Height of Shrub Canopy V_8 = Percent of Shrub Canopy Comprised of Hydrophytic Shrubs V_9 = Width of Vegetated Riparian Zone V_{10} = Percent Tree Canopy Cover V_{11} = Species Composition of Riparian Woody Vegetation

SI Equation Riparian

$$SI_{Riparian} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 + V_9 + V_{10} + V_{11}) / 11$$

5. Stream Habitat

Ecosystem functions and the associated variables that are addressed in steam habitats of the Lower Willamette River are highlighted in Table 31. A description of each habitat variable is then described below.

Table 30. Stream Habitat Valuation Variables and Corresponding Functions.

	Flow of Energy & Materials					Hydrology					Physical Habitat				Water Quality				Biological Interactions			
	Insolation/thermal inputs	Food Web	Organic inputs	Sediment production, transport & storage	Nutrient cycling	Groundwater recharge & storage	Base flow	Peak flow/flooding	Flood storage & attenuation	River/floodplain interaction	Structural complexity	Habitat connectivity	Habitat composition & dynamics	Refugia	Temperature	Sediment/Turbidity	Oxygen production	Contaminant fate & transport	Reproduction (spawning, nesting, etc.)	Growth & Survival	Competition	Predation/Parasitism
Percent Impervious Surface	X			X		X	X	X		X					X	X		X		X		
Floodplain Access			X	X	X	X		X	X	X	X	X	X	X		X				X		
Percent Area with Permanent Water							X					X		X					X	X		
Instream cover (LWD) Present			X					X			X	X	X	X						X		
Canopy Cover Over Stream	X	X	X												X				X	X		
Predominant Substrate Size in Riffle and Run Areas		X									X		X						X	X		
Habitat Types		X	X	X	X						X	X	X	X	X	X	X		X	X		
Pool Area	X	X	X								X	X	X	X	X		X		X	X		
Maximum Water Temperature During Low Flows															X				X	X		

Stream Variables

5.1 Percent Impervious Surface

Percent impervious surface is measured though the use of GIS mapping to identify the proportion of impervious surfaces at a given site.

Table 31. V_1 = Percent Impervious Surface (SMRC 2010)

% Effective Impervious Area	Suitability Index Value
0 – 10%	1.0
11 – 25%	0.4
26 – 60%	0.1
> 60%	0

5.2 Floodplain Access

A stream's ability to access its floodplain is important in absorbing flow energy during high flow events contributing to channel diversity by creating variable velocities both within and outside the stream channel (COTE 2010). Floodplain access is defined as the potential of a stream channel to access its floodplain. Floodplain access is calculated by dividing OHW by wetted width. Larger floodplain access scores indicate a greater potential interaction between the river and its floodplain.

Table 32. V_2 = Floodplain Access (COTE 2010)

Floodplain Access (Ordinary High Water/Wetted Width)	Suitability Index Value
< 1.0	0
1.0 – 1.5	0.3
1.5 – 2.0	0.6
2.0 – 2.5	0.8
> 2.5	1.0

5.3 Percent Area with Permanent Water

The percent area with permanent water is the proportion of the stream channel that is perennially wetted in relation to bank full width.

Table 33. V_3 = Percent Area with Permanent Water (modified from WDFW 1997)

% Area of Permanent Water	Suitability Index Value
0-10	0
10-25	0.6
25-50	1.0
>50	0.2

5.4 Large Wood Debris Volume

Large wood is either natural or cut, with some part of the piece within the active channel of the river. The minimum size for counting a piece of large wood is 6 inches in diameter by 10 feet in length. Large wood debris is measured as the volume of large wood below OHW per unit area. Large wood provide instream cover and refugia for aquatic species and structure for physical and biogeochemical processes.

Table 34. V_4 = Small stream Large Wood Debris Volume (ft3/ft2) (COTE 2010)

Volume (ft3/ft2)	Suitability Index Value
0	0
0.02 – 0.061	0.7
0.062 – 0.110	0.7
0.111 – 0.202	0.9
>0.202	1.0

5.5 Canopy Cover Over Stream

Canopy cover is defined as the proportion of area covered by a vertical projection of the outermost perimeter of the natural spread of trees and shrubs within the canopy (COTE 2010).

Table 35. V_5 = Canopy Cover Over Stream (%) (Adapted from COTE 2010)

Canopy Cover (%)	Suitability Index Value
0	0
< 10%	0.1
10 – 30%	0.4
30 – 60%	0.6
60 – 90%	0.8
> 90%	1.0

5.6 Predominant Substrate Size in Riffle or Run Areas

The predominant substrate size in riffle or run areas is a categorical valuation of the dominant substrate found in salmonid spawning habitats.

Table 36. V_6 = Predominant Substrate Size in Riffle or Run Areas (Raleigh, et al. 1984)

Class	Description	Suitability Index Value
A	Gravel, cobble or small boulders predominant; limited amounts of large boulders, or bedrock	1.0
B	Cobble, gravel, boulders, and fines occur in approximately equal amounts	0.6
C	Fines, bedrock, or large boulders are predominant. Cobble and gravel are < 25%	0.3

5.7 Habitat Type

Habitat type is defined as the dominant aquatic habitat type found at the site.

Table 37. V_7 = Dominant Aquatic Structure (COTE 2010)

Dominant Aquatic Structure	Suitability Index Value
Alcove	1.0
Backwater channel	0.8
Backwater pool	1.0
Intermittent	0.5
Log jam	0.4
Mud flat	0.4
Cascade	0.4
Dammed pool	1.0
Lateral scour pool	0.8
Plunge pool	0.7
Trench pool	0.8
Rapid	0.5
High gradient riffle	0.5
Low gradient riffle	0.5
Run/glide	0.7
Sand/gravel bar	0.4
Waterfall	0
Other	0

5.8 Pool Area

Proportion of pool area is estimated in relation to the total wetted width found at the project site.

Table 38. V_8 = Pool Area (COTE 2010)

Percent Pools Per Acre	Suitability Index Value
0	0
< 10%	0.1
10 – 20%	0.3
20 – 30%	0.5
30 – 40%	0.7
> 40%	1.0

5.9 Maximum Water Temperature During Low Flows

Temperature maximums are calculated during summer low flows over a 7 day average. Lower temperatures are preferred tolerances for juvenile rearing as well as adult migration. As temperatures increase, juvenile rearing thresholds are first exceeded followed by those tolerated by adults during migration.

Table 39. V_9 = Maximum Water Temperature During Low Flow (USEPA 2003)

Temperature (°C)	SI*
<12	1.0
16	0.8
18	0.7
20	0.6
>20	0

Table 40. Stream Model Equation

Stream Model	
	V_1 = Percent Impervious Surface V_2 = Floodplain Access V_3 = Percent Area with Permanent Water V_4 = Large Wood Debris Volume V_5 = Canopy Cover Over Stream V_6 = Predominant Substrate Size in Riffle and Run Areas V_7 = Habitat Types V_8 = Pool Area V_9 = Maximum Water Temperature During Low Flows

SI Equation Stream	$\mathbf{SI_{Stream} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 + V_9) / 9}$

6. Grassland Habitat

Ecosystem functions and the associated variables that are addressed in the grassland habitats of the Lower Willamette River are highlighted in Table 42. A description of each habitat variable is then described below.

Table 41. Grassland Habitat Valuation Variables and Corresponding Functions.

	Flow of Energy & Materials					Physical Habitat				Biological Interactions			
	Insolation/thermal inputs	Food Web	Organic inputs	Sediment production, transport & storage	Nutrient cycling	Structural complexity	Habitat connectivity	Habitat composition & dynamics	Refugia	Reproduction (spawning, nesting, etc.)	Growth & Survival	Competition	Predation/Parasitism
Percent Areal Cover of Woody Vegetation			X		X	X	X			X	X		
Percent Areal Cover of Non-native Herbaceous Vegetation										X	X		
Ratio of Native Forbs to Native Perennial Graminoids Areal Cover			X		X					X	X		
Distance to Closest Other Grassland Habitat						X	X	X		X	X		
Size of Closest Other Grassland Habitat Within 5 Miles						X	X	X		X	X		
Degree Grassland Habitat Enhances Habitat Functions or Services for Adjacent/Proximate Significant Habitats		X	X			X	X	X	X	X	X		

Grassland Variables

6.1 Percent Areal Cover of Woody Vegetation

Percent areal cover is defined as the percent of the ground surface shaded by a vertical projection of the canopies of woody vegetation.

Table 42. V_1 = Percent Areal Cover of Woody Vegetation (Adamus 2009)

Areal Cover (%)	Suitability Index Value
<1	0.7
1-5	1.0
5-15	0.5
15-30	0.3
>30	0

6.2 Percent Areal Cover of Non-native Herbaceous Vegetation

Percent areal cover of is defined as the percent of the ground surface shaded by a vertical projection of the canopies of non-native herbaceous vegetation.

Table 43. V_2 = Percent Areal Cover of Non-native Herbaceous Vegetation (adapted from Adamus 2009)

Areal Cover (%)	SI
<5	1.0
5-25	0.7
25-50	0.5
50-75	0.3
>75	0

6.3 Ratio of Native Forbs to Native Perennial Graminoids

This variable is measured as the proportion of native forbs to native grass, sedge, or rush cover.

Table 44. V_3 = Ratio of Native Forbs to Native Perennial Graminoids Areal Cover (adapted from Adamus 2009)

Areal Cover Forbs : Graminoids (%)	Suitability Index Value
>80% Forbs : < 20% Graminoids	0.7
60-80% Forbs : 20-40% Graminoids	1.0
40-60% Forbs : 40-60% Graminoids	0.5
20-40% Forbs : 60-80% Graminoids	0.3
<20% Forbs : >80% Graminoids	0

6.4 Distance to Closest Other Grassland Habitat

The distance to the closest other grassland habitat can be measured with GIS, aerial photography or other maps.

Table 45. V_4 = Distance to Closest Other Grassland Habitat (adapted from Adamus 2009)

Distance (Miles)	SI
<0.25	1.0
0.25-0.5	0.5
0.5-1	0.3
>1	0

6.5 Size of the Closest Other Grassland Habitat Within 5 Miles

The size of the closest other grassland habitat can also be assessed with GIS, aerial photography or other available maps.

Table 46. V_5 = Size of Closest Other Grassland Habitat Within 5 Miles (adapted from Adamus 2009)

Size (acres)	Suitability Index Value
30-100	1.0
10-30	0.8
1-10	0.5
0.25-1	0.3
<0.25	0

6.6 Degree that Grassland Habitat Enhances Habitat Functions/Services for Adjacent/Proximate Significant Habitats

This variable estimates the degree which this grassland habitat enhances habitat functions or services for adjacent/ proximate significant habitats (may be a different habitat type, e.g., wetland)?

Table 47. V_6 = Degree that the grassland habitat enhances habitat functions or services for adjacent/proximate significant habitats (adapted from Adamus 2009)

Degree	Suitability Index Value
HIGH: The parcel significantly enhances adjacent/proximate habitats through connectivity, buffering, permeability, etc.	1.0
MEDIUM: The parcel moderately enhances adjacent/proximate habitats through connectivity, buffering, permeability, etc.	0.7
LOW: The parcel minimally enhances adjacent/proximate habitats through connectivity, buffering, permeability, etc.	0.4
NONE: the parcel does not enhance adjacent/proximate habitats	0

6.7 At-Risk Species Occurrence/Use on the Site

Table 48. V_7 = Special Status Species Occurrence/Use on the Site (adapted from Adamus 2009)

Degree	Suitability Index Value
Documented Use for Life Cycle Phase: One or more special status species are documented to use the site for completion of one or more life cycle phase	1.0
Documented Presence/Unknown Use: One or more special status species have been documented to occur on site; behavior unknown	0.6
No Documented Use but Habitat is Suitable: The site is likely to provide habitat for one or more special status species, but there is no documentation of use	0.2
No Documented Use and Habitat is Unsuitable: The site is not likely to provide habitat for one or more special status species	0

Table 49. Grassland Habitat Model

Grassland Model	
Grassland	V_1 = Percent Areal Cover of Woody Vegetation V_2 = Percent Areal Cover of Non-native Herbaceous Vegetation V_3 = Ratio of Native Forbs to Native Perennial Graminoids Areal Cover V_4 = Distance to Closest Other Grassland Habitat V_5 = Size of Closest Other Grassland Habitat Within 5 Miles V_6 = Degree Grassland Habitat Enhances Habitat Functions or Services for Adjacent/Proximate Significant Habitats V_7 = Special Status Species Occurrence/Use on the Site

SI Equation Grassland

$$SI_{Grassland} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7) / 7$$

7. Upland Forest Habitat

Ecosystem functions and the associated variables that are addressed in the upland forest habitats of the Lower Willamette River are highlighted in Table 51. A description of each habitat variable is then described below.

Table 50. Upland Forest Habitat Valuation Variables and Corresponding Functions.

	Flow of Energy & Materials					Physical Habitat				Biological Interactions			
	Insolation/ thermal inputs	Food Web	Organic inputs	Sediment production, transport & storage	Nutrient cycling	Structural complexity	Habitat connectivity	Habitat composition & dynamics	Refugia	Reproduction (spawning, nesting, etc.)	Growth & Survival	Competition	Predation/Parasitism
Basal Area										X	X		
Number of Snags			X		X	X				X	X		
Percent Tree Canopy Closure										X	X		
Average Height of Overstory Trees						X				X	X		
Tree Canopy Number of Snags 10 to 25 cm DBH / 0.4 ha			X		X	X				X	X		
Distance to Open Land							X			X	X		
Average DBH of Trees										X	X		

Upland Forest Variables

7.1 Basal Area

Basal area is measured by taking the diameter at breast height (DBH) for every tree within in a certain area of land (usually per acre or hectare). This variable is an indicator of a forest's productivity and growth rate.

Figure 12. V_1 = Basal Area (modified from Schroeder 1983a)

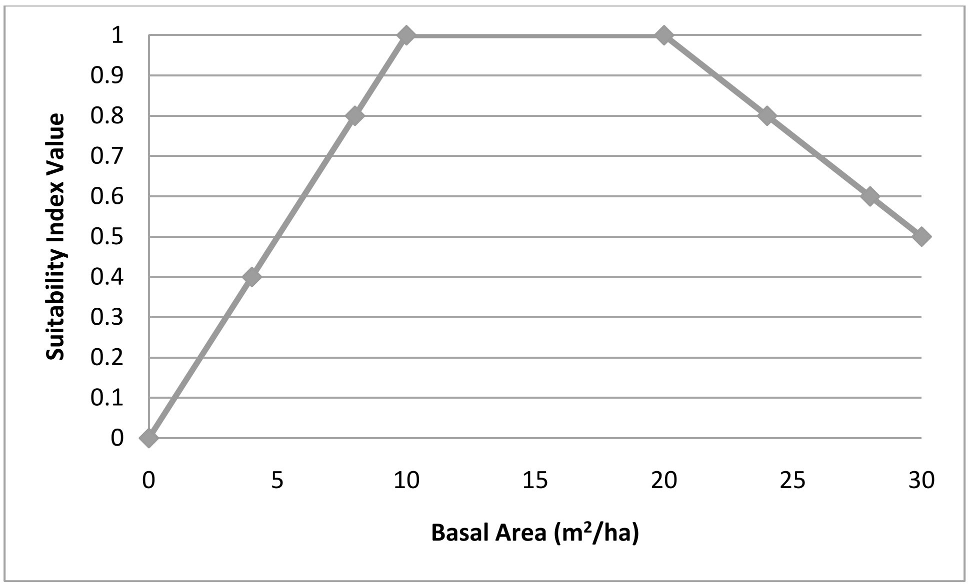


Table 51. V_1 = Basal Area (modified from Schroeder 1983a)

Basal Area (m^2/ha)	Suitability Index Value
0	0
4	0.4
8	0.8
10	1.0
20	1.0
24	0.8
28	0.6
30	0.5

7.2 Number of Snags

This variable is measured by determining the basal area of snags within an acre.

Figure 13. V_2 = Number of Snags (modified from Schroeder 1983a)

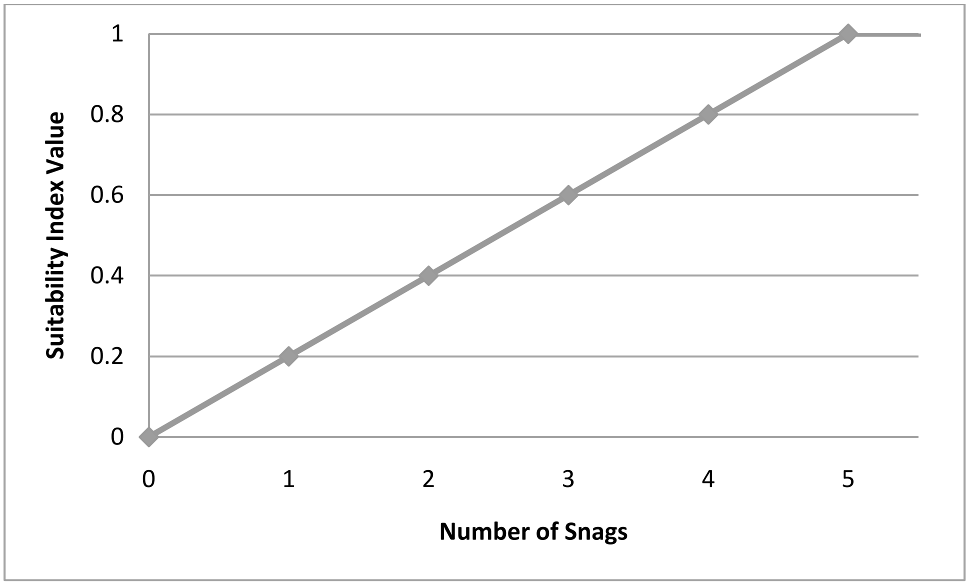


Table 52. V_2 = Number of Snags (modified from Schroeder 1983a)

Number of Snags	Suitability Index Value
0	0
1	0.2
2	0.4
3	0.6
4	0.8
>5	1.0

7.3 Percent Tree Canopy Closure

Percent tree canopy closure is defined as the percent of the ground surface shaded by a vertical projection of the canopies of woody vegetation.

Table 53. V_3 = Percent Tree Canopy Closure (Allen 1982) (USFWS 1980)

Percent canopy closure	Suitability Index Value
0 - 20	0
20 - 30	0.2
30 - 50	0.5
50 - 70	0.8
70 - 80	1.0
80 - 100	0.3

7.4 Average Height of Overstory Trees

The average height of overstory trees measures the average height of trees at the site. This is measured from the average height from the ground surface to the top of those trees which are >80 percent of the height of the tallest tree in the stand.

Figure 14. V_4 = Average Height of Overstory Trees (modified from Schroeder 1983b)

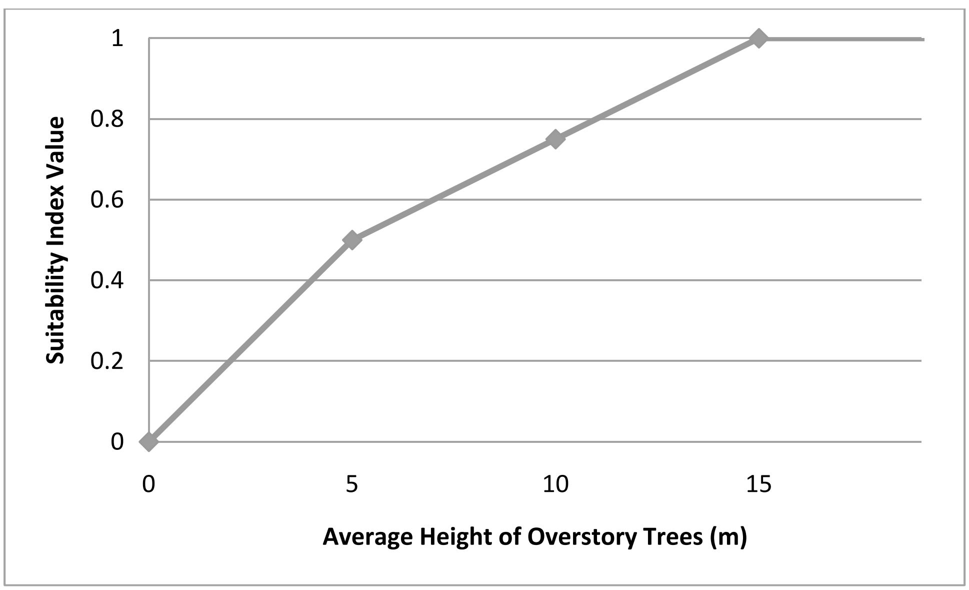


Table 54. V_4 = Average Height of Overstory Trees (modified from Schroeder 1983b)

Height (m)	Suitability Index Value
0	0
5	0.5
10	0.75
>15	1.0

7.5 Distance to Open Land

The distance to open land can be measured using GIS, aerial photography, or other available maps.

Figure 15. V_5 = Distance to Open Land (modified from USFWS 1978)

Table 55. V_5 = Distance to Open Land (modified from USFWS 1978)

Distance (miles)	Suitability Index Value
0	1.0
1.5	1.0
2	0.8
3	0.4
4	0

7.6 Average DBH of Trees

This variable measures the average DBH for trees at the site.

Figure 16. V_6 = Average DBH of Trees (modified from USFWS 1978)

Table 56. V_6 = Average DBH of Trees (modified from USFWS 1978)

Average DBH (inches)	Suitability Index Value
0	0
6	0
8	0.2
10	0.6
>12	1.0

Table 57. Upland Forest Model

Upland Forest Model	
	V_1 = Basal Area V_2 = Number of Snags V_3 = Percent Tree Canopy Closure V_4 = Average Height of Overstory Trees V_5 = Distance to Open Land V_6 = Average DBH of Trees

SI Equation Upland

$$SI_{Upland} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6) / 6$$

8. Wetland Habitat

The Oregon Department of State Lands requires that a functional assessment be conducted to fulfill the needs of state permitting and compensatory wetland mitigation programs. For the wetland habitat areas, the Oregon Rapid Wetland Assessment Protocol (ORWAP) is recommended to assess the functions and values of wetlands. ORWAP is a standardized protocol applicable to wetlands of any type anywhere in Oregon. ORWAP specifically provides information on the function, value, service, condition, stressors, and sensitivity of the wetland in question.

The ORWAP procedures involve an office and a field component, in which 140 indicators are assessed onsite, as well as from information gathered mainly from websites and aerial imagery. The office component involves an aerial image assessment, a delineation of the wetland area with topo and wetland maps, a soils assessment using soils survey maps, and queries on other web pages to obtain information such as water quality, and habitat quality. Field data collected includes an assessment of each vegetation type and soil type on site, a qualitative delineation of the wetland boundary, identification of hydrologic characteristics and an assessment of non-native species and impairments.

The data are entered into an Excel spreadsheet from which logic models are programmed to produce scores on a 0 – 10 scoring scale for several wetland indicators including function, value, service, condition, stressors, and sensitivity. The ORWAP methodology (Adamus et al 2009) is provided in Appendix A of this document.

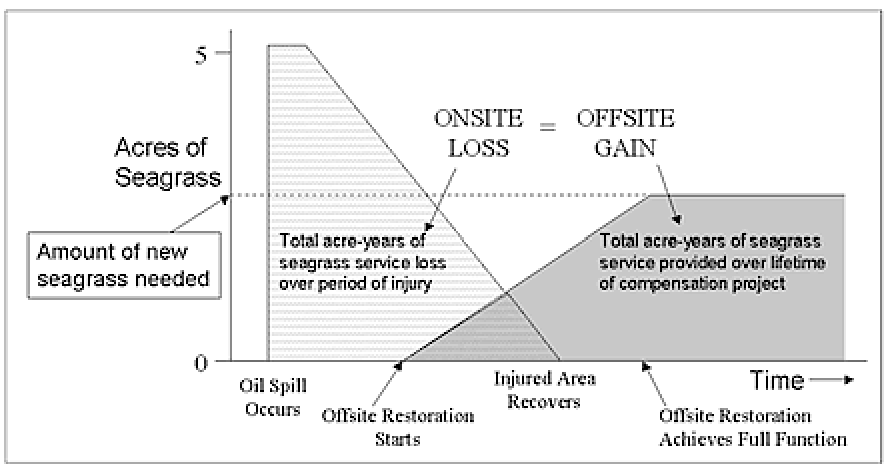
Wetland mitigation to fulfill the requirements of the River Plan will be limited to within the City of Portland boundaries.

9. Habitat Equivalency Analysis

The final step in this habitat valuation method is to run the Habitat Equivalency Analysis (HEA) model using the output from the suitability indices models. HEA is an analytical framework, developed by NOAA, for determining the amount of mitigation needed to compensate for the interim or permanent losses of a resource. HEA calculates the amount of mitigation needed by establishing an equivalency between what is lost and what is gained through the mitigation project over time. Compensation is also gained for temporal losses of habitat resources through mitigation projects providing additional resources of the same type.

Typically, HEA has been used to assess damages from such actions as oil spills, hazardous substance releases, vessel groundings, etc. The HEA method is specifically used in cases of habitat injury when the function of the injured area is ecologically equivalent to the function that will be provided by the replacement (mitigated) habitat. Figure 17 shows a depiction of the loss in services caused by a spill and the replacement of those services provided through construction of new habitat.

Figure 17. Diagram showing the onsite services lost and the offsite services gained over time (from NOAA 1995).



HEA can be employed to evaluate ecological function gain from restoring habitats by comparing habitat in an area before and after restoration occurs. Four factors are considered in the HEA equation: 1) a valuation of all habitats found on the site before and after restoration; 2) estimates of the time needed for each restored habitat to achieve its full ecological function value; 3) the duration that the restored habitats will continue to fully function; and 4) a discounting factor (Wolotira 2008).

The basis for pre- and post-restoration habitat values will be determined through use of a HEP model developed for the riverine, riparian, stream, and upland habitats, and ORWAP for wetland habitats.

The duration of restoration sites is usually based on legal documents prohibiting future use of the site for any purpose other than fully functional habitat (usually identified in legal documents as "in perpetuity"). In this case, "in perpetuity" translates into a finite period, for example, no more than 300 years when discounting (the fourth factor) is considered.

To make past and future losses and gains comparable, a discount factor must be applied. The regulations and NOAA (1999) recommend using a 3 percent discount rate when scaling compensatory restoration for discounting interim service losses and restoration falling within industry standards. A discount rate accounts for an item of high current value gradually losing its worth over time.

The total value for each habitat is a function of its initial value; an annual discount factor; an annual percent increase towards full value; the final value that the habitat can attain; a product of the discount factor times the annual habitat benefits; and the minimum number of years that the restoration site will exist. The summation of habitat value is expressed as a function of discounted ecological services over an area through time or discounted Service Acre Years. Below is the HEA model and a description of the inputs.

TOTAL HABITAT VALUE (THV) is represented by the formula:

$$THV = \sum_{Y_i=1}^{Y_f} [((1+d)^{(Y_b - Y_i)})(Y_i / Y_f)(V_f - V_0)] + \sum_{Y_i=Y_f+1}^{n} [((1+d)^{(Y_b - Y_i)})(V_f - V_0)]$$

where:

Y_i= the i^{th} year

Y_f = final year, or year when habitat reaches full ecological function;

d = annual discount rate, or 0.03;

Y_b = baseline year of the life of the habitat (usually "1");

n = number of years of habitat existence = 300;

V_0 = initial (unrestored) value of habitat. (before or after the impact?)

V_f = maximum (or final) value of the restored habitat

The habitat values both before and after restoration or impact are assessed through two habitat evaluation procedures: suitability indices models for riverine, riparian, stream, grassland, and upland habitats, and ORWAP for wetland habitats as described above.

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