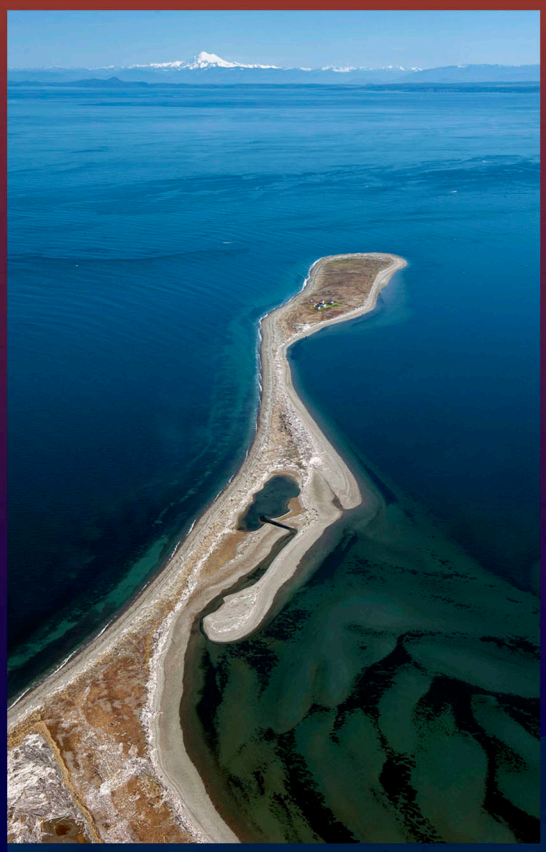
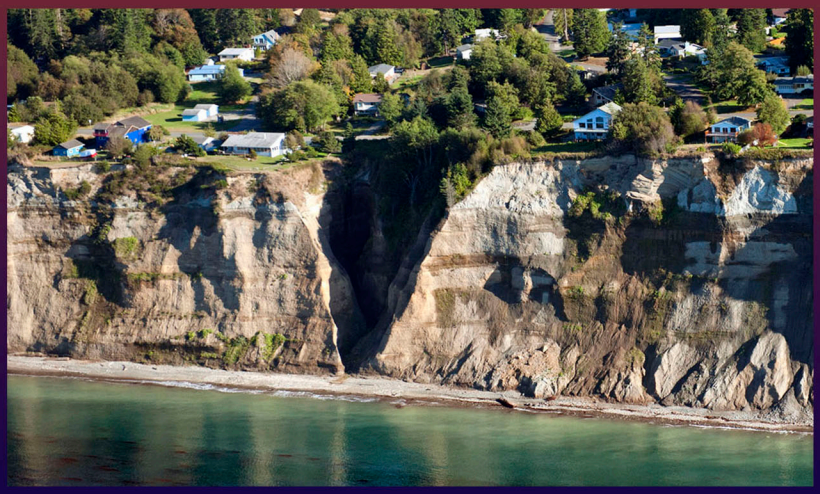
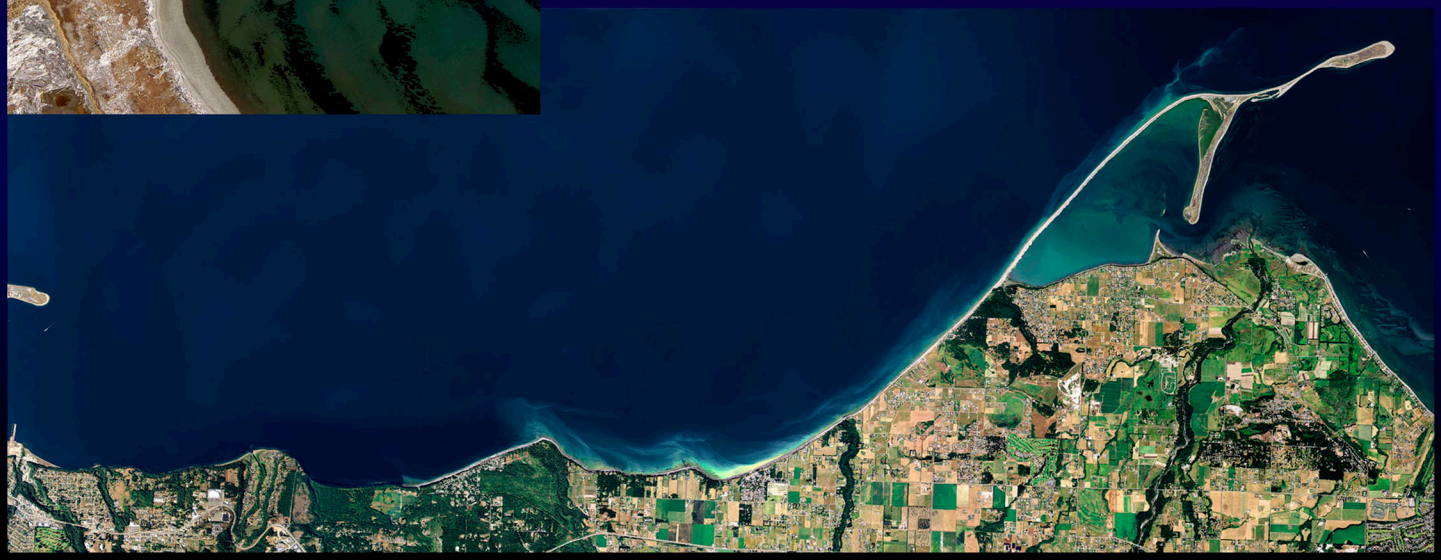
Dungeness Drift Cell

Parcel Prioritization and Conservation Strategy







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Dungeness Drift Cell: Land Parcel Prioritization and Conservation Strategy

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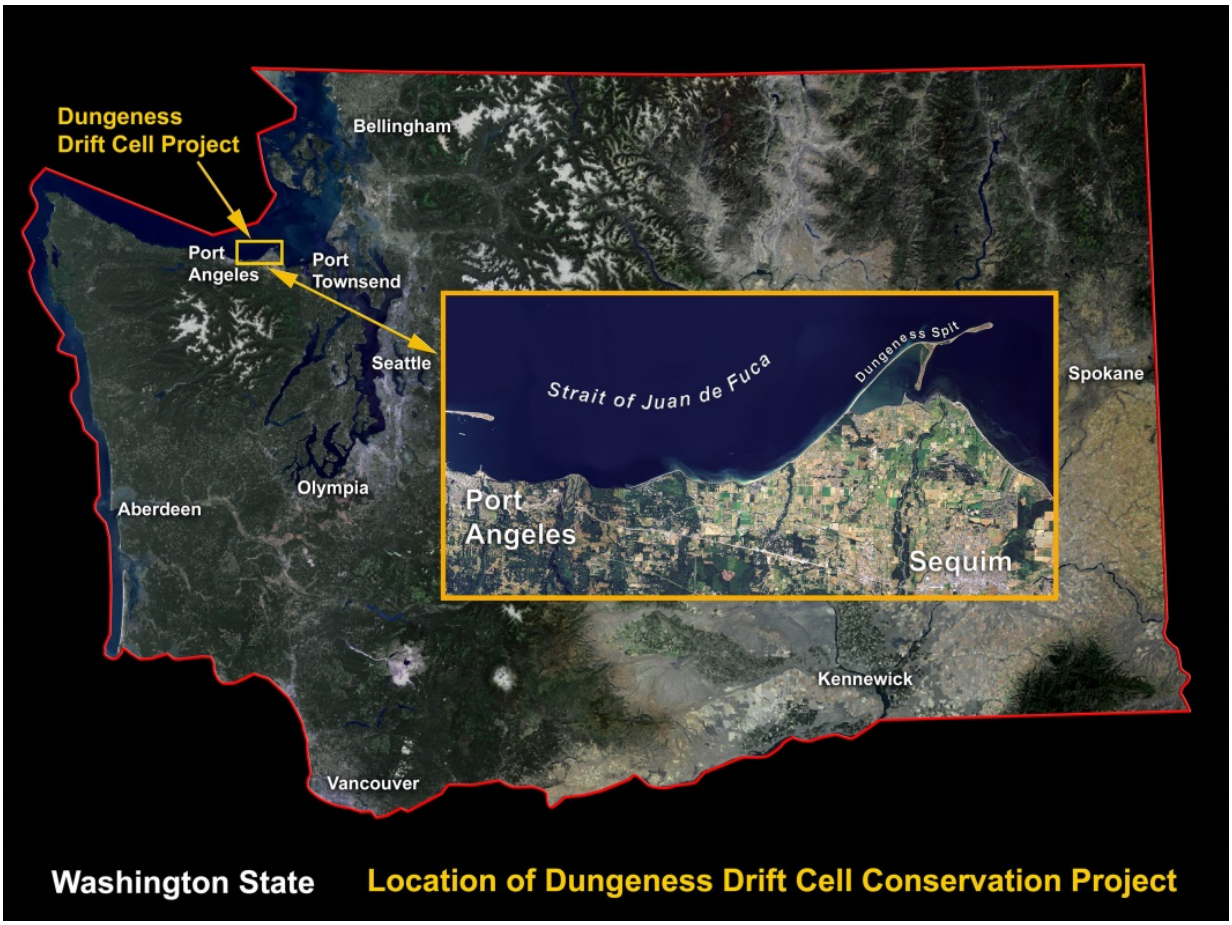

Figure 1: Project Location Map. The Dungeness Drift Cell is located on the North Olympic Peninsula of Washington State.

Introduction

The 5-mile long Dungeness Spit and its associated 5-square mile Dungeness Bay are national treasures for their immense scenic, recreational, and natural resource values. The Spit and Bay are the centerpieces of a national wildlife refuge, which is a major recreational destination for beach walking, birding, wildlife watching, and crabbing. A multitude of healthy and imperiled fish and wildlife species, including salmon, char, marine mammals, wading birds, waterfowl, raptors, and butterflies, inhabit the rich estuarine ecosystem created by the Spit. The Bay contains bountiful populations of clams, oysters, and crab. A half mile from the end of the Spit stands the historic New Dungeness Lighthouse, built in

Figure 2: Dungeness Spit and Dungeness Bay

1857. To the Jamestown S'Klallam Tribe, the Spit and Bay are supremely important cultural resources.

Aquatic habitats on the northern Olympic Peninsula, including Dungeness Bay, support salmon and shellfish populations that are important economic resources and are integral to the Jamestown S'Klallam Tribe's cultural identity. Over the past 100 years many of these fish populations have declined significantly, and thus a major goal of the Tribe is to restore and conserve healthy, harvestable, and sustainable numbers of traditional fish and shellfish. Since the 1980's the Tribe has worked to conserve shorelines, protect water quality, and restore habitat forming processes in local rivers and bays, especially the Dungeness River, Jimmycomelately Creek, Dungeness Bay, Washington Harbor, and Sequim Bay. A part of this work is focused on ensuring the continued existence and health of the area's natural spits, which not only provide valuable fish and wildlife habitat and are important cultural sites for the Tribe, but also create bays, harbors, and protect shorelines from erosion by waves.

The Drift Cell

Made only of highly erodible sand, gravel, and cobbles, Dungeness Spit and its Bay protrude deep into the stormy waters of the Strait of Juan de Fuca. Powerful forces erode shorelines to the west and east, while the Spit remains intact. Upon the Spit, strong waves push sediment east until it is lost into deep water (depth ≥ 240 feet, Figure 4). For each grain of sand that traverses the length of the Spit and then disappears off its tip, replacement sand must arrive or the Spit will begin eroding away.

Many marine shorelines receive some amount of sediment from one source or another. In Washington, the most common sources are the erosion of uplands bordering the shoreline and the silt, sand, and gravel delivered by freshwater streams. Once on the beach, sediment is moved along the shoreline by

Figure 3: Strait of Juan de Fuca, Dungeness Spit, Graveyard Spit, and Dungeness Bay

waves, tidal currents, and winds. This movement is called *longshore drift*. Often sediment will move in predominately one direction - *down-drift*. Sediment also moves away from shore into deep water and this is called *offshore drift*. In some rare locations a significant and continuous supply of sediment moves along the shoreline in predominately one direction and accumulates into an accretion shoreline

feature, such as a spit. This combination of a sediment supply and an accretion landform is called a *drift cell*.

Dungeness Spit was formed and is maintained (fed) by a steady supply of sediment delivered to the Strait from nearby streams, most notably Morse, Siebert and McDonald Creeks, and a complex of eroding coastal bluffs. These sediment sources along with the Spit itself comprise the Dungeness Spit Drift Cell (hereafter referred to as the Dungeness Drift Cell or drift cell). The great majority of the Spit's sediment comes from bluff erosion. The complex of high bluffs stands generally 100 to 240 feet in height and extends west of the Spit for 10.4 miles. The bluffs erode at various rates - on average one foot per year – and deliver an enormous quantity of sediment to the beach. Driven east by waves and currents, a percentage of the sand, gravel, and cobbles reaches and maintains the Spit. Without this constant nourishment the Spit and hence the Bay would wash away.

Figure 4: Sediment Drifting Off Dungeness Spit

The drift cell's down-drift terminus is the tip of Dungeness Spit. By examining historic and contemporary air photos and consulting data provided by Coastal Geologic Services, we concluded that the up-drift boundary of the Dungeness Drift Cell lies approximately at the mouth of Lee's Creek near Port Angeles, some 10.5 coastline miles west of Dungeness Spit. Along the south shore of Dungeness Bay, a slowly eroding bluff extends for 1.5

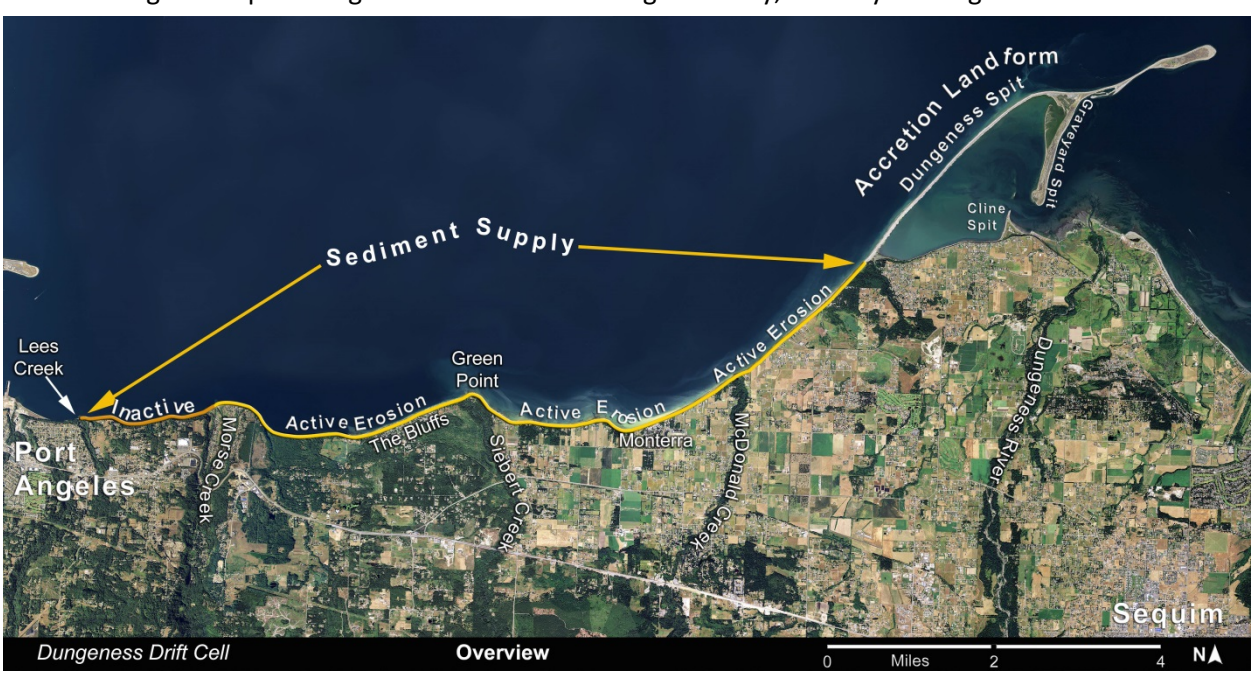

Figure 5: Dungeness Drift Cell

miles between the base of Dungeness Spit and Cline Spit. Sediment derived from the Dungeness Bay bluff drifts primarily east to Cline Spit and little, if any, of this sediment reaches Dungeness Spit. The Dungeness River contributes sediment to Cline Spit and possibly a small quantity to Graveyard Spit. The River does not appear to contribute any significant amount of sediment to Dungeness Spit.

Figure 7: Feeder Bluff in the Dungeness Drift Cell

Spits at Risk

Ediz Hook in Port Angeles provides a case history relevant to the conservation of Dungeness Spit. Located 10 miles west of Dungeness Spit, the Hook is a once-natural spit which similarly protrudes deep into the wave-swept Strait of Juan de Fuca. In early photographs Ediz Hook looks much like today's Dungeness Spit. Ediz Hook's drift cell extends about 4.7 miles west of the Hook to the Elwha River mouth and is fed by sediment originating from the Elwha River and from eroding bluffs, including a 3-mile stretch of especially erodible feeder bluff. In a 1972 report, the U.S. Army Corps of Engineers estimated that prior to human disturbance, approximately 15 percent of the drift cell's sediment originated from the Elwha River and 85 percent originated from bluff erosion. The Corps estimated that by the 1930's the combined effects of the Elwha River dams and bulkheading along the bluffs had

Figure 6: Ediz Hook 1884 and 1997, and Ediz Hook Feeder Bluffs

decreased sediment inputs to the drift cell by about 75 percent. By the late 1930's Ediz Hook had begun eroding so severely that major bulkheading projects commenced along its shoreline. The Corps attributes the sudden, dramatic erosion of the Hook to the effect of reduced sediment recruiting into

the drift cell. By 1951 it had become necessary to armor virtually the entire outer shoreline of Ediz Hook to prevent the Hook from eroding away. By the 1960's the Hook's bulkheads were undermined and failing to such an extent that local forces – the City of Port Angeles, the Crown Zellerbach Mill, and the U.S. Coast Guard – could no longer keep pace, and thus the Corps was petitioned to intervene. In 1973 the Corps accepted responsibility for maintaining the Hook, beginning with a $4,890,000 revetment project and a projection of $423,800 in perpetually required annual maintenance. The Ediz Hook experience clearly demonstrates that Dungeness Spit and its ecosystem can remain healthy only as long as natural quantities of sediment continue drifting to the Spit.

Dungeness Drift Cell Conservation

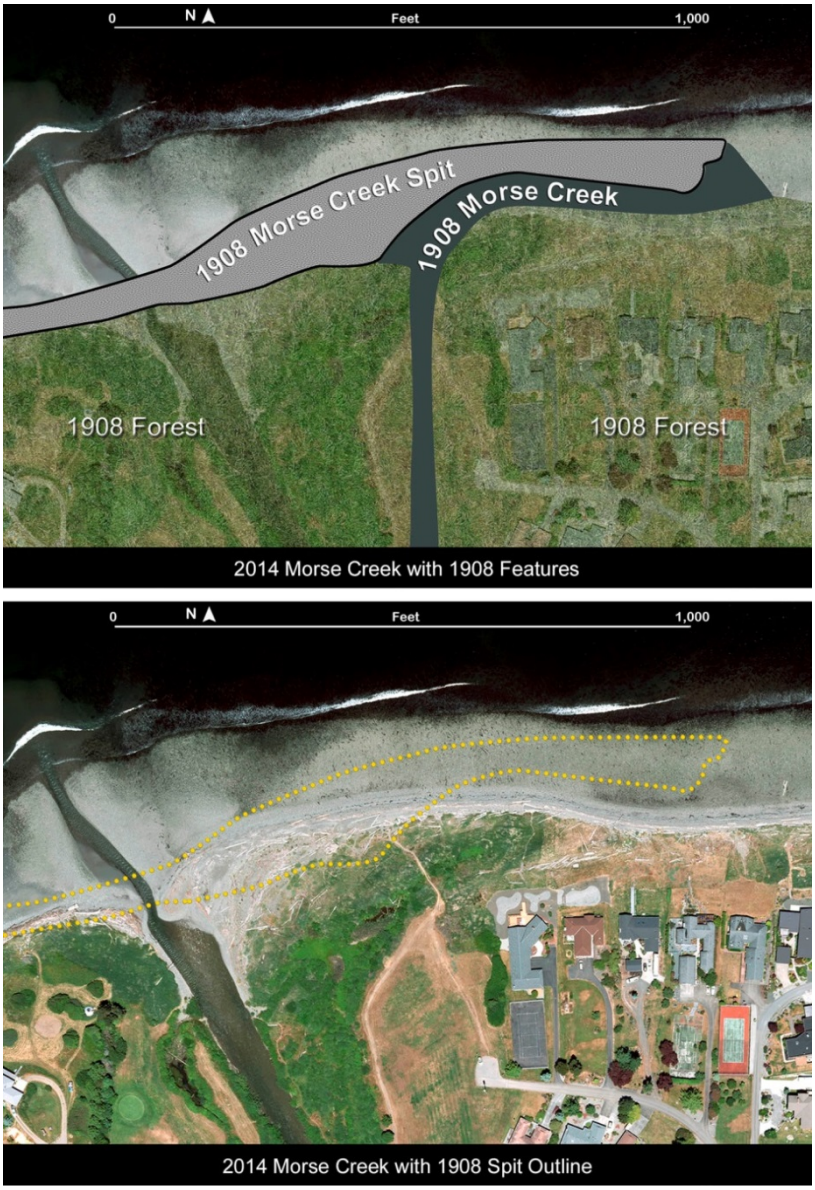

Figure 8: Former Morse Creek Spit

Since the mid-1800's when Europeans began settling in the Dungeness Drift Cell, the bluff tops have been increasingly logged, farmed, and then built up with residential buildings and infrastructure. As the bluffs naturally erode and deliver their sediment to the beach, structures built atop the bluffs become ever closer to the edge. Once a structure becomes imperiled by a retreating bluff, property owners have generally responded by retreating themselves: demolishing, abandoning, or moving their structure farther landward. In several limited cases landowners have attempted to halt the natural erosion in front of their structure by placing rip rap at the bluff's toe.

By 2013 slightly more than 1.5 miles (15%) of the drift cell's bluff shoreline had been treated with some type of erosion control measure, most commonly the placement of rock rip rap

armoring. The majority (1.5 miles) of this armoring consists of a 1915 railroad grade, now converted to the Olympic Discovery Trail, located along the westernmost reach of the drift cell, between Lee's Creek and Morse Creek. The railroad grade was not built specifically to serve as shoreline armoring, but its length is armored with rip rap to prevent the grade itself from eroding. Although the railroad grade is located both directly against and in some locations seaward of the bluff toe, it has not completely stopped erosion of the "protected" bluff which continues to slump and slide. Fortunately, this upper end of the drift cell does not appear to have been a historically important sediment source for Dungeness Spit. However, the Morse Creek Spit, a small accretion landform once located immediately down-drift of the 1.5 miles of armored bluff, declined from being intact in 1939 to being entirely eroded

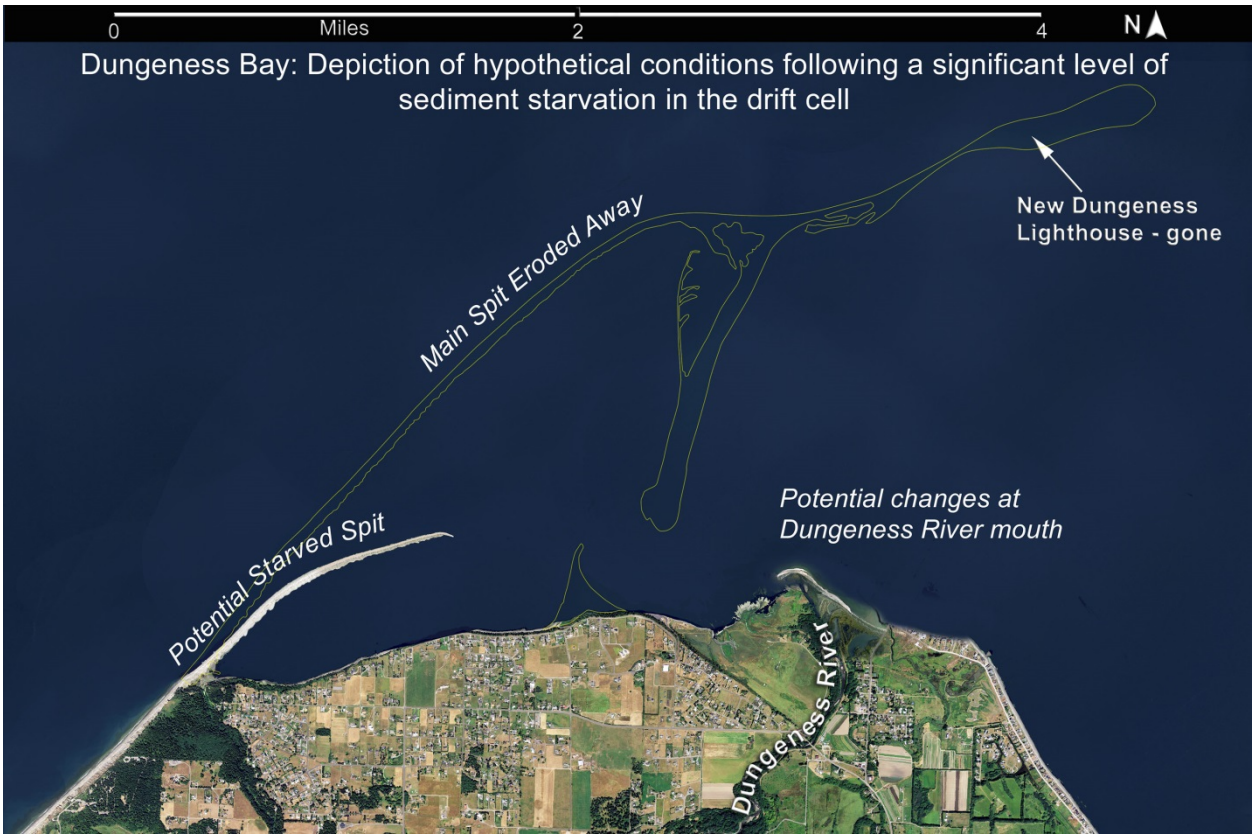

Figure 9: Hypothetical Conditions at Dungeness Bay Following Potential Drift Cell Starvation

away and disappeared by 2005 (Figure 8).Because tall, highly erodible bluffs are costly to armor and maintain, the drift cell's most active sediment-generating feeder bluffs remain un-armored. However, as residential and commercial development continues upon the bluffs, concern increases that harmful shoreline armoring will begin to occur, with the possible result that Dungeness Spit will then become sediment starved, begin eroding away, and ultimately disappear forever along with its Bay. In an effort to ensure that this potential economic, environmental and cultural catastrophe never occurs, the Tribe and other stakeholders have begun developing a strategy to permanently conserve Dungeness Drift Cell sedimentary processes. The primary conservation tools proposed for use are 1) the direct conservation of feeder bluff properties by purchasing either fee-simple titles or conservation easements, and 2) the implementation of voluntary incentives for landowners to permanently refrain from armoring their

feeder bluff properties. An essential step required to effectively implement these tools is to first prioritize the drift cell land parcels based on their potential to deliver sediment to Dungeness Spit.

Drift Cell Miles

To provide a consistent, simple, and accurate method for referring to locations or segments along the drift cell, we use *drift cell miles* (DCMs), which are similar in concept to river miles (Figure 10). Beginning at the ordinary high water mark at the spit's terminus, a line is traced and measured the entire length of the drift cell. The line follows the spit's crest, moving updrift towards the sediment source. Beyond the spit, drift cell miles continue to be measured at roughly the toe of the bluff. Where stream mouths are crossed, a straight line is drawn across the mouth between bluff toes. The drift cell mile line ends at the uppermost point where sediment bound for the spit reaches the beach. In the Dungeness Drift Cell, we estimated that this point is located at the mouth of Lees Creek, DCM 15.55.

Figure 10: Dungeness Spit Drift Cell with Drift Cell Miles (DCM's). Imagery NAIP 2013

Prioritization of Land Parcels

The conservation project's goal is to ensure the continued delivery of sediment to the Spit in natural quantities and by natural means, for a planning period of 200 years. To prioritize land parcels for conservation, it is crucial to know the relative quantity of sediment recruiting from various bluff locations and ultimately reaching the Spit. Because they have an undefined and relatively minor

importance to Dungeness Spit, those bluff sediments originating west of Morse Creek (fully armored since 1915) and east of Dungeness Spit's base, along with the sediments delivered by the various streams, are not considered here. This planning effort focuses solely on the marine bluffs between Morse Creek and Dungeness Spit, Drift Cell Mile 5.10 to 13.55. We further narrowed our focus to exclude publicly owned parcels, public and private roads, and the few armored parcels just east of Morse Creek. Figure 11 shows the area of focus.

The Focus Area

The focus area includes approximately 8 miles of shoreline along the shoreline bluff top. Except where the stream valleys of McDonald, Siebert, and Bagley Creeks have cut notches, the bluffs are continuous throughout this reach. Much of the area landward of the bluff crest is a relatively flat glacial plain. Bluff top properties near the bluff edge afford marine and mountain views making them popular for residential development. The area within the former lake bottom at Lake Farm road is an exception with an incline from much of the property up to the bluff crest.

The entire focus area is zoned for residential development, with some 70% of the parcels developed by mid-2014. Parcels are generally rectangular with sizes ranging from 0.14 acres to 47.85 acres. Although

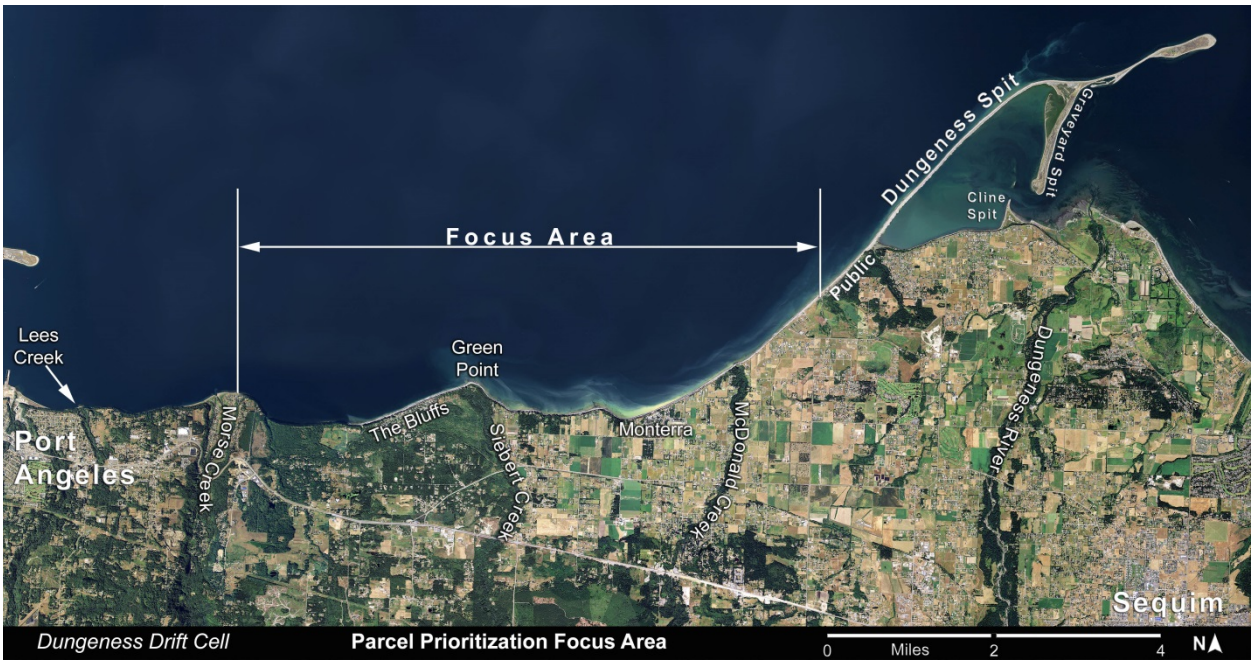

Figure 11: Dungeness Drift Cell- Prioritization Focus Area 2014

much of the development is rural in nature, two residential developments, Monterra and "The Bluffs", were developed at suburban densities. Many of their shoreline lots are approximately 100-feet wide. These two developments contain about 40% of the focus area's total parcels, while occupying only 8% of the total area. Nine parcels along Gehrke Road, immediately east of Green Point, are also smaller and clustered more tightly than those in the adjacent areas.

For prioritization, we selected land parcels (Clallam County 2010) that border the shoreline and properties that are likely to become shoreline parcels during the next 200 years of bluff erosion. Slightly over 400 parcels fall within the 200 year erosion band. After removing roads and publicly owned parcels from the planning process, 382 privately owned parcels remained to be prioritized.

Erosion Rate Study

The first step taken to inform our prioritization effort was to estimate contemporary bluff erosion rates. We geo-rectified high resolution aerial photographs for the years 1956, 1976, 1997, 2008, and 2010, and then located the bluff edge at 64 reference locations for the maximum number of these years as was possible. Differences in bluff edge locations were measured and erosion rates, also known as *bluff recession rates,* were calculated. Associated Geographic Information System (GIS) datasets were created and are used throughout this prioritization.

Figure 12: Measurement of bluff erosion.

Criteria for Prioritizing Land Parcels

Several stakeholder meetings were hosted to discuss prioritization concepts and to identify criteria, including geophysical, social, economic and practical factors that could be used to prioritize parcels for conserving sediment delivery to Dungeness Spit. The stakeholders discussed a long list of criteria which were narrowed and combined to approximately a dozen important factors.

Stakeholders acknowledged that due to the number and diversity of parcels within the focus area, no single organization or funding source would likely to be able to fully implement the conservation strategies being developed by the Tribe and stakeholders. Since each organization and each funding source will have slightly different requirements and conservation tools, the stakeholders concluded that prioritization criteria should be grouped into two categories: Geophysical Criteria and Implementation Criteria. Geophysical criteria are those that best predict the relative volume of sediment that each parcel will likely deliver to the Spit over the next 200 years under natural conditions. Implementation Criteria are important factors that an organization would use to decide which of the high geophysical-priority parcels best fit their funding source, their organizational goals and capacities, and the conservation mechanisms available to them. Note: This document describes the Jamestown S'Klallam Tribes planning efforts and reflects the Tribe's priorities for implementation of Dungeness Drift Cell Conservation. Meanwhile, the North Olympic Land Trust (NOLT) is exploring additional conservation mechanisms that go beyond the typical acquisition via fee-simple or conservation easement. Appendix D results from the work completed by North Olympic Land Trust in partnership with the Jamestown S'Klallam Tribe with a grant from the Puget Sound Acquisition and Restoration fund, through their Project Implementation and Development Award, grant #14-1028.

Combining Criteria and weighting:

Potential prioritization criteria are expressed in a variety of units. For example, erosion rate = feet per year, distance from the base of the Spit = miles, parcel geometry = shoreline length/parcel depth, and parcel size = acres. To convert these criteria into comparable units, a simple additive multi-criteria decision system was used. In this system, all of the criteria are converted into unit-less values between zero and 1. This is accomplished by dividing all the values for a criterion by the highest value for that criterion (this is sometimes referred to as normalization). Some of the criteria are ratios or categorical data that do not require normalization. Once the values for each criterion are processed so they range from 1 to zero, they can be combined through simple addition. Although non-normal data will behave differently than normally distributed data using this method, we found that normalization combined with weighing of the criteria worked well for the needs of this project.

Once normalized, each criterion is designed so that it can be used alone or combined with other criteria. Combining criteria is achieved through addition. Adding a number of criteria together will

$$Prioritization\ score = cA + cB + \cdots$$

$$Weighted\ Prioritization\ score = 2(cA) + cB + cC + \cdots$$

result in a prioritization (score) for each parcel. Where criterions are not equal in their relative importance, weighting can be used. Weighting simply involves placing a multiplier next to criteria that are more important than others. For example, multiplying Criterion A times two, then adding it to Criteria B and C will result in a prioritization score where Criterion A has twice as much influence on the outcome as either B or C. This will be further explained using examples given below.

Geophysical Sediment Delivery Prioritization

The relative amount of sediment contributed to Dungeness Spit from any given parcel is determined by numerous factors, which can be placed in two categories:

- *Factors affecting the quantity of sediment delivered to the beach*. This includes the parcel's location relative to the bluff edge, bluff height, composition, and erosion rate.
- *Factors affecting the percentage of sediment reaching the Spit*. This includes the parcel's proximity to the Spit and its location within the drift cell relative to features that affect longshore drift, such as Green Point.

Delivery to the beach:

The most basic factor influencing the quantity of material delivered to the beach from a given parcel is whether or not that parcel currently contains an eroding bluff. This criterion is labeled "First Row" (Table 1). A First Row parcel is a property that is located against the shoreline and is currently eroding at some rate. A Second Row parcel is located with the 200-year erosion band but is landward of another parcel and is not currently delivering any sediment to the beach. Second Row parcels will begin to produce sediment later in the 200-year planning period, after the adjacent First Row parcel has eroded entirely away. While the conservation project's goal is to conserve the natural sediment supply and natural shoreline processes for the next 200 years, priority was given to parcels that deliver sediment now (First Row parcels) versus later (Second Row parcels).

Table 1: Geophysical Criteria

	Geophysical Criteria			
Criterion Name	**First Row**	**Proximity Index**	**Erosion Rate Index**	**Bluff Height**
Criterion Code	**F**	**P**	**E**	**H**
Criterion Description	First Row grants a single point to all parcels that border the shoreline (2014). All other parcels receive a zero.	The Proximity Index is the normalized inverse of each parcel's distance from the base of the Spit. Closest parcel = 1, farthest parcel = 0.02.	E is the normalized average annual reach erosion rate, based on the Tribe's measured bluff recession rates from historic aerial photographs.	High bluffs (170 feet and higher in elevation) receive 0.015 point. Bluffs lower than 170 feet receive a zero.

The second elemental factor influencing sediment delivery to the beach is bluff erosion rate. In the Dungeness Drift Cell, site-specific bluff erosion rates can be extremely variable (0 to 17 feet per year) from year to year.

Table 2: Bluff Erosion Rates

Drift Cell Mile	Erosion Rate (feet per year)	Reach
5.94 to 8.60	1.25	Voice of America to Tradewinds Lane
8.60 to 10.31	0.75	Tradewinds Lane to West Gehrke Road
10.31 to 10.77	0.15	West Gehrke Road to Siebert Creek
10.77 to 13.61	0.7	Siebert Creek to Buchanan Drive

However, relatively smooth stretches of shoreline indicate that erosion rates within reaches tend to be uniform over long periods of time. Otherwise the shoreline would be extremely jagged. Using information from the Tribe's erosion rate study, mean annual erosion rates for entire reaches were estimated. Reaches received an erosion rate index based upon their estimated mean annual erosion rate. Each parcel within a reach then received that same erosion rate index.

Bluff height determines the quantity of sediment delivered to the beach for any given amount of bluff recession. Throughout the easternmost 6.15 miles of bluff (DCM 5.1 to 11.25), the bluff height averages approximately 112 feet and ranges from about 90 to 144 feet (Figure 13). The undulation of these bluff heights does not appear to warrant discriminating between parcels due to their bluff height. Within

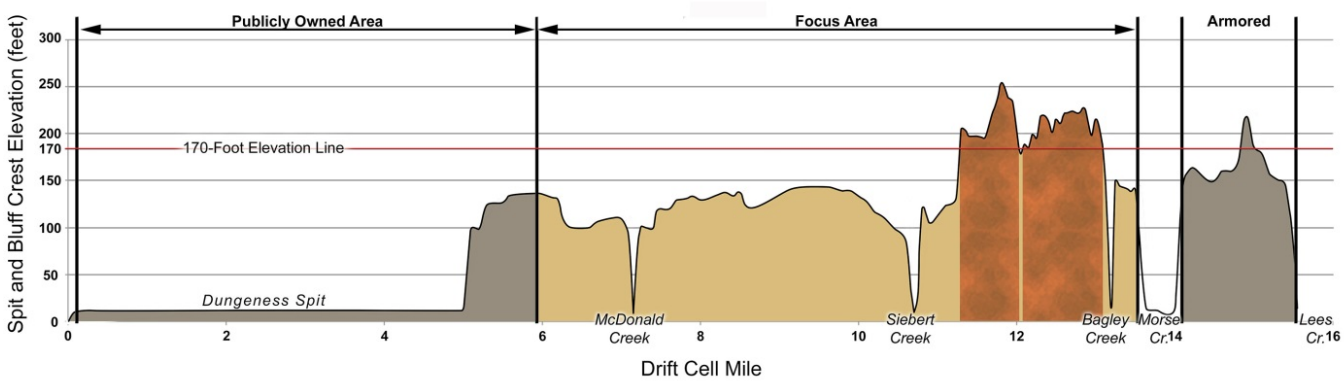

Figure 13: Bluff Elevation vs. Drift Cell Mile. Bluff Height = Bluff Elevation – 9 feet.

"The Bluffs" development however, between DCM 11.25 and 11.3 the bluff suddenly jumps to heights averaging about 203 feet and in one location exceeds 240 feet. These relatively greater heights extend to the Bagley Creek ravine at DCM 13.1. To address the juxtaposition of such dramatically divergent bluff heights within "The Bluffs", we segregated the parcels based on their bluff crest elevations being higher or lower than 170 feet. (The Dungeness Drift Cell bluffs originate at a toe-elevation of approximately 9 feet. Hence, bluff height equals bluff crest elevation minus 9 feet). Parcels with bluff

crest elevations exceeding 170 feet receive 0.015 added to their prioritization score. Application of this scoring criterion elevates the scores of the highest bluff parcels above those of nearby, down-drift lower bluff parcels, especially within The Bluffs. The effect of bluff height criterion on the ordering of first-row parcels extends only to the eastern side of Green Point at DCM 10.3.

Delivery to the Spit:

Once bluff sediment has reached the beach, it is subject to wind, wave, and tidal forces that move it predominately eastwards. As sediment moves along, a percentage drifts offshore and out of the drift cell. This percentage is thought to be a function of the distance between the source and the Spit. Additionally, certain features along the way, such as Green Point, may deflect a larger percentage offshore. Thus, sediment delivered to the beach closer to the Spit is more likely to reach the Spit as contrasted with sediment that lands on a beach farther west from the Spit. Therefore a criterion was developed that measured the planer distance between the Spit and each parcel. This criterion is labeled "Proximity Index".

Sediment delivery prioritization score:

Combining the criteria for Proximity, Erosion Rate, Front Row, and Bluff Height into a single prioritization score involved adding 2.25 times the Proximity Index (P) value to 2.25 times the Erosion Rate (E) plus the Front Row (F) and Bluff Height (H) values (see equation below).

$$Score = 2.25(P + E) + F + H$$

The proximity of a parcel to the Spit and the average erosion rate of its reach are 2.25 times more important than the parcel being in the front row at the beginning of the 200-year planning period and

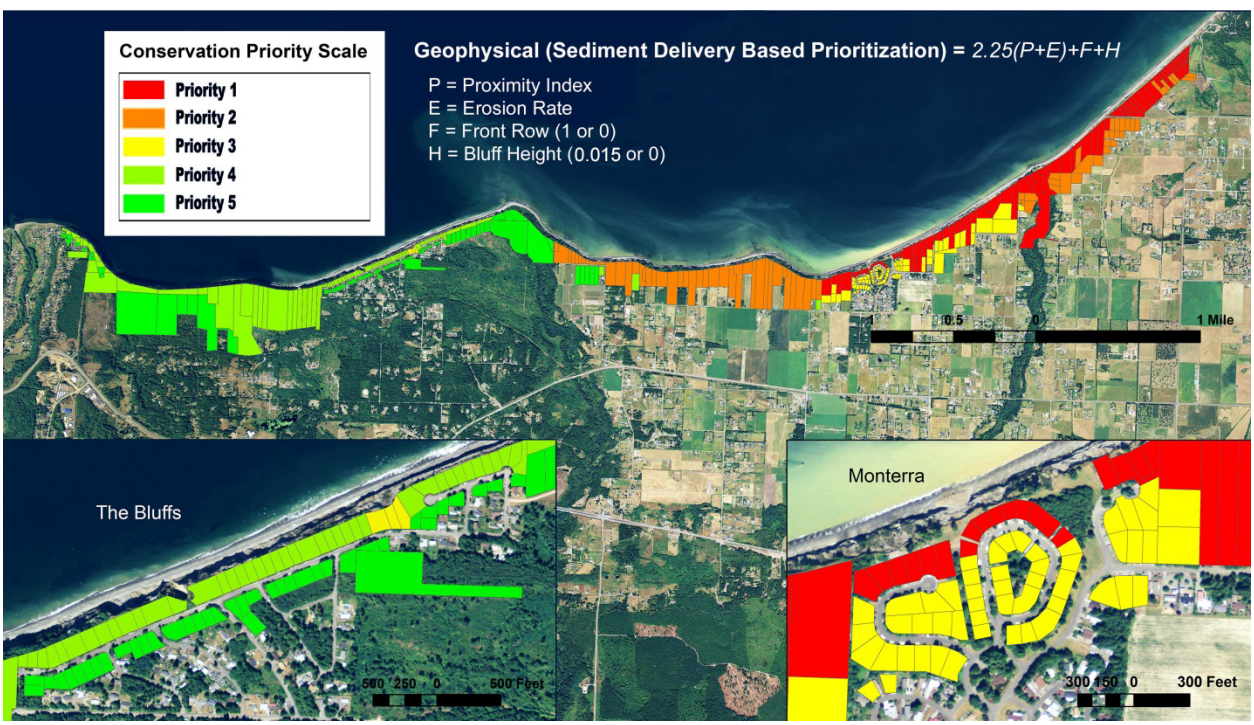

Figure 14: Sediment Delivery Prioritization- Each parcel is scored based on 2.25 times their proximity and erosion potential values plus one for front row parcels and 0.015 where bluff elevation exceeds 170 feet.

bluff height. Regardless, front row parcels are a higher priority for conservation than adjacent second row parcels.

For ease of evaluation, the final scores are converted to a familiar 0-10 scale with the highest ranking (most geophysically important parcel) receiving a score of 10.

Figure 14 is a graphic representation of the geophysical (sediment delivery) prioritization. Parcels with the greatest potential to deliver sediment to the Dungeness Spit are shown in Red and should be the focus of early conservation efforts. Green parcels are areas where later efforts will be focused. Note that the graphic divides the data into quantiles based on their scores. Once an organization is ready to begin implementing this conservation plan, the actual parcel scores may be more meaningful than the colored map image. Final scores for each parcel ranked from highest score to lowest can be found in Appendix A. Appendix B has the rankings ordered by drift cell mile while Appendix C has the rankings in order by parcel number.

Implementation Criteria

Geophysical prioritization is a powerful tool for drift cell conservation, yet it cannot operate independently of economic factors, organizational priorities, and landowner willingness. Landowner willingness (willingness to sell fee-simple or conservation easement or willingness to cooperate with the conservation measure) is likely the most important implementation criterion.

Table 3: Implementation Criteria list, codes, and descriptions.

	Implementation Criteria								
Criterion Name	**Parcel Geometry**	**Size Index**	**Opportunity Index**	**Hazard Index**	**Relocation Index**	**Immediacy of Threat**	**Length of Shoreline**	**Cost Effectiveness**	**Non Relocation Index**
Criterion Code	**G**	**S**	**O**	**HI**	**R**	**I**	**L**	**C**	**nR**
Criterion Description	Ratio of area (acres) inside the 200-year erosion band to the total acres on the top of the bluff	Acres of contiguous property owned by a single entity. Normalized by dividing each value by the largest value.	Assumes that conservation measures will be easier to implement on undeveloped parcels. Undeveloped parcels receive a score of 1, while developed parcels	Years to Contact is sorted into categories to produce four Hazard Indexes: 1.0, 0.5, 0.25, and 0. Parcels receiving a score of 1.0 have less than 10 Years to Contact.	Parcels with a residential structure that can be relocated outside the 100-year erosion band receive 1 point. All other parcels receive 0.	A combination of hazard index, ability to relocate structures, and structure density. Assumes that heavily developed areas are the most likely to be armored.	Length in feet of the bluff crest. Normalized by dividing the value by the highest value.	The property's monetary value divided by shoreline length, then normalized.	This is the opposite of Relocation Index. Should not be combined with Relocation Index.

Year by year, day by day, or even minute by minute landowner willingness can change, so this important factor could not be included in our analysis. To address the differing priorities among implementing organizations, the various conservation mechanisms, grant requirements, and some of the human aspects of the conservation effort, the stake holders developed a number of implementation criteria.

The following implementation criteria are designed to have values ranging from 0 to 1.They can be added and used with a subset of parcels (i.e. the highest ranking parcels from the Geophysical Prioritization) or combined with the geophysical criteria to score all the parcels. The resulting scores will rank parcels where the highest total score is the most suitable parcel for implementing the conservation measure, assuming landowner willingness. The implementation criteria are listed and define in Table 3.

Parcel Geometry:

Parcels along the Dungeness Drift Cell come in various dimensions and shapes. Most are rectangular, often with the narrow side abutting the shoreline. The Parcel Geometry criterion was developed for cases where an organization is seeking to maximize the amount of land within the 200 year erosion band that could be conserved with one landowner through the use of fee-simple land purchases or conservation easements. Parcel Geometry is the parcel's acreage within the 200 year erosion band divided by the total upland parcel area (*adjusted parcel area* - does not including the bluff face or any tidelands). Thus, where the entire upland area lies within the 200-year erosion band, Parcel Geometry equals 1. Properties containing land outside of the 200-year erosion band will have parcel geometry indices less than 1. Note: at the time of this analysis, parcel boundaries available to the Tribe are rough

Figure 15: Before and after example of Adjusted Parcel Acres. Adjusted Parcel Acres includes only area landward of the bluff crest. Adjusted Parcel Acres are for planning purposes only.

in many ways. Many are not based on surveys and boundaries are not regularly updated. As the bluff erodes and the shoreline migrates landward, many of the parcels lose acreage. This loss of land is not reflected in the parcel dataset. Most parcels reflect the shoreline at the time the land division was recorded or the shoreline location when the parcel was created. Therefore, adjusted parcel area includes only the area located inland from the bluff crest, so that older or poorly mapped parcels do not receive an improper score.

Size Index:

Using the adjusted parcel area and ownership information, Size Index is created by combining all the contiguous parcels owned by a single owner or a single ownership group. Ownership groups can be married couples, trusts, or even corporations. There are many family trusts with holdings along the drift cell. This criterion assumes that it will be easier and possibly cheaper to conserve more property when working with larger parcels or blocks of parcel under a single ownership then conserving many smaller parcels under the control of numerous owners.

Opportunity Index:

This criterion gives a single point to properties that are undeveloped, as of early 2014. It assumes that conservation measures will be easier and possibly cheaper to undertake on undeveloped land as contrasted with developed parcels, and that, according to landscape ecology principles, it's generally better to conserve a larger area of land.

Years to Contact and Hazard Index:

Each residential and commercial building within the focus area was assessed for the number of years remaining until the building will be endangered by bluff erosion. This assessment was expressed as *Years to Contact*. Years to Contact is estimated by dividing the distance between the bluff crest and a

Figure 16: Examples of distance from bluff edge to structure.

point 15 feet in front of the structure (safety buffer) by the erosion rate in that area. Fifteen feet was established as a safety buffer because once the bluff crest erodes to within 15 feet, a single erosional event could cause the house to fall off the bluff. In several cases landowners have relocated residences before the bluff crest has eroded within 15 feet. Parcels with low Years to Contacts values are a higher priority for addressing with conservation measures.

Table 4: Analysis of Years to Contact

Years to Contact Categories (2012)	*Hazard Index* Score (2012)	Number of Parcels (2012)
<10	1	7
>10 to 40	0.5	23*
>40 to 100	0.25	68
>100	0	168
No Structure	0	117
Total Number of Parcels *2 were moved in 2014		382

All the prioritization criteria are designed to produce maximum values of one. Therefore in the case of Years to Contact, the values were sorted into categories to produce four Hazard Indexes: 1.0, 0.5, 0.25, and 0. A Hazard Index of one indicates the presence of a residence or commercial building with a Years to Contact value of 10 or less, while a Hazard Index of zero means that the structure has a Years to Contact value greater than 100 (Table 4).

Example calculation of Years to Contact and Hazard Index (Figure 15): Fifteen feet (width of the Safety Buffer) subtracted from 160 feet (distance of the house to the bluff edge) equals 145 feet. Dividing 145 feet by the erosion rate of 1 foot per year yields a Years to Contact value of 145 years. If on average, the erosion rate remains 1 foot per year, in 145 years this house will be 15 feet from the bluff crest. Had the structure not already been moved, it would be imperative that the house be moved back from the edge or be dismantled.

Relocation Index:

The ability to relocate a structure landward from the bluff crest (move it farther from harms-way) may be a key component of a conservation measure or strategy. Moving structures back from the bluff crest is a time proven and effective strategy for dealing with coastal erosion. Although moving a structure any distance provides some benefit we only considered cases where the parcel contains sufficient area to relocate the structure outside the 100-year erosion band. Relocation Index adds a single point to any structure that can be relocated onto the same parcel or a neighboring parcel owned by the same owner. This determination was done by visual interpretation from the 2013 air photographs in the GIS. Field verification and landowner willingness would still be required.

Immediacy of Threat:

Immediacy of Threat combines a structure's hazard index, the lack of room for structure relocation, and neighborhood development density into a single categorical criterion that assesses the likelihood that a landowner would attempt to slow bluff erosion through bluff modification or armoring. It is assumed that fear and financial ability are the primary factors that would lead a landowner to attempt to armor a high bluff property. While we are unable to measure fear or financial ability, structures with a low Years to Contact (high Hazard Index) will create fear for the owner. Fear may turn to desperation, especially where the landowner does not own sufficient property to move the structure back from the bluff.

Hence, structure owners with a low *Years to Contact* value and no relocation potential are likely to be the most fearful bluff property owners. It is also assumed that a group of property owners has a greater chance of mounting a high bluff armoring effort than a single landowner. The following decision matrix (Table 5) is used to determine the threat category (high to low) for any structure.

Table 5: Immediacy of Threat matrix. Each structure is placed into categories based on Years to Contact, neighborhood development concentration, and potential to relocate the structure. The categories are High, Medium-High, Medium, Low.

Years to Contact	Neighborhood Concentration	Relocation potential	Immediacy of Threat Category	Value
<50	Concentrated	No	High	1
50 to 200	Concentrated	No	Medium-High	0.5
<200	Concentrated	Yes	Medium	0.25
<200	Not Concentrated	N/A	Medium	0.25
>200	N/A	N/A	Low	0
No Structure	N/A	N/A	Low	0

Length of Shoreline:

Length of shoreline was recorded using the top of the bluff crest instead of the traditional ordinary high water or high tide line. This measurement simulates the value that would be generated by using a tape to measure the distance from boundary edge to boundary edge roughly along the bluff crest. The crest line is a consistently delineated and somewhat generalized line that was previously plotted and was easily used to generate length in feet in the GIS. Implementing a conservation measure that protects shorelines from future armoring would be enhanced by ranking parcels at least partly based on the length of shoreline that would be protected.

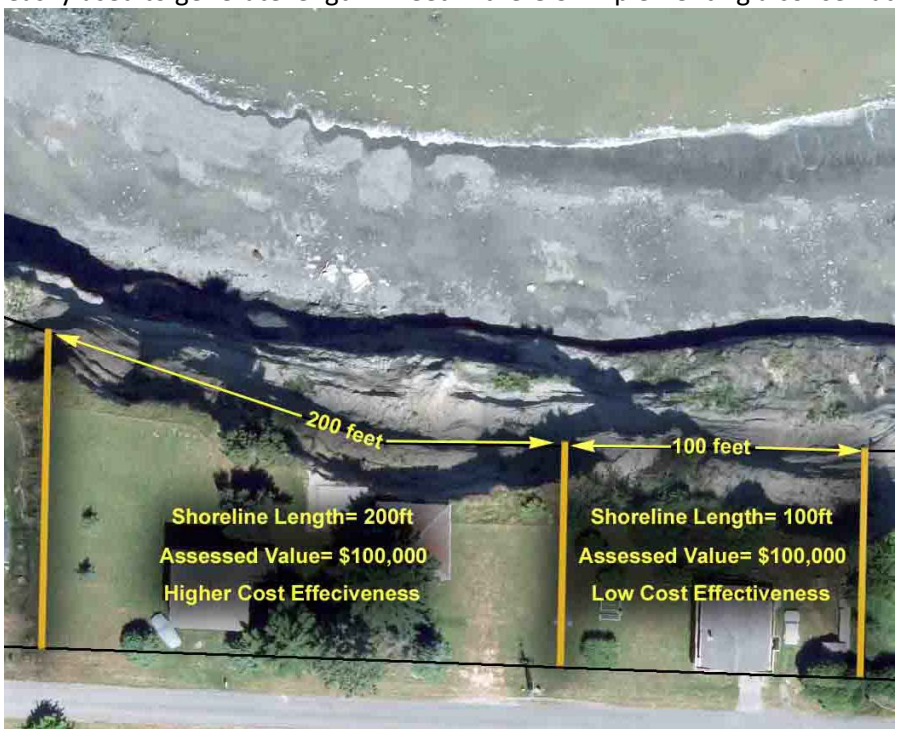

Figure 17: Cost Effectiveness Index- (Hypothetical example)- two parcels with the same assessed value where the parcel on the left has twice as much shoreline therefore has a higher Cost Effectiveness Index.

Cost Effectiveness Index:

Cost Effectiveness is calculated by dividing length of shoreline by the assessed value. Assessed values are determined by Clallam County and are very rough. Fair market value should be verified by a qualified property appraiser. Cost effectiveness assumes that the cost of the conservation

measure will be related to the fair market value of the property and that cost effective implementation will be more likely on properties more feet of shoreline to be conserved per dollar spent. The index is created by normalizing the resulting data.

No-Relocation Index:

The No-Relocation Index is the opposite of the Relocation Index and should not be used in combination with the Relocation Index. Recognize that Immediacy of Threat Index includes relocation potential as one of its underlying metrics. For some implementation projects, it may be desirable to prioritize (or sort) parcels that contain a structure with no room to relocate it on the current owner's property.

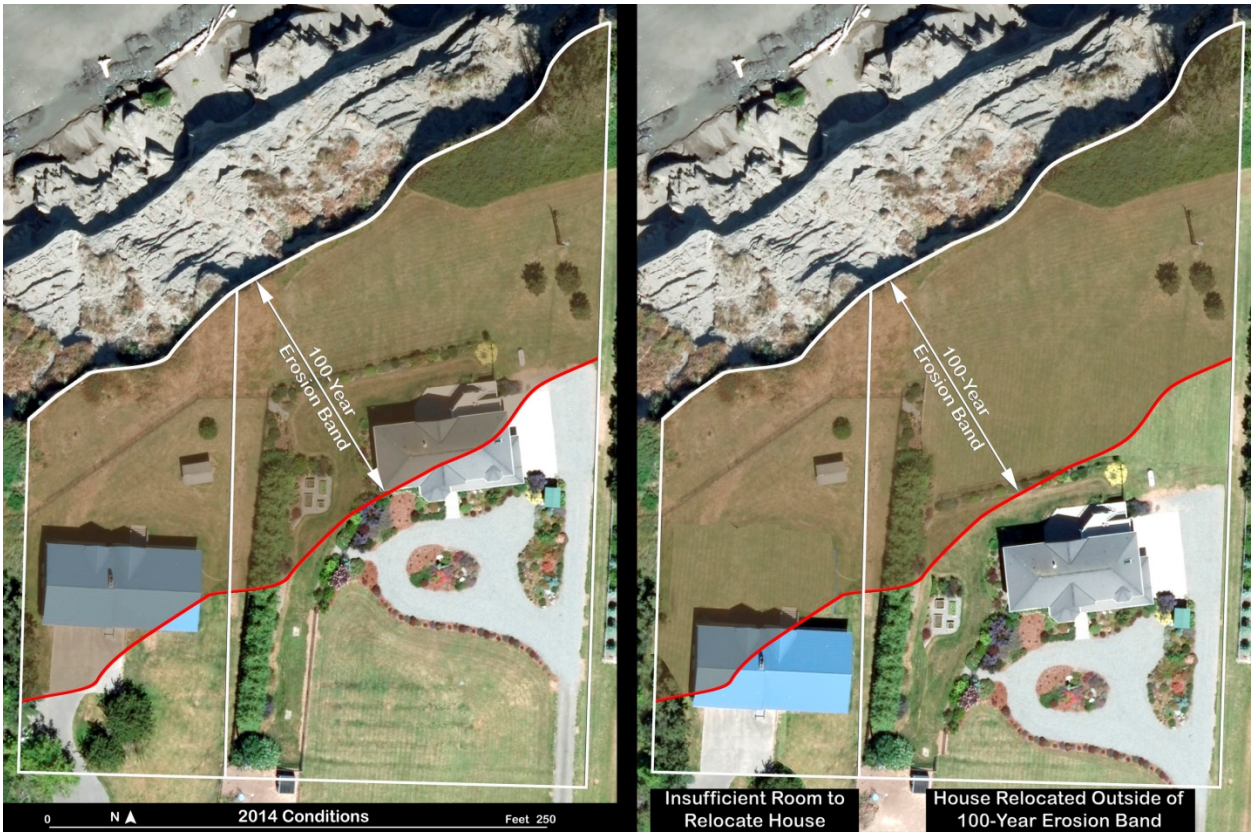

Figure 18: Examples of relocation potential.

Parcels with a structure and no relocation potential are given one point; parcels with no structure or with a structure that has relocation potential are given no points.

Implementation Prioritization

Combining implementation and geophysical criteria can be as simple as adding together the scores for each criteria that an organization wishes to use. However, this should often be an iterative process that uses the careful application of weightings to achieve the proper balance among criteria. The final outcome will be a list of potential candidates for a given conservation measure or incentive program. Without knowing which funding source or which incentive program may be available, implementation

prioritizations can only be generated for several common conservation measures such as fee-simple acquisition, conservation easements, and restoration/relocation.

Fee-simple Acquisition:

Purchasing real property so that it may be managed as habitat or to conserve habitat and habitat forming processes is a common conservation mechanism. The Tribe has successfully purchased property using a number of funding sources to protect and restore floodplain habitats along local rivers and streams. When working to conserve the sediment supply for the Dungeness Spit purchasing parcels may preferred in some cases. For this prioritization, the geophysical $2.25(P + E) + F + H$ results would most likely be combined with parcel geometry and cost effectiveness.

Traditional Conservation Easement:

Protecting valuable natural resources, such as fish and wildlife habitat, through the purchase of conservation easements is a staple of the North Olympic Land Trust. The Land Trust has previously conserved a number of larger parcels along the Dungeness Drift Cell based solely upon their habitat value, without considering the parcel's sediment delivery potential. The Land Trust generally limits their interest to parcels 15 acres and larger that have received high scores using their project selection criteria scoring system. Within the focus area only a few parcels of this size remain and they tend to rank quite low on the Geophysical Prioritization rankings. We urge the Land Trust to adopt a drift cell-specific rating system that recognizes that certain land parcels less than 15 acres in size provide sediment essential to the maintenance of major off-site priority habitats. These parcels, regardless of size, should be considered for conservation using traditional conservation easements. The Tribe has no history of purchasing or holding conservation easements and is most likely to serve as a stakeholder, collaborator, or partner in a drift cell conservation easement program. The following prioritization could be used to create a list of suitable target parcels for conservation easements.

Bluff-Face Conservation Easement:

This is a yet to be developed, specific type of conservation easement designed solely to purchase landowners' rights to armor their shoreline. Because it only addresses sediment supply conservation without otherwise encumbering a property, this is an especially appealing potential conservation tool and could be a very cost effective measure. Landowners would sell a conservation easement specific to the bluff face, which would prohibit shoreline armoring. No other property right would be affected, and property owners would retain full use of their land and structures until such time, possibly many generations in the future, that the property has eroded away.

Relocation or Removal of Structures:

Ever since development of bluff-top properties began in the Dungeness Drift Cell, property owners' primary methods of addressing hazard risks caused by bluff erosion have been to relocate and remove structures before they become gravely imperiled. Where assurance can be provided that natural erosion of the property will not be interfered with by the current or future owners, structure relocation/removal could likely be combined with another conservation mechanism, such as a traditional conservation easement, bluff edge conservation easement or fee-simple acquisition. Prioritization criteria for

relocating or removing structures may include Relocation Index, Non-Relocation Index, Geophysical Score, Hazard Index, Immediacy of Threat, and Cost Effectiveness.

Conclusions and Conservation Strategy

Maintaining the health and natural structure of Dungeness Spit is a high priority for the Jamestown S'Klallam Tribe. To ensure conservation of this important cultural, recreational, and economic resource, the Tribe, along with stakeholders and partners, will undertake a long-term strategy to conserve both the sediment source and its delivery to Dungeness Spit.

Early conservation efforts will focus on the bluff system between Morse Creek and the Spit. Starting with parcels identified as Priority 1, landowner willingness will be assessed and funding will be sought to implemented conservation measures. In upcoming years, the Tribe will seek funding and partnerships to conserve as much of the sediment source as possible. These efforts may involve the use of multiple conservation tools including, but not limited to:

- Fee-simple purchases that result in conservation ownership.
- Incentives to landowners to relocate structures.
- The purchase of traditional conservation easements. Since it does not generally hold conservation easements, the Tribe will seek to collaborate with organizations more readily suited for this task such as the Land Trust, Washington Department of Fish and Wildlife (WDFW), and Clallam County. Once a willing partner is in place to hold easements, the Tribe will work to find funding for conservation easements that protect natural bluff erosion.

While this plan provides an essential starting place for conservation planning and action, the Tribe will continue to be engaged with stakeholders, scientists, and agency staffs to develop a better understanding of physical processes occurring within the Dungeness Drift Cell and to adaptively manage our efforts as new information becomes available.

Because this is a large effort and voluntary stewardship is complex, a collaborative multi-organizational effort is clearly required to complete this important work. New conservation tools are needed. Puget Sound wide efforts are underway to better understand what motivates shoreline owners and to develop educational tools to help increase the level of understanding of the importance of maintaining natural processes that ultimately create and maintain many of the shoreline features that attract people to this area.

Acknowledgements

The Tribe is grateful to the USEPA and NWIFC for their vision and support for drift cell conservation. The North Olympic Land Trust and Puget Sound Partnership helped advance the prioritization and move this effort forward. Thank you to all the stakeholders who provided feedback and thoughtful comments on early drafts.

Appendices

Appendices A, B, & C are sorted lists of land parcel prioritization scores. Each is sorted using a different column to provide multiple methods of finding a particular parcel, region, or score range. Given the dynamic ever-changing nature of the drift cell, drift cell mile hundredths are not in geologic terms a useful measure. However, for the purposes of these lists drift cell miles were expanded to include hundredths of a mile. This allowed for better sorting of parcels in Appendix B.

Appendix D is the North Olympic Land Trust's report, "Conservation Tools for the Dungeness Drift Cell and Land Trust Priorities". This document was developed in partnership with the Jamestown S'Klallam Tribe with a grant from the Puget Sound Acquisition and Restoration fund, through their Project Implementation and Development Award, grant #14-1028.

Appendix E is a set of 2014 orthophotos labeled with drift cell miles.

Appendix F is a set of 2013 oblique air photos labeled with drift cell miles.

Appendix G is the document, "Estimates of Feeder Bluff Recession Rates in the Dungeness Spit Drift Cell, Clallam County, Washington".