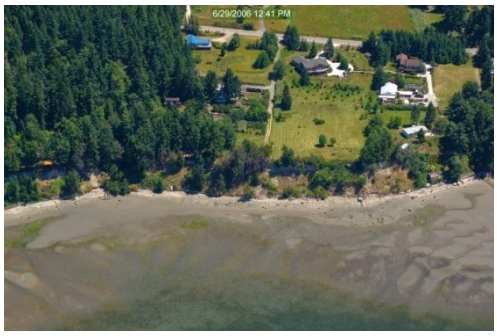

Puget Sound Shoreline Parcel Segmentation Report

Prepared for: WA Department of Fish and Wildlife and WA State Department of Natural Resources

Prepared by: Coastal Geologic Services, Inc.

Prepared as part of the project: Social Marketing to Reduce Shoreline Armoring

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Project Background

The Puget Sound Marine & Nearshore Grant Program, co-led by Washington Departments of Fish and Wildlife and Natural Resources, funded this project with the goal of reducing the total amount of traditional "hard" armor along Puget Sound marine shorelines. This can be accomplished by a combination of reducing new armor and removing existing armor. Hard armor refers to structures placed on the upper beach and at the toe of bluffs typically to reduce erosion, and is referred to using a variety of terms in the Puget Sound region, including the terms bulkhead, seawall, revetment, and rockery. Armor has been associated with numerous negative impacts to the Puget Sound nearshore. The *Social Marketing Strategy to Reduce Puget Sound Shoreline Armoring* project describes how we can overcome barriers and motivate residential landowners to voluntarily choose alternatives to hard armor.

This project team has used social marketing principles to research and design a program that will help reduce the amount of hard armor along Puget Sound marine shorelines. It resulted in:

- A Sound-wide GIS database of residential marine shore properties, including audience segmentation based on shore characteristics, and prioritization based on high value shoreforms and habitats with documented ecological impacts from shore hardening
- Descriptions of priority segments in terms of size, demographics and additional parcel data
- Desired audience behaviors for each segment
- Prioritized list of barriers and motivations for each desired armoring behavior
- Social marketing strategies and interventions to encourage the desired behaviors
- Toolkit for stakeholders to use in implementing social marketing campaigns in Puget Sound
- Detailed evaluation plan and report that details all project findings

The goal for this project is to create a social marketing behavior change strategy designed to influence priority segments of residential shoreline landowners to make behavior changes related to shore armor in order to achieve grant program goals. The strategy will focus on realistic approaches that use research-based incentives to overcome the specific barriers to reducing shore armor among key target audience segments.

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Introduction

The Puget Sound shoreline parcel database was developed to better understand spatial patterns in shoreline characteristics at the parcel-unit scale. Previous mapping efforts have been conducted to understand physical and ecological conditions in the Puget Sound region (Simenstad et al. 2011, WDNR 2001, and MacLennan et al. 2013). We use the term Puget Sound in this project to represent the Puget Sound region extending north to the Canadian border and west to Cape Flattery. Prior to this effort, there has been limited understanding of the parcel characteristics and these data have never before been linked.

Approximately 57% of the length of the Puget Sound shore is privately owned residential property. By better understanding ownership characteristics and shoreline conditions at the parcel-unit scale we can identify and inform regional priorities for improved shoreline management, and develop better tools for restoration, such as social marketing (e.g. incentive programs).

The shoreline parcel segmentation assessment is a key part of a comprehensive effort to identify target audiences for social marketing and behavior change strategies related to shore armor. The objective of the parcel segmentation is to delineate residential shoreline properties, and their owners, into target audiences based on specific shoreline conditions, several of which are linked with specific behaviors related to shoreline management and stewardship. Each segment has been quantified and characterized to further inform the later elements of this larger study.

Methods

The Puget Sound shoreline property geodatabase was developed by assembling and linking several existing regional data sets. No new data was collected as part of the development of this database. The methods applied to develop the shoreline property geodatabase and the attributes used to segment and describe the parcels are described below.

Parcel Data

The first step to achieve these objectives was to ready the statewide parcel data for integration with other data sets and reduce it in scale to our area of interest—residential shoreline property owners of Puget Sound. We began by reviewing the draft 2012 Washington State parcel database, which is still a work in progress by a team of geographers at the University of Washington. The UW team assimilated parcel data from each county and local jurisdiction in the State of Washington into a single comprehensive parcel data base. We understand that the parcel data was acquired from local jurisdictions in 2009 however we do not know how frequently updates were applied by local assessors.

Initially, the UW dataset was missing site addresses for Jefferson and Mason counties. The address data for these counties were brought into our database by acquiring data directly from the county assessor databases. Unfortunately many inconsistencies exist in the ways that the different jurisdictions managed, updated, and refined their parcel data. Individual jurisdictions have different data attributes, therefore some review and analysis was required to reduce the dataset down to include only residential shoreline parcels in the Puget Sound region. Some jurisdictions applied more advance GIS techniques to clean up the digitizing of their parcel polygons, while others had many small slivers, and common line layers. Correcting all inconsistencies and original digitizing errors went beyond the scope of this project however some data clean-up was applied to avoid snags in geoprocessing. Imperfect lines however were not all corrected therefore shoreline length data should be used with caution.

Following a comprehensive review, residential properties that encompass marine and estuarine shores were selected from the statewide dataset. This was achieved by first reviewing and selecting all appropriate state land use codes specific to residential development and then applying more refined queries to identify additional parcels outside of the more obvious codes. Attributes necessary for this effort were then identified to be maintained for this data product. For example the presence of a home was determined by land use codes exclusively. The specific attributes that were retained were identified in collaboration with the project team and client and then aggregated from several different databases associated with the larger statewide parcel database.

The parcel data set includes all residential parcels in the Puget Sound region (also referred to as the Salish Sea) west to Cape Flattery and north to the Canadian border (including Point Roberts) into Puget Sound, south Puget Sound inlets, and Hood Canal. Residential parcels located within federal lands were not included in the data set. Residential parcels on tribal lands were however included.

The parcel boundaries were extended waterward to intersect the WDNR ShoreZone shoreline using a process referred to as "euclidian allocation" to facilitate linking the parcel data with the standard state shoreline (WDNR 2001). Often parcel bounds and the high water shoreline were slightly offset resulting in this necessary and time-intensive geoprocessing task. The entire data set required manual quality review of this process and any erroneous projections of the parcel boundaries were manually corrected to the extent possible within available time. Errors typically occurred where the shoreline was more complex or crenulated or the parcel boundaries were not perpendicular to the shoreline, therefore when they were extended the angle offset was amplified. Properties that did not include ownership of the shoreline but included only tidelands were removed from the geodatabase.

The parcel is the fundamental unit of analysis in the geodatabase. All supporting data were linked with the parcels, including some of the original county parcel data that was compiled into the UW statewide dataset. Parcel numbers (named PolyID in the geodatabase) and address data were maintained to facilitate forthcoming social marketing research and future end-user outreach efforts. Additional datasets were linked with parcel data to inform shoreline conditions relevant to audience segmentation. For example, parcels that encompass shore armor and forage fish spawning areas were identified and spatially linked to parcel data. The geodatabase attribute table includes several other fields that have value for understanding the segment population. Table 1 displays the abbreviations, attributes, and data sources included in the project geodatabase.

Shoreforms, Armor, and Habitat

Sound-wide data sets including: shore armor, geomorphic shoretype, WDFW forage fish habitat data, and other information relevant to restoration/conservation planning were linked to the shoreline parcels. This linkage was performed in GIS using the intersect tool, which spatially linked the supplemental data sets onto the target shoreline layer (parcels).

Considerable data processing was performed on the various source data sets prior to linking the data sets. For example, shore armor data were compiled from multiple data sets into a single layer prior to being linked with the parcel data. Shore armor and geomorphic shoretype data were compiled from MacLennan et al. (2013) and Simenstad et al. (2011). Shoretype descriptions and data sources are found in Table 2. The more recent field-based data (MacLennan et al. 2013) were defaulted to in all newly mapped areas, and higher resolution data were used where it was available (Whitman et al. 2012 for San Juan County shore armor and pocket beaches). Where armor mapping data were missing including outside of mapped net shore-drift cells, Simenstad et al. (2011) armor and shoretype data were used. Parcels were considered armored if they had 20ft or more of shore armor.

The original source of the shoretype data was maintained in the final parcel attribute table. If more than a single shoretype occurred within a given parcel the dominant and subdominant shoretype were noted in the attribute table. All data were compiled onto the WDNR ShoreZone shoreline (WDNR 2001) which was then linked with the parcel data.

Other data sets were linked with the parcel data that could be useful to end-users in identifying priority sites for restoration or conservation. Documented forage fish spawn habitat data acquired from WDFW

was linked with the parcels (WDFW 2010). Restoration benefit values were assigned to armored parcels based on the occurrence of forage fish spawning habitat and feeder bluffs (see Restore_Benefit, Table 1). The percent of armored feeder bluffs in the local drift cell provides a measure of degradation to sediment supply processes which can enhance the end-user's understanding of site context and condition of the larger drift cell in which the subject parcel is found. PSNERP priority strategies (restore, protect, or enhance) for beach systems were also linked with each parcel to enable end-users to link in with regional priorities and objectives (Cereghino et al. 2012).

Table 1. Key attribute names, descriptions and data sources in the parcel geodatabase.

Attribute Name	Description	Data Source
PolyID	Parcel number	WA State Parcel database
OwnerName	Owner name	WA State Parcel database
OwnerAddressFull	Owner address	WA State Parcel database
SiteAddressFull	Site address (if a structure exists)	WA State Parcel database
StateLandUseCD	Land use codes (State)	WA State Parcel database
SourceLandUseDescription	Local land use code (local jurisdiction)	WA State Parcel database
MarketValueLand	Land value	WA State Parcel database
MarketValueImprovements	Developed value	WA State Parcel database
TabularAcres	Parcel size	WA State Parcel database
ImprovedAcres	Improved acres	WA State Parcel database
UnimprovedAcres	Unimproved acres	WA State Parcel database
Residential	Land use codes indicates a home is present on the parcel	CGS applied queries
ShorelineLen	Shoreline length	CGS applied queries (WDNR 2001)
ShoretypeDom	Hybrid shoretypes	Dominant shoretype (MacLennan et al. 2013, Simenstad et al. 2011)
ShoretypeSub	Hybrid shoretypes	Sub-dominant shoretype(MacLennan et al. 2013, Simenstad et al. 2011)
ArmorLen	Armor Length	CGS query
ArmorPresent	Armor P/A (presents < 20 ft)	CGS query
ErosPotential	Erosion potential	CGS query
MaxFetch	Exposure	Shorezone, calculated max exposure, WDNR 2001
ForageFish	Documented forage fish spawning habitat	WDFW (2010)
DriftCell	Drift cell	MacLennan et al. 2013
PctModFB	Percent armored feeder bluff	CGS query
PSNERPBeachStrategy	PSNERP regional priority strategies (enhance, restore or protect) for beaches	Cereghino et al. 2012
Restore_Benefit	High = Armored feeder bluffs and armored forage fish spawning areas, Very High = Armored feeder bluffs with forage fish spawning (also)	WDFW 2010, MacLennan et al. 2013.

Table 2. Shoretype names, abbreviations, descriptions and data sources.

Shoretype	Abbreviation	Data Source	Description
Feeder bluff	FBE	MacLennan et al.	Coastal bluff with active erosion and/or mass wasting which

exceptional		2013	periodically supplies substantial volumes of sediment to the nearshore in greater quantities with a shorter recurrence interval than feeder bluffs.
Feeder bluff	FB	MacLennan et al. 2013	Coastal bluff with active erosion and/or mass wasting which periodically supplies moderate volumes of sediment to the nearshore with a longer recurrence interval than FBE segments.
Bluff backed beach	BLB	Simenstad et al. 2011	Bluff that is currently armored and it is unknown if it was historically a feeder bluff or not.
Transport zone	TZ	MacLennan et al. 2013	A bluff or bank which supplies minimal but not appreciable sediment input to the nearshore from erosion/mass wasting, and does not have an accretion shoreform present. Littoral sediment is typically transported alongshore. The bluff face typically has considerable coniferous vegetation with few signs of disturbance from landslides activity or is of very low relief such that sediment input is very limited.
Accretion shoreform/ Barrier beach	AS/BAB	MacLennan et al. 2013/Simenstad et al. 2011	Sediment sinks or depositional shores. Areas of the marine shoreline where sediment is deposited either currently or has done so in the past.
Low energy shores	NAD-LE	MacLennan et al. 2013	Very sheltered shores, commonly protected by barrier (spit). These shores have No Appreciable Drift (NAD) of nearshore sediment due to lack of wave energy to entrain and transport sediment.
Pocket beach	PB	Simenstad et al. 2011	Beach contained between two (bedrock) headlands.
Bedrock shores	NAD-B	MacLennan et al. 2013	Bedrock shores. These shores have No Appreciable Drift (NAD) of nearshore sediment due to a lack of sediment due to bedrock geology.
Delta shores	NAD-D	MacLennan et al. 2013	Shores associated with large river systems and area dominated by fluvial processes.

Shoretypes and exposure were used together to estimate the erosion potential at a given site. Exposure data from the WDNR ShoreZone database was referenced for this use (Table 3, WDNR 2001). Table 4 displays the relationships between shoretype, exposure and the associated erosion potential categories. Source datasets and geoprocessing details are included in the metadata files of the project geodatabase.

Table 3. Wave energy categories based on calculated exposure categories in the WDNR ShoreZone database.

Wave Energy	Calculated Exposure (miles)
Low	Very Protected, Protected
Med	Semi-Protected
High	Semi-Exposed, Very Exposed

Table 4. Erosion potential categories based on combined wave energy and shoretype. See Table 2 for shoretype abbreviations and descriptions.

Wave Energy	FBE	FB	TZ	AS/BAB	NAD-LE	PB	NAD-B
Low	Med EP	Med EP	Low EP	Low EP	No EP	Low EP	No EP
Med	High EP	Med EP	Med EP	Low EP	No EP	Low EP	No EP
High	High EP	High EP	Med EP	Med EP	No EP	Med EP	No EP

Parcel Segmentation

Behavior objectives were identified by WDFW in the earliest phases of this project (Table 5). These objectives were refined and paired with appropriate shore conditions and then assigned to parcels that fit the criteria to delineate parcel segments (Table 6). Relevant shore conditions included shoretype, erosion potential, the presence of a structure, and whether or not the parcel is currently armored. Behavior objectives and associated shore characteristics did not directly address the feasibility of certain behaviors which would require higher resolution assessment of on-the-ground conditions. For example, to confidently recommend bulkhead removal, one must first consider the setback and potential risk to structures on the property. These data (setbacks and structures) are not available Sound-wide and were not scoped as part of this project. Therefore feasibility was not addressed and should be considered as part of finer resolution studies.

Table 5. Behavior objectives driving delineation of segments.

Endstate Behaviors to Consider Based on Parcel Type & Erosion Potential
Leave shore unarmored
Remove all hard armor
Remove a portion of armor
Replace hard armor with soft shore protection[1]
Maintain native vegetation (trees, shrubs, groundcover, backshore)[2]
Plant native vegetation (trees, shrubs, groundcover, backshore)
Address water drainage reaching bluffs[3]
Build further from the shore than current regulations require
Install soft shore protection on unarmored property (where needed for erosion control)
Move home further from the shoreline
Obtain expert advise

[1] Soft shore protection entails: applying beach nourishment and or large logs to beach/storm berm to buffer erosion, resloping/regrading bluffs that are actively eroding, and various combinations of the these techniques to reduce shore erosion with minimal impacts to nearshore ecosystem processes.

[2] Backshore is defined as the upper zone of a beach beyond the reach of normal waves and tides, landward of the beach face. The backshore is subject to periodic flooding by storms and extreme tides, and is often the site of dunes and back-barrier wetlands.

[3] Drainage management should not route untreated stormwater from driveways, roads, or yards with any chemicals added to marine or fresh waters without adequate treatment; sites which do not require drainage management for reducing erosion should not install it for these and other reasons (such as broken pipes entering Puget Sound)

Table 6. Parcel segments, shore characteristics, and endstate behaviors.

Segment #	Segment Abbreviation	Shore Characteristics	Leave shore unarmored	Remove all armor	Remove portion of armor	Replace armor with soft shore protection	Maintain Native Vegetation	Plant native vegetation	Reduce surface water drainage to bluffs	Build with generous setback	Install soft armor on unarmored property	Move home	Obtain professional advice on options
1	NANHNEP	No Armor, No Home, No Erosion Potential	X				X			X			X
2	NANHLMHEP	No Armor, No Home, Low-Moderate-High Erosion Potential	X				X	X	X	X			X
3	NAHPNEP	No Armor, Home present, No Erosion Potential	X				X	X	X				X
4	NAHPLMHEP	No Armor, Home present, Low-Moderate-High Erosion Potential	X				X	X	X		X	X	X
5	ANHNEP	Armor, No Home, No Erosion Potential		X			X			X			X
6	ANHLMHEP	Armor, No Home, Low-Moderate-High Erosion Potential		X	X	X	X	X	X	X			X
7	AHPNEP	Armor, Home Present, No Erosion Potential		X		X	X						X
8	AHPLMEP	Armor, Home Present, Low-Moderate Erosion Potential		X	X	X	X	X	X			X	X
9	AHPHEP	Armor, Home Present, High Erosion Potential		X	X		X	X	X			X	X

Results

The physical and ecological characteristics of all shoreline residential parcels were analyzed Sound-wide and across the different segment populations, the results of which are described below.

Sound-wide Summary of Ecological and Physical Characteristics

Parcel data were analyzed Sound-wide, within each of the 12 Puget Sound counties with marine shorelines, and across each of the segments associated with potential target behaviors (Table 6). A small fraction (less than 1%; 228 parcels) of the parcels found in the database had multiple parts (polygons) but were associated with a single parcel number. These multi-part parcels were maintained as individuals records within the parcel geodatabase, but data were summarized by individual parcel number.

In total 45,276 residential shoreline parcels were identified the Puget Sound region. Cumulatively these parcels extended across almost 1,400 miles, which represents roughly 57% of the Puget Sound marine shore. Kitsap County had more residential parcels than other counties by count, accounting for 17% of the residential shoreline parcels Sound-wide. Island and Mason counties followed Kitsap in parcel count.

In contrast, Clallam, Snohomish, and Whatcom counties had the least number of residential shoreline parcels (Table 7).

Considerable variability was documented in the range of parcel shoreline lengths in the region, with far greater average parcel shoreline length in rural counties (e.g., San Juan) as compared to the more urban counties (e.g., King). San Juan County had the greatest length of shoreline in residential ownership (282 miles, 20% of Sound-wide total) as well as the greatest range of shoreline lengths across parcels (Table 7). Kitsap, Mason, Pierce, and Island counties also have large total lengths of residential parcels (all greater than 140 miles). The average parcel shoreline length is greatest in San Juan County followed by Clallam County. The shortest average parcel shoreline length was found in King and Snohomish counties.

Table 7. Distribution of shoreline residential parcels in Puget Sound counties

County	Number of parcels	Shore length in mi	% of parcels Sound-wide	Min length in ft	Max length in ft	Mean length in ft
Clallam	991	46.1	2%	16	4,863	245
Island	5,831	136.9	13%	5	3,918	124
Jefferson	3,313	119.1	7%	6	4,979	190
King	3,463	69.2	8%	1	5,076	106
Kitsap	7,806	201.0	17%	4	6,544	136
Mason	5,584	157.2	12%	0	11,764	149
Pierce	5,156	141.5	11%	4	9,053	145
San Juan	4,608	282.3	10%	6	33,476	323
Skagit	1,979	63.1	4%	2	5,828	168
Snohomish	1,675	36.5	4%	4	3,204	115
Thurston	2,663	82.1	6%	5	3,013	163
Whatcom	2,207	58.8	5%	4	4,810	141
Sound-wide	**45,276**	**1,393.8**	**100%**	**0**	**33,476**	**163**

Shore Armor

Forty-eight percent of residential shoreline parcels in the Puget Sound region were mapped as armored covering 29% of the total shoreline length (Table 8). An armored parcel was defined as a parcel with 20 ft or more of shore armor. This minor threshold was created as it was the minimum mapping unit for the primary armor data set (MacLennan et al. 2013). It also functions as a realistic error margin for (spatial) error associated with the mapping process of linking the high water and the parcel shorelines (discussed in *Methods*). Therefore some parcels that are classified as unarmored may have a limited extent of armor (0-19 ft), such as the footings or short reaches of armor at a stairway or other beach access.

The greatest portions of armored residential shoreline were located along the central, eastern shore of Puget Sound, including: King, Pierce, and Kitsap counties (Table 8). Counties with a larger share of unarmored shore included: Clallam, Island, Jefferson, San Juan, and Whatcom counties (Figure 1). Most parcels across the region were mapped as either entirely armored or unarmored. Only a small percent of parcels had a more limited length of armor (25-75% armor, Figure 2).

Parcels that measured less than one-acre in size were 50% more likely to be armored than those greater than one-acre. Armor present on small parcels covered 75% more of each parcel's shore than on

armored larger (>1 acre) parcels. On average, a shoreline that is comprised of small parcels (< 1 acre) had 2.5-times the armor length, than larger (>1 acre) parcels. Small parcels appeared to have 76% longer armor per parcel area.

Table 8. Armored residential shoreline parcels across each Puget Sound County.

County	Number of parcels	Parcels with armor	% Parcels with armor	Shore length in mi	Armored shore length in mi	% Armored shore length	Portion of Sound-wide Armor
Clallam	991	219	22%	46.1	5.3	11%	1%
Island	5,831	2,056	35%	136.9	31.7	23%	8%
Jefferson	3,313	948	29%	119.1	18.8	16%	5%
King	3,463	2,780	80%	69.2	47.8	69%	12%
Kitsap	7,806	4,701	60%	201.0	88.1	44%	22%
Mason	5,584	3,307	59%	157.2	59.6	38%	15%
Pierce	5,156	3,428	66%	141.5	70.6	50%	17%
San Juan	4,608	488	11%	282.3	10.2	4%	3%
Skagit	1,979	877	44%	63.1	16.0	25%	4%
Snohomish	1,675	1,088	65%	36.5	17.4	48%	4%
Thurston	2,663	1,671	63%	82.1	34.2	42%	8%
Whatcom	2,207	311	14%	58.8	5.9	10%	1%
Sound-wide	**45,276**	**21,874**	**48%**	**1,393.8**	**405.6**	**29%**	**100%**

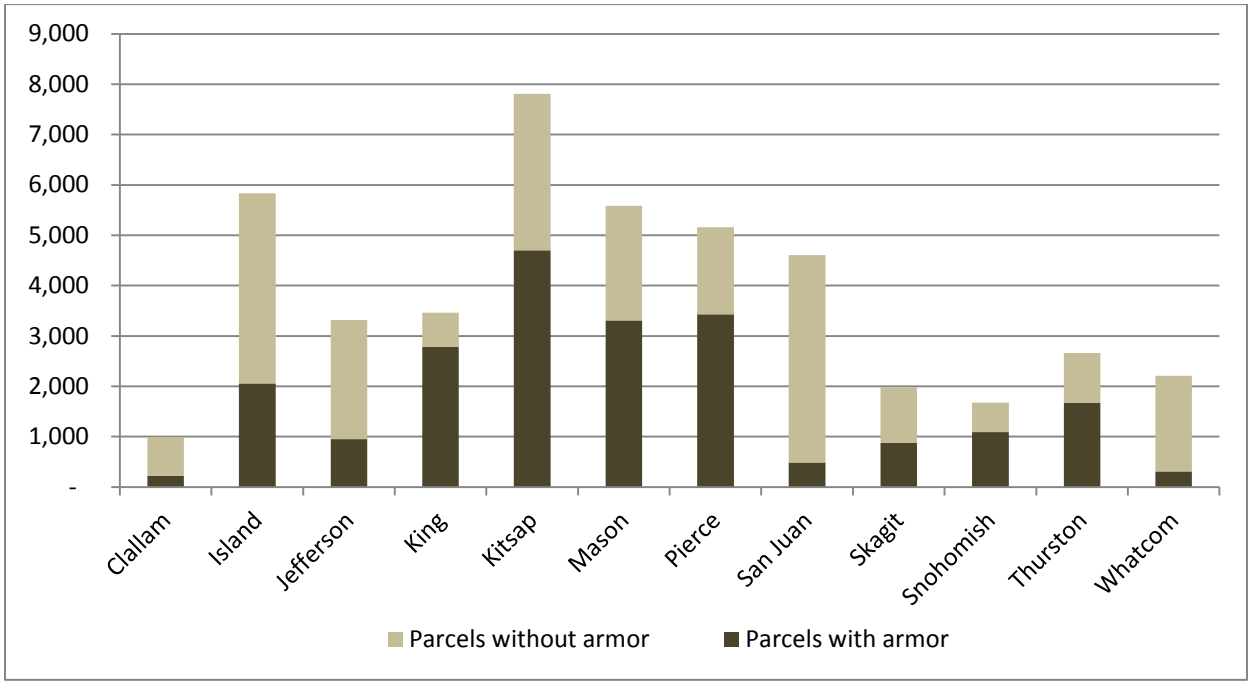

Figure 1. Number of armored and unarmored residential shoreline parcels in Puget Sound counties.

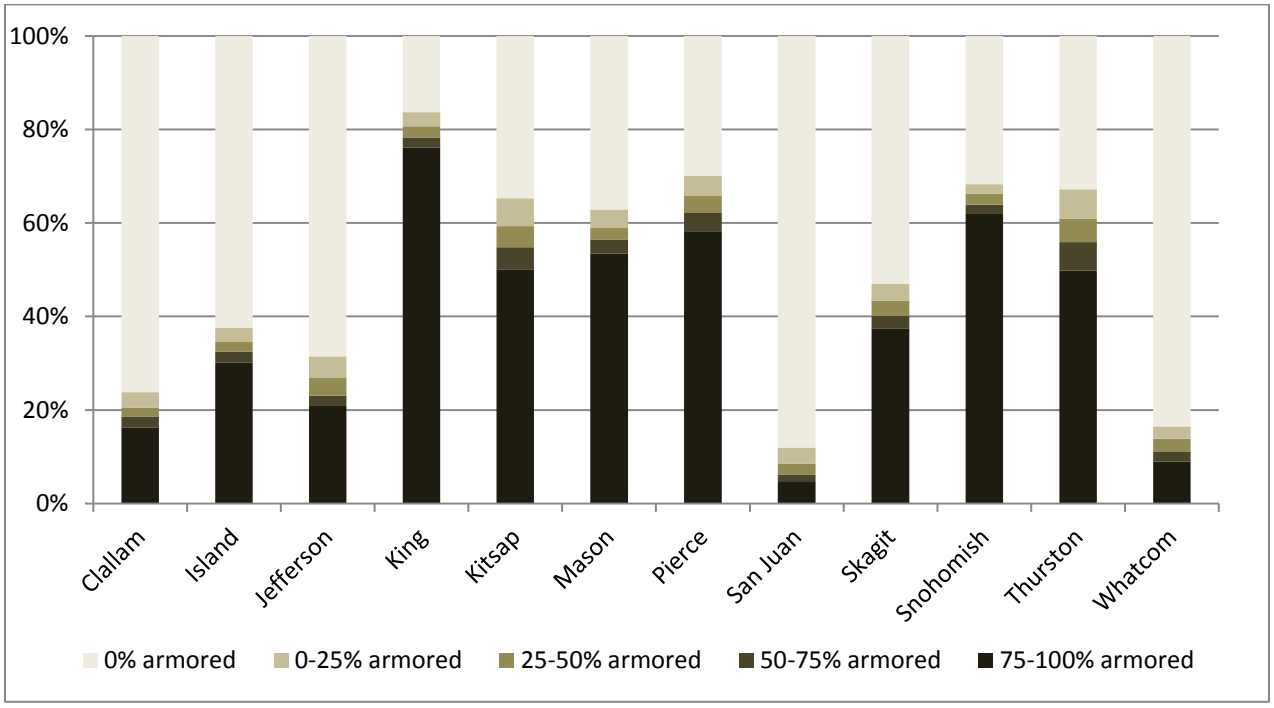

Figure 2. Percent of residential shoreline parcels with different extents of shore armor in Puget Sound counties.

Shoretypes

The most frequently armored shoretypes were artificial shores (NAD-AR) and bluff backed beaches (BLB). The shoretype bluff backed beaches were used only at armored bluffs, in which it is not known if the shore was a historic feeder bluff. Artificial shores are heavily modified shores in which various combinations of shore armor, fill, and dredging have dramatically altered shoreline conditions. Unarmored artificial shores were surprisingly common and appear to be a product of fill placement and dredging, such as within marina communities, and source-data errors (such as imperfect shore armor data). Excluding these shoretypes that are generally armored or altered otherwise by definition, transport zones were the most abundant shoretype that were armored across all residential shoreline parcels (Figure 3). Greater than 60% of the parcels within transport zones were mapped as armored. Transport zones are bluffs that are not eroding rapidly or contributing significant sediment to the nearshore. More than 40% of parcels mapped as accretion shoreforms were armored. A considerable portion of parcels located within areas with No Appreciable Drift due to low energy (NAD-LE) and bedrock (NAD-B) were mapped as armored. These latter shoretypes have no erosion potential and rarely require armor for erosion control.

These summaries reflect the dominant shoretype mapped within a parcel. Subdominant shoretypes were also mapped where appropriate and a second shoretype occurred within the parcel boundaries. Where multiple shoretypes were mapped within a single parcel, it was not documented in the database which shoretype that the armor was originally mapped within. Therefore there are likely some parcels in which the armor occurs in the alternate (subdominant) shoretype. For example, a large parcel in San Juan County that was predominantly mapped as NAD-B (bedrock) had a subdominant shoretype mapped as a pocket beach. Shore armor is mapped as present in the parcel; however it is not apparent in the dataset that the armor is actually located on the pocket beach rather than the dominant bedrock shore.

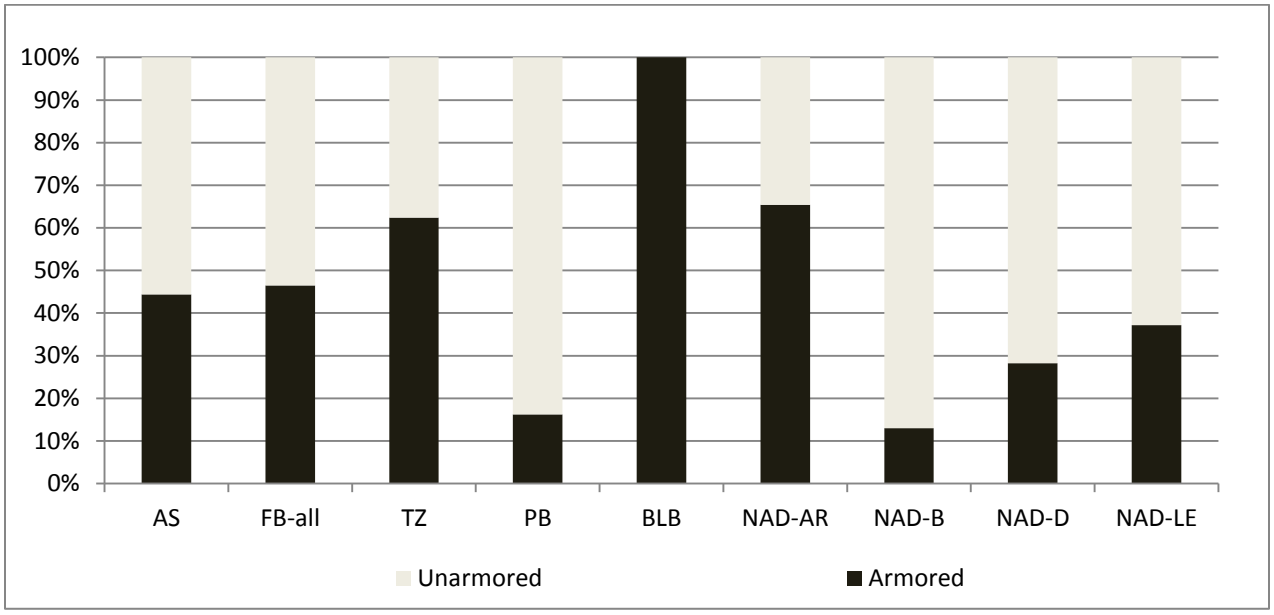

Figure 3. Percent of parcels armored and unarmored by shoretype of residential shoreline parcels in Puget Sound. AS = Accretion Shoreform, FB-all = All Feeder Bluff types, TZ = Transport Zones, PB = Pocket Beaches, BLB = armored Bluffed-Backed-Beaches, unknown if feeder bluff or not, NAD-AR = No Appreciable Drift – Artificial, NAD-B = No Appreciable Drift-Bedrock, NAD-D = No Appreciable Drift-Delta, NAD-LE = No Appreciable Drift-Low Energy.

Forage Fish Spawning Areas

Forage fish spawning was documented on 26% of the residential shoreline parcels in the Puget Sound region (Table 9). Fifty-eight percent of these parcels were also mapped as armored. Because most parcels are largely armored, it is likely that armor and spawning habitat is co-located, potentially resulting in habitat loss or degradation to spawning areas. The greatest portion of Sound-wide forage fish spawning was mapped in parcels located in Thurston (61%) and Island counties (41%). Counties with shore armor mapped along more than 50% of the parcels with documented forage fish spawning habitat include: Island (50%), King (76%), Kitsap (62%), Mason (67%), Pierce (70%), Skagit (55%), Snohomish (58%), and Thurston counties (71%). Please be mindful when interpreting these results that additional parcels with forage fish spawning and shore armor may exist in these counties outside of residential parcels, as (armored or unarmored) public or commercial lands are not included in the database or these data summaries. Figure 4 shows how the database can be used to display parcels with documented forage fish spawning along parcel with and without shore armor.

A considerable number of feeder bluff parcels with documented forage fish spawning areas are armored (Table 10). Removing armor from parcels with either or both of these characteristics would benefit nearshore ecosystem processes and habitats. Therefore parcels with either shore armor along a feeder bluff or documented forage fish spawning were flagged as having “high” restoration benefit. If a parcel had both of these characteristics, then it was it was flagged as having a “very high” restoration benefit. Figure 5 shows how the database can be used to display armor and erosion potential across different parcels.

Table 9. Residential shoreline parcels with documented forage fish spawning (FFS) and shore armor across Puget Sound counties.

County	Number of Parcels with FFS	% of Total Parcel Count	Parcels with FFS and Armor	% Parcels with FFS and Armor	Parcel Shore Length with FFS in mi	Parcel Shore Length with Armor and FFS in mi	% Parcel Shore Length with FFS and Armor
Clallam	223	23%	39	17%	11.9	0.9	8%
Island	2,400	41%	1,199	50%	55.2	18.4	33%
Jefferson	815	25%	272	33%	35.0	6.3	18%
King	795	23%	602	76%	15.9	10.7	67%
Kitsap	1,993	26%	1,229	62%	54.9	23.3	42%
Mason	2,052	37%	1,380	67%	54.2	24.6	45%
Pierce	769	15%	540	70%	22.1	11.3	51%
San Juan	236	5%	42	18%	13.3	0.9	7%
Skagit	152	8%	84	55%	6.2	1.9	31%
Snohomish	349	21%	204	58%	8.2	3.3	40%
Thurston	1,620	61%	1,153	71%	45.6	24.3	53%
Whatcom	383	17%	49	13%	8.6	0.9	10%
Sound-wide	**11,787**	**26%**	**6,793**	**58%**	**331.1**	**126.7**	**38%**

Table 10. Residential feeder bluff shoreline parcels with documented forage fish spawning (FFS) and shore armor across Puget Sound counties.

County	Parcels with Armored Feeder Bluffs	Armored Shore Length of Armored Feeder Bluffs in mi	Parcels with Forage Fish Spawning and Armored Feeder Bluffs	Armor Length in Parcels with FFS and Armored Feeder Bluffs, in mi
Clallam	51	1.3	6	0.1
Island	239	3.7	147	2.1
Jefferson	291	5.6	86	2.3
King	1,000	19.0	195	4.0
Kitsap	1,236	22.5	461	8.3
Mason	807	16.6	439	8.0
Pierce	920	17.7	169	3.5
San Juan	202	3.9	19	0.4
Skagit	204	3.8	37	0.6
Snohomish	519	8.8	102	1.7
Thurston	432	8.7	333	6.7
Whatcom	60	1.0	12	0.3
Sound-wide	**5,961**	**112.6**	**2,006**	**38.0**

Figure 4. Documented forage fish spawning and shore armor on shoreline residential parcels in Puget Sound.

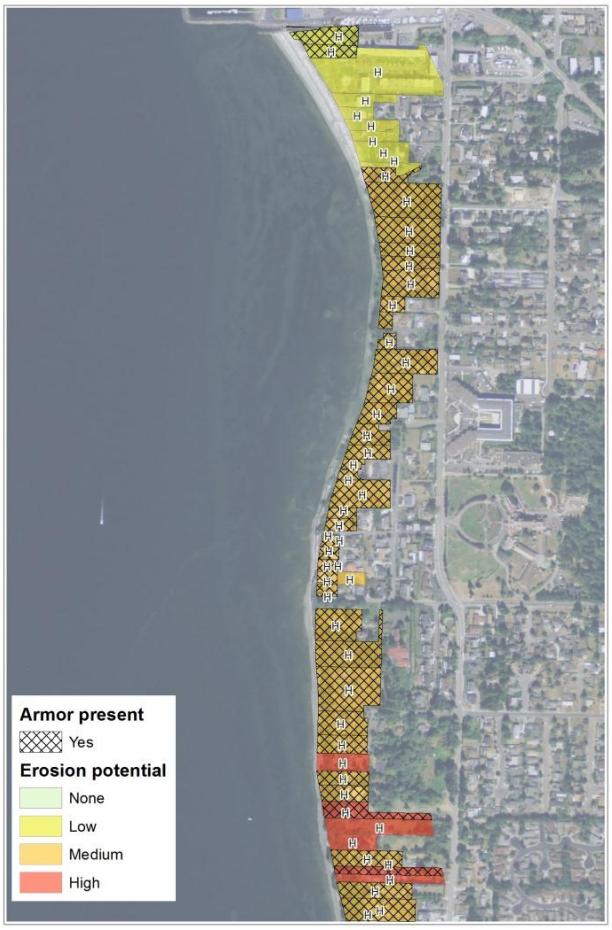

Figure 5. Armor, erosion potential and the presence of a home on shoreline residential parcels in Puget Sound.

PSNERP developed nearshore restoration strategies for beaches and among other nearshore systems. These beach strategies were assigned to shoreline parcels throughout the Puget Sound region to help end-users clearly recognize the areas that would most benefit from armor removal, prevention, and mitigation of armor impacts (Cereghino et al. 2012). Residential shoreline parcels were most commonly considered high restoration priorities (restore high, 30%), and enhancement priorities (enhance high, 20%, Table 11).

Table 11. PSNERP restoration strategy distribution across shoreline parcels.

Priority Area	Parcel Count	Percent
Restore High	13,430	30%
Enhance High	8,872	20%
Restore	5,823	13%
Enhance	5,685	13%
Protect High	1,701	4%
Protect	1,004	2%
None	8,761	19%
Totals	**45,276**	**100%**

The spatial distribution of the PSNERP strategies generally reflects the level of degradation to sediment supply processes within the local net shore-drift cell as well as other ecosystem conditions, which are described in Cereghino et al. (2012). Enhancement strategies were mapped on parcels predominantly located in King, Kitsap, Mason, and Pierce counties. Restoration strategies were most frequently mapped in parcels located in Island, Jefferson, and Kitsap counties. Protection strategies were more frequent in the least developed, more rural counties including: Jefferson, Clallam, Island and San Juan Counties (Figure 6).

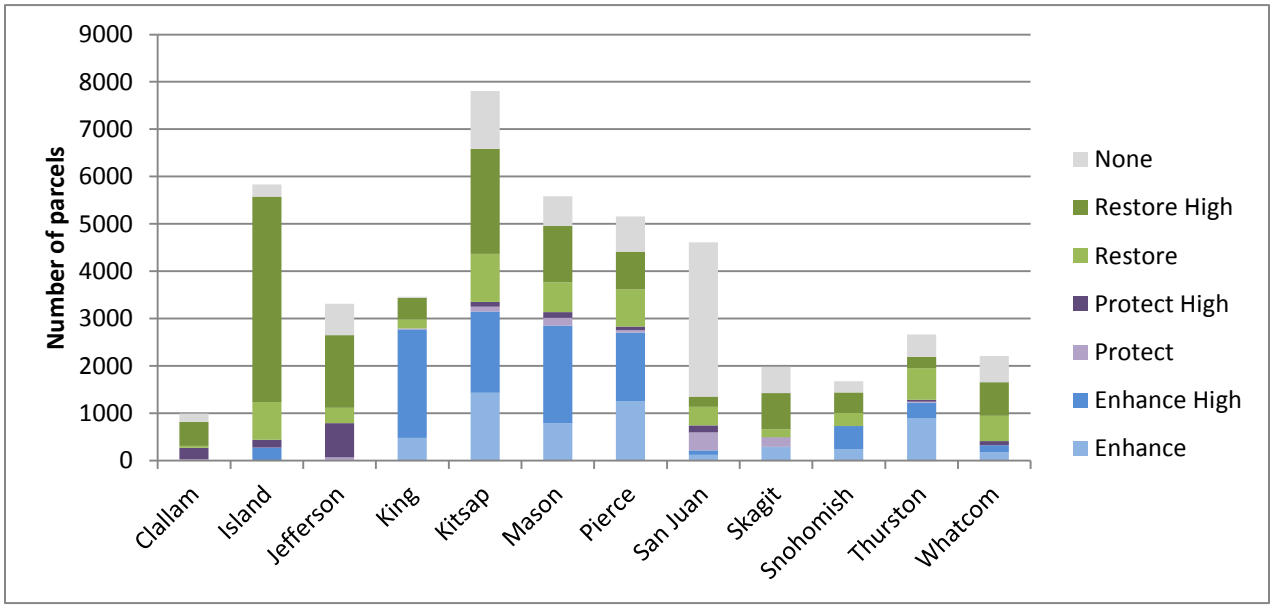

Figure 6. PSNERP strategies distribution at shoreline residential parcels in Puget Sound counties.

Segment Summary of Ecological and Physical Characteristics

Based on specific shoreline characteristics relevant to target shoreline management behaviors, all residential shoreline parcels were assigned to 1 of 9 different segments. Relevant shore conditions to segment assignments included: shoretype, erosion potential, the presence of a structure, and whether or not the parcel is currently armored. Each segment is aligned with several behavior objectives, each of which has been explored in greater detail in other elements of this study (Tables 5 and 6). The segments

were mapped and assigned as part of the Task 2 geodatabase, the distribution and character of which will be described in the following section.

Parcel segmentation showed that the greatest percent of the Puget Sound residential shoreline parcels were within Segment 8, which represent armored parcels with homes and low-moderate erosion potential (38%) and Segment 4, which include unarmored parcels with homes and low- high erosion potential (29%, Table 12). These segments (8 and 4) also represented the greatest shoreline length by segment. Segment 5 had the smallest population or least number of parcels, cumulatively representing less than 1% of the parcels. Segment 9 was the smallest population by shoreline length.

Table 12. Distribution of residential shoreline parcels in Puget Sound across each segment.

Segment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Armor Status	No Armor				Armor					
Home	No Home		Home		No Home		Home			
Erosion Potential	None	Low - High	None	Low - High	None	Low - High	None	Low-Mod	High	**Total**
Number of Parcels	1,316	4,823	4,057	13,206	222	2,370	1,539	17,273	470	45,276
Total Shoreline Length in mi	128.1	196.6	211.1	339.3	15.2	85.8	48.9	358.6	10.1	1,393.8
Number of Armored Parcels	-	-	-	-	222	2,370	1,539	17,273	470	21,874
Total Armor Length in mi	0.1	0.7	0.2	1.9	6.4	58.2	30.7	299.2	8.2	405.6
Percent Shoreline Armored	0%	0%	0%	0.6%*	42%	68%	63%	83%	81%	29%
Total % Shoreline Length	9.2%	14.1%	15.1%	24.3%	1.1%	6.2%	3.5%	25.7%	0.7%	100%
Total % of Parcel Count	3%	11%	9%	29%	0%	5%	3%	38%	1%	100%

Table 13. Distribution of parcels across Puget Sound counties within each segment population.

Segment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Armor Status	No Armor				Armor				
Home	No Home		Home		No Home		Home		
Erosion potential	None	Low - High	None	Low - High	None	Low - High	None	Low-Mod	High
Clallam	3%	5%	1%	3%	1%	2%	0%	1%	7%
Island	3%	14%	2%	22%	3%	10%	2%	10%	9%
Jefferson	12%	16%	7%	9%	17%	6%	6%	4%	7%
King	0%	6%	0%	3%	1%	16%	2%	13%	13%
Kitsap	12%	14%	9%	14%	38%	17%	45%	20%	3%
Mason	13%	15%	6%	9%	10%	16%	8%	16%	2%
Pierce	12%	9%	7%	6%	11%	15%	19%	16%	6%
San Juan	23%	4%	50%	12%	2%	1%	2%	2%	7%
Skagit	1%	1%	5%	6%	1%	1%	5%	4%	28%
Snohomish	3%	4%	1%	2%	4%	7%	2%	5%	5%
Thurston	10%	3%	6%	3%	7%	7%	7%	8%	0%
Whatcom	8%	8%	5%	9%	5%	2%	2%	1%	14%
Sound-wide	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Segment 8, which represented the largest segment population, was largely comprised of parcels located in Kitsap (20%), Mason (16%), Pierce (16%), and King (13%) counties (Table 13). Very few parcels from Clallam (1%), Whatcom (1%), San Juan (2%), Jefferson (4%), Skagit (4%), and Snohomish (5%) Counties were included in this segment. Segment 4 was largely comprised of parcels from Island (22%), Kitsap (14%), and San Juan (12%) counties. Segment 4 also included smaller portions (9%) in Jefferson, Mason and Whatcom Counties (Table 13). Fifty-percent of Segment 3 was located in San Juan County alone. Forty-five percent of Segment 7 was located in the sheltered shores of Kitsap County.

Small portions (e.g. 0-19 ft) of shoreline were mapped as armored in Segments 1-4, though the shores in these segments were predominantly unarmored (Figure 7). Armored segments (5-9) exhibited some variability in the percent of the parcel with shore armor, though the majority of the parcels in each of these segments were predominantly armored (75-100% of the parcel shoreline length). Segments 8 and 9 had the greatest portion of parcels that were (near) completely armored. In contrast, a larger portion (25-35%) of the parcels in Segments 5, 6, and 7 were partially armored (25-75%, Figure 7).

Armored parcels that include feeder bluffs and forage fish spawning areas were exclusively found in Segments 6, 8 and 9. Eight-hundred and forty-three (843) parcels were armored feeder bluffs without homes, which could represent great opportunities for restoration. Cumulatively these armored feeder bluffs without landward homes encompassed just under 32 miles of shore. Two-hundred and fifty-five (255) of these same parcels also included documented forage fish spawning habitat along approximately 6.3 miles of Puget Sound shore. Therefore bulkhead removal targets should be focused in these parcels in which there appears to be no potentially threatened structures and large benefits resulting from armor removal.

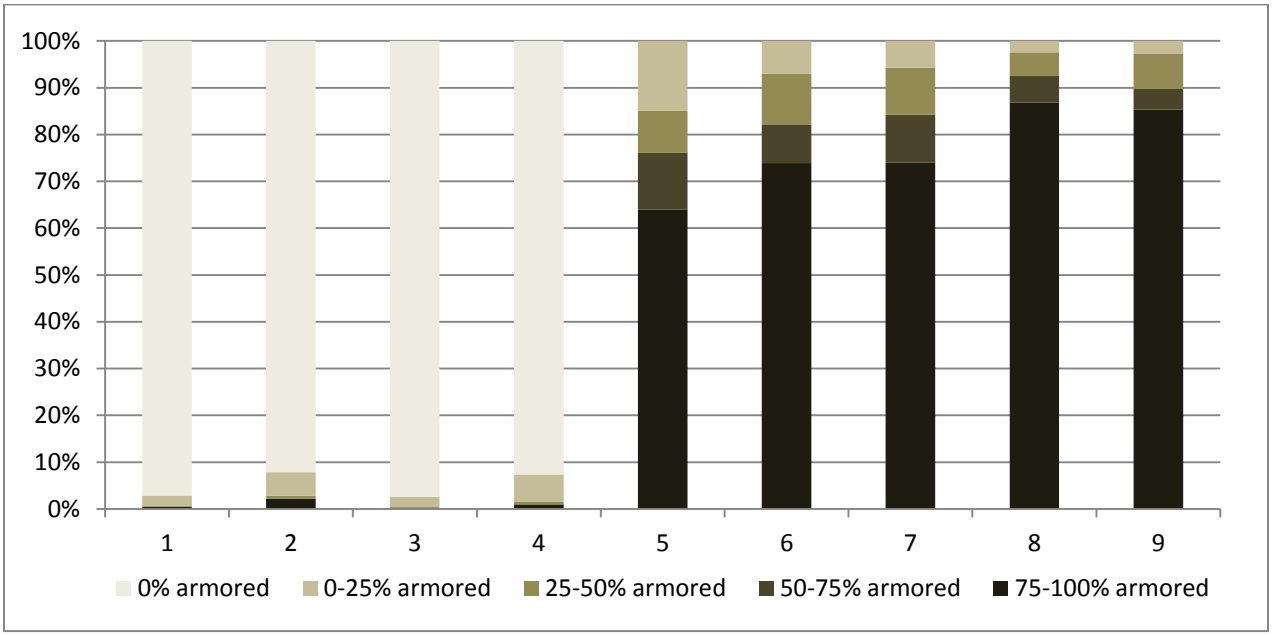

Figure 7. Percent of shoreline residential parcels in Puget Sound with shore armor across each parcel segments.

Data Limitations and Uncertainty

This database was developed to aid in the formation of restoration, conservation, outreach and education strategies for Puget Sound residential shoreline property owners. The database was created by integrating a number of existing databases each of which had its own limitations and sources of error. Users of this database should be mindful of the various limitations and sources of uncertainty in the database, some of which are described further below as well as in the metadata files of the GIS geodatabase.

Each of the limitations and sources of errors in the source data were carried forward in this product, therefore users should be aware and use the data appropriately. Sources of error and uncertainty include: spatial error, assessor data error, and other forms of error and uncertainty associated with the status of the source data sets. The types of spatial error include: limited spatial accuracy of parcel geometry, error associated with the process used to link shoreline parcels with other shoreline data sets, and the spatial accuracy of other shoreline data sets. Parcel geometry is not exact, such as a parcel plat map or property survey, and the digital geometry does not represent the legal boundaries of each individual property. Therefore it would not be appropriate to use these data to enforcement shoreline management regulations. The process used to link the parcel data with other data sources on the WDNR shoreline, extended the parcel boundaries waterward, which could lead to inaccuracies in parcel boundaries. Although all parcel boundaries were manually reviewed and many were manually adjusted to minimize this source of error, it could not be entirely eliminated. The spatial accuracy of the source data – such as shoretype data, is another potential source of error. Shoretype data were created for use at 1:24,000 scale, which contrasts the resolution of the shoreline parcel geometry. In addition, the minimum mapping unit for much of the shoretype mapping was 20 ft alongshore, therefore features including shore armor that are shorter than 20 ft in length are unlikely to have been mapped in the dataset and would not be included in the database. Similarly, the WDFW documented forage fish spawn data includes many false negatives, as not every beach on Puget Sound has been sampled. Therefore

some beaches that are not mapped as spawning habitat may actually represent beaches that have not been sampled, rather than beaches that were sampled with no documented spawn. There are also considerable limitations associated with the status of the shoreline armor data. Although the most current shoreline armor data were integrated for this use, some errors and old data exists in the data base. For example, in some areas, armor was mapped 10-15 years ago, and considerable new armor has been installed since the original source mapping took place.

As described in the methods section, the original statewide parcel database was compiled by geographers from University of Washington from the county and local jurisdiction assessors' data. The frequency of updates and refinements to the original assessor data appeared to vary considerably by jurisdiction. Therefore, some ownership, address, and tax code data may not be current. Many corrections and refinements were applied as part of this project, which are reflected in the final geodatabase. In addition, there was considerable inconsistency in the ways that each jurisdiction used the data resulting in the CGS project team having to deduce conditions from land use codes, such as the presence of a home.

Many opportunities exist to refine and (further) clean up this database. Cleaning up address data could help end-users to reach property owners. Updating and improving source data sets would also improve the overall data set. Sound-wide shore armor mapping could be updated and improved in many areas throughout the Puget Sound. Data gaps associated with historic geomorphic conditions could be filled, as there is a limited extent of remaining Puget Sound shoreline in which it remains unknown if an armored bluff was historically a feeder bluff (or not). In addition, because land use codes were used to deduce whether or not a home was present on a parcel, additional queries and refinements to this very relevant attribute could be applied. In addition, some anomalous parcel geometry could be refined, and organized in a more spatially intuitive framework.

Summary and Conclusions

The shoreline residential parcel database is rich in information and value and can be used in many ways to better understand Puget Sound nearshore conditions. Some of the most relevant information learned from this effort is presented below, which can be used to improve and inform restoration, conservation, outreach, and education strategy development:

- 48% of residential parcels Sound-wide were mapped as armored; 29% of total residential shoreline length. Most armored parcels are within areas where it may be feasible for alternatives to hard shore armor, such as armor removal and/or soft shore protection.
- Most parcels are either entirely armored or unarmored. Because armor is rarely required along an entire parcel to protect structures, this result indicates that that partial removal may be feasible at many parcels.
- The most frequently armored shoretypes are transport zones, which are not eroding rapidly. Considerable armor was mapped along other shoretypes that are not characteristically erosive - including accretion shoreforms (<40%) and NAD-LE/low energy shores with no erosion potential (<35%).
- Forage fish spawning is documented along 25% of shoreline parcels, 58% of which are armored. More than 50% of the parcels with forage fish spawning are armored in Island (50%), King (76%), Kitsap (62%), Mason (67%), Pierce (70%), Skagit (55%), Snohomish (58%), and Thurston counties (71%). The impact of hard armor along these critical shoreline habitats will worsen over time with sea level rise. Armor removal or replacement with alternative techniques would benefit

nearshore resources along these shores. In addition, these forage fish spawning habitats along armored shores are exceptionally vulnerable to implications of climate change. Because forage fish are a central element of the marine food web, their populations are important to the health of the species that depend on them as a food source, from shore birds, to salmon, to orcas.

- There are close to 6,000 parcels with armored feeder bluffs; 2006 of which also include forage fish spawning habitat. These parcels represent high and very high benefit (respectively) parcels for armor removal. Eight-hundred and forty-three (843) parcels with armored feeder bluffs do not have a home present, cumulatively measuring just less than 32 miles of shoreline. Two-hundred and fifty-five (255) of these same parcels also include documented forage fish spawning habitat along approximately 6.3 miles of Puget Sound shore. Therefore, bulkhead removal targets should be focused in these parcels in which there appear to be no potentially threatened structures and large benefits resulting from armor removal.
- Many opportunities exist to refine and (further) clean up this database, including updating source data sets. Shore armor data should be updated Sound-wide and eventually re-integrated with the parcel data. Data gaps associated with historic geomorphic conditions could also be filled. In addition, building setback distances could be added to the database to further inform the feasibility of target behaviors among other valuable uses.

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