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APPENDIX A: PROTOCOL RECOMMENDATIONS FOR EVALUATING POCKET ESTUARY AND EMBAYMENT HABITATS IN PUGET SOUND

A PROTOCOL FOR REPORTING POCKET ESTUARY COMMON INDICATORS



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Date: August 19, 2019

Credits: This project has been funded wholly or in part by the United States Environmental Protection Agency under Assistance Agreement [CE-01J31901] The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.



Executive Summary:

Insert executive summary one-pager – to be completed in coordination with PSP

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Purpose:

The purpose of protocol is to provide recommendations to support consistent mapping, calculation, and reporting of Common Indicator metrics for pocket estuary and embayment habitats in Puget Sound. The protocol recommendations presented in this report are based primary on the results of a [PSEMP Salmon Work Group workshop](#) on pocket estuaries (SWG 2018) and the protocols developed by the Skagit River System Cooperative (Beamer et al. 2015; Beamer et al. 2018). This document will provide the following information:

1. **Background:** Description of the Puget Sound Partnership’s role in salmon recovery and how Common Indicators support salmon recovery in Puget Sound;
2. **Indicator Definitions:** Definitions required to establish consistent calculation, reporting, and interpretation of Common Indicator metrics for pocket estuary and embayment habitats;
3. **Considered Approaches, Guidelines, and Datasets:** Descriptions of existing protocols, guidelines, and datasets that were used to inform the development of the recommended approach;
4. **Recommended Approach:** Overview of the Common Indicator metrics and reporting, recommended protocols and methods used to develop the data needed to calculate pocket estuary and embayment Common Indicator metrics, description of data layer structures and attributes, GIS methods detail and metric calculations, and supplemental elements; and
5. **Next Steps and Future Directions:** Identification of data gaps, unresolved issues, and potential future directions that should be considered for the pocket estuary Common Indicator.

Background:

The Puget Sound Partnership (PSP) is a state agency leading a regional effort to restore and protect Puget Sound habitats and recover Puget Sound salmon. To support recovery planning and tracking progress of Puget Sound Chinook salmon (listed as Endangered under the Endangered Species Act) habitat, a common set of indicators (Common Indicators) have been developed that provide a framework for Lead Entities to report on the status of key salmon habitat metrics and to report progress towards recovery through restoration actions. Common Indicators have been developed for marine, nearshore, riverine, and terrestrial habitats, and standardized protocols are necessary to ensure that Common Indicators are calculating and reported consistently to support regional and local evaluations of progress towards recovery and recovery planning.

The pocket estuary and embayment Common Indicators framework includes the following metrics for:

- (1) **Pocket estuary and embayment count;**
Reported as the count of pocket estuary and embayment habitats that are accessible to non-natal juvenile Chinook salmon.
- (2) **Pocket estuary and embayment habitat that is accessible to salmon;**
Reported as the sum of all pocket estuary and embayment habitat area that is accessible to non-natal juvenile Chinook salmon.
- (3) **Extent of connected tidal wetlands;**
Reported as the sum of all tidal wetland habitat associated with pocket estuary and embayment habitats that are accessible to non-natal juvenile Chinook salmon.
- (4) **Extent of functional tidal channels;**

Reported as the sum of all tidal channel habitat associated with pocket estuary and embayment habitats that are accessible to non-natal juvenile Chinook salmon.

Pocket estuaries are partially enclosed low energy nearshore habitats with potentially depressed salinities that can provide important rearing and refuge habitat for juvenile Chinook salmon after they have left their natal estuaries (Beamer et al. 2006). Although pocket estuaries are contemporarily described in marine basins with more energetic shoreline processes (e.g., Whidbey Basin, Beamer et al. 2006), protected embayments in lower energy marine basins (e.g., South Sound) may also provide important non-natal estuary-like (e.g., reduced salinity) rearing habitats for juvenile Chinook. Because of the potential importance of pocket estuary and embayment habitats for juvenile Chinook salmon, restoration and protection of these habitats is a priority for watershed recovery plans (PSP 2005).

Indicator Definitions:

Establishing consistent and clear definitions for pocket estuary and embayments and their indicator metrics are an important component in developing protocols for consistent calculation and reporting. The definitions developed in this report were adapted from previous and ongoing work (e.g., Redman et al. 2005; Beamer et al. 2006, 2015, 2018; McBride et al. 2009; Beechie et al. 2017; Stefankiv et al. *In Review*) to fit within the framework covered by other Common Indicator protocols (e.g., river deltas/estuaries). This section provides definitions and descriptions for what habitats are considered in this Common Indicator protocol, how accessibility and functionality are defined, and what habitat components are considered.

Pocket Estuaries and Embayments:

There are currently no minimum or maximum size thresholds that define a pocket estuary or embayment habitat that would be included, but this protocol will exclude all recognized large river deltas (Ramirez and Simenstad 2018) as well as small deltas that lack seaward barrier landforms that form a protected low-energy lagoon or impoundment. Large and small delta features will be monitored and reported under the Estuaries Common Indicator protocols (e.g., Ramirez and Simenstad 2018). For the purposes of this Common Indicator protocol, pocket estuaries and embayments are defined as follows:

Pocket estuaries and embayments: Partially enclosed shoreline features that have low-energy habitat features (e.g., tidal channels, tidal marshes, large wood accumulations, and impoundments) and potentially depressed salinity due to freshwater inputs (e.g., from small streams, groundwater, runoff, or other freshwater sources) that are not within the geomorphic boundary of recognized large river delta systems.

Given that there are a number of existing nearshore landform classification systems in use for Puget Sound, we developed a table to document how pocket estuaries and embayment features considered in this protocol may align with other landform classification systems used in the Puget Sound region (Table 1). The information presented in Table 1 is intended to help Lead Entities and users to understand what landform feature types are considered in this protocol based on different landform classification systems that are used in the Puget Sound region.

Within each pocket estuary and embayment, there are habitat components that will be mapped to support Common Indicator metric calculations. The habitats that will be mapped represent aggregations of finer habitat classifications that are described in Beamer et al. (2018). For the purposes of this

Common Indicator protocol, the following descriptions are provided for the core habitat components that will be mapped for metric calculation:

Accessible habitat area: The total subtidal and intertidal area contained by habitat forming feature(s) (e.g., spit or barrier beach) and the range of tidally influenced area that includes tidal wetland and tidal channel area as described below that is accessible to non-natal juvenile Chinook salmon.

Tidal wetland habitat: All vegetated marsh surfaces (e.g., estuarine emergent marsh, estuarine scrub shrub, forested riverine tidal) that are tidally influenced within the accessible habitat area as described above, which excludes tidal channel area as described below that is contained within the tidal wetland habitats.

Tidal channel habitat: All visible tidally influenced channel features (e.g., blind tidal channels, tidal channels, sloughs, distributaries, low tide terraces, and impoundments) contained within the accessible habitat area described above as defined by the vegetated edge of a tidal wetland.

Accessibility and Functionality:

Tidal connectivity is an important aspect of pocket estuary habitat given that pocket estuaries and embayment habitats provide important rearing habitat for non-natal Juvenile Chinook salmon. Non-natal juvenile Chinook must migrate from their natal estuaries (large river deltas with rivers that typically support spawning Chinook salmon populations) through the nearshore environment to access these pocket estuary and embayment rearing habitats.

For the Common Indicator metrics considered in this protocol, classification of pocket estuary and embayment habitats as accessible is based on the presence of tidal connectivity between the habitat and Puget Sound and the assumption that non-natal Chinook salmon can physically access the habitat. The classification of habitats as accessible based on these criteria does not imply that non-natal juvenile Chinook salmon preferentially use the habitat, rather the classification merely indicates that fish can physically access the habitat based on the presence of tidal connectivity. Functionality is also an important aspect that can be used to evaluate the degree to which habitats may support non-natal juvenile Chinook salmon. For the purposes of the pocket estuary Common Indicator metrics, functionality is synonymous with accessibility in that a site classified as accessible will be considered functional for calculating and reporting metrics.

The presence of tidal connectivity will primarily be determined through remote sensing and observation of visible surface water connections between the habitat and Puget Sound (e.g., through tidal channels or embayment fronts), although field surveys may be required to accurately determine the presence of tidal connectivity at particular sites (Beamer et al. 2018). Furthermore, it is important to note that some features may become closed or reopen over time due to natural processes or development (Beamer et al. 2018). Tracking the accessibility of pocket estuary features over time is likely important as this information can be used in recovery planning (e.g., identify restoration opportunities and evaluate sources of changes over time).

For this protocol, accessibility and functionality are defined as follows:

Accessible and Functional: The presence of tidal connectivity (via tidal channels or an embayment mouth) that non-natal juvenile Chinook salmon can use to access the pocket estuary habitat.

Inaccessible/Closed and Non-functional: Lack of visible or documented tidal connectivity due to natural or artificial barriers (e.g., tide gates, transportation causeways, barrier beaches, spits).

Table 1. Feature types in other shoreline classification systems that may be classified as pocket estuaries for this protocol. All bolded features may be classified as pocket estuary and embayment habitats in this protocol assuming they do not occur within the geomorphic tidal floodplain of a large river delta system. Values are lists by classification systems and are not intended to be linked or nested across rows.

RITT Common Framework (Bartz et al. 2013)				McBride et al. (2009)		Beach Strategies (CGS 2017)	
Broad habitats	System types	System subtypes	Shoreline types	Shoreshape	Geomorphic Unit	Systems	Landforms
Estuarine	Major river systems	Natal Chinook estuaries	Drowned channels	Embayments and Estuaries	Tidal channel marsh	River deltas	River-dominated deltas
			River-dominated (fan) deltas		Tidal channel lagoon		Wave-dominated deltas
			Tidal Deltas		Drowned channel		Tide-dominated deltas
			Delta lagoons		Drowned channel lagoon		Fan deltas
Nearshore marine	Drift cell systems	Coastal landforms	Barrier beaches		Tidal delta	Embayments	Open coastal inlets
					Tidal delta lagoon		Barrier estuaries
		Bluff backed beaches	Sediment source beaches		Delta		Barrier lagoons
			Depositional beaches		Delta lagoon		Closed lagoons/marshes
			Beach seeps		Longshore lagoon	Beaches	Bluffs
			Plunging sediment bluffs		Closed lagoon/marsh		Barriers
		Pocket estuaries (embayments)	Drowned channel lagoons		Pocket beach lagoon	Rocky coast	Plunging
			Tidal delta lagoons		Pocket closed lagoon/marsh		Platform
			Longshore lagoons		Pocket beach estuary		Pocket beaches
			Tidal Channel lagoons/marshes	Open shoreline	Pocket beach		
			Closed lagoons and marshes		Beach seep		
			Open coastal inlets		Depositional beach		
	Rocky shorelines	Rocky pocket estuaries	Pocket beach lagoons		Sediment source beach		
			Pocket beach estuaries		Barrier beach		
			Pocket beach closed lagoons and marshes		Veneered rock platform		
					Rocky shoreline		
		Rocky beaches	Veneered rock platforms		Plunging rocky shoreline		
			Rocky shorelines		Plunging sediment bluff		
			Plunging rocky shorelines				
			Pocket beaches				

Considered Approaches, Guidelines, and Datasets:

A number of previous and ongoing efforts have developed approaches, guidelines, and datasets that were considered in developing the recommended approach for the pocket estuary Common Indicator protocol. This section provides a brief overview of the primary sources considered in developing the recommended approach. This information is intended as background information to support the development of the pocket estuary Common Indicator metrics by providing an overview of the datasets and guidelines that can be used to support development the required datasets to report and calculate the pocket estuary Common Indicator metrics.

Salmon Habitat Status and Trends Monitoring Program (SHSTMP):

The SHSTMP team is currently developing a protocol document (Stefankiv et al. In Review) that is an update of the original Technical Memo (Beechie et al. 2017). We obtained a review copy to evaluate updates to nearshore protocols and status and trends datasets that could inform the development of protocols for Pocket Estuary Common Indicators. Metrics for pocket estuaries are identified in the update, which include embayment area (total, wetted, and vegetated area) and embayment connectivity (width of embayment opening). However, protocols describing the identification and mapping of pocket estuary features and habitat components are not yet developed. The SHSTMP has created an updated shorezone layer from the Salmon and Steelhead Habitat Inventory and Assessment Program (SSHAP) shoreline database, with geomorphic shoreforms that can be used to identify/locate pocket estuary habitats throughout Puget Sound (SHSTMP 2018). Protocols for mapping estuary habitats are already developed in the SHSTMP and have been adopted by the PSP for estuaries Common Indicators. It is assumed that the SHSTMP pocket estuary protocols will be similar to the approach used in the estuary strata (e.g., tidal channel and marsh features digitized from aerial imagery with tidal exceedance layers used to delineate the extent of tidal influence), but these still need to be developed.

GIS Census of Pocket Estuaries in Whidbey Basin (Beamer et al. 2018):

A draft report on a GIS based census mapping of pocket estuaries for Whidbey Basin was obtained from Eric Beamer, which provides a very detailed description of protocols they used to map pocket estuary habitats, connectivity, and change (2005 to 2014). This protocol covers pocket estuaries and connectivity, classifying and mapping habitat types within pocket estuaries, and data sources used to map and identify features. The methods described in the protocol are very detailed and likely go beyond the detail that can be initially done at the Puget Sound scale. However, they describe a standardized protocol that can be used to develop each component of the pocket estuaries Common Indicators. NAIP and Google Earth imagery used in this protocol are available at the Puget Sound scale, as are oblique shoreline images (DOE 2014), but other higher resolution county specific and LiDAR imagery and data sources may not be available the Puget Sound extent.

Beamer et al. relied on a number of sources to identify where pocket estuaries are within Whidbey Basin. Once pocket estuaries are identified at the Puget Sound scale, their protocol could be used for mapping the location (point at the mouth) and classifying fish access potential (visible water connectivity). Mapping habitat features to the extent described in this protocol will be dependent on the data available at the Puget Sound scale (e.g., LiDAR elevations to delineate intertidal, backshore, and upland features). For each pocket estuary, polygon habitat features were mapped based on the RITT Common Framework, and the protocol provides a list and description of each habitat feature type mapped (e.g., subtidal and intertidal channels, fill, backshore berms, tidal marsh, etc.). These features

are used to quantify pocket estuary areas in aggregate and by different habitat feature types, which could be used to quantify areal habitat estimates for pocket estuaries Common Indicators (e.g., pocket estuarine habitat area that is accessible, extent of connected tidal wetlands, and extent of functional tidal channels). Connectivity and pocket estuary function were also assessed by evaluating tidal muting structures and habitat alterations, which can be used to inform the calculation of functional tidal wetland and channel area. Mapping of pocket estuary habitat features according to the protocols outlined in Beamer et al. (2018) took approximately 2-months to complete for the Whidbey Basin and western shores of Whidbey Island (SWG 2018).

Salmon Recovery Nearshore Chapter:

Pocket estuaries were identified and functionally classified for all 11 marine sub-basins using hill shaded digital elevation models, oblique shoreline images (DOE 2014), and hydrography layers as part of the nearshore chapter of the Salmon Recovery Plan (Redman et al. 2005). The nearshore chapter describes the methods in detail and resulting data set that provides the location of each identified pocket estuary and scoring for function based on the presence of freshwater inputs and anthropogenic impacts (e.g., dikes, fill, aquaculture, urbanization, armoring) and likely Chinook functions of the identified habitats (e.g., osmoregulation, refuge, feeding). These attributes are used to classify identified habitats as Properly Functioning, Not Properly Functioning, and At Risk. Given the transient nature of some pocket estuary habitats, potential development over time, and restoration actions over time, the data set produced from this regional analysis could serve as a snapshot of pocket estuary counts circa 2000-2002. These data can be used as a baseline or input dataset for the current pocket estuary inventory that represents more recent conditions. In addition, the functional classification matrix used in this analysis could be considered in the pocket estuary protocol for classifying features based on function.

Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) Change Analysis:

The PSNERP change analysis developed a Puget Sound scale geodatabase with a number of potentially useful data products that could support the development of Pocket Estuaries Common Indicators (Simenstad et al. 2011). The PSNERP change analysis dataset includes polygons for current and historical tidal wetland extents and classifications of shore forms and tidal wetland types, which could be used as a base layer to identify current and historical pocket estuary features at the Puget Sound scale. This dataset could be used to supplement the identification of pocket estuaries from the SHSTMP geomorphic shoreforms described above, while also providing historical context by allowing historical pocket estuaries to be identified and accounted for as well. Additionally, the polygon extents of tidal wetland habitats by geomorphic shore form types can be used to support the delineation of pocket estuary habitat area.

Pacific Marine and Estuarine Fish Habitat Partnership (PMEP) Current and Historical Estuary Extent:

This dataset was developed to provide accurate mapping of tidal wetland habitats and includes the entire Puget Sound basin (Available at: <http://www.pacificfishhabitat.org/data/estuary-extents>). The available data currently provides polygons that delineate areas subject to potential tidal inundation based on high resolution LiDAR digital elevation models. Current tidal wetland habitat extents are currently being developed from these data by PMEP and SHSTMP projects, which would provide consistency between the programs and the estuary protocols. However, the potential extent of tidal

inundation can be used as a base dataset to support the delineation of potential pocket estuary area once pocket estuaries have been identified.

Beach Strategies for Nearshore Restoration and Protection in Puget Sound:

This project aims to develop science-based strategies to guide future protection and restoration efforts on Puget Sound beaches (Project overview available at:

https://salishsearestoration.org/wiki/Beach_Strategies_for_Nearshore_Restoration_and_Protection_in_Puget_Sound). The updated shoretypes layer developed for this project could be used to inform the location of pocket estuary features at the Puget Sound scale, and may support improved identification of habitat alterations/function through updated spatial mapping of armoring at the Puget Sound scale.

San Juan County Pulling it all Together (PIAT) Analysis:

The PIAT analysis (Whitman et al. 2012) produced shoreline segments that were classified as pocket estuary like and lagoonal or estuarine embayments for the San Juan Islands. Although these features likely function differently than pocket estuaries within the contiguous oceanographic basins due to their distance from natal Chinook rivers, these features do potential support rearing of non-natal salmonids (Beamer, Skagit River System Cooperative, personal communication). Therefore, this dataset can be used to support identification and classification of pocket estuary features in San Juan County.

Recommended Approach for Calculating Common Indicator Metrics:

Metrics and Reporting:

The recommended approach for Pocket Estuary Common Indicator metrics is based primarily on the approach developed by Beamer et al. (2018) and outcomes of the PSEMP Salmon Working Group (SWG) pocket estuary meeting (SWG 2018). The recommended protocol addresses calculation of four pocket estuary Common Indicator metrics that are summarized and reported by Chinook Recovery Watershed (Figure 1). Chinook Recovery Watersheds are similar to WRIA and LE boundaries but differ in some areas and are tied to the Chinook Recovery Plans (Available at: <https://www.psp.wa.gov/salmon-recovery-watersheds.php>). The basic approach requires mapping of point features to identify pocket estuary and embayment features, and mapping of habitat areas associated with features that are accessible to non-natal juvenile Chinook salmon. See Figure 2 for a diagram showing the types of habitat features mapped for accessible area, tidal wetland area, and tidal channel areas, and Figure 3 for an example of mapped features from Beamer et al. (2018). Metrics can be summarized by WRIA, Chinook Recovery Watershed, and Lead Entity management areas. The following provides an overview of the metrics and reporting framework used for each Common Indicator metric:

(1) Pocket estuary and embayment count,

The pocket estuary count metric will be reported as the count of pocket estuaries that are accessible to non-natal juvenile Chinook salmon and count of features that are classified as closed or inaccessible. These mapped features are identified as described in the mapping methods section (Figure 2, Figure 3).

(2) Pocket estuary and embayment habitat that is accessible,

The accessible pocket estuary and embayment habitat metric is calculated and reported as the sum of all mapped habitat features for all identified pocket estuaries and embayments. This mapped area and reported value will include the mapped tidal wetland and tidal channel areas as described below and in the mapping methods section (Figure 2, Figure 3).

(3) Extent of connected tidal wetlands, and

This metric will be reported as the summed area of mapped tidal wetland habitat features for all identified accessible pocket estuary and embayment features. The mapped area for connected tidal wetland habitat will exclude mapped channel, impoundment, and subtidal features as described in the mapping methods section (Figure 2, Figure 3).

(4) Extent of functional tidal channels.

The area of all mapped tidal channel habitat area will be calculated and reported as the summed area of mapped connected tidal channel features for all identified accessible pocket estuary and embayment features. This reported area will exclude tidal wetland surface area as described in the mapping methods section (Figure 2, Figure 3).

Additional detail for summaries may be developed using other classifications (e.g., functional state, small stream presence, or feature type) to support future Common Indicator reporting needs when data are available or additional reporting requirements are needed. Furthermore, the spatial nature of these data will support summaries by other geographic extents (e.g., regional, oceanographic basin, major population group, etc.).

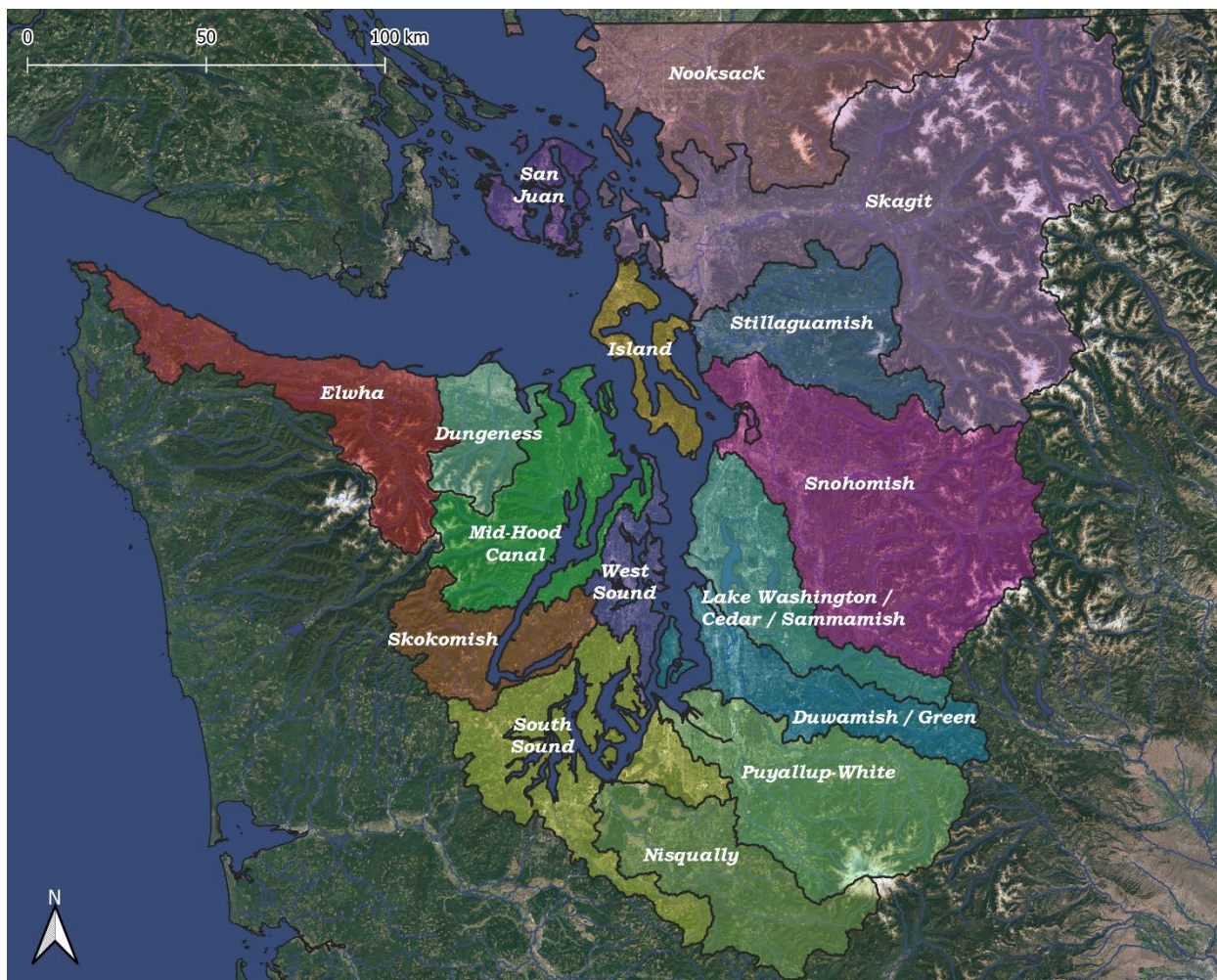


Figure 1. Map of Chinook Recovery Watershed boundaries that are used to summarize and report the Common Indicator metrics described in this protocol.

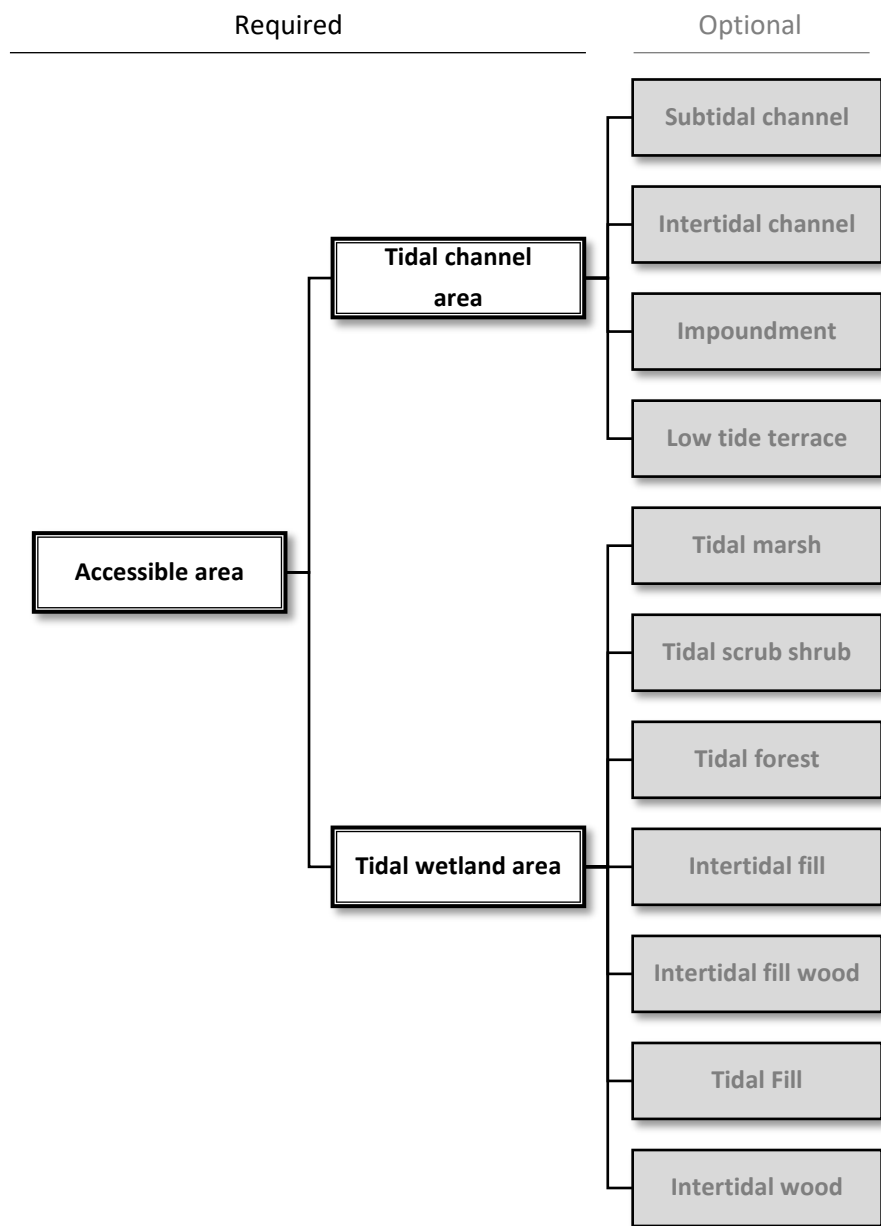


Figure 2. Mapped habitat features from Beamer et al. (2018) that are included in the mapped polygon areas used to calculate the Common Indicator metrics. Bolded habitat feature levels show the required level of mapping detail for the Common Indicator calculation, while optional sub habitat types are shown in light grey.

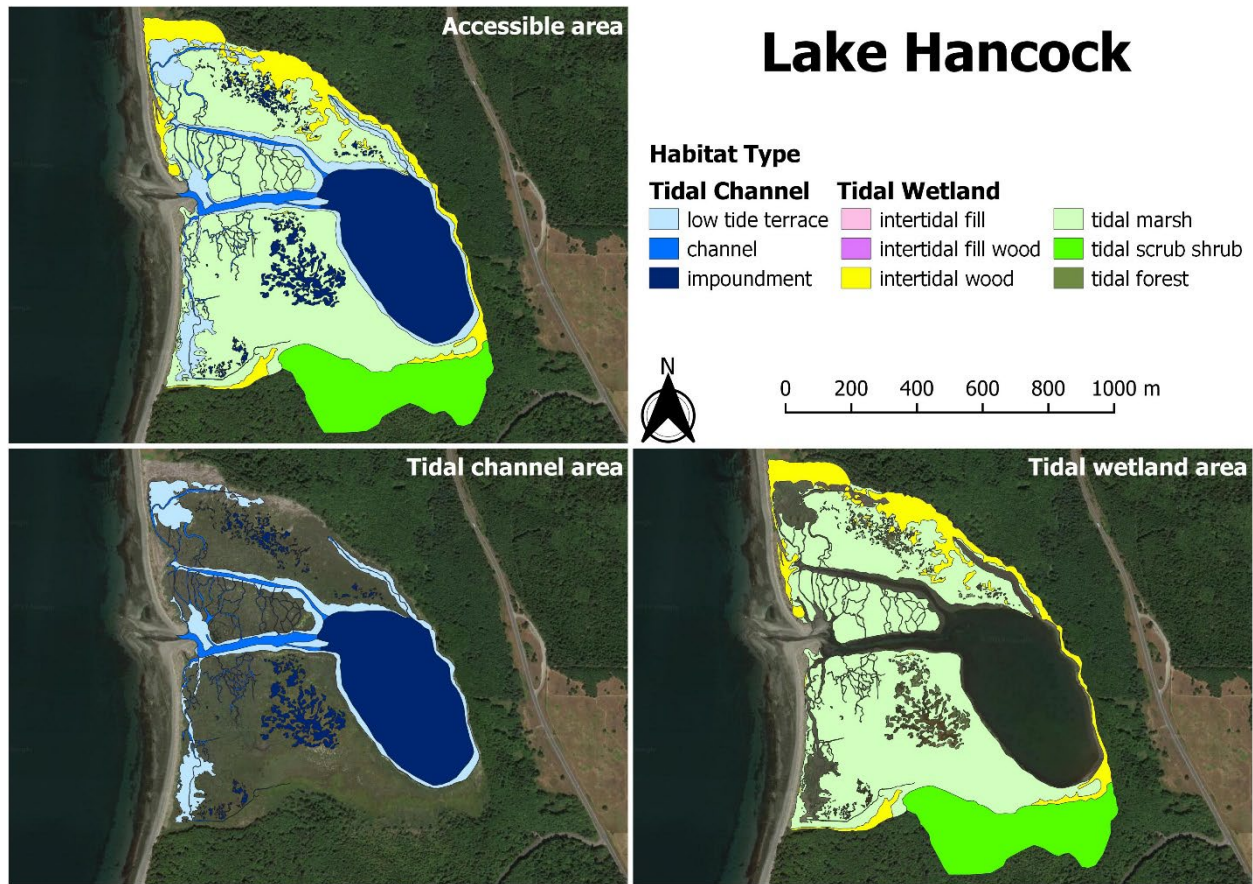


Figure 3. Map showing a pocket estuary with mapped habitat areas for accessible area, tidal wetland area, and tidal channel areas. The data shown here are from Beamer et al. (2018) and show an example of how sub habitat features are aggregated into the accessible area, wetland area, and channel areas as shown in Figure 2.

Mapping Methods:

All four of the Pocket Estuary Common Indicator metrics rely on a point layer dataset that will serve as a spatial inventory of pocket estuary and embayment features considered for reporting this Common Indicator. A preliminary inventory and point layer have been developed as a starting point to support calculation of the pocket estuary Common Indicator metrics. This inventory will be reviewed, updated, and maintained by Lead Entities in coordination with the Partnership to ensure that all appropriate pocket estuary and embayment features are included. In this section, we provide an overview of the methods that can be used to create, update, and maintain the spatial inventory of pocket estuary and mapping habitat features within each identified pocket estuary and embayment.

Spatial Inventory:

Remote sensing is the primary method for identifying and mapping features within each watershed and at the regional scale. A combination of remote sensing (e.g., aerial imagery or supplemental GIS data sources), field observations, supplemental data, and local area knowledge can be used to create the spatial inventory. A preliminary spatial inventory was completed to support development of this dataset, and we describe the data sources and methods used to create this preliminary dataset in this section. We also describe how this preliminary inventory can be updated to produce complete inventories of pocket estuary and embayment features within each watershed.

Preliminary Inventory:

While several potential regional and sub regional datasets have been developed for Puget Sound that provide information on pocket estuaries (e.g., location, shoreforms, extent, accessibility, and function), these datasets have not been synthesized into an up-to-date regionally consistent spatial inventory of pocket estuaries that would directly support Common Indicator calculations for pocket estuaries. To develop a regionally consistent inventory of pocket estuary and embayment features for Puget Sound, we reviewed data from multiple sources (Table 2) to identify potential pocket estuary features throughout Puget Sound based on the definitions provided in Beamer et al. (2018) and other shoreform classification frameworks (McBride et al. 2009; Bartz et al. 2013; CGS 2017). These regional datasets were reviewed with current aerial imagery and oblique shoreline imagery (DOE 2014) and used to identify and verify the presence of pocket estuary and embayment features; essentially, the regional datasets providing a geographic filter to focus this effort. Therefore, this approach did not produce a census product given that the entire shoreline was not inventoried or reviewed. However, the approach uses the best available regional data on shoreline geomorphology and habitat to provide a baseline inventory of pocket estuary habitats for the region.

Sub-regional datasets:

Several sub-regional datasets were available that provided detailed information for the Whidbey Basin and western shore of Whidbey Island (Beamer et al. 2018), San Juan Islands (Whitman et al. 2012), and Bellingham Bay (personal communication, A. Burns, City of Bellingham). The GIS census data for Whidbey Basin and the western shoreline of Whidbey Island (Beamer et al. 2018) were integrated directly and represent the mouth of pocket estuary features. These features represent confirmed pocket estuary habitats based on the recommended pocket estuary protocols. Some deviation from direct integration of the pocket estuaries reported in Beamer et al. (2018) for this inventory occurred in cases where features occurred within the mapped boundaries of a large river delta system. In these cases, the features within large river delta boundaries were omitted from this inventory.

The Pulling it all Together (PIAT) analysis (Whitman et al. 2012) produced shoreline segments that were classified as pocket estuary-like and lagoonal or estuarine embayments for the San Juan Islands. Although these features likely function differently than pocket estuaries within the contiguous oceanographic basins due to their distance from natal Chinook rivers, these features do potentially support rearing of non-natal salmonids (personal communication, E. Beamer, Skagit River System Cooperative). Therefore, these features were reviewed to determine potential pocket estuary features within the San Juan Islands.

Some maps of features that are considered pocket estuaries in the Nooksack Chinook Recovery Watershed were provided, which were used to identify features that were included in this inventory (personal communication, A. Burns, City of Bellingham).

Regional Datasets:

Several regional scale datasets were also used to identify potential pocket estuary features within Puget Sound, including the Nearshore Chapter of the Salmon Recovery Plan (Redman et al. 2005) and PMEP estuary points (PMEP 2018). Tabular data for coordinates of pocket estuaries identified in the Nearshore Chapter of the Salmon Recovery Plan were extracted and reviewed against aerial imagery, as were point locations of estuaries in Puget Sound in the PMEP (2018) database.

Several shoreline layers were also used, including the Beach Strategies (CGS 2017), SHSTMP shoreline (Beechie et al. 2017; SHSTMP 2018; Stefankiv et al. In Review), Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIA) shoreline database, and WADOE Coastal Landforms (MacLennan et al. 2013) mapping products. These layers provide a variety of shoreform classification attributes at regional scales that can be used to identify low energy and protected lagoon and embayment habitats (Table 2). The PSNERP Change Analysis layers (Simenstad et al. 2011) delineated tidal marshes classified as estuarine mixing and the PMEP (2018) potential tidal wetland extent was used to identify areas where elevations support tidal flooding inland of the shoreline, both of which were used to identify potential pocket estuary features along the shoreline. In addition, the PSNERP Change Analysis (Simenstad et al. 2011) layers also contains points for stream mouths, which were used as a source for classifying whether surface water inputs were likely within identified pocket estuary features.

Dataset Review and Creating the Inventory:

To develop the regional inventory, we first defined our analysis extent as all shorelines within Chinook Recovery Watershed boundaries of Puget Sound (Figure 1) that fall outside of currently defined large river delta boundaries (SHSTMP 2018). Large river delta boundaries are covered under the estuary protocol (Ramirez and Simenstad 2018) and are not considered in the pocket estuary protocol to prevent double counting of features.

For shorelines outside of the large river delta boundaries, we reviewed regional datasets collectively to identify potential pocket estuary features based on the attributes of these datasets (e.g., shoreform classifications or feature locations) and marked potential pocket estuary and embayment features based on observations from aerial imagery. The general approach was to review shoreline segments where shoreline geomorphology attributes from reviewed data sources and aerial imagery observations indicate the potential presence of protected embayment, lagoon, pocket estuary, or pocket beach habitats that are potentially accessible to non-natal Chinook salmon. These features may or may not contain surface water inputs from a stream, but generally have depressed salinities relative to the

surrounding area due to freshwater inputs (e.g., streams, runoff, groundwater, or nearby riverine inputs).

For each identified feature, accessibility was determined based on the presence of visible tidal connectivity to the habitat based on evidence from remote sensing (e.g., aerial imagery) or optional field observations (Figure 4). Accessibility is based only on whether non-natal juvenile Chinook salmon can potentially access the site at some point during the tidal cycle (e.g., through tidal channels or embayment fronts) and is not based on whether juvenile Chinook use of the site has been documented. For the purposes of the pocket estuary Common Indicator protocol, accessibility and functionality are considered the same and are based only on observations from aerial imagery that show tidal connectivity between the identified habitat and the Puget Sound. Site visits may be required to ultimately determine the connectivity or accessibility of a site.

For all pocket estuary or embayment features that are accessible, a single point will be placed at the seaward mouth or outlet (Figure 4). This will occur at either the middle of a wetted channel or bayfront depending on the geomorphology of the pocket estuary and should represent the narrowest point of constriction creating the enclosed and protected pocket estuary feature. The placed point does not need to be snapped to existing shoreline polylines, as the mouth can occur landward or seaward of the shoreline or shorezone boundary. In some cases, larger systems may appear to have multiple potential pocket estuaries contained within a larger unit. A single point should be placed at the mouth of the larger system rather than separate points within each system (Figure 5).

For closed features that do not appear to be accessible to non-natal juvenile Chinook salmon, points should be placed in the approximate geographic mean of the visible impoundment of water and accessibility should be classified as closed (Figure 4). Inventorying closed features can be used to keep track of transient systems that may naturally become closed or open due to longshore processes; changes due to development or restoration actions; and to identify or prioritize potential restoration opportunities.

Completing and Updating the Spatial Inventory:

Using the preliminary spatial inventory, identified features and classifications of accessibility should be reviewed using remote sensing of aerial imagery to verify whether identified features should be included in the inventory of pocket estuary and embayment features for each watershed. Given that the preliminary spatial inventory was derived from available datasets and does not represent a census of the shoreline, the shoreline should be reviewed using aerial imagery to identify and add missing features to the spatial inventory using the methods described above. Note that the imagery sources and source year should be noted for all features that are added to the inventory so that the pocket estuary count metric can be calculated for the correct time period and to keep track of features with changing accessibility over time.



Figure 4. Example of two accessible features (blue points) and a closed feature (orange point) with no visible sign of tidal connectivity to the Puget Sound. Note the location of the points at the mouth of the pocket estuary, and the inclusion of an obviously constructed feature that would still be considered as a pocket estuary or embayment feature in this protocol.

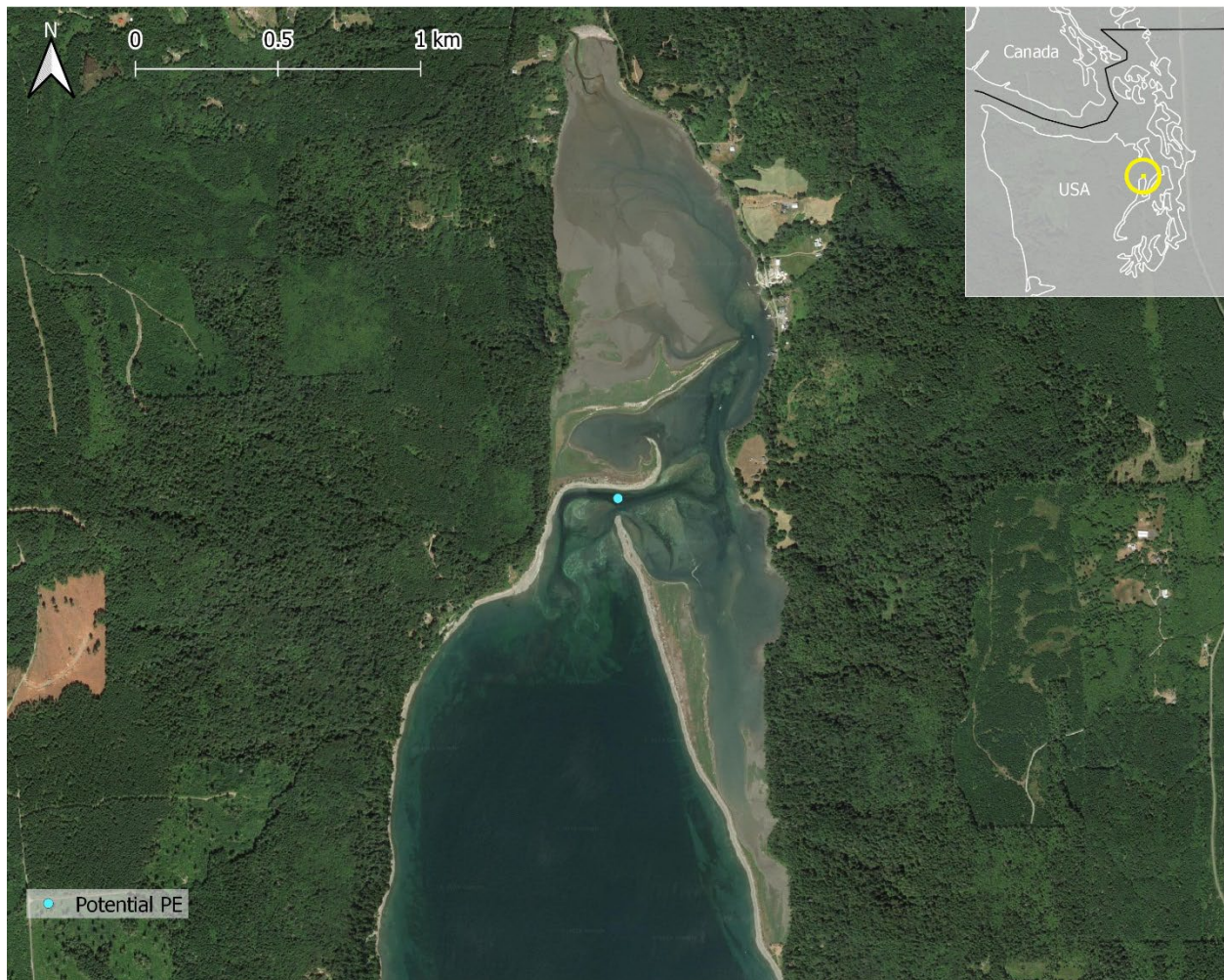


Figure 5. Example of a larger pocket estuary system showing a single point being placed near the mouth of the larger system rather than multiple points being placed in embayments within the system.

Table 2. Data sources and attributes used to identify pocket estuary features in Puget Sound. Years are based on the aerial imagery acquisition dates used for identifying or mapping pocket estuary features as reported in supporting documentation.

Source	Extent	Year(s)	Description
SHSTMP (2018) Large River Delta Boundaries	Puget Sound	2011, 2015	Polygon boundaries of large river delta units. These boundaries are used to exclude potential features within large delta units.
SHSTMP (2018) Shoreline Layer	Puget Sound	2009	Shoreline polyline with shoreforms classified as embayments modified from SSHIAP.
PMEP (2018) Current and Historical Estuary Extent	Puget Sound	2016	Polygon of potential tidal flooding based on elevation – does not include connectivity. Shows landward extent of potential tidal flooding.
PMEP (2018) Estuary Points	West Coast	2012	Points of estuaries in PMEP’s spatial data system. Some overlap with large river deltas but contains additional features.
Redman et al. (2005) Nearshore Salmon Recovery Plan Pocket Estuaries	Puget Sound	2000-2002	Tables with coordinates and functional classifications for pocket estuaries from aerial imagery analysis.
PSNERP Change Analysis (Simenstad et al. 2011)	Puget Sound	2006	Polygons of current wetland extents and types, polylines with shoreform classifications, and points for small stream mouths. Historical shoreforms and wetlands also available.
Beamer et al. (2018) GIS Pocket Estuary census	Whidbey Basin Whidbey Island	2005, 2014	Pocket estuary points and polygons of habitats, functional classifications, and connectivity.
PIAT (Whitman et al. 2012)	San Juan County	2008-2010	Polylines with shorelines classified as “pocket estuary like” and embayment estuaries and lagoons.
WAEYC Coastal Landforms (MacLennan et al. 2013)	Puget Sound	2012	Shoreline type polylines from feeder bluff mapping that include mapping of low energy shorelines where pocket estuaries occur.
Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) shoreline database (McBride et al. 2009)	Puget Sound	2007-2008	Shoreline polyline with shoreform classifications. Shoreline not corrected, but shorelines landward of polyline were noted in a separate attribute that could be used to identify lagoons and other embayment features.
Aerial imagery (Google Earth)	Puget Sound	2016-2019	Aerial imagery used to identify features and locate points at mouth of pocket estuary.
Oblique shoreline imagery	Puget Sound	1976-2017	Oblique images of shoreline that can be used to interpret connectivity and shoreform.
Additional sources to consider that could not be obtained prior to development of the preliminary inventory			
Todd et al. 2006 Unpublished technical report, PNPTC TR:06-01	Hood Canal and Straits	2006	Todd, S., N. Fitzpatrick, A. Carter-Mortimer, and C. Weller. 2006. Historical changes to estuaries, spits, and associated tidal wetland habitats in the Hood Canal and Strait of Juan de Fuca regions of Washington State. Unpublished technical report, PNPTC TR:06-01

Data Structure:

The spatial inventory of pocket estuary and embayment should be maintained as point data in GIS using the WA State Plane South NAD 83 HARN (EPSG 2927) Coordinate Reference System (CRS). This CRS is the WA State standard and conformance with this standard will ensure consistency across the region and provide consistent reporting that can be used to develop and maintain a regional spatial database.

A list of attributes, descriptions, and values are provided in (Table 3). Each feature should be attributed with a unique place name or ID [PE_ID] so that the spatial inventory and mapped habitat features can be associated with each feature (Table 3). The IDs for the point (Table 3) and mapped polygon features (Table 4) should be the same, but each site should have only one unique ID. If multiple points are placed for a single feature (e.g., a transient system that closes and opens over time or a connectivity restoration site) for multiple evaluation years, place names or ID [PE_ID] should be consistent between evaluation years. Coordinates for the placed point in WA State Plane South NAD 83 HARN (EPSG 2927) should be calculated in decimal degrees and used to attribute the [Latitude] and [Longitude] fields. This can be done using geometry calculation tools after all features are identified and points are placed.

Each feature will also be attributed with a [Source_Year] that identifies the year of the source that was used to identify the feature (Table 3). For remote sensing methods, this will be the year of the aerial imagery or spatial data source that was used to identify the feature and place the point. Additionally, each feature will be attributed with a [Eval_Year] that assigns features to an evaluation year for reporting (Table 3). The evaluation year will be used to distinguish features that may change over time with respect to connectivity (e.g., due to restoration, development, or natural processes).

Identifiers for Chinook Recovery Watersheds [CRW], Lead Entity Management Area [LE_AreaName], and Water Resource Inventory Area [WRIA] will also be added for each feature (Table 3). This can be done as a join or ArcToolbox Identity operation using the authoritative polygon boundaries after all features have been digitized or updated, or the attributes can be assigned at the time features are digitized or updated. The ID codes and values must be consistent to support summaries by geographic boundaries.

Accessibility will be attributed for each point [Fish_Access] at the time each point is placed or modified (Table 3). This classification is based on visible evidence from remote sensing as described in the spatial inventory methods above and is based on assumed accessibility for non-natal juvenile Chinook salmon.

The [Source] field will be used to identify the source used to identify and classify the feature and is a required field (Table 3). This will include aerial imagery, field survey, or data source references and should include a citation where possible. The [Notes] field is an optional field that can be used to capture observations or uncertainties that can be used to inform data QA/QC, summaries, and maintenance (Table 3). The [Validation] field is an optional field that can be used to note observations derived from field visits to the feature (Table 3). This may include notes on documented fish use or evaluations of connectivity and should include a reference to the source of information.

Table 3. Data structure for pocket estuary point data. *Denotes required fields for each feature.

Field	Type	Description	Values
FID*	Integer	Feature ID.	A unique value for each feature.
PE_ID*	Text string (length = 250)	Descriptive place name for pocket estuary or unique ID.	Descriptive place name for pocket estuary or unique ID.
Latitude*	Double	Coordinates for pocket estuary mouth.	Decimal degrees latitude of the pocket estuary mouth in WA State Plane South NAD 83 HARN (EPSG 2927)
Longitude*	Double	Coordinates for pocket estuary mouth.	Decimal degrees longitude (negative for west longitude) of pocket estuary mouth in WA State Plane South NAD 83 HARN (EPSG 2927).
SourceYear*	Integer	Year that the pocket estuary was identified based on the source used.	4-digit year – YYYY
Eval_Year*	Integer	Year that the record is being used to calculate metrics.	4-digit year – YYYY
CRW*	Text string (length = 50)	Name of Chinook Recovery Watershed.	CRW Name (see Table 4 for list of values)
LE_AreaName	Text string (length = 100)	Lead Entity Management Area	LeadEntityAreaName (see Table 4 for list of values)
WRIA	Integer	WRIA number the pocket estuary occurs within. Used to summarize and aggregate to WRIA, marine basin, and regional levels.	WRIA NR (Numbers 1-19, Not WRIA ID numbers) (see Table 4 for list of values)
Fish_Access*	Text string (length = 3)	Used to classify a feature as accessible to juvenile salmon.	1 – “YES” 2 – “NO”
Sources*	Text string (length = 250)	Description of sources used to ID or classify feature.	Aerial imagery, field survey, publication, data source, etc.
Notes	Text string (length = 250)	Notes to describe relevant information regarding values or observations, or QA/QC status.	Text string for notes. QA/QC status.
Validation	Text string (length = 250)	Notes describing any field validation of feature or classification.	Notes on documented fish use, verified accessibility, or other field verified information. Include citation where possible.

Table 4. List of values for Chinook Recovery Watershed names, WRIA NR IDs, and Lead Entity Area Names attributes that should be used when attributing data tables. This list also includes a cross-walk showing possible combinations of values given the fact that boundaries overlap in some areas.

Chinook Recovery Watershed	WRIA NR	Lead Entity Area Name
Nooksack	3	WRIA 1 Salmon Recovery Board Lead Entity
San Juan	8	San Juan County Community Development Lead Entity
Skagit	11	Skagit Watershed Council Lead Entity
Island	17	Island County Lead Entity
Stillaguamish	16	Stillaguamish River Salmon Recovery Co-Lead Entity
Snohomish	24	Snohomish Basin Lead Entity
Lake Washington / Cedar / Sammamish	31	Green, Duwamish, and Central Puget Sound Watershed (WRIA 9) Lead Entity
	31	Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Lead Entity
West Sound	30	West Sound Watersheds Council Lead Entity
Duwamish / Green	30	Green, Duwamish, and Central Puget Sound Watershed (WRIA 9) Lead Entity
	38	Green, Duwamish, and Central Puget Sound Watershed (WRIA 9) Lead Entity
Puyallup-White	44	Green, Duwamish, and Central Puget Sound Watershed (WRIA 9) Lead Entity
	44	Pierce County Lead Entity
	45	Pierce County Lead Entity
Nisqually	10	Nisqually River Salmon Recovery Lead Entity
South Sound	30	West Sound Watersheds Council Lead Entity
	41	WRIA 14 Salmon Habitat Recovery Committee Lead Entity
	45	Pierce County Lead Entity
	46	WRIA 13 Salmon Habitat Recovery Committee Lead Entity
Skokomish	30	Hood Canal Coordinating Council Lead Entity
	33	Hood Canal Coordinating Council Lead Entity
	41	Hood Canal Coordinating Council Lead Entity
Mid-Hood Canal	19	Hood Canal Coordinating Council Lead Entity
	19	North Olympic Peninsula Lead Entity for Salmon
	30	Hood Canal Coordinating Council Lead Entity
	33	Hood Canal Coordinating Council Lead Entity
Dungeness	19	Hood Canal Coordinating Council Lead Entity
	19	North Olympic Peninsula Lead Entity for Salmon
	20	North Olympic Peninsula Lead Entity for Salmon
Elwha	13	North Olympic Peninsula Lead Entity for Salmon
	20	North Olympic Peninsula Lead Entity for Salmon

Habitat Area Mapping:

For all features that were mapped and classified as accessible to non-natal juvenile Chinook salmon in the spatial inventory, habitat features will be mapped as polygons in GIS to support calculation of three of the Common Indicator metrics covered in this protocol (pocket estuary and embayment habitat that is accessible, extent of connected tidal wetlands, extent of functional tidal channels). These features will be mapped as polygons through remote sensing based primarily on available aerial imagery. Field surveys and additional remote sensing data may be used to refine mapping elements and products (e.g., LiDAR or topographic surveys), but these are not required to map the required habitat elements needed to calculate the Common Indicator metrics. Closed systems that are not accessible to non-natal juvenile Chinook salmon do not need to be mapped for habitat areas since these will not be reported for the Common Indicator metrics.

There are two required habitat types that are mapped in this protocol, which are a subset of additional optional habitat types (Figure 2). However, the total accessible area should be mapped initially to define the extent of tidal wetland and tidal channel features that will be mapped. Examples and detailed protocols can be found in Beamer et al. (2018), and an example of mapped features is provided in this report in Figure 3. All features described below will be digitized as polygons in GIS in WA State Plane South NAD 83 HARN (EPSG 2927) Coordinate Reference System (CRS) at a maximum scale of 1:1,000 using available aerial imagery (e.g., NAIP or Google Earth). The required features include the following elements and recommended approaches:

(1) **Total accessible area:**

This polygon will define the mapping extent for the pocket estuary and will contain the total area of subtidal and intertidal habitats associated with the feature from the mouth to the landward range of tidal fluctuation and flooding (Figure 2, Figure 3). The extent of total accessible area may be digitized as polygons based on supplemental data (e.g., PMEP tidal exceedance maps or LiDAR data) or from remote sensing interpretation of aerial imagery. **This polygon will contain the mapped tidal wetland and tidal channel features as described below, but the total accessible area metric will be calculated as the sum of mapped tidal channel areas and tidal wetland areas within each site.**

METHOD NOTES: The total accessible area should be mapped first as the mapped tidal wetland and channel features are subsets of this polygon feature. Beamer et al. (2018) indicated that subtidal and intertidal habitats were generally mapped at ≤ 3 -meters NAVD88 for North Sound. LiDAR or other high-resolution elevation data may be used to approximate the upper range of tidal influence to map the extent of accessible pocket estuary habitat using a fixed elevation datum. However, a fixed elevation cannot be used at a regional scale to definitively map the upper range of tidal influence due to natural variations in tidal forcing caused by surrounding topography and bathymetry. Therefore, mapped boundaries based on a fixed elevation contour should be corrected where needed using other remote sensing (e.g., aerial imagery interpretation, DOE (2014) shoreline photos), supplemental data sources (e.g., PMEP (2018) tidal exceedance boundaries), or field surveys to accurately map the extent of accessible habitat area.

(1) **Functional tidal channels:**

Mapping of tidal channel features is limited to unvegetated intertidal and subtidal channel, impoundment, and unvegetated low tide terrace features as determined from aerial imagery

interpretation (Figure 2, Figure 3). These mapped channels will include blind tidal channels or distributaries of small streams and will be limited to those channels that are connected to tidal flooding within the total accessible area delineated above. **The functional tidal channel area will occur within the total accessible area polygons as described above and should therefore be delineated after the total accessible area has been delineated.**

METHOD NOTES: For the purposes of this metric, functional tidal channel area is the area of tidally influenced unvegetated area that is accessible to non-natal juvenile Chinook salmon and is not determined by supplemental functional classifications described later in this document. Smaller channels within the vegetated marsh surface may be digitized as polylines that are buffered by a fixed 1-meter distance to create polygons of the smaller channels.

(2) **Connected tidal wetland area:**

The extent of connected tidal wetland habitat will be mapped as polygons of the vegetated marsh surface area as determined from aerial imagery interpretation and will exclude the mapped tidal channel area described above. Connected tidal wetlands will include vegetated tidal marsh, scrub shrub, forest wetland, intertidal wood, intertidal fill, and intertidal fill wood features as described in Beamer et al. (2018) within the range of tidal influence for all accessible habitats (Figure 2, Figure 3). **The tidal wetland area will occur within the total accessible area polygon as described above and should therefore be delineated after the total accessible area has been delineated.**

METHOD NOTES: The connected tidal wetland polygons can be derived by splitting the tidal channel area from the total accessible area polygon to avoid digitizing errors such as slivers or overlapping polygons that can introduce inaccuracies into the metric calculation.

Data Structure:

The tidal wetland area and functional tidal channels will be digitized and maintained as a single polygon dataset in GIS using the WA State Plane South NAD 83 HARN (EPSG 2927) Coordinate Reference System (CRS). This CRS is the WA State standard and conformance with this standard will ensure consistency across WRIAs and provide consistent reporting that can be used to develop and maintain a regional spatial database. This CRS also ensures that area metrics are consistently calculated based on feature geometries to support evaluation at regional scales. A list of attributes, descriptions, and values are provided in Table 4. Use of a consistent data structure will ensure that data can be synthesized at a regional scale to calculate and report the required Common Indicator metrics.

Each feature should be attributed with a unique place name or ID [PE_ID] so that the spatial inventory and mapped habitat features can be associated (Table 4). The IDs for the point (Table 3) and mapped polygon features (Table 4) should be the same, but each site should have only one unique ID. If multiple points are placed for a single feature (e.g., a transient system that closes and opens over time or a connectivity restoration site) for multiple evaluation years [Eval_Year], the IDs should be consistent between evaluation years. Fields for source year [Source_Year], evaluation year [Eval_Year], watershed [CRW, WRIA, and LE_AreaName], sources [Sources], notes [Notes], and validation [Validation] fields will be attributed as described in the spatial inventory methods (Spatial Inventory: Data Structure:).

The habitat type for the polygon feature [Habitat] is a required field and will include either tidal wetland area [Habitat = Tidal wetland] or tidal channel area [Habitat = Tidal channel] features (Table 4). Note that the final tidal channel and tidal wetland polygons will be separate features that will not overlap in the dataset, and therefore accessible area is derived as the sum of mapped tidal channel and tidal wetland area and will only be mapped preliminarily to define the extent of the tidal wetland and channel areas. Polygon areas [Area] will be derived in the CRS from the shape geometry as described in the GIS methods section (GIS Methods Detail:) and will be in acres. These polygon feature areas will be summed for each feature and watershed as described in the GIS methods detail metric calculation section (GIS Methods Detail:).

Table 5. Data structure for mapped polygon habitat areas. *Denotes required fields for each feature.

Field	Type	Description	Values
FID*	Integer	Unique feature ID	FID
PE_ID*	Text string (length = 250)	Descriptive place name for pocket estuary or unique ID.	Descriptive place name for pocket estuary or unique ID.
Source_Year*	Integer	Year that the pocket estuary was identified based on the source used.	4-digit year – YYYY
Eval_Year*	Integer	Year that the record is being used to calculate metrics.	4-digit year – YYYY
CRW*	Text string (length = 50)	Name of Chinook Recovery Watershed.	CRW Name (see Table 4 for list of values)
LE_AreaName	Text string (length = 100)	Lead Entity Management Area	LeadEntityAreaName (see Table 4 for list of values)
WRIA	Integer	WRIA number the pocket estuary occurs within. Used to summarize and aggregate to WRIA, marine basin, and regional levels.	WRIA NR (Numbers 1-19, Not WRIA ID numbers) (see Table 4 for list of values)
Habitat*	Text string (length = 20)	Polygon feature type.	1 – “Tidal wetland” 2 – “Tidal channel”
Area*	Double	Area of polygon in acres.	Area derived from geometry of feature in acres WA State Plane South NAD 83 HARN (EPSG 2927)
Sources*	Text string (length = 250)	Description of sources used to ID or classify feature.	Aerial imagery, field survey, publication, data source, etc.
Notes	Text string (length = 250)	Notes to describe relevant information regarding values or observations, or QA/QC status.	Text string for notes. QA/QC status.
Validation	Text string (length = 250)	Notes describing any field validation of feature or classification.	Notes describing any field validation of feature or classification.

GIS Methods Detail:

This section provides a basic description of the GIS workflow and tools used to map pocket estuary inventory point features and polygon habitat features for the required Common Indicator metrics. This section also describes the tools that can be used to calculate the required attributes for reporting the Common Indicator metrics. In many cases, multiple tools can be used to complete the same task in GIS. Therefore, the workflow presented in this section is intended as a guide to support GIS work and is not intended to prescribe a single required method or tool. The workflow, recommended tools, and metric calculation methods are described for both ArcMap and QGIS platforms.

Spatial Inventory:

(1) General mapping guidance:

- a. **Input layers.** Current or archived aerial imagery (e.g., NAIP, Google, or Bing) and oblique shoreline imagery (DOE 2014) as needed for remote sensing and interpretation; watershed boundary polygons (CRW, WRIA, or LE as required); and existing point file (if inventory is being updated) or new point file (see file creation below). NOTE: A preliminary spatial inventory has been created for the Puget Sound from available regional datasets. Input layers are required to be in Washington State Plane South NAD 83 HARN (EPSG 2927) coordinate system.
- b. **File creation.** If an existing spatial inventory is not used, a new file should be created to save the information to. The first step is to create the empty data file to store point feature data, including the attributes fields that will be affiliated with the feature. The file is required to be in Washington State Plane South NAD 83 HARN (EPSG 2927) coordinate system.
 - **QGIS** Layer > Create Layer > New Shapefile layer...
Input: Set *Geometry Type* to “point”
 - (i) Add fields for attributes using the *New Field* section.
 - (ii) See Table 3 for list of attributes and values.
 - **ArcMap** Data management Tools > Feature Class > Create Feature Class
Input: Set *Geometry Type* to “point”
 - (i) Data Management Toolbox > Fields > Add Field
 - (ii) See 2 for list of attributes and values

(2) Point delineation:

- a. **Objective.** Identify all pocket estuary and embayment features and place points at the seaward mouth or outlet for each identified feature (Figure 4).
- b. **Adding point features.** Points will be “heads- up digitized” on screen using the mouse to place points at the center of the mouth/outlet of each feature. See Mapping Methods section for Spatial Inventory for details on point placement.
 - **QGIS**
 - (i) Right-click the point feature layer > *Toggle editing*
 - (ii) [Digitizing Toolbar]> *Add point Feature*
 - (iii) Select location on map (at 1:1000 scale) to place point feature.
 - (iv) Attribute appropriate fields (see below and Table 3).
 - **ArcMap**
 - (i) [Editor Toolbar] > *Create Features*
 - (ii) [Create Features Window] Select point layer to edit
 - (iii) [Construction Tools Window] Select *Point*
 - (iv) Select location on the map (at 1:1000 scale) to place a point feature

(vii) Attribute appropriate fields (see below and Table 4).

(3) Attribution:

- a. See Table 3 for list of attributes and values.
- b. **Feature ID.** This field should contain an ID (e.g., place name or ID number) that is unique to that individual site, and this ID should remain consistent over time.
- c. **Latitude and Longitude.** Although stored in the feature geometry, it is preferable to have the latitude and longitude values stored as attributes of the feature decimal degrees to a minimum of the fifth signification figures.
 - **QGIS** Processing > Tool box > Vector table > Add X/Y fields to layer
Input: Feature points. Make sure the CRS field is set to 4326.
 - **ArcMap** Data management tools > Features > Add XY coordinates
Input: Feature Points.
Set: Environments > Output Coordinates to Geographic WGS CRS 4326.
- d. **CRW, WRIA, LE designation.** To designate each point with the proper CRW, WRIA and LE that it is located in, the feature points are intersected with the various boundary polygons.
 - **QGIS** Processing > Tool box > Vector Analysis > Intersection
Input: Point features, CRW / WRIA / LE polygons.
 - **ArcMap** Analysis toolbox > Overlay Toolset > Intersect
Input: Point features, CRW / WRIA / LE polygons.
- e. **Evaluation and source year.** These attributes will be used to identify the year of the source the feature was mapped from (e.g., photo year) AND the evaluation year (e.g., the year the Common Indicator metrics are being calculated for). These values will help keep track of changes in the data over time (e.g., due to natural changes, restoration, or development).
- f. **Fish access.** This attribute is based only on remote sensing interpretation, but may be informed by field surveys or local area knowledge. This attribute identifies whether or not non-natal juvenile Chinook can potentially access the site based on visible evidence of tidal connectivity between the site and Puget Sound (e.g., visible tidal channels or an open embayment mouth). Closed or inaccessible sites may and should also be digitized if possible, but these must be attributed with NO for fish access so that the Common Indicator metrics are calculated using accessible habitats only.
- g. **Sources.** This attribute provides a way to identify the sources that were used to identify the feature. This will primarily be an aerial imagery source and should provide enough detail so that someone can acquire the imagery for review later.
- h. **Notes.** This attribute will contain relevant notes of observations made during digitizing. This could be used to record notes on assumptions regarding connectivity (e.g., surface water connections, possible tidal barriers, or evidence of tidal fluctuations).
- i. **Validation.** This optional field can be used to record information on any ground truthing or field validations that have occurred at a site (e.g., confirmed tidal connectivity, tidal barriers, or fish use in addition to access). Reference to any external sources (e.g., publications should be cited if possible).

(4) Metric calculation:

- a. Select or filter for only features that were classified as accessible [Fish_Access] = "YES"
- b. Count of accessible features by CRW.

- **QGIS** Processing > Tool box > Vector Analysis > Count Points in Polygon
Input: Point features, CRW boundary polygons.
- **ArcMap** Analysis toolbox > Statistics Toolset > Summarize Within
Input: Point features, CRW boundary polygons.

Habitat Mapping:

(2) General mapping guidance:

- a. **Objective.** To map three core habitat extents for each identified feature; (1) accessible area, (2) tidal channel area, and (3) tidal wetland area.
- c. **Input layers.** Current or archived aerial imagery (e.g., NAIP, Google, or Bing) and oblique shoreline imagery (DOE 2014) as needed for remote sensing and interpretation; spatial inventory point file for locating sites to map; elevation data (e.g., LiDAR DEMs or PMEP Tidal Exceedance layers) as available or needed to map boundaries of tidal influence; existing polygon habitat layer(s) (if being updated) or new layer(s) (see file creation below). Input layers are required to be in Washington State Plane South NAD 83 HARN (EPSG 2927) coordinate system.
- d. **File Creation.** If creating a new layer, the first step is to create the empty data file to store polygon feature data, including the attributes fields that will be affiliated with the feature. A single polygon layer will contain the mapped features for accessible habitat area, tidal wetland area, and tidal channel area. Input layers are required to be in Washington State Plane South NAD 83 HARN (EPSG 2927) coordinate system.
 - **QGIS** Layer > Create Layer > New Shapefile layer...
Input: Set *Geometry Type* to “polygon”
 - (i) Add fields for attributes using the *New Field* section.
 - (ii) See Table 4 for list of attributes and values.
 - **ArcMap** Data management Tools > Feature Class > Create Feature Class
Input: Set *Geometry Type* to “polygon”
 - (i) Data Management Toolbox > Fields > Add Field
 - (ii) See Table 4 for list of attributes and values
- b. **Adding polygon features.** Polygon features will be “heads- up digitized” on screen using the mouse to place vertices. All polygons should be mapped at a maximum of 1:1,000 scale based on available data sets. See details below for each habitat type that will be mapped.
 - **QGIS**
 - (i) Right-click the polygon feature layer > *Toggle editing*
 - (ii) [Digitizing Toolbar]> *Add Polygon Feature*
 - (iii) Select location on the map (at 1:1000 scale) to place a vertex
 - (iv) Place vertices until the feature is adequately characterized
 - (v) Right click to complete the polygon
 - (vi) Attribute appropriate fields – see Table 4 for list
 - **ArcMap**
 - (i) [Editor Toolbar] > *Create Features*
 - (ii) [Create Features Window] Select polygon to edit
 - (iii) [Construction Tools Window] Select *Polygon*
 - (iv) Select location on the map (at 1:1000 scale) to place a vertex
 - (v) Place vertices until the feature is adequately characterized
 - (vi) Double click to complete the polygon
 - (vii) Attribute appropriate fields – see Table 4 for list

(3) Digitizing accessible area

- a. **Objective.** To map the extent of tidally influenced habitats that are accessible to non-natal juvenile Chinook salmon for **EACH** identified site. Only sites classified as accessible are mapped.
- b. **Adding polygon features.** Digitize a single polygon for each site that represents the total extent of accessible tidally influenced habitat associated with each identified feature.
 - **The accessible area polygon should be mapped first** as all other mapped features will be contained within and derived from this polygon.
 - **This single polygon for each site** will be used to create tidal wetland polygons after tidal channel features are mapped within the total accessible area as described below (see Figure 2 for flow chart of habitat types included in each habitat group, Figure 3 for an example map, and Beamer et al. (2018) for more details).
 - To map the accessible area polygon feature, digitize polygons to include the total subtidal and intertidal area contained by habitat forming feature(s) (e.g., spit or barrier beach) and the range of tidally influenced area that includes tidal wetlands and associated tidal channels that are accessible to non-natal juvenile Chinook salmon. Supplemental datasets (e.g., digital elevation models, oblique aerial imagery) and aerial imagery interpretation may be used to estimate the extent of intertidal and subtidal habitats contained within the feature.
 - The presence of tidal muting or blocking structures (e.g., levees, dikes, tide gates) should be used to define the extent of accessible area such that only the accessible area (tidally influenced area) is digitized.

(4) Digitizing tidal channel area

- a. **Objective.** To map the extent of tidal channel habitat that is accessible to non-natal juvenile Chinook salmon for **EACH** identified site. Only sites classified as accessible are mapped.
- b. **Adding polygon features.** Digitize polygon features for all identified tidal channel features within the accessible area polygon. Each identified site may contain multiple polygon features delineating tidal channel features. (see Figure 2 for flow chart of habitat types to map as tidal channel habitat, Figure 3 for an example map, and Beamer et al. (2018) for more details).
 - Small channels within vegetated marsh surfaces may be mapped as polylines and then buffered by a fixed width to create polygons for small channels. These will need to be merged to the tidal channel polygon layer to complete the dataset.
 - Tidal channels will be mapped based on evidence from aerial imagery, and will be mapped as the bankfull width of visible channels that occur within the vegetated tidal wetland extent.
 - Polygons for tidal channels should be digitized along the vegetated edge of channels within the vegetated tidal wetland extent.
 - Polygons for impoundments and unvegetated low tide terraces should be mapped with the tidal channel features, unless these are being mapped separately as described in the supplemental elements section.

(5) Deriving tidal wetlands from the tidal channels and total accessible area

- a. **Objective.** To derive the extent of tidal wetland habitat that is accessible to non-natal juvenile Chinook salmon for **EACH** identified site from the tidal channel area contained within the accessible area. Only sites classified as accessible are mapped.
- b. **Union Accessible Area with Tidal Channels Areas.** By merging the tidal channel areas with the accessible area, we neatly separate the accessible area into tidal channel areas, and those areas within the accessible area that are not tidal channels, which we'll classify as tidal wetlands.
 - **QGIS** (i) QGIS Processing Toolbox > Vector Overlay > *Union*
Input: Input Layer: Digitized accessible areas
Overlay layer: Digitized Tidal Channel Areas
(ii) Attribute appropriate fields for wetland area features
– see Table 4 for list
 - **ArcMap** (i) ArcMap Analysis Toolbox > Overlay > Union
Input: Input Features: Digitized accessible areas,
Digitized Tidal Channel Areas
(ii) Attribute appropriate fields for wetland area features
– see Table 4 for list

(6) Attribution:

- a. See Table 4 for list of attributes and values for the habitat area polygons.
- b. **PE_ID.** This field should contain an ID (e.g., place name or ID number) that is unique to that individual site, and this ID should remain consistent over time. This should be the same ID value assigned for the feature in the spatial inventory.
- c. **CRW, WRIA, LE designation.** To designate each polygon with the proper CRW, WRIA and LE that it is located in, the feature points are intersected with the various boundary polygons.
 - **QGIS** Processing > Tool box > Vector Analysis > Intersection
Input: Polygon features, CRW / WRIA / LE polygons.
 - **ArcMap** Analysis toolbox > Overlay Toolset > Intersect
Input: Polygon features, CRW / WRIA / LE polygons.
- d. **Evaluation and source year.** These attributes will be used to identify the year of the source the feature was mapped from (e.g., photo year) AND the evaluation year (e.g., the year the Common Indicator metrics are being calculated for). These values will help keep track of changes in the data over time (e.g., due to natural changes, restoration, or development).
- e. **Habitat.** Habitat type represented by each polygon.
- f. **Area.** Calculated habitat area for each polygon feature in acres WA Stage Plane South NAD 83 HARN (EPSG 2927).
 - **QGIS** Processing > Tool Box > Vector Geometry > Add Geometry Attributes
 - **ArcMap** Data Management Toolbox > Features > Add Geometry Attributes
- g. **Sources.** This attribute provides a way to identify the sources that were used to identify the feature. This will primarily be an aerial imagery source and should provide enough detail so that someone can acquire the imagery for review later.
- h. **Notes.** This attribute will contain relevant notes of observations made during digitizing. This could be used to record notes on assumptions regarding connectivity (e.g., surface water connections, possible tidal barriers, or evidence of tidal fluctuations).
- i. **Validation.** This optional field can be used to record information on any ground truthing or field validations that have occurred at a site (e.g., confirmed tidal connectivity, tidal barriers, or fish use in addition to access). Reference to any external sources (e.g., publications should be cited if possible).

(7) Metric calculation:

- a. Sum of Accessible area, tidal wetland area, and tidal channel area by CRW. Note that the metric calculation method described below will return the metrics based on the most recent Evaluation Year attributed in the datasets for each site. The method described below will need to be modified if different summaries are desired.

- **QGIS** Processing Toolbox > Vector Selection > *Select by expression*

Input: Input layer: Unioned Accessible Areas and Tidal Channels

Expression: "Eval_Year"=maximum("Eval_Year",group_by:="PE_ID"
,filter:="Habitat"='Tidal Channel')

Processing Toolbox > Vector Analysis > Basic Statistics for Fields

Input: Input Layer: Unioned Accessible Areas and Tidal Channels

Make sure the box for 'selected features only' is checked.

Repeat the process for 'Tidal Wetland' instead of 'Tidal channel' to get the sum of accessible Tidal wetland area.

Finally, to get the total sum of Accessible area, the areas of the tidal channels and tidal wetlands are added together.

- **ArcMap** Right-click on the polygon layer > *Open Attribute Table* > right-click on PE-ID Column > *Summarize...*

Input: Select a field to summarize: PE_ID

Choose one or more summary statistics...: expand "Eval_Year", check "Maximum"

Specify Output table: "PE_max_eval.dbf"

Right-click on polygon layer > Joins and Relates > *Join...*

Input: 1. Choose the field in this layer...: FID

2. Choose the table to join to...: PE_max_eval.dbf

3. Choose the field in the table...: OID

Join options: Select 'Keep only Matching Records'

Analysis Toolbox > Statistics > *Summary Statistics*

Input: Input Table: Joined polygon layer from above

Statistics Fields: Area

Case Field: PE_ID, Habitat

To get the total sum of Accessible area, the areas of the tidal channels and tidal wetlands are added together.

Alternatively, the data can be summarized in MS Excel to eliminate potential issues with joining .dbf files in ArcMap:

Analysis Toolbox > Statistics > *Summary Statistics*

Input: Input Table: PR polygon layer.

Statistics Fields: Area

Case Field: PE_ID, Habitat, Eval_Year

Save the output table, and load it into MS Excel. Use a “Pivot Table” to only summarize records relating the most recent Eval_Year for each PE_ID.

Supplemental Elements (Optional Recommendations):

In addition to the required elements described above, the identified features can also be attributed with additional information that can be used to support more detailed summaries and evaluation of the Common Indicator metrics. This section describes additional classifications that can be derived from remote sensing, supplemental data sources, or field evaluations that can be used to further attribute identified features. This section is intended to provide guidance on recommendations for these supplemental classifications to encourage regional consistency.

Identification of Small Stream Inputs:

Features identified in the spatial inventory can be classified based on the presence of small stream inputs. This can be determined based on remote sensing (e.g., visible presence of a small stream or delta fan in aerial imagery), supplemental data sources (e.g., NHD hydrography), or through local area knowledge or field survey. The presence of a small stream input is not a required qualifier for features considered in the protocol and Common Indicator reporting, as depressed salinities may occur within the site from other sources or processes (Beamer et al. 2018). Small stream input classifications should be simple and could include the following values;

- (1) **Yes** – aerial imagery, supplemental data sources, local area knowledge, or field surveys indicate the presence of a small stream input into the habitat, including ephemeral or intermittent streams;
- (2) **No** – no evidence of small stream input into the site.

Information regarding the source of the freshwater input classification can be recorded in the ‘notes’ field if additional explanation is warranted.

Classification of Functionality:

The current protocol recommendation considers all accessible habitats as functional, but functional classifications can be refined and developed to provide more detail for calculating and reporting these Common Indicator metrics. Beamer et al. (2018) provides a good framework for qualifying functionality based on a combination of remote sensing and field verification components that could be used to develop functional classifications. In that protocol, pocket estuaries are classified as functional if they are within a normal range of variability for reference sites (are within the statistical confidence limits of conditions derived from reference habitats); physical or biological processes not impaired by human causes (e.g., constructed structures, tidal muting structures, land uses, introduction of exotic species, etc.); and are not hydrologically muted, dredged or filled.

Functionality within the Common Indicator framework refers to “habitats that are performing, or capable of performing, in such a way that Puget Sound Chinook salmon recovery is aided and not impeded.” Features identified in the spatial inventory can be classified based on function from a combination of remote sensing, field survey, and local area knowledge or supplemental data sources. We recommend functional classifications and rational based on Beamer et al. (2018) as follows;

- (1) **Functional** – Pocket estuaries that have;
 - a. Tidal processes that are not restricted by artificial structures or modifications,
 - b. Conditions within normal range of variation for reference sites,
 - c. No evidence of dredging or fill,
 - d. No overwater structures present,
 - e. No shoreline armoring present, **AND**

- f. The pocket estuary is not classified as “Created” or “Modified.”
- (2) **Impaired** – Pocket estuaries that have;
- a. Structures present that mute tidal processes present but tidal connectivity is present,
 - b. Conditions are outside the normal range of variation for reference sites,
 - c. Dredge or fill present,
 - d. Overwater structures present,
 - e. Shoreline armoring present, **OR**
 - f. The pocket estuary is classified as “Created” or “Modified.”
- (3) **Closed** (Artificial OR Natural)– Potential pocket estuaries that have;
- a. Artificially blocked tidal connection (flood gates, dike, or levees) that blocks tidal connectivity to an area that would otherwise be subject to tidal flooding based on the elevation of the habitat (**Closed Artificial**), **OR**
 - b. Naturally blocked tidal connection (spit or barrier beach formation) that blocks tidal connectivity to an area that would otherwise be subject to tidal flooding based on the elevation of the habitat (**Closed Natural**).

Determining the normal range of variability relative to reference sites can be helpful in determining functionality. Analysis of allometric models and comparisons to functional reference sites for the same pocket estuary type and geographic region (e.g., aerial imagery analysis) can provide a framework for evaluating the function of site relative to reference sites. Note that allometric relationships for pocket estuary habitats are being developed (personal communication, Greg Hood, Skagit River System Cooperative) that are similar to those described in Hood (2015) for tidal wetlands associated with large river systems.

Tidal connectivity and muting may need to be determined through field validation, local area knowledge, or supplemental data sources as evidence from aerial imagery may not be sufficient to conclusively determine connectivity (Beamer et al. 2018). The current protocol assumes accessibility and connectivity based primarily on remote sensing evidence, but assessment of functionality as described here may be used to verify accessibility classifications from remote sensing.

Classification of Feature Types:

Features identified in the spatial inventory can be classified according to the classifications developed by Beamer et al. (2018), the RITT framework (Bartz et al. 2013), and Beach Strategies (CGS 2017). Shoreform classification schemes are summarized in (Table 1). This section provides more detail on the types of pocket estuary or embayment features that are considered in this protocol. This classification information can provide be used to refine evaluation or inventories of features based on different geomorphic characteristics. These classifications can be determined from remote sensing (e.g., aerial imagery), supplemental data sources (e.g., shoreform layers), local area knowledge, and field surveys. Classifications for pocket estuaries based on Beamer et al. (2018) include the following:

- (1) **Drift Cell Systems:** Pocket estuaries that are a subsystem of drift cell systems.
 - a. **Drowned channel lagoon** – *“a tidal or subtidal impoundment or coastal backwater formed landward of a barrier beach and into which a tidally inundated stream flows. Coastal longshore transport as well as small-scale fluvial processes and tides construct this geomorphology and associated habitats. A type of pocket estuary.”*

- b. **Longshore lagoon** – *“a tidal or subtidal impoundment or coastal backwater formed landward of a barrier beach. Longshore drift is the principal coastal process driving the formation of longshore lagoons. A type of pocket estuary.”*
- c. **Tidal channel lagoon** – *“low lying shoreline eroded by encroaching tides into tidal channels and tidal wetlands, across which a spit has formed seaward of the marsh to create a partially enclosed pocket estuary. A type of pocket estuary.”*
- d. **Tidal channel marsh** – *“tidal channel and marsh habitat complex formed by tides inundating low, broad valley floors along the shoreline.”*
- e. **Stream delta lagoon** – *“a tidal or subtidal impoundment or coastal backwater formed landward of a barrier beach and into which a stream delta and distributary channels flow. Coastal longshore transport as well as small-scale fluvial processes construct this geomorphology. A type of pocket estuary.”*
- f. **Created** – *“a coastal feature that resembles and functions ecologically as one of the previously listed geomorphic types, but which is known to be created by built structures or fill introduced into the nearshore. A type of pocket estuary.”*
- g. **Modified** – *“known to be a naturally formed pocket estuary historically, but its current condition has been so modified by human causes (e.g., dredging, intertidal filling, and armoring) that it does not resemble any of the natural geomorphic pocket estuary types. A type of pocket estuary.”*

(2) Rocky Shorelines:

- a. **Pocket beach estuary** – *“a tidal or subtidal impoundment or coastal backwater formed landward of a barrier beach within a pocket beach into which a stream flows. In the case of rocky shorelines on-shore erosion forms the barrier beach rather than longshore drift. For pocket beach estuaries tides and fluvial processes maintain a breach in the barrier beach and the resultant impoundment in low areas landward of the beach. A type of rocky pocket estuary.”*
- b. **Pocket beach lagoon** – *“a tidal or subtidal impoundment or coastal backwater formed landward of a barrier beach within a pocket beach along a rocky shoreline. In the case of rocky shorelines on-shore erosion forms the barrier beach rather than longshore drift, and tides maintain a breach in the barrier beach and the resultant impoundment in low areas landward of the beach. A type of rocky pocket estuary.”*
- c. **Pocket beach tidal marsh** – *“tidal channel and marsh habitat complex formed by tides inundating a pocket beach and eroding sediments deposited within the pocket beach by onshore erosion of the rocky shoreline. A type of rocky pocket estuary.”*
- d. **Created** – *“a coastal feature that resembles and functions ecologically as one of the previously listed geomorphic types, but which is known to be created by built structures or fill introduced into the nearshore. A type of rocky pocket estuary.”*
- e. **Modified** – *“known to be a naturally formed pocket estuary historically, but its current condition has been so modified by human causes (e.g., dredging, intertidal filling, and armoring) that it does not resemble any of the natural geomorphic pocket estuary types. A type of rocky pocket estuary.”*

In addition to the pocket estuary classifications developed by Beamer et al. (2018), protected low energy embayment features are also included in this protocol and may not fit the pocket estuary definitions and

classifications used in Whidbey Basin. These features can be classified generally as “**Embayments**” based on the shoreform types identified in the Beach Strategies.

Mapping of Habitat Subtypes:

Additional detail for the mapped habitat polygons may be desired given that the Common Indicator metrics only require mapping of total accessible habitat area, tidal wetland area, and tidal channel areas for each feature. Details on mapping additional habitat types within the delineated accessible area are described in Beamer et al. (2018) and include the following components;

- (1) **Tidal marsh**
- (2) **Tidal scrub shrub**
- (3) **Tidal forest**
- (4) **Tidal channel** (subtidal, intertidal, blind, and distributary channels)
- (5) **Impoundment**
- (6) **Low tide terrace**
- (7) **Intertidal fill**
- (8) **Intertidal fill wood**
- (9) **Tidal fill**
- (10) **Intertidal wood**

These optional habitat units can be mapped as polygons and then aggregated, summed, or dissolved as shown in Figure 2 to calculate and report accessible habitat area, tidal wetland area, and functional tidal channel area.

Next Steps and Future Directions:

Protocols for measuring change over time need to be developed for the pocket estuary Common Indicators. Some pocket estuary habitats are naturally transient and may open or close over time, and prograding or eroding delta fronts may naturally change the number, size, function, or form of accessible pocket estuaries in Puget Sound. In addition, development or restoration actions may also result in changes in the number, size, function, and form of accessible pocket estuaries in Puget Sound over time. Therefore, it is important that the inventory and mapping efforts be maintained over time so that both status and trends can be calculated. Although tracking recovery efforts can be quantified using PRISM project information, periodic assessments of pocket estuary conditions over time should be conducted. The pocket estuary spatial data structure has been setup to calculating change over time based on the source and evaluation year attributes.

To support the development of the spatial inventory of pocket estuary and embayment features and preliminary calculation of the pocket estuary and embayment count metric, a preliminary inventory was developed as part of this project based on available regional data sources. This preliminary spatial inventory needs to be reviewed and updated by Lead Entities and local area experts to support future calculation of the pocket estuary and embayment count metric and required habitat mapping associated with each identified pocket estuary and embayment feature.

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