

HABITAT EVALUATION PROCEDURES (HEP) PROGRAM HOW-TO MANUAL

This How-To Manual provides guidance on how a city or county that is regulated by Washington State's Shoreline Management Act can develop a Habitat Evaluation Procedures (HEP) program. This document describes how to generate HEP Zone polygons for the jurisdiction of interest, and describes how to configure a user-facing web map application and survey to allow users to calculate ecological impacts of shoreline development or habitat restoration projects using habitat units (HUs). This methodology is applicable to aquatic areas where salmonids are present. The methods used to develop the HEP Zones for Lake Washington are used to demonstrate how to generate HEP Zones and provide specific examples of data sources and workflows. Any geoprocessing tools specified in this document refer to tools available in ArcGIS Pro and are highlighted in **bold**. At least a moderate level of experience using GIS software is required to use this How-To Manual to create HEP Zone polygons for their region of interest. For definitions of technical terms used in this document, please see Appendix A. For additional background regarding the HEP Program, please see Appendix B.

SOFTWARE REQUIREMENTS

- ArcGIS Pro or other GIS software (for HEP Zone development)
- ArcGIS Online account (for web map and using Survey123 to develop the Habitat Unit Calculator form development)

SPATIAL DATA REQUIREMENTS

- Topobathymetry
- Delineated shoreline
- Aquatic habitat conditions
- Riparian conditions
- Overwater structures (if applicable)

CREATING THE HEP ZONES LAYER

ESTABLISHING THE STUDY AREA

The geographic extent of any HEP analysis is specific to the behavior of its target species. The riparian and aquatic extent need to be defined as described below. The shoreline itself is defined by the best available shoreline delineation data based on the location of the

ordinary high water mark (OHWM) within the relevant jurisdiction. The riparian study area is typically defined by a homogenous **Buffer** distance landward from the delineated shoreline. For this program, the shoreline buffer is a minimum of 200 feet, which defines the landward extent of the Shoreline District per Washington State's Shoreline Management Act (SMA) in most areas. However, in some areas the extent of the Shoreline District may extend farther than 200-ft due to the presence of associated wetlands or critical area buffers. The aquatic study area is flexible but needs to extend at least as far into the water as potential shoreline developments or restoration projects are expected to occur. Other region-specific geographic delineations based on how target species use the area may be necessary as well on a case-by-case basis. Data availability may also determine the study area extent.

LAKE WASHINGTON EXAMPLE

The study area for the Lake Washington HEP analysis was bounded along the shoreline by the Seattle city limits. Specific to this region, the western extent was established at the boundary between Union Bay and the Montlake Cut. The riparian study area extended 200 feet landward from the OHWM (Toft et al. 2003). The aquatic study area was defined by the City of Seattle outer harbor line, which is the waterward extent of where development can occur. The only exception was the eastern boundary of Union Bay, which was drawn arbitrarily as no harbor lines exist at that location. It is recommended to create two separate study area boundary polygons representing the riparian study area and aquatic study area, as certain processing steps require clipping to only one of these study areas. For example, data relating to aquatic habitat conditions will only be clipped to the aquatic study area as it does not apply to riparian areas.

GENERATING DEPTH ZONES AND RIPARIAN ZONE POLYGONS

The first phase involved in developing aquatic HEP Zones is creating depth zone polygons. To get started, locate and download the most current and highest resolution topobathymetry dataset available that covers the entire aquatic study area.

Topobathymetry data is the foundation of building HEP Zones, so this must be available in order to create a HEP Zone dataset. The amount and elevation range of depth classes are dependent on how target species use aquatic habitat within the study area and should be determined based on input from subject matter experts. Once the depth zone thresholds are determined, use the **Reclassify** tool to convert the topobathymetry layer into a new raster where cells represent their associated depth classes. The next step is to convert the reclassified raster into polygons using the **Raster to Polygon** tool, using the simplify polygons option if necessary to reduce the complexity of the polygons. Lastly, **Clip** the depth zones to the aquatic study area.

To create the riparian zone polygon, create a **Buffer** zone on the landward side of the shoreline line. This also represents the riparian study area. The distance of this buffer is 200 feet landward from the OHWM, which is the extent of the Shoreline District.

Lastly, review the depth zones to check for any locations where depth zones are skipped, likely due to very steep slopes or errors in the topobathymetry dataset. Anywhere a zone is skipped, create a narrow polygon (e.g., 5 feet) using the **Buffer** tool and classify it as the skipped depth zone to ensure no zones are skipped as zones progress waterward (see example in Figure 1). Combine the riparian zone polygon with the depth zone polygons using a geoprocessing tool such as **Union** or **Merge** to complete this phase of the analysis.

LAKE WASHINGTON EXAMPLE

For the Lake Washington HEP analysis, depth zone polygons were derived from topobathymetry data provided by the City of Seattle. The topobathymetry layer was reclassified into three depth zones, with elevation thresholds determined by subject matter experts to reflect juvenile Chinook salmon habitat usage tendencies. Specifically, the Shallow Aquatic zone was defined from 18.75 ft NAVD88 (OHWM) to 8.91 ft NAVD88. The Mid Aquatic zone was defined from 8.91 ft to -0.94 ft NAVD88. Lastly, the Deep Aquatic zone was defined as depths of -0.94 ft NAVD88 and below. Note that OHWM is determined for each geographic area through the local jurisdiction's Shoreline Master Program.

The reclassified bathymetry layer was then converted into polygons, which were clipped to the aquatic study area. Additionally, a Shallow Aquatic 5-ft buffer zone was manually added along the shoreline anywhere one didn't already exist to ensure no Riparian Zones were immediately adjacent to Mid Aquatic zones. Similarly, a Mid Aquatic 5-ft buffer zone also needed to be added at the western extreme of the study area along the northern shore of the Montlake Cut to avoid the Shallow Aquatic zone being adjacent to the Deep Aquatic zone. An example of the final combined depth and riparian zones are provided in Figure 1.

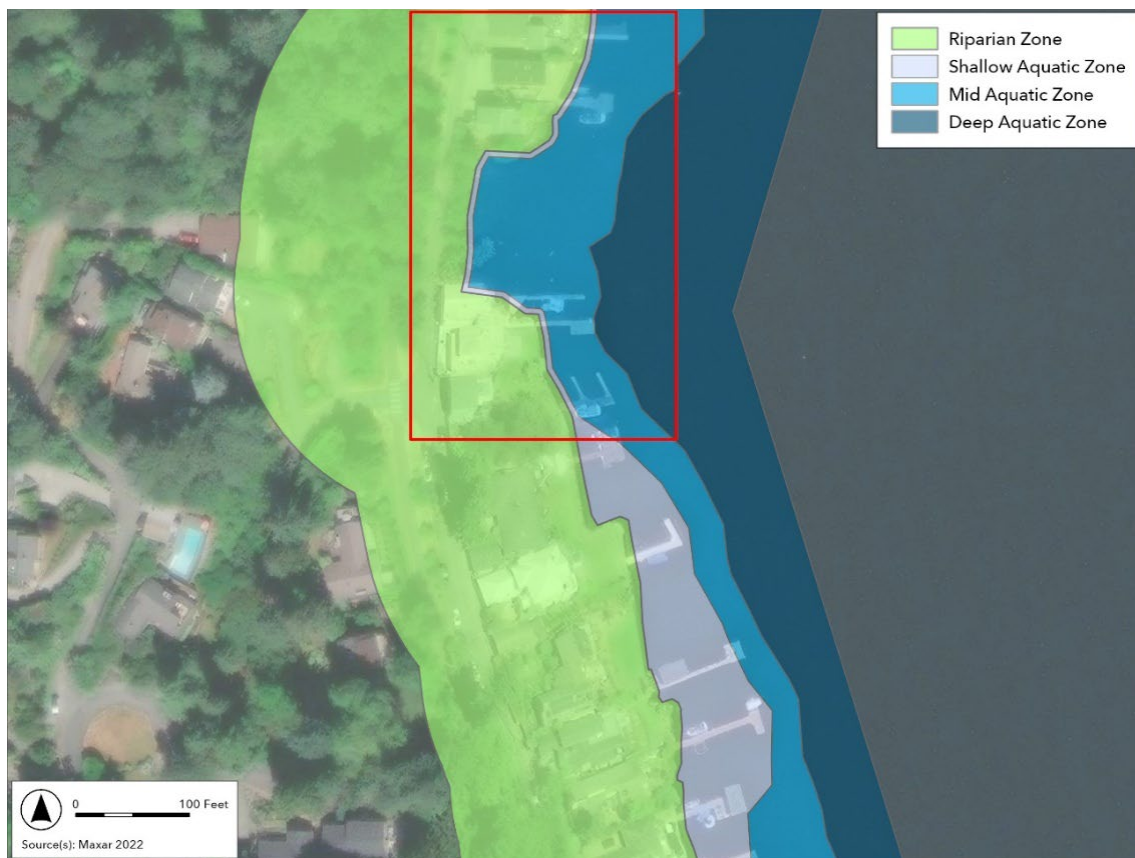


Figure 1: Example of depth and riparian zones developed for Lake Washington. The red box highlights an area where a 5-ft shallow aquatic buffer was added between the riparian zone and the mid aquatic zone to ensure depth zones progress sequentially from the shoreline waterward.

GENERATING HABITAT CONDITION POLYGONS

The next phase of creating HEP Zones involves creating habitat condition polygons for both the aquatic and riparian study areas. These habitat condition polygons represent the habitat condition metrics relevant to the target species, and should be based on input from regional subject matter experts. These metrics/attributes may include, but are not limited to, aquatic habitat conditions such as substrate, submerged aquatic vegetation (SAV), slope, and shoreline condition. These may also include riparian habitat conditions such as bank condition and upland vegetation type. Ideally, a single shoreline survey data source would provide data for all habitat condition metrics, however, multiple data sources may need to be referenced in order to obtain data for all relevant habitat condition metrics.

Most shoreline condition data tends to be available in linear format. To convert into polygon format, a simple workflow can be applied to each linear dataset. First, generate points along the linear features every 1 ft using the **Generate Points Along Lines** tool. Then use the **Create Thiessen Polygons** tool to create polygons using the previously created point layer as the input layer, ensuring that the option to retain all fields is selected. The

result is an array of polygons where any location within each polygon is closer to the associated input point than any other input point (Figure 2). For the aquatic study area, **Clip** the Thiessen polygon layer to the aquatic study area and **Dissolve** the polygons based on all aquatic habitat condition attributes. The result is a polygon layer covering the full aquatic study area, where each polygon has a unique combination of habitat condition metrics compared to adjacent polygons. Similarly, **Clip** the Thiessen polygon layer to the riparian study area and **Dissolve** the polygons based on all riparian habitat condition attributes. Combine the riparian habitat condition polygons with the aquatic habitat condition polygons using a geoprocessing tool such as **Union** or **Merge** to complete this phase of the analysis.

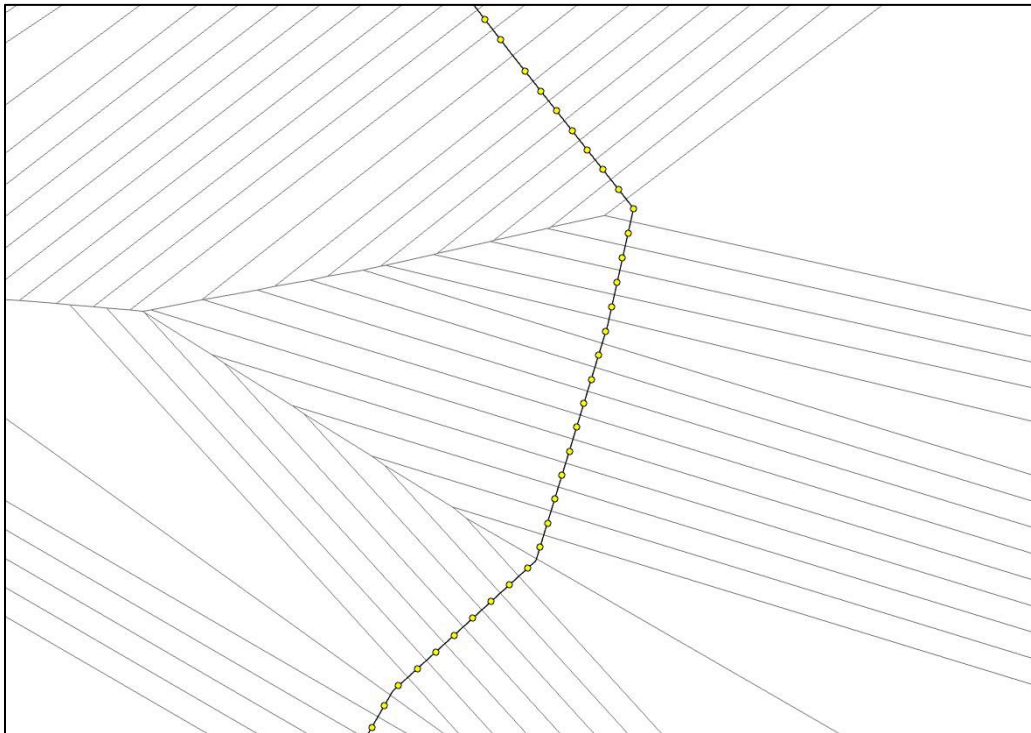


Figure 2: Example output of Thiessen Polygons. These polygons were created using points spaced 1 foot apart along the shoreline. All areas within each polygon are closest to the associated point.

LAKE WASHINGTON EXAMPLE

For the Lake Washington HEP analysis, shoreline areas were delineated and classified using the procedures described in Toft et al. (2003). Polygons were generated using four habitat condition metrics included in the Toft shoreline data: substrate, submerged aquatic vegetation (SAV), shoreline condition, and upland vegetation type. Appendix C includes a list of potential classifications for each of these metrics. To convert the linear shoreline data to polygons, points were generated along the shoreline every 1 ft. These points were used to create Thiessen polygons, which were then clipped to the aquatic study area and dissolved based on substrate, SAV, and shoreline condition. Similarly, the Thiessen polygons were clipped to the riparian study area and dissolved based on

shoreline condition and upland vegetation type. An example of the resulting aquatic and riparian habitat condition zones is provided in Figure 3.



Figure 3: Example of Habitat Condition zones. See Appendix B for a full list of potential substrate, SAV, shoreline condition, and upland vegetation types.

COMBINING DEPTH ZONES, HABITAT CONDITION POLYGONS, AND OVERWATER STRUCTURES

Once the depth zones and habitat condition polygons are created, use the **Intersect** geoprocessing tool to combine the layers. There should now be one layer covering the full study area with attributes describing the depth zone, aquatic habitat conditions, and riparian habitat conditions. The shoreline condition attribute applies to both aquatic and riparian habitat conditions.

If overwater structures are present, locate the most current and accurate overwater structure data available covering the full aquatic study area. If there is no publicly available

data, it may be necessary to digitize overwater structures using high resolution satellite imagery. If available, associate any data describing overwater structure height to the overwater structure polygons. For example, this may describe whether a structure is floating, a low dock, or high dock.

Research has documented that juvenile salmonids avoid swimming under overwater structures, which forces them into deeper water where they are more exposed to predators. Therefore, an additional attribute is necessary to describe whether an overwater structure extends into the Deep Aquatic zone. Add a new “Deep Dock” (or similar) attribute to the overwater structure layer to indicate if a structure extends into a Deep Aquatic zone. If a structure extends into the Deep Aquatic zone, the entire structure should be classified as crossing into the Deep Aquatic zone. This can be accomplished by selecting all Deep Aquatic zones, applying a **Select by Location** query to select the overwater structures intersecting the selected Deep Aquatic zones, and using **Field Calculator** to populate the Deep Dock attribute with “Yes,” which indicates the structure does extend into the Deep Aquatic zone. Switch the selection and populate the remaining overwater structures with “No” to indicate structures not extending into the Deep Aquatic zone.

Apply a 5-ft **Buffer** to the overwater structures layer to account for 1) reduced lighting in partially shaded areas adjacent to the overwater structures related to sun angle and 2) high usage by predators of juvenile Chinook salmon (Tabor et al. 2004). The structure height and deep dock attributes should be retained within this buffer zone. Use the **Identity** geoprocessing tool to incorporate the overwater structure polygons and their 5-ft buffers into the previously created polygons containing depth zone and habitat condition attributes.

LAKE WASHINGTON EXAMPLE

For the Lake Washington HEP, overwater structure polygons were provided by the City of Seattle. An additional attribute was appended to the layer identifying overwater structures extending into deep water, defined as any overwater structures crossing into a Deep Aquatic depth zone. Lastly, overwater structure height details were spatially joined to the overwater structure polygons from a point shapefile provided by the City. Using the height information, each overwater structure was classified as a high dock (at least 2 m over water), low dock (less than 2 m over water), or floating dock. A small number of overwater structures did not have height data associated with them. In these cases, the overwater structures were assumed to have the same height as the nearest overwater structure with a known height. Ideally, in cases where dock height is unknown, field visits would be conducted to determine height.

Buffers of 5 ft were created surrounding the overwater structure polygons, which were then merged with the overwater structures polygons. After finalizing the overwater structure

layer, the Identity tool was used to incorporate this data into the previously generated depth zone/shoreline habitat condition layer (Figure 4).



Figure 4: Example of overwater structures and 5-ft buffers incorporated into existing depth/habitat condition polygons

ADDING ADDITIONAL MODIFIERS AND FINAL PROCESSING STEPS

For any study area, there may be region-specific modifier attributes that need to be added to the HEP Zones layer. For example, this may be an attribute that identifies whether a location is within a certain distance to a significant tributary or other location of significance. If multiple scoring models are used in the region's HEP analysis, an attribute will need to be added that identifies where each model was applied. For each modifier attribute needed, create a new layer with polygons populated with attributes describing the modifier being added. This new layer should cover the full extent of the study area. For each new layer, use either the **Intersect** or **Identity** geoprocessing tool to combine the new modifier layer with the previously created HEP Zones layer.

Once all modifier attributes have been added, review each attribute and populate any null cells with "Not Applicable" or a similar description. For example, any polygons within the Riparian Zone should be classified as "Not Applicable" for substrate and any other aquatic

habitat condition attributes. Remove any additional fields that were added during geoprocessing steps, such as feature ID fields that were generated while running the **Intersect** or **Identity** tools.

Lastly, add a new attribute called “HEP_ID” to serve as a stable, unique identifier for the final HEP Zone layer. The recommended option for populating this attribute is to populate with sequential numbers starting at 1 and append a text code to the end of all HEP IDs to identify the study area.

LAKE WASHINGTON EXAMPLE

One additional modifier was applied to the Lake Washington HEP Zones with the purpose of classifying an area’s proximity to the mouth of the Cedar River. Research suggests that juvenile Chinook salmon show relatively high use of shoreline areas close to the Cedar River mouth, with the edge of the high use area occurring about 6 km away from the mouth (Tabor et al. 2006). Tabor also expects the high habitat use to diminish with distance from the mouth, with the next tier extending from 6 to 12 km away from the mouth. Using these distance thresholds, three zones were digitized covering the Lake Washington study area, described using local landmarks (Figure 5). Areas within 6 km of the Cedar River mouth were classified as “South of Pritchard,” areas between 6-12 km from the Cedar River mouth were classified as “Seward to Pritchard,” and areas further away were classified as “No Modification.” These “Proximity Zones” were then intersected with the existing HEP Zones layer. A final review was conducted to ensure all attributes were fully populated, and any irrelevant attributes were removed. Additional modifiers could be added depending on the target species’ habitat needs and preferences and availability of local datasets.



Figure 5: Delineation of Proximity Zones for the Lake Washington HEP

The final step was to create the HEP ID attribute. Cells were populated with sequential numbers using the “Sequential Number” function within the Field Calculator (the “Helper” type must first be changed to “Function”). The text “LW” was appended to the end of all HEP IDs to ensure the HEP IDs were unique to Lake Washington. The addition of a text identifier is critical if HEP Zones are being created for multiple subregions, to avoid the possibility of duplicate numerical IDs across subregions.

CONFIGURING THE HEP WEB APPLICATION

Once the geoprocessing of the HEP Zones layer is complete, the next step is to configure a user-facing web application to allow users to calculate the impacts of their proposed shoreline development or restoration project. This can be accomplished by associating the HEP scoring model with the attributes included in the HEP Zones layer via the Habitat Unit Calculator form in ArcGIS Online.

CONFIGURING THE HABITAT UNIT CALCULATOR FORM

It is recommended to use Habitat Units (HUs) to determine impacts of shoreline development projects and benefits of shoreline restoration projects. The scoring method used to generate HU values is based on a method developed by the U.S. Fish and Wildlife Service (USFWS) to document the quality and quantity of available habitat for certain wildlife species (USFWS 1980). This allows for a scientifically defensible quantification of HUs that can be used to balance shoreline development impacts with restoration project mitigation benefits.

To automate the HU calculation process, there are multiple software platforms and approaches that could be utilized. For this How-To Manual, configuring a Habitat Unit Calculator form using Esri’s Survey123 Connect XLSForm structure will be described. An example XLSForm created for the Lake Washington region is provided in Appendix C.

Within the “choices” tab of the XLSForm, create lists for the regions (if more than one exists) and shoreline zones with the appropriate names/labels listed. For each habitat condition metric and modifier metric, insert an appropriate list name describing the metric under the “list_name” column. For each subclass of a metric, insert the associated weight for each subclass as a decimal under the “name” column. These numerical values will eventually be used to automate HU calculations based on user responses in the Habitat Unit Calculator form. Write the subclass description associated with each weighting in the “label” column to provide users with an interpretable menu of options. Refer to the list of metrics and names included in Appendix C for an example of how to structure this portion of the XLSForm for the Lake Washington HEP survey.

Within the “survey” tab of the XLSForm, add any relevant background questions such as name, email, and project number. Then add a question that prompts the user to select the appropriate geographic region (if more than one exists). Then create a “group” block for each geographic region that contains all questions and calculations specific to each geographic region. If there is only one geographic region, the “group” block does not need to be added. Create a “repeat” block within each “group” block. This will provide users with the ability to create a unique entry for each HEP Zone overlapped by their project footprint. Within the “repeat” block, add a question that requires the user to select the relevant Shoreline Zone. Next, add a question that requires the user to input the area in square feet, which is measured in the web application (see next section). Then, add a question for each metric that could require a response from a user, depending on the Shoreline Zone for each entry. Fill out the “relevant” column so that only the questions relevant to the Shoreline Zone appear upon selecting the Shoreline Zone. For example, the upland riparian vegetation question would only apply to a Riparian HEP Zone. All questions within the “repeat” block will need to be added for pre- and post-project conditions. Question configuration should be identical for pre- and post-project conditions, with the only difference being the “name.” A simple way to differentiate is to append “_PRE” onto the pre-project conditions question names, and “_POST” to the post-project condition names. Refer to the survey configuration table in Appendix C for an example of the structure and syntax used to configure these questions for the Lake Washington HEP survey.

After adding all of the metric- and modifier-related questions, the next step is to add a series of “calculation” and “note” question types which will automatically calculate HUs using survey responses as inputs. This will also need to be done for both pre- and post-project conditions. The calculation structures will be specific to the study area, but will essentially be a square footage multiplied by a series of weighting values. These calculations will be dependent on the weightings inserted in the “survey” tab for each metric and modifier, as well as metric weightings and Shoreline Zone weightings defined in the HEP framework. Create a separate “calculation” and “note” question for each potential Shoreline Zone, as each Shoreline Zone has unique calculation weightings. Create two more “calculation” question types to sum the HUs and the square footages of all entries as they are added. Enclosing all of the questions and calculations within a “repeat” block enables a user to add multiple entries in cases where a project footprint overlaps multiple HEP Zones.

After the pre- and post- “repeat” blocks, add two “calculation” and “note” pairs for both the pre- and post-project conditions. These will be used to calculate and display the total HUs and square footages for the user. Lastly, add two more “calculation” and “note” pairs to calculate the change in HUs and square footage from pre- to post-project conditions. The change in square footage question is included as a quality assurance question, as the total change in area should be zero since this tool is measuring habitat condition change

over a defined area/project extent. Optionally, add additional “calculate” questions if answer-dependent customizations are desired (e.g., red font for negative values, green for positive). Refer to the “calculation” column within the survey configuration table in Appendix C for an example of the syntax used to configure these calculations for the Lake Washington HEP survey. A screenshot of a portion of the resulting user-facing Habitat Unit Calculator form is provided in Figure 6.

Enter your Name:*

Enter your Email:*

Enter your Project Number (if available):

Which region does your project fall within?*
If your project falls within two regions, please complete a separate form for the area falling within each region.

Lake Washington ▼

Lake Washington Form ▼

HEP Zone Entries: Pre-Project (1) ▼

🗑️ 1 ➕

Select the Shoreline Zone:

-Please select- ▼

What is the square footage of your project overlapping this HEP Zone?

Is this area within a Proximity Zone of significance?

-Please select- ▼

Figure 6: Screenshot of the Habitat Unit Calculator form to be completed by users

CONFIGURING THE HEP WEB APPLICATION CON'T

To complement the Habitat Unit Calculator form, users must have access to a map-centric web application in order to measure square footages of HEP Zones overlapped by their project footprint. The configuration described here refers specifically to developing an application using Esri's Experience Builder platform.

The first step is to add HEP Zone polygons to a web map. Optionally, add additional reference layers that may be useful to orienting users, such as parcels and roads. Configure pop-ups within the web map so that only attribute information needed for filling out the form is visible.

Within the Experience Builder application editor, add the web map created in the previous step to the application, ideally as the focal point of the page. The components listed below should be added somewhere on the application layout in a prominent location. A screenshot of the web application built for the City of Seattle HEP program is provided in Figure 6.

1. Link to the Habitat Unit Calculator Form

- a. Enables users to open the associated Habitat Unit Calculator form in a new window to complete with the support of the web application.

2. Draw widget

- a. Enables users to draw and measure polygons for each HEP Zone overlapped by their project footprint. Each polygon will correspond to one entry in the associated Habitat Unit Calculator form.
- b. It is recommended to use the Draw widget rather than the Measure widget because previous drawings are retained, which allows users to keep track of which HEP Zones they have entered.
- c. Make "Polygon" the only option for Drawing Tools
- d. Toggle on the "Enable Measurement" option
- e. Enable "Geometry guides" and "Feature to feature" snapping options

3. Add Data widget

- a. Enables users to add their own spatial data to the web map. This is especially useful if a user has a project footprint layer handy to help guide their measurements.
- b. Toggle on the ability to add data from a user's own AGOL account, a URL, or from a user's own files.

4. Layer List

- a. Enables users to toggle on/off layers as needed

5. Legend

6. Search bar

- a. Can be configured to allow users to search by parcel number, address, or other available reference information.

7. Reference Information

- a. It's recommended to include buttons that link to a User Guide, an "About this page" window, and any other useful links.
- b. It's also recommended to include brief instructions to orient users to the available widgets and links.

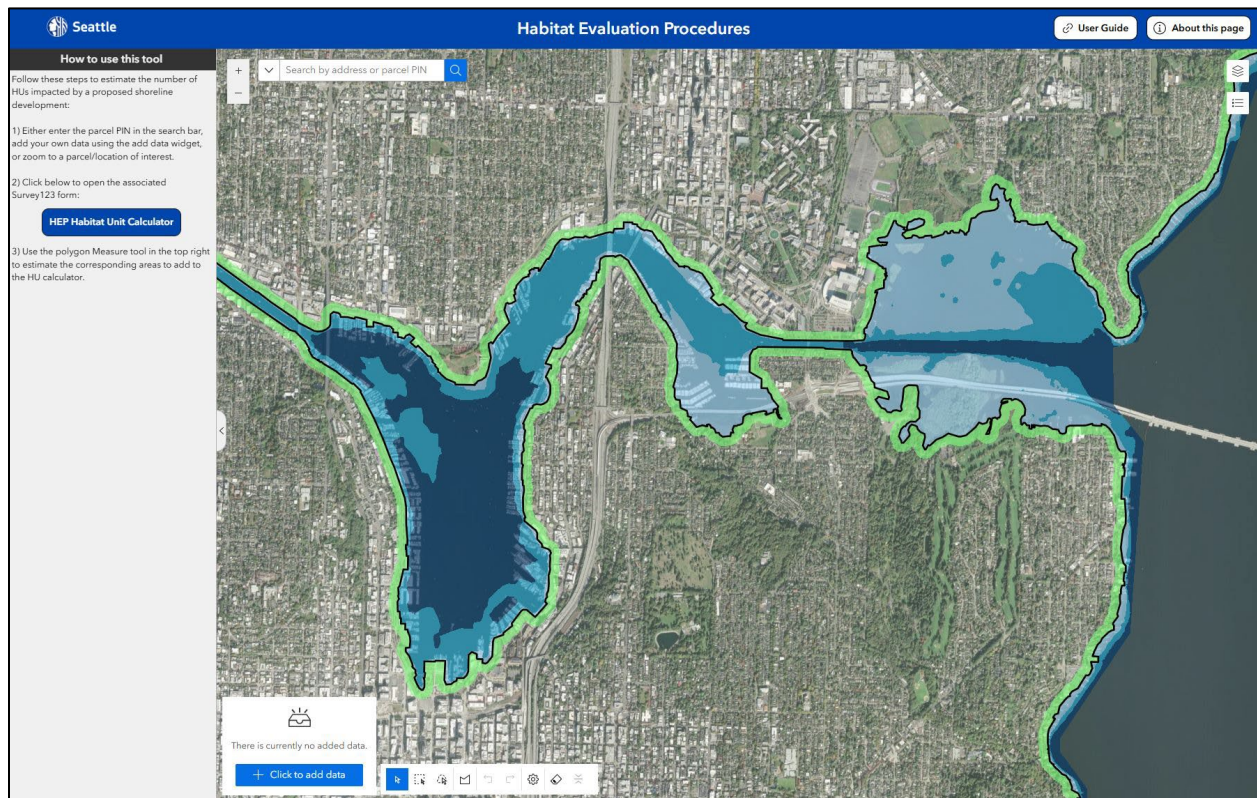


Figure 7: Screenshot of Experience Builder web application configured for the City of Seattle HEP program.

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APPENDIX A – DEFINITION OF TERMS

Aquatic habitat conditions: any metrics that contribute to the condition of the aquatic zone as it relates to juvenile salmonid habitat quality. Examples include substrate and submerged aquatic vegetation.

Bank/Shoreline condition: the material that is along the shoreline between the terrestrial habitat and the aquatic habitat, examples include beach, natural vegetated, rip-rap, vertical bulkhead.

Delineated shoreline: the best available data defining the location of the ordinary high water mark (OHWM) within the relevant jurisdiction.

Geoprocessing tool: any tool that can be used for analyzing or manipulating geospatial data.

Habitat condition metrics: any measurable category describing the condition of the aquatic or riparian zone as it relates to juvenile salmonid habitat quality.

Habitat Evaluation Procedures (HEP): a standardized procedure for determining the impacts of and providing mitigation for a standard set of development activities that occur within the City's Shoreline District.

Habitat Unit (HU): a standardized unit of measurement used to document the quality and quantity of habitat for selected species, developed by the U.S. Fish and Wildlife Service.

Habitat Unit Calculator: a form created using Esri's Survey123 software that calculates the change in HUs from pre- to post-project conditions based on a user's inputs for habitat condition metrics.

Riparian conditions: any metrics that describe the terrestrial condition of the shoreline banks and adjacent uplands as it relates to juvenile salmonid habitat quality. Examples include shoreline bank condition and upland vegetation type.

Subject Matter Expert: an identified expert in the field of the target species and geographic area that guides the development of the habitat function framework tailored to the ecological setting and habitats of the project area.

Thiessen polygons: Polygons generated from a set of points, where each polygon defines an area around its associated point, within which any location is closer to that point than any of the other points.

Topobathymetry: an elevation model dataset containing elevation data above sea level (topography) and below sea level (bathymetry).

APPENDIX B – HABITAT EVALUATION PROCEDURES

BACKGROUND

This appendix describes the Habitat Suitability Index (HSI) models that are used in developing the Habitat Evaluation Procedures (HEP) program developed for the City of Seattle (City) shoreline using examples from the marine shoreline model.

State and local law, in order to ensure no net loss of ecological functions during shoreline development, require that habitat lost during development be mitigated by the creation of equal habitat through habitat restoration. This is termed mitigation and occurs through the local permitting process.

The City has developed a Habitat Evaluation Procedures (HEP) program to establish a standardized procedure for determining impacts and mitigation for a standard set of development activities that occur within the City within the Shoreline Jurisdiction. The Shoreline Jurisdiction includes the area landward 200-ft of the shoreline and the areas that are in and over the water. Additionally, payment for a fee-in-lieu of mitigation will be a part of this program.

The standardized procedure for determining impacts and providing mitigation is habitat units based on a method developed by the US Fish and Wildlife Service (USFWS) to document the quality and quantity of available habitat for selected wildlife species (USFWS 1980). This results in a scientifically defensible delineation and quantification of habitat units that can be used to balance shoreline development impacts with mitigation project values.

HEP provides the ability to document the quality and quantity of available habitat for selected wildlife species and allows comparison of the relative values of a given site over time and/or the relative values of other areas. HEP is based on the assumption that the value of habitat to a given species can be described by an HSI, which ranges in value from 0.0 to 1.0, representing unsuitable to optimal habitat quality, respectively. Any habitat model that can be transformed to this range is potentially applicable. The index value is multiplied by a given area of available habitat to obtain habitat units that can be used for comparative purposes (e.g., the loss from shoreline development, relative to the gains from habitat mitigation).

The City's HEP program is evaluating shoreline ecological function through the lens of habitat requirements for juvenile Chinook salmon (City of Seattle 2006). Developing a framework based on one species allows for consistency in measuring impacts and establishing equivalency between different types of shoreline impacts. The City's shoreline provides habitat to a variety of other aquatic and terrestrial species which are impacted by many of the same shoreline processes that impact Chinook salmon; a focus on Chinook salmon will support habitat conditions for many other shoreline species.

Chinook salmon are the focus because of their protected status under the Endangered Species Act (ESA). Juvenile Chinook salmon have similar marine nearshore habitat requirements to those of juvenile summer chum salmon and bull trout, which are also ESA listed. These species are dependent on regional nearshore and marine resources for rearing as outmigrants (Chinook and chum) and as resident sub-adults or adults (Chinook and bull trout) (Redman et al. 2005).

A panel of subject matter experts provided knowledge and insight into the primary uses and functions of the City of Seattle (City) marine and freshwater shorelines by juvenile Chinook salmon. This information was used to develop HSI models representative of the City's shoreline areas with respect to ecological services for Chinook salmon as part of the City's HEP program. The experts consulted included Kurt Fresh (NOAA), Roger Tabor and Mark Celedonia (USFWS), Aaron Bosworth (WDFW), Kollin Higgins (King County), Lauren Urgenson and Scott Stolnack (WRIA 8), Jason Toft and Jeff Cordell (University of Washington), Matt Luxon, Jenny Love, Ron Gouguet, and Abby Hawley (Windward), Paul Schlenger (ESA), Paul DeVries (R2 Resources), Ed Connor, Julie Hall, Michelle Koehler, Ben Perkowski and Maggie Glowacki (City of Seattle).

The resulting model will be used to evaluate the City's shoreline on a landscape scale using readily available GIS data and individual shoreline development or habitat enhancement projects on a project-specific scale using site drawings. Habitat features (e.g., riparian vegetation) are assigned associated habitat values over their areal extent on the landscape, be it project or landscape scale.

GEOGRAPHIC SCOPE

Habitat units and costs were developed for four subareas of the City's shoreline environment: the Duwamish River, the Puget Sound Shoreline including Shilshole Bay, Lake Union and the Ship Canal, and Lake Washington.

MODEL STRUCTURE

The model was applied to shoreline segments extending from -15 ft MLLW (or as far waterward as shoreline development is expected to extend) to 200 ft landward of the ordinary high water (OHW) line. On a project-specific scale, portions of this area unaffected by the project were not included in the evaluation.

Each segment of the shoreline was divided into depth zones. For the Puget Sound and Duwamish River subareas, these depth zones consisted of intertidal and subtidal zones. For Lake Union and Lake Washington subareas, these depth zones consisted of shallow, mid, and deep aquatic zones. The riparian zone was assessed separately, with a generally lower weighting factor since it only indirectly influences juvenile Chinook habitat. An HSI for each depth zone was calculated separately and was weighted based on relative importance to juvenile Chinook salmon, as determined by the subject matter experts (see example for the Puget Sound subarea in Table 1).

Table 1. Relative weighting factors for Duwamish and Puget Sound subarea shoreline zones

Shoreline Zone	Elevation	Duwamish	Puget Sound
Riparian	OHW to 200 ft inland	0.20	0.30
Intertidal	-4 ft MLLW to OHW	0.55	0.40
Subtidal	-15 ft MLLW to -4 ft MLLW	0.25	0.30

A suite of metrics relating to habitat suitability were each classified using values from 0 to 1 corresponding to unsuitable to optimal habitat value, respectively. Table 2 shows an example of weightings for the substrate metric for the Puget Sound subarea.

Table 2. Substrate suitability index for the Puget Sound subarea

Habitat Condition	Habitat Value
Silt/sand/gravel	1.0
Cobble/boulder	0.3
Concrete, anthropogenic debris, compacted sediments, pilings	0.1

Within each depth zone, each relevant metric was also assigned a weight from 0 to 1 relative to its importance to Chinook habitat with all weights summing to 1. The zone-specific HSI score was calculated as the importance-weighted sum over all metrics. Table 3 shows an example of how metrics were weighted for the shallow aquatic depth zone for Lake Washington.

Table 3. Metric weightings within the Lake Washington subarea

Metric	Metric Weight
Shoreline Condition	0.5
Substrate Composition	0.3
Submerged Aquatic Vegetation	0.2

Habitat units associated with any given metric are calculated as the product of the area (in square feet), habitat value, metric weight, and depth zone weighting factor. Losses or gains in habitat units resulting from shoreline development or habitat enhancement projects are calculated as the change in habitat units over all metrics prior to (baseline) and post-project.

HABITAT SUITABILITY METRICS

The HSI model is constructed to be as simple as possible with few metrics and each metric having few possible values (1.0 = optimal habitat, 0.5 or lower = intermediate quality habitat, 0.1 = poor quality habitat, and 0 = unsuitable habitat). The metrics listed below were included in at least one of the four subareas:

- Bank/shoreline condition
- Riparian vegetation
- Bed slope
- Substrate composition
- Submerged aquatic vegetation

Additionally, modifiers were applied as multipliers to the total HSI calculation:

- Overwater structures
- Proximity to Cedar River (Lake Washington only)

For detailed information regarding the development of the HEP model for the City of Seattle's four geographic subareas see the following reports:

Puget Sound and Duwamish River HEP (Windward 2016)

Lake Union and the Ship Canal Updated HEP (ESA 2022)

Lake Washington HEP (ESA 2023)

REFERENCES

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Redman S, Myers D, Averill D. 2005. Regional nearshore and marine aspects of salmon recovery in Puget Sound. Puget Sound Action Team.

USFWS. 1980. Habitat evaluation procedures (HEP). ESM 102. US Fish and Wildlife Service, Division of Ecological Services, Washington, DC.

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APPENDIX C – HABITAT UNIT CALCULATOR FORM EXAMPLE

Survey123 XLSForm (Habitat Unit Calculator Form) – list of choices

List name	name	label
Region	Lake Washington	Lake Washington
Region	Lake Union/Ship Canal	Lake Union/Ship Canal
Region	Lower Duwamish/Puget Sound	Lower Duwamish/Puget Sound
Shoreline_Zone_LW	Riparian Zone	Riparian Zone
Shoreline_Zone_LW	Shallow Aquatic	Shallow Aquatic
Shoreline_Zone_LW	Mid Aquatic	Mid Aquatic
Shoreline_Zone_LW	Deep Aquatic	Deep Aquatic
Shoreline_Condition_LW	1.0	Natural/Beach
Shoreline_Condition_LW	0.5	Landscaped
Shoreline_Condition_LW	0.1	Riprap/Bulkhead
Riparian_Zone_Condition_LW	1.0	Natural Forested/Herbaceous
Riparian_Zone_Condition_LW	0.7	Natural Shrub-Scrub
Riparian_Zone_Condition_LW	0.1	Garden/Lawn
Riparian_Zone_Condition_LW	0.0	Impervious
Substrate_LW	1.0	Sand/gravel/mixed fines/mud/organic
Substrate_LW	0.9	Mixed coarse
Substrate_LW	0.7	Cobble
SAV_LW_Shallow	1.0	No SAV (Absent)
SAV_LW_Shallow	0.1	SAV (Present)
SAV_LW_Mid	1.0	No SAV (Absent)
SAV_LW_Mid	0.5	SAV (Present)
Proximity_LW	1.0	No
Proximity_LW	1.1	Seward to Pritchard
Proximity_LW	1.2	South of Pritchard
Deep_Dock_LW	0.9	Yes
Deep_Dock_LW	1.0	No
OWS_Height_LW	1.0	No overwater structure
OWS_Height_LW	0.5	High Dock
OWS_Height_LW	0.3	Low Dock
OWS_Height_LW	0.1	Floating Dock

Survey123 XLSForm (Habitat Unit Calculator Form) – survey questions and calculations

type	name	label	calculation	relevant	bind::type
text	Name	Enter your Name:			
text	Email	Enter your Email:			
text	Project	Enter your Project Number (if available):			
select_one Region	Region	Which region does your project fall within?			
begin group	LW_form	Lake Washington Form		{(Region)}= 'Lake Washington'	
begin repeat	LW_HEP_Zone_repeat_PRE	HEP Zone Entries: Pre-Project			
select_one Shoreline_Zone_LW	Shoreline_Zone_LW_PRE	Select the Shoreline Zone:			
decimal	LW_square_footage_PRE	What is the square footage of your project overlapping this HEP Zone?			
select_one Shoreline_Condition_LW	Shoreline_Condition_LW_PRE	Select the Shoreline Condition:		{(Shoreline_Zone_LW_PRE)}='Riparian Zone' or {(Shoreline_Zone_LW_PRE)}='Shallow Aquatic'	
select_one Riparian_Zone_Condition_LW	Riparian_Zone_Condition_LW_PRE	Select the Riparian Zone Condition:		{(Shoreline_Zone_LW_PRE)}='Riparian Zone'	
select_one Substrate_LW	Substrate_LW_PRE	Select the Substrate:		{(Shoreline_Zone_LW_PRE)}='Shallow Aquatic' or {(Shoreline_Zone_LW_PRE)}='Mid Aquatic'	
select_one SAV_LW_Shallow	SAV_LW_Shallow_PRE	Select the Submerged Aquatic Vegetation:		{(Shoreline_Zone_LW_PRE)}='Shallow Aquatic'	
select_one SAV_LW_Mid	SAV_LW_Mid_PRE	Select the Submerged Aquatic Vegetation:		{(Shoreline_Zone_LW_PRE)}='Mid Aquatic'	
select_one Proximity_LW	Proximity_LW_PRE	Is this area within a Proximity Zone of significance?		{(Shoreline_Zone_LW_PRE)}='Shallow Aquatic'	
select_one OWS_Height_LW	OWS_Height_LW_PRE	If applicable, select the height of the overwater structure:		{(Shoreline_Zone_LW_PRE)}='Mid Aquatic'	
select_one Deep_Dock_LW	Deep_Dock_LW_PRE	Does any part of the overall project include an overwater structure that extends into the Deep Aquatic Zone?		{(Shoreline_Zone_LW_PRE)}='Riparian Zone'	
calculate	HU_Calc_Riparian_LW_PRE		round(((\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(Shoreline_Condition_LW_PRE)*0.5*0.15) + (\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(Riparian_Zone_Condition_LW_PRE)*0.5*0.15),2)	{(Shoreline_Zone_LW_PRE)}='Riparian Zone'	decimal
note	HU_Calc_Riparian_Note_LW_PRE	Riparian Habitat Units: \${HU_Calc_Riparian_LW_PRE}		{(Shoreline_Zone_LW_PRE)}='Riparian Zone'	
calculate	HU_Calc_Shallow_LW_PRE		round(((\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(Shoreline_Condition_LW_PRE)*\$(OWS_Height_LW_PRE)*\$(Deep_Dock_LW_PRE)*0.5*0.5) + (\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(Substrate_LW_PRE)*\$(OWS_Height_LW_PRE)*\$(Deep_Dock_LW_PRE)*0.3*0.5) + (\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(SAV_LW_Shallow_PRE)*\$(OWS_Height_LW_PRE)*\$(Deep_Dock_LW_PRE)*0.2*0.5),2)	{(Shoreline_Zone_LW_PRE)}='Shallow Aquatic'	decimal
note	HU_Calc_Shallow_Note_LW_PRE	Shallow Habitat Units: \${HU_Calc_Shallow_LW_PRE}		{(Shoreline_Zone_LW_PRE)}='Shallow Aquatic'	
calculate	HU_Calc_Mid_LW_PRE		round(((\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(Substrate_LW_PRE)*\$(OWS_Height_LW_PRE)*\$(Deep_Dock_LW_PRE)*0.5*0.25) + (\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(SAV_LW_Mid_PRE)*\$(OWS_Height_LW_PRE)*\$(Deep_Dock_LW_PRE)*0.5*0.25),2)	{(Shoreline_Zone_LW_PRE)}='Mid Aquatic'	decimal
note	HU_Calc_Mid_Note_LW_PRE	Mid Habitat Units: \${HU_Calc_Mid_LW_PRE}		{(Shoreline_Zone_LW_PRE)}='Mid Aquatic'	
calculate	HU_Calc_Deep_LW_PRE		round((\$LW_square_footage_PRE)*\$(Proximity_LW_PRE)*\$(OWS_Height_LW_PRE)*\$(Deep_Dock_LW_PRE)*0.1,2)	{(Shoreline_Zone_LW_PRE)}='Deep Aquatic'	decimal
note	HU_Calc_Deep_Note_LW_PRE	Deep Habitat Units: \${HU_Calc_Deep_LW_PRE}		{(Shoreline_Zone_LW_PRE)}='Deep Aquatic'	
calculate	HU_Sum_LW_PRE		round(number(coalesce((\$HU_Calc_Riparian_LW_PRE),0)) + number(coalesce((\$HU_Calc_Shallow_LW_PRE),0)) + number(coalesce((\$HU_Calc_Mid_LW_PRE),0)) + number(coalesce((\$HU_Calc_Deep_LW_PRE),0)),2)		decimal
calculate	Area_Sum_LW_PRE		round(number(coalesce((\$LW_square_footage_PRE),0)),2)		decimal
end repeat					
begin repeat	LW_HEP_Zone_repeat_POST	HEP Zone Entries: Post-Project			
select_one Shoreline_Zone_LW	Shoreline_Zone_LW_POST	Select the Shoreline Zone:			
decimal	LW_square_footage_POST	What is the square footage of your project overlapping this HEP Zone?			
select_one Shoreline_Condition_LW	Shoreline_Condition_LW_POST	Select the Shoreline Condition:		{(Shoreline_Zone_LW_POST)}='Riparian Zone' or {(Shoreline_Zone_LW_POST)}='Shallow Aquatic'	
select_one Riparian_Zone_Condition_LW	Riparian_Zone_Condition_LW_POST	Select the Riparian Zone Condition:		{(Shoreline_Zone_LW_POST)}='Riparian Zone'	
select_one Substrate_LW	Substrate_LW_POST	Select the Substrate:		{(Shoreline_Zone_LW_POST)}='Shallow Aquatic' or {(Shoreline_Zone_LW_POST)}='Mid Aquatic'	
select_one SAV_LW_Shallow	SAV_LW_Shallow_POST	Select the Submerged Aquatic Vegetation:		{(Shoreline_Zone_LW_POST)}='Shallow Aquatic'	
select_one SAV_LW_Mid	SAV_LW_Mid_POST	Select the Submerged Aquatic Vegetation:		{(Shoreline_Zone_LW_POST)}='Mid Aquatic'	
select_one Proximity_LW	Proximity_LW_POST	Is this area within a Proximity Zone of significance?		{(Shoreline_Zone_LW_POST)}='Shallow Aquatic'	
select_one OWS_Height_LW	OWS_Height_LW_POST	If applicable, select the height of the overwater structure:		{(Shoreline_Zone_LW_POST)}='Mid Aquatic'	
select_one Deep_Dock_LW	Deep_Dock_LW_POST	Does any part of the overall project include an overwater structure that extends into the Deep Aquatic Zone?		{(Shoreline_Zone_LW_POST)}='Riparian Zone'	
calculate	HU_Calc_Riparian_LW_POST		round(((\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(Shoreline_Condition_LW_POST)*0.5*0.15) + (\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(Riparian_Zone_Condition_LW_POST)*0.5*0.15),2)	{(Shoreline_Zone_LW_POST)}='Riparian Zone'	decimal
note	HU_Calc_Riparian_Note_LW_POST	Riparian Habitat Units: \${HU_Calc_Riparian_LW_POST}		{(Shoreline_Zone_LW_POST)}='Riparian Zone'	
calculate	HU_Calc_Shallow_LW_POST		round(((\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(Shoreline_Condition_LW_POST)*\$(OWS_Height_LW_POST)*\$(Deep_Dock_LW_POST)*0.5*0.5) + (\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(Substrate_LW_POST)*\$(OWS_Height_LW_POST)*\$(Deep_Dock_LW_POST)*0.3*0.5) + (\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(SAV_LW_Shallow_POST)*\$(OWS_Height_LW_POST)*\$(Deep_Dock_LW_POST)*0.2*0.5),2)	{(Shoreline_Zone_LW_POST)}='Shallow Aquatic'	decimal
note	HU_Calc_Shallow_Note_LW_POST	Shallow Habitat Units: \${HU_Calc_Shallow_LW_POST}		{(Shoreline_Zone_LW_POST)}='Shallow Aquatic'	
calculate	HU_Calc_Mid_LW_POST		round(((\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(Substrate_LW_POST)*\$(OWS_Height_LW_POST)*\$(Deep_Dock_LW_POST)*0.5*0.25) + (\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(SAV_LW_Mid_POST)*\$(OWS_Height_LW_POST)*\$(Deep_Dock_LW_POST)*0.5*0.25),2)	{(Shoreline_Zone_LW_POST)}='Mid Aquatic'	decimal
note	HU_Calc_Mid_Note_LW_POST	Mid Habitat Units: \${HU_Calc_Mid_LW_POST}		{(Shoreline_Zone_LW_POST)}='Mid Aquatic'	
calculate	HU_Calc_Deep_LW_POST		round((\$LW_square_footage_POST)*\$(Proximity_LW_POST)*\$(OWS_Height_LW_POST)*\$(Deep_Dock_LW_POST)*0.1,2)	{(Shoreline_Zone_LW_POST)}='Deep Aquatic'	decimal
note	HU_Calc_Deep_Note_LW_POST	Deep Habitat Units: \${HU_Calc_Deep_LW_POST}		{(Shoreline_Zone_LW_POST)}='Deep Aquatic'	
calculate	HU_Sum_LW_POST		round(number(coalesce((\$HU_Calc_Riparian_LW_POST),0)) + number(coalesce((\$HU_Calc_Shallow_LW_POST),0)) + number(coalesce((\$HU_Calc_Mid_LW_POST),0)) + number(coalesce((\$HU_Calc_Deep_LW_POST),0)),2)		decimal
calculate	Area_Sum_LW_POST		round(number(coalesce((\$LW_square_footage_POST),0)),2)		decimal
end repeat					
calculate	HU_Total_LW_PRE		round(number(sum((\$HU_Sum_LW_PRE))),2)		decimal
note	HU_Total_Note_LW_PRE	Pre-Project Total Habitat Units: \${HU_Total_LW_PRE}			
calculate	Area_Total_LW_PRE		round(number(sum((\$Area_Sum_LW_PRE))),2)		decimal
note	Area_Total_Note_LW_PRE	Pre-Project Total Area (square feet): \${Area_Total_LW_PRE}			
calculate	HU_Total_LW_POST		round(number(sum((\$HU_Sum_LW_POST))),2)		decimal
note	HU_Total_Note_LW_POST	Post-Project Total Habitat Units: \${HU_Total_LW_POST}			
calculate	Area_Total_LW_POST		round(number(sum((\$Area_Sum_LW_POST))),2)		decimal
note	Area_Total_Note_LW_POST	Post-Project Total Area (square feet): \${Area_Total_LW_POST}			
calculate	HU_Change_LW		round((\$HU_Total_LW_POST) - \$(HU_Total_LW_PRE),2)		decimal
calculate	HU_Change_LW_color		if((\$HU_Change_LW) < 0, concat(" ", \$(HU_Change_LW), ""), concat("+", \$(HU_Change_LW), ""))		
note	HU_Change_Note_LW	Change in Habitat Units: \${HU_Change_LW_color}			
calculate	Area_Change_LW		round((\$Area_Total_LW_POST) - \$(Area_Total_LW_PRE),2)		decimal
calculate	Area_Change_LW_msg		if((\$Area_Change_LW) = 0, concat(" ", \$(Area_Change_LW), " ""), if((\$Area_Change_LW) > 0, concat("+", \$(Area_Change_LW), " There should be no change in area from pre- to post-project. Please review your area measurements."), concat("+", \$(Area_Change_LW), " There should be no change in area from pre- to post-project. Please review your area measurements."))		
note	Area_Change_Note_LW	Change in Total Area (square feet): \${Area_Change_LW_msg}			
end group					

