memorandum

9 pages

date: October 20, 2009

to: Jeremy Freimund, Lummi Nation Water Resources Manager

fr: Jim Johannessen LEG, MS, and Jonathan Waggoner, CGS

re: **Lummi Reservation – Final West Beach Summer 2009 Beach Monitoring**

Introduction

Topographic surveying along an approximately 6,300 ft length of beach along the western shoreline of the Lummi Peninsula (West Beach) was completed on July 8 and 9, 2009. Beach topography along this shoreline was also collected during the summer or fall of 2003, 2005, and 2006. The purpose of this topographic monitoring is to document beach and bluff toe change (often erosion) in order to provide trend data for use in shoreline management along West Beach. As part of this 2009 monitoring effort, management recommendations specific to the shoreline fronting the property at 2751 Haxton Way were developed. Data collection using a newly acquired ground-based laser scanner by Western Washington Geology professors occurred simultaneous to Coastal Geologic Services data collection in 2009, however these data were not processed at the time the report was prepared.

Methods

Surveying was conducted with a Leica TCR1105 total station and direct rod measurements using a 2-person Coastal Geologic Services, Inc. (CGS) survey crew. The station was set up on monuments established by CGS during the October 2003 baseline survey (November 10, 2003 Memorandum). Topographic mapping extended from the vegetation line or bluff toe waterward to the low tide terrace. The features mapped alongshore (when present) were: the break in slope between the high tide beach and the low tide terrace, beachface topography, storm berm crests, and the vegetation line or bluff toe. Colluvium at the toe of the bluff was surveyed where applicable. The bluff face was also captured using the reflectorless setting of the total station in the vicinity of setup locations (every 1,000 ft alongshore). Topographic and beach features were surveyed every 500 ft alongshore, at previously established profile locations, with additional topography collected midway between Profiles. The bluff face and colluvium were surveyed at the profiles containing those features.

Survey points were imported, corrected, and processed using AutoCAD Civil 3D 2008. Profiles were displayed at previously established locations every 500 ft alongshore starting approximately 500 ft north of Gooseberry Point and continuing to approximately 6,000 ft north of Gooseberry Point (Sheet 1). The first profile was labeled 0.5 (500 ft north of Gooseberry Point at 2599 Lummi View Drive), the second 1.0 (1,000 ft north), and so on. Profile 6.0, the northern-most extent of the study area, was located waterward of 2945 Leeward Way.

Topographic and profile data were used to create a current topographic surface of the beach along West Beach. This surface was used to create a 2 ft contour interval map at 1"=400'. Note that the surface is not as accurate between profiles as this was a profile-based sampling effort. Profiles were drawn at 1"=25' horizontal, with a 2X vertical exaggeration. Aerial photography from Pictometry International Corp. dated March 11, 2004 was included for reference only.

Results

Beach Profiles

In this section, a comparison of surveyed beach topography between August 2006 and July 2009 will be presented. Profile cross sections from south (Profile 0.5) to north (Profile 6.0) will be discussed first. A more general discussion of beach change will follow. Photos of each profile taken during the July 2009 survey looking south (alongshore) and east (towards the bluff) are provided for reference purposes (Photo Pages 1-4). The photographs show the general character of the beach and lower bluff toe.

Surveying had fallen approximately 10 ft short of Profile 0.5 in 2006, but the beachface had experienced minor erosion above mean higher high water (MHHW) relative to Cherry Point (NOAA station 9449424, at +9.15 ft MLLW), and minor accretion below MHHW since 2005 (Sheet 2). The beachface above +5 ft MLLW at Profile 1.0 has remained stable to slightly accretional since 2006, while below that very minor erosion was seen. The opposite condition was seen in Profile 1.5 where above +7 ft MLLW the beachface lowered slightly, and very minor accretion was seen lower on the beachface. The toe of the high-tide beach at Profile 1.5 had shifted waterward by 7 ft, although it was slightly lower in elevation than in 2006. Profile 2.0 was generally slightly higher in elevation than seen in 2006 except near MHHW where a storm berm was in 2006. The beachface at Profile 2.5 accreted substantially since 2006, being generally 0.5 ft above the 2006 elevation, and as much as 1.8 ft higher directly in front of the concrete bulkhead. The beachface at Profile 3.0 eroded substantially with up to 1.3 ft vertical lowering near the toe of the high-tide beach. The bluff face, which started between Profile 2.5 and 3.0, has continued to recede with up to 2.5 ft of horizontal erosion since 2006. Profile 3.5 was eroded somewhat both very low and very high on the beachface, while remaining relatively stable between +3 and +8 ft MLLW.

Profile 4.0 contained the first section of high bluff surveyed directly (Sheet 3). The bluff face has steadily eroded by up to 5.2 ft horizontal since 2003, with the toe receding 2.0 ft (0.33 ft/yr). The beachface was stable to erosional with up to 0.6 ft of vertical lowering in the middle beachface since 2006. A minor storm berm at approximately +10 ft MLLW was seen in 2009. Profile 4.5 was slightly accretional above +7 ft MLLW where a storm berm was seen in 2009, and slightly erosional lower on the beachface. Profile 5.0 has remained relatively stable since 2006 with only minor accretion just below MHHW. The bluff face there has also remained quite stable, although the face of the colluvium has steepened somewhat since 2006. The beachface at Profile 5.5 has remained quite stable, although some erosion of colluvium occurred at the toe of the bluff. The northern-most end of the study area, Profile 6.0, was stable to slightly erosional.

Area-Wide Surface Change

The beach surface change analysis for the 2006 to 2009 period, which included beach topography at approximately 250 ft intervals between Profiles during these two years, showed variable pockets of erosion and accretion throughout the surveyed area (Sheet 4). Between Profiles 0.5 and 1.5 the beach was generally slightly lower than seen in 2006. A larger pocket of accretion, particularly within the low-tide terrace, is evident between Profiles 1.5 and 3.0. Immediately north of Profile 3.0 a pocket of erosion resulted in as much as 2 ft of vertical lowering of the beachface. Erosion also occurred on the low-tide terrace in that area, but was 1 ft or less of vertical lowering. North of Profile 3.5 smaller pockets of erosion and accretion are evident, without the apparent trends seen in the southern end of the study area. Erosion appears to be the most evident change in the study area north of Profile 3.5 although there is an area of accretion between Profile 5.5 and Profile 6.0.

Almost half the study area remained relatively stable, with less than 0.25 ft vertical change between 2006 and 2009 (Sheet 4). Throughout the comparison area (including a broad section of low-tide terrace) approximately 8,700 cubic yards (cy) of sediment eroded and approximately 5,200 cy accreted. Therefore, a total of 3,500 cy of sediment was transported out of the study area. A separate examination of the surface change on the high-tide beach only shows 4,560 cy of erosion and 1,740 cy of accretion on the high-tide beach for a net loss of 2,280 cy. Most of the high-tide beach erosion occurred in small increments (less than 1 ft of lowering) across a broad area. One large pocket of upper beach erosion occurred between Profiles 3.0 and 3.5 and a second large pocket of upper beach erosion occurred between Profile 4.0 and Profile 4.5. A large area of high-tide beach accretion was evident between Profiles 1.5 and 3.0. Much of the material was likely transported during the relatively strong winter of 2006-2007, as much of colluvium was heavily colonized by vegetation during the July 2009 survey. Many of the large windstorms between 2006 and 2009 coincided with low- or mid- tides, which apparently caused lesser bluff erosion than seen in previous years.

A more long-term examination of beach surface change was made between the initial monitoring survey in October 2003 and the more recent July 2009 survey (Sheet 5). The southern end of the study area (Profiles 0.5 to 1.0) experienced minor accretion over this nearly six year period, particularly in the vicinity of Profile 0.5 where the beachface was up to 0.6 ft higher than in 2003. This area is on the north limb of Gooseberry Point, which is a cuspate foreland (long-term accretional spit that receives net shore-drift sediment from two directions; Johannessen and MacLennan 2007a). This area was also mapped as an "accretion shoreform" (Bauer 1976, Johannessen and Chase 2006). Minor upper beachface lowering was seen near Profile 1.5. From Profile 2.0 to the northern study area extent (Profile 6.0) consistent erosion was the dominant trend where up to 1.4 ft of vertical lowering was seen low on the beachface between Profiles 3.0 and 3.5. This area was mapped as feeder bluff (Bauer 1976), which is consistent with beach erosion and bluff recession. Some accretion at the very upper beachface was also evident at Profiles 2.5 to 3.0, likely an accumulation of colluvium at the bluff toe. A larger area of upper beach accretion was evident north of Profile 4.5, particularly at Profile 5.0, where colluvium had accumulated at the bluff toe, and much of it appeared to have been distributed across the beachface.

LiDAR Comparison

A surface change analysis was also conducted using the 2009 survey and the 2005 and 2008 LiDAR data sets. The LiDAR data sets were collected March 6-13, 2005 and July 2-5, 2008 for the Lummi Nation. The LiDAR was provided in NAVD88 datum, which was converted to MLLW using NOAA's VDatum tool by adding 0.75 ft to the elevations for the entire data set. Initial examination of the LiDAR data showed some discrepancies, as comparison of the two surfaces showed the 2008 LiDAR to be approximately 0.5 ft above the 2005 LiDAR in many areas of the beach as well as in areas of little change such as parking lots and road surfaces. While this was within the stated accuracy of both LiDAR data sets, and a comparison could be made without correcting the discrepancy, such a comparison could produce misleading information. Three ground surface points in the vicinity of Haxton Way and Emma Rd obtained during the 2006 and 2009 surveys were available for use in examining elevation differences between the LiDAR data sets and the survey. The average difference in elevation was calculated using the three points to determine that the 2005 LiDAR data was 0.216 ft lower than survey datum, and the 2008 LiDAR was 0.207 ft higher than survey datum (Table 1). The LiDAR data were vertically shifted by these amounts for use in this analysis, and it must be noted that the correction was not based on extensive points across the study area.

Table 1. Elevation differences between LiDAR data sets and survey points.

	Elevations (ft MLLW)			Elevation difference	
Location	**Survey**	**2005 LiDAR**	**2008 LiDAR**	**2005 LiDAR**	**2008 LiDAR**
Gravel lot at Haxton Way and Emma Rd	10.480	10.225	10.547	-0.255	0.067
Road surface at Haxton Way and Emma Rd	10.819	10.757	11.082	-0.062	0.263
Concrete driveway at 2589 Haxton Way	11.299	11.591	11.591	-0.331	0.292

The majority (55%) of the adjusted 2005 LiDAR to 2009 survey comparison showed less than 0.25 ft of vertical change throughout the study area (Sheet 6). The comparison area showed 4,450 cy of erosion and 4,320 cy of accretion for a total loss of 130 cy from the area. The 2008 LiDAR to 2009 survey data comparison showed the majority (70%) of the study area was within 0.25 ft of the 2009 survey. Approximately 4,050 cy of erosion and 1,285 cy of accretion was computed for a total loss of 2,763 cy between 2008 and 2009. Therefore the LiDAR data suggested that there was accretion between 2005 and 2008, primarily on the upper beach since the 2005 LiDAR data coverage did not extend low on the beach.

These data should be considered with caution for purposes other then landscape scale analysis due to the nature of the LiDAR data. Bare-earth LiDAR data sets such as the ones used in this study undergo pre-processing to remove vegetation, buildings, and erroneous points. After removing all but the last return from each pulse there are still many returns that came back from above the ground, To get to a bare-earth surface the anomalies must be removed. To remove these spikes the LiDAR is sent through an automated process that looks at areas of very steep, sudden slopes in areas that are relatively flat and smooths those areas out by removing those points from the final dataset. The processing tends to also smooth sharp changes in elevation such as those found at the toe and crest of bluffs within the study area.

The stated elevation accuracy for the LiDAR data introduces an additional concern when comparing the data to other data sets as even a small elevation difference can produce a very large volume change over a large study area. The 2008 LiDAR accuracy report states a 1 sigma of 0.11 ft, so ~95% of points are within 0.22 ft of the ground surface. The 2005 LiDAR report states accuracies of 0.50-0.66 ft for 95% of points. Surveying can certainly produce well-placed points at accuracies better than 0.1 ft.
Surveyed topography also places a human element in point selection. The person on the ground can see where slopes change, and make the choice to pick out points to represent the surface itself. The number of survey points on each profile (250 ft spacing alongshore) was generally 6-8 points, such that virtually all changes in slope were captured. The surveyed points do not get altered, nor do they experience the deviation in vertical accuracy that LiDAR does. Surveying, although not sampling as densely alongshore as with LiDAR, therefore appears to provide a greater level of accuracy and repeatability for high bank

shores, although limitations do exist and obtaining survey data for very large areas is generally expensive.

Summary and Discussion

Examination of beach surface changes along West Beach was described in this report for the period between the initial monitoring survey in October 2003 and the more recent July 2009 survey (Sheet 5). The 2009 survey dataset is the most accurate data collected by CGS to date for the West Beach due to a greater density of profiles, survey points and detail at the bluff toe area.

The southern end of the study area (Profiles 0.5 to 1.0) experienced minor accretion, particularly in the vicinity of Profile 0.5 where the beachface during 2009 was measured to be up to 0.6 ft higher than in 2003. Some accretion in this area is expected, as this is the north limb of Gooseberry Point, a cuspate foreland. Minor upper beachface lowering was evident near Profile 1.5 with moderate erosion from Profile 2.0 to the northern study area extent with up to 1.4 ft of vertical lowering seen low on the beachface between Profiles 3.0 and 3.5. This area was mapped as feeder bluff (Bauer 1976) where beach erosion and bluff recession is expected. Some accretion at the very upper beachface was also evident at Profiles 2.5 to 3.0 and north of Profile 4.5, which appeared to be an accumulation of colluvium at the bluff toe from numerous landslides.

Overall, the beach surface change measured between 2003 and 2009 appears to be consistent with the erosion potential for these shore reaches as presented in the *Lummi Reservation Coastal Protection Guidelines* (Johannessen and MacLennan 2007b). The southern portion of the West Beach study area, south of Profile 3.0, was mapped as “moderate erosion potential”. The minor erosion to very minor accretion for the south end since 2003 corroborates the 2007 shore reach characterization. The area from Profile 3.0 north was all mapped as “high erosion potential” (Johannessen and MacLennan 2007b). The trend of beach change was not all consistent in this area since the 2003 surveying, but the bluff has been subjected to toe erosion and landsliding over much of this area.

A new examination of shore change rates was made using the new survey data as compared to the 2003 survey data collected by CGS. Horizontal shore change rates were calculated based on the 2003 and 2009 ground survey data (Table 2, Figure 1). The new rates are far more accurate than the rates in *Coastal Protection Guidelines* (Johannessen and MacLennan 2007b) that were estimated using historic maps and available aerial photographs. These new data are also for a different time period, which could explain differences in erosion rates relative to the earlier data.

The upper beachface shore change was measured at +8 ft MLLW, just below the location of MHHW. Since 2003, neither erosion nor accretion was the consistent pattern at the upper beach. Erosion was the clear upper beach trend at Profiles 2.0 to 3.0 (0.3 ft/yr to 1.3 ft/yr), and mostly minor accretion at the ends of the study area over the last six years. Change rates at the +8 ft MLLW elevation are more indicative of the entire high tide beach profile than changes at +2 ft MLLW. The lower beachface, measured at +2 ft MLLW (or +4 at Profiles 1.0, 2.5, 5.5, and 6.0) elevation, had accreted at Profiles 0.5 through 1.5, while erosion predominated from Profile 2.0 north to Profile 6.0. The highest erosion rate was at Profile 3.0 at -2.3 ft/yr. This can be compared to the measured bluff toe change rate at Profile 4.0 of -0.33 ft/yr since 2003 and “typical” coastal erosion rates in North Puget Lowland of -0.2 to -0.4 ft/yr (Keuler 1988).

Table 2. Horizontal change rates for +8 and +2 ft MLLW between 2003 and 2009 (except as noted).

Profile	+8 ft MLLW Rate (ft/yr)	+2 ft MLLW Rate (ft/yr)
0.5	0.8	0.8
1.0	0.1	0.8*
1.5	0.1	0.5
2.0	-0.6	-0.8
2.5	-0.3	-0.6*
3.0	-1.3	-2.3
3.5	0.0	-0.8
4.0	0.2	-0.3
4.5	0.0	-0.4
5.0	1.2	-2.4
5.5	0.2	-1.2*
6.0	0.3	-0.5*

*: profile ended before +2 ft MLLW in 2003, so +4 ft MLLW was used at this Profile

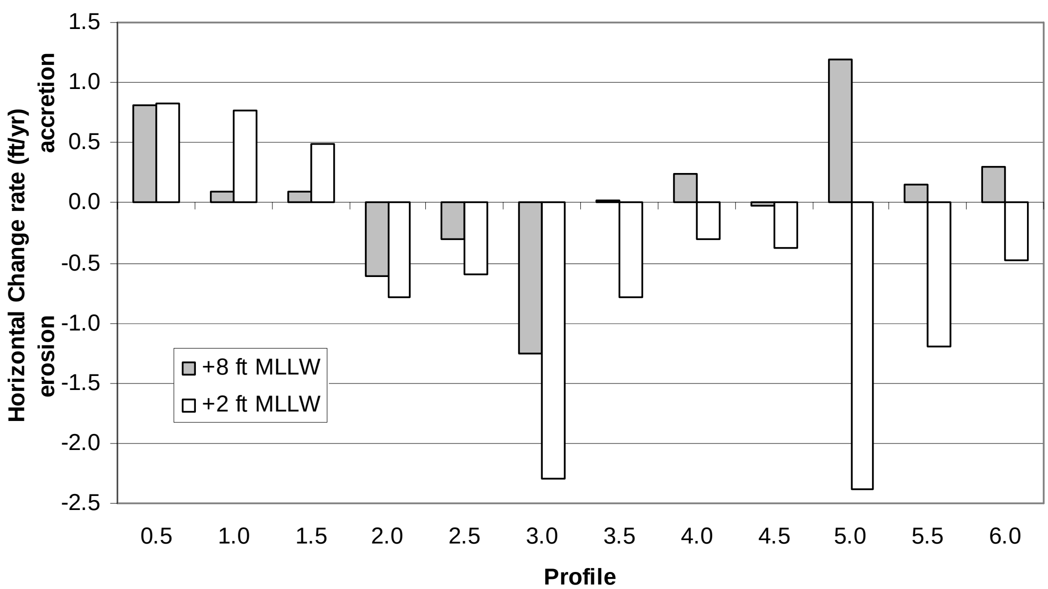


Figure 1. Horizontal change rates for +8 and +2 ft MLLW between 2003 and 2009 (except as noted).

Lower beachface horizontal change rates tend to agree with the above assessment. Profiles 0.5 through 1.5 had accreted between 2003 and 2009 while Profiles 2.0 through 6.0 had eroded (Table 2, Figure 1). Upper beachface change appeared to show a similar trend, although inputs of bluff sediment due to toe erosion and landslides appear to have been substantial enough during recent years to offset some of the upper beach coastal erosion that may have occurred without this sediment input.

The estimated erosion work from the *Lummi Reservation Coastal Protection Guidelines* (Johannessen and MacLennan 2007b) included two data points that fall within the current study area. Transect A from the older work was located between Profiles 4.5 and 5.0, and had a stated change rate of -0.4 ft/yr (erosion) from the toe of the high tide beach for the 1947-1999 period. This is consistent with the more accurate data from 2003 to 2009. Profile B from the *Coastal Protection Guidelines* was located between

Profiles 5.5 and 6.0 and had a change rate of -0.7 ft/yr, which is also consistent with the more accurate new data, which showed lower beach erosion and minor upper beach accretion in the 2003-2009 period.

The minor to moderately large beach and bluff change observed in recent years along West Beach have serious implications for the bluff top residences, as well as appurtenant structure such as shore access stairways. No effort was made to quantify bluff crest recession rates in this study. This may be needed in the future.

LiDAR data comparison included some difficulties in the process. The LiDAR data were provided in NAVD88 datum, while the survey data were in MLLW datum. While corrections were applied using the best available tool for the purpose, error is introduced any time a correction must be applied. Additionally, the two LiDAR data sets, while within the stated elevation accuracy, appeared to be approximately 0.5 ft off from each other. A closer examination of this difference should be conducted before these two data sets are used further to evaluate elevation changes over time.

2751 Haxton Way

A separate discussion of the property at 2751 Haxton Way is included here to inform management practices at this property. Previous data collection included measurements of the beachface waterward of the bulkhead, but did not include the area behind the bulkhead. The 2009 survey effort was the first year that included detailed topographic mapping landward of the concrete bulkhead fronting 2751 Haxton Way (Sheet 7). The bulkhead stretched a total length alongshore of 150 ft. The northern 40 ft was set 9 ft back closer to the bluff relative to the remainder of the bulkhead. The waterward portion of the bulkhead was located at +6.8 to +7.0 ft MLLW, well out on the active beachface. Cracks in the concrete wall face separated the bulkhead into three large pieces, although they were still held together by the structural rebar (Photo Page 5). The cracks have allowed waves to reach behind the bulkhead, and appear to provide a means for sediment to be transported out to the greater beach system, albeit at an apparently slow rate. The concrete sections have been hard-hit by waves, and were tilted landward at various angles, but the wall sections had not fallen to the beach. The northern section appeared much more stable, and remained in its original vertical condition. The fill material and bluff soils that were likely present behind the wall were largely eroded by the time of the 2003 surveying. The 2001 oblique aerial photograph showed the rock had been placed landward of the bulkhead, which appeared cracked already (Photo Pages 5 and 6). Between 2001 and 2009., some amount fill was lost landward of the concrete bulkheads, and several additional landslides occurred. Bluff soil was more exposed by 2006 (oblique photo), as a number of bank face trees were lost along the majority of the area landward of the concrete bulkhead.

A large amount of debris remained behind the southern section of bulkhead in 2009 (Photo Page 5). The debris consisted of pieces of broken concrete, rock, old sections of bluff staircase, sections of pipe, and various pieces of flotsam and jetsam that had been thrown behind the wall by wave action. One large tree, which had apparently fallen just prior to a January 2001 field visit, remained leaning out over the central portion of the bulkhead. Several similar bulkheads were observed north of 2751 Haxton Way, and all have failed completely, remaining as concrete slabs on the beach. The recent high input of bluff sediment from slides to the beach will likely be lost to continued littoral drift in the coming years, unless the high rate of landsliding continues. This may add the impacts of ongoing wave attack reaching the concrete bulkhead, which has numerous cracks. This may contribute to wall sections becoming further degraded.

The beach waterward of the bulkhead at the 2751 Haxton Way property experienced erosion between 2003 and 2005 and also in a smaller area, between 2005 and 2009 (Sheet 8). Erosion was less than 1 ft (vertical) in both periods, but the beach did progressively lower in the area waterward of the bulkhead. The upper beach erosion was less in the upper-most beach close to the bluff toe. The bluff toe has receded approximately 7 ft adjacent to the south end of the bulkhead and approximately 2 ft adjacent to the north end of the bulkhead.

The bluff face behind the bulkhead at 2751 Haxton Way was failing and receding despite the presence of the bulkhead during the period of study, indicating that the bulkhead no longer provides the level of protection it was designed for. Under existing conditions, it appears that the staircase is not located in a stable location, and may be lost due to wave attack during a severe windstorm or through bluff failure following a heavy rainfall.

Examination of the LiDAR bluff face surfaces from 2005 and 2008 landward of the bulkhead at 2751 Haxton Way showed some change. The lower bluff face receded in the southern and middle sections, while the lower bluff face was more waterward in the north end, suggesting the addition of some colluvium from slide(s) may have reached the bluff toe. The upper bluff was shown as accretional between 2005-2008 (+/- 2 ft) suggesting inaccuracy of the LiDAR, with little apparent change in other locations.

The mobile home that was located adjacent to the bluff crest was removed after the 2000-2001 bluff failures. Now the waterward portion of the uplands is used as a parking lot (Photo Page 6). The examination of upland features was not part of the current effort, but the lack of a vegetated bluff crest buffer to both reduce surface water runoff and increase the soil-binding qualities of fibrous-rooted trees and shrubs does not aid in slope stability. Drainage may also be an area for improvement at this site. Additional bluff crest recession is very likely at this site as beach erosion has occurred, the bluff remains oversteepened, vegetation management is not as good as it could be, and wave attack does reach the bluff toe, although at a reduced level as compared to shore reaches with no form of a bulkhead. The bulkhead is also causing increased wave refraction at the un-bulkheaded areas adjacent to both ends. This has likely contributed to additional erosion adjacent to the bulkhead, particularly the north end.

Given the condition of the southern 110 ft of the bulkhead, it is unlikely that it will continue to provide even the degraded level of bluff protection that it currently provides over the medium or long term. Failure of the bulkhead appears to be unavoidable unless it is completely reconstructed. We recommend the following actions be considered for the site:

1. Ensure that the upland drainage is controlled in the developed portion of the property to greatly reduce overland flow at the bluff crest so surface water does not de-stabilize the existing bluff.
2. Plant fibrous-rooted native vegetation along a 20-30 ft wide band of the uplands at the bluff crest
3. Attempt limited planting of the bluff face using appropriate fibrous-rooted native vegetation in areas of relatively low slope (a concentrated effort is not recommended as revegetation success may be quite limited on the bluff face due to ongoing instability).
4. When and it the existing beach access stairway is damaged, remove the existing 110 ft southern section of the bulkhead.
5. Soft shore protection does not seem appropriate in this moderately high wave energy setting, as soft shore would not be robust enough to provide shore protection for any length of time.

6. Retain the northern 40 ft section of the bulkhead if it is needed to protect the toe of a repaired/replaced beach access stairway. A new section of return wall would be required at the south end of the wall sections left in place to protect the new stairway, which should extend into the bluff toe some distance.
7. Portions of the stairway will probably need to be relocated (northward) to avoid the unstable area above the southern and middle sections of the concrete bulkhead.
8. A stair tower would provide a more stable beach access system that would very likely significantly outlast a rebuilt conventional stairway for this location (and be considerably more expensive).
9. Federal and tribal permits will be required for this work.

Future Work

We recommend repeating this topographic surveying work at a 2-5 year interval or following large storm seasons in the future to monitor beach and bluff toe change. Good baseline data has already been obtained for 3 time periods and repeating the work at a longer interval of up to 5 years should be sufficient, Surveying in summer using survey control established by CGS would allow the continued monitoring of the intertidal beach as well as bluff recession and landslides. Increased effort should be put into surveying the lower-most bluff across the bluff portions of the study area to better document bluff recession.

References

Bauer, W., 1976/1974. The drift sectors of Whatcom County marine shores: Their shoreforms and geo-hydraulic status. Whatcom County Planning Commission, 74 p., 1 map.

Johannessen, J.W., and M.A. Chase, 2006. Final Technical Memorandum: Whatcom County Feeder Bluff Mapping and Drift Cell Ranking Analysis. Prepared for Parametrix Inc., Whatcom County PDS, and Marine Resource Committee, 25 p plus appendices.

Johannessen, J. and A. MacLennan. 2007a. Beaches and Bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Johannessen, J. and A. MacLennan. 2007b. Final Lummi Reservation Coastal Protection Guidelines, Prepared for: Lummi Indian Business Council, by Coastal Geologic Services, 58 p.

Keuler, R.F., 1988, Map Showing Coastal Erosion, Sediment Supply, And Longshore Transport In The Port Townsend 30- By 60-Minute Quadrangle, Puget Sound Region*, Washington*: U.S. Geological Survey Miscellaneous Investigations Map I-1198-E, scale 1:100,000.

(Continued on following page)

Coastal Geologic Services Inc.

Jim Johannessen,
Licensed Engineering Geologist, MS

Jonathan Waggoner
Environmental Scientist

Attachments:

Sheet 1. July 2009 topography
Sheet 2. Cross Sections for Profiles 0.5 to 3.5
Sheet 3. Cross Sections for Profiles 4.0 to 6.0
Sheet 4. Surface Change 2006 to 2009
Sheet 5. Surface Change 2003 to 2009
Sheet 6. Surface Change LiDAR to 2009
Sheet 7. Beach Topography at 2751 Haxton Way
Sheet 8. Surface Change at 2751 Haxton Way
Photo Page 1. View of Profiles 0.5-1.5 looking south and east
Photo Page 2. View of Profiles 2.0-3.0 looking south and east
Photo Page 3. View of Profiles 3.5-4.5 looking south and east
Photo Page 4. View of Profiles 5.0-6.0 looking south and east
Photo Page 5. Ground photos of bulkhead fronting 2751 Haxton Way
Photo Page 6. Oblique aerial photographs of 2751 Haxton Way shoreline from 2001 and 2006

WEST BEACH LUMMI PENINSULA
Beach Topography, July. 2009

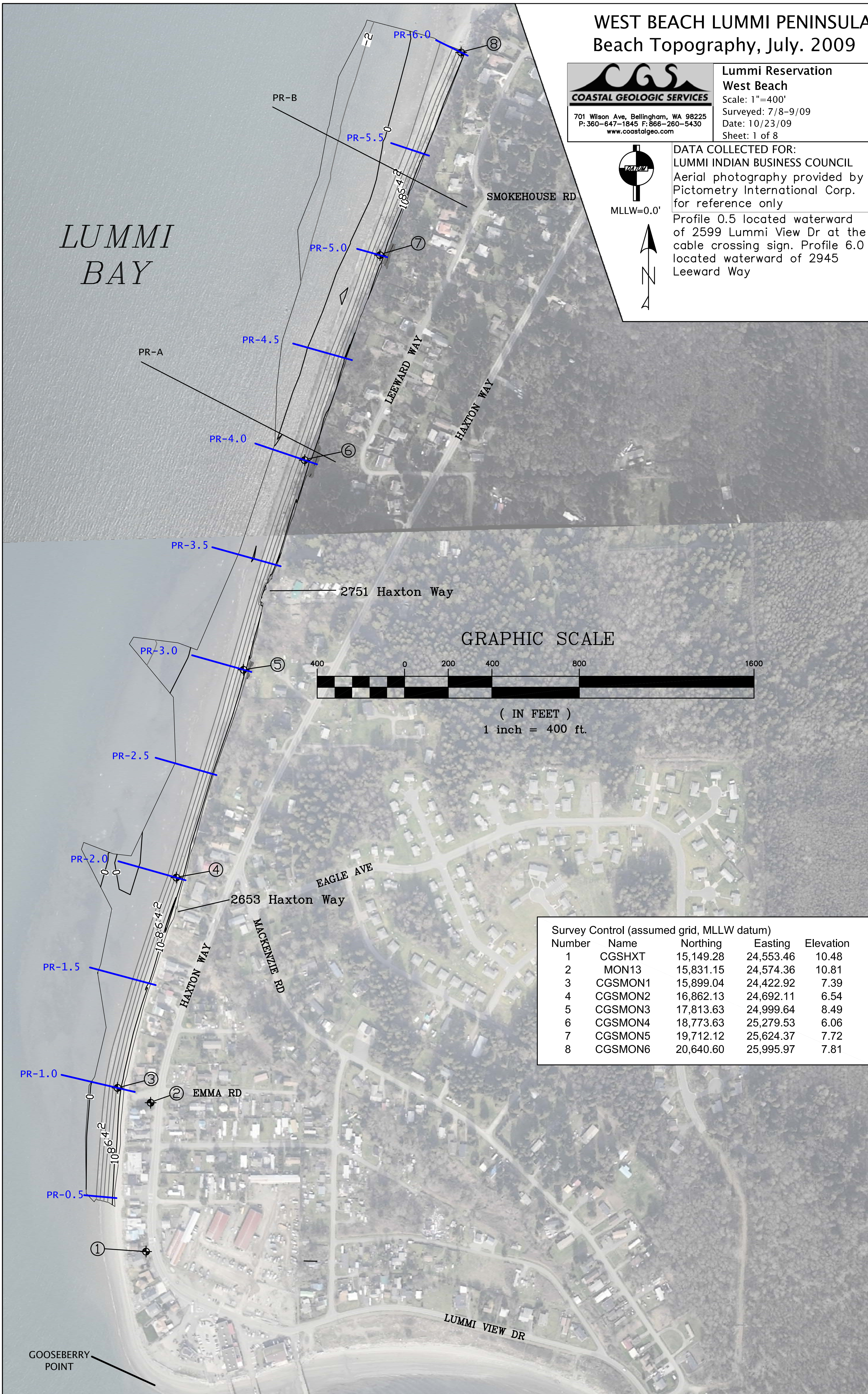
CGS COASTAL GEOLOGIC SERVICES
701 Wilson Ave, Bellingham, WA 98225
P: 360-647-1845 F: 866-260-5430
www.coastalgeo.com

Lummi Reservation
West Beach
Scale: 1"=400'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 1 of 8

DATA COLLECTED FOR:
LUMMI INDIAN BUSINESS COUNCIL
Aerial photography provided by Pictometry International Corp. for reference only

DATUM
MLLW=0.0'

Profile 0.5 located waterward of 2599 Lummi View Dr at the cable crossing sign. Profile 6.0 located waterward of 2945 Leeward Way



Survey Control (assumed grid, MLLW datum)

Number	Name	Northing	Easting	Elevation
1	CGSHXT	15,149.28	24,553.46	10.48
2	MON13	15,831.15	24,574.36	10.81
3	CGSMON1	15,899.04	24,422.92	7.39
4	CGSMON2	16,862.13	24,692.11	6.54
5	CGSMON3	17,813.63	24,999.64	8.49
6	CGSMON4	18,773.63	25,279.53	6.06
7	CGSMON5	19,712.12	25,624.37	7.72
8	CGSMON6	20,640.60	25,995.97	7.81

WEST BEACH LUMMI PENINSULA
Cross Sections, July 2009

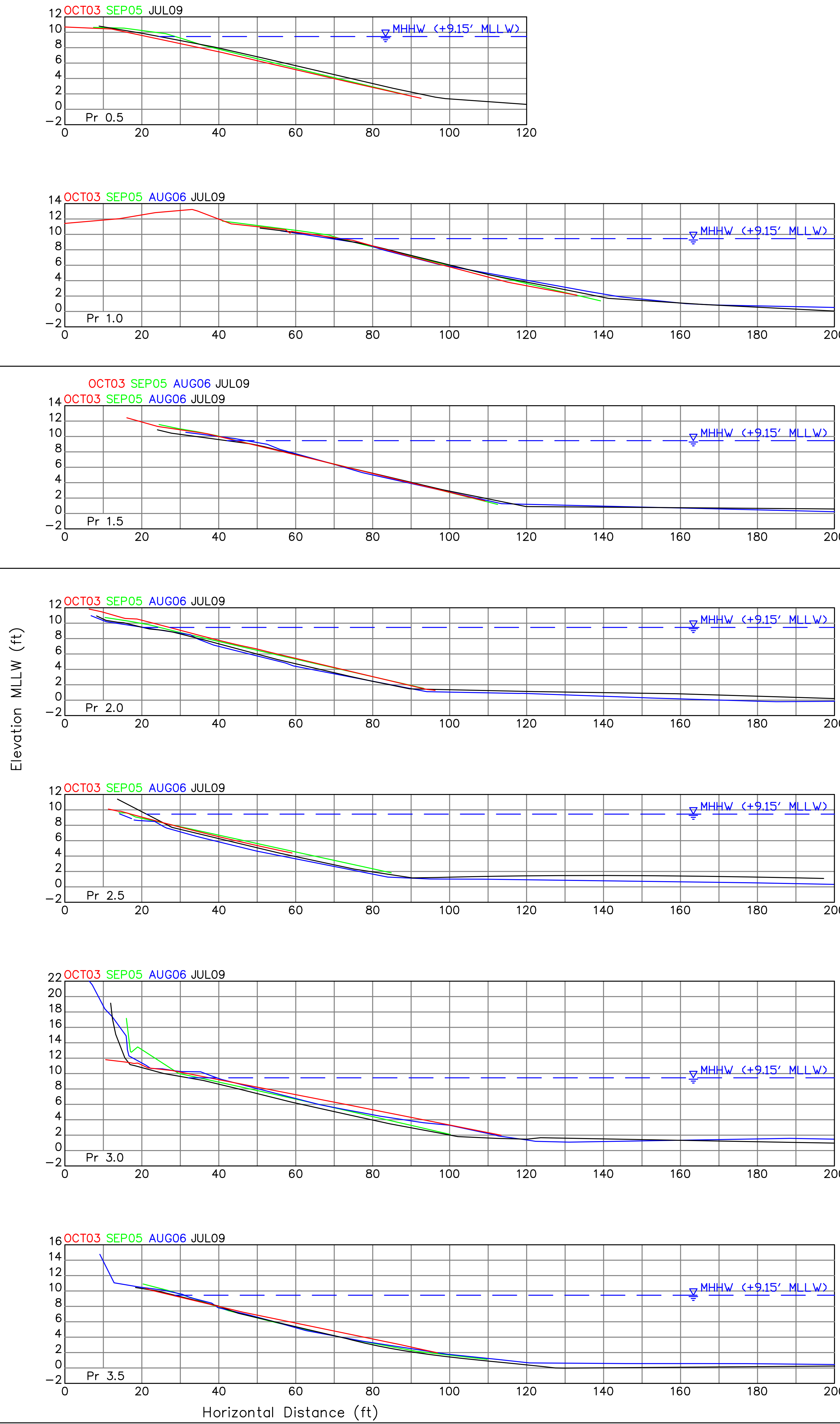
Transects at 500 ft spacing with transect 0.5
approximately 500 ft N of Gooseberry Point

MLLW=0.0'

COASTAL GEOLOGIC SERVICES
701 Wilson Ave, Bellingham, WA 98225
P: 360-647-1845 F: 866-260-5430
www.coastalgeo.com

Lummi Reservation
West Beach
Scale: H:1"=25'/V:1"=12.5'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 2 of 8

DATA COLLECTED FOR: LUMMI INDIAN BUSINESS COUNCIL



WEST BEACH LUMMI PENINSULA
Cross Sections, July 2009

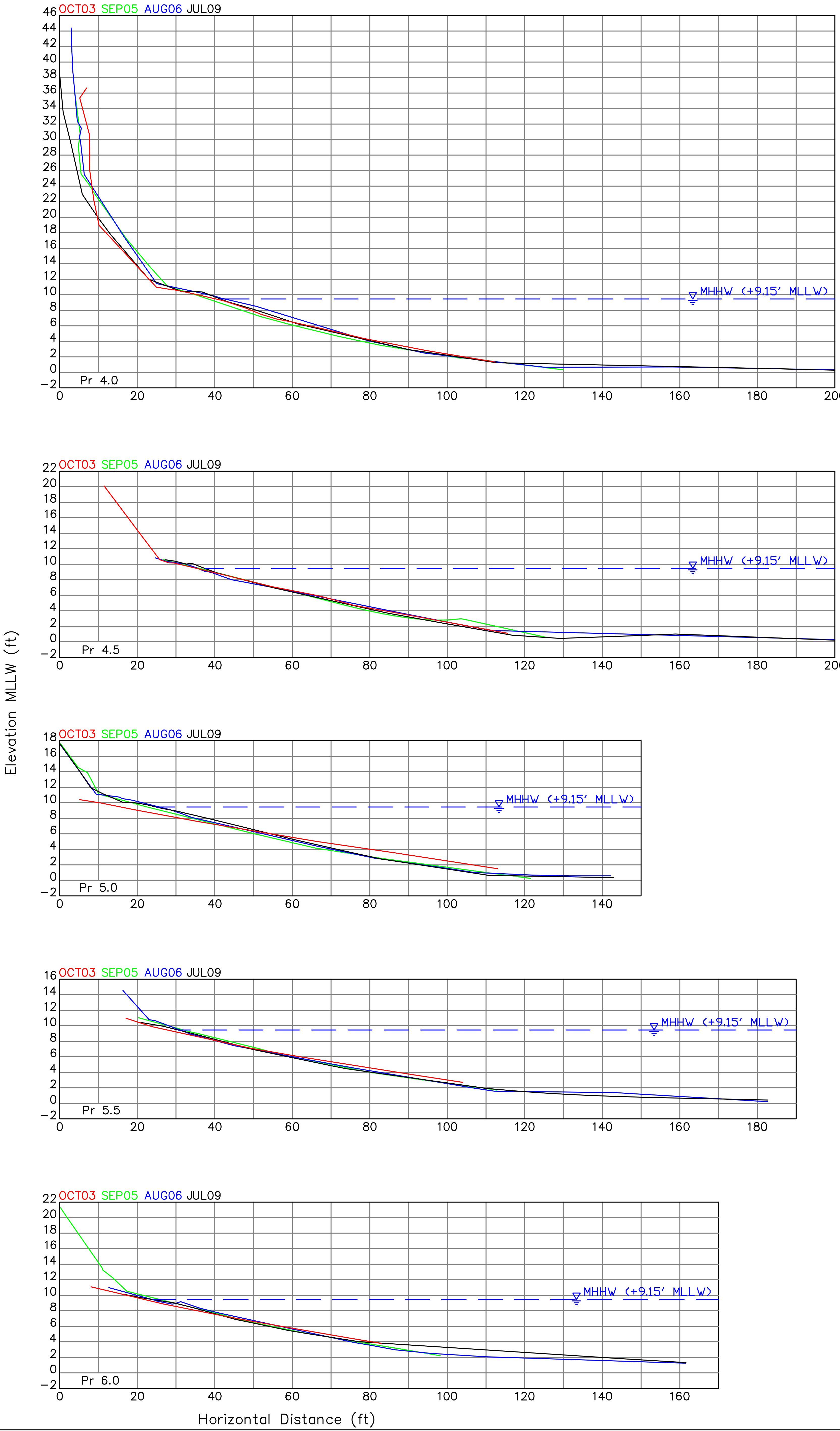
Transects at 500 ft spacing with transect 0.5
approximately 500 ft N of Gooseberry Point

DATUM
MLLW=0.0'

COASTAL GEOLOGIC SERVICES
701 Wilson Ave, Bellingham, WA 98225
P: 360-647-1845 F: 866-260-5430
www.coastalgeo.com

Lummi Reservation
West Beach
Scale: H:1"=25'/V:1"=12.5'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 3 of 8

DATA COLLECTED FOR: LUMMI INDIAN BUSINESS COUNCIL



WEST BEACH LUMMI PENINSULA
Surface Change 2006 to 2009

COASTAL GEOLOGIC SERVICES
701 Wilson Ave, Bellingham, WA 98225
P: 360-647-1845 F: 866-260-5430
www.coastalgeo.com

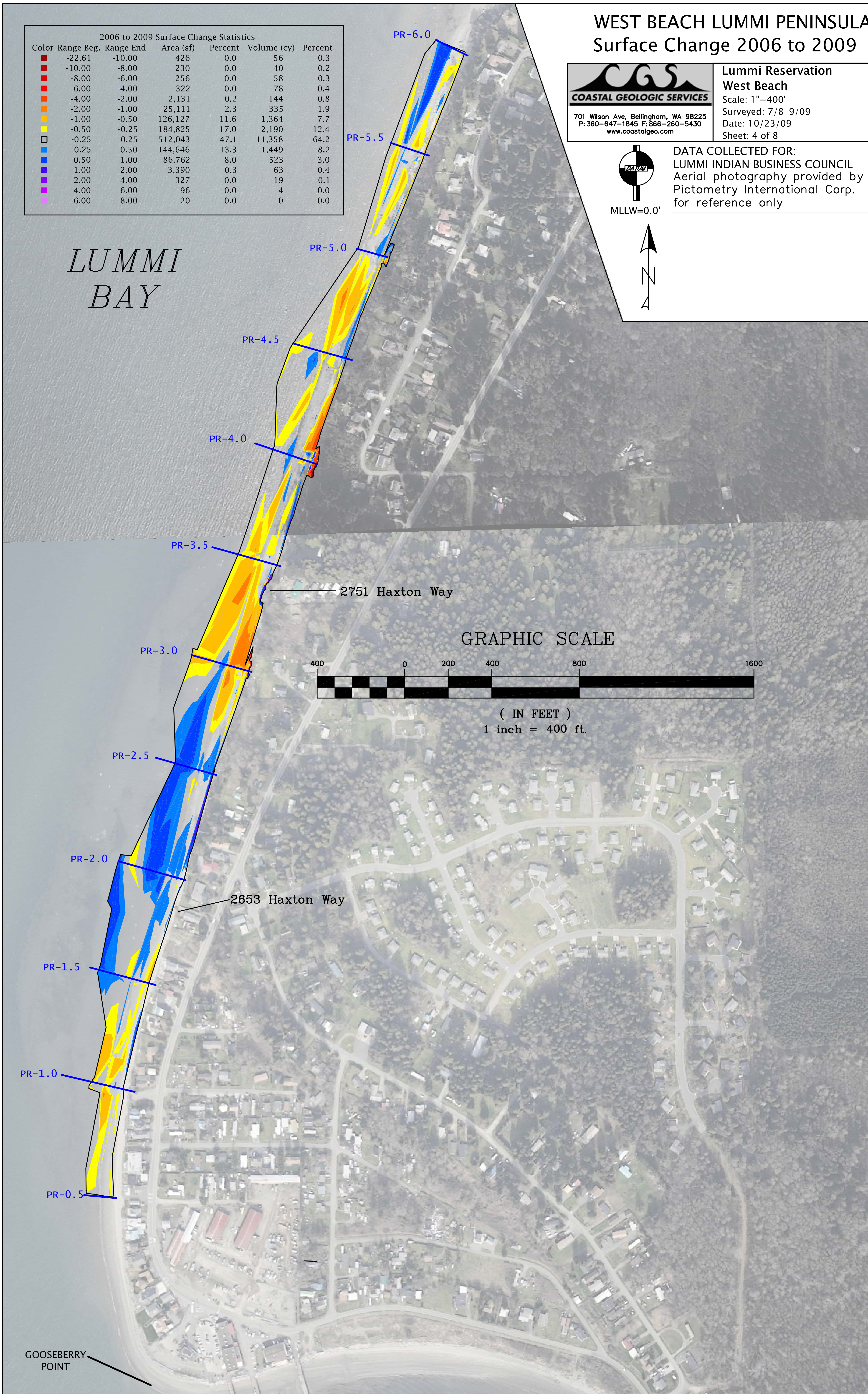
Lummi Reservation
West Beach
Scale: 1"=400'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 4 of 8

DATA COLLECTED FOR:
LUMMI INDIAN BUSINESS COUNCIL
Aerial photography provided by Pictometry International Corp. for reference only

MLLW=0.0'

2006 to 2009 Surface Change Statistics

Color	Range Beg.	Range End	Area (sf)	Percent	Volume (cy)	Percent
■	-22.61	-10.00	426	0.0	56	0.3
■	-10.00	-8.00	230	0.0	40	0.2
■	-8.00	-6.00	256	0.0	58	0.3
■	-6.00	-4.00	322	0.0	78	0.4
■	-4.00	-2.00	2,131	0.2	144	0.8
■	-2.00	-1.00	25,111	2.3	335	1.9
■	-1.00	-0.50	126,127	11.6	1,364	7.7
■	-0.50	-0.25	184,825	17.0	2,190	12.4
□	-0.25	0.25	512,043	47.1	11,358	64.2
■	0.25	0.50	144,646	13.3	1,449	8.2
■	0.50	1.00	86,762	8.0	523	3.0
■	1.00	2.00	3,390	0.3	63	0.4
■	2.00	4.00	327	0.0	19	0.1
■	4.00	6.00	96	0.0	4	0.0
■	6.00	8.00	20	0.0	0	0.0



WEST BEACH LUMMI PENINSULA
Surface Change 2003 to 2009

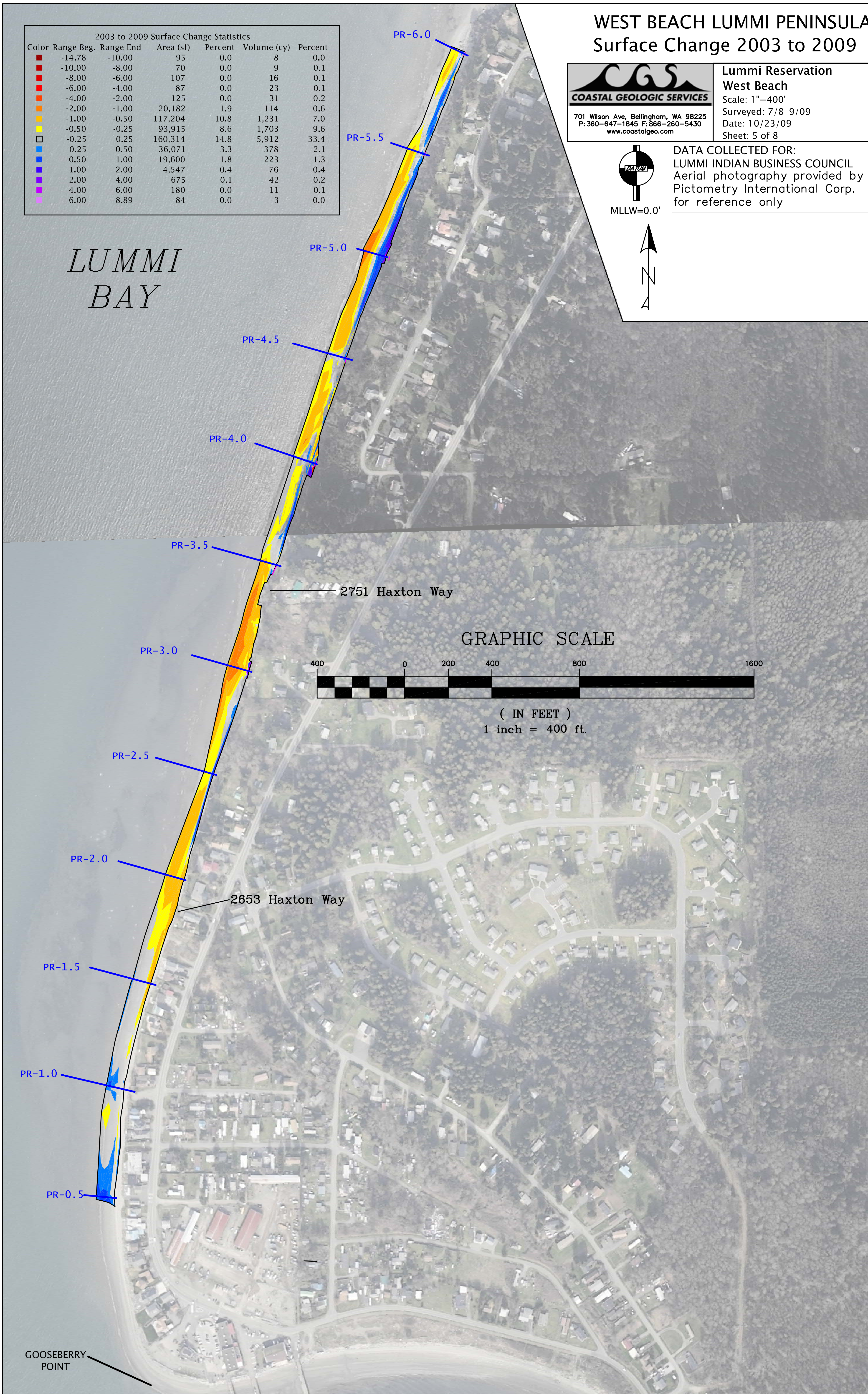
COASTAL GEOLOGIC SERVICES
701 Wilson Ave, Bellingham, WA 98225
P: 360-647-1845 F: 866-260-5430
www.coastalgeo.com

Lummi Reservation
West Beach
Scale: 1"=400'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 5 of 8

DATA COLLECTED FOR:
LUMMI INDIAN BUSINESS COUNCIL
Aerial photography provided by Pictometry International Corp.
for reference only

2003 to 2009 Surface Change Statistics

Color	Range Beg.	Range End	Area (sf)	Percent	Volume (cy)	Percent
	-14.78	-10.00	95	0.0	8	0.0
	-10.00	-8.00	70	0.0	9	0.1
	-8.00	-6.00	107	0.0	16	0.1
	-6.00	-4.00	87	0.0	23	0.1
	-4.00	-2.00	125	0.0	31	0.2
	-2.00	-1.00	20,182	1.9	114	0.6
	-1.00	-0.50	117,204	10.8	1,231	7.0
	-0.50	-0.25	93,915	8.6	1,703	9.6
	-0.25	0.25	160,314	14.8	5,912	33.4
	0.25	0.50	36,071	3.3	378	2.1
	0.50	1.00	19,600	1.8	223	1.3
	1.00	2.00	4,547	0.4	76	0.4
	2.00	4.00	675	0.1	42	0.2
	4.00	6.00	180	0.0	11	0.1
	6.00	8.89	84	0.0	3	0.0



WEST BEACH LUMMI PENINSULA
LiDAR to 2009 Survey Surface Change Comparison

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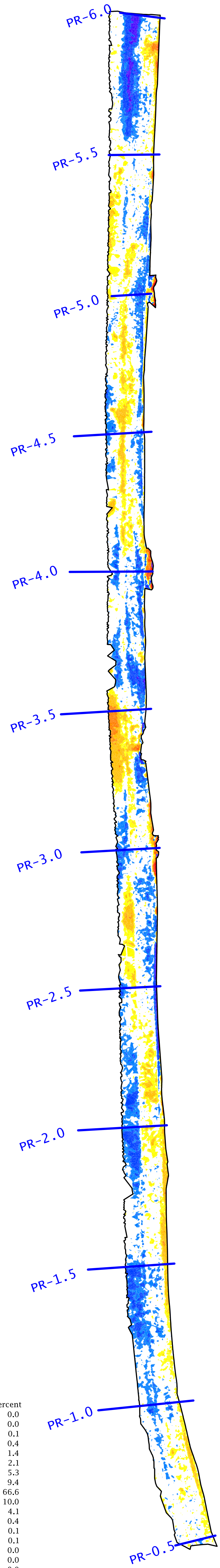
Lummi Reservation
West Beach
Scale: 1"=400'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 6 of 8

DATA COLLECTED FOR: LUMMI INDIAN BUSINESS COUNCIL

March 2005 to July 2009

LUMMI BAY

GRAPHIC SCALE
0 400 800
(IN FEET)
1 inch = 400 ft.



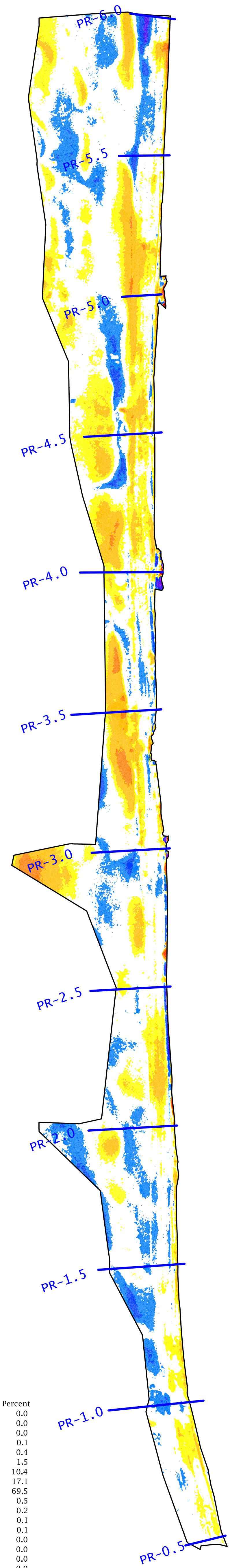
2005 LiDAR to 2009 Survey Surface Change Statistics

Color	Range Beg.	Range End	Area (sf)	Percent	Volume (cy)	Percent
	-11.80	-10.00	9.0	0.0	0.3	0.0
	-10.00	-8.00	44.1	0.0	1.7	0.0
	-8.00	-6.00	270.0	0.0	11.1	0.1
	-6.00	-4.00	675.7	0.1	44.1	0.4
	-4.00	-2.00	2,672.9	0.3	146.3	1.4
	-2.00	-1.00	8,457.2	1.1	225.4	2.1
	-1.00	-0.50	52,915.2	6.6	561.7	5.3
	-0.50	-0.25	102,048.8	12.8	1,000.5	9.4
	-0.25	0.25	441,690.7	55.4	7,098.3	66.6
	0.25	0.50	127,122.2	15.9	1,070.1	10.0
	0.50	1.00	54,967.5	6.9	433.9	4.1
	1.00	2.00	6,330.6	0.8	47.0	0.4
	2.00	4.00	89.8	0.0	10.8	0.1
	4.00	6.00	53.7	0.0	6.1	0.1
	6.00	8.00	34.0	0.0	2.7	0.0
	8.00	10.00	15.2	0.0	1.0	0.0
	10.00	16.58	6.9	0.0	0.4	0.0

July 2008 to July 2009

LUMMI BAY

GRAPHIC SCALE
0 400 800
(IN FEET)
1 inch = 400 ft.



2008 LiDAR to 2009 Survey Surface Change Statistics

Color	Range Beg.	Range End	Area (sf)	Percent	Volume (cy)	Percent
	-11.80	-10.00	67.5	0.0	4.4	0.0
	-10.00	-8.00	50.8	0.0	6.6	0.0
	-8.00	-6.00	126.2	0.0	12.7	0.0
	-6.00	-4.00	613.8	0.0	34.9	0.1
	-4.00	-2.00	1946.0	0.1	121.8	0.4
	-2.00	-1.00	54363.4	3.5	501.9	1.5
	-1.00	-0.50	361024.3	23.1	3510.0	10.4
	-0.50	-0.25	440892.1	28.2	5759.3	17.1
	-0.25	0.25	665149.3	42.5	23383.5	69.5
	0.25	0.50	32534.9	2.1	172.8	0.5
	0.50	1.00	6586.8	0.4	78.6	0.2
	1.00	2.00	1054.8	0.1	29.1	0.1
	2.00	4.00	311.3	0.0	21.3	0.1
	4.00	6.00	80.3	0.0	9.2	0.0
	6.00	8.00	44.3	0.0	5.2	0.0
	8.00	10.00	27.5	0.0	2.4	0.0
	10.00	16.58	21.3	0.0	2.3	0.0

WEST BEACH LUMMI PENINSULA
Beach Topography at 2751 Haxton Way

COASTAL GEOLOGIC SERVICES
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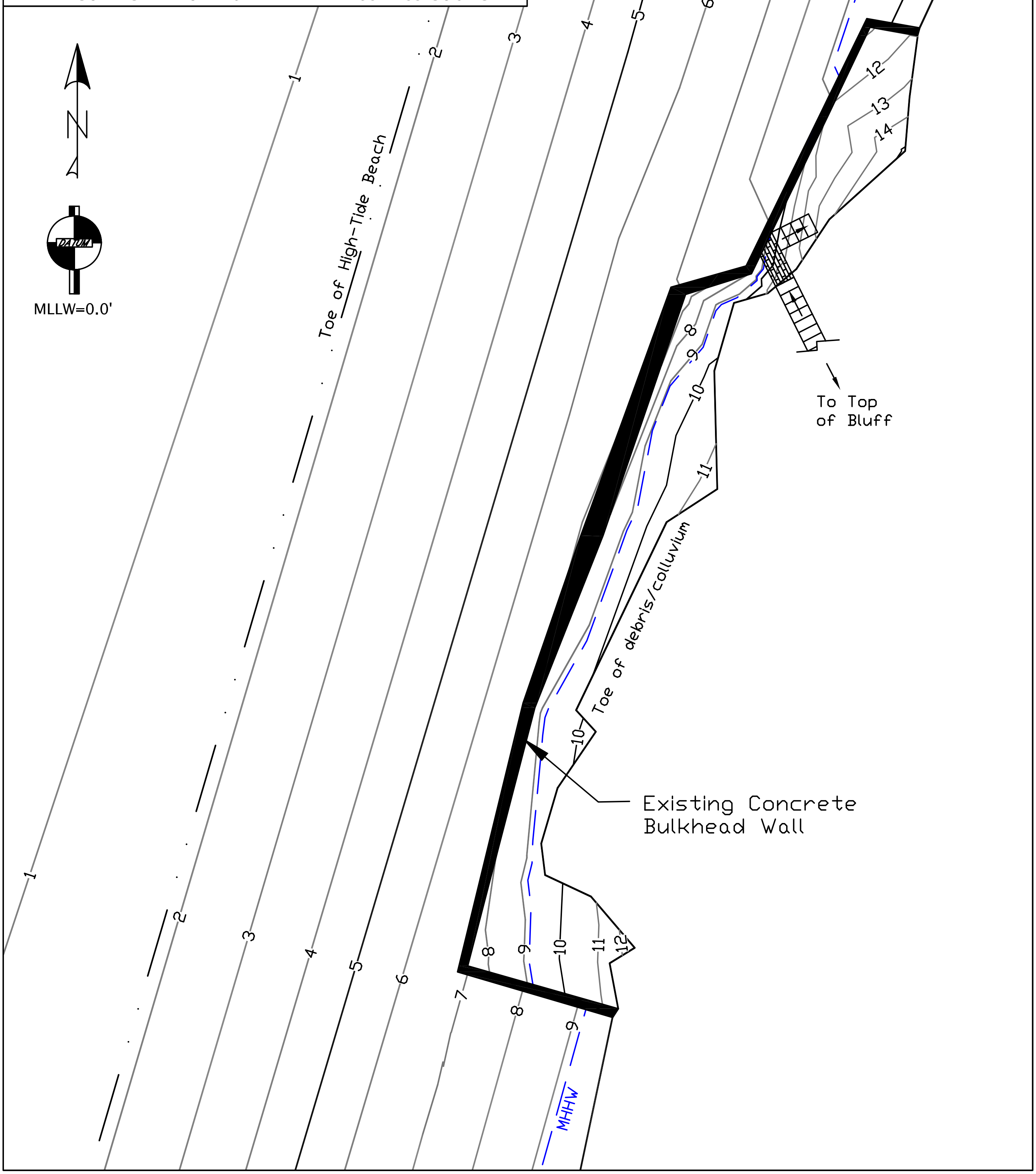
Lummi Reservation
West Beach
Scale: 1"=20'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 7 of 8

DATA COLLECTED FOR: LUMMI INDIAN BUSINESS COUNCIL



WEST BEACH LUMMI PENINSULA
Surface Change at 2751 Haxton Way

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Lummi Reservation
West Beach
Scale: 1"=20'
Surveyed: 7/8-9/09
Date: 10/23/09
Sheet: 8 of 8

DATA COLLECTED FOR: LUMMI INDIAN BUSINESS COUNCIL

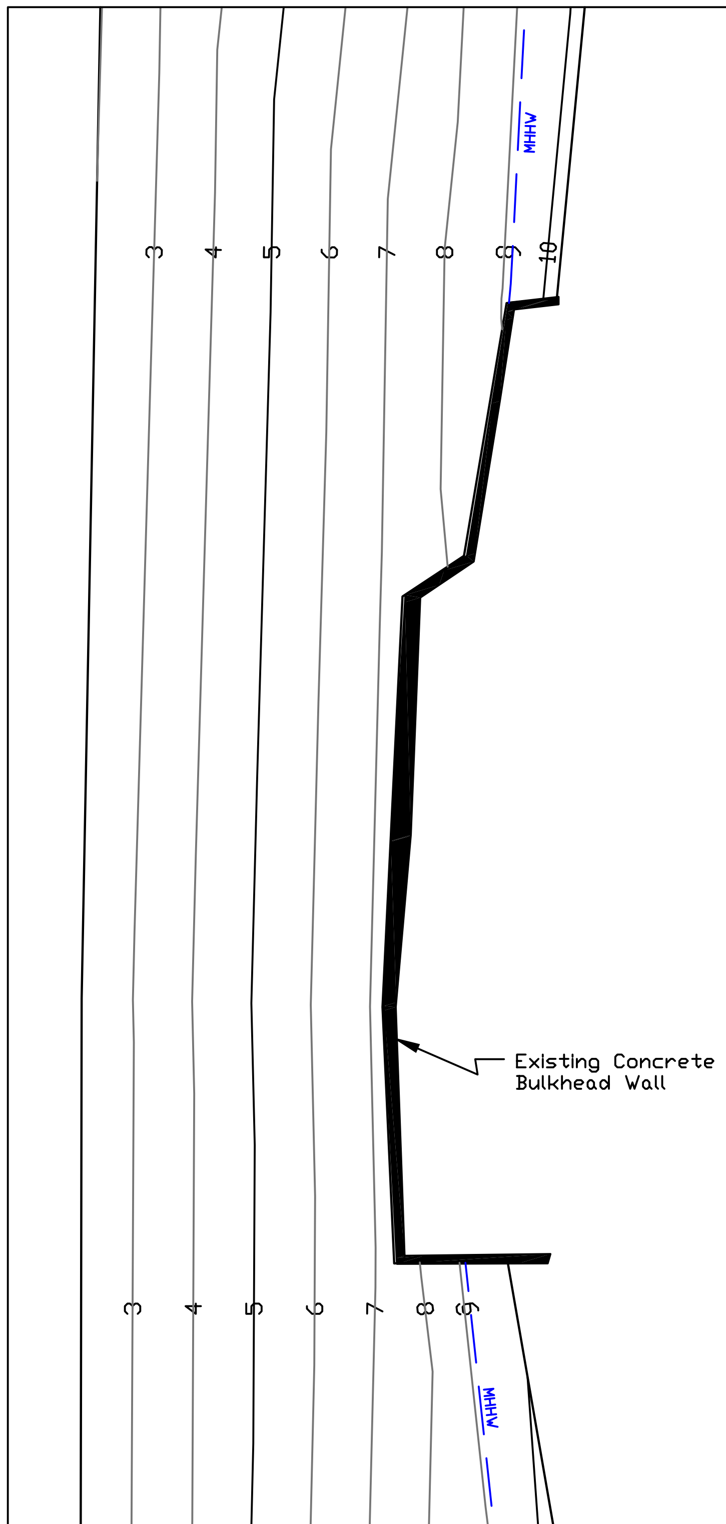
Surface Change Legend

Color	Range Beg.	Range End
orange	-2.00	-1.00
light orange	-1.00	-0.50
yellow	-0.50	-0.25
white	-0.25	0.25
light blue	0.25	0.50
blue	0.50	1.00

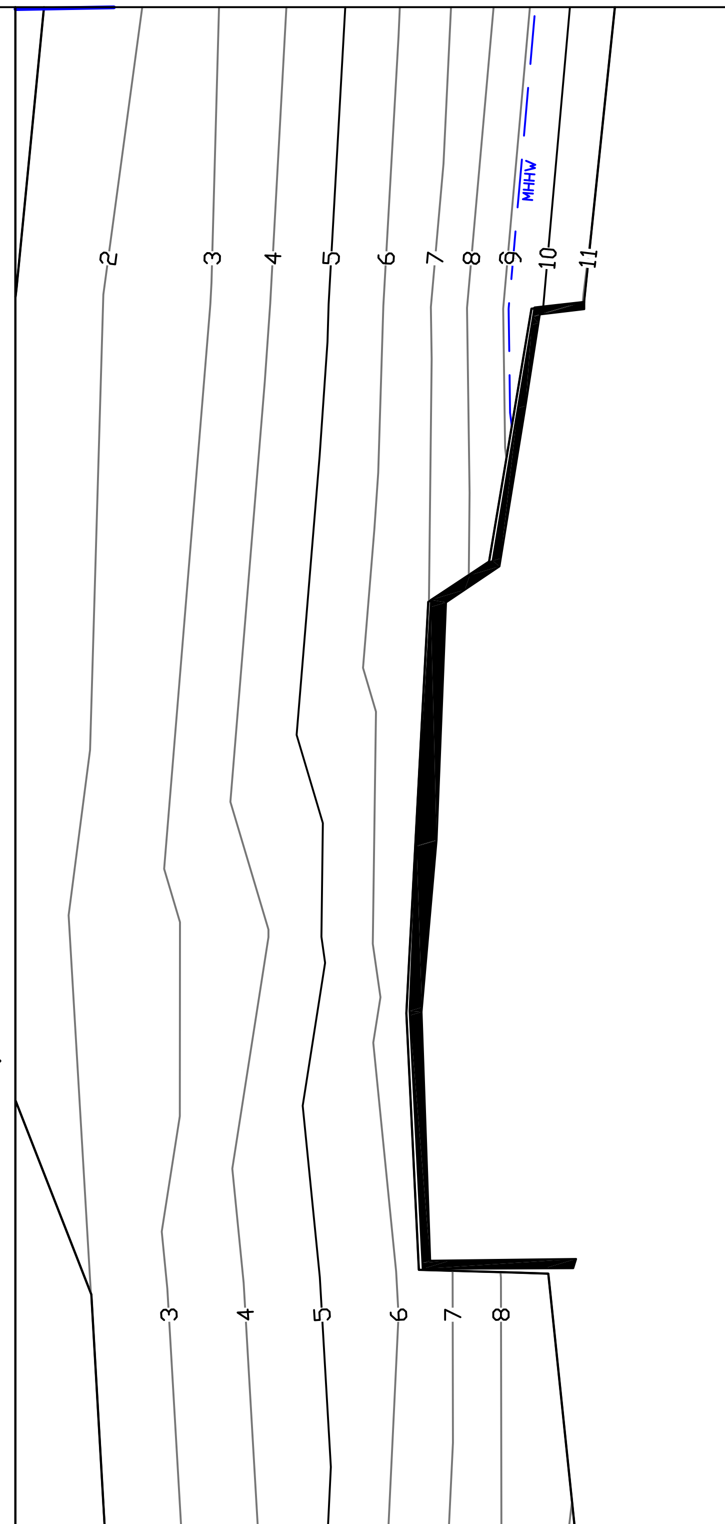
MLLW=0.0'

note: No data was collected behind the bulkhead prior to 2009, so comparison can only be made waterward of the wall.

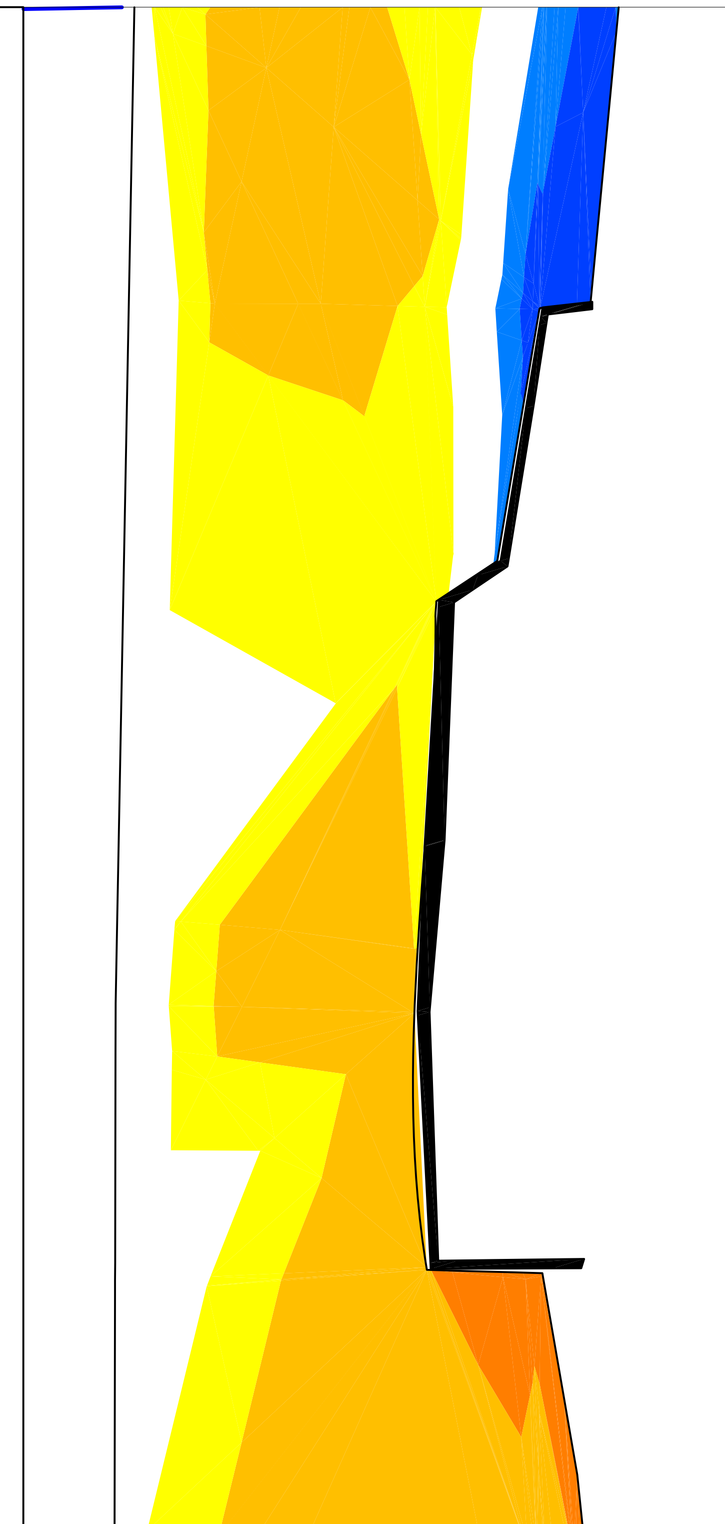
October 2003 Topography



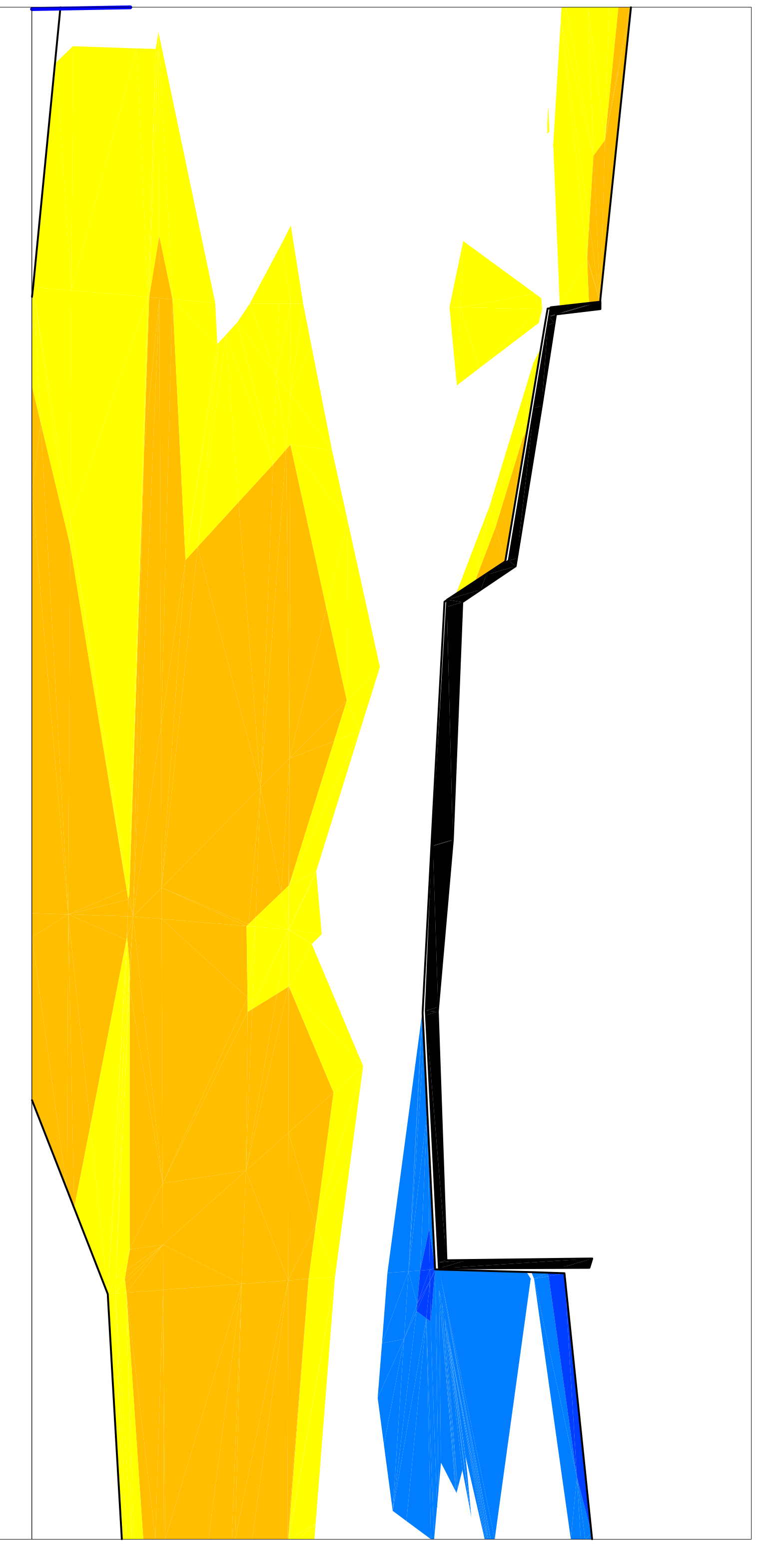
September 2005 Topography



October 2003 to September 2005



September 2005 to July 2009



Profile 0.5 South

Profile 0.5 East

Profile 1.0 South

Profile 1.0 East

Profile 1.5 South

Profile 1.5 East

Photo Page 1. Views of profiles 0.5 through 1.5 looking south and east


Profile 2.0 South


Profile 2.0 East


Profile 2.5 South


Profile 2.5 East


Profile 3.0 South


Profile 3.0 East

Photo Page 2. Views of profiles 2.0 through 3.0 looking south and east


Profile 3.5 South


Profile 3.5 East


Profile 4.0 South


Profile 4.0 East

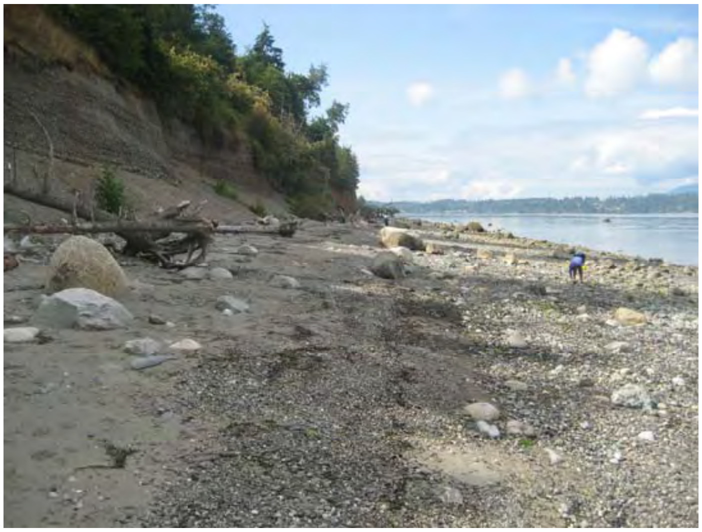

Profile 4.5 South


Profile 4.5 East

Photo Page 3. Views of profiles 3.5 through 4.5 looking south and east

Profile 5.0 South

Profile 5.0 East



Profile 5.5 South

Profile 5.5 East

Profile 6.0 South

Profile 6.0 East

Photo Page 4. Views of profiles 5.0 through 6.0 looking south and east

1/22/02

7/8/09 – note that beach is slightly higher

10/24/03

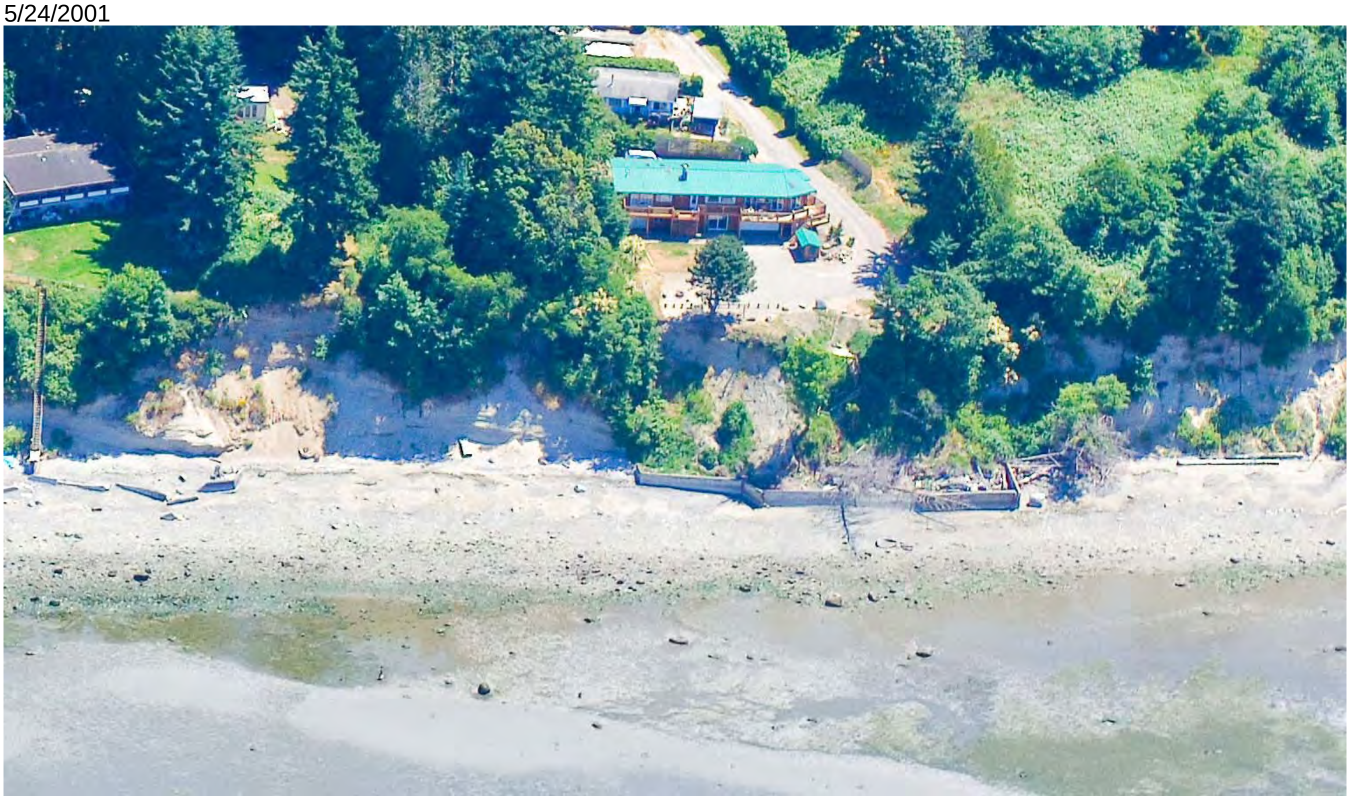
7/8/09

11/11/03

7/8/09

Photo Page 5. Views of the concrete bulkhead at 2751 Haxton Way, photo dates shown

5/24/2001



6/28/2006

Photo Page 6. Oblique aerial photographs of the shoreline fronting 2571 Haxton Way from 2001 and 2006. Photos courtesy WA Dept of Ecology.