PHYSICAL MONITORING/ BEACH PROFILING LUMMI SHORE ROAD PROJECT:

Summer 2008, Year 10 Monitoring

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INTRODUCTION

A physical beach monitoring program was initiated in the fall of 1996 at Lummi Nation as part of the effort to repair and upgrade Lummi Shore Road and Lummi View Drive. Monitoring was designed to define beach processes and characterize the extent and dynamics of potential surf smelt (*Hypomesus pretiosus*) spawning habitat, in order to obtain baseline data and to plan for the future. Specifically, the physical and related biological monitoring (conducted by Lummi Natural Resources with past assistance from WA Dept. of Fisheries and Wildlife) programs were designed to allow tribal resource mangers to mitigate negative effects of revetment construction on existing surf smelt spawning habitat, as well as sand lance (*Ammodytes hexapterus*) spawning habitat.

A new rock revetment, totaling approximately 9,400 ft in length, was constructed by the Army Corps of Engineers between September and December 1998. The rock revetment was an addition to the existing 2,500 ft “Section 14” revetment near the northern end of the study area, constructed in 1994; now the entire Bellingham Bay and Portage Bay bluff toe along Lummi Shore Road is armored with large rock.

The beach was nourished with 4,000 cubic yards (cy) of pit run gravelly sand in February 1999 (Dillon and Johannessen 1998 provides background), and 1,540 cy in February 2000 (Table 1). The beach was nourished for the third time (year 3) in February 2001 with 500 cy of 1-8 mm rich “scalpings”. No nourishment was placed in 2002, as it was deemed unnecessary. In February 2003, the beach was nourished with 2,000 cy of beach and bank sediment that was excavated at the time of revetment construction and was stockpiled at the old staging area. This volume was calculated by Coastal Geologic Services (CGS) to be the equivalent to 750 cy of 1-8 mm sediment. No nourishment sediment was placed since 2003.

Beach monitoring in Project Year 10 (February 2008 to January 2009) was conducted in late August 2008. The goal was to accurately document beach conditions and the fate of past beach nourishment sediment and allow for assessment of the success of the program in recreating potential surf smelt spawning habitat. During all monitoring periods, beach conditions were documented through repeating established beach profiles, sediment sampling, and photography. No new surf smelt egg data was available for Project year 10.

METHODS

See Physical Monitoring/Beach Profiling at Lummi Shore Road Restoration Project, Spring 1997 (Johannessen 1997) and Spring-Summer 1999 (Johannessen 1999) for description of beach profiling, sediment sampling, and surf smelt habitat field and analysis methods.

RESULTS

All results are presented graphically in this report. August 2008 data were processed and appended to all of the data products presented herein. Narrative of the data is presented here, but extensive description was not included as to not produce an overly long report and obscure review of the numerous data products. Summary and Conclusions are provided later in the report that synthesize results of the 10-year period between the best baseline data period of 1998 versus 2008 data. Recommendations for future management are also provided at the end of the report.

Profile and sediment sample locations are shown in Figure 1. Beach profile plots are found in Appendix 1, beach photo pages are found in Appendix 2, and beach volume change tables are found in Appendix 3 (all attached). A graphic comparison of potential surf smelt spawning habitat polygons is attached as a 24” by 48” map. The map contains field surveyed potential spawning areas from each summer 1998-2003, and the summers of 2006 and 2008 (no field data was collected in the summers of 2004, 2005, or 2007).

Much of the discussion in this report is framed in terms of the four main alongshore sub-sections of the revetment and beach at Lummi Shore Road. These areas are delimited by the truck turnarounds that protrude approximately 30 ft waterward of the general trend of the revetment toe (Figure 1). These features have modified sediment transport and the distribution of beach features to a fair extent.

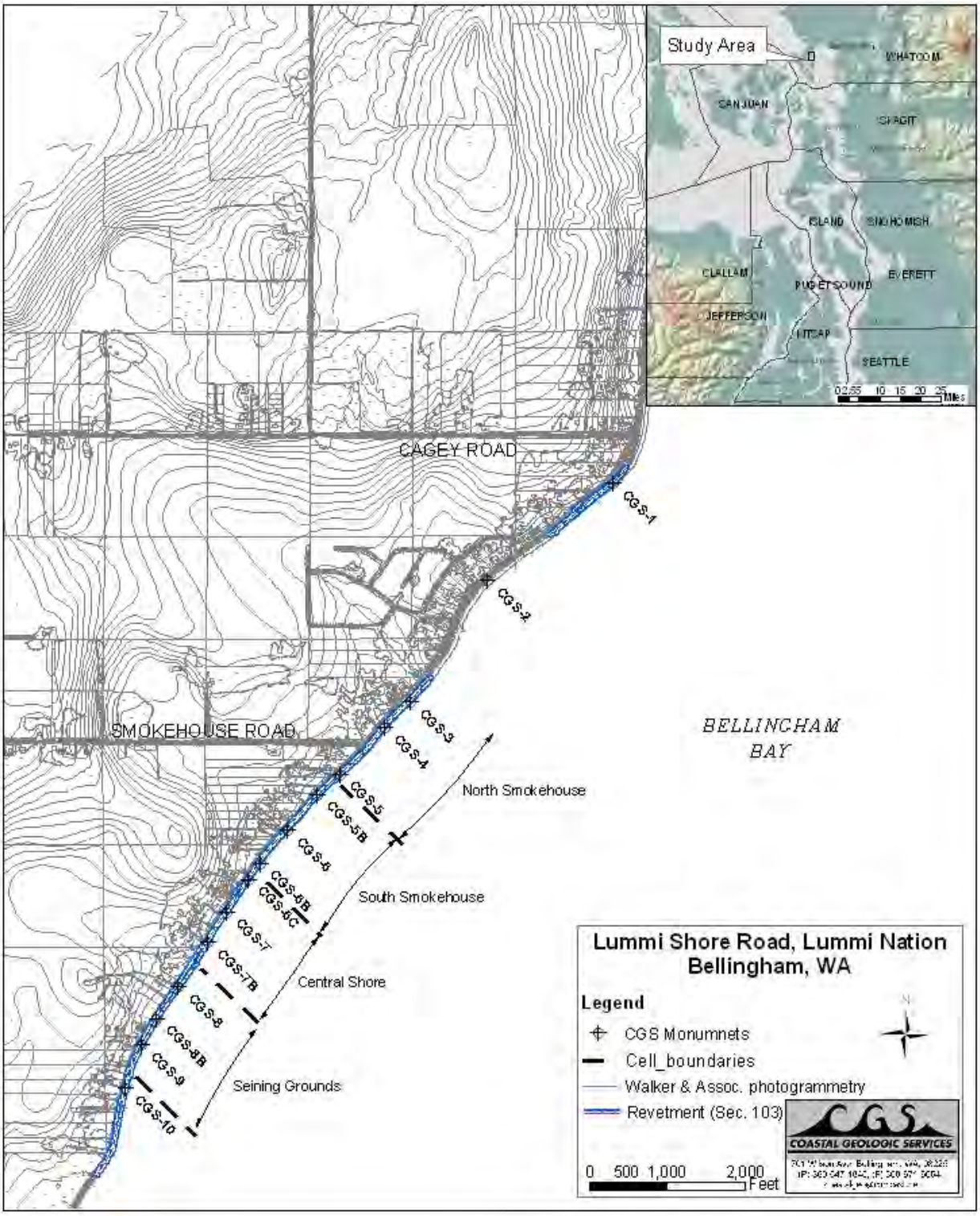

Figure 1. Vicinity map of revetment and nourishment project area showing location of profiles grouped by sub-cell (which are divided by truck turnarounds).

Beach Elevation at Revetment Toe

Profile 10, which has not been monitored since February 1999, was again briefly visited during summer 2008, but beach elevation at revetment toe was the only observation made. The pre-revetment beach at this location extended up to +11.1 ft MLLW during summer 1998 monitoring. Immediately following revetment construction however, the toe elevation was +6.7 ft MLLW, as the revetment extended a significant distance out over the beach. This was largely due to the inability to move the road landward. During 2008 monitoring the toe elevation was +7.1 ft MLLW, slightly above the as-built location, but still much lower than 1998 pre-revetment conditions.

In general, the elevation of the beach at the revetment toe in the Seining Grounds sub-cell has remained relatively stable, with a small amount of elevation gain (Table 1, Figure 2). However, the southern portion of the sub-cell (at Profile 9) appears to be loosing sediment, which has been at a lower elevation than the other two profiles since 2003. Profile 9 was 3.1 ft lower than in 1998, but only 0.2 ft below initial design elevation. The north end of the sub-cell however, was at the same elevation as seen in 1998, 1.8 ft above the design

The Central Shore has shown the most decline in beach elevation at the revetment toe, with more than 1 ft in average (vertical) decline since 1998 (Figure 3). All three profiles now average 0.6 ft below the design elevation of the revetment toe. The upper beach at Profile 7 in 2008 was 2.7 ft below pre-revetment 1998 levels.

As a whole, the South Smokehouse sub-cell has also exhibited a steady decline in upper beach elevation since 1998, although not as sharp at the Central Shore (Figure 4). The northerly direction of net shore-drift is more evident in that cell, with the southern end (at Profile 6B) substantially lower than the northern end (at Profile 5B). The northern end of the sub-cell has remained above design elevation for every year monitoring data was collected there, while the southern end has remained below design since 2002.

The North Smokehouse sub-cell differs from the other sub-cells in that no truck turnaround was constructed at the north end of the cell, and therefore no impediment to net shore-drift exists there. Beach elevation at the revetment toe at Profiles 4 and 5 was approximately 3.5 ft lower than in pre-revetment conditions (1998; Figure 5). The upper beach elevation at both profiles increased slightly between 1999 and 2003 as nourishment sediment was transported northeastward, and then generally decreased through 2008 to approximately +7 ft MLLW. The revetment toe elevation has been below design for all but one monitoring period.

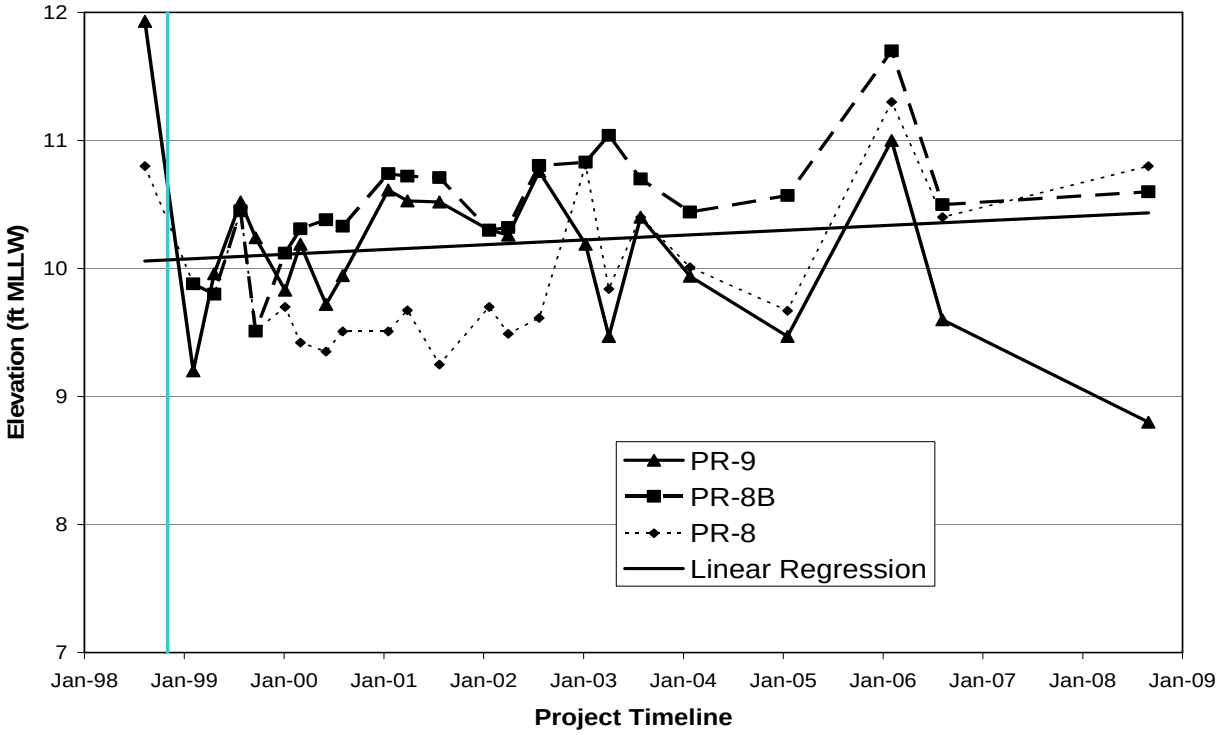

Figure 2. Beach elevation at revetment toe, Seining Grounds. Vertical line indicates timing of revetment construction.

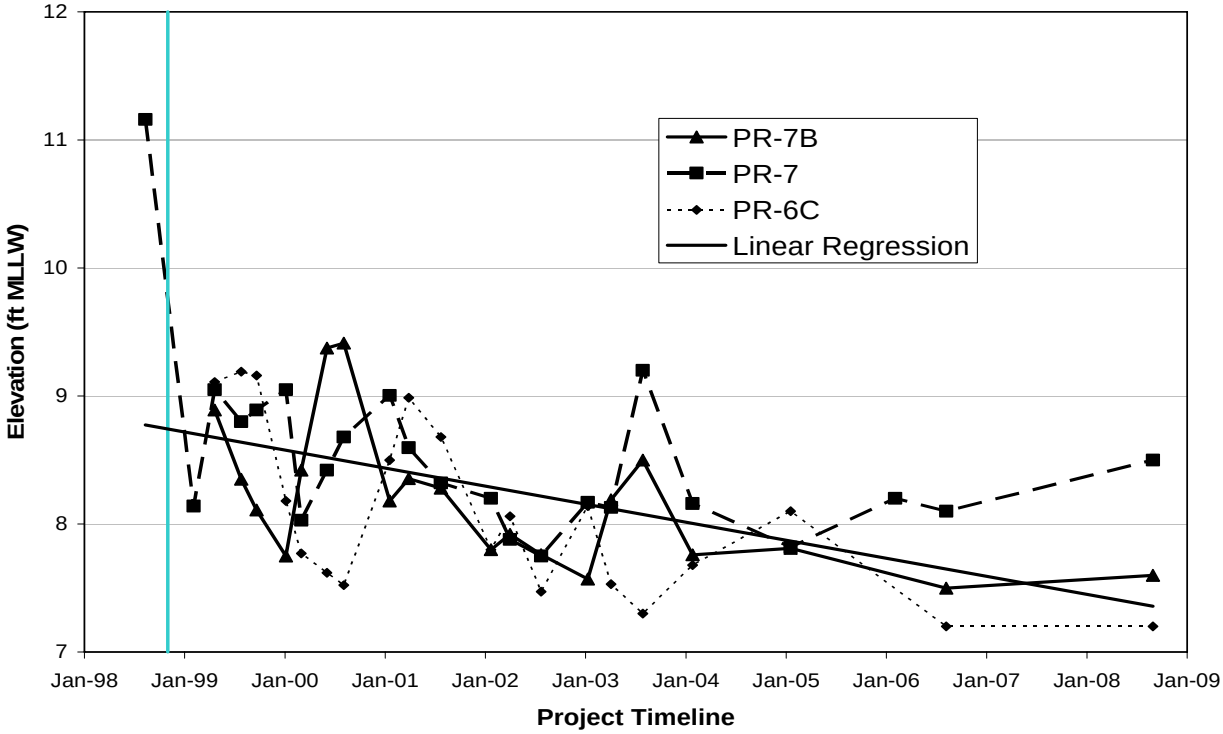

Figure 3. Beach elevation at revetment toe, Central Shore. Vertical line indicates timing of revetment construction.

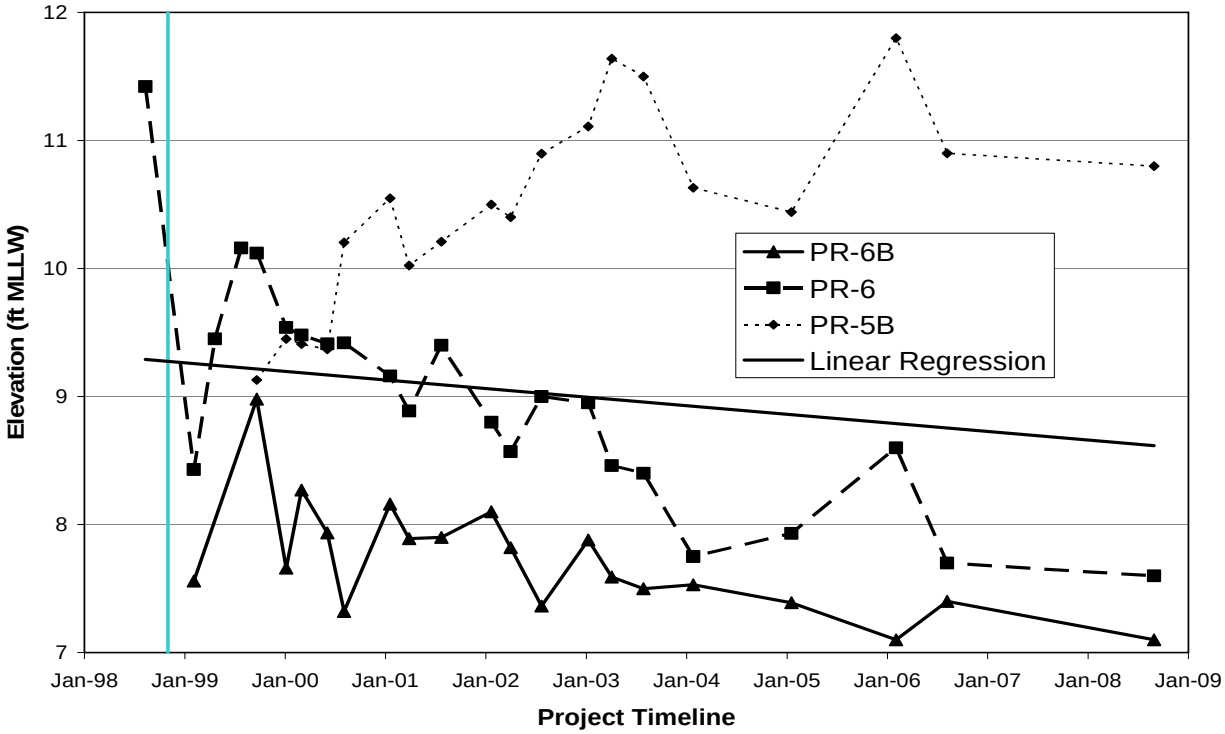

Figure 4. Beach elevation at revetment toe, South Smokehouse. Vertical line indicates timing of revetment construction.

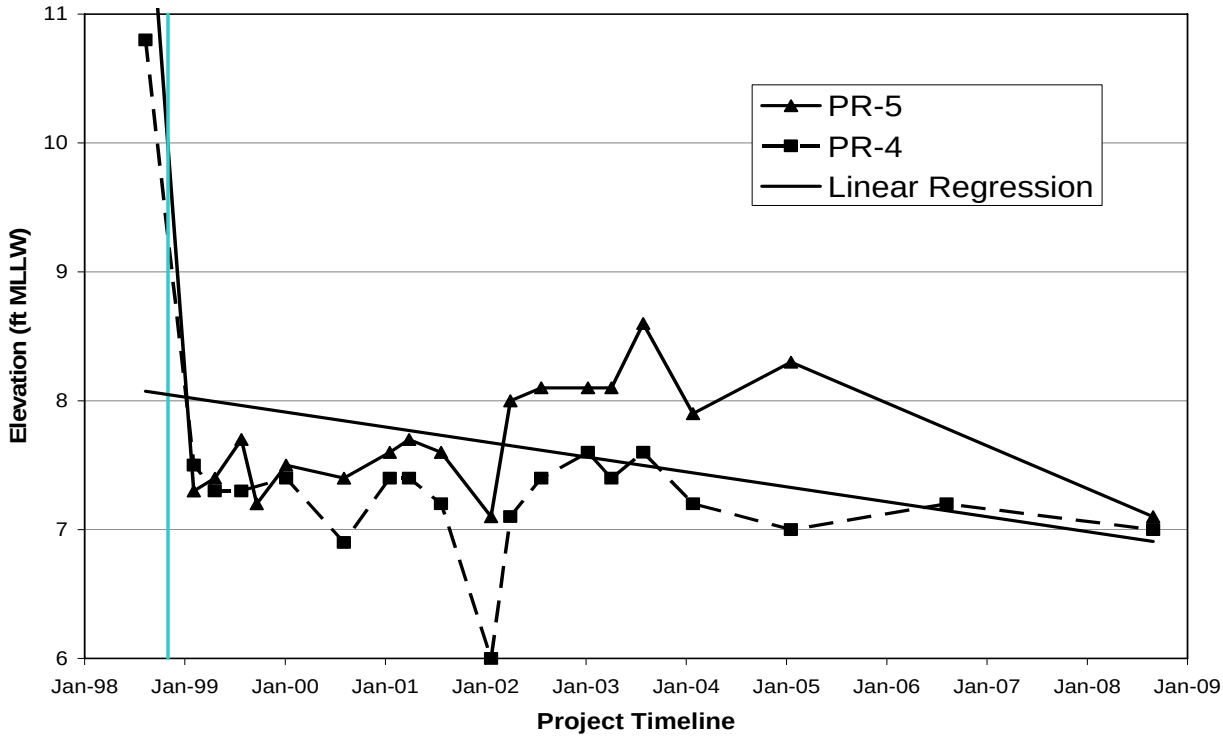

Figure 5. Beach elevation at revetment toe, North Smokehouse. Vertical line indicates timing of revetment construction. Note different elevation range of chart. Profile 5 was at +12.3 ft MLLW in 1998.

Beach Profiles and Volume Change

Beach nourishment was carried out 4 times between 1999 and 2003. No nourishment sediment has been added since 2003 (Table 1). Sediment volume change during various time steps is discussed here, as measured between each group of 3 beach profiles. Volume changes due to loss of upper beach area and sediment underneath the revetment is not considered here. Beach profiles are presented in Appendix 1, and photos at long-term profile locations are presented in Appendix 2.

Relative to pre-revetment and pre-nourishment in the Seining Grounds, the beach profiles was considerably lower at the south end (Profile 9) and considerably higher at the north end (Profile 8). Lower beachface erosion was observed at all 3 profile locations since 1998, which caused the profile to move landward at the south end and become steeper in the north end.

The Seining Grounds sub-cell has remained at roughly the same volume of sediment (down only 115 cy) as seen in summer 1998 (Table 2, Figure 5). After 2003, the total volume change in the Seining Grounds was minimal until 2006, when the volume change was negative. The overall trend for the 11 year period has been a steady decline in volume.

The entire beachface and lower beach have eroded a small amount since 1998 in the central portion of the Central Shore (Profile 7). Nourishment sediment created the highest beach profiles in 1999-2000. The beach profile in summer 2008 was generally equal to or very slightly lower than all previous years surveyed. Beach photos show numerous intertidal boulders in 1998, which were largely removed during revetment construction. However, due to rock toppling and ongoing erosion, the boulder cover has increased substantially since 1999.

Since 1998 the Central Shore sub-cell has lost 849 cy of sediment as compared to pre-construction (Table 3, Figure 6). Each nourishment event has led to a small increase in sediment volume, followed by a larger, steady decline in volume over time. While there does appear to have been some sediment transported into the cell from the Seining Grounds sub-cell, the sediment has been transported out to the northeast a bit faster.

In the central South Smokehouse sub-cell, the beach profile was slightly lower in summer 2008 as compared to 1998 (Profile 6). Minor erosion has occurred in the south end, and at the lower beach in the north end since 1999. Again, beach slope was greatest at the north end adjacent to the truck turnaround.

Of the three sub-cells, the South Smokehouse has lost the most sediment since 1998. Initial nourishment in 1999 resulted in very large gains in volume in this reach due to transport of nourishment sediment from the other two sub-cells. Those gains were quickly lost, resulting in a low beach and gradual but steady decline in sediment volume. Monitoring in 2008 showed the total volume to be 1,289 cy below 1998 pre-revetment levels.

Beach profiles in the North Smokehouse sub-cell revealed moderate, ongoing erosion, with substantial lowering at Profile 4, since 1998. A mid beachface sand bar that was highest pre-revetment and present through 2003 at various levels at Profile 5 was not present in 2008. The profiles were generally the lowest of all years with summer data in 2008.

Table 1. Lummi Shore Road study area sub-cells and nourishment volumes, which occurred in late winter, following winter monitoring.

Sub-Cells/ Area	**Seining Grounds**	**Central Shore**	**South Smokehouse**	**North Smokehouse**	**Section 14 North**	**Total Nourishment Volume (cy)**
Road Stations	270 – 284	284 – 300	300 – 314	314 – 333	333 – 370	
Profiles	9, 8B, 8	7B, 7, 6C	6B, 6, 5B	5, 4, 3*	2*, 1*	
1999 Vol. (cy)	1,333	1,333	1,333	0	0	4,000
2000 Vol. (cy)	784	756	0	0	0	1,540
2001 Vol. (cy)	500	0	0	0	0	500
2002 Vol. (cy)	0	0	0	0	0	0
2003 Vol. (cy)	1,000	1,000	0	0	0	2,000
2004 Vol. (cy)	0	0	0	0	0	0
2005 Vol. (cy)	0	0	0	0	0	0
2006 Vol. (cy)	0	0	0	0	0	0
2008 Vol. (cy)	0	0	0	0	0	0
Total Vol. (cu)	3,617	3,089	1,333	0	0	7,040

Note: * These profiles are sampled less frequently.

Table 2. Summary of volume changes in Seining Grounds sub-cell from 1998 to 2008, grouped by season, above +4.0 ft MLLW. Table 2b includes the data for Figure 5 and can be found in Appendix 3.

Winter to Winter (cy)		Summer to Summer (cy)	
		1998 - 1999	+695
1999 - 2000	-460	1999 - 2000	-745
2000 - 2001	-161	2000 - 2001	+434
2001 - 2002	+22	2001 - 2002	-536
2002 - 2003	+108	2002 - 2003	+418
2003 - 2004	-71	2003 - 2006	-218
2004 - 2005	-44		
2005 - 2006	-12	2006-2008	-255
		1998 - 2008	-115

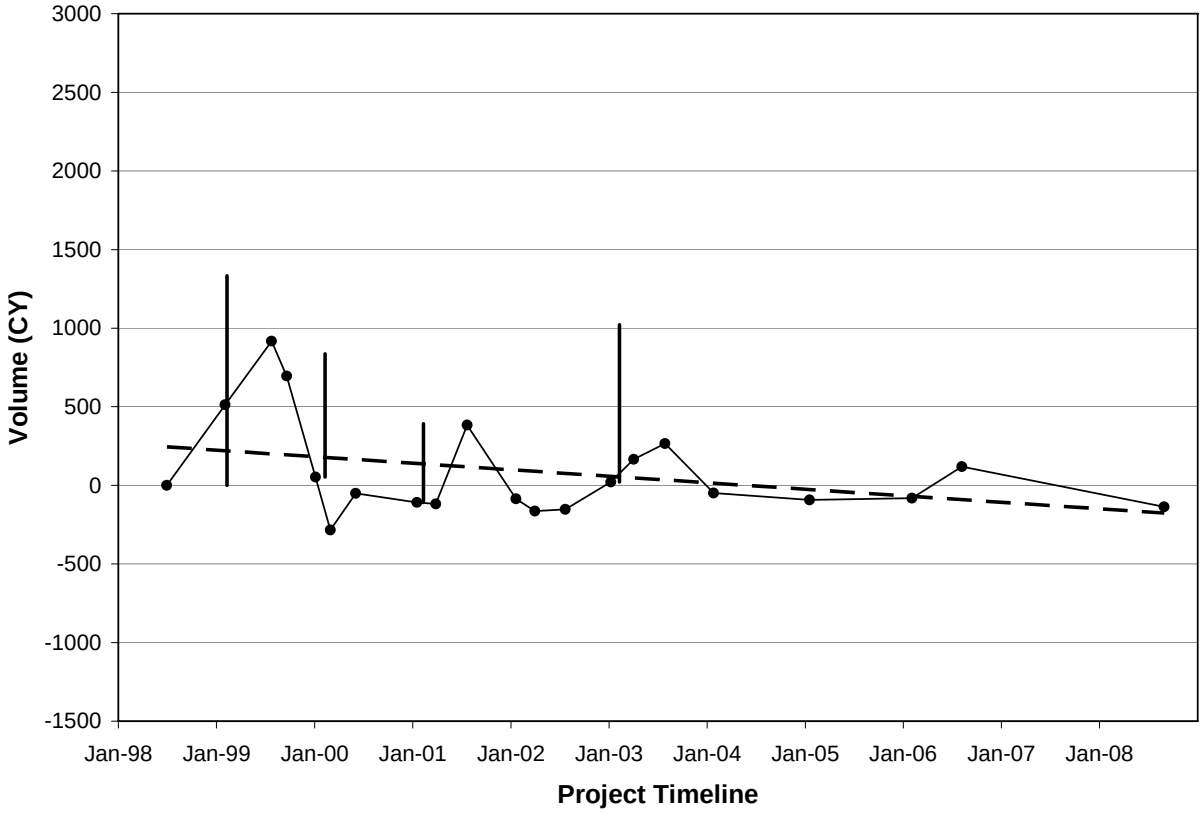

Figure 5. Plot of cumulative volume changes in Seining Grounds sub-cell from summer 1998 to summer 2008, above +4.0 ft MLLW. Vertical black lines indicate timing and volume of nourishment sediment within the sub-cell. Dashed line indicates 11-year trend.

Table 3. Summary of volume changes in Central Shore sub-cell from 1998 to 2008, grouped by season, above +4.0 ft MLLW. Table 3b includes the data for Figure 6 and can be found in Appendix 3.

Winter to Winter (cy)		Summer to Summer (cy)	
		1998 - 1999	+30
1999 - 2000	-1,208*	1999 - 2000	-72
2000 - 2001	-28	2000 - 2001	-318
2001 - 2002	-317	2001 - 2002	-342
2002 - 2003	-334	2002 - 2003	+186
2003 - 2004	+291	2003 - 2006	+88
2004 - 2005	-136		
2005 - 2006	-39	2006 - 2008	-131
		1998 - 2008	-849

*One or more volume time period set was not used because profile was not established at that time.

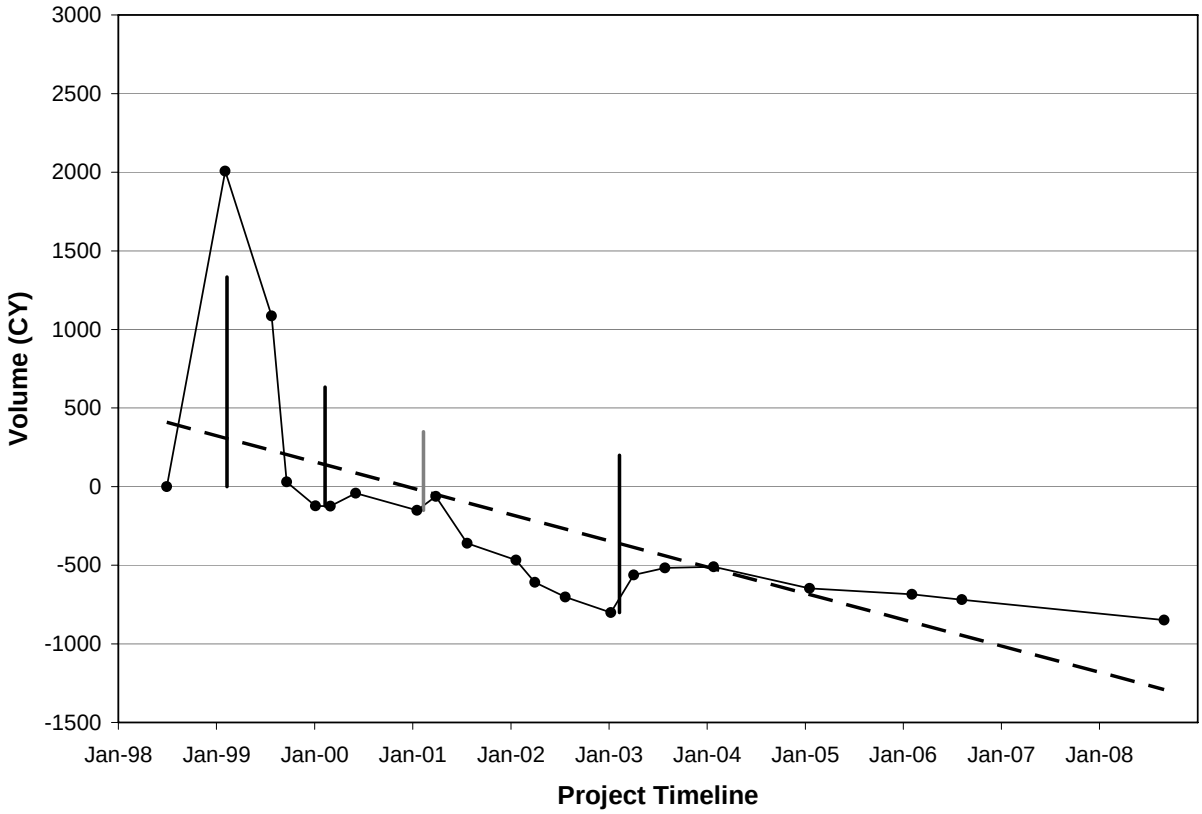

Figure 6. Plot of cumulative volume changes in Central Shore sub-cell from summer 1999 to summer 2008, above +4.0 ft MLLW. Vertical black lines indicate timing and volume of nourishment sediment within the sub-cell; vertical grey lines indicates same in southern adjacent sub-cell. Dashed line indicates 11-year trend.

Table 4. Volume changes in South Smokehouse sub-cell from 1998 to 2008, grouped by season, above +4.0 ft MLLW. Table 4b includes the data for Figure 7 and can be found in Appendix 3.

Winter to Winter (cy)		Summer to Summer (cy)	
		1998 - 1998	+4,295
1999 – 2000	-2,821	1999 - 2000	-5,443
2000 – 2001	-284	2000 - 2001	+95
2001 – 2002	+88	2001 - 2002	-242
2002 – 2003	-241	2002 - 2003	-67
2003 – 2004	+81	2003 - 2006	+100
2004 – 2005	-223		
2005 – 2006	+159	2006 - 2008	+53
		1998 - 2008	-1,292

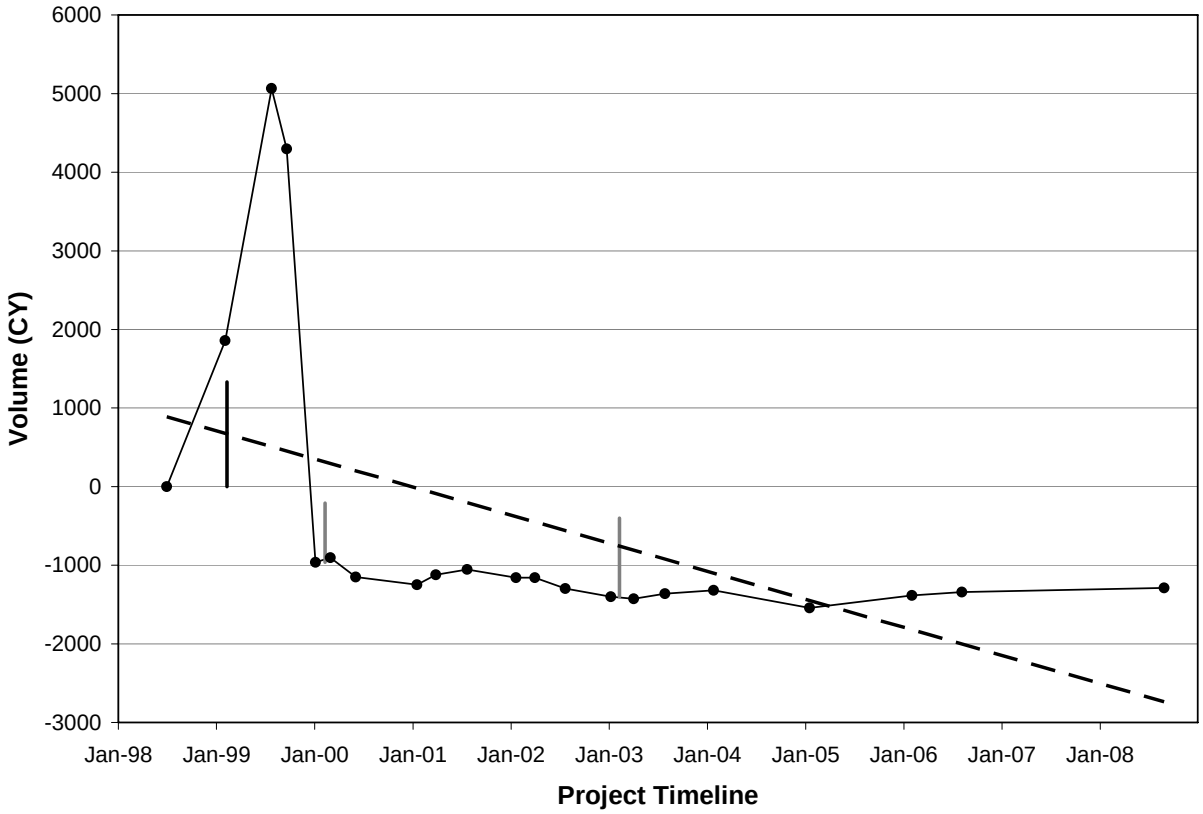

Figure 7. Plot of cumulative volume changes in South Smokehouse sub-cell from summer 1999 to summer 2008, above +4.0 ft MLLW. Vertical black lines indicate timing and volume of nourishment sediment within the sub-cell; vertical grey lines indicates same in southern adjacent sub-cell. Dashed line indicates 11-year trend.

Beach Sediment

The Seining Grounds sub-cell's forage fish spawning substrate has exhibited the same trend for northeastward sediment transport as other monitored indicators. Profile 9 has seen a slow but steady decline in suitable grain sizes since 1998 (Figure 8a). Both the upper and lower sediment samples from the potential surf smelt spawning band contained less than the target 40% by weight of 1 to 8 mm sediment in 2008 (Table 5). While the southern end of the cell has grown coarser, the northern end has been getting finer. Since 1998 Profile 8 has increased in available spawning substrate by approximately 5% per year (Figure 8c). A majority of samples since 2001 have contained more than 60% suitable grain sizes. No sediments were collected at Profile 8B in 2008.

Within the Central Shore sub-cell the amount of suitable grain sizes has remained relatively steady since 1998, with a slightly increasing trend (Figure 9). This area contained very limited fine sediment pre-revetment and pre-nourishment. Between 20 and 40% suitable sediment has typically been found at Profile 7 over the 11 year period. Only Profile 7 has been sampled since 2003 though, and the beach was low enough at the revetment toe to preclude sampling at +8.5 ft MLLW (or the substrate was essentially large riprap). With the trend for northeastward sediment transport and impoundment against the southern side of the truck turnarounds, sediment at Profile 7B appeared coarser than Profile 7, and Profile 6C appeared finer with more suitable forage fish spawning substrate.

The South Smokehouse sub-cell was very similar to the Central Shore in that sediment samples have seen a very slight long-term gain in forage fish substrate since 1998 pre-revetment conditions (Figure 10). However, the beach at the revetment toe was too low to allow for sampling at +8.5 ft MLLW. The percent of fines has decreased somewhat since 2005. Since 1998 most sediment samples in the reach had at least some suitable grain sizes for surf smelt spawning.

Table 5. Sediment size classes used in this report based on the Wentworth (1922) Scale, and those used by WDFW in previous work. Sediment best suited for surf smelt is 1 to 7 mm (Pentilla 1978). CGS work examines 1-8 mm sediment as equivalent, encompassing 0 to -2 phi.

Phi Size	Sediment Type	Grain Size (coarser than)		Equivalent Tyler Screen Size (mm)
		(inches)	(mm)	
- 6	Cobble	2.5	64	53.8
- 5	Cobble	1.25	32	26.7
- 4	Pebble	0.6	16	13.3
- 3	Pebble	0.3	8	6.7
- 2	Pebble	0.16	4	3.33
- 1	Granule	0.08	2	1.65
0	Very coarse sand	0.04	1	0.83
+1	Coarse sand	0.02	0.5	0.42
+2, finer	Med. Sand, silt, clay	<0.02	<0.5	<0.42

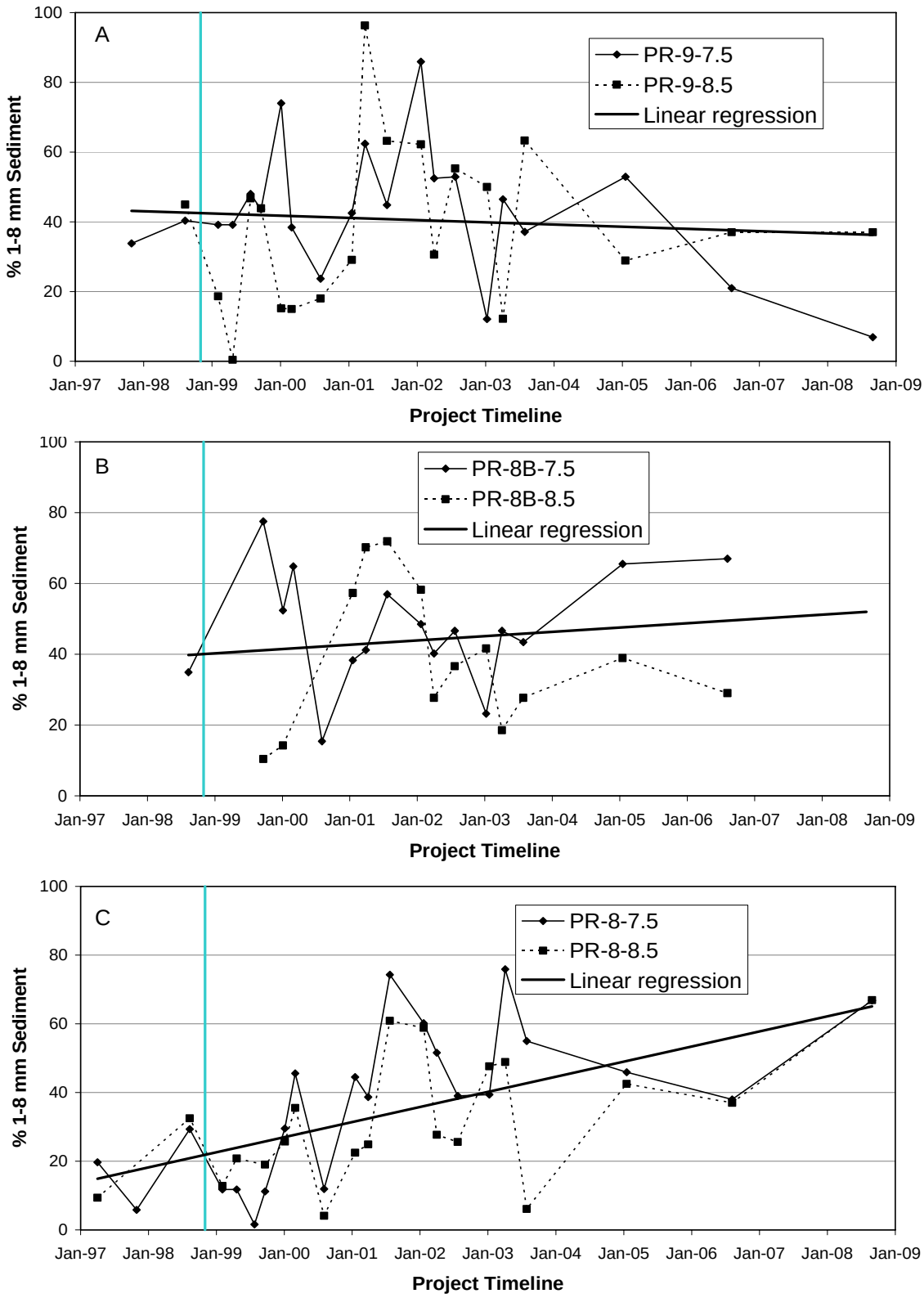

Figure 8a-c. Percent suitable surf smelt habitat (1-8 mm), Seining Grounds at profiles 9, 8B, and 8. Vertical line indicates timing of revetment construction. Surf smelt spawn peak typically occurs during summer months. No sediments were collected from Profile 8B during monitoring in 2008.

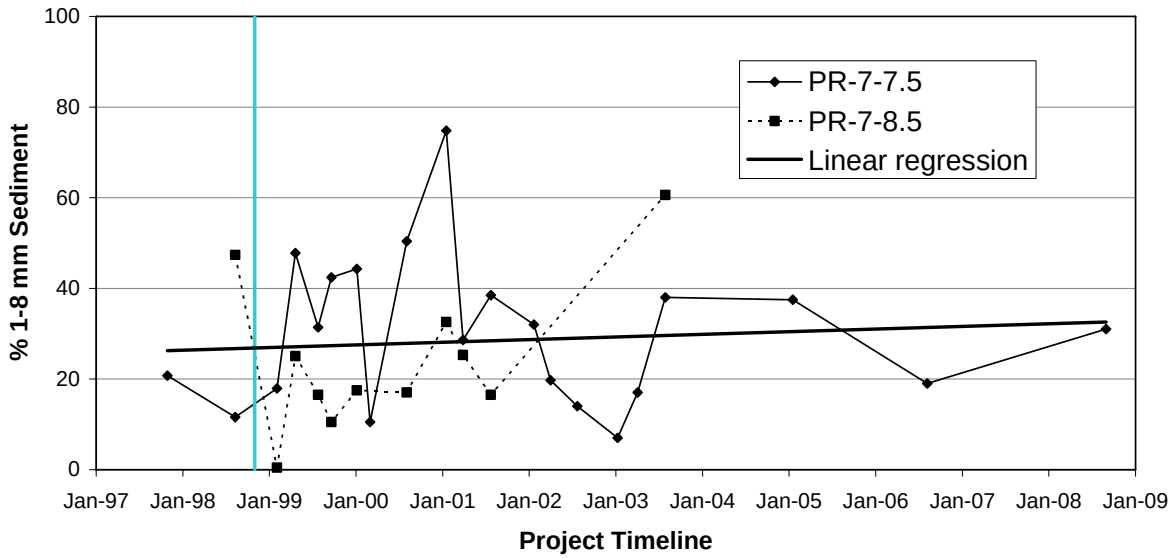

Figure 9. Percent suitable surf smelt habitat (1-8 mm), Central Shore. Vertical line indicates timing of revetment construction. Surf smelt spawn peak typically occurs during summer months. Beach elevation at revetment toe was less than +8.0 ft MLLW since January 2005 in this location and therefore no data exists for the upper sample elevation. SHRINK LEGEND

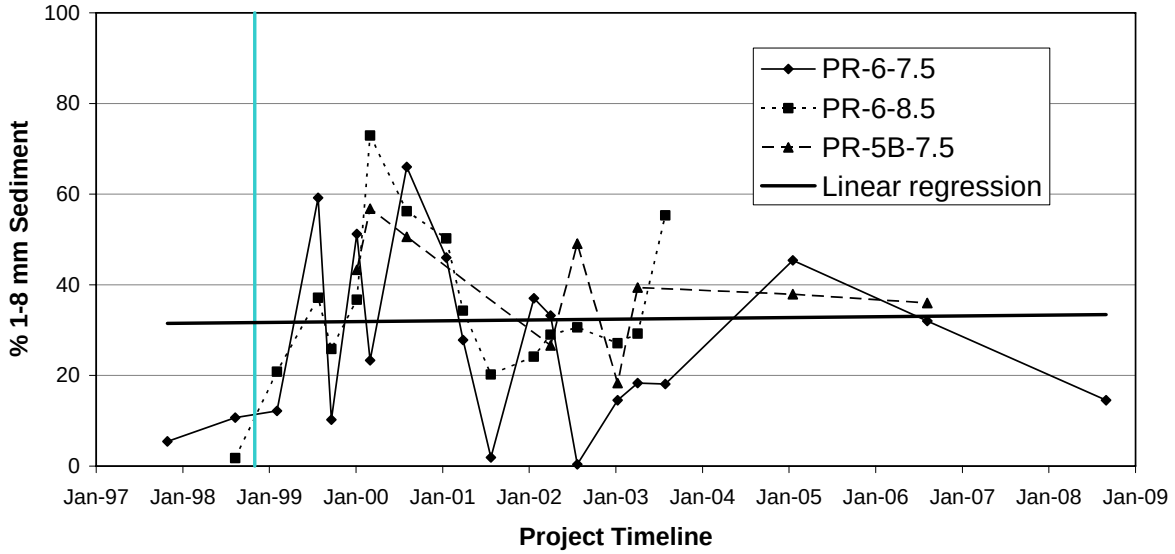

Figure 10. Percent suitable surf smelt habitat (1-8 mm), South Smokehouse. Dashed vertical line indicates timing of revetment construction. Surf smelt spawn peak typically occurs during summer months. Beach elevation at revetment toe of Profiles 5B and 6 was less than +8.0 ft MLLW since January 2005 in this location and therefore no data exists for the upper sample elevation. No sediments were collected from Profile 5B during monitoring in 2008.

Forage Fish Spawning Habitat

The total area of potential surf smelt spawning habitat, as mapped in the summer by substrate size alone, has declined since revetment construction and initial nourishment. However, since 1999 the aerial coverage of potential surf smelt spawning habitat has remained above the target 30,000 ft^2 (Table 6). At the present rate of decline, the total spawning habitat would fall below 30,000 ft^2 by summer 2012. Although the truck turnarounds have locally altered sediment grain size, overall the distribution of potential spawning substrate areas has remained roughly the same since 1998 (see large format map in Appendix 3 for spatial extents of potential spawning areas).

Of all the sub-cells, the Seining Grounds has consistently contained more potential surf smelt spawning habitat area than any other (Table 6, Figure 11). This is likely a result of lower energy due to the protective influence that Portage Island and its spit complex has on the sub-cell. The south end of the potential spawning area has gradually migrated back northward to the pre-revetment position in the Seining Grounds, while the north end remained slightly further north then pre-revetment and nourishment. Potential habitat area in 2008 has fallen to 77% of 1998 levels, and 63% of 1996 levels (with data of lower quality than from 1998). While the Seining Grounds may be close to an equilibrium volume of sediment (see page 7), the gradual northward trend of potential surf smelt habitat between 1999 and 2008 suggests that nourishment may be required in the near future to maintain good surf smelt habitat.

Table 6. Potential surf smelt habitat polygons area (in square feet) during the summer in the study area from 1998-2008, and comparison to pre-nourishment data. The mitigation plan called for 30,000 ft^2 or more of surf smelt habitat. See large format map in Appendix 3 for spatial extents of potential spawning areas.
"-" indicates no data was collected.

Year (Summer)	South of Seining Grounds	Seining Grounds	Central Shore	South + North Smokehouse	Total
1996	0	32,480	6,683	22,924	62,087
1998	0	26,338	0	12,026	38,364
1999	0	23,601	11,000	9,228	43,829
2000	0	28,243	4,136	7,531	39,910
2001	0	29,182	6,090	14,730	50,002
2002	2,996	31,669	2,354	9,572	46,591
2003	1,649	30,526	4,100	15,595	51,870
2006	-	27,384	1,554	6,257	35,195
2008	1,103	20,320	1,003	13,232	35,568
Average '96, '98 Pre-Nour	0	29,409	3,342	17,475	50,226
Avg '99-'08 Post-Nour	943	27,275	4,320	10,878	43,281

Notes: 1996 data from Dillon and Johannessen (1998), collected by MaKay.
1998-2008 Data from CGS, collected by CGS, initially with MaKay, through surveying.

A small, but decreasing potential spawning area was present south of the Seining Grounds in 2002, 2003, and 2008 (Table 6, Appendix 3 large format map). This was likely due to southward transport of some of the nourishment sediment, but may also have been from northward transport of fines from the Portage Spits. As the size of this area has progressively decreased with time since beach nourishment, it is likely most of this sediment was from nourishment sediment that was transported southward around the truck turnaround at road station 269 during northeast winds.

The Central Shore sub-cell has had the smallest amount of potential surf smelt habitat of the original three cells nourished, including in 1998 when none was found. Small habitat areas were identified in 1996 (6,700 ft^2). Following initial nourishment, 11,000 ft^2 of habitat was recorded, but after persistent erosion the 2008 quantity was only 9% of that peak amount. Therefore, as nourishment has only been able to create significant habitat area for a few years, it appears that the relatively low elevation of the revetment toe and relatively high wave energy in this reach do not allow for stability of fine sediment (Figure 11).

The combined South and North Smokehouse sub-cells have fluctuated more widely in potential spawning habitat area than the other cells, although the general decline has been similar (Figure 11). Total area in 2008 was above that surveyed in 1998, but only a little above half the 1996 level. All post-revetment years with data showed much reduced areas as compared to the less rigorously collected 1996 data.

Overall the suitable spawning substrate total area increased to a peak in 2003, following the most recent nourishment event, and then declined by 2006. The long-term trend has been the loss of approximately 500 ft^2 of habitat per year since 1998.

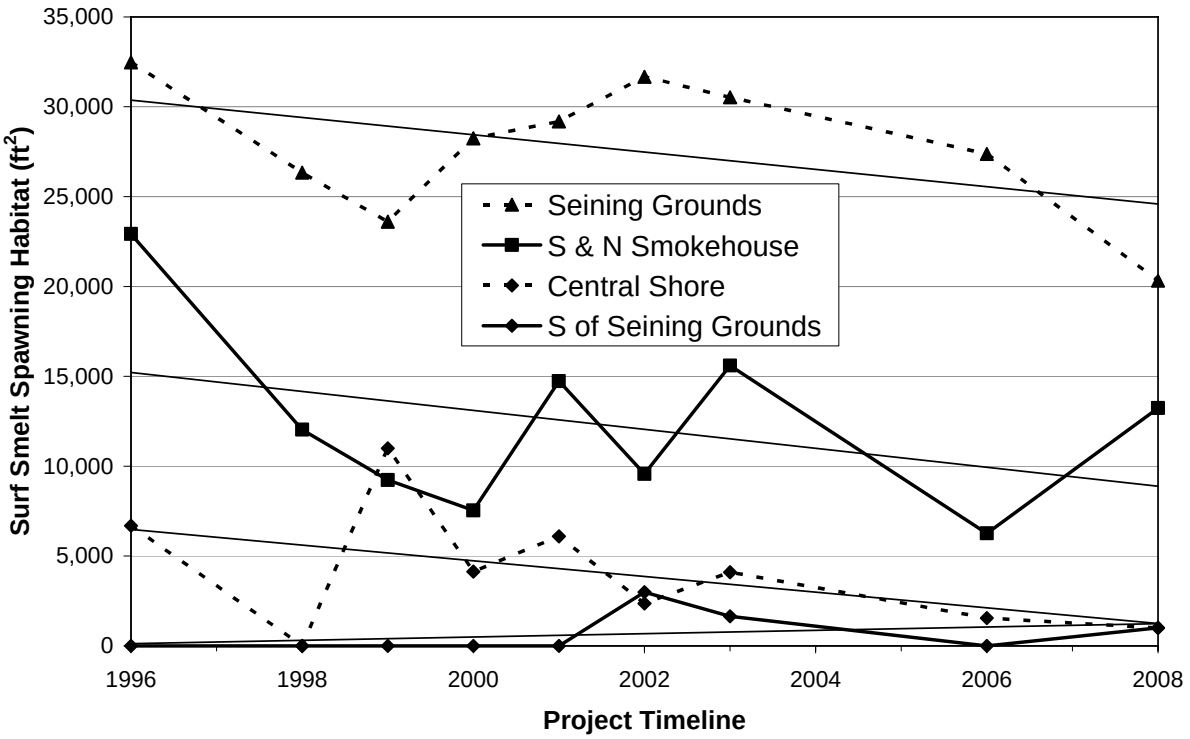

Figure 11. Potential surf smelt habitat polygons area (in square feet) during the summer in the study area from 1996 to 2008. Linear regression for each series shown as thin black line.

Table 7. Potential surf smelt spawning habitat polygons lengths alongshore (in feet) in the study area for summer 1998 to 2008, and winter 2005 (approximate distances only). The mitigation plan called for 3,000 to 4,000 ft of length total (Dillon and Johannessen 1998).

Year (Summer)	South of Seining Grounds	Seining Grounds	Central Shore	South + North Smokehouse	Total
1998	0	983	0	786	1,772
1999	0	1,261	788	0	2,049
2000	0	1,324	578	796	2,698
2001	0	1,338	576	1,152	3,066
2002	203	1,509	149	568	2,429
2003	142	1,287	488	873	2,790
2005 (Winter)	0	1,510	235	750	2,495
2006	0	1,314	101	870	2,285
2008	86	1,168	102	740	2,096

SUMMARY AND CONCLUSIONS

The Seining Grounds appears to be the most stable sub-cell within the project area, largely due to the protection from waves provided by Portage Island and associated spit complex. The beach elevation at the revetment toe has increased somewhat over the past 10 years. Also, the largest portion of potential forage fish habitat has remained in this sub-cell since construction in 1999, although the total area has steadily declined since then. Northeastward sediment transport caused by prevailing southerly winds is quite evident in this sub-cell, as since 1998 sediment has coarsened in the south and grown finer to the north.

It appears that wave energy is highest within the Central Shore sub-cell, possibly due to the combination of wave exposure and refraction around Portage Island and its spits. Beach elevation has steadily declined since 1998, and the revetment (which was constructed 1 ft vertically lower than in the Seining Grounds) now covers much of the potential forage fish spawning band. Sediment transport appears to be rapidly through this cell, as it has repeatedly received nourishment both directly and indirectly through transport from the south, yet the total sediment volume is below 1998 levels. Potential surf smelt spawning habitat, which was only present in one of the two pre-revetment summers, has also been declining since construction. However, the habitat seen has consistently been relatively high in adequate grain sizes.

Within the South Smokehouse sub-cell the beach elevation at the revetment toe has been gradually declining overall since 1998, although the toe at Profile 5B has been rising. This reflects the overall trend for northward sediment transport with resulting impoundment on the south side of the truck turnarounds. Since 1998 this sub-cell has both received the least direct nourishment sediment (only the initial 1,333 CY) and has lost the most sediment of the three main sub-cells.

Results of monitoring in Project Year 10 have shown the continued trend of northward sediment transport across the site. Prevailing southerly windstorms have repeatedly transported sediment to the north both within cells and around the truck turnarounds into adjacent cells. It appears that the placement of sediment within the southern two cells, and the Seining Grounds in particular, has attained the desired result of being redistributed throughout the cells to the north.

The main project goal of providing more then 30,000 ft^2 of potential forage fish spawning substrate has been attained during every year that monitoring data was collected. However, the total amount of spawning substrate has gradually declined over time. Lower and mid beachface erosion was observed at all long-term beach profile locations except Profile 8 indicating the continued erosional nature of this shore, and loss of local bluff sediment input, the area of suitable spawning substrate will not remain above the goal without continued nourishment. Using the 10-year trend as a predictor, forage fish spawning habitat will fall below 30,000 ft^2 during summer 2012.

Revetment maintenance and beach cleanup should be carried out in the next few years as large numbers of revetment boulders have toppled to the intertidal beach, particularly in the Central Shore and southern end of the South Smokehouse, and areas further north. This occurred several years after revetment construction, but to our understanding, has not occurred since. Work should not be carried out between May to September due to potential surf smelt spawning during that period.

NOURISHMENT RECOMMENDATIONS

The nourishment to date within the Seining Grounds sub-cell has been performing well through August 2008. The majority of the length alongshore (1,168 ft) within the Seining Grounds sub-cell appeared suitable for surf smelt spawning. A narrow band in the South Smokehouse sub-cell (740 ft long) appeared suitable for surf smelt spawning. Only the northern 102 ft of the Central Shore sub-cell appeared suitable for surf smelt spawning, as nourishment sediment was retained by the truck turnaround at the northern end of the cell.

Trends of decreasing suitable substrate indicate that nourishment appears needed in the near future. Given the short time available in winter 2008-2009, nourishment is recommended for late winter 2009-10 or at the latest in late winter 2010-2011. As nourishment would need to occur prior to February 15, planning for this ahead of time would be required.

The cumulative upper beach sediment eroded from the three sub-cells was more than 2,256 cy since 1998 (the ends of the sub-cells beyond profiles were not included in calculations) including nourishment inputs. Past nourishment events added between 500 and 4,000 cy. The 2003 nourishment added 2,000 cy of old beach and bank material that had been stockpiled during construction, which has persisted fairly well. Given all of this, it is recommended to add 2,000 cy of stockpiled material if it can be accessed, and if not, approximately 1,200 cy of gravelly sand bank run material, to rebuild the beach profiles and add a significant amount of 1-8 mm sediment.

Beach monitoring and potential surf smelt habitat polygon mapping should be continued in summer 2009 if possible. Due to a lack of winter monitoring in 2008, winter 2010 should also conducted to provide pre-nourishment data.

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Wentworth, C. K., 1922, A Scale of Grade and Class Terms for Clastic Sediments, Journal of Geology, v. 30, p. 377-392.

Coastal Geologic Services, Inc.

Jim Johannessen, Licensed Engineering Geologist, MS Jonathan Waggoner, BS

ATTACHMENTS:

Appendix 1: Beach Profiles

Profile plots – Seining Grounds – Summer comparison
Profile plots – Central Shore – Summer comparison
Profile plots – South Smokehouse – Summer comparison
Profile plots – North Smokehouse – Summer comparison

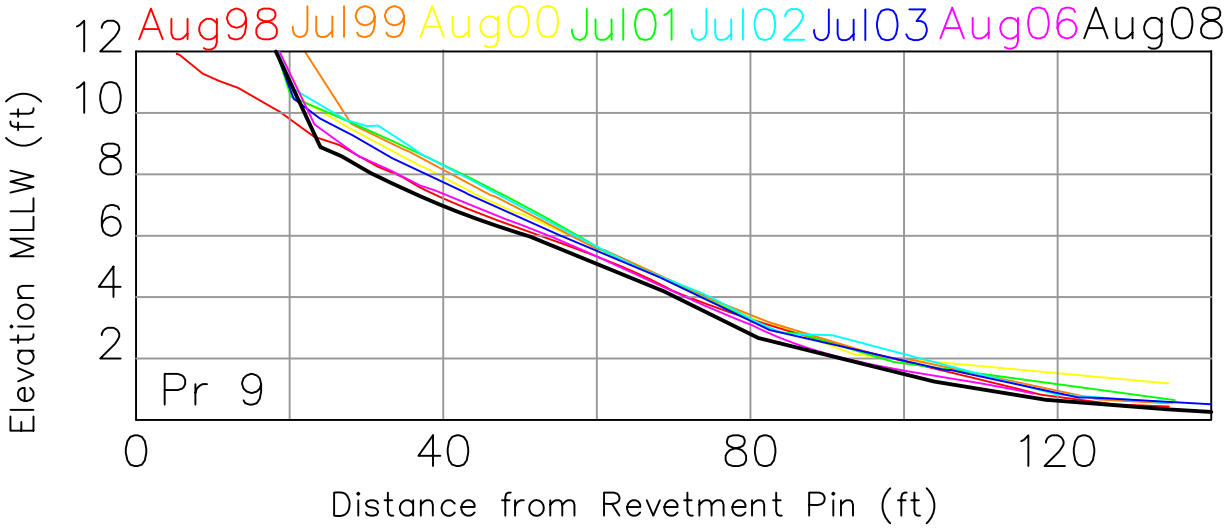
Appendix 2: Photo Log

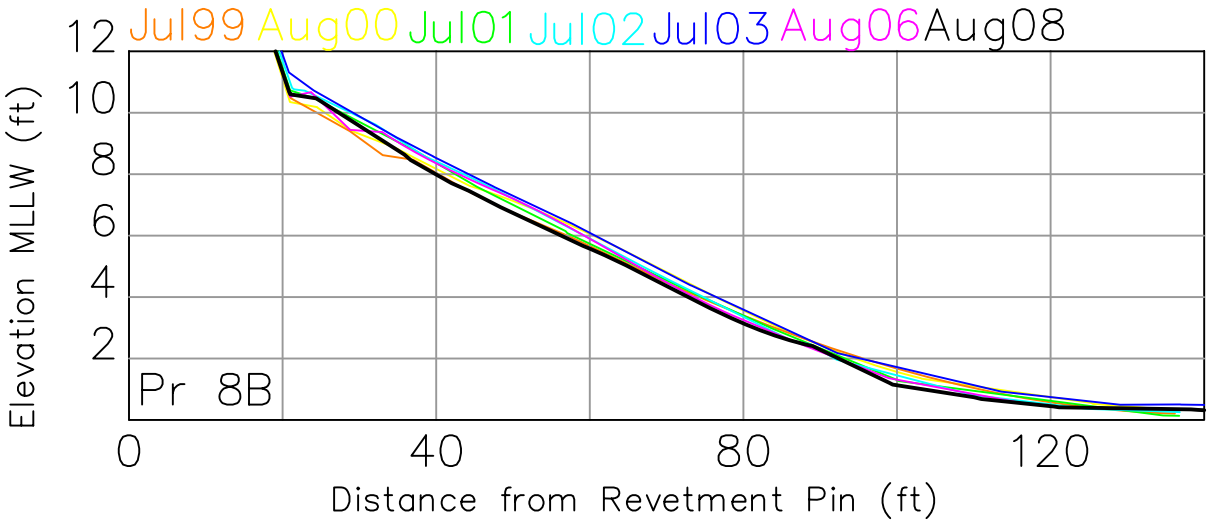
Photo log – Profile 8B (Seining Grounds) –Summer
Photo log – Profile 7 (Central Shore) – Summer
Photo log – Profile 6 (South Smokehouse) –Summer

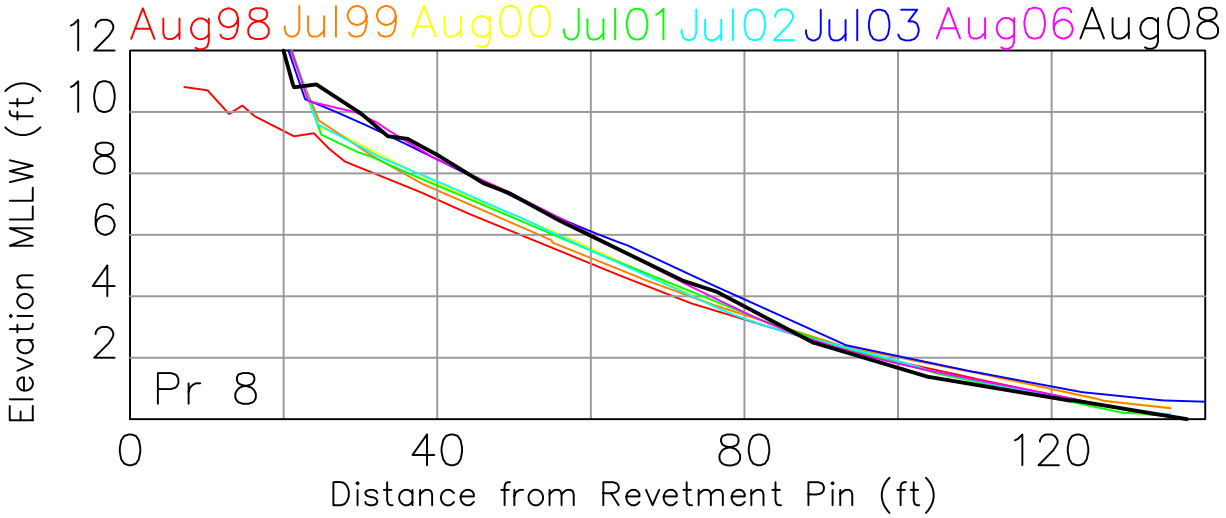
Appendix 3: Beach Volume Change and Sediment Data Tables

Table 1. Revetment toe/upper beach elevation
Table 2b. Summary of volume changes in Seining Grounds sub-cell
Table 3b. Summary of volume changes in Central Shore sub-cell
Table 4b. Summary of volume changes in South Smokehouse sub-cell
Table 5. Summer of percent suitable forage fish sediment
Comparison of Potential Surf Smelt Spawning Habitat Polygons, 1998-2008 – 24” by 48”

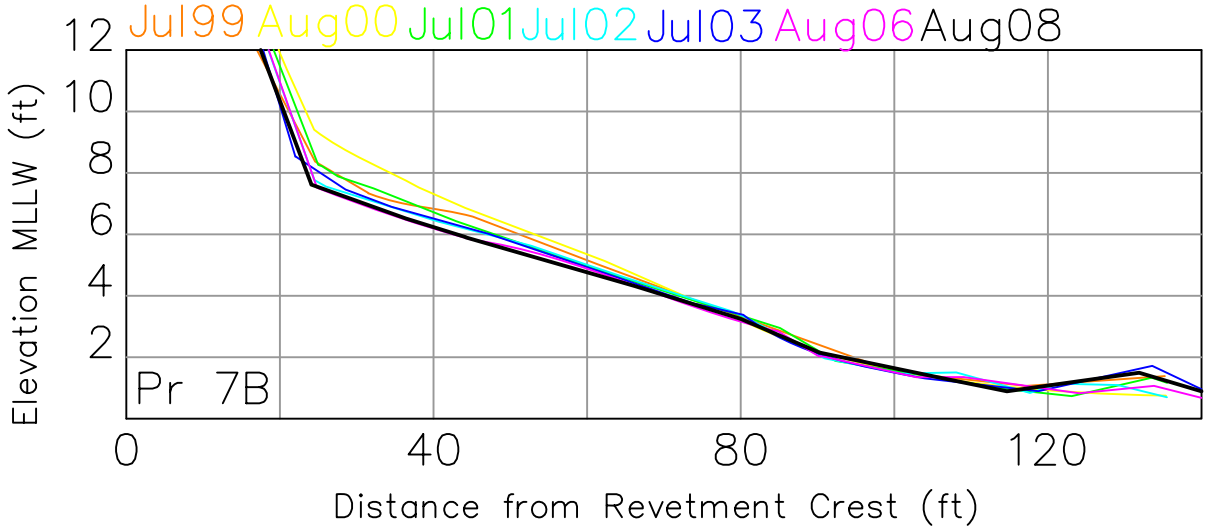
Lummi Shore Road Beach Monitoring Profiles
Seining Grounds (Pr 8, 8B, 9) - Summer

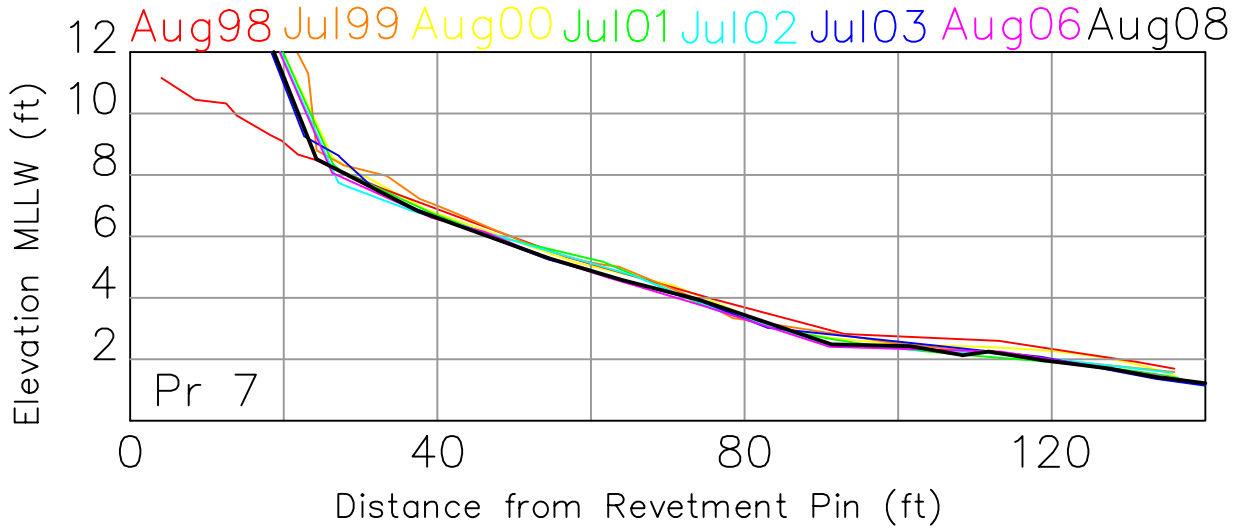


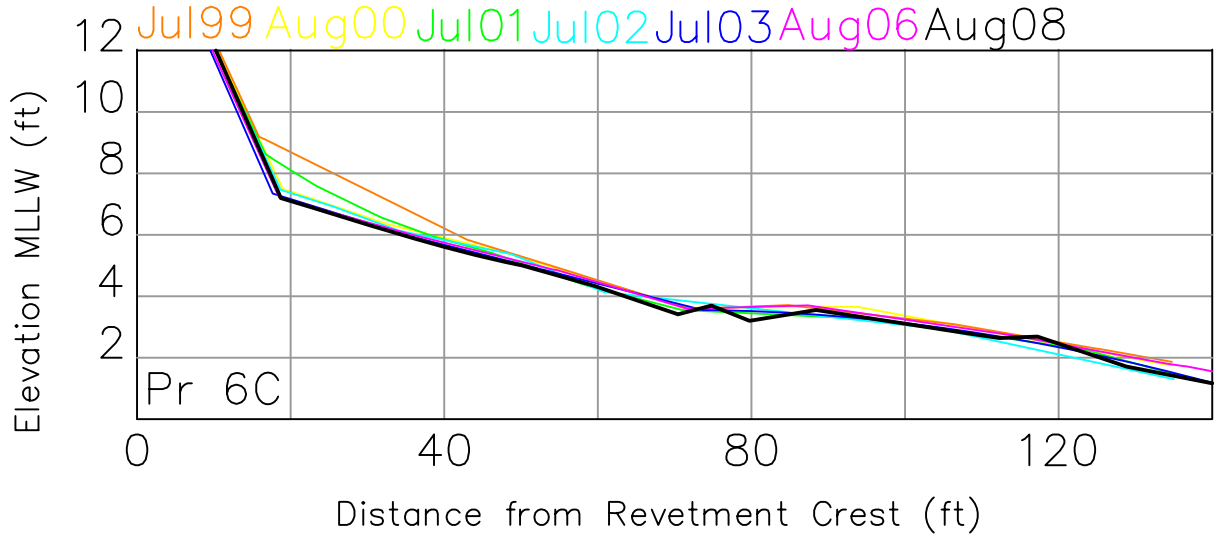




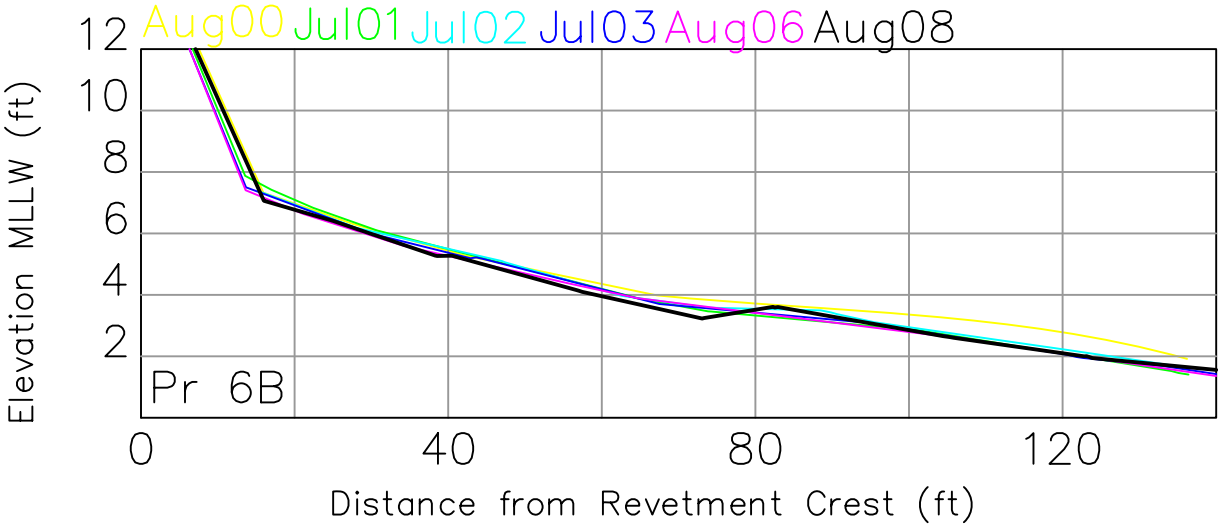
Lummi Shore Road Beach Monitoring Profiles
Central Shore (Pr 6c, 7, 7b) - Summer

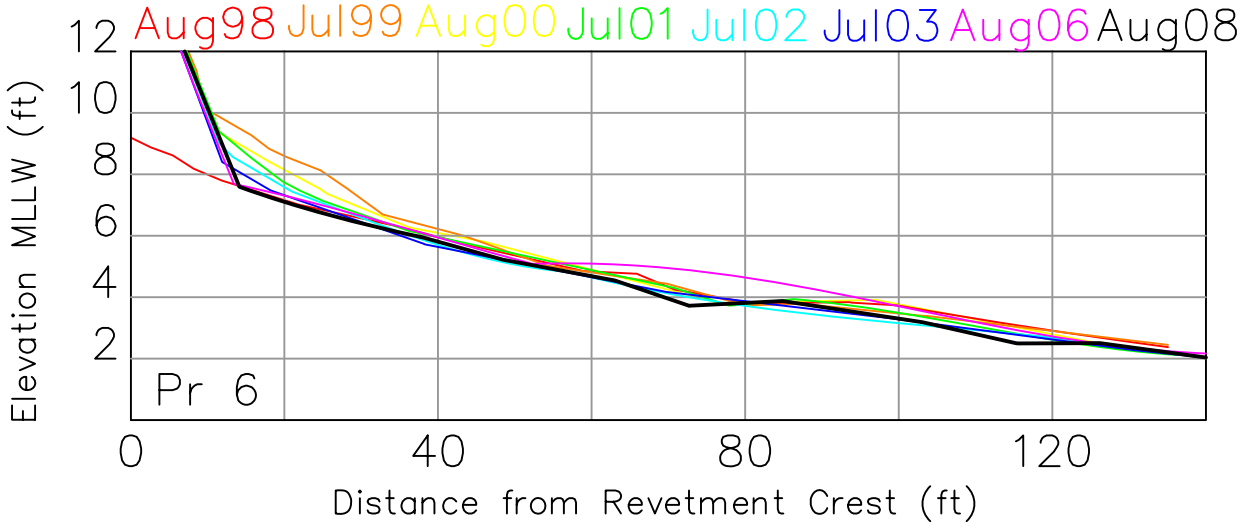


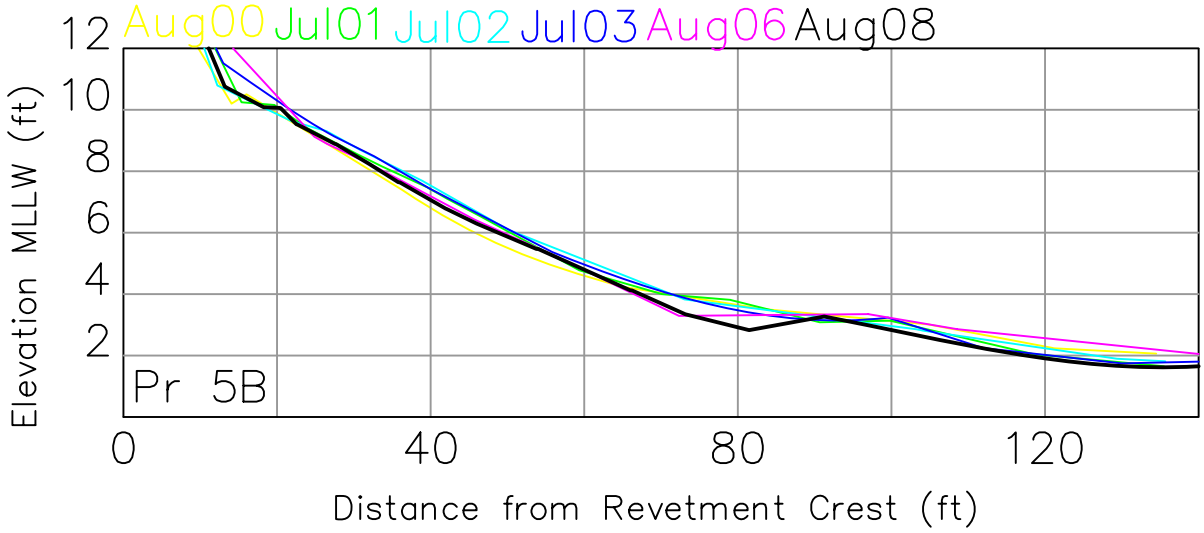




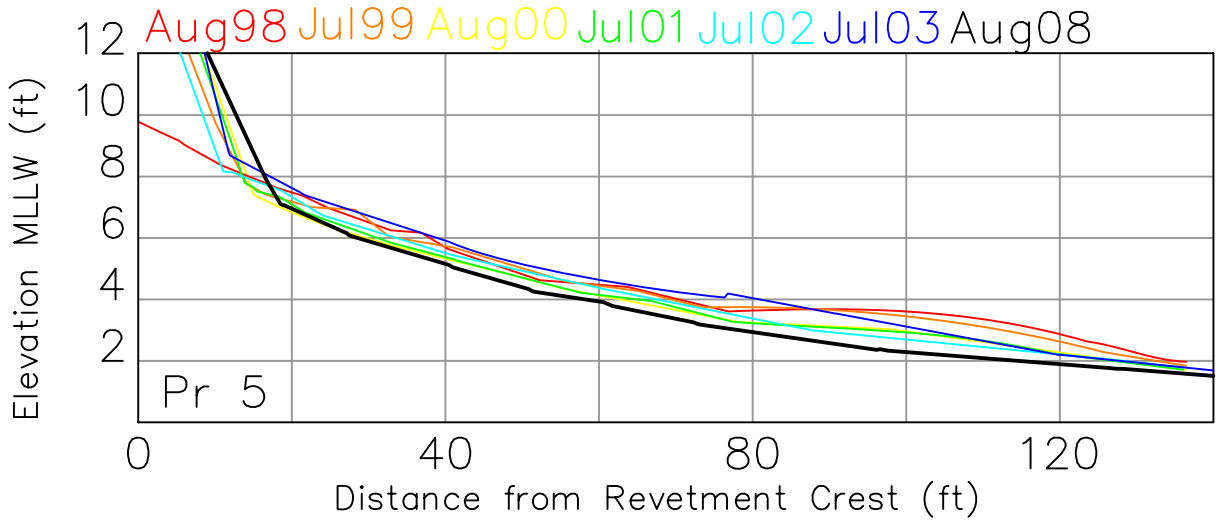
Lummi Shore Road Beach Monitoring Profiles
South Smokehouse (Pr 5B, 6, 6B) - Summer

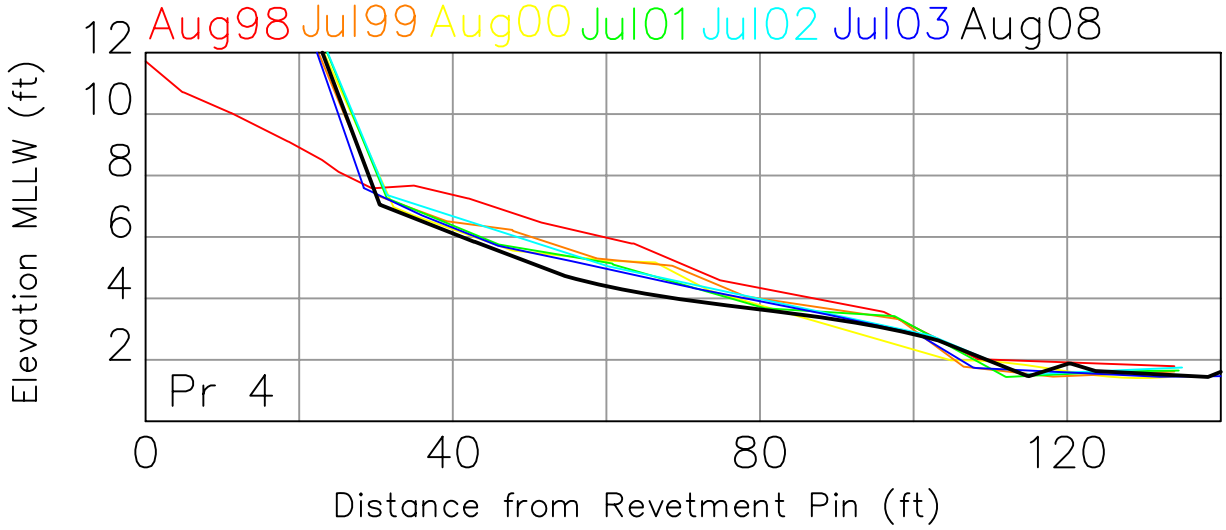






Lummi Shore Road Beach Monitoring Profiles
North Smokehouse (Pr 5, 4) - Summer





Lummi Shore Road Beach Monitoring Photos
Profile 6 (South Smokehouse) – Summer

August 1998

July 1999

August 2000

July 2001

July 2002

July 2003

August 2006

August 2008

Lummi Shore Road Beach Monitoring Photos
Profile 7 (Central Shore) – Summer

August 1998

July 1999

August 2000

July 2001

July 2002

July 2003

August 2006

August 2008

Lummi Shore Road Beach Monitoring Photos
Profile 8B (*=8) (Seining Grounds) – Summer

August 1998*

July 1999

August 2000

July 2001

July 2002

July 2003

February 2006

August 2008

Appendix 3

Table 1. Revetment toe/ upper beach elevation at each profile location for different survey periods compared to design elevation. All data is in feet above local MLLW; dash means no data. Data also presented in Figures 2-7.

	Profile	**9**	**8B**	**8**	**7B**	**7**	**6C**	**6B**	**6**	**5B**	**5**	**4**
	Sub-cell	**Seining Grounds**			**Central Shore**			**S Smokehouse**			**N Smokehouse**	
	Road Sta.	**271**	**275+50**	**280**	**287**	**292+50**	**296**	**300+50**	**305+50**	**312**	**315+50**	**323+50**
Yr10	8/08	8.8	10.6	10.8	7.6	8.5	7.2	7.1	7.6	10.8	7.1	7.0
Yr 8	8/06	9.6	10.5	10.4	7.5	8.1	7.2	7.4	7.7	10.9	-	7.2
	2/06	11.0	11.7	11.3	-	8.2	-	7.1	8.6	11.8	-	-
Yr 6	1/05	9.5	10.6	9.7	7.8	7.8	8.1	7.4	7.9	10.4	8.3	7.0
Yr 5	1/04	9.9	10.4	10.0	7.8	8.2	7.7	7.5	7.8	10.6	7.9	7.2
	7/03	10.4	10.7	10.4	8.5	9.2	7.3	7.5	8.4	11.5	8.6	7.6
	4/03	10.8	10.8	9.6	7.8	7.8	7.5	7.4	9.0	10.9	8.1	7.4
Yr 4	1/03	10.2	10.8	10.8	7.8	8.2	8.1	7.9	9.0	11.1	8.1	7.6
	7/02	10.8	10.8	9.6	7.8	7.8	7.5	7.4	9.0	10.9	8.1	7.4
	4/02	10.3	10.3	9.5	7.9	7.9	8.1	7.8	8.6	10.4	8.0	7.1
Yr 3	1/02	10.3	10.3	9.7	7.8	8.2	7.8	8.1	8.8	10.5	7.1	6.0
	8/01	10.5	10.7	9.2	8.3	8.3	8.7	7.9	9.4	10.2	7.6	7.2
	3/01	10.5	10.7	9.7	8.4	8.6	9.0	7.9	8.9	10.0	7.7	7.4
Yr 2	1/01	10.6	10.7	9.5	8.2	9.0	8.5	8.2	9.2	10.5	7.6	7.4
	8/00	9.9	10.3	9.5	9.4	8.7	7.5	7.3	9.4	10.2	7.4	6.9
	3/00	10.2	10.3	9.4	8.4	8.0	7.8	8.3	9.5	9.4	-	-
Yr 1	1/00	9.8	10.1	9.7	7.8	9.1	8.2	7.7	9.5	9.5	7.5	7.4
	9/99	10.2	10.4	9.5	8.1	8.9	9.2	9.0	10.1	9.1	7.2	-
	7/99	10.5	10.5	9.6	8.4	8.8	9.2	-	10.1	-	7.7	7.3
	5/99	9.6	9.7	9.4	8.4	9.2	9.2	-	9.5	-	-	-
	4/99	10.0	9.8	9.4	8.9	9.4	9.1	-	9.5	-	7.4	7.3
	3/99	9.9	10.3	9.1	8.7	9.6	7.6	-	9.2	-	-	-
Pre-Nour	2/99	9.2	9.9	8.2	-	8.1	-	7.6	8.4	-	7.3	7.5
	Design	9.0	9.0	9.0	8.0	9.0	8.0	8.0	8.0	8.0	8.5	8.0
	8/98	11.9	-	10.8	-	11.2	-	-	11.4	-	12.3	10.8

Table 2b. Summary of volume changes in Seining Grounds sub-cell from summer 1999 to summer 2008, above +4.0 ft MLLW.

Nour. Events (cy)	Time period	Cut (cy)	Fill (cy)	Net (cy)
	Summer 1998 – Winter 1999	-407	+920	+513
1,333	Winter 1999 – Spring 1999	-172	+576	+404
	Spring 1999 – Summer 1999	-309	+86	-222
	Summer 1999 - Winter 2000	-662	+20	-642
784	Winter 2000 - Spring 2000	-391	+54	-337
	Spring 2000 - Summer 2000	-1	+235	+234
	Summer 2000 - Winter 2001	-129	+71	-58
500	Winter 2001 – Spring 2001	-83	+73	-10
	Spring 2001 – Summer 2001	-20	+522	+502
	Summer 2001 – Winter 2002	-520	+51	-470
	Winter 2002 – Spring 2002	-146	+69	-77
	Spring 2002 – Summer 2002	-89	+100	+11
	Summer 2002 – Winter 2003	-88	+263	+174
1,000	Winter 2003 – Spring 2003	-70	+214	+144
	Spring 2003 – Summer 2003	-107	+207	+100
	Summer 2003 – Winter 2004	-320	+4	-315
	Winter 2004 – Winter 2005	-87	+43	-44
	Winter 2005 – Winter 2006	-70	+82	+12
	Winter 2006 – Summer 2006	-38	+237	+200
	Summer 2006 – Summer 2008	-301	+46	-255

Table 3b. Summary of volume changes in Central Shore sub-cell from summer 1998 to summer 2008, above +4.0 ft MLLW.

Nour. Events (cy)	Time period	Cut (cy)	Fill (cy)	Net (cy)
	Summer 1998 – Winter 1999	-31	+2,038	+513
1,333	Winter 1999 – Spring 1999	-1,716	+795	-921
	Spring 1999 – Summer 1999	-1,100	+44	-1,056
	Summer 1999 - Winter 2000	-285	+133	-152
756	Winter 2000 - Spring 2000	-192	+190	-2
	Spring 2000 - Summer 2000	-65	+147	+82
	Summer 2000 - Winter 2001	-254	+146	-108
	Winter 2001 – Spring 2001	-151	+240	+89
	Spring 2001 – Summer 2001	-338	+39	-299
	Summer 2001 – Winter 2002	-171	+64	-107
	Winter 2002 – Spring 2002	-185	+44	-141
	Spring 2002 – Summer 2002	-141	+47	-94
	Summer 2002 – Winter 2003	-182	+83	-99
1,000	Winter 2003 – Spring 2003	-39	+279	+239
	Spring 2003 – Summer 2003	-113	+159	+46
	Summer 2003 – Winter 2004	-168	+174	+6
	Winter 2004 – Winter 2005	-170	+34	-136
	Winter 2005 – Winter 2006	-177	+138	-39
	Winter 2006 – Summer 2006	-196	+163	-33
	Summer 2006 – Summer 2008	-161	+29	-131

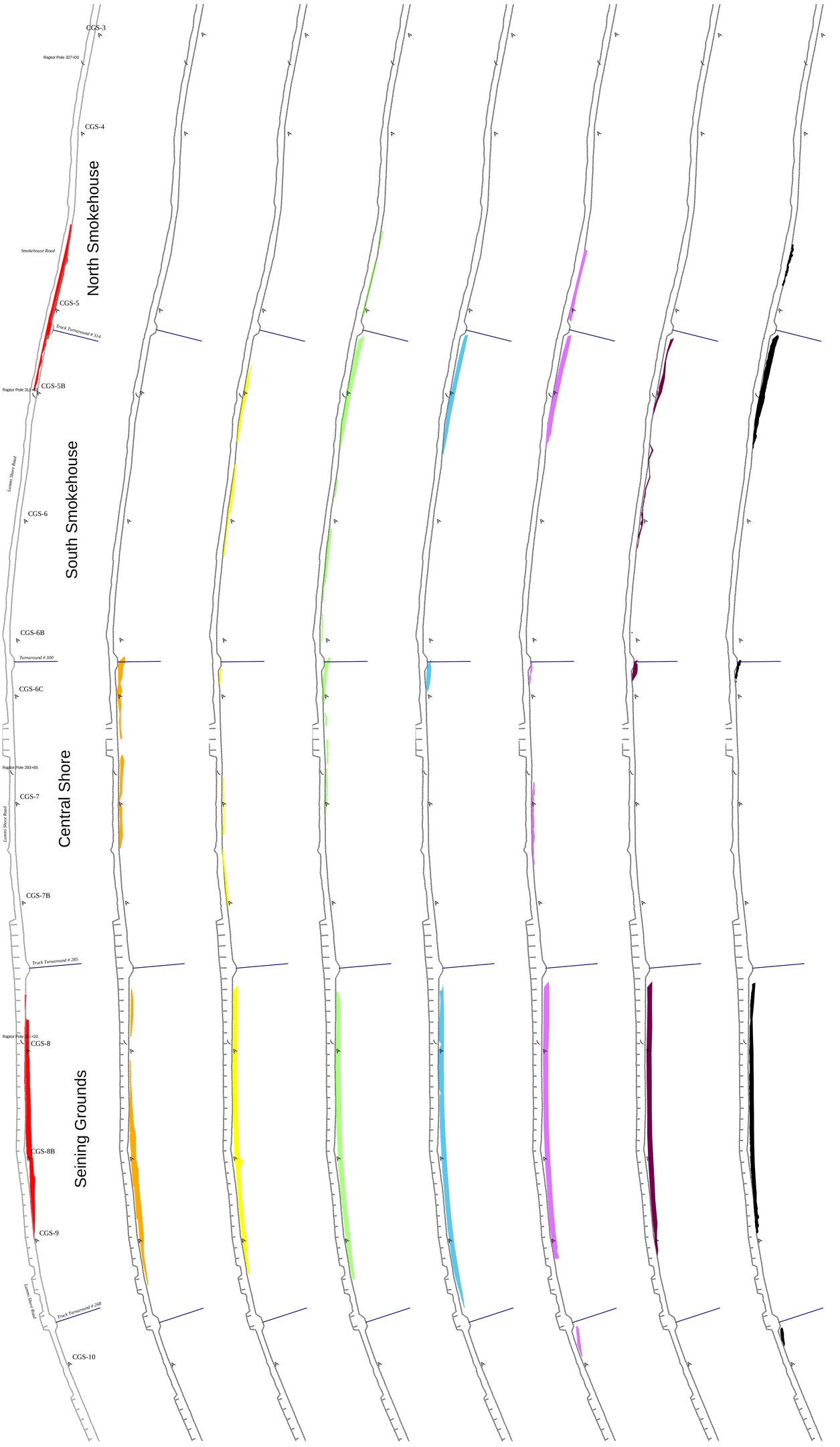
Table 4b. Summary of volume changes in South Smokehouse sub-cell from summer 1998 to summer 2008, above +4.0 ft MLLW.

Nour. Events (cy)	Time period	Cut (cy)	Fill (cy)	Net (cy)
	Summer 1998 – Winter 1999	**-810**	**+2,228**	**+1,858**
1,333	Winter 1999 – Spring 1999	**-156**	**+3,364**	**+3,207**
	Spring 1999 – Summer 1999	**-989**	**+219**	**-770**
	Summer 1999 – Winter 2000	**-5,259**	**+1**	**-5,258**
	Winter 2000 - Spring 2000	**-83**	**+142**	**+59**
	Spring 2000 - Summer 2000	**-294**	**+50**	**-244**
	Summer 2000 - Winter 2001	**-131**	**+32**	**-99**
	Winter 2001 – Spring 2001	**-61**	**+186**	**+125**
	Spring 2001 – Summer 2001	**-42**	**+111**	**+69**
	Summer 2001 – Winter 2002	**-187**	**+81**	**-106**
	Winter 2002 – Spring 2002	**-86**	**+88**	**+2**
	Spring 2002 – Summer 2002	**-306**	**+168**	**-138**
	Summer 2002 – Winter 2003	**-279**	**+174**	**-105**
	Winter 2003 – Spring 2003	**-255**	**+228**	**-27**
	Spring 2003 – Summer 2003	**-265**	**+330**	**+65**
	Summer 2003 – Winter 2004	**-71**	**+114**	**+43**
	Winter 2004 – Winter 2005	**-233**	**+10**	**-223**
	Winter 2005 – Winter 2006	**-34**	**+193**	**+159**
	Winter 2006 – Summer 2006	**-151**	**+192**	**+41**
	Summer 2006 – Summer 2008	**-211**	**+264**	**+53**

Table 5. Summary of percent of suitable sediment (1-8 mm) for surf smelt spawning from Summer 1998 to Summer 2008. Samples from +7.5 and +8.5 ft MLLW. (0 indicates no habitat sediment, included in mean; - indicates no data, not included in mean.)

Period	PR-6	PR-7	PR-8	PR-8B	PR-9	MEAN
Summer 2008 +7.5’	15	31	67	-	7	30
+8.5’	-	-	67	-	37	52
Summer 2006 +7.5’	32	19	38	67	37	39
+8.5’	-	-	37	29	21	12
Winter 2005 +7.5’	45	38	46	66	53	50
+8.5’	-	-	43	39	29	37
Summer 2003 +7.5’	18	38	55	43	37	38
+8.5’	55	61	6	28	63	43
Spring 2003 +7.5’	18	17	76	47	47	41
+8.5’	29	17	49	19	12	25
Winter 2003 +7.5’	15	7	39	23	12	19
+8.5’	27	-	48	42	50	42
Summer 2002 +7.5’	0	14	39	47	53	31
+8.5’	31	-	26	37	55	37
Spring 2002 +7.5’	33	20	52	40	53	40
+8.5’	29	-	29	29	31	30
Winter 2002 +7.5’	37	32	60	49	86	53
+8.5’	24	-	59	58	62	51
Summer 2001 +7.5’	2	39	74	57	45	43
+8.5’	20	17	61	72	63	47
Spring 2001 +7.5’	28	29	39	41	62	40
+8.5’	34	25	25	70	96	50
Winter 2001 +7.5’	46	75	44	38	42	49
+8.5’	50	33	23	57	29	38
Summer 2000 +7.5’	66	50	12	15	18	32
+8.5’	56	17	4	6	24	21
Spring 2000 +7.5’	23	11	46	65	39	37
+8.5’	73	0	36	0	15	25
Winter 2000 +7.5’	51	44	30	0	74	40
+8.5’	37	18	26	0	15	19
Fall 1999 +7.5’	10	42	11	78	44	37
+8.5’	19	66	0	65	59	42
Summer 1999 +7.5’	60	31	2	35	48	35
+8.5’	37	17	0	0	47	20
Spring 1999 +7.5’	-	48	12	-	39	33
+8.5’	-	25	21	-	0	15
Summer 1998 +7.5’	11	12	29	-	40	23
+8.5’	2	47	33	-	45	32

1998 through 2008 Surf Smelt Spawning Habitat
Lummi Shore Road Project



Map Product of Lummi GIS Department, October, 2008
Lummi GIS Department makes no claim as to the completeness, accuracy, or content of any data contained herein.
This map is not intended to reflect the tideland boundaries of the Lummi Reservation. No part of this document may be reproduced without the prior consent of the Lummi Nation. All warranties of fitness or merchantability for a particular purpose are hereby disclaimed.

Data showing Surf Smelt Spawning Habitat areas was prepared by Jim Johannessen , Coastal Geologic Services, Inc., 1998, 1999, 2000, 2001, 2002, 2003, 2006, 2008.
Waterward extent of 1998-2000 data trimmed to +6.5' MLLW
"As-Built" revetment plan prepared by U.S. Army Corps, 1999
Map projection and horizontal datum as per local grid system.
Vertical datum based on Gooseberry Point Tidal Datum (MLLW=0').

Legend

(RaptorsPoles

A CGS Survey Control Monumnets

Revetment As-Built

Surf Smelt Habitat

- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2006
- 2008

0 90 180 270 360 450 540 630 720 810 900

Feet

1:2,000

Revetment constructed in winter 1998-1999.
1998 surf smelt habitat data represents pre-construction conditions.
1999 habitat reflects "as-built" conditions following initial nourishment.
Renourishment of the Seining Grounds sub-cell occurred in 2000, 2001, and 2003.
Renourishment of the Central Shore sub-cell occurred in 2000 and 2003.
No renourishment of the South Smokehose sub-cell has occurred to date.