

**MEMO**           **16 Jan 2014**  
**FROM**       **Paul Cereghino, NOAA Restoration Center**  
**TO**           **Walter Heady, The Nature Conservancy**  
                  **Jen Kassakian,**  
**RE**           **Estuary Inventory in Puget Sound**

Following the January 14-15 symposium, I thought it would be useful to write down my personal opinions about the resources available to conduct an inventory of non-river delta sub-estuaries of Puget Sound, and how such work could be conducted to support restoration and protection planning.

### **Background**

Simenstad et al. 2011 presents [a geodatabase currently housed at WAGDA](#) that describes Puget Sound shorelines and provides the basis for a series of interagency analyses intended to inform nearshore ecosystem management in Puget Sound. These data and analyses include features that could be used to define an inventory of sub-estuaries in Puget Sound from Cape Flattery to the Canadian Border and all islands within.

The challenge is twofold: 1) knowing what objects to designate as a sub-estuaries, and 2) at what scale to group those objects given that Puget Sound contains estuaries within estuaries within estuaries.

One of the fundamental communication challenges in ecosystem restoration is to describe the location and extent of past, ongoing, and completed work. Most restoration and protection projects are currently described by dots and project metrics. PMEP work could help define a spatial organization for Puget Sound that has utility for local conservation planning. Alternately a rapid paraphrasing of existing work could likely satisfy some of PMEP's objectives, while adding nothing to existing work.

### **Geospatial resources and their issues**

The PSNERP data explicitly organize information into 812 drift cells (called Shoreline Process Units). The Puget Sound basin, from mountain divides to a depth of 10m off shore has been divided into drainage units that align with boundaries primarily associated with change in drift cell function. The shoreline is a single line (hereafter called the "shore-line"), divided into segments to describe estimated direction of net sediment drift and into units based on a geomorphic shoreline land form classification. This shore-line is based on previous work by DNR (ShoreZone inventory) and is an approximation of ordinary high water, and includes some representation of *most* coastal features. Four embayment shoreforms are described in the PSNERP shore-line line work, [as described by Shipman 2008](#): Open coastal inlet, barrier estuary, barrier lagoon, closed lagoon marsh.

Drift cells frequently overlap at zones divergence and convergence. Embayments and stream mouths are represented as line segments and points respectively, and are thus embedded within one or often two overlapping drift cells. For example, most large coastal inlets occur in a zone of no-appreciable-drift located at the intersection of two shoreline process units.

PSNERP found a large number of embayment features that are not described by the ShoreZone shore-line. These are referred to as "off-line features". These features, typically barrier lagoons and estuaries are captured as attributes of the associated shoreline segment, typically a barrier beach. These off-line features are described in terms of type and shoreline length, but are not represented by lines.

Puget Sound tidal hydrology is complex. A single elevation cannot be used to consistently describe the extent of tidal flooding. Historical and current wetland polygons, derived from digitized Geodetic Survey maps and NWI respectively, are available and commonly overlap the "shore-line". Wetland polygons are not associated with specific shoreline segments—thus the embayment shorelines and their wetlands are relatively independent. Wetland

area is summarized at the process unit level, and wetland area and loss of wetland area has been used as indicators of ‘service potential’ and ‘degradation’ at this scale. A average process unit is around 4km long usually contains 0 to 2 on-line or offline embayment features and a couple creek mouths. There is wide variation, with some process units stretching for 10s of km.

A parallel [study by McBride et al 2009](#) describes the same shore-line using a different geomorphological classification, which includes additional categories assumed to be important for fish use. Several shoreline types could be described as estuary features are included that are not considered by the PSNERP work. For example McBride et al identifies pocket beach estuaries in rocky shorelines, and drowned streams as a specific class of embayment. While conceptual cross walks between Shipman and McBride have been completed, there has been no spatially explicit comparison of these two data sets.

[Cereghino et al 2012](#) uses PSNERP and some McBride data to define a population of 260 embayments that exist relatively independent of beach functions, as well as a population of beach process units that contain embayments, and uses cluster analysis to divide these systems into groups based on their size and complexity (see sections 3.3 and 3.4 for the results of this analysis.)

Further biotic data, like the distribution of fringing eelgrass beds are available in [the ShoreZone Inventory](#), but have not been integrated into these analyses.

Thus the following line segments associated with the Puget Sound shore-line could all be considered to varying degrees as “sub-estuaries” components of Puget Sound:

| Description                | Count | Notes                                                                                                                                                                                                                                                                     |
|----------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Delta Process Units        | 16    | Polygons defined by Simenstad et al 2011. They overlap with adjacent shoreline process units. Additional characterization work is underway for systems targeted for large scale restoration (primarily Nooksack, Skagit, Stillaguamish, Snohomish, Nisqually, Skokomish.) |
| Inlet Process Units        | 260   | These are shoreline segments with either OCI or BE where McBride indicates drowned stream valley. These are embayment features where their structure is believed to be <i>relatively</i> independent on barrier beach formation.                                          |
| PSNERP on-line embayments  | 416   | OCI, BE, BL, CLM. These are segments that are part of the DNR Shore-line, and are protected low energy shorelines, with no-appreciable-drift. 48 out of 416 historical segments are now ‘artificial’ landforms.                                                           |
| PSNERP off-line Embayments | 481   | BE, BL, CLM.<br>299 out of 481 objects currently exist with the remainder having been completely filled.                                                                                                                                                                  |
| McBride Segments           | ??    | There has been no analysis as to how these segments relate to the                                                                                                                                                                                                         |

|                          |      |                                                                                                                                                                                                                                                                                                                                   |
|--------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          |      | PSNERP data. The presence of drowned stream channel segments was used to identify inlet process units by Cereghino et al to support strategy development. 27 pocket beach estuaries mostly located in San Juan Islands have been advocated as important for San Jan ecosystems.                                                   |
| Stream Mouth Points      | 2810 | 286 of these are located within delta 2524 are located along shorelines outside of delta process units. An unknown proportion of these are associated with some other kind of embayment feature. These points could be developed as data sources to describe an area of drainage or association with anadromous fish populations. |
| Shoreline Process Units  | 812  | 812 overlapping drift cell units have been identified. Rou                                                                                                                                                                                                                                                                        |
| Embayment Strategy Sites | 628  | This is a subset of the 628 shoreline process units which contain either historically or currently a Simenstad embayment line segment. A variety of attributes describing the relative importance of the drift cell to providing embayment functions are associated with each unit.                                               |
| ShoreZone Segments       | ??   | Biological features of shorelines have been described by DNR including fringing eelgrass beds and macroalgae which provide estuarine nursery functions in many portions of Puget Sound.                                                                                                                                           |

### **Suggestions**

The PMEP estuary definition is insufficiently precise to recommend a specific method of identifying an inventory unit. It fails to ascribe any threshold for the scale of the freshwater input, the area of tidal wetland, some specific salinity regime, or the presence of some geomorphic attribute that describes the end of the estuary and the beginning of the sea.

In addition Puget Sound has a continuum of estuarine wetland complexes from individual embayment features or stream mouths, to bays composed of several of these features, to inlets containing multiple bays, to regions containing multiple inlets. There is no generally agreed upon objective basis for grouping Puget Sound estuarine features into some unit consisting of multiple nearby shoreline features. There are many different ways of describing 'places' but the edges are always fuzzy.

Because of this, the sub-basin unit developed by PSNERP and the Puget Sound Partnership may provide the best method of grouping estuarine function between individual shoreline segments, and all of Puget Sound. The PSNERP sub-basins were used in Section 3.3 of Schlenger et al 2011 which discusses patterns of degradation, and

Section 4.3 of Cereghino et al. 2012 which identifies potential restoration targets by sub-basin. There may be some logic to dividing the central basin into east and west shorelines, however that logic leads to many other divisions that also have merit.

Puget Sound sub-estuaries features are identified by a mixture of polygons, lines and points. However these data provide a poor basis for describing management units or locating the efforts underway aimed at changing those conditions. Some effort to describe a population of sub-estuary sites would support characterization of these sites, and allow for a more systematic inventory of restoration and protection work.

I would anticipate the following tasks could lead to an integration of existing regional data that would greatly improve our ability to inventory, locate, and describe management strategies for conservation of sub-estuary elements in Puget Sound.

**Task 1 – identify the polygons, lines and dots that represent “estuarine components”.** This has been largely described above.

**Task 2 – Define a polygon that appropriately describes each of these features.** This would be most viably done using some kind of buffer function. We would need to define buffers or thresholds that describe the upland, waterward, and along-shore extent of an estuary feature which is currently a dot or line segment. PSNERP currently uses a 200m landward buffer to describe a shoreline zone, and a 10m depth interval as a surrogate for the photic zone. Definition of a long shore extent is most problematic.

**Task 3 – Aggregation of polygons into management units.** Some set of criteria would be necessary to group individual estuary feature polygons that are overlapping or nearby into complexes of polygons. These criteria may allow for more than one level of aggregation. Aggregation of features into an estuarine management unit could be based on cultural, ecological or geophysical criteria. A clear intent for aggregation would need to be defined based on the desired management outcome. The purpose of a management unit would be to support cohesive conservation planning within an ecologically meaningful system, while responding to both cultural perceptions of place, and the legal jurisdictions of management agencies (See Figure 1).

**Task 4 – Characterize management units and associate with existing Process Units, wildlife observations, and Watersheds.** A wide range of data both geophysical, biological, and anthropogenic change, are available to describe the character of sub-estuary polygons. Fully attributed polygons could support multi-variate analysis that would provide a management context for each polygon, and by using some kind of cluster analysis, we could better define management cases.

I recognize that this effort is beyond the scope of PMEP activity, but I thought that describing a potentially useful scope of planning work, may help the PMEP team decide how to position their work to support what I believe to be a current local planning gap.

**Figure 1 – Two maps of South Sound showing estuarine features nested within estuarine features.** South Sound provides the most complicated example of the potentially fractal geometry in estuarine networks. In my opinion, a development of the Puget Sound System would need to address these kinds of patterns.

