



Spatial Analysis of Small Overwater Structures in Puget Sound

Puget Sound Restoration Fund | Gray McKenna

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Prepared for Puget Sound Restoration Fund

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Overview

This report describes the deliverables and analysis methods for the Impacts of Overwater Structures to Salmon and Kelp supporting GIS Analysis project, per the April 17, 2025 agreement between Puget Sound Restoration Fund and Gray McKenna. This analysis leverages the existing Puget Sound Overwater Structures spatial dataset (NOAA, 2023) and suite of additional existing datasets to evaluate the distribution, sizing, and spacing of Small Overwater Structures (SOWS) in Puget Sound at multiple spatial scales and the spatial relationship between SOWS and other important environmental data.

The Puget Sound Overwater Structures dataset contains over 12,000 polygons that represent overwater structures in Washington waters as digitized from multiple years of imagery (Oleksander et al. 2019, Beechie et al. 2023). This dataset was filtered down to 7,000 polygons that meet the definition of SOWS as described in Lambert et al. 2023. In task 1, the distribution, size, and spacing of SOWS features were analyzed at multiple spatial scales, including marine sub-basins, counties, drift cells, and shore type (shore form) units. In task 2, SOWS features were related with a suite of environmental spatial datasets, including shoreline geomorphology, sedimentation supply, shoreline armoring, nearshore vegetation, and forage fish usage.

The resulting new spatial datasets provide insights into the distribution of SOWS throughout Puget Sound and their relationship with geomorphological and biological characteristics of the marine environment. These datasets can inform future analyses of the impacts of Small Overwater Structures on marine habitats and species in Puget Sound.

In this report, field names (attributes) are italicized. Feature class, feature dataset, and geodatabase file names are enclosed in quotations. All analysis was conducted using ArcGIS Pro 3.4.3 and the associated ArcPy Python library (Esri, Redlands, CA). Analysis and results all use the NAD 1983 HARN State Plane Washington South projected coordinate system.

1. Geographical Summaries of SOW Statistics

Task: Relate overwater structure features with geographical unit identities of interest, and summarize counts, mean size, spacing, and density of small (<540m² total area) overwater structures (SOWS, dock/pier in NOAA dataset) within geographical units of interest. Results are reported in spatial data layers (feature class/shapefile) and raw .csv tables.

1.1 Data Deliverables

All data generated for this project is delivered as ArcGIS feature classes in a file geodatabase and .csv exports of attribute tables (Table 1).

Table 1. List of data deliverables associated with task 1.

File Name	Format(s)	Description
NOAA_SOWS_Filtered_GeoUnitIDs	.csv, feature class	NOAA OWS dataset, filtered to relevant definition of SOWS, with all geographical unit IDs spatially joined
OWS_2023updates_6_5_2023_GeoUnitIDs	.csv, feature class	Original NOAA OWS dataset with geographical unit IDS spatially joined
Subbasins_SOWS_Stats	.csv, feature class	WADNR Floating kelp subbasins with SOWS counts, areas, density, and spacing summarized within based on filtered NOAA SOWS dataset
Counties_SOWS_Stats	.csv, features class	WA State Counties with SOWS counts, areas, density, and spacing summarized within based on filtered NOAA SOWS dataset
DriftCells_SOWS_Stats	.csv, feature class	WDFW Beach Strategies Drift Cells with SOWS counts, areas, density, and spacing summarized within based on filtered NOAA SOWS dataset
Shoretypes_SOWS_Stats	.csv, feature class	WDFW Beach Strategies Shoretypes polygons with SOWS counts, areas, density, and spacing summarized within based on filtered NOAA SOWS dataset
SOWS_geographic_summary	.py	Python script that calculates SOWS statistics for input polygons, used to generate _Stats datasets
SOWS_data_dictionary	.xlsx	Lists and describes fields for all tables/feature classes delivered.

1.2 Analysis Methods

1.2.1 Data Preparation

The dataset “Puget Sound Over Water Structures 2021” (NOAA Fisheries 2023) was accessed on 2025-04-11. This spatial layer – shapefile “OWS_2023updates_6_5_2023” – was filtered to include only features smaller than 560 m² (*Area_M* < 560), and only features where *Structure Type* was equal to “Dock/Pier” or “Buoy/Float” and Structure Complexity was equal to “smalldock”, “marina”, or “float.” These filters were applied based on the definition of small overwater structures in WAC 220-600-380 as described in Lambert et al. 2022 & Lambert et al. 2023 (Table 2). In the 2023 version of the NOAA dataset used in this analysis, “buoy” was no longer a Structure Complexity type.

Table 2. SOWS definitions (left) from Lambert et al. 2023 and NOAA Overwater Structure classifications (right) from Beechie et al. 2023. Bolded values in the NOAA table right were included in this analysis.

SOWS Definitions (Lambert et al. 2023)		NOAA Overwater Structure classifications (Beechie et al. 2023)	
Structure type	Definition	Structure Type	Structure Complexity
Docks	Structures that are fixed to the shoreline but floating on the water.	Dock/Pier	smalldock (<560 m2), largedock (>560 m2),
Piers	Fixed piling supported structures.		marina , building, pilings, staircase
Floats (Rafts)	Floating structures that are moored, anchored, or otherwise secured in the water, but not directly connected to the shoreline.	Bridge	bridge, culvert, unknown
		Boat Rail	boat rail, boat ramp
Ramps	Gangways that connect a pier or shoreline to a float and provide access between the two. Pilings associated with these structures are timber, steel, or reinforced concrete, or composite posts that are driven or jacked into the bed.	Buoy/Float	float , buoy
		Aquaculture	net pen, shellfish, unknown
		Log boom	log boom

The NOAA dataset includes overwater structures digitized from multiple years of imagery, so in some cases, multiple overlapping features represent the same structure. To address this, the dataset was filtered to retain only the feature(s) from the most recent year of imagery for each structure. This was completed by using Summary Statistics (ArcGIS Pro 3.4, Esri, Redlands, CA) to calculate the maximum value of the field *Img_Year* for each unique *OWS_ID*, then retaining only features where *Img_Year* was equal to the maximum year for that structure. Any features that were marked as absent in the most recent imagery year (*F2021* == 0) were also removed from the dataset. Finally, the filtered dataset was evaluated for any remaining duplicated features using the *OWS_ID* field. Two features had the same *OWS_ID* (10902) but appeared to be unique features and were left as is. Several multipart features were left as is (*OWS_ID* 7664,

1568). Multiple instances of true duplicates, with identical geometries and attributes, were identified (*OWS_ID* 6487, 13440, 13441, 13442, 13443, 13446, 2469, 5104, 2182) and duplicates were removed. One feature had two slightly varying polygons (*OWS_ID* 1322) that mostly overlapped; only the one present in *F2013-2016* and *F2021* was retained for this analysis.

The complete filter logic is shown in **Figure 1**. The resulting filtered dataset contained 7002 features out of 12,987 original total features (Figure 2).

```
(Structure = 'Dock/Pier' OR Structure = 'Buoy/Float')  
AND Area_M < 560  
AND (Complexity = 'smalldock' OR Complexity = 'marina' OR Complexity = 'float')  
AND F2021 = 1  
AND Img_Year = MAX_Img_Year
```

Figure 1. SQL Query used to filter original NOAA overwater structures dataset to just small overwater structures relevant for this analysis.

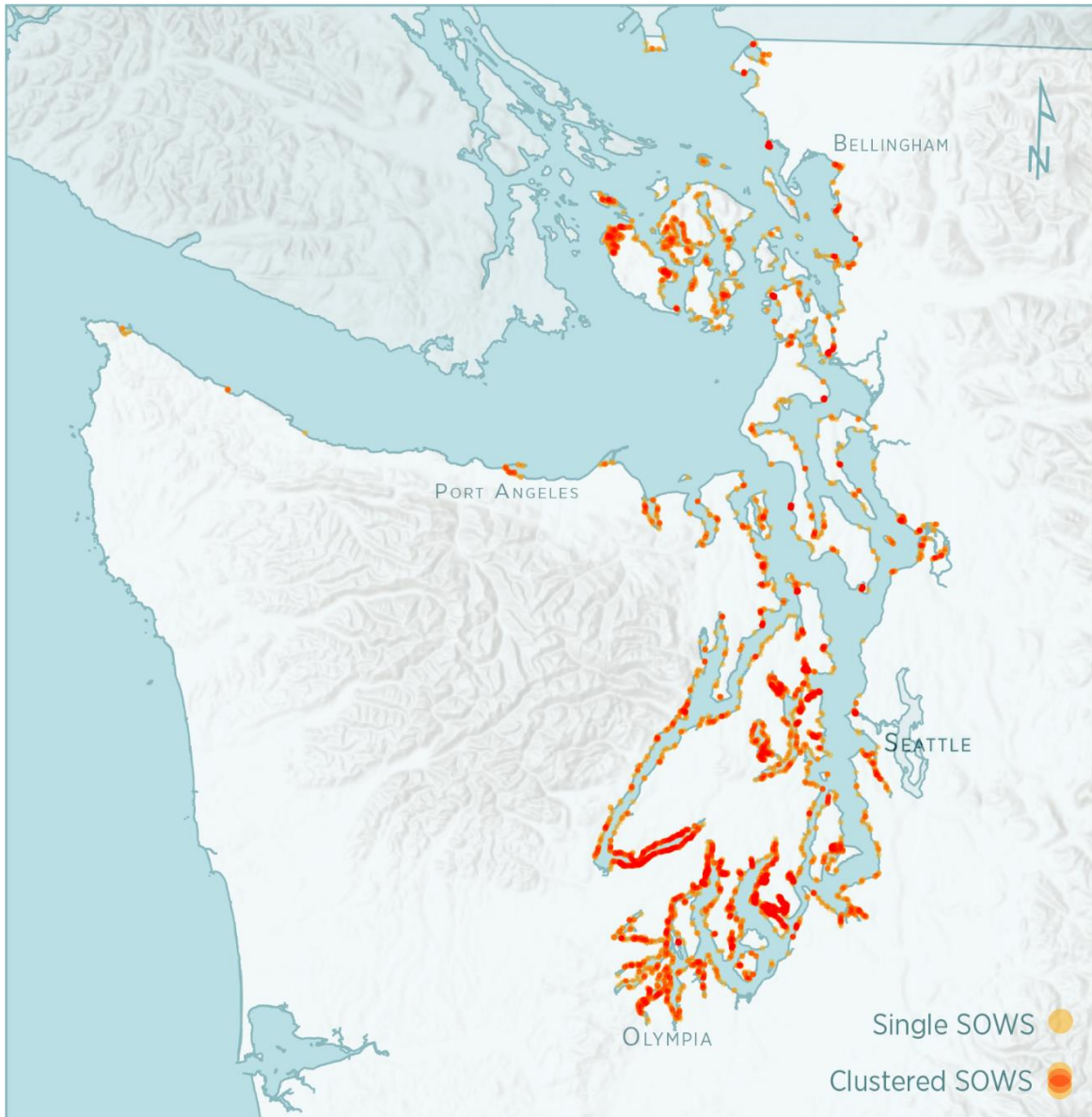


Figure 2. Map of Small Overwater Structures (SOWS) in Puget Sound based on filtering the NOAA Overwater Structures Dataset. Individual SOWS centroids are shown as orange dots, overlapping orange dots, indicating a higher density of SOWS, are shown in red.

1.2.2 Joining Geographic Unit IDs to SOWS Features

To enable future analysis of SOWS within particular geographic units of interest, a new version of the NOAA OWS layer was generated where each row/feature has the appropriate geographic unit identifiers assigned. This was completed for both the filtered version of the dataset, described above, and the original version of the dataset “OWS_2023updates_6_5_2023,” so that end users can apply different filters to define SOWS later if desired.

Four spatial datasets with geographic units were identified as being of interest to this project: Subbasins from the Floating Kelp Vital Sign project (Berry et al. 2023), Washington State Counties (WA DNR), and Beach Strategies Drift Cells and Shoretypes (WDFW). Spatial joins were

used to assign the geographic unit ID to each SOWS feature that fell within a given polygon for Subbasins, Counties, and Drift Cells. In some instances, SOWS fell outside of the polygons in question; for example, SOWS in the Duwamish waterway fall outside of the boundary of Central Puget Sound in the subbasin layer, which stops at the river mouth. These SOWS features have NULL values in those instances.

For Drift Cells, the feature classes NGF_DriftCellOnshore_400ft and NGF_DriftCellsAquatic were merged and dissolved on the field *DCName*; these polygons were used to associate the appropriate *DCName* attribute to each SOWS feature. There were some areas around Whidbey Island where the DriftCellsAquatic and DriftCellOnshore features were slightly offset (not touching) along the shoreline; to avoid potential errors in analysis from these internal gaps, the Onshore features were buffered by 25ft and overlaps were removed before merging and dissolving with the Aquatics feature class.

For Shoretypes, the only available dataset with the unique ID field *StypeID* was in the phase 2 beach strategy data (BeachStrat_SF line feature class in beach-strategies-phase2_2023.gdb, WDFW). SOWS centroids were snapped to the nearest Shoretype line from this dataset and the field *Stype_ID* was spatially joined to the SOWS features.

The outputs from this process are two feature classes and their corresponding .csv tables with overwater structure features that have the appropriate geographic unit IDs assigned. A description of each geographic unit ID field and its source is available in the data dictionary provided with this report.

1.2.3 Summarizing SOWS Statistics within Geographic Units

For each of the four geographic datasets described above, the count, size, density, and spacing of SOWS within each polygon of each input dataset above were calculated using the same workflow, scripted with the ArcPy module (Esri, Redlands, CA; McKenna 2025).

Given that Drift Cells and Shoretypes are line features, polygon features were used to represent the area associated with each line feature. For Drift Cells, the combined “NGF_DriftCellOnshore_400ft” and “NGF_DriftCellsAquatic” feature classes, as described in section 1.2.2, were used for this analysis. For Shoretypes, the *StypeID* field from the line features was joined to the “NGF_ShoretypesAquatic” and the “NGF_ShoretypesOnshore_400ft” feature classes; the latter was buffered by 25 ft with overlaps removed to fill the gaps between the Aquatics and Onshore feature classes. These were then merged and dissolved on the *StypeID* field, generating a polygon feature class where most Shoretype line features were represented by polygons. Due to some geometry mismatches within the source dataset between Shoretypes line and the Aquatics and Onshore polygons, not all lines are represented.

To calculate the number of SOWS within each geographic polygon of interest, the Summarize Within tool (ArcGIS Pro) was used to tally the total number of SOWS polygons within each geographic unit polygon. The result was stored in the field *sows_count*.

To calculate summary statistics for SOWS area within each geographic polygon, the Summarize Within tool was used to calculate the mean, sum, minimum, maximum, and standard deviation of the field *Area_M* for all SOWS features that fell within each polygon.

To calculate SOWS density, first the Summarize Within tool was used to calculate the total length of shoreline in kilometers within each geographic polygon, based on the dataset “Puget Sound marine shorelines 2018” (NOAA Fisheries 2018, accessed 2025-03-30). Then, the counts field calculated above was divided by the total shoreline length field to generate a density field of SOWS per km, *density_sows_km*. An example of the summary of SOWS area and density is shown in Figure 3.

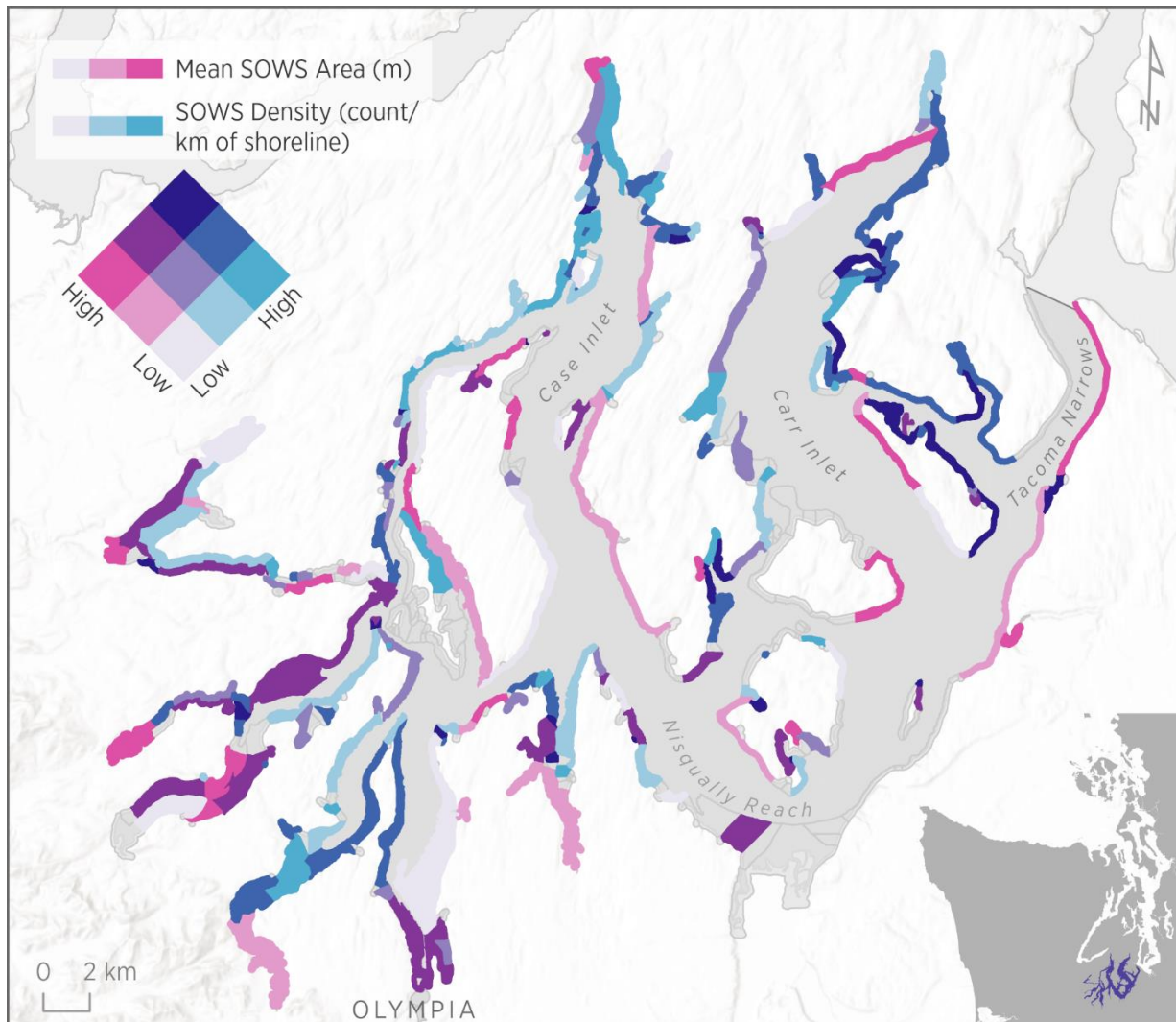


Figure 3. Bivariate visualization of SOWS Mean Area (pink) and SOWS Density (count per km of shoreline) (blue) for each Drift Cell in South Puget Sound. Drift Cells that contain SOWS with larger average sizes (Area) are shown with darker pink; Drift Cells with denser SOWS presence are darker blue; overlaps between these attributes are indicated by purple

To calculate the spacing between SOWS along the shoreline in each geographic polygon, first the centroid for each SOWS feature was generated. The centroids were then snapped to the nearest edge of the shoreline. The shoreline feature class used in this step of the analysis was the NOAA 2018 Puget Sound marine shorelines dataset, which generally follows the same contour as the ECY Coastal Atlas and ShoreZone at Ordinary High Water. The shoreline was split at each snapped centroid location with a search tolerance of 1 Foot to account for miniscule geometric offsets that can prevent proper splitting if a search tolerance is not applied. Split shoreline segments that crossed a boundary of the input geographic polygons were removed from the layer so that only the distance between SOWS that fell within the same geographic polygon, and not with SOWS in neighboring polygons, were considered for the analysis.

The length in kilometers for each of these subdivided shoreline segments that represent distance between SOWS was calculated using the Calculate Geometry tool. Finally, the Summarize Within tool generated the mean, sum, minimum, maximum for the length of the split shorelines. The resulting fields (*sows_dist_km*) describe the summary statistics of distance between SOWS centroids within each geographic polygon. This workflow is visualized in **Figure 3**.

For any polygons with no SOWS within them, null values fill each statistics column. If only 1 SOW was present in a polygon, spacing, mean, and standard deviation attributes are also NULL. A complete list of the new fields calculated for each new SOWS summary layer is presented in Table 3, and also in the data dictionary provided with this documentation.

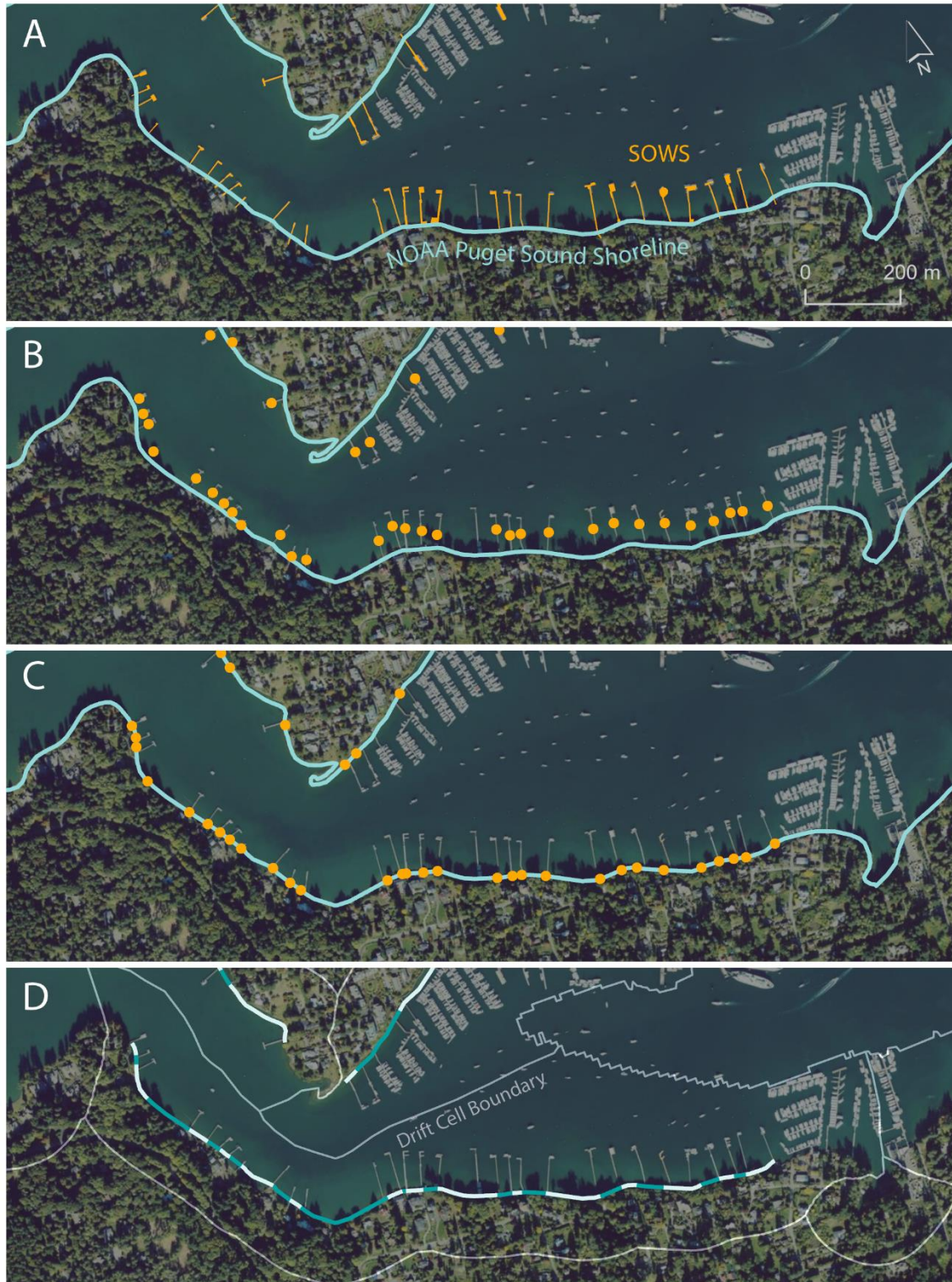


Figure 3. SOWS spacing analysis workflow example. A) SOWS polygons in orange and NOAA Puget Sound Shoreline (2018) in blue. B) SOWS centroids are generated. C) Centroids are snapped to the nearest shoreline edge. D) Shoreline is split at centroids into smaller line segments, shown in alternating light and dark blue. Only inner segments (those that do not cross summary polygon boundaries, Drift Cells in this example) are retained. Statistics are then calculated on the lengths of shoreline segments within each summary polygon.

Table 3. List of new fields generated for SOWS summary statistics for each geographic unit.

Name	Alias	Type	Description
mean_sows_Area_M	Mean SOWS Area (m)	Double	Mean of Area_M values for all SOWS that fall within feature; NULL values indicate no SOWS within feature
sum_sows_Area_M	Sum SOWS Area (m)	Double	Sum of Area_M values for all SOWS that fall within feature; NULL values indicate no SOWS within feature
min_sows_Area_M	Min SOWS Area (m)	Double	Minimum Area_M values for all SOWS that fall within feature; NULL values indicate no SOWS within feature
max_sows_Area_M	Max SOWS Area (m)	Double	Maximum Area_M values for all SOWS that fall within feature; NULL values indicate no SOWS within feature
std_sows_Area_M	Standard Deviation SOWS Area (m)	Double	Standard Deviation of Area_M values for all SOWS that fall within feature; NULL values indicate no SOWS within feature
sows_count	Count of SOWS	Long Integer	Total number of SOWS within feature
total_shoreline_km	Total Shoreline (km)	Double	Total length of shoreline (NOAA 2018) in kilometers that falls within feature
density_sows_km	SOWS Density (count/km)	Double	Count of SOWS within feature divided by Total Shoreline within feature
mean_sows_dist_km	Mean SOWS Spacing (km)	Double	Mean distance, centroid to centroid, of SOWS along shoreline in kilometers within feature
sum_sows_dist_km	Sum SOWS Spacing (km)	Double	Total distance, centroid to centroid, of SOWS along shoreline in kilometers within feature. Excludes the alongshore distance between most distal SOW and feature edge.
min_sows_dist_km	Min SOWS Spacing (km)	Double	Minimum distance, centroid to centroid, of SOWS along shoreline in kilometers within feature
max_sows_dist_km	Max SOWS Spacing (km)	Double	Maximum distance, centroid to centroid, of SOWS along shoreline in kilometers within feature
std_sows_dist_km	Standard Deviation SOWS Spacing (km)	Double	Standard deviation of distance, centroid to centroid, of SOWS along shoreline in kilometers within feature

2. SOWS Related to other Environmental/Ecological Spatial Data

Task: Relate overwater structure features with other environmental/ecological spatial data in Puget Sound. Results will be reported in spatial data layers (feature class/shapefile) and raw .csv tables.

2.1 Data Deliverables

Table 4. List of deliverable datasets associated with task 2.

File Name	Format(s)	Description
NOAA_SOWS_Filtered_EnvData	.csv, feature class	NOAA OWS polygon dataset, filtered to relevant definition of SOWS, with all environmental data fields joined
SOWS_data_dictionary	.xlsx	Lists and describes fields for all tables/feature classes delivered.

2.2 Analysis Methods

2.2.1 Data Preparation

The filtered version of the NOAA OWS dataset, described in 1.2.1, was used for this task. A suite of publicly available environmental data was acquired for this task, including datasets for coastal geomorphology, shoreline armoring, forage fish and sediment supply management recommendations, nearshore vegetation, and forage fish spawning data. Details for each data source and access information are described in the following section.

Most data was already in the appropriate projection, except WDFW forage fish data, which was projected from WGS84 to NAD 1983 HARN State Plane Washington South (WKID 2927) to match all the other data analysis conducted in this project.

2.2.2 Spatial Joins of SOWS to Environmental Datasets

To relate appropriate data fields from the input datasets, data was either spatially joined directly to the SOWS polygons from polygon sources or, in the case of line data, SOWS centroids, generated using the Feature to Point tool, were snapped to the nearest line using the Snap tool with a 1-km snapping tolerance and attributes were then spatially joined. Joined fields were compiled into a single feature class of SOWS polygons using the *OWS_ID* field, resulting in a polygon layer where each SOWS feature has all relevant environmental data associated, where it exists.

All data was QAQC'd by visually inspecting the resulting feature and ensuring the attributes joined had a logical spatial relationship with the source dataset. Any null data was double

checked to ensure it reflected a true null, where attributes could not be joined because no meaningful spatial relationship existed.

A summary table of the joined fields from each data source is presented in Table 5, as well as in the data dictionary provided with this report. Further descriptions on how this was accomplished for each dataset are presented below.

Shoretype (“Coastal Landform” ECY Coastal Atlas)

The dataset “Puget Sound Feeder Bluffs and Coastal Landforms” (Washington Department of Ecology, 2023) describes geomorphic type along a continuous shoreline. This dataset was accessed March 30, 2025, and the feature class “SEA_GEO_LandformsFeederBluffs” was used for analysis.

This dataset is a continuous shoreline. SOWS centroids were snapped to the nearest line segment, and then the attributes *Shoretype*, *Historic_FB*, *Landslide*, *Toe_Erosion*, *DCELL_NR*, and *CELL_TYP* were spatially joined from each line segment to the SOWS centroids. A handful of null values were returned where SOWS fell more than 1-km away from this shoreline, far up the Duwamish River.

Armored Shoreline (PSNERP Database)

The armored shoreline dataset used for this project was the “fd_armoring” feature class from the “T2_Shoreline_Alteration” feature dataset in the geodatabase “PS_PSNERB_CA_3.0.gdb” (Puget Sound Nearshore Restoration Project, 2012), accessed on April 30, 2025. It describes shoreline armoring presence or absence along the same shoreline used in the ECY Coastal Atlas, described above.

This dataset is also a continuous shoreline. SOWS centroids were snapped to the nearest line segment and the field *Armor_YN*, which contains a binary Yes (Y) or No (N) description of shoreline armoring, was spatially joined to the centroids. The field *GSU_ID*, a unique identifier in the PSNERP database, was also spatially joined to enable joining additional fields from the PSNERB database in the future.

Beach Strategies Phase 2 (WDFW)

SOWS were also spatially related to multiple feature classes in the Beach Strategies phase 2 dataset (Washington Department of Fish and Wildlife), accessed April 11, 2025. This dataset describes restoration and protection management recommendations for forage fish and sediment supply for drift cells, armored bluffs, and unarmored bluffs along the same shoreline as the ECY Coastal Atlas.

Of the three feature classes of interest in this dataset (“BeachStrat_AB”, “BeachStrat_DC”, “BeachStrat_UB”), only “BeachStrat_DC” is a continuous shoreline. The Armored Bluff lines and Unarmored Bluff lines are non-continuous but follow the geometry of the Drift Cell shoreline. SOWS centroids were snapped only to the “BeachStrat_DC”, and those centroids were used to create relationships between all three Beach Strategies linear feature classes. Spatial joins were used to append the attributes *FFS_DC_RestMgtRec*, *FFS_DC_ProtMgtRec*, *SS_DC_RestMgtRec*, *SS_DC_ProtMgtRec*, *SS_AB_RestMgtRec*, *FFS_AB_RestMgtRec*, *SS_UB_ProtMgtRec*, *FFS_UB_ProtMgtRec* from the Beach Strategies feature classes to the SOWS. In instances where either the Beach Strategies datasets had null values in these fields, or for Armored Bluffs and Unarmored Bluffs, where there was no intersection with the SOWS, null values were populated in the SOWS dataset. To enable relating this data to future versions of the Beach Strategies dataset, the unique identifier fields *DCName*, *ArmorID* and *UnArmorID* were also joined. After snapping to the Drift Cell shoreline, only 4% of SOWS centroids fell on an Unarmored shoreline segment and only 16% fell on an Armored shoreline segment.

The centroid snapping method here was preferable to directly relating SOWS polygons to the Drift Cell onshore/offshore polygons (as described in Section 1.2.3 of this report) because the Armored and UnArmored Bluff layers do not have similarly corresponding polygons delineating the area that they represent. Therefore, using the centroid snapping method was more consistent in establishing spatial relationships between SOWS and the three Beach Strategy Phase 2 datasets.

Eelgrass (Submerged Vegetation Monitoring Program, WA DNR)

The Submerged Vegetation Monitoring Program (SVMP) dataset, accessed on April 11, 2025, was used to relate information about eelgrass presence, distribution, and status (Dowty et al. 2022). The SVMP polygons span 1-km sections of shoreline from Ordinary High Water down to -6.1 m MLLW and report on eelgrass species presence as well as long-term and recent trends in eelgrass abundance, based on towed underwater video transect surveys.

To assess whether SOWS coincided with SVMP sites with eelgrass presence, SOWS features were spatially joined with the SVMP polygon dataset, “site_polygons” in the geodatabase “SVMP_distribution.gdb.” If any part of a SOWS polygon fell within an SVMP polygon, *veg_class*, *long_term_trend*, and *recent_trend* from SVMP were joined to the SOWS feature, as well as the fields *site_code* and *site_name* to enable the ability to link SOWS to future updates to the SVMP data, which retains unique *site_codes* across each data distribution. The fields *samp_status_disp* and *nyrs* were also included to contextualize the amount of eelgrass survey data informing the presence and trends fields.

88% of SOWS fell within the SVMP polygons; the 12% of SOWS for which no SVMP data was joined were primarily either onshore small docks shallow of the ordinary high water line or offshore docks or floats deeper than -6.1 m MLLW, or in a few instances in the San Juans, docks on very small islands not monitored by the SVMP program. Refer to the SVMP user guide (Dowty et al. 2022) for additional information about the Program and interpretation of the dataset.

Floating Kelp (Floating Kelp Indicator & Floating Kelp Linear Extent, WA DNR)

To establish the relationship between SOWS and floating kelp status and trends in Washington, SOWS features were spatially joined with both the Subbasins and Locations polygons from the Floating Kelp Vital Sign Indicator, which at the time of data access, included floating kelp survey data through 2022 (Berry et al. 2023). Data was accessed on April 11, 2025. Floating kelp status is reported at the subbasin level, and so for every SOWS that fell within a subbasin, the appropriate subbasin name, code, and floating kelp status fields were joined. 99% of SOWS were within a subbasin except for a handful of those that fell shallow of the marine water boundary, e.g. SOWS within the Duwamish River.

The Floating Kelp Indicator reports floating kelp trends at 173 locations around the state. Locations are smaller units within each subbasin. For SOWS that fell within a location boundary, the `unit_id`, `location`, and `species` fields were all joined, as well as the kelp bed area recent and long term trend fields and the associated notes. Only 10% of SOWS fell within an Indicator location. Of those SOWS that fell within an indicator location, 14 intersected with the Floating Kelp – maximum bed extent layer and 6 intersected with the Floating Kelp – bed extent in most recent year layer. For SOWS within a location, this was reported as 0 (no intersection) or 1 (intersection) in the respective fields; for those not within a location, this field is null.

Forage Fish Data (WDFW)

To evaluate the relationship between SOWS and forage fish, SOWS were analyzed against WDFW Forage Fish data (Washington Department of Fish and Wildlife, 2020), downloaded on April 12, 2025, and projected to Washington State Plane South to align with the rest of the data and analysis in this project. According to the metadata, this version of the dataset includes data through August 2019. SOWS features were intersected with “Herring_Spawning” and “Pre_spawner_Herring_Holding_Areas” polygon feature classes. If any part of a SOWS feature overlapped with these polygons, a 1 was returned, otherwise a zero was returned in the respective fields. 857 SOWS (12%) intersected with some portion of a herring spawning area, but no SOWS intersected with any pre-spawner holding areas.

SOWS centroid, snapped to the ECY shoreline as described above, were spatially joined to the Sand_Lance_Spawning and Smelt_Spawning line feature classes using a 25 ft tolerance to

account for minor offsets between the ECY shoreline and the forage fish lines. The centroids snapped to the ECY shoreline were used because that shoreline is continuous, so it can be used to establish the most appropriate alongshore location to associate with each SOWS and is coherent with the spatial relationships established with other datasets in this task. 332 SOWS centroids (5%), when snapped the nearest ECY shoreline edge, intersected with Sand Lance spawning habitat, and 2,841 (41%) snapped SOWS centroids intersected with Smelt Spawning habitat.

In the WDFW dataset, smelt spawning and sand lance spawning habitat are represented by line features that generally follow Ordinary High Water, but spawning habitat for these species is likely to occur between this Mean High Water or Mean Higher High Water and +5' to +7' MLLW (P. Dionne, WDFW, pers. comm.). Because of the method used to snap SOWS centroids to the shoreline, some offshore or onshore features may be associated with smelt or sand lance spawning habitat in this results dataset even though they do not technically intersect the intertidal habitat elevation where spawning is likely to occur. A detailed elevational analysis of SOWS is recommended for better untangling this relationship, but is beyond this scope of this report.

Table 5. List of data sources, field names, and descriptions for attributes joined to SOWS from other environmental datasets in Task 2.

Source	Name	Description
PNSERP	GSU_ID	index field that SOWS centroid is associated with
PNSERP	Armor_YN	armoring status (yes/no) of shoreline that SOWS centroid is associated with
ECY Coastal Atlas	Shoretype	definition of shoretype based on SOWS centroid location along shoreline
ECY Coastal Atlas	Historic_FB	Historic Feeder Bluff status based on SOWS centroid location along shoreline
ECY Coastal Atlas	Landslide	Landslide status based on SOWS centroid location along shoreline
ECY Coastal Atlas	Toe_Erosion	ECY Coastal Atlas Toe Erosion status based on SOWS centroid location along shoreline
ECY Coastal Atlas	DCELL_NR	ECY Coastal Atlas Toe Drift Cell Name based on SOWS centroid location along shoreline
ECY Coastal Atlas	CELL_TYP	ECY Coastal Atlas Toe Drift Cell Type based on SOWS centroid location along shoreline
ECY Coastal Atlas	DCName	Drift Cell Name that SOWS centroid is associated with
WDFW Beach Strategies Phase 2	FFS_DC_RestMgtRec	Drift Cell Forage Fish Restoration Management Recommendation for shoreline that SOWS centroid is associated with

Source	Name	Description
WDFW Beach Strategies Phase 3	FFS_DC_ProtMgtRec	Drift Cell Forage Fish Restoration Protection Recommendation for shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 4	SS_DC_RestMgtRec	Drift Cell Sediment Supply Restoration Management Recommendation for shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 5	SS_DC_ProtMgtRec	Drift Cell Sediment Supply Restoration Protection Recommendation for shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 6	ArmorID	ArmorID field from Beach Strategies database from shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 7	SS_AB_RestMgtRec	Armored Bluff Sediment Supply Restoration Management Recommendation for shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 8	FFS_AB_RestMgtRec	Armored Bluff Forage Fish Restoration Management Recommendation for shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 9	UnArmorID	UnArmorID field from Beach Strategies database from shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 10	SS_UB_ProtMgtRec	UnArmored Bluff Sediment Supply Protection Management Recommendation for shoreline that SOWS centroid is associated with
WDFW Beach Strategies Phase 11	FFS_UB_ProtMgtRec	UnArmored Bluff Forage Fish Protection Management Recommendation for shoreline that SOWS centroid is associated with
WA DNR SVMP	site_code	site_code for SVMP polygon that SOWS falls within
WA DNR SVMP	site_name	site name for SVMP polygon that SOWS falls within
WA DNR SVMP	veg_class	vegetation class (Eelgrass species presence/absence) for SVMP polygon that SOWS falls within
WA DNR SVMP	long_term_trend	long term trend in eelgrass for SVMP polygon that SOWS falls within
WA DNR SVMP	recent_trend	recent trend in eelgrass for SVMP polygon that SOWS falls within
WA DNR SVMP	samp_status_disp	eelgrass sampling status for SVMP polygon that SOWS falls within
WA DNR SVMP	nyrs	number of years of eelgrass sampling data for SVMP polygon that SOWS falls within
WA DNR Floating Kelp Vital Sign	sub_basin_code	sub basin code from Floating Kelp Vital Sign that SOWS falls within

Source	Name	Description
WA DNR Floating Kelp Vital Sign	sub_basin_name	sub basin code from Floating Kelp Vital Sign that SOWS falls within
WA DNR Floating Kelp Vital Sign	status	status of Floating kelp for subbasin that SOWS falls within
WA DNR Floating Kelp Vital Sign	unit_id	unit id for Floating Kelp Vital Sign location polygon that SOWS falls within
WA DNR Floating Kelp Vital Sign	location	location for Floating Kelp Vital Sign location polygon that SOWS falls within
WA DNR Floating Kelp Vital Sign	species	species present within Floating Kelp Vital Sign location that SOWS falls within
WA DNR Floating Kelp Vital Sign	final_trend_bed_long	long term trend in floating kelp bed area for location that SOWS falls within
WA DNR Floating Kelp Vital Sign	final_trend_bed_recent	recent (5 yr) trend in floating kelp bed area for location that SOWS falls within
WA DNR Floating Kelp Vital Sign	final_trend_notes_bed_long	comments on long term trend in floating kelp bed area for location that SOWS falls within
WA DNR Floating Kelp Vital Sign	final_trend_notes_bed_recent	comments on recent (5 yr) trend in floating kelp bed area for location that SOWS falls within
WA DNR Floating Kelp Vital Sign	kelp_bed_max_int	For SOWS that fall within a Floating Kelp Vital Sign location polygon, indicates whether SOWS intersects the maximum extent kelp bed polygon (0 = no, 1 = yes)
WA DNR Floating Kelp Vital Sign	kelp_bed_most_recent_int	For SOWS that fall within a Floating Kelp Vital Sign location polygon, indicates whether SOWS intersects the most recent extent kelp bed polygon (0 = no, 1 = yes)
WDFW Forage Fish	Herring_Spawning	Indicates whether SOWS feature intersects Herring Spawning habitat falls within Sand Land Spawning habitat (0 = no, 1 = yes)
WDFW Forage Fish	Sand_Lance_Spawning	Sand Lance Spawning rt eelgrass for Spawning polygon that SOWS falls within
WDFW Forage Fish	Smelt_Spawning	Indicates whether SOWS centroid, snapped to shoreline, falls within Sand Land Spawning habitat (0 = no, 1 = yes)

2.3 Notes on Data Usage

Many of the environmental and biological datasets of interest here use line features to describe characteristics of the shoreline rather than polygons delineating all the boundaries of the phenomenon that they represent. This presents inherent challenges in creating meaningful spatial relationships between polygon representations of SOWS with these linear representations of habitat characteristics. To create most of those relationships, the centroids of SOWS were snapped to the most appropriate continuous shoreline and then attributes of linear features that SOWS centroids coincided with were joined back to SOWS features. This may result in instances where a SOWS actually falls at a higher or lower elevation than the linear feature intends to represent, but receives the attributes of the line feature nonetheless. A future analysis might assess the tidal elevation of all SOWS features and define the tidal elevation of all the linear features in order to create more precise spatial relationships. Recent high-resolution bathymetric models in the MLLW datum (e.g. Cowdrey 2024) may make this feasible, however, working with these large datasets and researching the appropriate tidal elevations for the source dataset was beyond the scope of this report.

References

- Beechie, Timothy J. et al. (2023). Puget Sound Habitat Status and Trends 2023 Update: Delta Habitats and Overwater Structures. <https://doi.org/10.25923/m767-tw97>
- Berry H., W.W. Raymond, D.C. Claar, P. Dowty, E. Spaulding, B. Christiansen, L. Ferrier, J. Ledbetter, N. Naar, T. Woodard, C. Palmer-McGee, T. Cowdrey, D. Oster, S. Shull, T. Mumford, M. Dethier. (2023). Floating Kelp Monitoring in Washington State: Statewide Summary. Washington Department of Natural Resources report. https://www.dnr.wa.gov/publications/aqr_nrsh_kelp_statewide_summary_report_23.pdf
- Dowty, P., Ferrier, L., Christiaen, B., Gaeckel, J. and Berry, H. (2022). Submerged Vegetation Monitoring Program: 2000-2020 Geospatial Database User Manual. Olympia, WA: DNR Nearshore Habitat Program. https://www.dnr.wa.gov/publications/aqr_nrsh_svmp_database_user_manual.pdf
- Lambert Max R. et al. (2023) *Do small overwater structures impact marine habitats and biota?* Pacific Conservation Biology. doi:10.1071/PC22037
- McKenna, G. (2025) *sows-kelp-gis* (v1.0). [Source Code]. Github. <https://github.com/graymckenna96/sows-kelp-gis>
- NOAA Fisheries. (2018). *Puget Sound marine shorelines 2018* [Shapefile]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. <https://www.fisheries.noaa.gov/resource/map/salmon-habitat-status-and-trend-monitoring-program-data>
- NOAA Fisheries. (2023, July 3). *Puget Sound over water structures 2021* [Shapefile]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. <https://www.fisheries.noaa.gov/resource/map/salmon-habitat-status-and-trend-monitoring-program-data>
- Puget Sound Nearshore Ecosystem Restoration Project. (2012). *Geospatial methodology used in the PSNERP comprehensive change analysis of Puget Sound*. Washington State Geospatial Data Archive. https://wagda.lib.washington.edu/data/geography/wa_state/wageol/metadata/PSNERP%20CA%20GEOSPATIAL%20METHODOLOGY.pdfwagda.lib.washington.edu+1Salish+Sea+Restoration+1
- Stefankiv, Oleksandr et al. (2019). *Salmon Habitat Status and Trends: Monitoring Protocols*. <https://doi.org/10.25923/w8y2-vj33>

Washington Department of Ecology (2023). *Puget Sound Feeder Bluffs and Coastal Landforms*.
<https://geo.wa.gov/datasets/waecy::puget-sound-feeder-bluffs-and-coastal-landforms>

Washington Department of Fish and Wildlife. (2020). *Beach Strategies geodatabase* [Geospatial dataset]. <https://geodataservices.wdfw.wa.gov/hp/beach-strategies/>

Washington Department of Fish and Wildlife. (2020). Forage Fish Spawning Surveys. [Geospatial Dataset] <https://data-wdfw.opendata.arcgis.com/maps/11a6019b3f40448d8cdaf22b12a2964f/about>

Washington State Department of Natural Resources. (n.d.).
WADNR_PUBLIC_Cadastre_OpenData [Feature service]. Retrieved April 16, 2025, from
https://gis.dnr.wa.gov/site3/rest/services/Public_Boundaries/WADNR_PUBLIC_Cadastre_OpenData/FeatureServer

Cowdrey, T. (2024). Washington State USGS CoNED MLLW Bathymetric DEM [Data Set].
Washington State Department of Natural Resources, Nearshore Habitat Program.
https://gis.dnr.wa.gov/image/rest/services/Aquatics/WA_bathymetry_CoNED_MLLW/ImageServer