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Jefferson County Marine Shoreline Restoration Prioritization: Summary of Methods

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Summary of Methods

The purpose of the present paper is to describe our approach to developing a GIS-based restoration prioritization tool for the update of the Shoreline Master Program (SMP) for Jefferson County, Washington. Washington State jurisdictions are updating SMPs, and a significant feature of the guidelines is the requirement that local governments include within shoreline master programs a *real and meaningful* strategy to address restoration of shorelines (Washington Administrative Code, WAC 173-26-186(8)). The state guidelines emphasize that any *development must achieve no net loss of ecological functions.* The guidelines set as a goal using restoration *to improve the overall condition of habitat and resources,* and make *planning for and fostering restoration* an obligation of local government (Table 1).

Table 1. Washington Administrative Code.

From WAC 173-26-201(2)(c):
Master programs shall also include policies that promote restoration of ecological functions, as provided in WAC 173-26-201 (2)(f), where such functions are found to have been impaired based on analysis described in WAC 173-26-201 (3)(d)(i). It is intended that local government, through the master program, along with other regulatory and nonregulatory programs, contribute to restoration by planning for and fostering restoration and that such restoration occur through a combination of public and private programs and actions. Local government should identify restoration opportunities through the shoreline inventory process and authorize, coordinate and facilitate appropriate publicly and privately initiated restoration projects within their master programs. The goal of this effort is master programs which include planning elements that, when implemented, serve to improve the overall condition of habitat and resources within the shoreline area of each city and county.

Study Area

Jefferson County is located in western Washington stretching from Hood Canal across the Olympic Mountains to the Pacific Ocean (Figure 1). It borders the Straight of Juan de Fuca, where it meets Admiralty Inlet, receiving marine waters from the Pacific Ocean and freshwater input from several large river systems in Hood Canal. This marine shoreline prioritization framework applies to East Jefferson County, Washington; the marine shorelines in West Jefferson County consist of Federal and Tribal lands not subject to Jefferson County jurisdiction under the SMA.

The shorelines that are included in this assessment can generally be characterized as *partially exposed, semi-protected* or *protected* according to Dethier (1990). These marine shorelines are grouped into two contiguous management areas, termed Water Resource Inventory Areas (WRIAs), with similar geomorphological conditions. First, WRIA 17 encompasses most of East Jefferson County, including shorelines on the Strait of Juan de Fuca, Admiralty Inlet, and North Hood Canal (Figure 1). This area is characterized by large and small bays with streams that do not originate in the Olympic Mountains, and many shorelines with seasonal streams or direct sheet flow. Second, a small portion of WRIA 16 is within Jefferson County, with shorelines on north Hood Canal. This area is characterized by large rivers – the Dosewallips and Duckabush – originating in the Olympics as well as smaller lowland streams. Since some East Jefferson County marine shorelines are connected to upland areas by perennial streams or rivers, while others are not, two general categories of shorelines were developed for this study: *1) protected with large river or lowland perennial stream watershed, and 2) protected with seasonal streams or sheet flow*.

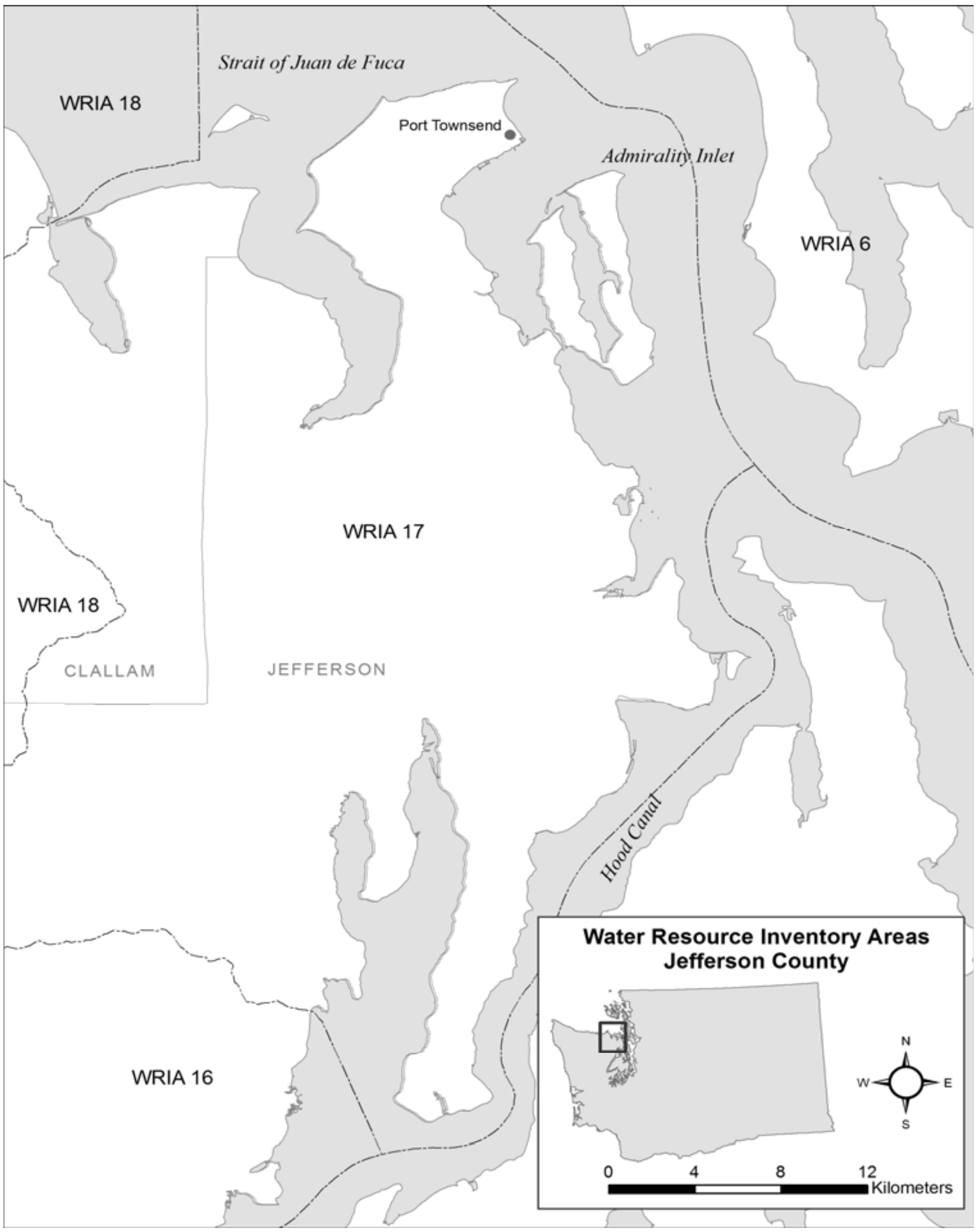

Figure 1. Water Resource Inventory Areas (WRIAs) of Washington State in the vicinity of East Jefferson County.

Conceptual Framework

The prioritization framework uses existing data to assess stressors and controlling factors as indicators of ecosystem degradation and the relative potential for various conservation and restoration strategies. Measurable stressors to controlling factors affecting ecosystem structures and ecosystem processes occur at a variety of scales, including the landscape, watershed, riverine, and marine shoreline scales. In this study, stressors at watershed and riverine scales are grouped as "upland stressors" indicating watershed condition. Stressors within the jurisdictional boundary, 200 feet inland of the Ordinary High Water Mark (OHWM) and including associated natural wetlands (under the Shoreline Management Act), are grouped as "coastal stressors."

The scoring and prioritization of Jefferson County shorelines relies on the use of a conceptual model to identify natural disturbances and potential anthropogenic impacts or "stressors" on controlling factors. Controlling factors, such as sediment supply, in turn affect ecosystem structures (e.g., plant communities) and ecosystem processes (e.g., sediment accretion), which together produce ecosystem functions such as targeted fisheries (see Figure 2). Related early conceptual models were reviewed by Thom and Wellman (1996). These were further developed by Williams et al. (2004) for application in a nearshore assessment of Bainbridge Island, Washington. More recently, models were adapted for the Lower Columbia River Estuary by Johnson et al. (2003), Thom et al. (2005a,b), and Evans et al. (2006) and by the Puget Sound Partnership (unpublished). In addition, conceptual models with a focus on salmonid habitat have previously been developed specifically for Jefferson County (May and Peterson 2003).

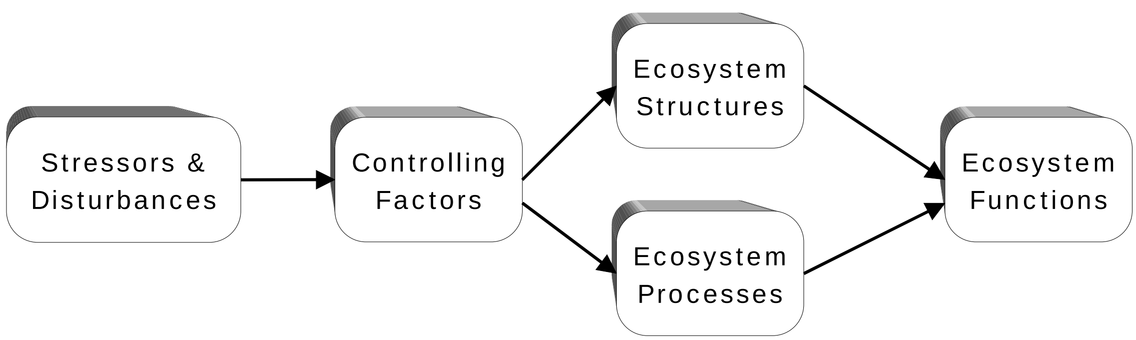

Figure 2. The major categories and structure of a typical conceptual model used in ecosystem analysis.

On the basis of this information, this prioritization framework includes the following controlling factors significant on marine shorelines of Jefferson County: wave energy/disturbance, light, substrate, sediment supply (e.g., feeder bluff, backshore, alongshore, armored), depth/slope, hydrology (e.g., tides, river flow), water properties (including water quality), and watershed condition. Some controlling factors, such as flow, can be estimated by surrogates such as watershed size.

Scale

As the foundation for prioritizing restoration, we developed scores for stressors and ecological functions of Jefferson County shorelines at three scales: ShoreZone Unit, Drift cell reach, and Watershed (Fig. 3). In assessing the potential for restoration it is critical to know the level of damage to the ecosystem at these scales. For example, in order to maintain a restored ShoreZone unit, shoreline processes (e.g., sediment delivery) must be intact within the "landscape" (i.e., drift cell scale and larger). The nexus of the watershed and the nearshore zone provides another basis for ranking the condition of the nearshore ecosystem.

The ShoreZone Units, further described below, incorporate both geomorphological and ecological attributes (Berry et al. 2001). The drift cell reach scale was delineated by J. Johannessen (unpubl. data), using data related to net shore drift. Breaks are at divergence zones and areas with no appreciable drift. For the watershed scale, two watershed units were considered: large to medium size rivers with headwaters in the Olympics or significant watershed area in the rain-on-snow zones; and smaller perennial lowland streams within the rain-dominated zone.

Geomorphic Classes

Because the relevance of stressors and controlling factors varies by shoreline geomorphic type, we classified the entire shoreline according to seven landforms and scored each ShoreZone Unit per its assigned geomorphic class: 1) low bank, 2) high bluff, 3) barrier, 4) rocky shore, 5) river (estuarine) delta, 6) embayment, and 7) lagoon (Appendix 1). These geomorphic classes were synthesized for Jefferson County based on geomorphic categories developed for Puget Sound by Terich (1987) and Shipman (2004). They are consistent with those used in the Bainbridge Island nearshore assessment (Williams et al. 2004). Two of the seven classes are associated with rivers and streams.

Datasets

The datasets used as part of this restoration prioritization tool are all readily available from public data consortiums or local governments. The foundation of this work is the ShoreZone data set from the 1994-2000 Washington State ShoreZone Inventory by the Nearshore Habitat Program in the Washington State Department of Natural Resources (DNR), Aquatic Resources Division (Nearshore Habitat Program 2001). The homogenous units of shoreforms were delineated based on a helicopter survey and videography; a geomorphologist and marine ecologist described the attributes in each unit (Berry et al. 2001). To arrive at the ShoreZone Units for use in this prioritization tool, we used ArcGIS Desktop to delineate polygons between each pair of ShoreZone Unit endpoints; polygons extend 200 feet inland of the Mean High Tide (MHT) line defined by the Washington State DNR (2005), and 2000 feet seaward or until they meet a polygon associated with another ShoreZone Unit. There are 402 ShoreZone Units in East Jefferson County.

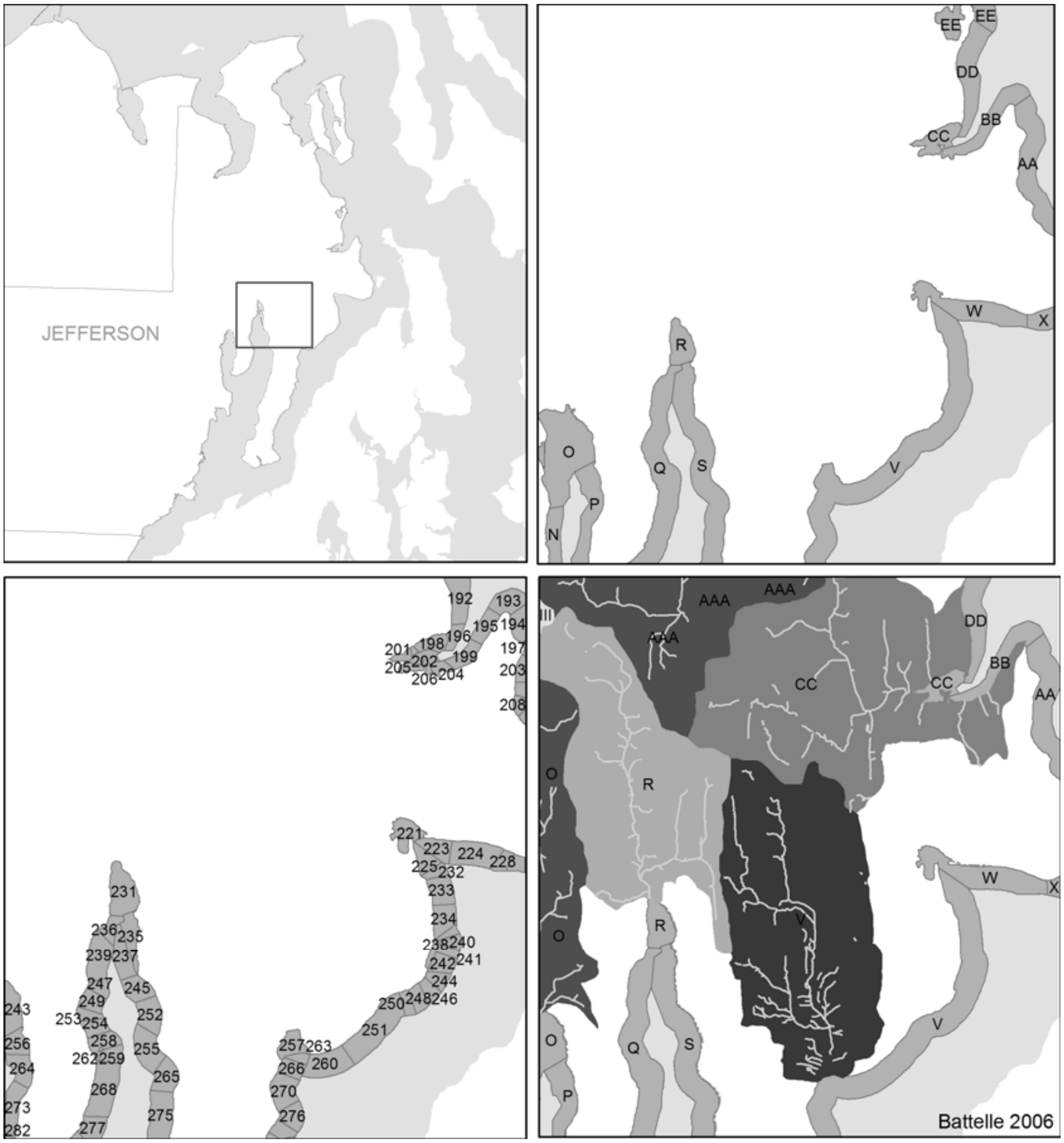

Figure 3. Maps illustrating various scales of prioritization tool. Upper left: Jefferson County, with expanded area in box; Upper Right: Drift Cell Scale; Lower Left: ShoreZone Unit Scale; Lower Right: Watershed Scale.

A salmon habitat assessment in GIS (May and Peterson 2003) used in our Jefferson County watershed analysis will not be readily available for analyses by other jurisdictions; however, these parameters can easily be calculated. Data from that report applied to our analysis were percent forest cover, road density, and number of road or utility crossings per stream mile. Additionally, the riparian vegetation quality score calculated by May and Peterson (2003) was used to characterize stream condition. This score was based on the quantity of native (coniferous dominated and mixed coniferous-deciduous) forest within a delineated (200-ft) riparian buffer zone.

Datasets for stressors were primarily acquired from Jefferson County and various state agencies (Table 2). Datasets were only included in the analysis if they were of high quality and covered all of East Jefferson County; an important criterion of a systematic approach. For example, given the importance of mass wasting events as a natural process on Pacific Northwest marine shorelines, available data were insufficient to identify anthropogenic erosion county-wide, and this data set was eliminated from the analysis. The only exception to this principle was made on the basis of a high-quality dataset developed by Todd et al. (2006) describing historic stressors on “spit-marsh” and “stream-delta” complexes that together comprise only a small proportion of Jefferson County’s shorelines.

Datasets for stressors such as dredge, fill, dikes, and tide gates were lacking for East Jefferson County, but included in Todd et al. (2006), which also rated the relative condition of habitat complexes. The relative condition index calculated by Todd et al. (2006) primarily represents percent habitat area lost since historical condition (derived from T-sheets), and connectivity within the habitat complex.

To incorporate this data set in our analysis, we weighted each of the components of the relative condition score considering those that were absent from other data sources. On this basis, in the stressors scoring, fill, dikes, and dredging are weighted the most heavily, because these were not represented by other data; armoring and roads were already quantified through other data sets and were weighted less (Table 3). The controlling factors score for fill (CF Score=14, Table 5) was applied because fill was the most frequent of the three impacts in the East Jefferson County area according to the analysis by Todd et al. (2006). While there is some uncertainty about the origins and impacts of rafts of drift logs on marshes (Todd pers. comm. 10/23/06), they were classed as a stressor in Todd et al. (2006) and low scores were assigned in this system to avoid overstating possible impacts. Table 3 illustrates how the scores were applied.

Table 2. Datasets used in analysis, by stressor.

Stressors	***Data Sources***
Roads	Jefferson County 2006; WADNR 2006
Fish Passage Barriers	WDFW SalmonScape 2005
Shoreline Armoring (e.g., bulkheads, rip rap)	Hirschi et al. 2003
Land Use	Spatial Sciences Imaging, Inc. 2002
High Risk Septic	Jefferson County (date unknown)
Marinas	Hirschi et al. 2003
Shoreline Modifications (launch ramps, rail launches)	Hirschi et al. 2003
Shoreline Modifications (docks)	Hirschi et al. 2003
Shoreline Modifications (Stairs)	Hirschi et al. 2003
Shoreline Modifications (Jetties/Groin)	Hirschi et al. 2003
Shellfish closure area	WA Department of Health 2006
WADOE facilities of interest	WA Department of Ecology 2005
Fill	Todd et al. (2006)
Dredge	Todd et al. (2006)
Diking	Todd et al. (2006)

Table 3. Application of Todd et al. (2006) dataset scores to stressor scoring of Jefferson County shorelines.

Todd et al. (2006) Direct Impacts	*Todd et al. (2006) Relative Condition Score*	*Stressor Score*
Fill, Dikes, and/or Dredging	Lost or severely impaired	5
Armoring, Road or Roads, and/or Drift Logs	Lost or severely impaired	3
Fill, Dikes, and/or Dredging	Moderately impaired	3
Armoring, Road or Roads, Unknown, and/or Drift Logs	Moderately impaired	1
Dredging, Drift Logs, and/or Fill	Functional	1
Shellfish, Unknown	Functional	0
Fill	Unrated	3
Armoring	Unrated	1
Unknown	Unrated	0

In some cases, we created a new data set for analysis based upon one or more existing data sets (e.g. data set for shoreline modifications was broken up into constituent types of modifications, each with its own implications for shoreline impact). Manipulations for scoring were also required, though in most cases the original data were left intact, just condensed or culled for the attributes of interest. For example, land use was characterized by Landsat land cover classifications (2002). Landsat classifications were collapsed into three general categories: High impervious surface or highly impacted; natural community converted for agriculture, grass, or early succession forest; and natural ecosystem (Table 4). The proportion of each polygon in each of the three classes was calculated and multiplied by associated stress factors 5, 3, or 0. These results were summed for the land use stressor score.

Table 4. Condensed classification of 17 Landsat categories for use in scoring.

High impervious surface or highly impacted	*Natural community converted for agriculture, grass, or early succession forest*	*Natural ecosystem*
Commercial / Industrial / Transportation	Acreages / Rural Residential	Bare Rock / Sand / Clay
High Intensity Residential	Herbaceous Rangeland /	Deciduous Forest
Low Intensity Residential	Pasture / Hay	Evergreen Forest
Quarries / Strip Mines / Gravel Pits	Recent Clear Cut	Mixed Forest
Transitional	Shrub and Brush	Open Water
Urban / Recreational Grasses		Woody Wetlands

Scoring
At each scale, attributes from GIS layers and other data sets were evaluated for their influence on identified controlling factors within a given unit. At the ShoreZone Unit (SZU) Scale, scores were derived for two general categories: stressors (a sum of negative anthropogenic impacts for a given unit) and functions (a sum of positive ecological functions). At the drift cell reach scale scores from SZUs were aggregated and standardized for length. Additionally, a watershed stress score was derived to provide an indication of impact within the watersheds of a Drift Cell. The details of scoring will be described below.

Stressor Scoring: ShoreZone Unit Scale
Using the conceptual framework, a list of shoreline stressors was compiled (Table 2, above). Each stressor was evaluated for its potential to act on the controlling factors. For example, the controlling factor "light" is affected by the stressor "dock shading." Impacts to the controlling factors are manifested in effects on habitat structures and functions. Stressors within the SZU polygons were scored relative to affected controlling factors and geomorphic classes. To accomplish this, we used best professional judgment to identify the controlling factor considered to be most influenced by each stressor (primary), as well as other (secondary) controlling factors affected (Table 5). In order to account for the fact that some stressors have greater impacts than others (i.e. multiple controlling factors are influenced), a weighting factor based on the degree of influence of each stressor was then calculated (Table 5). This factor was used as a multiplier for the stressor score calculated for each ShoreZone Unit as further described below.

Simply, scoring for each stressor at the ShoreZone Unit scale is as follows:

$\text{Score}_{\text{SZUx}}$ = (Geomorphic Modifier) $\sum$ (Individual Stressor Score*Controlling Factor Weight)

Stressor scoring formulas were developed individually for each stressor based on a review of summary statistics on the ranges and frequencies of stressors and their effects in East Jefferson County. The scoring method for each stressor is summarized in Appendix 2; additionally ranges for raw data and notes on data manipulations are provided. The range of raw scores for each stressor was broken into quintiles and a normalized score of 1-5 was assigned to each ShoreZone Unit for each stressor, with 1 being minimally impacted and 5 being heavily impacted by the given stressor.

For each stressor, the normalized score was multiplied by the controlling factor weighting factor. For example, in SZU 221, the normalized score for impact of roads was 1. Multiplied by the controlling factor weight for roads (14), we arrived at the final score for that stressor in SZU 221 of: 14. This score was summed with scores from the other stressors, to arrive at a final score for SZU 221 of 49.

Because not all SZUs have similar geomorphology, an additional modifier was used to account for geomorphologic variability. The modifier takes into account the possibility for interactions of each stressor and controlling factor within a unit with Geomorphic Type X. For example, in an SZU with geomorphic type "rocky shore," it is unlikely that we would see fish passage barriers or filled wetlands; therefore the modifier works to account for the fact that some stressors may not be relevant. Continuing with the example above, the geomorphic modifier for SZU 221, classified as "Estuarine Delta," is 0.93. The overall score for SZU 221=49(0.93)=45.6.

Table 5. Stressors affecting controlling factors in the nearshore ecosystem.

	Controlling Factors[*]							
Stressors	**Wave Energy/ Disturbance**	**Light**	**Substrate**	**Sediment Supply**	**Depth/ Slope**	**Hydrology**	**Water Properties**	**Sum (Stressor Weighting Factor)**
Roads	1		1	1		10	1	14
Fish Barriers						10	1	11
Armoring (e.g., bulkheads, rip rap)	10		1	10	1	1		23
Land Use		1		1		1	10	13
High Risk Septic		1					10	11
Marinas	1	1					10	12
Shoreline Modifications (launch ramps, rail launches)	1		1	1	10	1	1	15
Shoreline Modifications (docks)	1	10						11
Shoreline Modifications (Stairs)		1		10				11
Shoreline Modifications (Jetties/Groin)	10			1		1		12
Shellfish closure area		1					10	11
WADOE facilities of interest							10	10
Fill	1		1	1	10	1		14
Dredge			1	1	10	1	1	14
Diking	1		1	1	1	10	1	15

Functions Scoring: ShoreZone Unit Scale

Similar to the stressors scoring, each SZU was scored for ecological function using data sets that pertained to such functions as eelgrass, wetlands, etc. (Table 6). Scoring systems are constrained by available data, and in an absence of complete or comprehensive data, some functions (e.g. rare plants and wetlands, Table 6) may only be

[*] Primary controlling factors are scored as a 10 and secondary controlling factors as a 1 for each stressor.

scored as present or not present (1 or 3) with less weight on presence than other functions for which more reliable datasets were available. Most of the functions data are marine in nature, with the given function present at or below MHHW. For this reason, a geomorphic modifier was not applied to the scoring of functions, though we recognize that geomorphology likely influences the occurrence of given functions.

Table 6. Ecological function data sources.

Ecological Function	*Data Sources*
Herring Spawning	WDFW 2003
Herring Holding	WDFW 2002
Surf Smelt Spawning	WDFW 2005
Sand lance Spawning	WDFW 2005
Geoducks	WDFW 1992
Rare Plants	WADNR Natural Heritage Program 2006
Wetlands	Jefferson County 2001
Eelgrass	WADNR ShoreZone Inventory 2001
Bull Kelp	WADNR ShoreZone Inventory 2001
Intertidal Macroalgae	WADNR ShoreZone Inventory 2001

The scoring approach for ecological functions uses a five-point scale: 1 represents "not present," 3 represents "intermediate function" (e.g., patchy habitat distribution or close proximity to some documented functions), and 5 represents "documented functions" or "continuous habitat distribution" (Table 7).

Table 7. Ecological function scoring.

	Scores		
	1	3	5
Herring Spawning, Herring Holding, Surf Smelt Spawning, Sand lance Spawning, Geoducks	If not present	N/A	If present
Rare Plants, Wetlands	If not present	If present	N/A
Eelgrass, Bull Kelp, Intertidal Macroalgae	If not present	If patchy	If continuous

Drift Cell Reach Scale

Scores for the Drift Cell Reach (DCR) scale were calculated for both stressors and functions. To arrive at DCR scores, each ShoreZone Unit score was weighted by the length of DCR it comprised and the scores were averaged. This way we accounted for the length of shoreline influenced by any given score at the finest scale. For example, if a DCR was made up of 4 ShoreZone Units with scores 5, 10, 5, and 20, a straight average would result in a score of 10 for that DCR. However, by weighting the individual scores by a percent of overall DCR length, we were able to account for the heterogeneous sizing of ShoreZone Units. These calculations were peformed for both stressors and functions.

Watershed Stress Index

After first scoring the marine shoreline reaches for functions and stressors directly associated with conditions in the 200' shoreline and nearshore zone, a watershed stress score was applied to those marine reaches (13) that are directly connected to perennial freshwater inputs. Most marine reaches in East Jefferson County do not have associated perennial streams upland, and were not scored for watershed stress. The remaining reaches were affected by medium to large rivers with headwaters in the Olympics or significant area in the rain-on-snow zone, and/or smaller perennial lowland streams mainly within the rain-dominated zone. The watershed stress score was applied at the Drift-Cell Reach scale on the premise that flow from perennial rivers and creeks affects receiving waters from the river mouth via longshore transport within a drift cell. Where more than one river or creek enter a Drift-Cell Reach, scores were averaged on a per unit area of watershed basis.

The watershed stress score combines the following five factors: 1) riparian fragmentation as measured by road and utility crossings per stream mile; 2) watershed-scale road density; 3) riparian vegetation quality; 4) watershed-scale percent forest cover; and 5) hydrological alterations score, i.e. alterations to delivery, movement, and loss of water (cf. Stanley et al. 2005). Data layers for the first four were developed by May and Peterson (2003) and are described more fully in that report.

Road and utility crossings per stream mile represent the fragmentation of the riparian landscape, a significant determinant of ecosystem structure and function (Sedell et al. 1990; Wahlberg et al. 1996; Hiebeler 2000). Road density represents road impact on the watershed scale. Riparian vegetation quality represents streamside conditions directly contributing to water quality delivered to nearshore marine areas (Naiman and Bilby 1998). Watershed-scale forest cover is intended as an integrative indicator of the watershed's ecological condition, and in rural areas is a more powerful indicator of some hydrological processes and stream quality than impervious surface (Booth et al. 2001, 2002). The hydrological alterations score was developed by Washington State Department of Ecology staff in a related project underway to develop scoring for landscape condition based on Stanley et al. (2005). The hydrological alterations score applies loss of forest in specific areas, for example in the rain on snow zone, to specific hydrological processes such as surface water delivery timing. On this basis, we do not believe these indicators are redundant.

Decision Framework

A range of strategies is available to shoreline managers including creation, enhancement, restoration, conservation, and preservation. The selection of a management strategy for a particular site depends upon information regarding its probability of success. The relative levels of disturbance at the site (i.e., ShoreZone Unit) and landscape (i.e., Drift cell reach, Watershed) scales provide a critical basis for this assessment (NRC 1992). In particular, if restoration is under consideration, then the goal will be for the site to ultimately become self-sustaining (Bradshaw 1987; NRC 1992), a condition that is only possible if landscape processes either within or outside the site are sufficiently intact to support it (Allen and Hoekstra 1987, Diefenderfer et al. 2005).

Therefore, we suggest that restoration is contraindicated by high levels of disturbance on both scales unless landscape scale restoration is also feasible; enhancement, creation of an alternate system, or limited development may be viable alternatives under these conditions. With low disturbance on both scales, preservation strategies to protect sites from disturbances, or conservation strategies directed at specific ecological values may be most appropriate. Sites with moderate to high disturbance within relatively undisturbed landscapes are good candidates for restoration based on the success criterion. Sites with moderate disturbance at one or both scales have a wider range of potentially successful strategies. Ecosystem functions provided by a site historically or at present offer another level of goal-setting: management of targeted functions, in contrast to the probability of successfully maintaining or restoring an ecosystem.

Understanding the probability of success as represented by site and landscape scale stressors and functions provides a critical variable in a general formula for prioritizing restoration projects:

$$\text{Site score} = (\Delta\text{function x size x success}) \div \text{cost}$$

In this equation, a proposed project receives a higher score if it provides greater change in ecological function, covers a larger area, has a greater probability of success, and costs less. The ecological function variable may be measured in any indicator relevant to project goals, for example, habitat capacity to support targeted fish and wildlife, or increased opportunity for fish and wildlife to access the habitat. Function is typically compared to conditions at a less disturbed reference site and measured in terms of change from initial conditions.

Summary

In summary the principles of this systematic prioritization approach are as follows:

- Uses a *conceptual model* that provides a scientifically defensible framework
- Uses ecologically relevant *spatial scales*
- Considers *hydrologic context*
- Focuses on *existing high quality, quantitative GIS data* (state, tribal, and local county sources)
- Uses *simple scoring*; minimum interpretation = maximum consistency, avoids redundancy or “double dipping”
- Scoring is guided by *quantitative data*: Critical parameter values are derived from literature or percentile distributions of data
- The probability of success of a project, and appropriate strategies, are dependent on the *level of disturbance* at site and landscape scales

This model represents an attempt to provide an objective, science-based, and logical approach to measuring the state of the marine shoreline and adjacent watersheds that can be used for making management decisions. Central to the approach is a conceptual model. The scoring of stressors and functions is simple and transparent, and may easily be modified as scientific understanding of nearshore ecosystems increases.

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Appendix 1: Geomorphic Classes

Primary Geomorphic Classes[†]

"Not Associated with Stream/Delta"

1. *Low Bank* – Landward component of a larger landform that always includes a beach. Slope often greater than 40% (though not very wide); usually greater than 15%; height less than 5 meters; usually narrow foreshore (beach) with high water line at or on the bank; trees at waterline often indicate low bank rather than beach or wide backshore class; raised bedrock terraces assigned low bank if characterized by a sand and gravel beach; backed by low scarp.
2. *High Bluff* – Landward component of a larger landform that always includes a beach. Slope greater than 40%; height greater than 5 meters; often unstable or with visible face; sediment source often from backshore; high stairs and setback houses also indicate bluff.
3. *Barrier* – Depositional beaches without bluffs behind them. Includes spits, tombolos, looped bars, cuspate forelands, and other landforms. A well-developed backshore area is typically wider than beaches in front of bluffs, and may support lagoons or marshes. Wide beach face; slope less than 15%; wide backshore is key to distinguishing between bank and beach; spits and barrier beaches are generally self-evident. This class may also include pocket beaches, which are isolated from longer reaches, without net-shore drift, and limited in sources of sediment input and loss.
4. Rocky Shore – Backshore rocky; foreshore often bedrock with veneer of other substrata; raised terraces with bedrock classified as rocky if shoreline characterized by little sediment movement. This class may also include pocket beaches, which are isolated from longer reaches, without net-shore drift, and limited in sources of sediment input and loss.

"Stream/Delta"

5. River (Estuarine) Deltas – Larger deltaic systems with extensive marine (tides and salinity) influence upriver and multiple distributary channels (at least in their unmodified condition.) Sediment deposited across the delta plain, i.e. the lowermost portion of the river floodplain and an extensive intertidal and subtidal pro-delta flat. This classification has been scaled for Jefferson County such that there are 4 deltas within the County.
6. Embayments – Where fresh water from a terrestrial drainage mixes with marine water in an embayment protected from significant wave action by small size and/or configuration; often formed by barrier beaches.

[†] In some cases, Shipman (2004) and Shipman (pers. comm., 8/8/06) are quoted directly in the definitions.

Secondary Geomorphic Class Identification

7. Lagoon – Shallow bodies of salty or brackish water separated from the open marine environment by a thin strip of land; lagoons may empty completely at low tide (extensive tide flats), and are open or closed based on presence of a persistent tidal inlet.

In some cases, Shipman (2004) and Shipman (pers. comm., 8/8/06) are quoted directly in the above definitions.

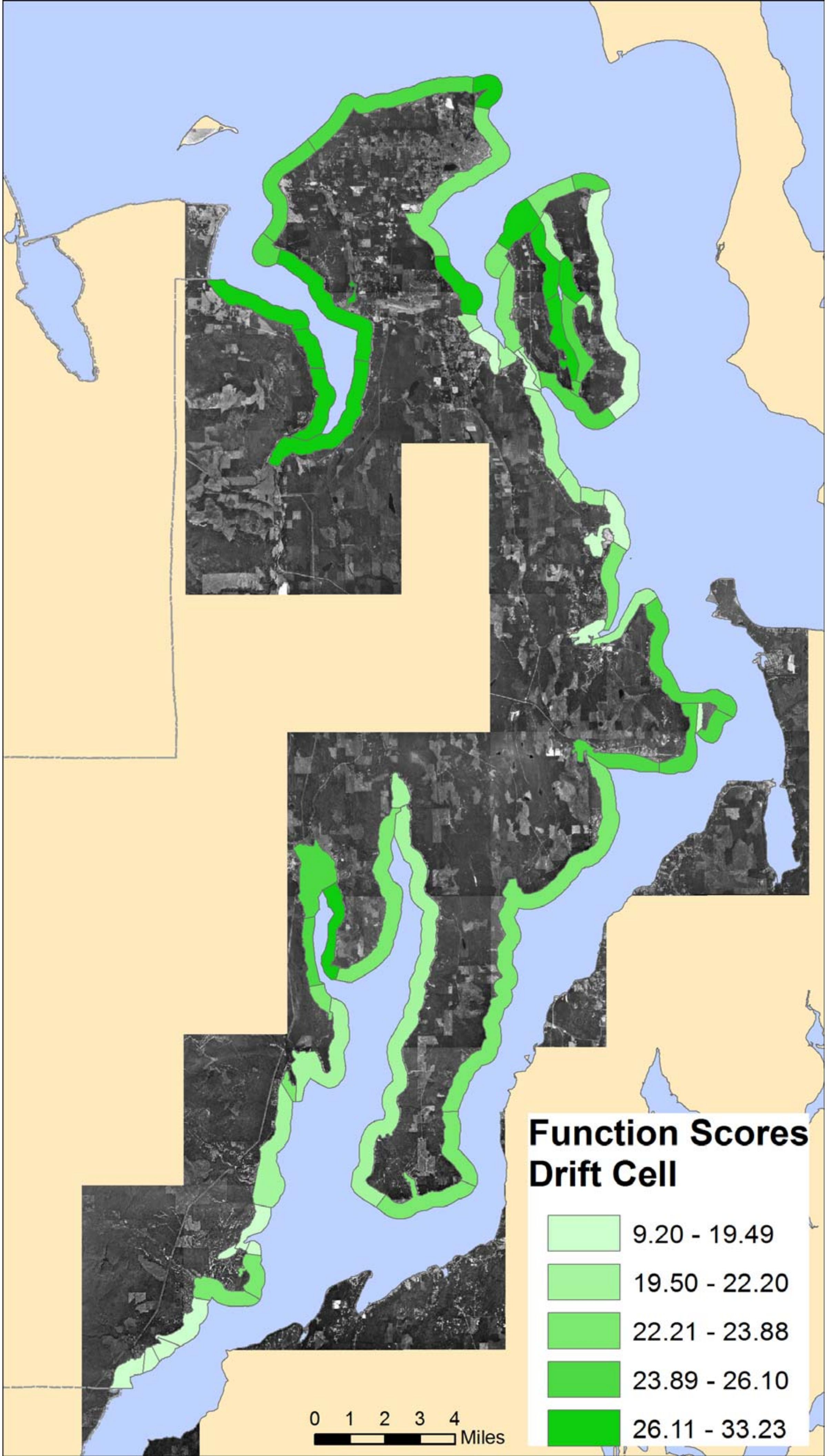
Table A-1. Comparison of Geomorphic Classes used in this Study to Shipman 2004.

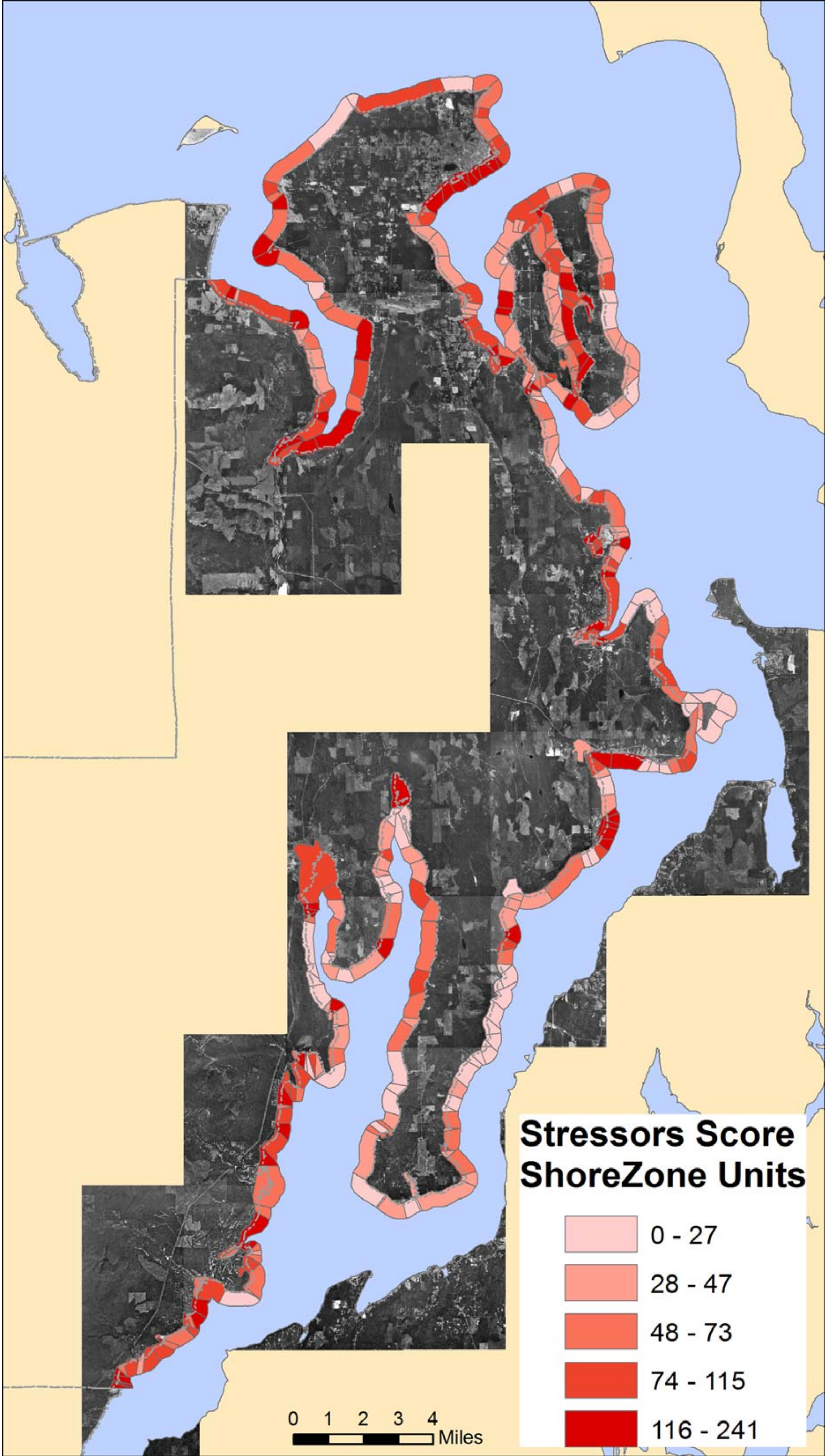
Jefferson County Geomorphic Classes	***Corresponding Shipman (2004) Geomorphic Classes***
Low Bank	Coastal Bluffs
High Bluff	Coastal Bluffs
Barrier	Barrier Beaches; Pocket Beaches
Lagoon	Lagoon
Rocky Shore	Rocky Shores
River (Estuarine) Deltas	River (Estuarine) Deltas
Embayments	Estuaries

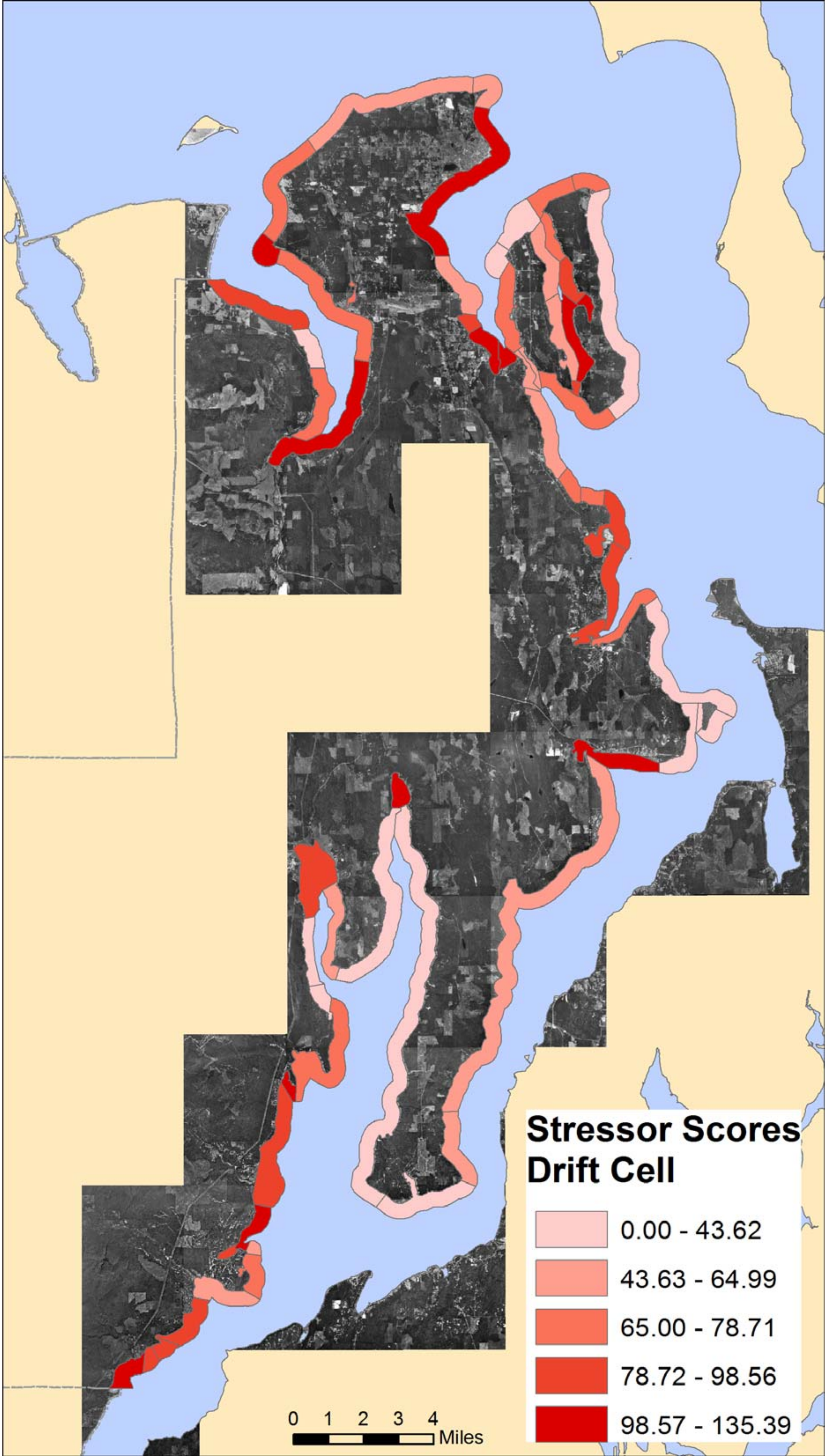
Appendix 2: Stressor scoring descriptions and raw data summary.

Stressor	*Data Processing Description*	*Scoring*	*Raw Data Summary* Mean	Min	Max	*Notes*
Roads	The roads layer is a combination of two roads data sets that encompassed paved and non-paved roads in Jefferson County	Length of road per upland area of SZU	.0018	0	.0175	Normalized for final score 0-5
Fish Barriers	Describes barriers on stream	Barriers per reach; Based upon composite score (see notes)	0.38	0	13	Scoring involved classifying the types of barriers and assigning scores as follows: 0=No barrier; 1=Barrier on Non Fish-bearing Stream; 2=Partial Barrier; 3=Total Barrier; the number of each type was multiplied by the rank for each type and a composite score was attached to each SZU. Composite scores ranged from 0 to 13; these were normalized for a final score per unit of 0-5.
Docks	GIS layer describing shoreline modifications; modifications were analyzed by type, one of which is dock-pier	Feature per reach	0.39	0	26	The number of docks/piers per reach was counted and the counts normalized for a score of 0-5.
Launch ramps, Rail launches	GIS layer describing shoreline modifications; modifications were analyzed by type; launch ramps and rail launches were considered one type of modification	Feature per reach	0.14	0	2	The number of launches per reach was normalized for a score of 0-5.
Stairs	GIS layer describing shoreline modifications; modifications were analyzed by type; jetties and groins were considered one type of modification	Feature per reach	0.65	0	12	The number of stairs per reach was normalized for a score of 0-5.
Jetties, Groins	GIS layer describing shoreline modifications; modifications were analyzed by type; jetties and groins were considered one type of modification	Feature per reach	0.03	0	2	The number of jetties/groins per reach was normalized for a score of 0-5.
Facilities	Facilities of interest from WA State Dept.	Feature per reach area	0.08	0	5	Both “Active” and “Inactive” facilities were included. The number of facilities per reach was normalized for a score of 0-5.

	of Ecology					
Marinas	Marinas	Percent of shoreline length taken up by marinas per reach	1.4%	0%	100%	Percentage of shoreline taken up by marinas normalized for a score of 0-5.
Armoring	Extent of shoreline armoring in each reach	Length of armored area per ShoreZone unit length	12%	0%	100%	Percentage of shoreline that is armored normalized for a score of 0-5.
High Risk Septics	Georeferenced database of permitted septic systems	Number of septics per reach area (upland area only)	0.26	0	4.43	The number of septics per hectare was normalized for a score of 0-5. Septic systems were considered “high risk” if permitted before 1986 or greater than 20 yrs. old; while this does not mean they are failing, they are at higher risk for failure than newer systems.
Shellfish Beach Closure		Number of beach closures of varying types per shorezone unit.	2.29	0	25	0=no closure 1=closed for all shellfish 2=closed for butter clams only Preliminary score = (Code 0 count * 0) + (Code 1 count * 5) + Code 2 count * 3) This gave a 0 to beaches without any closures, and weighted shorezone units heaviest if they were closed to all shellfish. Vibrio warnings were not included as closures, as this is a naturally occurring pathogen. Composite scores ranged from 0 to 25; these were normalized for a final score per unit of 0-5.
Aquaculture: Growing Areas		Proportion of ShoreZone unit area comprised of growing area	0.56	0	1	Included everything in the dataset as a growing area, regardless of classification (i.e., approved, conditional, prohibited, restricted, unclassified, and uplands).
Land Use (based on Area)		Composite of the proportion of ShoreZone unit areas assigned to high, middle, and low impact levels; (see notes)	0.32	0	3.42	Assigned a high impact, middle impact, or low impact level to each “type” of land area defined in the dataset. High impact = 1) commercial, industrial, transportation; 2) high intensity residential; 3) low intensity residential; 4) quarries, strip mines, gravel pits; 5) transitional; and 6) urban, recreational grasses. Medium impact = 1) acreages, rural residential; 2) herbaceous rangeland, grassland; 3) pasture, hay; 4) recent clear cut; and 4) shrub and brush rangeland. Low impact = 1) bare rock, sand, clay; 2) deciduous forest; 3) evergreen forest; 4) mixed forest; 5) open water; and 6) woody wetlands. Multiplied the proportion of high, medium, and low impact areas by a factor of 5(high), 3(med), and 0(low), then summed to get a preliminary score for each shorezone unit. Composite scores ranged from 0 to 3.42; these were normalized for a final score per unit of 0-5.


Function Scores
Drift Cell
9.20 - 19.49
19.50 - 22.20
22.21 - 23.88
23.89 - 26.10
26.11 - 33.23
0 1 2 3 4
Miles


Stressors Score
ShoreZone Units
0 - 27
28 - 47
48 - 73
74 - 115
116 - 241
0 1 2 3 4
Miles



Stressor Scores
Drift Cell
0.00 - 43.62
43.63 - 64.99
65.00 - 78.71
78.72 - 98.56
98.57 - 135.39
0 1 2 3 4
Miles

Read Me

This document is intended to accompany Excel worksheets developed for Jefferson County as part of the Restoration Prioritization undertaken by the Pacific Northwest National Laboratory Marine Sciences Laboratory for the County's Shoreline Master Program update, supported by the Washington State Department of Ecology.

Scope of Work

The Pacific Northwest National Laboratory Marine Sciences Laboratory (MSL) was contracted to develop a GIS-based restoration prioritization tool as part of the Shoreline Master Program update. This tool is designed to be used by Jefferson County in land use planning, with specific reference to restoration planning. This tool does not take the place of the Inventory and Characterization required as part of the SMP update, though it may provide information for such an effort. MSL worked with the Washington State Department of Ecology (Ecology) to incorporate multiple scales of analysis, with Ecology focusing on watershed scale processes and impacts and MSL focusing on smaller scale impacts on marine shorelines. The data contained within the accompanying spreadsheets were aggregated by MSL.

Geographic Region

The geographic extent of this work is the marine shoreline of east Jefferson County, WA from Discovery Bay to Hood Canal. The shoreline is defined as follows: from ordinary high water (OHW) (as per State hydrology GIS layer) the shoreline extends 200 ft. upland and 2000 ft. seaward.

Limitations

The approach used in this restoration prioritization tool is to aggregate existing data sets of stressors (those impacts which negatively affect controlling factors) and functions (those positive attributes occurring in a naturally functioning system) and to score them based upon occurrence within a specific geographic context. The result is a broad spectrum evaluation of areas of low/high stress and low/high function. The scales of analysis in this work are ShoreZone Unit, Drift Cell Reach, and Watershed; whereby, Shorezone Units are based upon the state ShoreZone Inventory (Nearshore Habitat Program 2001), Drift Cell Reaches are defined by net shore-drift data in Keuler (1988) and Johannessen (1992), and Watersheds are based on Ecology's present Jefferson County analysis. In some cases, the DNR ShoreZone Units have been modified due to the shoreline buffer used.

Some specific known limitations include:

- The analysis was limited to available data sets: many of these may be out of date; with few exceptions, MSL limited data sets to those that were comprehensive for the County; data sets used may not be the most descriptive or predictive of lost ecological function but linkages to controlling factor impacts have been drawn.

- The finest unit of analysis (ShoreZone Unit) is still larger than a parcel or potential restoration "site;" this tool was intended to provide an overview of impacts and regions of impact and therefore the scale may not allow for the inclusion of features occurring at a local scale.
- Scoring varied by stressor and function, but generally for stressors adhered to the following convention: raw data divided into 6 bins with 0=0 and the rest of the results being divided into fifths from the lowest score to the highest score (e.g., where raw scores ranged from 0-250, 0=0, 1=1-50, 2=51-100, 3=101-150, 4=151-200, 5=201-250). Most functions data are categorical, and the general convention for functions scoring was as follows: 1 represents "not present," 3 represents "intermediate function" (e.g., patchy habitat distribution or close proximity to some documented function), and 5 represents "documented functions" or "continuous habitat distribution."
- Separating zeros from null values is difficult; for functions such as rare plants and forage fish spawning, a zero doesn't necessarily mean the function is absent, but rather that no one has documented it at a given location.
- Geomorphic context is important; while MSL incorporated a geomorphic modifier, wave energy was not explicitly accounted for and may affect sites at a local scale.
- Stressors often impact more than one controlling factor; however, incorporating interactions into scoring is not intuitive. We have used the controlling factor weight as a means to account for multiple impacts, but recognize the actual weight is subjective.
- For both the geomorphic modifier and the controlling factors weight, sensitivity analysis showed very little change with weighting.

Representation

Final scores for both stressors and functions were imported into ArcGIS for graphical representation. The accompanying worksheets allow the end-user (Jefferson County) to look at particular units and determine what may be driving the scores for those units.

Data distributions and scoring conventions are described in greater detail in the November, 2006 Methods Summary written by MSL, submitted to Jefferson County.

Though not part of this contract, MSL has drafted a report describing the general approach to this body of work and how this and other prioritization efforts can be used for restoration planning; this paper will be submitted as a scientific journal article in 2007 and may be cited at present as follows:

Diefenderfer, HL, KL Sobocinski, RM Thom, CW May, SL Southard, AB Borde, C Judd, J Vavrinec, and NK Sather. In Preparation. Multi-Scale Analysis of Restoration Priorities for Marine Shoreline Master Planning. Pacific Northwest National Laboratory, Marine Sciences Laboratory, Sequim, Washington.

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Keuler, R.F. 1988. Map showing coastal erosion, sediment supply, and longshore transport in the Port Townsend 30- by 60-minute quadrangle, Puget Sound region, Washington. U.S. Geological Survey Miscellaneous Investigations Map I-1198-E. Scale 1:100,000.

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Nearshore Priortization Journal Manuscript Status

Although not a contracted deliverable, Battelle Marine Sciences Laboratory prepared a journal manuscript in December 2007 for publication that describes in further detail the methods, results, and discussion of the nearshore prioritization work completed for this SMP project and included in the Jefferson County SMP Shoreline Restoration Plan.

Abstract - Planners are being called upon to prioritize marine shorelines for conservation status and restoration action. This study documents an approach to determining the conservation or restoration strategy most likely to succeed, based on current conditions at local and landscape scales. The analysis is structured by an ecosystem conceptual model, which identifies anthropogenic impacts, or stressors, as well as targeted ecosystem functions. A scoring system, weighted by geomorphic class, is applied to available spatial data on stressors and functions at three scales: shorezone unit, drift cell reach, and watershed. Appropriate conservation and restoration strategies are paired with sites based on the likelihood of producing resilience to disturbance given the condition of local and landscape scale ecosystem structures and processes. This decision framework augments historical conditions and change analysis, as well as ecosystem valuation, providing a science-based planning tool in GIS.

As of June 2008, the manuscript is now in revision for Environmental Management. Reviewers provided feedback in late May 2008. The manuscript may be cited as:

Diefenderfer, HL, KL Sobocinski, RM Thom, CW May, SL Southard, AB Borde, J Vavrinec, and NK Sather. In Revision. Multi-Scale Analysis of Restoration Priorities for Marine Shoreline Planning. *Environmental Management.* 2008.