Biennial Report of Sand Beaches; Hancock County, 2001

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Executive Summary

The goal of this report is to identify and quantify areas of shoreline change on Hancock County beach and smaller Downtown Bay St. Louis beach. In addition, the occurrence or lack of shoreline change is compared to physical properties of the beach and surrounding modifications. The information is provided to help make informed maintenance, construction, and management decisions. Detailed analysis of site-specific conditions that create shoreline erosion is beyond the scope of this report; this is meant to be a step toward that important goal.

From 1994 to 2001 the Hancock County Beach was maintained to a consistent, but continuously decreasing, beach width. Volume changes, which more accurately portray beach change, indicate that sediment has generally moved from the "dry" beach to the submerged "wet" portion of the beach. No estimates were made on the loss of sediment onshore to Beach Blvd. Long-term (1994 to 2000) analysis of shoreline and volume change shows a moderate to high loss of sediment and associated shoreline retreat. During this period 60% of the shoreline retreated at rates higher than 1.5 m/yr (5 ft/yr) with total sediment loss of about 12,000 cubic yards per year. Near-term shoreline change (1997 to 2001) represents the period following renourishment profile adjustment and has less shoreline retreat and volume loss. Only 30% of the shoreline retreated at more than 1.5 m/yr and total sediment loss was negligible. Based on the near-term trends, the beach will need to be renourished in about 10 years (2012) if conditions and management strategies remain unchanged.

The Downtown Bay St. Louis beach is retreating more rapidly than the County beach in areas that have been renourished. More than 2/3 of the southern portion of the shoreline, which has been renourished, has near-term shoreline retreat of more than 1.5 m/yr. The northeastern portion is stable, with only a few areas of shoreline retreat. Given the high change rate, the beach will need future renourishment in less than 10 years if conditions remain unchanged.

The data included in this report are available at many different scales and in digital format from the Mississippi Department of Environmental Quality, Office of Geology.

Introduction

The Hancock County Beach (Figure 1) is a valuable asset to residents and visitors alike. Beaches are vital environmental, cultural, recreational, and economic resources; they help maintain the health and productivity of adjacent coastal waters and provide for diverse cultural and recreational activities. Moreover, in Mississippi, they are important in limiting infrastructure damage and protecting the 75-year-old seawall. Thus, with an increase in development along the Mississippi Gulf Coast, the beaches are becoming an even more valuable asset. For these reasons along with the increasing costs of maintenance and renourishment projects, the Mississippi Office of Geology will continue to update local communities on the state of their sand beaches so that corrective actions can be taken before problems (expenses) become severe.

This is the second interim report (see Schmid, 2000a for earlier report); it is meant to update coastal governments on the state of their beaches from a coastal geology perspective and highlight areas that may require more or less resource allocation. More in-depth analyses, including surface and subsurface geology and total-sand-volume calculations, have been completed (see Schmid, 2001a and Schmid, 2001b). The data presented here include Global Positioning System (GPS) shoreline surveys and beach profiles along the beach from Bay St. Louis to the end of the renourished beach in Waveland; this study encompasses the years of 1994 to 2001.

Changes during the period between 1994 and 2000 are used to analyze the longer-term trends, especially as they relate to the emplacement of a new beach and its adjustment to the natural conditions. Analyses of changes between 1997 and 2001 are mainly to document the steady state behavior (following initial adjustment) of the beach and where future problems may occur. This is an important distinction; long-term data can be skewed by the initial adjustment phase immediately following renourishment, thus masking the behavior during the present, semi-equilibrium conditions that are used to project the beach's behavior into the future.

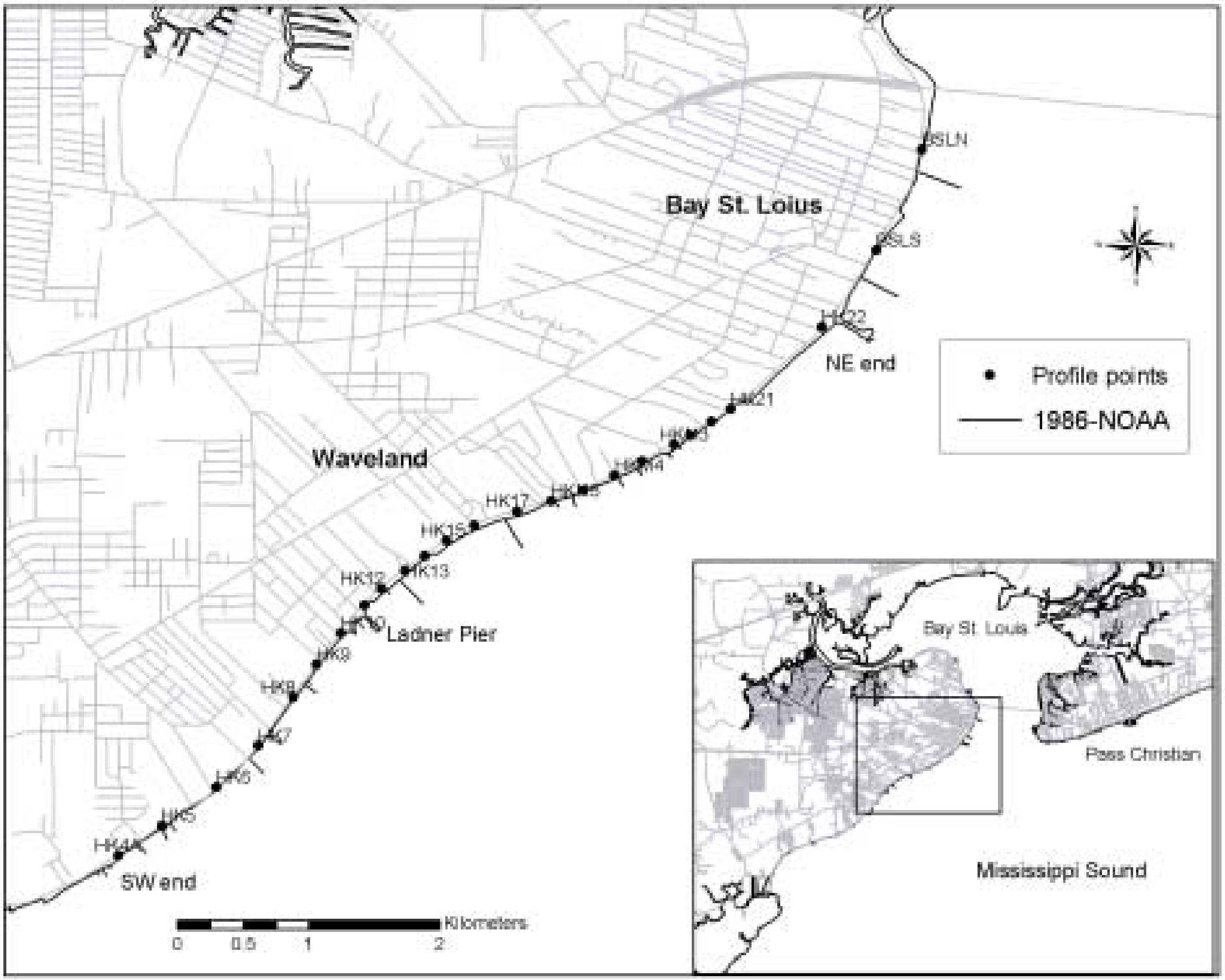

Figure 1. Hancock County base map with profile locations.

Methods

Two methods were used to map and describe beach change, both above and below sea level. Shoreline surveys of the mean high water (MHW) line were carried out using backpack style GPS (Global Positioning System) receivers with an accuracy of 1-2 meters (3-6 ft.). To supplement the data, beach profiles with accuracies of inches were used to measure volume changes and beach shape. To analyze the survey data within the bounds of the physical setting, aerial photography in the form of Digital Ortho Quarter Quads (DOQQ's) were used in a Geographic Information System (GIS) as a base map. These data files were downloaded from the Mississippi Automated Resource Information System (MARIS).

The MHW line has been chosen as a repeatable datum for the GPS shoreline surveys, which were done in the summer and spring months. The error in determining the high tide line is, based on comparison of multiple surveys of the same beach area, on the order of 0-3 meters (0-10 ft.). Thus, the overall accuracy of the method is generally about 2-5 meters (6-16 ft.) (Hutchins and Oivanki, 1994). GPS surveys of the high tide position were carried out in 1994, 1996, 1997, 1999, 2000, and 2001.

To highlight and examine areas with significant shoreline change a buffer analysis was performed using a Geographic Information System (GIS). The technique highlights any portion of the latter shoreline with retreat or accretion (change) of more than a predetermined value from the earlier shoreline. For example, if a 10 m buffer is used when comparing 1994 and 2000 shorelines, only the areas where the 2000 shoreline is separated from the 1994 shoreline by more than 10 m is highlighted. If the highlighted portion is shoreward of the 1994 shoreline it is retreating, if it is seaward of the 1994 shoreline it is advancing.

Two values were chosen to highlight moderate and high change. These values were based on the percentage of the distances between the 1994 and 2000 shorelines (Figure 2). Distances were divided by 6 years to arrive at a yearly change. About 50% of the shoreline changed less than 9 m (Figure 2) and for analysis purposes was considered nearly stable. 33% of the shoreline changed from 9 to 18 m (1.5 to 3.0 m/yr) and were considered moderately changing. The remaining 20% with values from 18 to 27 m (3 to 4.5 m/yr) were considered highly changing. Previous studies of shoreline retreat (Otvos, 1976; Schmid, 2000a;b; 2002) have used values at or below these to highlight significant change.

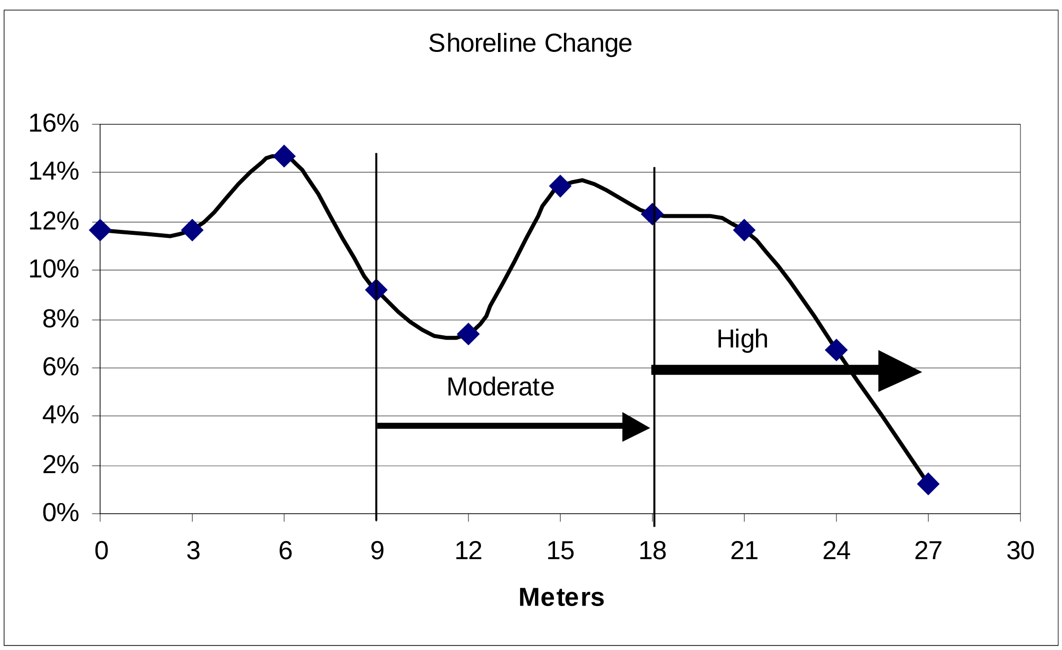

Figure 2. Graph of shoreline change percentages.

In an effort to summarize the shoreline and its spatial characteristics, it was broken into individual 50m segments. Shoreline angle was computed for each segment and compared to shoreline change. Culvert locations were digitized from obvious departures in shoreline patterns from 1993 to 2001, located by visual inspection of orthophotos, and taken from previous databases with culvert locations. Some of the smaller culverts may have been missed; however, an earlier study (Schmid, 2000c) demonstrated that shoreline response is affected mainly by larger diameter culverts.

These GPS surveys and analysis techniques, although a good technique to highlight problem areas, do not show how well the beach can withstand the effects of storm-related or astronomical high tides. In many locations wind tides can advance the shoreline several tens of meters (50+ ft.) beyond the mapped shoreline. During these events the shape or elevation of the beach is critical in protecting infrastructure and limiting erosion. In addition, beach maintenance and storm water runoff from the coastal roads are periodic events that can obscure local trends. Therefore, the GPS surveys, though largely representative of erosion and accretion, are augmented by higher accuracy beach profiles.

Beach profiles are performed using traditional survey grade instruments giving accuracies on the order of one inch. They have been taken since 1993 on the Hancock County beach; the data for this report come mainly from 1994, 1997, 2000, and 2001 surveys. Unfortunately, beach profiles are time consuming and therefore only performed at set locations along the shore. Spacing between beach profiles is determined by structures (e.g., harbors), access, degree of change based on GPS surveys, and change in beach morphology (e.g., dunes).

Beach profiles are aligned at right angles to the shoreline, beginning at the seawall, and ending at depths around –4 feet (up to chin of survey personnel), which typically corresponds to the sand/mud boundary. Elevations are based on benchmarks or station elevations along the seawalls that reference National Geodetic Vertical Datum 1929 (NGVD-29). Beach profiles encompass nearly the whole beach system, from seawall to the start of deeper water and the change from a sandy to a muddy bottom. It is, thus, a more accurate technique to describe changes that take place. Beach profiles represent changes caused by beach maintenance, wind loss, storm runoff, and high tides and, thus, are not compromised because of them.

In this report, beach profiles were used to calculate sand volume change over the studied periods, highlight areas of erosion and accretion, and document the evolution of sediment transport features (i.e., megaripples and sand waves). Volume change per linear foot of beach width was also computed to provide real estimates of sand loss or gain for both the longer term (6 years) and the shorter term (3 to 4 years). Volume changes have been computed for the entire profile, the dry beach (above 0 elevation), and the beach below sea level to about –4 feet. Values from the most recent profile surveys (2000 and 2001) were taken to document the volume of sediment pumped onto the beach and lateral changes in renourished sediment, and to separate future change patterns from quick changes that occur on newly renourished beaches as they adjust to achieve a state of semi-equilibrium.

Hancock County Results – 1992 to 2000

The Hancock County beach has been broken into two sections; this section covers the County beach between Waveland and Bay St. Louis (Figure 1) and is broken into a north portion (north of Ladner Pier) and southern portion (south of Ladner Pier). The overall shoreline orientation is influenced by the north and south headlands and the embayment near Ladner Pier. Seawall heights on the County beach are typically below 6 feet elevation and thus offer little protection from storm surge. The second section covers the Bay St. Louis Downtown Beach, where seawall heights are significantly higher and afford much more protection to upland infrastructure.

As discussed previously, buffer widths for the County beach analysis were based on the overall change of the shoreline between 1994 and 2000. Areas with less than 9 m (30 ft) of change in the six-year period (1.5 m/yr) are treated as stable or effectively maintained as such. Areas with 9 to 18 m (30 to 60 ft) of change are considered retreating (eroding) or advancing (accreting); areas with more than 18 m (3.5 m/yr; 11.5 ft/yr) of change are considered highly retreating or highly advancing. To maintain consistency, buffer widths used for the Bay St. Louis beach are the same as the County beach. Profile results for each section are separated into volume change (total, onshore, and offshore) and profile geometry (shape).

The County beach was renourished in 1993-94 from borrow material taken about 300 to 600 m offshore of the northeastern part of the beach (Figure 3). The Bay St. Louis Downtown beach was renourished in 1996 from a borrow area on the northwest side of the Highway 90 bridge. Since the renourishment, beach width has been maintained to a large degree by moving sediment seaward using heavy equipment. Despite these efforts, beach widths have decreased on nearly all portions of both beaches. Moreover, beach elevations have also generally decreased, setting the stage for increased retreat in the future. Only so much sand can be moved seaward before the entire beach becomes too low to continue the practice. In this case, a new solution is required. The time frame for this eventual problem will be discussed.

Northeastern Hancock County (Bay St. Louis to Ladner Pier)

The shoreline between Bay St. Louis and Ladner Pier is about 4500 to 4800 m (3 miles) depending on the sinuosity of beach during the survey. Of the total, 1500 m is directly landward of the borrow pit used for the 1994 renourishment (Figure 3). There are several groin structures (closed and open culverts) that have created some noticeable shoreline perturbations. Longshore transport is generally from NE to SW although there are areas that indicate the opposite direction. Longshore transport does not appear to be as prominent as on the Harrison County shoreline (Oivanki, 1997).

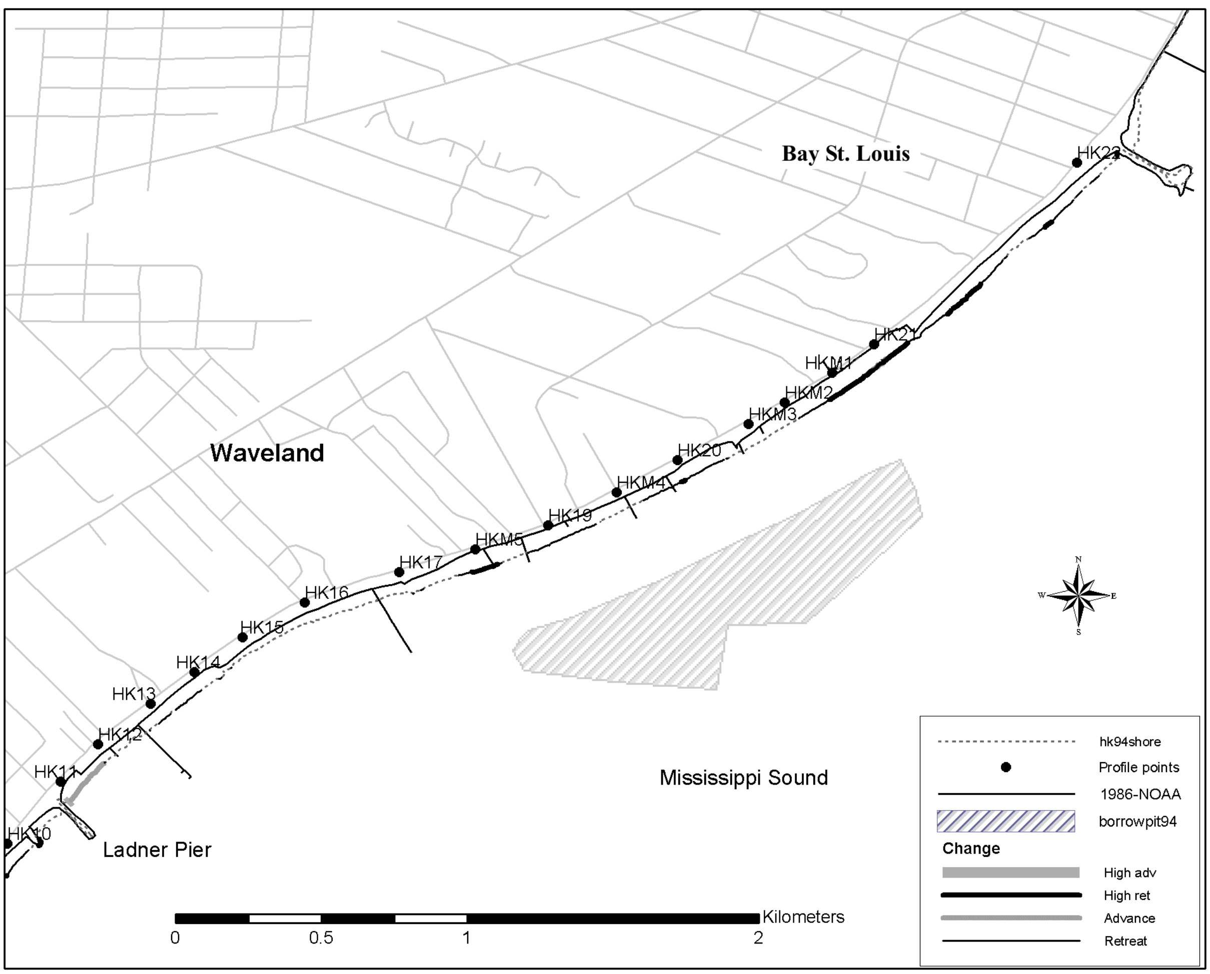

Figure 3. Long-term shoreline advance and retreat from Bay St. Louis to Ladner Pier.

Long-term shoreline change

Long-term shoreline values

Comparison of the 1994 and 2000 GPS shoreline surveys provides a long-term average of where and how much shoreline retreat and advance are occurring. Of the 3 miles of shoreline in this portion, more than one third is retreating at more than 1.5 m/yr (5 ft/yr) (Table 1); only 5% is advancing at more than 1.5 m/yr. This shows a clear trend toward erosion, which is typical of most beaches in the Gulf of Mexico and around the world. Given this erosional trend, sections that erode the quickest are an even more important problem and are a weak link in the beach and costly in terms of maintenance. Areas with more than 3 m/yr (10 ft/yr) of retreat are considered highly eroding. These areas are the most costly as more work must be done to move sand or, alternatively, they create a situation where it is necessary to renourish more often. Fourteen percent (14%) of the shoreline along this stretch is classified as highly eroding. Taken in total almost one half of the beach has a long-term retreat beyond 1.5 m/yr (5 ft/yr). A similar analysis on Harrison County beach in the same time frame (1993 to 2000) showed only 27% retreating at more than 1 m/yr (3.3 ft/yr) (Schmid, 2002). The high level of retreat can be partially explained by inclusion of the immediate adjustment period following renourishment in 1994.

Table 1. Long-term shoreline change on northeastern Hancock County beach

Total Shoreline(m)	9-18 m retreat (m)	> 18 m retreat (m)	> 7 m advance (m)
4495	1508	617	190
Percentage %	33.5%	13.7%	4.2%

Long-term shoreline trends

Locally, the most pervasive area of retreat is north of HK M5 (Figure 3), which is located across from Aiken Road, to the boat launch in Bay St. Louis (HK 22). Other than that stretch, there is only a small area near HK 13 that showed retreat beyond 1.5 m/yr. Areas with high retreat (3.0 m/yr; 10 ft/yr) are in a 700 m stretch from HK M2 (300 m south of Ramenada St.) on the south end to between HK 21 and HK 22 on the north. Another area of high retreat is at HK M5 (near Whispering Pines Rd.). Most of these areas are near the borrow pit location, although, based on the 1986 shoreline, there appears to have been high retreat in these areas prior to the borrow pit being excavated.

To determine the association with culverts and shoreline angle the shoreline was broken in 50 m segments. Segments with any part containing retreat were considered retreating even if only a very small part was retreating; the same process was applied to advancing segments. Some segments contain both attributes. The segment approach is not used in this report to map locations, only to statistically describe the shoreline. In the segment approach to shoreline retreat, 58% of the shoreline is retreating (once again this value is higher than actual because of the technique) and 4% is advancing (Table 2). The segment values are very close to the actual values, suggesting that shoreline retreat occurs in groups or clusters along the shoreline.

The segment approach is used to investigate the relationship between shoreline change and drainage culverts (groins) that are commonplace on the shoreline in Mississippi. When walking on a beach one might notice sediment built-up on one side of a culvert. This is created by the longshore current direction (parallel to the beach), which transports sediment towards either the SW or NE on the Hancock Beach. As this process is continual and is a modification of the natural shoreline, it is reasonable to consider it as a potential cause of shoreline retreat. In parts of the Gulf and Atlantic Coasts, large groins have created significant erosion on the downdrift portion of the structure (Everts, 1983).

To determine the association of culverts with long-term change, 50 segments with change were compared to segments within 25 m of culverts. Twenty-five (25) meters was chosen to assure that at least two segments per culvert were included. Using the percent of retreating segments (58%) and advancing segments (4%) as a baseline – no distinction between culvert and regular shoreline – the percentages of change segments compared to culverts can be studied.

Of the total eroding segments, 48% were within 25 m of a culvert (Table 2). The total shoreline (50 m segments) within 25 m of a culvert was 2200 m and 57% was classified as eroding. In both erosional segments near culverts / total erosional segments (48%) and erosional segments near culverts / shoreline near culverts (57%), the values were at or lower than the baseline (58%). Thus, this comparison of long-term retreating shoreline near culverts and the total percentage of retreating segments suggest that culverts as a whole on this stretch of beach do not concentrate erosion. This does not mean that culverts are not factors in causing erosion, as different size (diameter) culverts have distinctly different effects on beach response (Schmid, 2000c) and in specific locations they are certainly large factors.

Culverts do appear to be a factor in concentrating advance. Using the same technique, 75% of the advancing segments are near a culvert (or groin). A comparison of the baseline advance (4%) and the advance segments near culverts/culvert shoreline (7%) indicates that culverts (groins) are concentrating areas of shoreline advance. A closer look at culvert sizes and shoreline retreat is necessary to better quantify the process, but at first look, culverts as a whole do not appear to be the controlling factor in shoreline retreat patterns, but do appear to control shoreline advance patterns.

Table 2. Culvert shoreline statistics on northeastern Hancock County beach

Total Shoreline (m)	Culvert Shoreline (m)	Retreat Segments (m)	Advance Segments (m)	Ret. Segments near culverts (m)	Adv. Segments near culverts (m)
4495	2200	2600	200	1250	150
	Shoreline near culverts %	Ret. Segments/ Tot. Shoreline %	Adv. Segments/ Tot Shoreline %	Ret. Segments near culv/ Ret. Segments %	Adv. Segments near culv/ Adv. Segments %
	49%	58%	4%	48%	75%
		Ret. Segments near culverts/Culvert shoreline %	Adv. Segments near culverts/Culvert shoreline %		
		57%	7%		

To determine if erosional segments show any relation to the shoreline angle, the shoreline orientations of all 50 m segments were compared to the orientation of 50 m retreating segments. In both, the average shoreline orientation (direction facing the Sound) was about 147 degrees; however, the difference in percentage of each total within the five-degree interval (Figure 4) suggests that the interval from 140 to 150 degrees has a slightly higher percentage of retreating segments. In contrast, shoreline segments with the most easterly orientation are typified by advance on the updrift sides of culverts (groins) and/or structures. Also noticeable as low retreat areas are shoreline segments with orientations between 160 and 170 degrees.

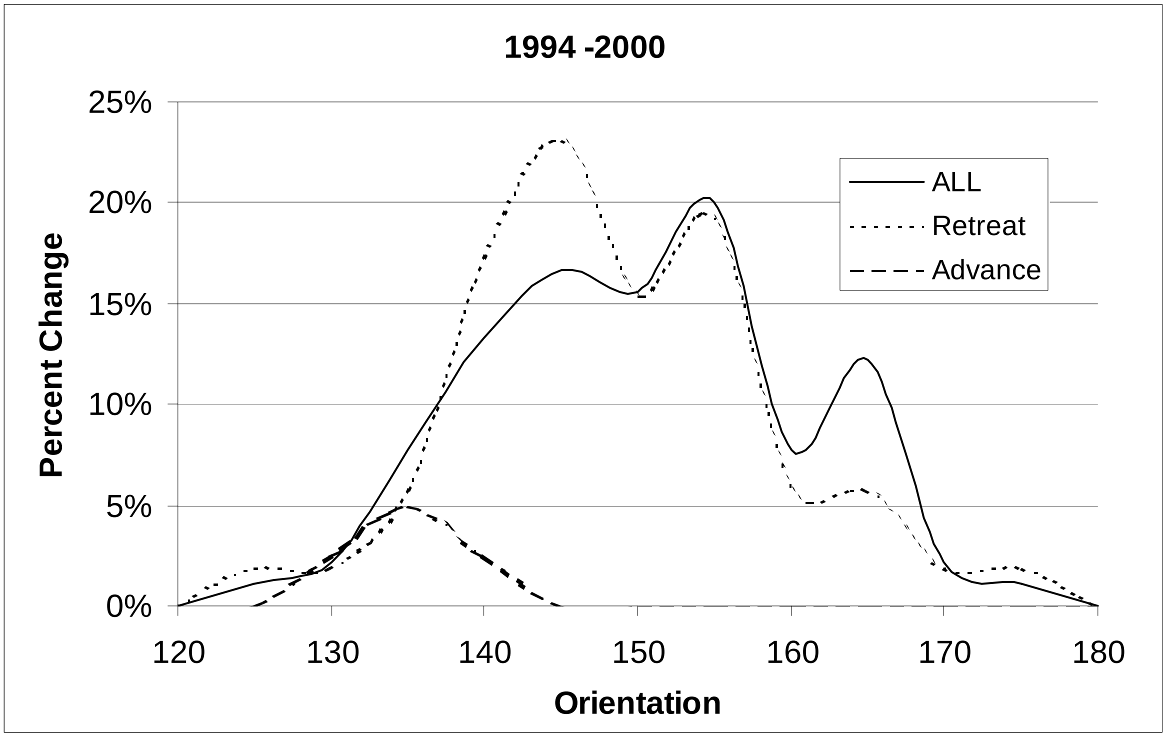

Figure 4. Shoreline angle (x) and shoreline change percentage (y).

Long-term beach profile surveys

Long-term profile change patterns

Total volume change is measured in cubic yards per foot of beach in a year. So, for example, a –2.5 cubic yard/ft change on a 500 ft (150 m) stretch of beach would lose 1250 cubic yards per year. The change is measured from the seawall out to a water depth of approximately 4 ft. Mapping the changes helps in understanding the system's sinks and sources. The results on northeastern Hancock County beach indicate that the northeastern two-thirds of the shoreline has a complex sediment transport regime with high positive change adjacent to high negative change (Map 1). The southern one-third has a uniform pattern and is dominantly gaining sediment volume. There are inconsistencies between the shoreline change and total volume change, notably at HK M1, HK 13 and HK 21, where volume change is positive, but there is moderate to high shoreline retreat. This suggests that the nearshore portion (underwater) of these areas is gaining sediment while the onshore (dry beach) is losing sediment.

To examine the differences in nearshore and onshore changes the profile change was computed both for the nearshore (Map 2) and onshore portions (Map 3). The break between the two parts of the profile was typically just below the zero elevation (NGVD) and corresponds to the location where the beach slope becomes nearly flat. Generally speaking, the nearshore change was positive on most profiles and the onshore changes were negative.

Intuitively, onshore change patterns (Map 3) are in better agreement with the shoreline change values. Areas with the highest losses are also associated with shoreline retreat; areas with low loss and volume gain are associated with little change and shoreline advance. HR 13 is the one location that is inconsistent as it had a positive volume change but had shoreline retreat. Overall, the highest negative changes are typically north of HK M5; to the south onshore negative volume changes are lower. This suggests a NE to SW longshore drift trend.

The nearshore changes (Map 2) suggest that the profiles with positive total change but associated with shoreline retreat have a higher positive nearshore (underwater) change. The nearshore volume change follows the same trend as the total volume trend. The northeastern half is typified by areas of high positive change adjacent to areas of high negative change suggesting the presence of discrete transport cells. The southern half is uniform with only slight changes indicating a single or consistent transport regime. The net positive trend suggests an offshore-directed sediment transport regime, which is consistent with short period wave erosion.

Long-term profile volumes

As the changes are measured in volumetric units (cubic yards/ft of beach) it is possible to compute volume change for the entire stretch of beach by multiplying the volume times the length of each profile division. This computation is an estimate that is dependent on the distance between profiles, such that closely spaced profiles will provide a better estimate than profiles spaced far apart. The profiles for Hancock County beach are closely spaced so the estimate should be good.

Table 3. Long-term volume change on northeastern Hancock County beach in cubic yards

Total volume change (yr)	Onshore volume change (yr)	Nearshore volume change (yr)
-6,386	-13,501	7,115
Total volume change (94-00)	**Onshore volume change (94-00)**	**Nearshore volume change (94-00)**
-38,318	-81,006	42,688

Long-term volume changes (Table 3) suggest that about half of the lost onshore sediment is deposited on the nearshore portion of the beach. The other half is lost either beyond the nearshore platform (past about –4 ft) or lost onshore due to wind (wind loss). Without running experiments at the site on the wind-transported sediments it is difficult to assign values to the two components of overall lost sediment. However, given the persistent offshore-directed sediment transport, it is likely that offshore losses are higher than onshore losses.

Profile geometry

Profiles at each measured location are provided in the Appendix I. There are two distinctly different profile patterns on the Hancock County beach: long profiles with an extensive flat nearshore and rapid drop off at the nearshore – offshore boundary, and short steep profiles with a steeper sloping nearshore and less dramatic drop off at the nearshore boundary. The areas with the long profiles (HK M5 to HK 22) are positioned along the headlands, whereas the short profiles (HK 11 to HK 17) are in the small embayment. It also appears that the underlying geology (Pleistocene units) has an influence on the profiles and the thickness of the Holocene sediments, which directly influences the profile (Schmid, 2001a;b). In both cases, the general trend is towards accretion on the nearshore and erosion on foreshore to onshore portion of the profile. This is a common response to sea level rise (Figure 5), and to artificial renourishment.

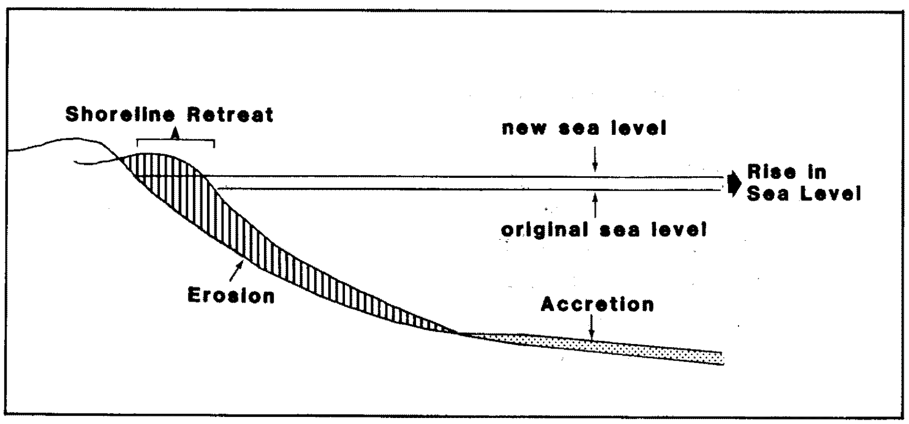

Figure 5. Generalized Bruun rule sea level rise (from Bruun, 1962).

Near-term shoreline change

Near-term shoreline values

The same techniques and values of shoreline change that were used in the long-term analysis were also used for the period 1997 to 2001 (Table 4). Predictably, the amount of shoreline with retreat, most notably high retreat, was less in the recent analysis than the long-term because the shoreline had attained a level of semi-equilibrium. Nonetheless, there are still areas with high retreat, suggesting that these areas will cause problems in the future.

Table 4. Near-term shoreline change on northeastern Hancock County beach

Total Shoreline (m)	6-12 m retreat (m)	> 12 m retreat (m)	> 6 m advance (m)
4693	1310	208	325
Percentage %	27.9%	4.4%	6.9%

The total shoreline with more than 1.5 m/yr of shoreline retreat decreased from nearly 50% in the long-term to just over 30% in the near-term. This 30%, however, is a fairly high value when compared to the Harrison County beach, which had an overall average of 27% retreating at the lower value of 1 m/yr during the same time. The percentage of advance is also lower than on the Harrison County Beach.

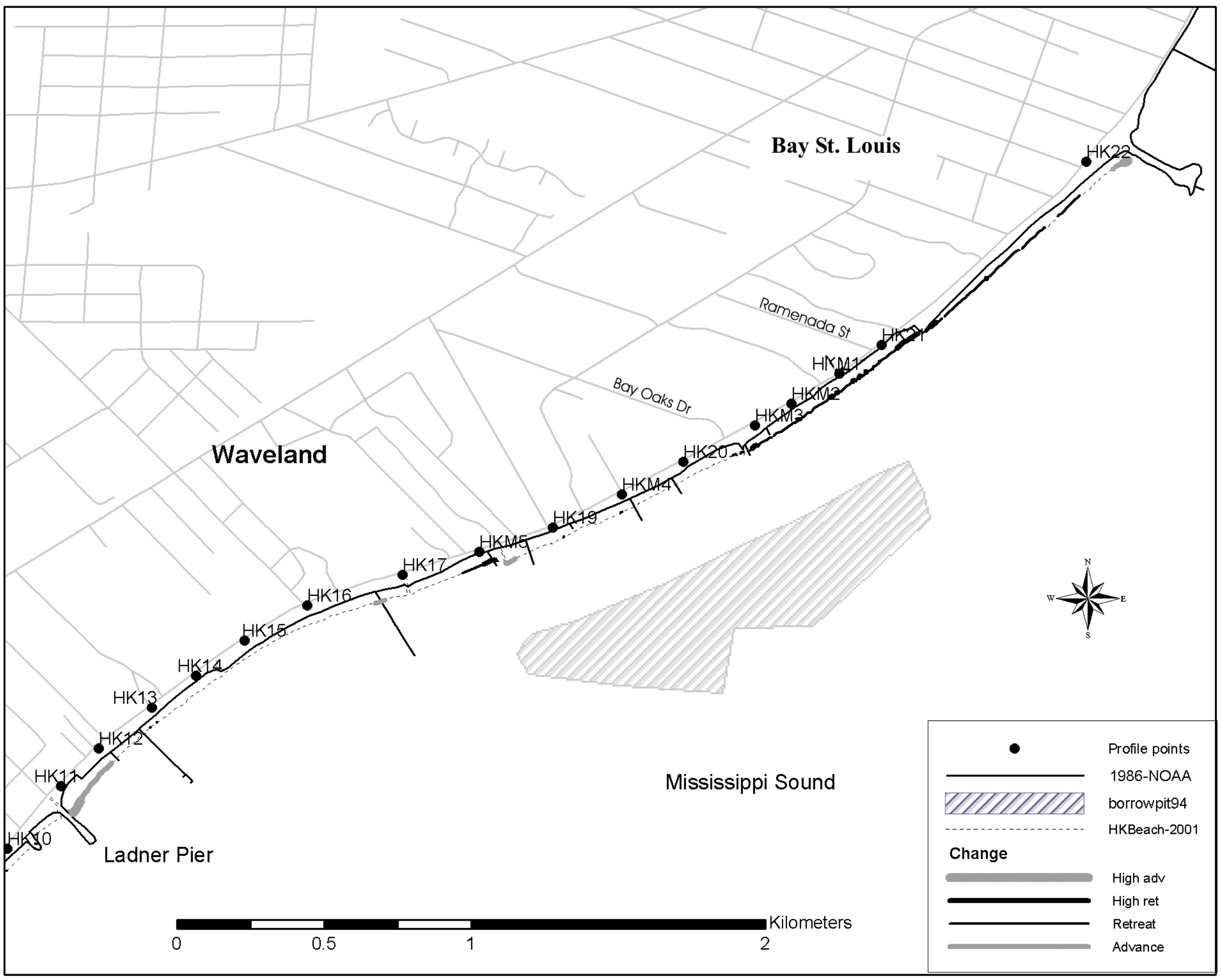

Figure 6. Near-term shoreline change locations and levels.

Near-term shoreline trends

Given that the near-term change levels reflect present conditions, it is reasonable to assume that they also represent the near future conditions. Therefore, from a management standpoint these trends are important to understand. The most easily recognizable trend (Figure 6) is the high retreat north of HK M3, which begins at the open drainage culvert (across from Bay Oaks Drive). Most of the high shoreline retreat (about 70%) is located between the open culverts at Bay Oaks Dr. and just north of Ramenada St. It appears that this section is cut off from both longshore drift directions by the open culverts. To the north of Ramenada St. the shoreline is uniformly retreating and together with the aforementioned area constitute about 90% of the shoreline with retreat beyond 1.5 m/yr. This is both the good and bad news. The area that makes up the last 10% is near HK M5 on the SW side of the open culvert there.

Like in the long-term analysis, the only area with advance is on the southwest end near the Ladner Pier. This may be a source of sediment that could be moved to the eroding sections.

The factor that culverts play in the shoreline retreat along this portion of the Hancock County beach was summed up in the previous section. Despite the fact that culverts as a whole do not concentrate erosion, the results from the near-term analysis suggest that open culverts in certain locations are concentrating the erosion.

The relationship between shoreline orientation and near-term shoreline change is similar to the long-term change and shoreline orientation. Like the long-term dataset, the near-term has a higher level of erosion between 140 and 150 degrees (Figure 7). Unlike the long-term trend the shoreline segments with 150 to 160 degree orientations are lower than the average. These locations are where the big change between long-term and near-term shoreline change occurred. In effect, these locations had probably been out of equilibrium for the first couple of years following renourishment but had achieved a state of equilibrium since then. Orientations between 140 and 150 degrees appear to be associated with higher shoreline change as a result of dominant wave direction and shoreline configuration.

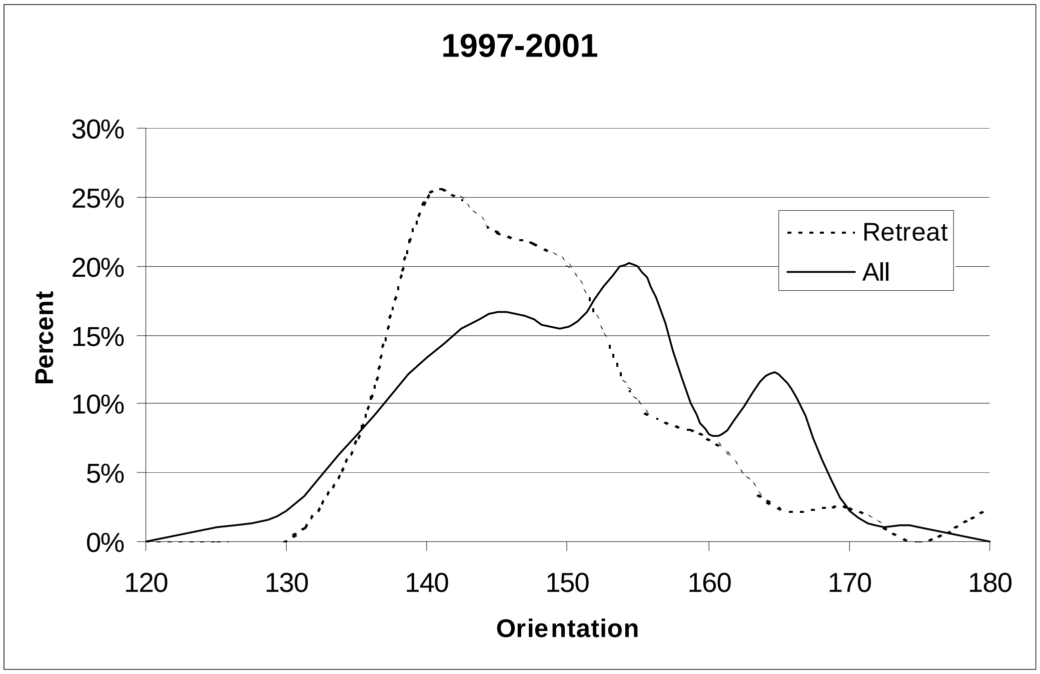

Figure 7. Orientation of shoreline and shoreline retreat areas.

Near-term beach profile surveys

Near-term profile change patterns

Near-term volume changes (Maps 4, 5, and 6) are somewhat inconsistent with near-term shoreline change. For example, the northeastern third of the profiles, northeast of HK M3, have low loss values in onshore volume change (Map 6) and total volume change (Map 4) (as compared with all profiles in Hancock County), but have the most shoreline erosion. When this occurs, it suggests that the onshore and nearshore profile has grown vertically (gained elevation); on the nearshore this is typically due to dune growth, which is a positive change that promotes long-term stability. Indeed, many of these northeastern profiles have shown appreciable dune growth (Appendix 1). For this reason, it is important to look at both shoreline change and volumes.

In the broadest terms, the shoreline between Ladner Pier and Bay St. Louis can be broken into thirds based on the near-term profile data. The northeastern third, north of HK M3 generally shows low total overall losses and a trend towards nearshore gain. The middle third, between HK M5 and HK M3, is typified by the highest losses in the northeastern part of the Hancock County beach system, with both high onshore loss and low offshore gain. This area is shoreward of the borrow pit, and is on the slight headland. The southern third has a mixed signature with low loss on the onshore portion, but inconsistent trends with regards to the nearshore and total volumes.

Near-term profile volumes

Near-term volume on the northeastern portion of the beach has an overall positive change (Table 5). Onshore near-term volume change is almost identical to the long-term change, which is surprising given that the initial adjustment following the renourishment should have skewed the long-term data towards a higher loss. Given the results, it is reasonable to assume a uniform onshore loss rate of around 13,500 cubic yards per year.

Table 5. Near-term volume change on northeastern Hancock County beach in cubic yards

Total volume change (yr)	Onshore volume change (yr)	Nearshore volume change (yr)
7,290	-13,463	20,753
Total volume change (97-01)	Onshore volume change (97-01)	Nearshore volume change (97-01)
29,159	-53,852	83,011

Nearshore volume change was positive, like the long-term change. However, it was about three times higher than in the long-term. This suggests that the loss during the initial adjustment was largely transported offshore (deeper than 4 ft) and that after the adjustment the amount escaping the nearshore platform was reduced, possibly as a result of partial filling of the borrow pit. The overall positive change suggests that there has been some longshore drift from the north or south and/or onshore transport of sand from offshore. In any case, the positive volume change on the nearshore indicates that much of the sediment lost from the onshore is still resident on the beach system.

Comparison of long-term and near-term

This portion of the Hancock County beach showed similar trends and shoreline retreat values in both the long and near-term. The biggest difference between the long-term and near-term was the positive volume change on the nearshore. The positive overall volume in the near-term suggests that most of the sediment lost from the onshore portion of the beach is staying within the system. Consistent values of onshore change in both time periods helps future forecast of sediment volumes. Spatial shoreline retreat trends were similar in both time series, with slightly higher values (total meters) in the long-term, which is to be expected.

Local hot spots

Based on long-term and near-term shoreline and total volume changes, the critical hot spots in this beach section are areas near HK M3 and HK M5. In each of these areas there is high onshore loss and high shoreline retreat. HK M5 also has high offshore loss, so it is the most critical. The high shoreline retreat between HK M3 and HK 22 is also an area that is a potential problem. All of these areas and especially HK M5 and HK M3 should be monitored more closely, and/or preferentially maintained to promote shoreline stability.

Southern Hancock County (Ladner Pier to SW Waveland)

This portion of the Hancock County shoreline begins southwest of Ladner Pier and ends at the small terminal groin marking the end of the 1994 renourishment. Shoreline data suggest that this area had a higher level of adjustment following the renourishment than did the previous section. Unfortunately, profile locations are spaced further apart on this section of beach and therefore interpretations based on the data are necessarily less detailed.

Long-term shoreline change

Long-term shoreline values

Comparison of the 1994 (post renourishment) and 2000 shoreline positions on this 3 km (1.75 mi) stretch of beach indicates that shoreline change is dominated by high levels of retreat (> 3 m/yr) (Table 6). In all, more than 80% of the shoreline is retreating at more than 1.5 m/yr; of that, almost 50% is retreating at more than 3 m/yr (Table 6). Shoreline advance of more than 1.5 m/yr is all but absent. The high level of shoreline retreat is a clear sign that the nearshore environment was highly out of equilibrium with the newly renourished beach.

Table 6. Long-term shoreline change on southern Hancock County beach

Total Shoreline (m)	9-18 m retreat (m)	> 18 m retreat (m)	> 9 m advance (m)
2990	1031	1432	25.5
Percentage %	34.5%	47.9%	0.9%

Long-term shoreline trends

The trend is for nearly uniform shoreline retreat (Figure 8). The shoreline near HK5 and between HK10 and Ladner Pier are the only two with less than 1.5 m/yr of retreat. These two areas appear, using the 1986 shoreline and the seawall position, to have had some vestiges of a beach before renourishment. This appears to be an important factor, such that areas to the north of HK8 had a slight beach (based on 1986 data) and generally have lower retreat values.

Unfortunately, this is not unlike the "chicken and egg" argument because it is reasonable to assume that in areas with lower shoreline retreat there would also be a beach left from the earlier 1967 renourishment. Nevertheless, the two patterns are consistent.

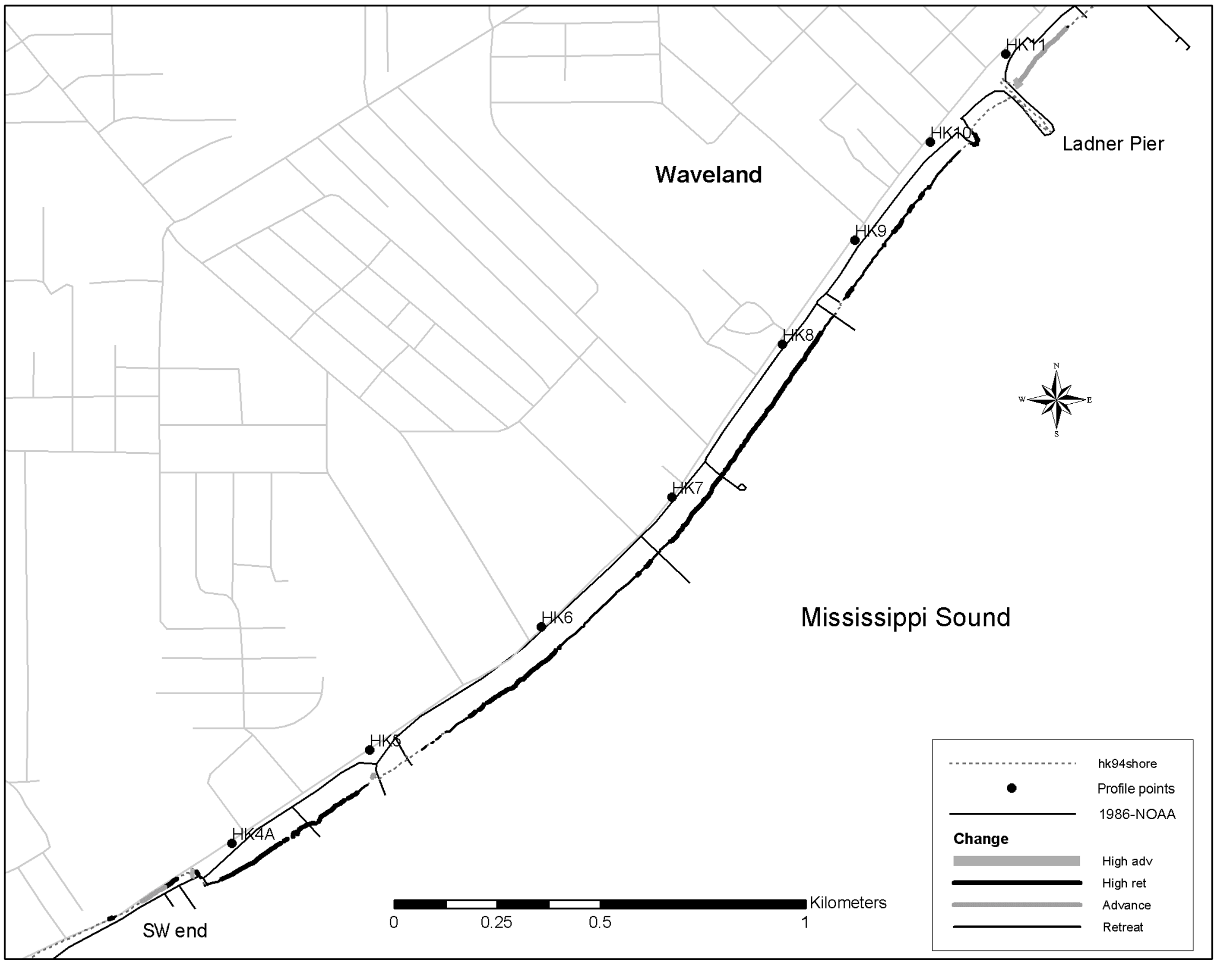

Figure 8. Shoreline retreat and advance from Ladner Pier to HK4A.

Because of the overwhelming amount of long-term shoreline retreat, it does not appear to be related to culverts or other shoreline structures. This is not necessarily true for the present conditions, which will be examined in the following sections.

Like culverts, the overall retreat signature probably precludes any relationship to shoreline orientation. However, the average shoreline angle on this part of Hancock County is about 138 degrees, which is slightly more easterly oriented than the northeastern portion of the shoreline (north of Ladner Pier).

Long-term beach profile surveys

Long-term change patterns

Total profile volume change (Map 1) is very nearly uniform along this part of the beach. The only areas with slightly different results are at the SW end of the beach. HK4A has a decidedly negative overall volume change, an outcome of its location at the end of the beach. HK5 is located just updrift of a groin that has trapped sand on its updrift side (northeastern) both prior to and following the 1994 renourishment. Like the total volume change, nearshore change (Map 2) is consistent along the beach, except at HK4A. Onshore change (Map 3) is decidedly negative, with only HK5 showing some reduction in loss.

Volumes

Volume change for the southern portion (Table 7) of the beach is very similar to the northeastern portion of the beach (Table 2). The length of the southern beach section is about 1.5 km less so the change is about 33% higher per length of beach, which is consistent with the high level of shoreline change measured on the southern section. The breakout between nearshore volume change and onshore volume change suggests, like the northeastern section, that about 50% of the long-term onshore loss can be accounted for by nearshore gain.

Table 7. Long-term volume change on southern Hancock County beach

Total volume change (yr)	Onshore volume change (yr)	Nearshore volume change (yr)
-5,750	-13,805	8,055
Total volume change (94-00)	Onshore volume change (94-00)	Nearshore volume change (94-00)
-34,500	-82,830	48,330

Profile geometry

Like the northeastern portion of the study area, the profiles (Appendix I) can be broken into two different groups – short, steep profiles in the embayment (HK10 to HK8) and long, gently sloping profiles on the headland section (south of HK8). The length of the profiles increases towards the south and may reflect the presence of an underlying Pleistocene beach ridge (Gulfport Formation) (Schmid, 2001a;b). Nearshore accretion (elevation increase) is limited on the southernmost profiles; this may be due to the length of the nearshore or because of higher longshore currents. All of the profiles show the growth of dunes running parallel to the beach road, which is an important factor in limiting infrastructure damage given the low elevation of the beach (only about 4 ft above sea level).

Near-term shoreline change

Near-term shoreline values

Of the 3 km of beach, about 20% is experiencing shoreline retreat beyond 1.5 m/yr; less than 1% is retreating at more than 3 m/yr (Table 8). Shoreline advance of more than 1.5 m/yr is absent. There is a very noticeable change between the long-term change (Table 6) and near-term change, especially in the high retreat category. The dramatic change is an example of how post renourishment adjustment and 'normal' conditions differ.

Table 8. Near-term shoreline change on southern Hancock County beach

Total Shoreline (m)	6-12 m retreat (m)	> 12 m retreat (m)	> 6 m advance (m)
3250	720	17	1
Percentage %	22.2%	0.5%	0.0%

Near-term shoreline trends

Retreat locations on the southern part of the Hancock County beach (Figure 9) are less grouped than in the northeastern part. There is a general retreat signature on the headland areas from HK7 to HK8. There was very little retreat to the north of HK8 and only pockets of retreat south of HK7. Of the southern pockets, the most notable is at HK4A, which represents the end of the renourished beach.

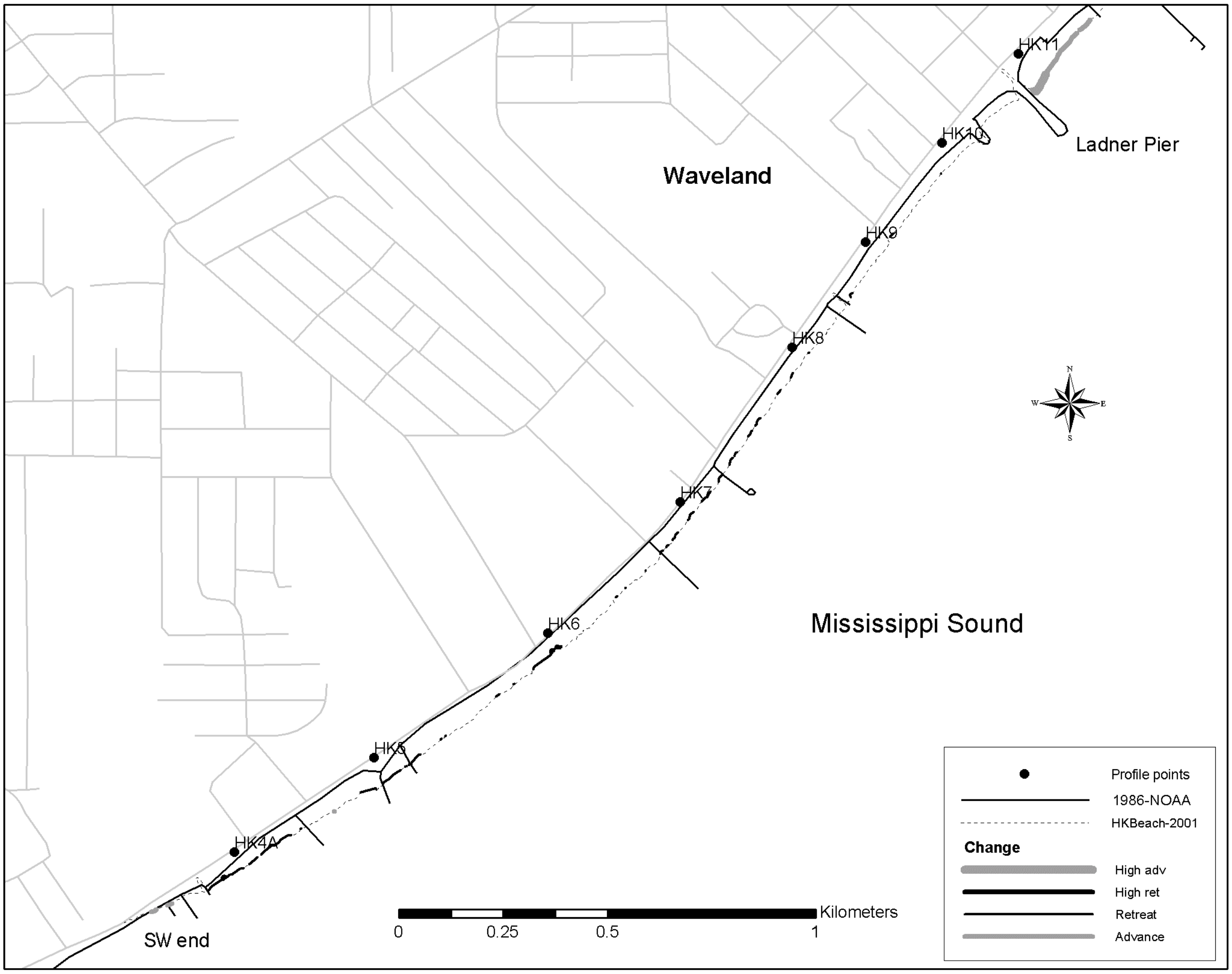

Figure 9. Nearterm shoreline change from Ladner Pier to HK4A.

As the near-term shoreline retreat has a more scattered pattern than the dominant pattern in the long-term, it is possible to compare the occurrence of retreat with culverts and shoreline orientation. The total number of 50-m segments with shoreline retreat is about 60% of the total shoreline segments (Table 9). Once again, this value is high due to the technique. The large difference between the real value and the value used in this technique is indicative of the scattered nature of retreat. This 60% can be looked at as a baseline, such that a higher value suggests there is a factor increasing the amount of erosion and a lower value suggests there is a factor decreasing the amount of erosion. In both erosional segments near culverts / total erosional segments and erosional segments near culverts / shoreline near culverts the values were below the baseline 60% (Table 9). As both of these numbers are lower than the total erosion percentage (60%) it suggests that, overall, culverts are not clustering shoreline retreat. This does not mean that culverts do not play a role, as there are several areas where retreat occurs downdrift (to the south) of culverts, indicating that these particular culverts are playing a role in the retreat there.

Table 9. Culvert shoreline statistics on southern Hancock County beach

Total Shoreline (m)	Culvert Shoreline (m)	Retreat Segments (m)	Advance Segments (m)	Ret. Segments near culverts (m)
3250	2300	1950	50	1150
Shoreline near culverts %	Ret. Segments/ Tot. Shoreline %	Adv. Segments/ Tot Shoreline %	Ret. Segments near culv/ Ret. Segments %	Ret. Segments near culverts/Culvert shoreline %
71%	60%	2%	59%	50%

Southern Hancock County shoreline has a more easterly orientation than the northeastern half, with an average orientation of about 138 degrees. Unlike the northeastern half, which had a particular shoreline orientation with higher retreat, the southern half has nearly uniform retreat in all orientations (Figure 10) – so that there does not appear to be any strong relationship between shoreline orientation and shoreline retreat in the near-term data. The only orientation that shows a slight increase is 140 degrees (where Retreat is higher than All), which is the same as the northeastern part of the beach system.

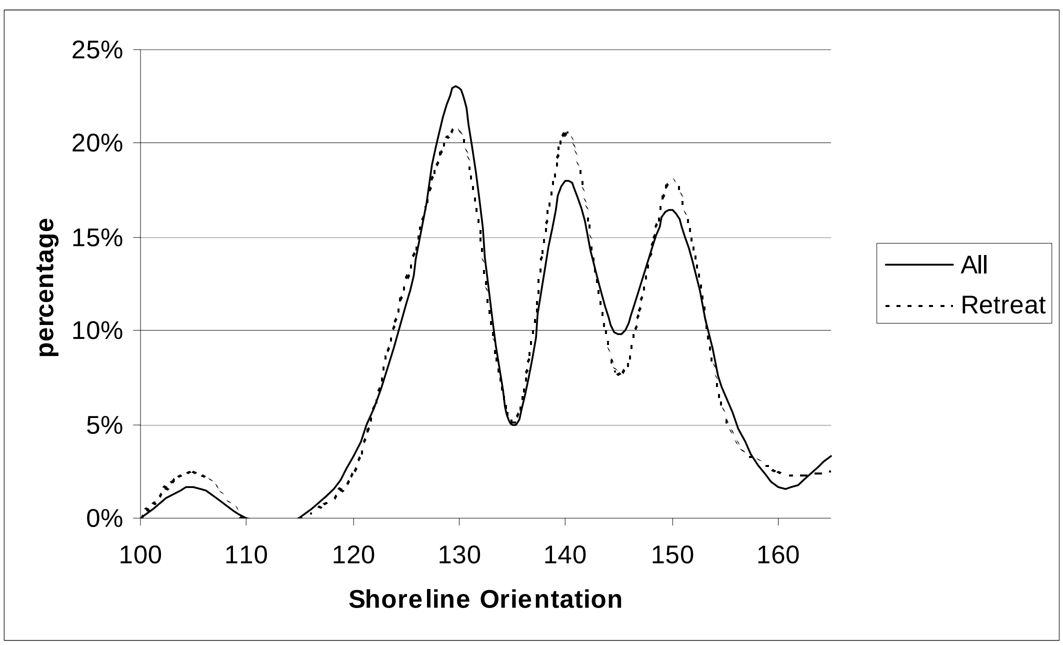

Figure 10. Orientation of shoreline and retreat segments on southern Hancock County beach.

Near-term beach profile surveys

Near-term change patterns

Near-term total volume change (Map 4) and nearshore volume change (Map 5) are consistent, in that they suggest that the shoreline has three ‘compartments’; two have decidedly negative volume change and the third has a positive volume change. The positive volume change area is between HK6 and HK7; the two negative volume change areas are to the south and north of the positive area. This suggests that the two flanks of the headland are areas of high sediment loss while the headland is gaining sediment. This generally goes against what is expected and may be the result of sediment trapping at the Ladner Pier on the north flank and loss of sediment beyond the renourished beach on the south flank. Low onshore loss at HK7 and HK4A (Map 6) where retreat is more dominant is also surprising. It appears that the upper (higher elevation) portions of these profiles (Appendix I) lost less sediment than the surrounding ones.

Near-term volumes

Onshore volume change remains very stable at about 13,000 cubic yards per year on the southern portion of Hancock County beach (Table 10). The value is nearly identical to the long-term value, like the northeastern section, which also had very similar long-term and near-term values. Of the 13,000 cubic yards, only about one third can be accounted for as positive change on the nearshore platform. The remaining two thirds were lost farther offshore, downdrift of the study area, and as wind loss. Once again, determining how much was lost in each mode is difficult.

Table 10. Near-term volume change on southern Hancock County beach in cubic yards

Total volume change (yr)	Onshore volume change (yr)	Nearshore volume change (yr)
-8,541	-12,968	4,427
Total volume change (97-01)	Onshore volume change (97-01)	Nearshore volume change (97-01)
-34,164	-51,872	17,708

Comparison of long-term and near-term

In contrast to the northeastern section, the southern section has a significant amount of change between time periods, which indicates that significant post renourishment adjustment took place. Long-term shoreline retreat is prevalent over about 80% of the shoreline; this was reduced to only about 25% in the near-term. In general terms the volume change was fairly consistent in that this portion of beach is generally losing more sediment, both in the long and near-term, than the northeastern half. Nearshore volume change decreased in the near-term, and is probably associated with a switch from post renourishment nearshore enhancement to a more equilibrium type of nearshore enhancement sediment regime.

Local hot spots

Hot spots are difficult to pinpoint in the southern part of Hancock County beach based on shoreline retreat. High levels of retreat in the long-term and only moderate to low levels in the near-term present difficulties in assessing particular locations. Profile changes in the long-term and near-term provide a more consistent picture of the beach system. Based on the data presented, the HK4A and HK7 to HK8 shoreline compartments have the highest propensity for shoreline retreat and erosion.

Hancock County Beach – A Look at the Entire System

Based on GPS and profile data, the Hancock County beach shows moderate to high shoreline retreat (Table 11) and volume loss (Table 13) over the long-term and more moderate to low change (Tables 12 and 13) in the near-term. Shoreline advance is all but absent over the study area and indicates that little if any new sandy sediment is entering the system; however, some muddy sediment (clay and silt) is being deposited on the nearshore (Schmid, 2001b).

Table 11. Total long-term shoreline change on Hancock County beach

Total Shoreline	9-18 m retreat (m)	> 18 m retreat (m)	> 9 m advance (m)
7485	2539	2049	215.5
Percentage %	33.9%	27.4%	2.9%

Table 12. Total near-term shoreline change on Hancock County beach

Total Shoreline	6-12 m retreat (m)	> 12 m retreat (m)	> 6 m advance (m)
7943	2030	225	326
Percentage %	25.6%	2.8%	4.1%

The change in shoreline percent classified as retreating between the long and near-term data highlights the effects of post renourishment adjustment. For the first several years the shoreline and profile were out of equilibrium with the wave/wind conditions and subsequently retreated rapidly. The long-term data show that more than 60% of the shoreline has retreated at levels of more than 1.5 m/yr. The near-term data show an entirely different system with retreat on the order of 30% of the shoreline. The near-term value is comparable to, but higher than, the amount occurring in Harrison County.

Mechanical maintenance of the shoreline position is coming at the expense, in most cases, of beach volume above high tide (dry beach) that leads to lower beach elevations. Dune growth, however, helps offset the elevation loss and protect the upland infrastructure. Movement of sediment to re-establish the shoreline position invariably causes some sediment to move offshore where it resides on the wide, shallow, nearshore (underwater) platform portion of the beach. If it stays on the platform or builds the platform seaward it helps buffer wave attack. If it moves farther seaward beyond the platform it is effectively lost from the system, although sediment transported past the platform may ultimately help create a wider platform at some locations in the future.

The most notable shoreline trend is the decrease in shoreline retreat in the short term once the beach had became equilibrated with the wave conditions. Initial retreat was highest in the southern portion of the study area and subsequently decreased to the lowest in the near-term. The northeastern section showed a similar trend, but the difference was less dramatic. The only area with any shoreline advance was just north of Ladner Pier, which indicates an overall NE to SW longshore transport direction.

Although some culverts are clearly affecting the localized shape of the shoreline, especially the large open culverts, the typical drainage culverts do not appear to be a major factor in causing shoreline retreat. Their quantitative role in creating shoreline retreat is still an unanswered question, as shoreline maintenance probably masks some of their effects. Open culverts are more clearly concentrating shoreline retreat on the northeastern section.

The orientation of the shoreline (direction facing the Sound) may be a factor on the northeastern portion of the beach system. This part of beach is more southerly oriented and, thus, more prone to longshore drift, which may be part of the reason why open culverts have more influence on shoreline retreat on the northeastern portion. The southern portion is more easterly oriented and probably has a higher offshore/onshore directed sediment transport. Unfortunately, the southern terminus of the beach is oriented more southerly and thus has a higher longshore transport component. This causes the sediment that is transported to the nearshore part of the beach here to be moved past the end of the beach and lost from the system.

Volumetrically, the highest total loss occurred during the long-term period and was about 12,000 cubic yards per year (Table 13). The near-term total loss was only about a tenth of the long-term and is consistent with the achievement of an equilibrium profile. Onshore volume change was consistent in both periods at about –27,000 cubic yards per year; nearshore volume change was markedly different between years. It is possible that the lower long-term nearshore volume increase was due to a winnowing of the finer sediment that could be more easily moved beyond the beach system and lost to the offshore. The near-term volume change in the nearshore is remarkably high; it suggests that some ‘new’ sediment is being added to the system.

Table 13. Total volume change in the long-term and near-term

Period	Total volume change (cubic yards/yr)	Onshore volume change (c.yds/yr)	Nearshore volume change (c.yds/yr)
Long-term	-12,136	-27,306	15,170
Near-term	-1,251	-26,431	25,180

Beach Forecasts

An important question to answer, and one that can be reasonably achieved given the data, is what to expect in the future. Forecasts of the future conditions are based mostly on the near-term data, because the profiles and shoreline position had become equilibrated with the coastal processes during this period. Forecasts of the future conditions are made more complex by the possibilities of large storms or short-term changes in conditions, such as a series of powerful cold fronts. The future predictions should be balanced with these factors in mind.

Volumes

One way to arrive at a lifespan estimate is to look at how long it will take before the onshore beach volume is zero. Based on earlier work (Schmid, 2001b), there are about 700,000 cubic yards of fill sediment as of 1999 on the onshore portion of the beach. Using an onshore volume change of about -27,000 cubic yards per year, the beach’s ultimate lifespan is about 25 more years (2027). At this point there would be no beach left in front of the seawall. Clearly, this would not happen uniformly; there would be areas with little or no beach left before this time and areas with sediment remaining after this point.

Based on the non-uniform shoreline change, an alternate estimate is based on the premise that the most rapidly eroding shoreline areas control the useful life of the beach. It is suggested that after these areas loose the sand in front of the seawall the system would behave differently and erosion of adjacent areas would increase. If we assume that the beach volume is uniformly distributed along the shoreline, such that each foot of beach contains the same amount of volume, then the areas with the highest onshore retreat would have little volume left on the dry beach after about 12 years (2014). Beach maintenance may change this situation as sediment is moved from area to area by equipment, but it provides a good estimate based on the present management practices and natural conditions.

Shoreline change

Another technique to forecast the beach lifespan is to use shoreline change rates. To make the predictions, shoreline change values from 1997 to 2001 were used as representative of the future conditions. Shoreline change is more difficult to forecast because it is site specific and subject to changes in maintenance, profile shape, and weather. Future shoreline retreat is based on measured yearly averages multiplied by the prediction period. Four prediction periods were chosen (10, 15, 20 and 25 years) to correspond to the volume prediction time envelope, and the amount (length) of exposed seawall was computed (Figure 11). The higher the length of seawall exposed, the less beach is left. The results indicate that in about 10 years (2012) the most erosion-prone areas will begin to encroach on the seawall. After 15 years the seawall will become quickly exposed, and at 25 years more than half of the seawall will be exposed.

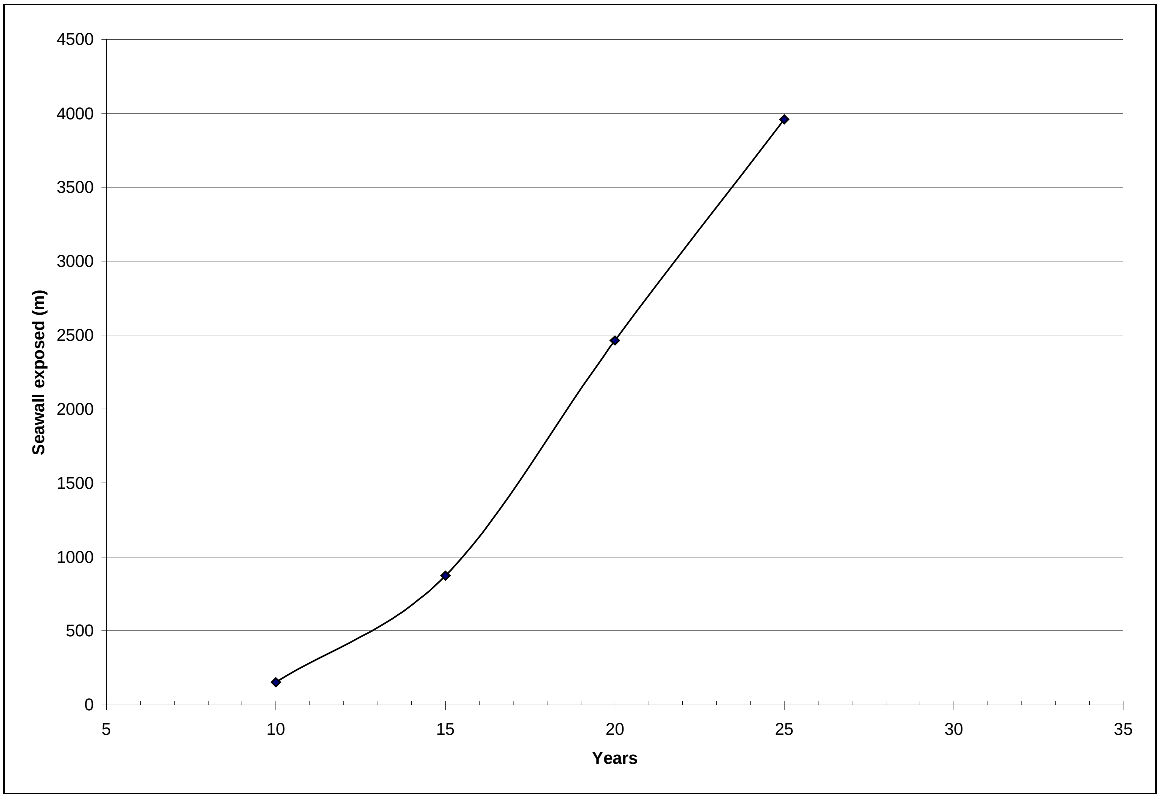

Figure 11. Extrapolated seawall exposure from 2007 to 2027.

Beach lifespan

The two independent data sets both suggest that the lifespan of the present beach is between 10 and 25 years. From a management standpoint the earlier date (2012) is the most important as it signals the beginning of a rapid change and loss of beach. The earliest point of seawall encroachment appears to be around eight years from present (2010), and should be considered as a point for planning a new renourishment.

These dates are based on the 'status quo' such that any planned beach scraping activities or local renourishments will change the beach's longevity and response. It is expected that planned beach scraping will prolong the beach's lifespan, especially if the areas of primary concern, the 'hot spots', are addressed; however, monitoring activities should be emphasized so that any ancillary problems can be addressed quickly.

Bay St. Louis Beach

Shoreline trends

The Downtown Bay St. Louis beach was renourished in 1996. Change from 1996 to 1999 (1998) was very rapid over most of the area, with about two thirds of the shoreline experiencing retreat of more than 4.5 m/yr (15 ft/yr). Some areas retreated over 30 m (100 ft) in three years. Clearly, these rates are not indicative of the present shoreline retreat processes and are the result of profiles achieving an equilibrium with the conditions. The dramatic rates of shoreline retreat, given the semi-protected location of Downtown Bay St. Louis beach, may be the result of using finer grained sediment in the renourishment than that used at Hancock County beach. Sediment for the Bay St. Louis renourishment came from a borrow pit just north of the Highway 90 bridge.

Given that the early data are highly influenced by the equilibrium process, later data sets, encompassing the years between 1999 and 2001, are used to highlight persistent areas of retreat that may affect the overall management of the beach in the future. The area of investigation is also expanded to include the shoreline up to the Bay-Waveland Yacht Club. The overall shoreline length is 2.5 km (1.3 mi); the renourished portion is 1.4 km and ends just north of the BSLN profile location.

Table 14. Bay St. Louis shoreline change

Total Shoreline (m)	4.5 to 9 m retreat (m)	> 9 m retreat (m)	> 4.5 m advance (m)
2500	908	126	74
Percentage %	36.3%	5.0%	3.0%

Table 15. Downtown Bay St. Louis shoreline change

Renourished Shoreline (m)	4.5 to 9 m retreat (m)	> 9 m retreat (m)	> 4.5 m advance (m)
1400	814	124	0
Percentage %	58.1%	8.9%	0.0%

About 40% of the beach (Table 14) is experiencing shoreline retreat beyond 2.25 m/yr (7.4 ft/yr). This is a high value considering that the beach had several years to adjust to conditions. About 90% of the retreat is occurring on the renourished portion of the beach, which is to be expected (Table 15). The renourished beach is in a higher energy regime and by definition has historically experienced higher retreat than the non-renourished portion to the north. This is highlighted by the fact that 98% of the high retreat (4.5 m/yr; 15 ft/yr) is on the renourished portion of the shoreline.

There are two apparent longshore drift directions; north of Highway 90, the longshore drift is toward the south, and south of Highway 90 the longshore drift is towards the north. Because more than two thirds of the renourished shoreline (Figure 12) is retreating, the entire shoreline could be considered a 'hot spot'. The northeastern portion, beyond the renourished area, is stable.

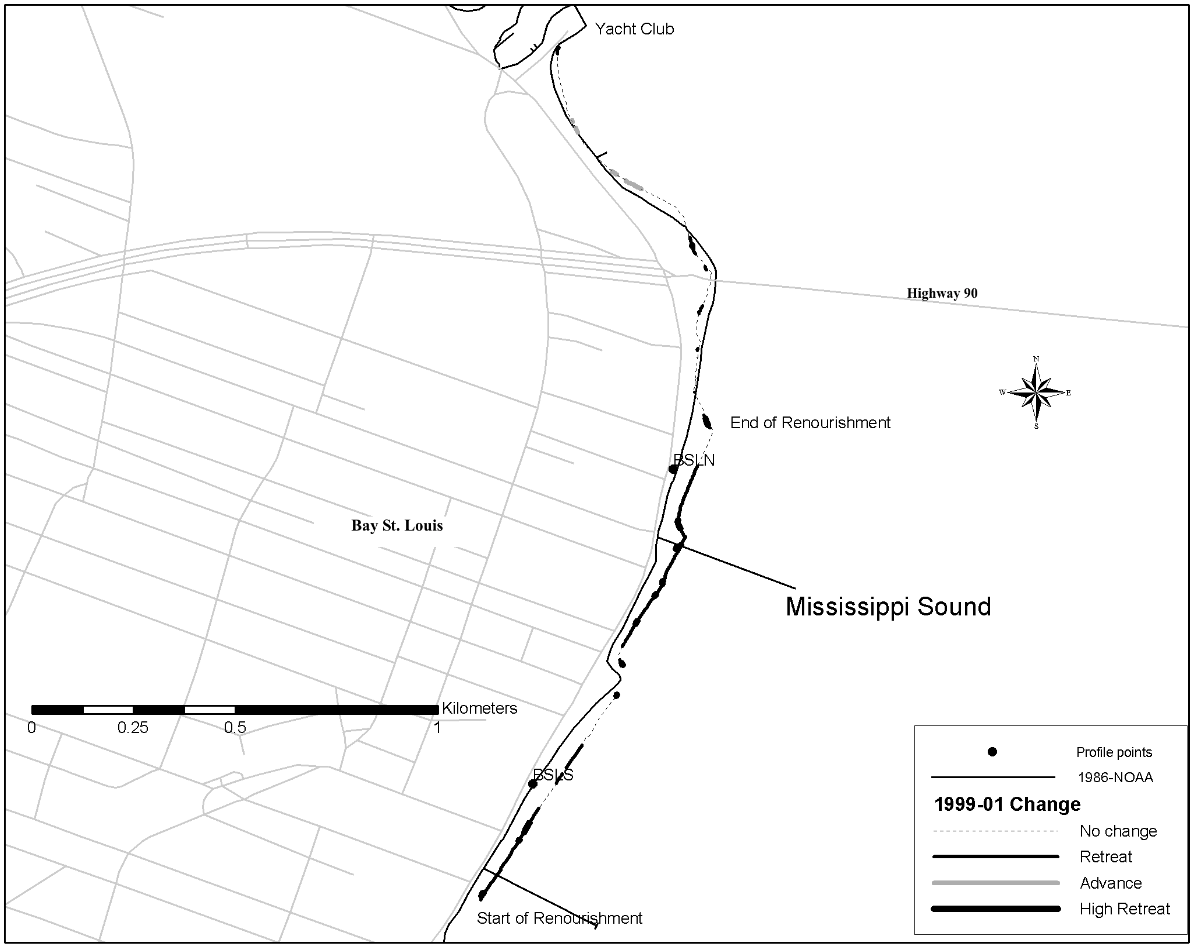

Figure 12. Shoreline change on Downtown Bay St. Louis beach.

Profile Data

Two profiles were established on the Downtown Bay St. Louis beach in 1999. The southern profile (BSLS; Appendix I) is located on a stable section of the beach and also shows no volume change over the two-year period. The northeastern profile (BSLN; Appendix I) is representative of areas with more than about 2 m/yr of shoreline change; it has lost 3.0 cubic yards/ft of beach per year. The total sand volume above the zero elevation at this profile is 28 cubic yards/ft. If the present rate of loss continues the lifespan of the beach at this location is about 10 years. Assuming that it is representative of the areas with 2 m/yr of retreat (58% of the renourished beach), 10 years (2012) is probably an optimistic estimation of the beach's useful lifespan, as much of it may be lost before that date.

Conclusions

Analysis of near-term and long-term data on the Hancock County beach and Downtown Bay St. Louis beach highlight the differences between the post renourishment adjustment period and the semi-equilibrium period. Long-term volume and shoreline change is dramatically higher because of the post renourishment period and should not be used to extrapolate future trends. The long-term change does, however, highlight areas with the highest energies and propensity for change.

Near-term change is a more useful indicator of conditions that will exist in the future, if the system remains unchanged. Total volume change and shoreline retreat are significantly lower during the near-term period. In general, the Hancock County beach is fairly stable in the near-term. There are specific areas, however, that do require more attention, and thus represent the most important areas to monitor in the overall stability of the beach (Balsillie and Clark, 2001). These areas are more costly to deal with and may hasten the need to renourish.

The Downtown Bay St. Louis beach is experiencing higher retreat than the County beach. The northeastern, natural portion is probably receiving sediment from the renourished beach and as such is stable.

Based on the data gathered and presented the following conclusions can be made about the beaches in Hancock County:

1) Long-term shoreline change (1994 to 2000) averaged about 1.5 m/yr over the Hancock County beach; 60% of the beach displayed more than 1.5 m/yr of shoreline retreat. Near-term change was about half as much as long-term change and is slightly higher than change levels on the Harrison County beach.

2) The highest areas of shoreline change occurred on the northeastern portion of the Hancock County beach. Shoreline retreat appears to show some dependency on shoreline angle on the northeastern half of the County beach. Specific open culverts appear to be influencing shoreline retreat, but culverts in general did not appear to be concentrating retreat.

3) The Hancock County beach system from the seawall to the edge of the nearshore platform (-4 ft) loses about 7,000 cubic yards/year based on the average of long-term and short term change. The subaerial beach system (above mean low tide) loses about 27,000 cubic yards/year. Thus, there are about 20,000 cubic yards/year moved from the dry beach to

the nearshore platform where it either creates a wider platform or a thicker one. The existence of the extensive nearshore platform is a factor in the general stability of the beach, especially in the near-term once the profiles had adjusted.

4) Given the present (near-term) rates of shoreline and profile volume change, the Hancock County beach will need to be renourished in approximately 10 years (2012) if no alternate activities are planned.

5) The renourished Downtown Bay St. Louis beach is retreating more rapidly than the County beach. The northeastern portion, however, is stable. Ten years (2012) is an optimistic estimate of the useful lifespan for the renourished part of the beach should it continue to evolve at present rates. Some portions of this beach have lost more than 35 m (115 ft) since being renourished.

Data

This report is meant to be an overview; more localized study and analysis can be done upon request. The data gathered from 1993 to present are available from the Mississippi Office of Geology.

Acknowledgments

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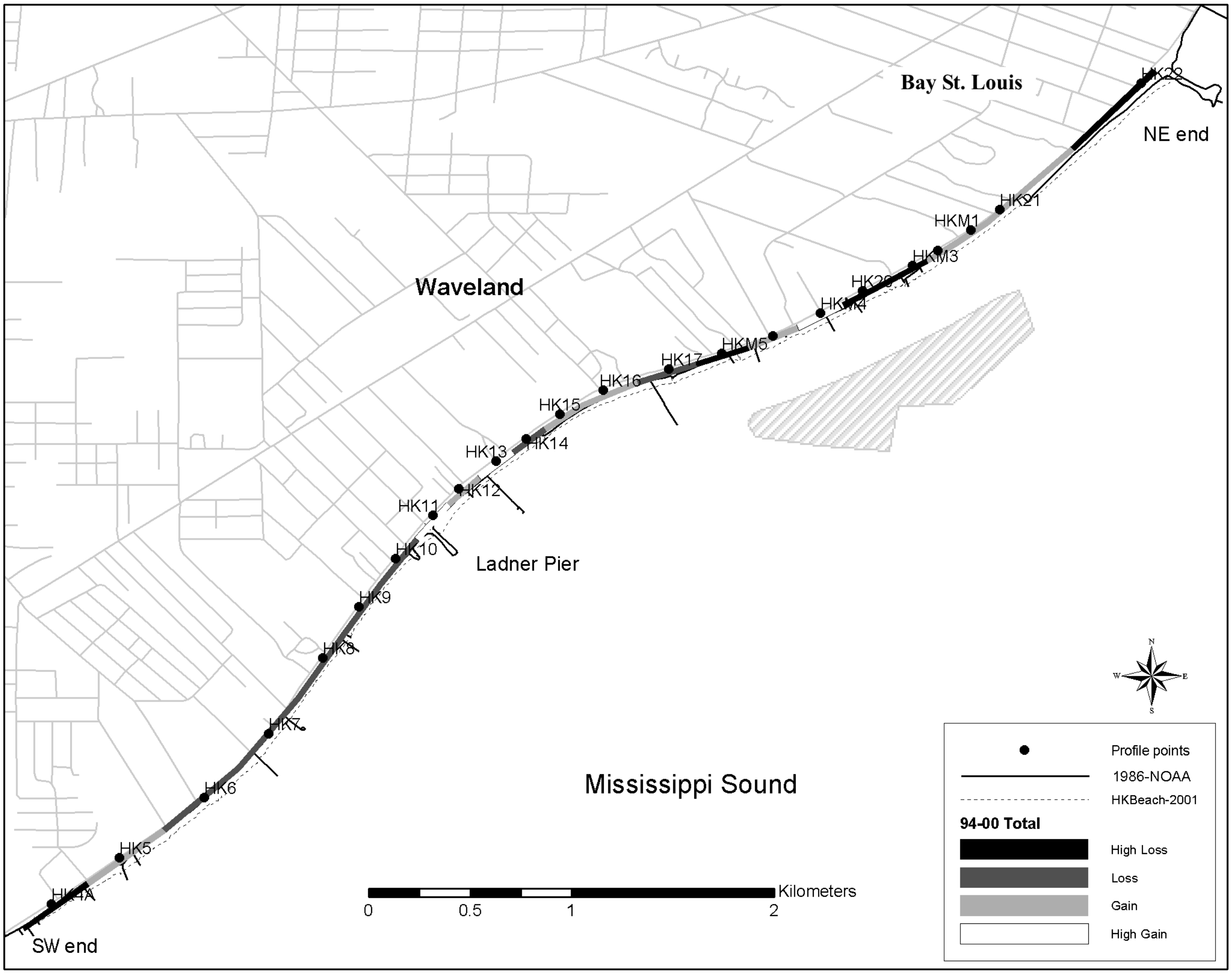
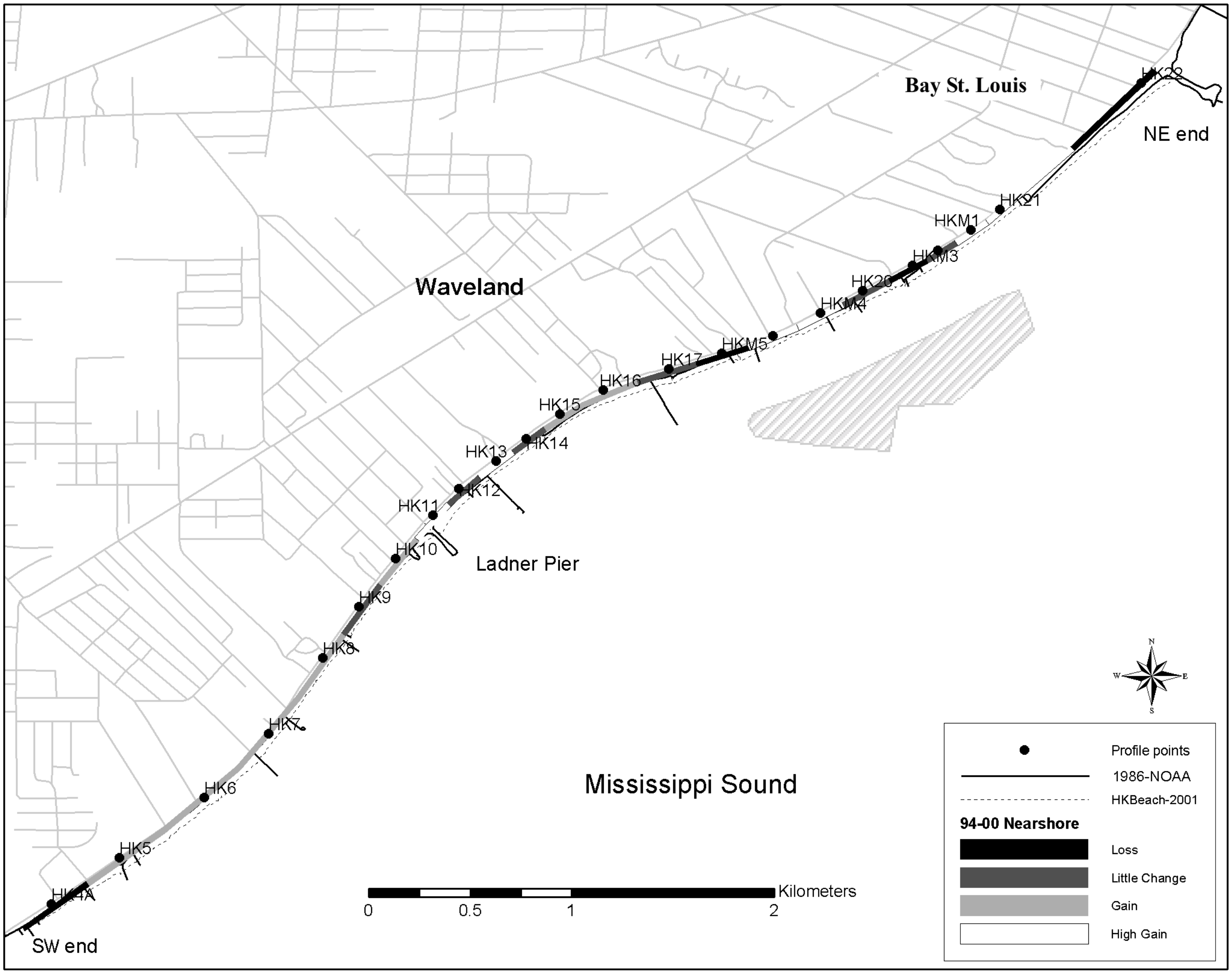
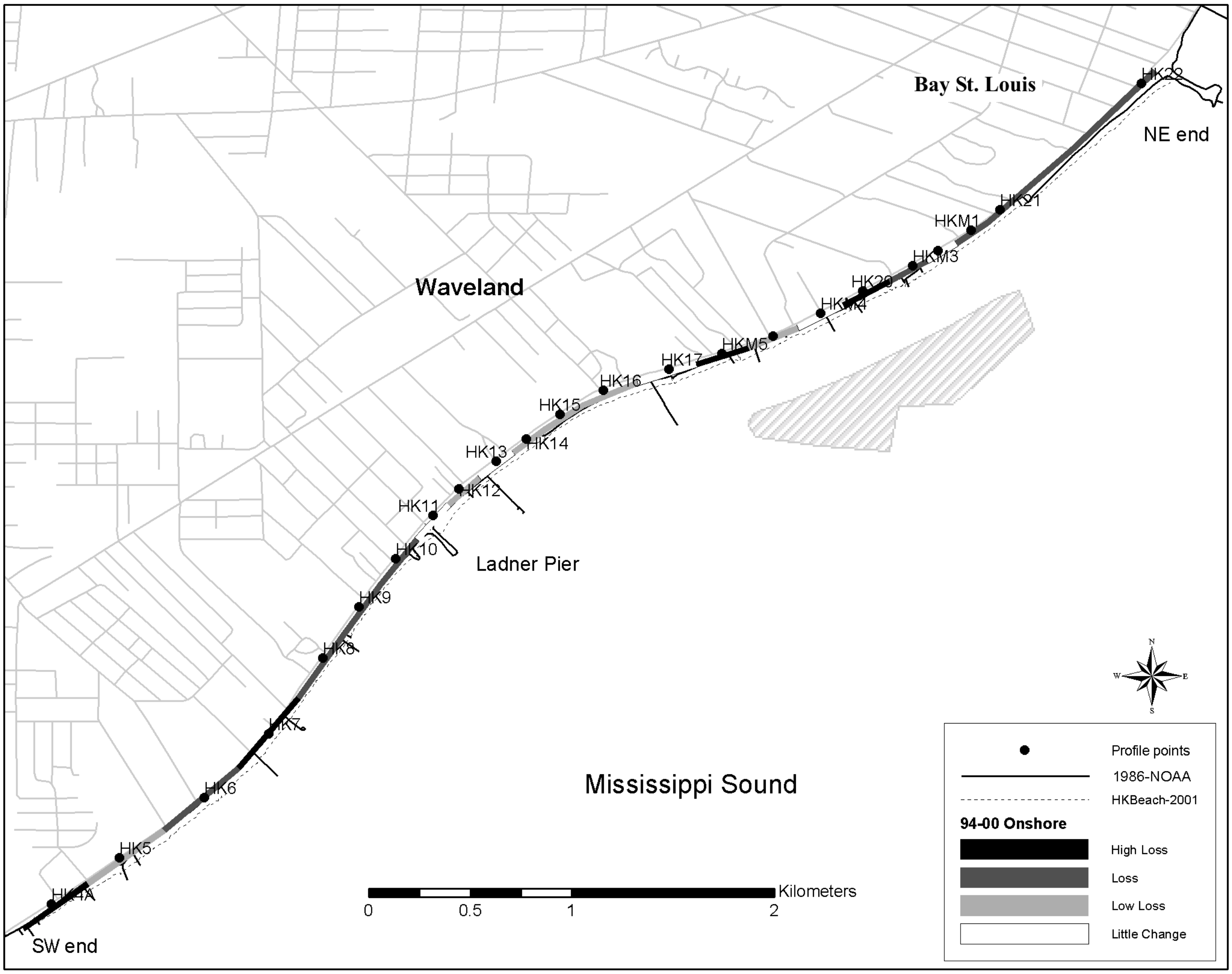
Maps



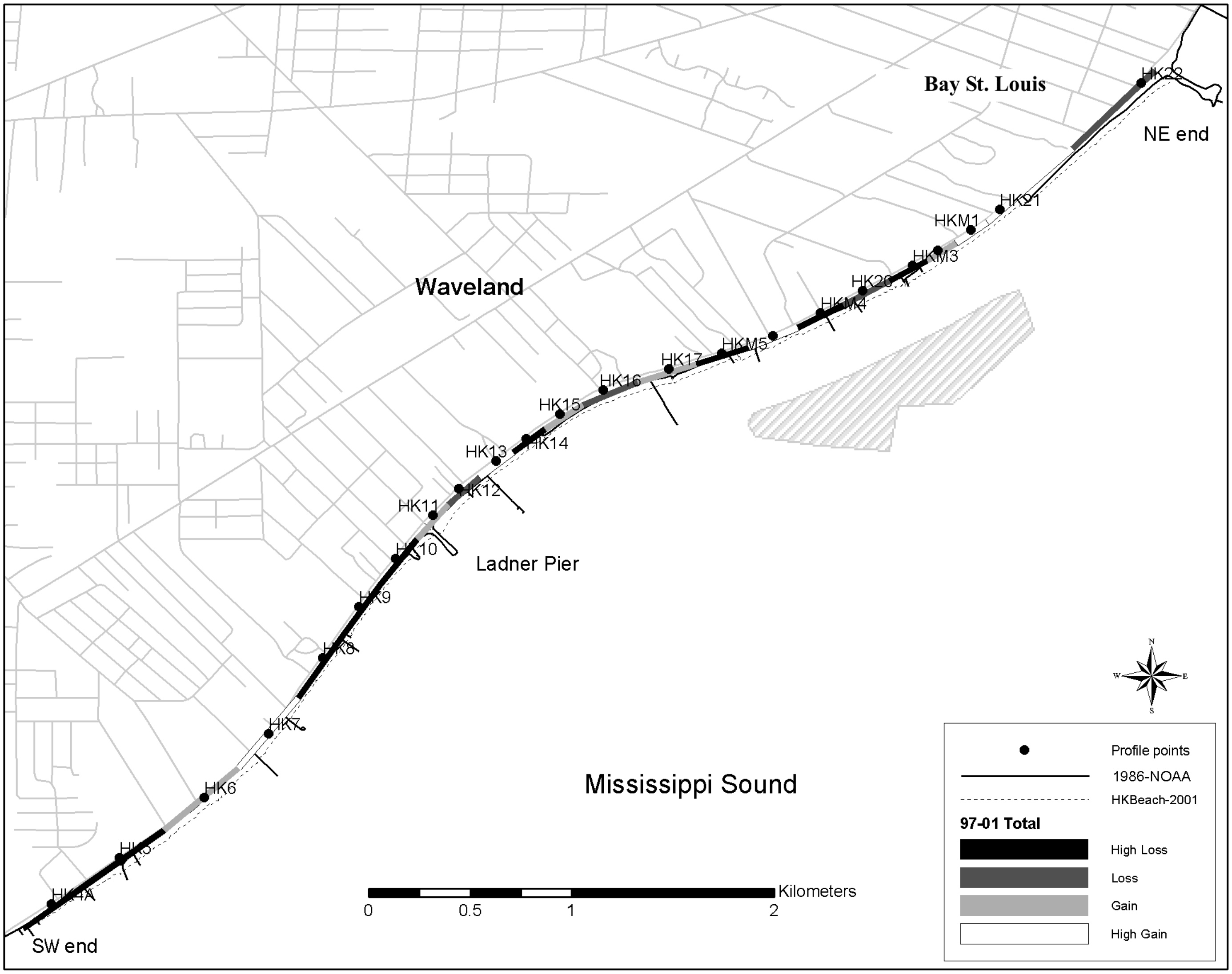
Map 1. 1994 to 2000 total profile volume change.



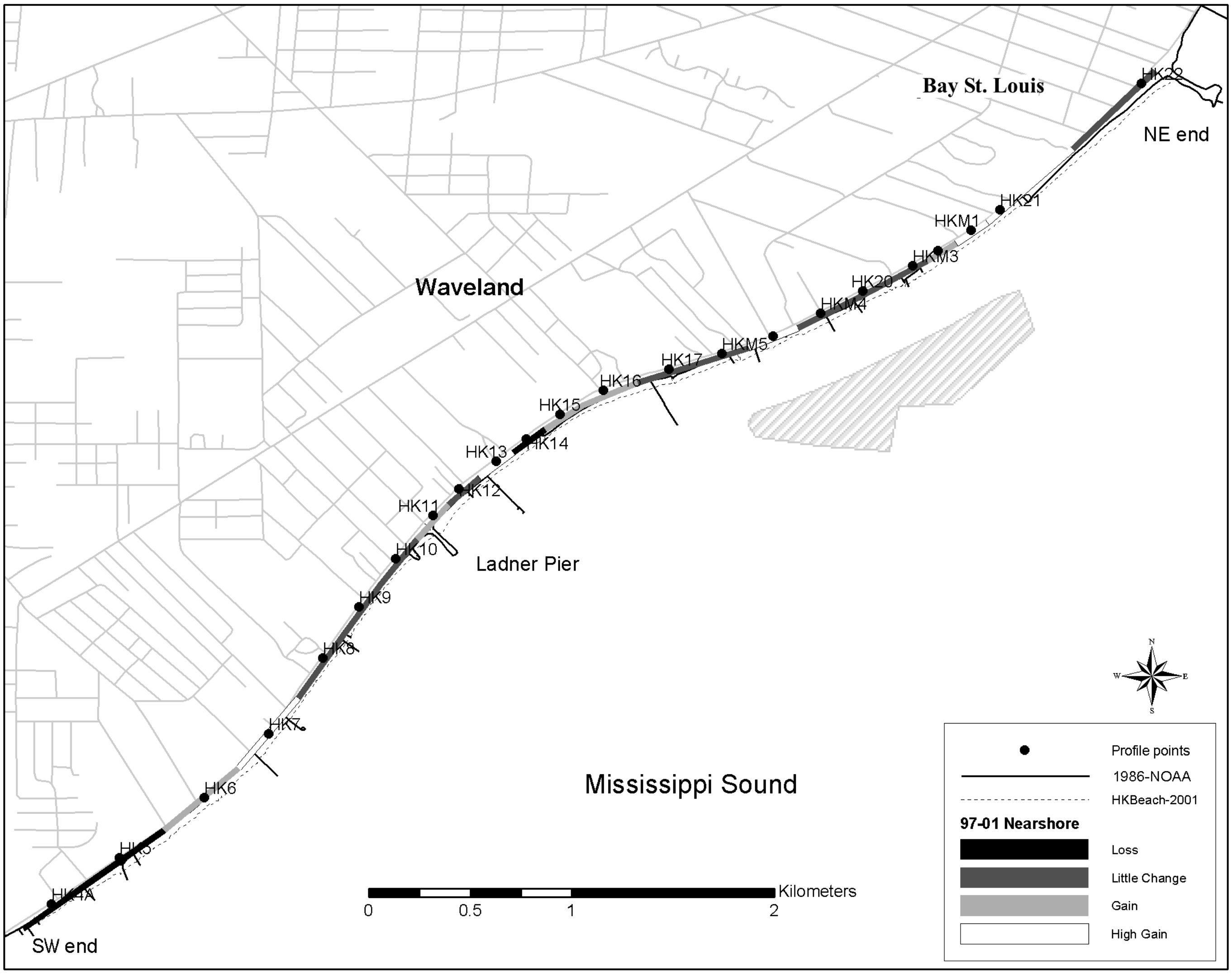
Map 2. 1994 to 2000 nearshore volume change.



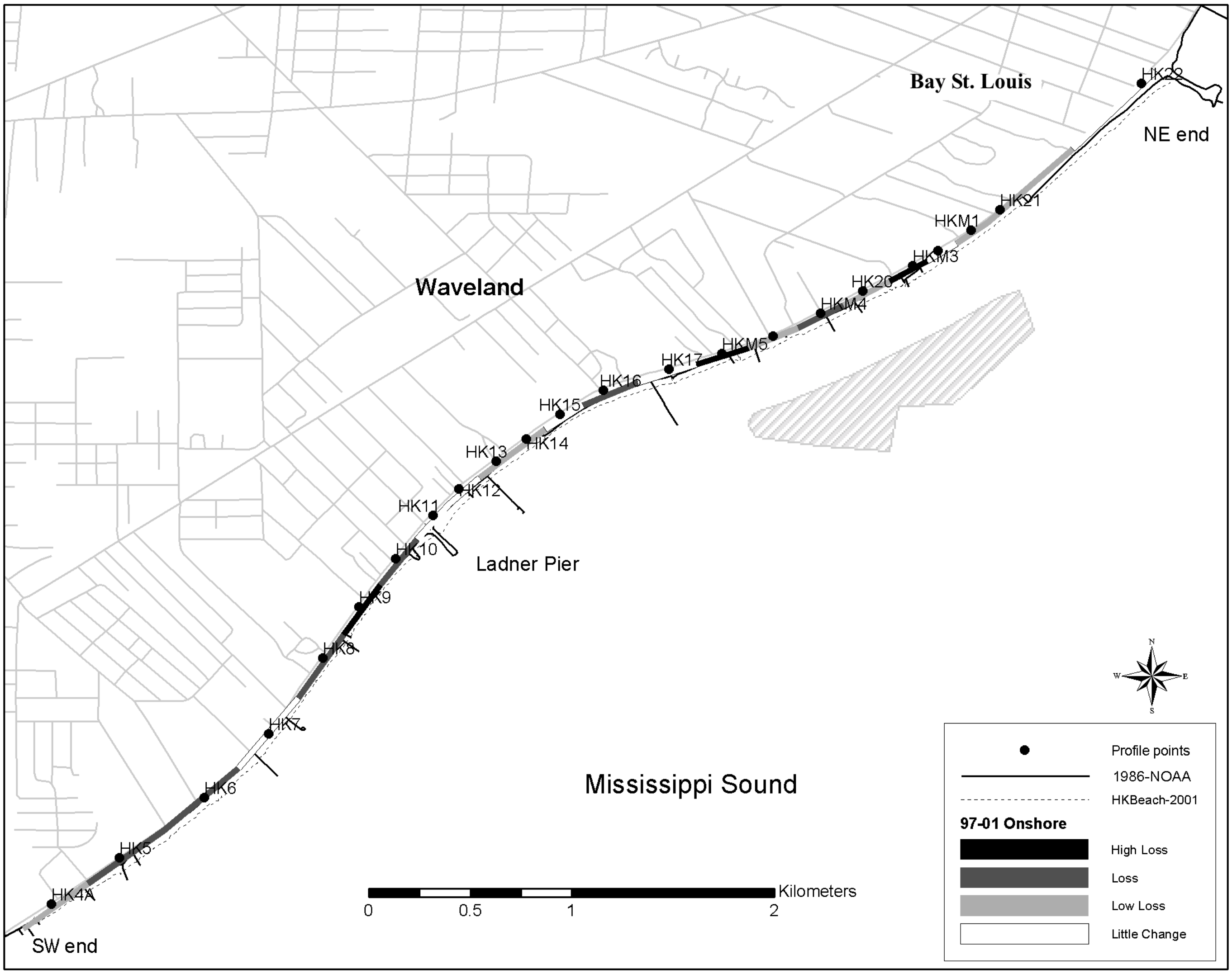
Map 3. 1994 to 2000 onshore volume change.



Map 4. 1997 to 2001 total volume change.

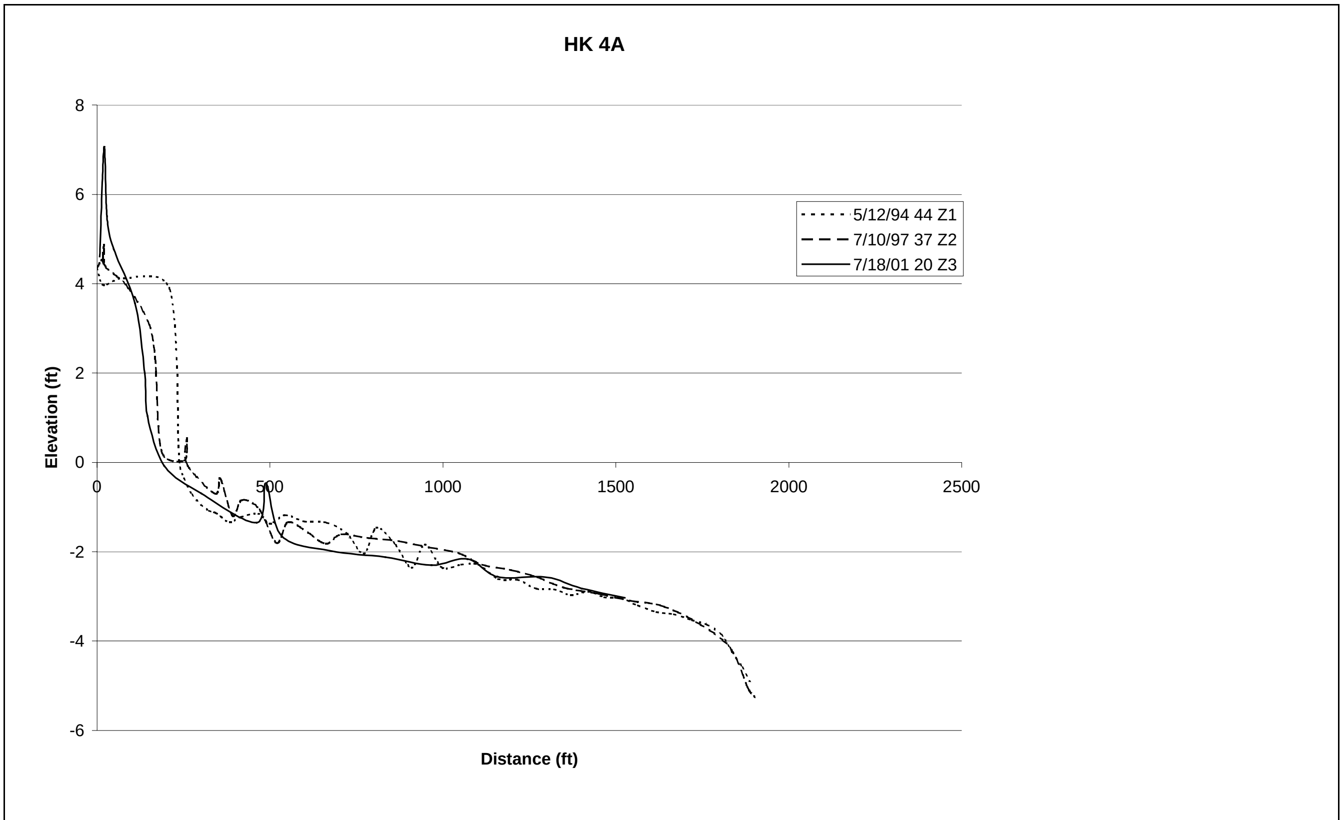


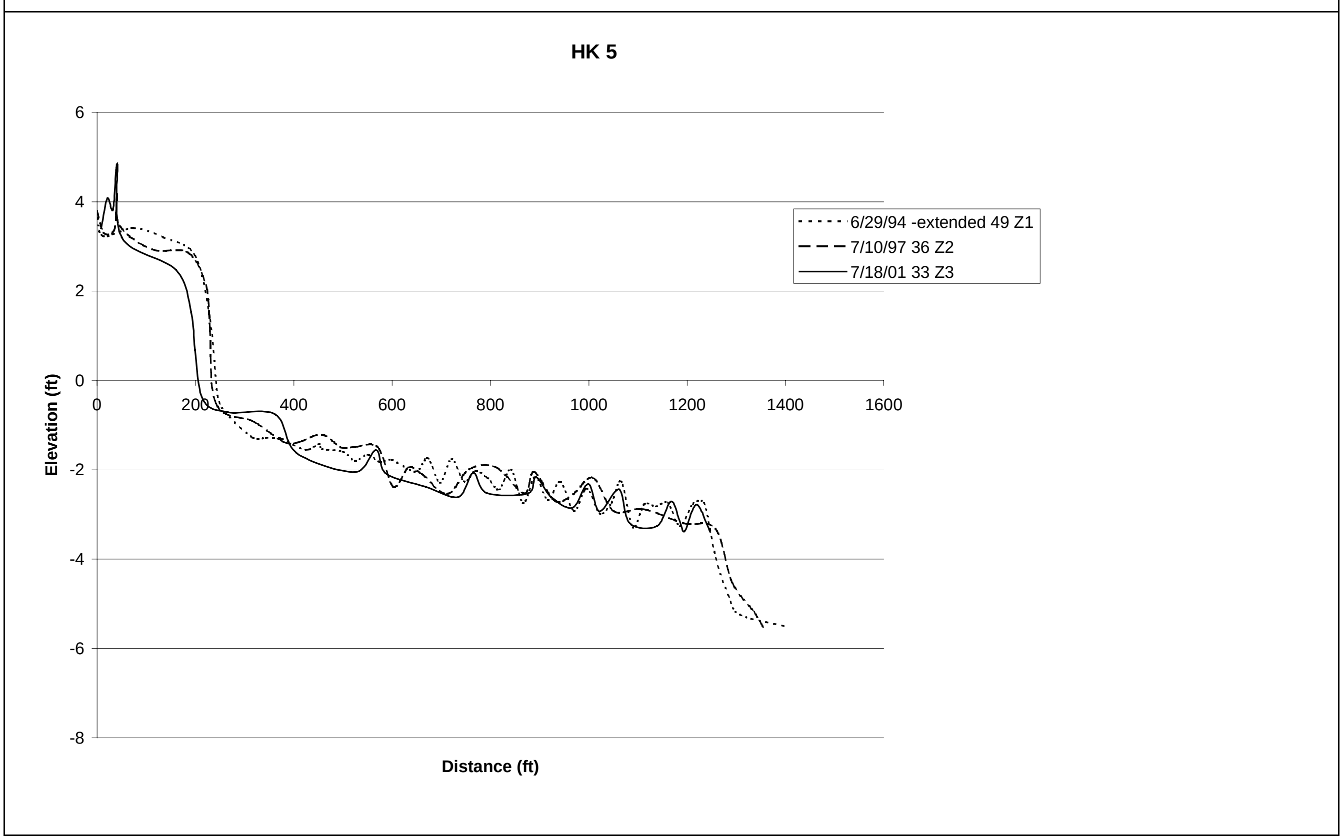
Map 5. 1997 to 2001 nearshore volume change.

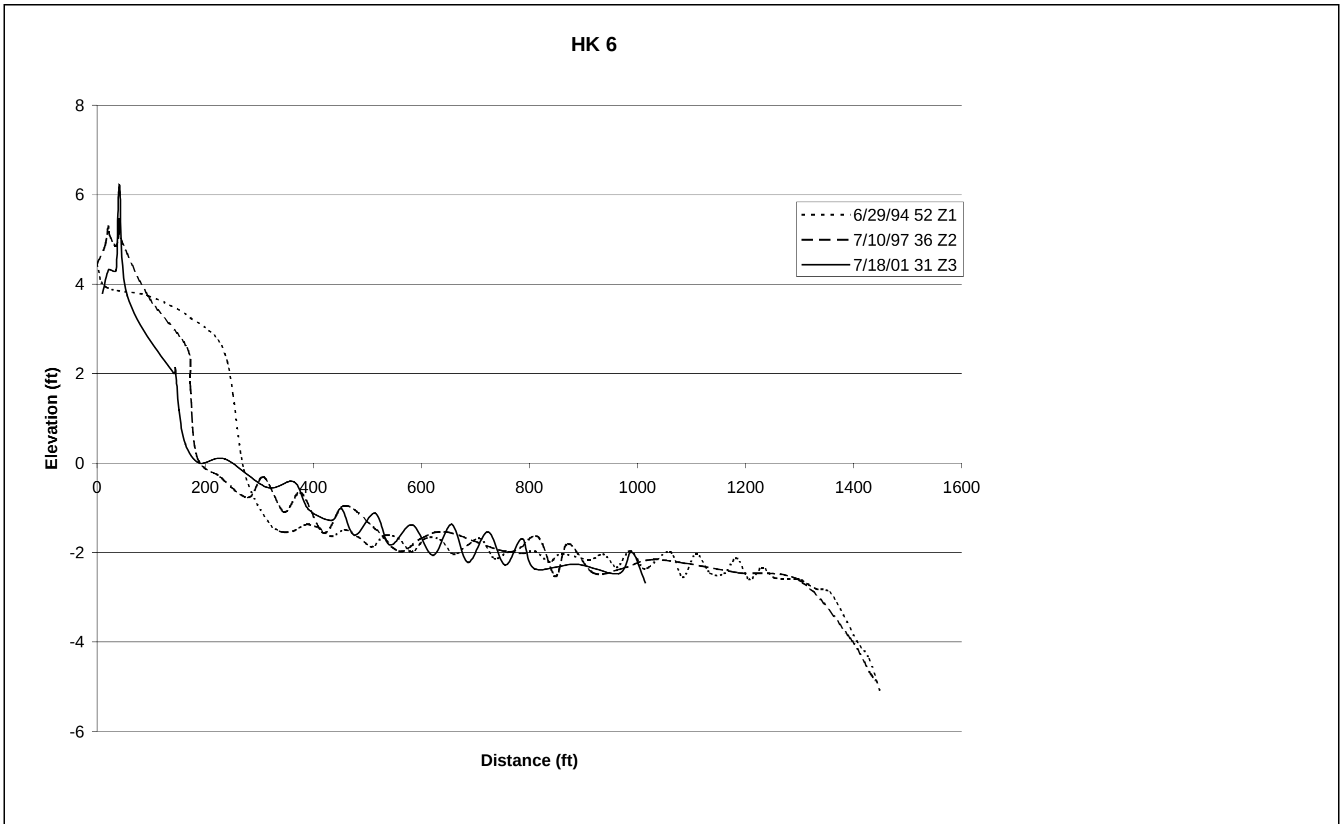


Map 6. 1997 to 2001 onshore volume change.

Appendix I. Profiles



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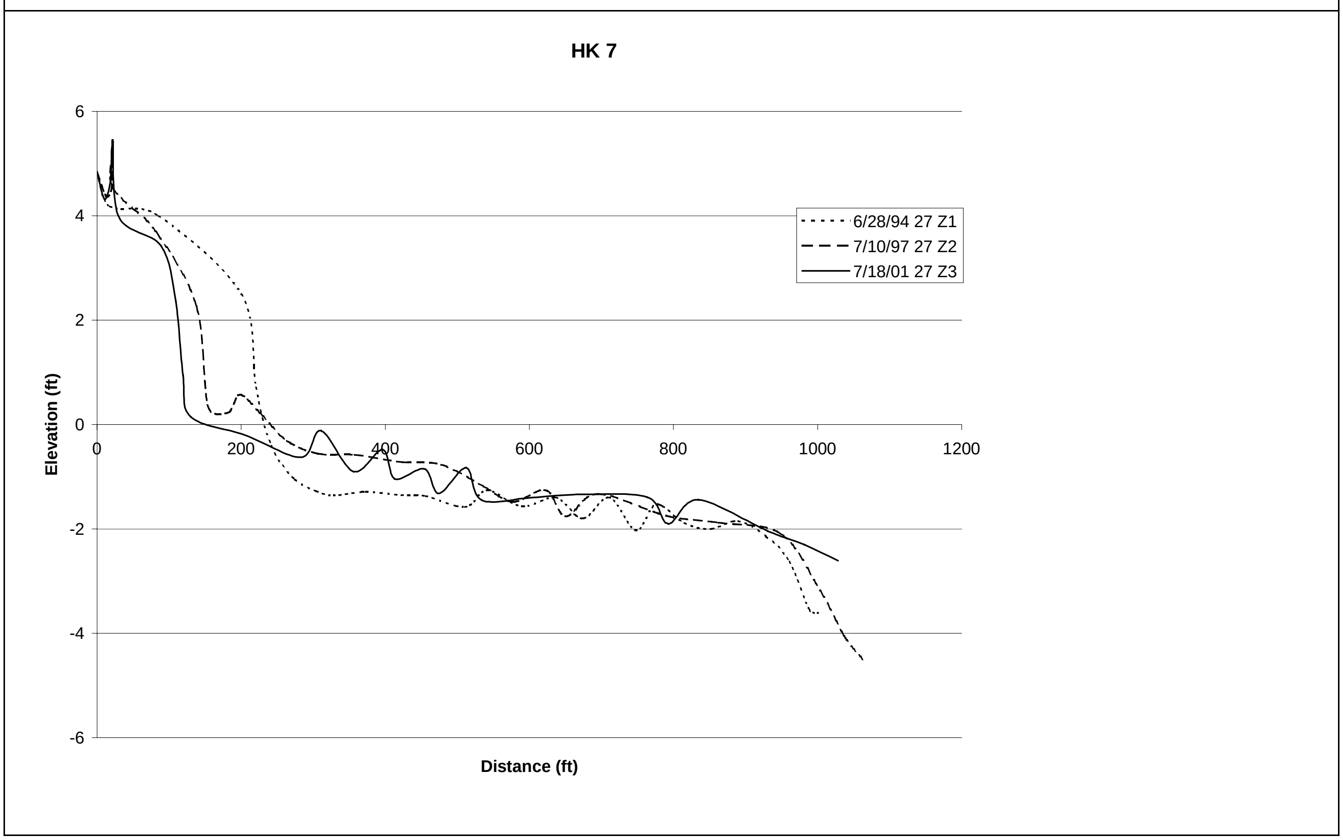
6
4
2
0
-2
-4
-6
Elevation (ft)
0
200
400
600
800
1000
1200
1400
1600
Distance (ft)
6/29/94 52 Z1
7/10/97 36 Z2
7/18/01 31 Z3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-2
-4
-6
Elevation (ft)
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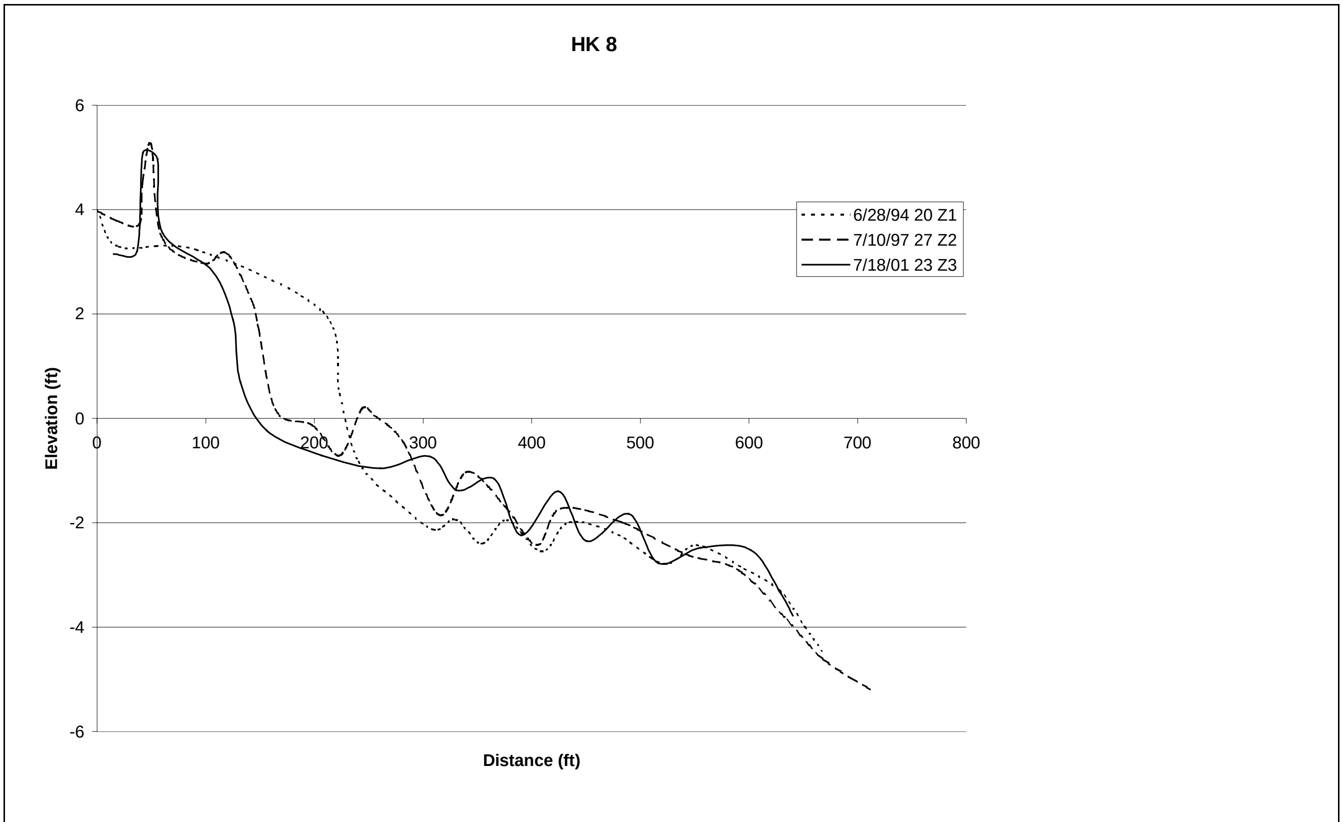
600
800
1000
1200
Distance (ft)
6/28/94 27 Z1
7/10/97 27 Z2
7/18/01 27 Z3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Elevation (ft)
Distance (ft)
6/28/94 20 Z1
7/10/97 27 Z2
7/18/01 23 Z3
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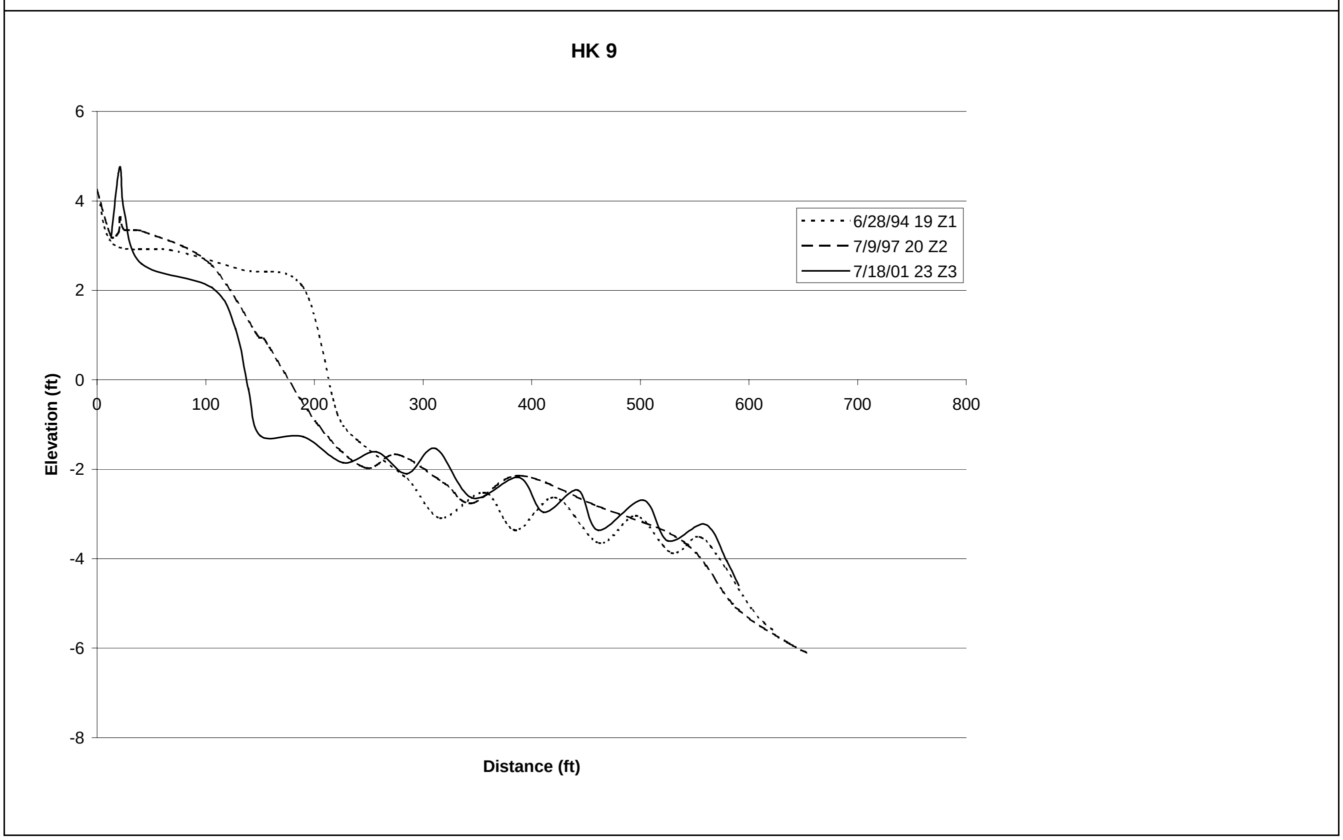
-2
-4
-6
0
100
200
300
400
500
600
700
800


HK 9
Elevation (ft)
Distance (ft)
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7/9/97 20 Z2
7/18/01 23 Z3
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-6
-8
0
100
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500
600
700
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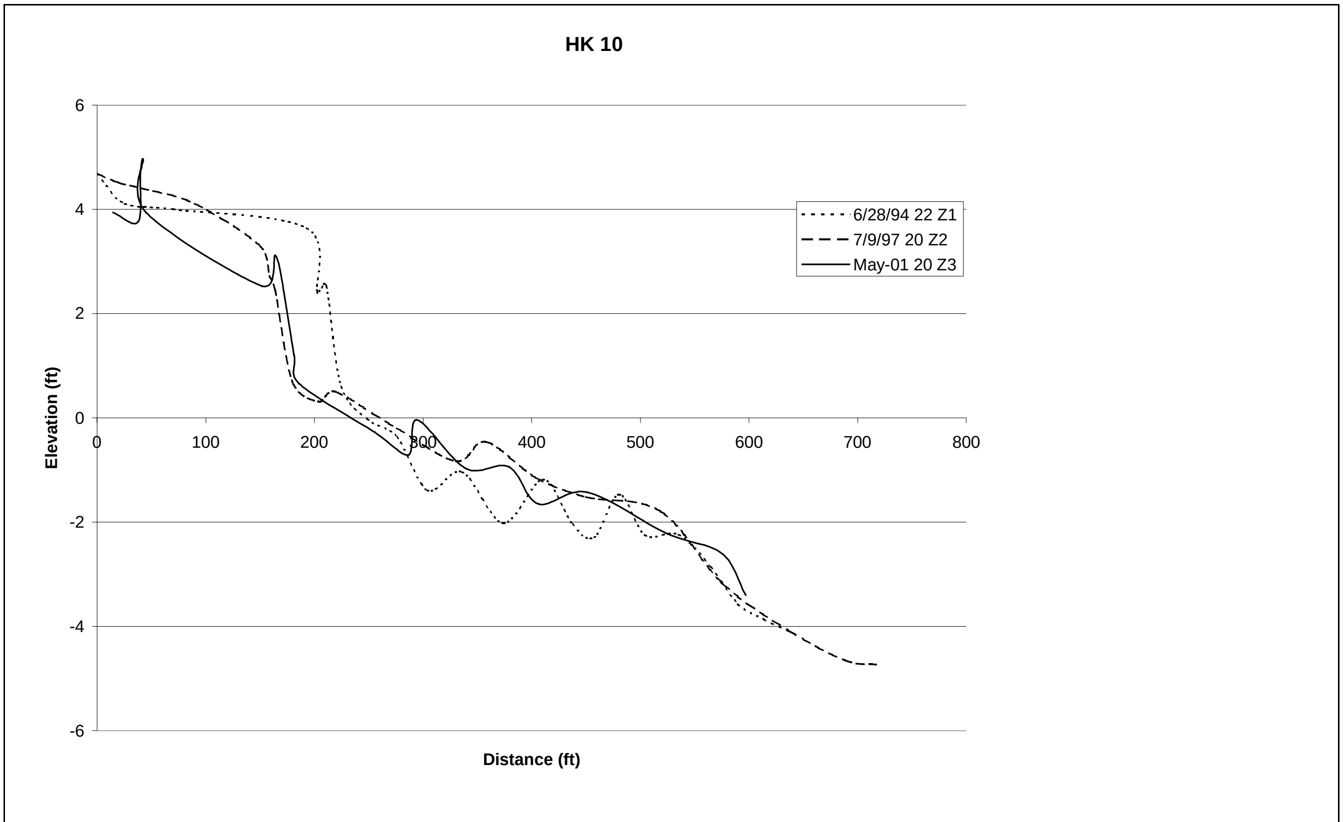
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Elevation (ft)
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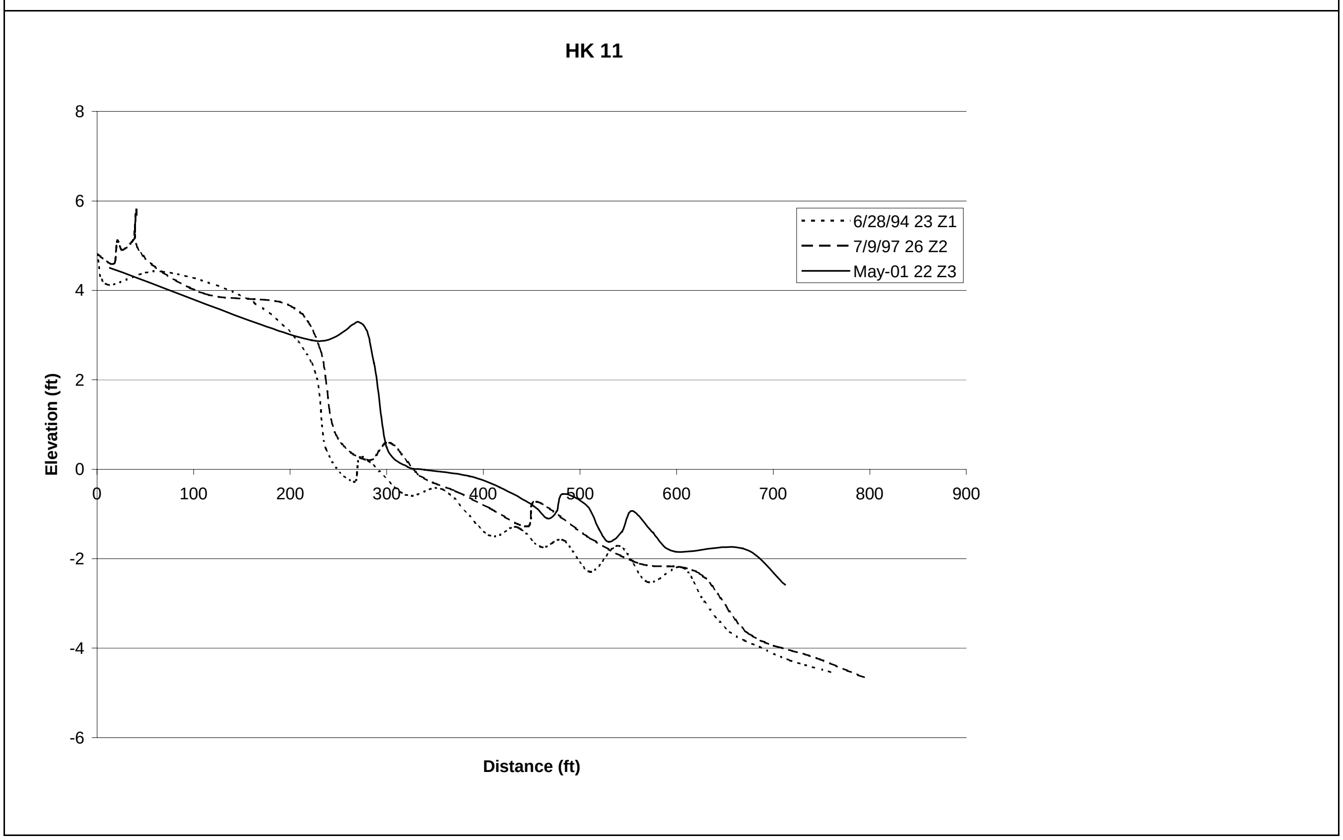
Distance (ft)
6/28/94 22 Z1
7/9/97 20 Z2
May-01 20 Z3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Elevation (ft)
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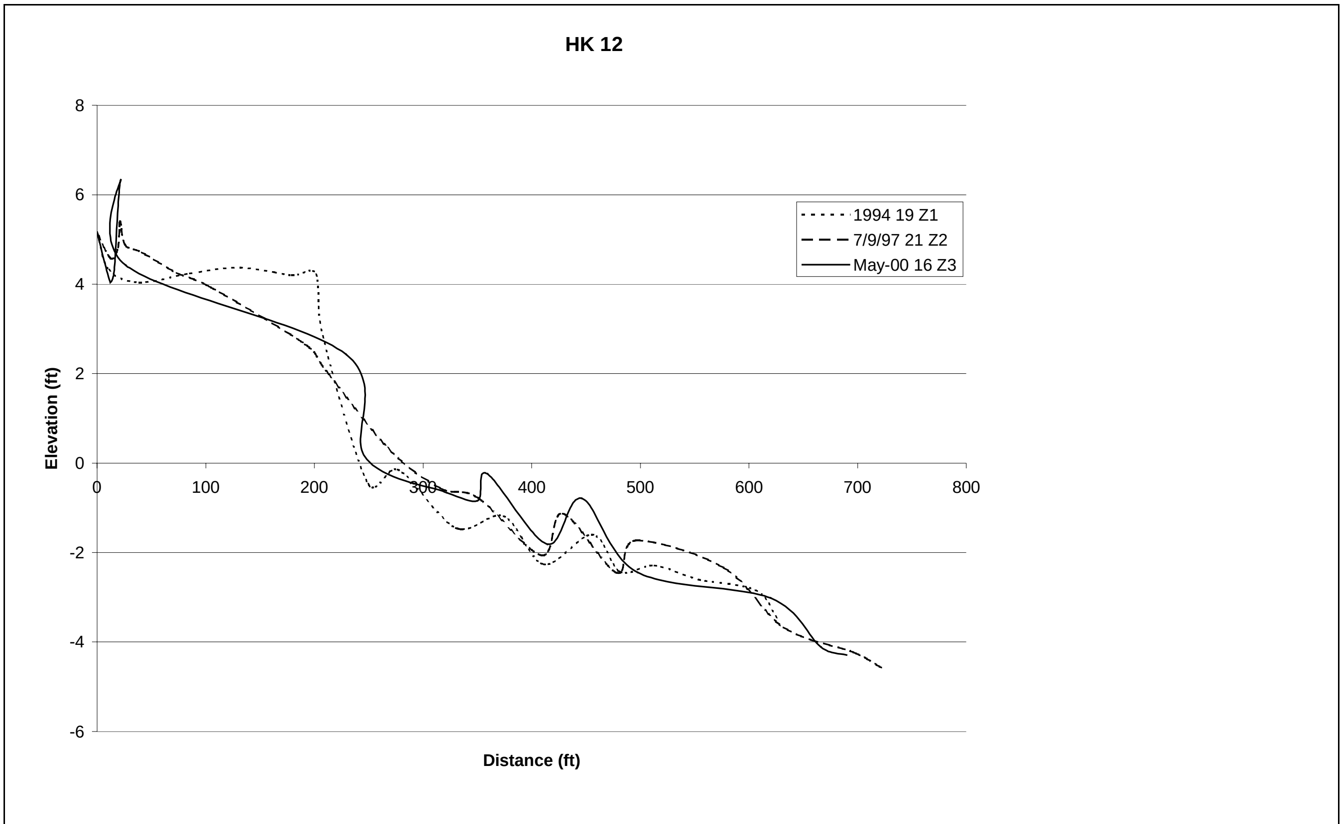
900
Distance (ft)
6/28/94 23 Z1
7/9/97 26 Z2
May-01 22 Z3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6
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-2
-4
-6
Elevation (ft)
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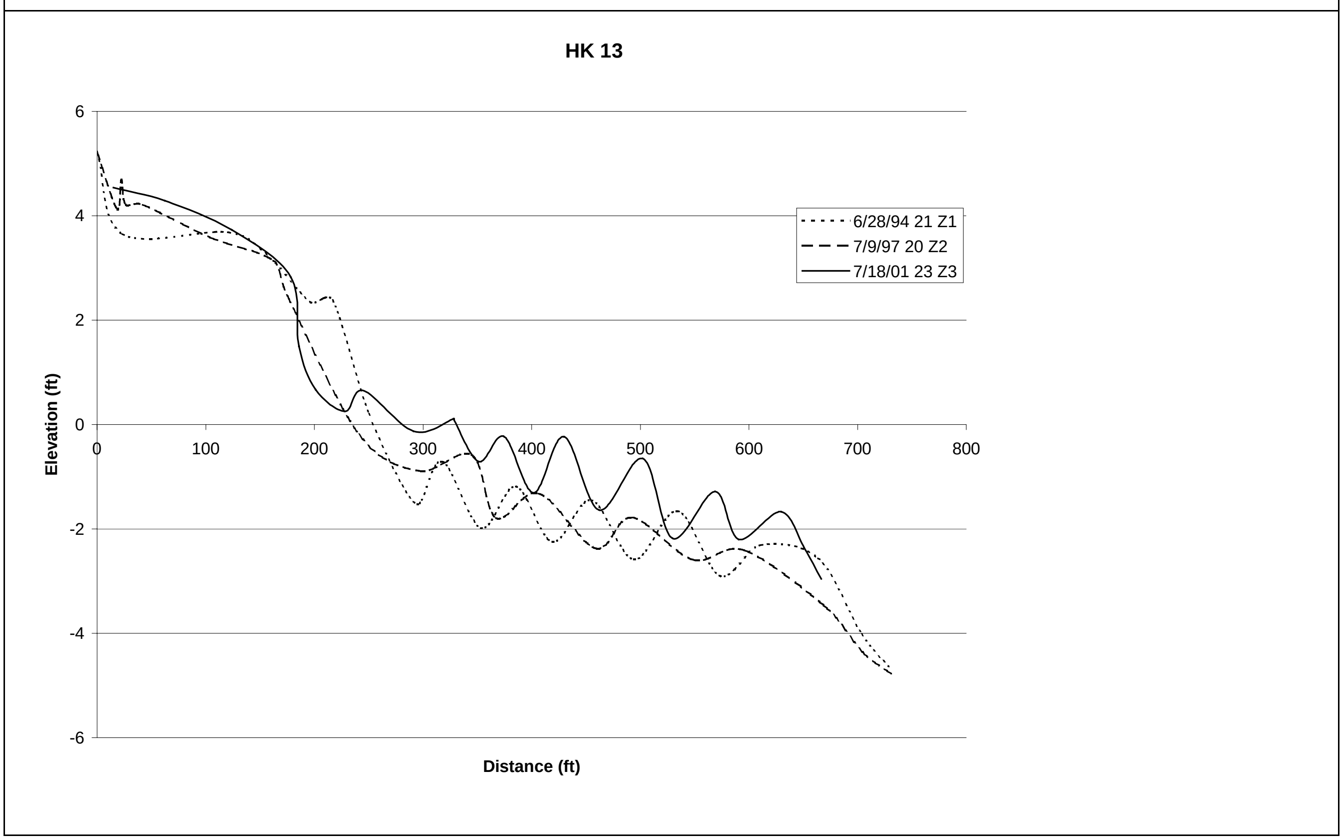
200
300
400
500
600
700
800
Distance (ft)
1994 19 Z1
7/9/97 21 Z2
May-00 16 Z3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-2
-4
-6
Elevation (ft)
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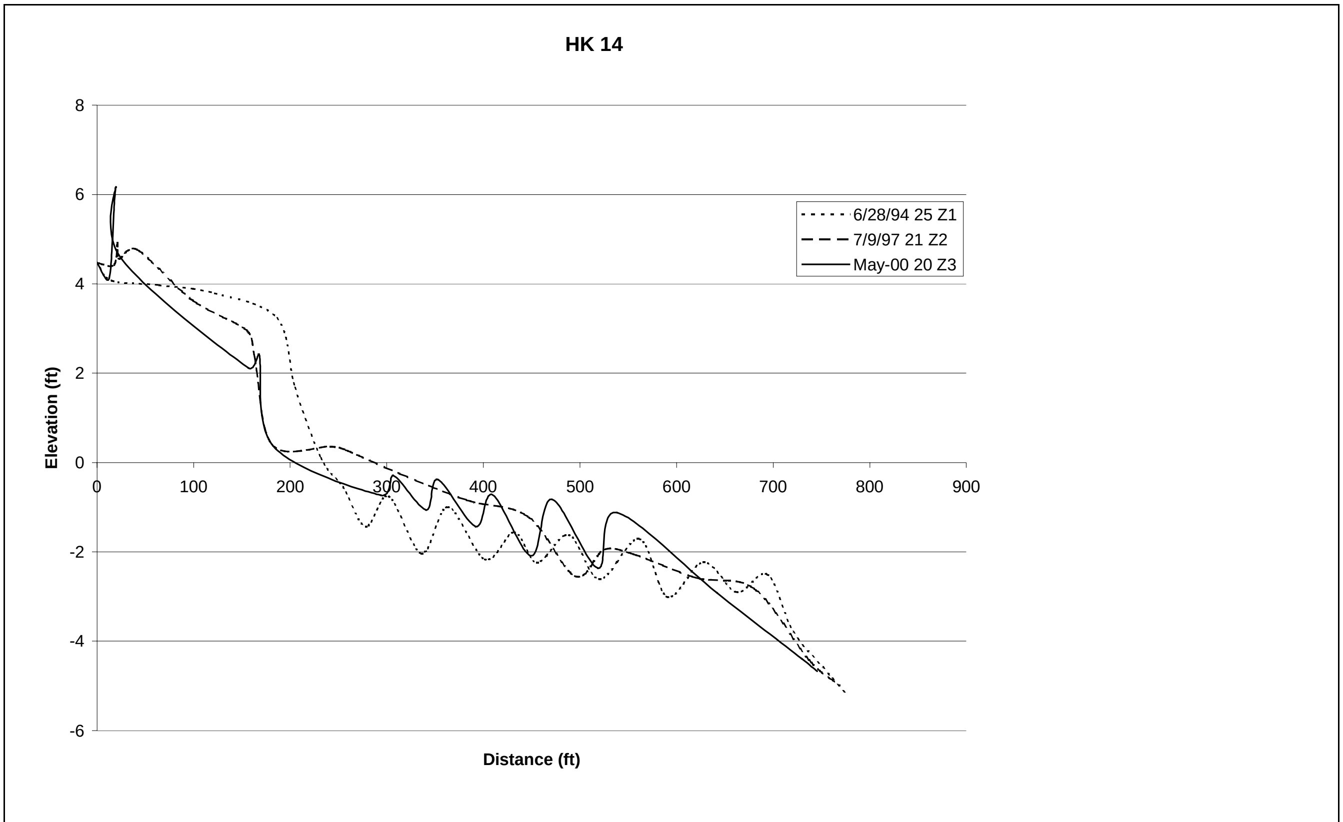
100
200
300
400
500
600
700
800
Distance (ft)
6/28/94 21 Z1
7/9/97 20 Z2
7/18/01 23 Z3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Elevation (ft)
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600
700
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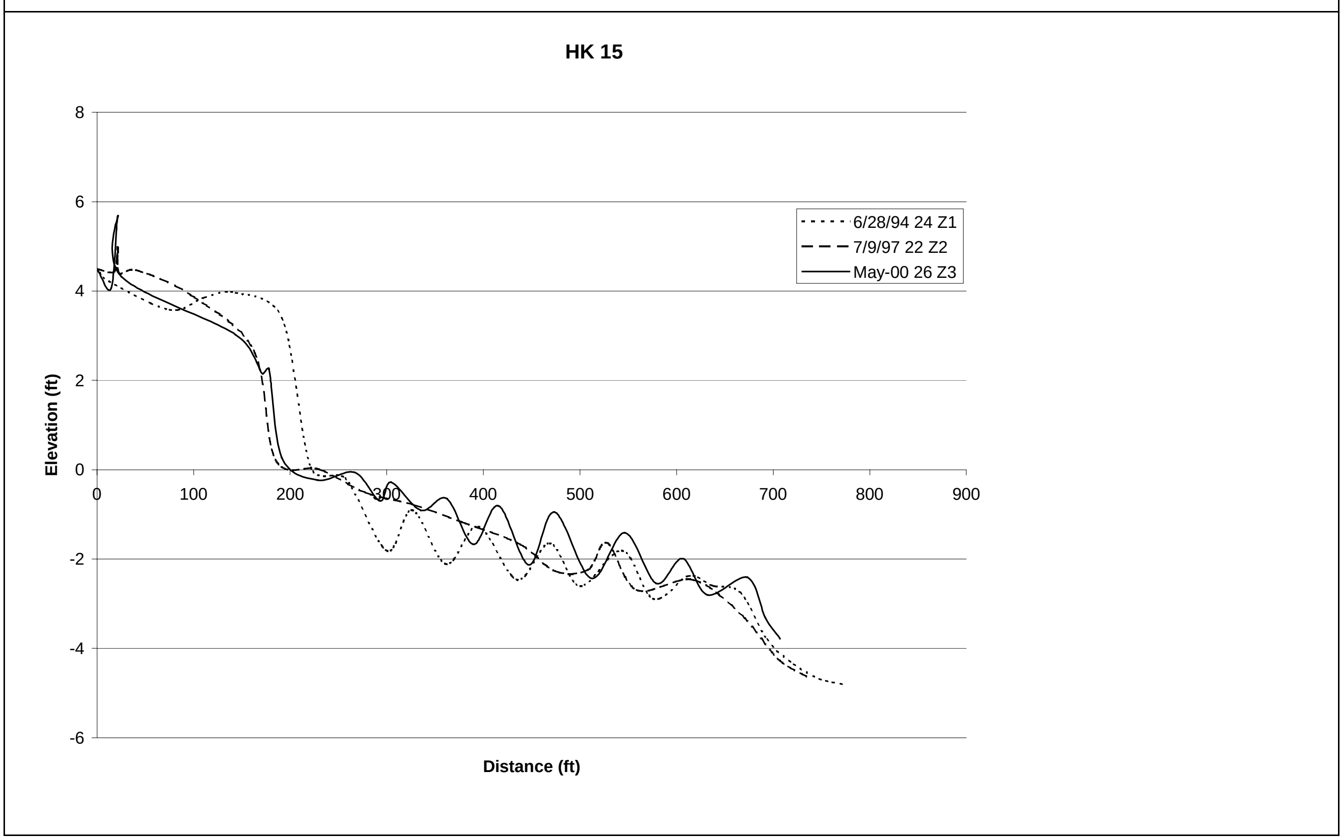
900
Distance (ft)
6/28/94 25 Z1
7/9/97 21 Z2
May-00 20 Z3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-2
-4
-6
Elevation (ft)
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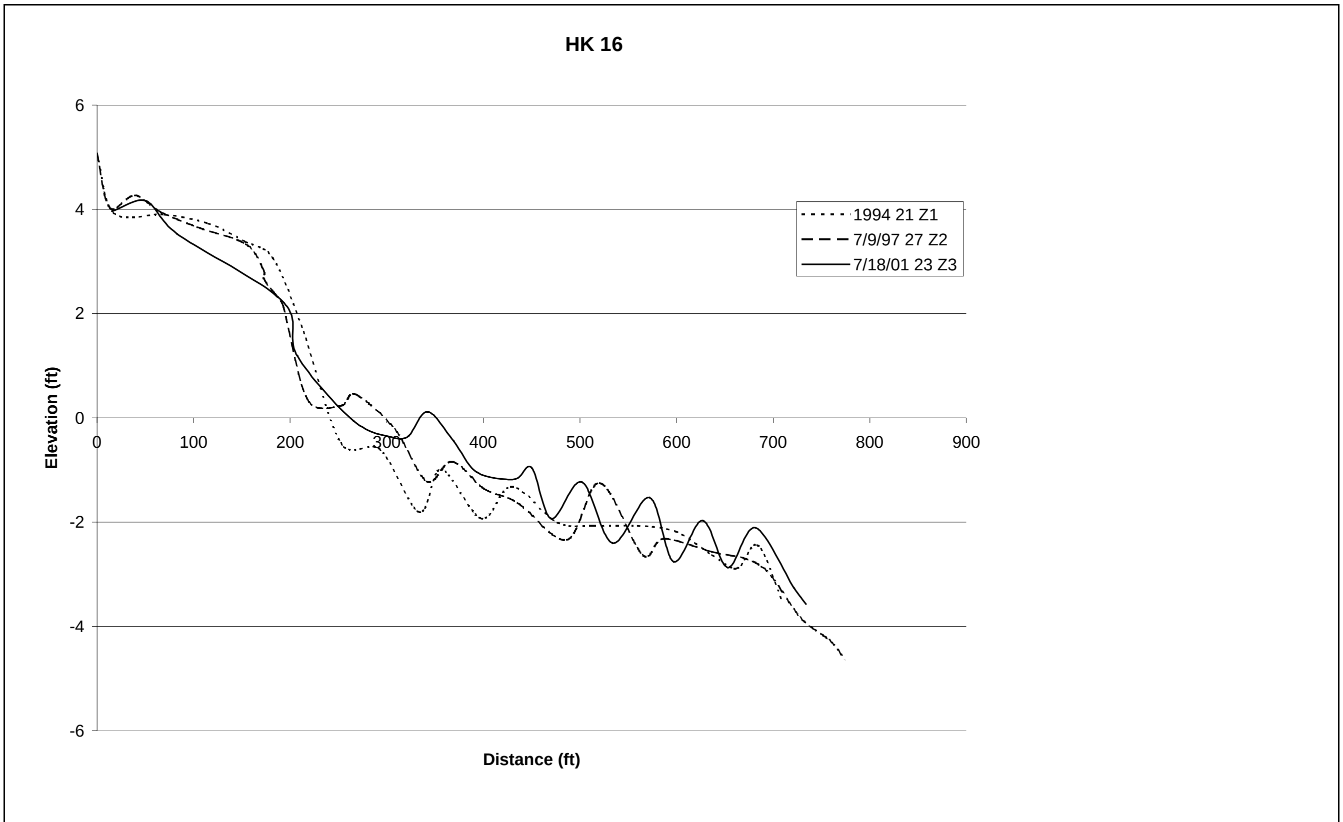
400
500
600
700
800
900
Distance (ft)
6/28/94 24 Z1
7/9/97 22 Z2
May-00 26 Z3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Elevation (ft)
Distance (ft)
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0
-2
-4
-6
0
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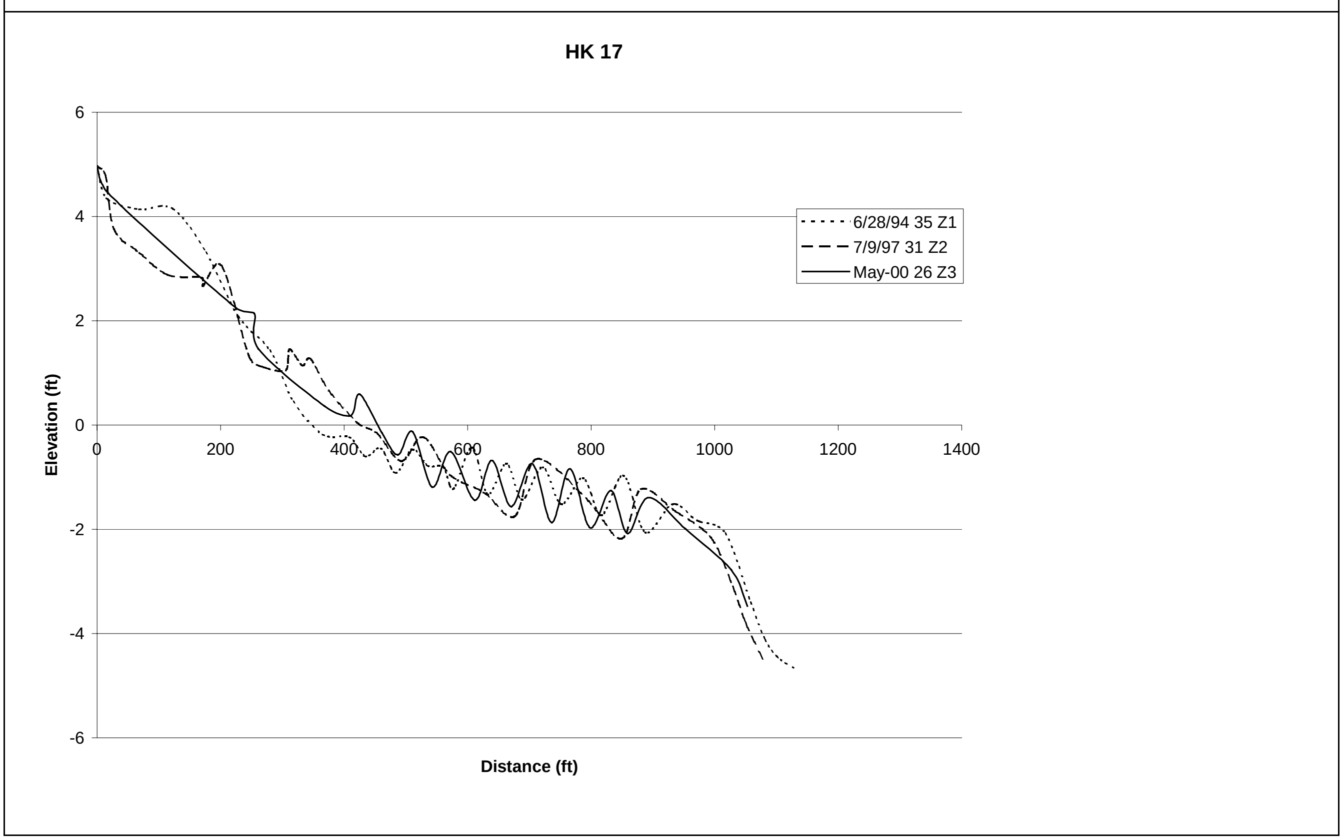
200
300
400
500
600
700
800
900
1994 21 Z1
7/9/97 27 Z2
7/18/01 23 Z3


HK 17
Elevation (ft)
Distance (ft)
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2
0
-2
-4
-6
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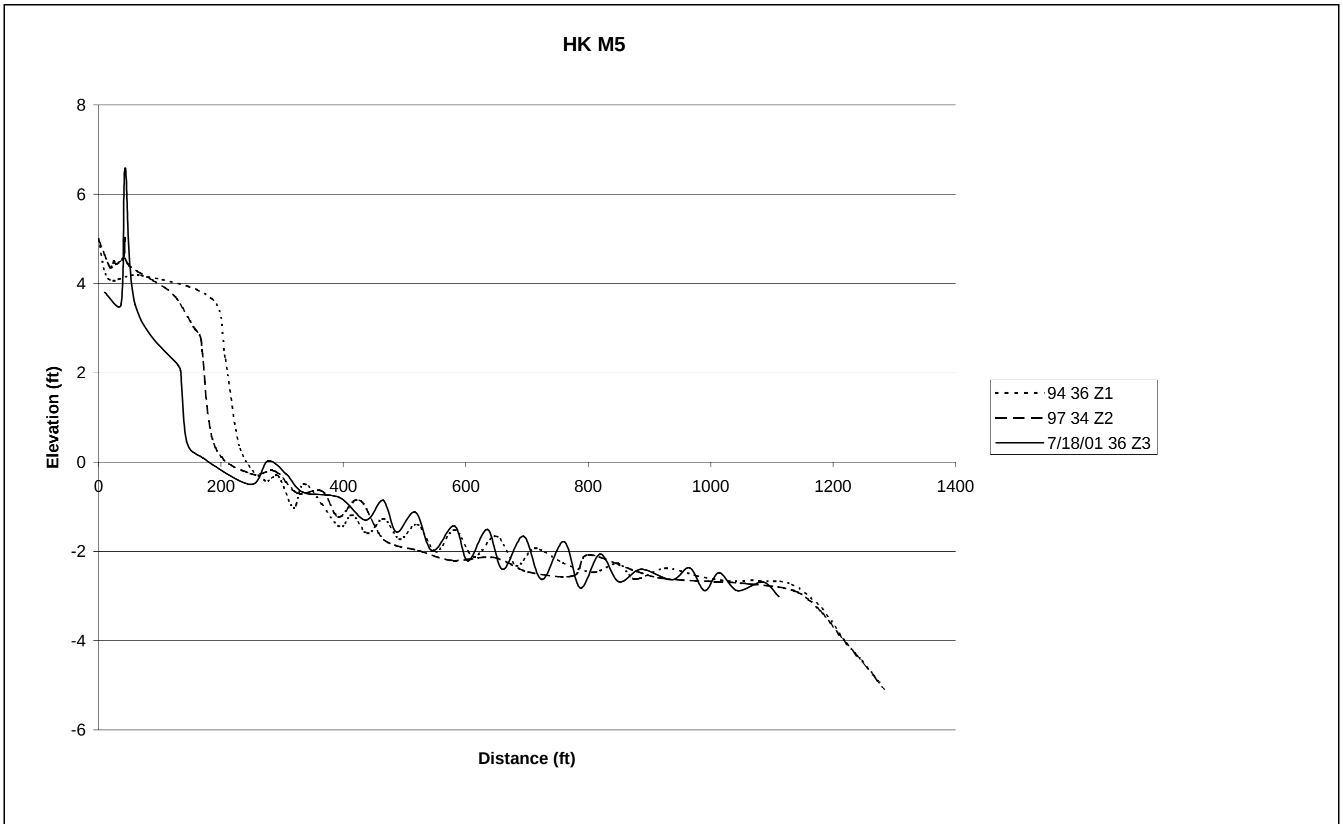
400
600
800
1000
1200
1400
6/28/94 35 Z1
7/9/97 31 Z2
May-00 26 Z3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Elevation (ft)
Distance (ft)
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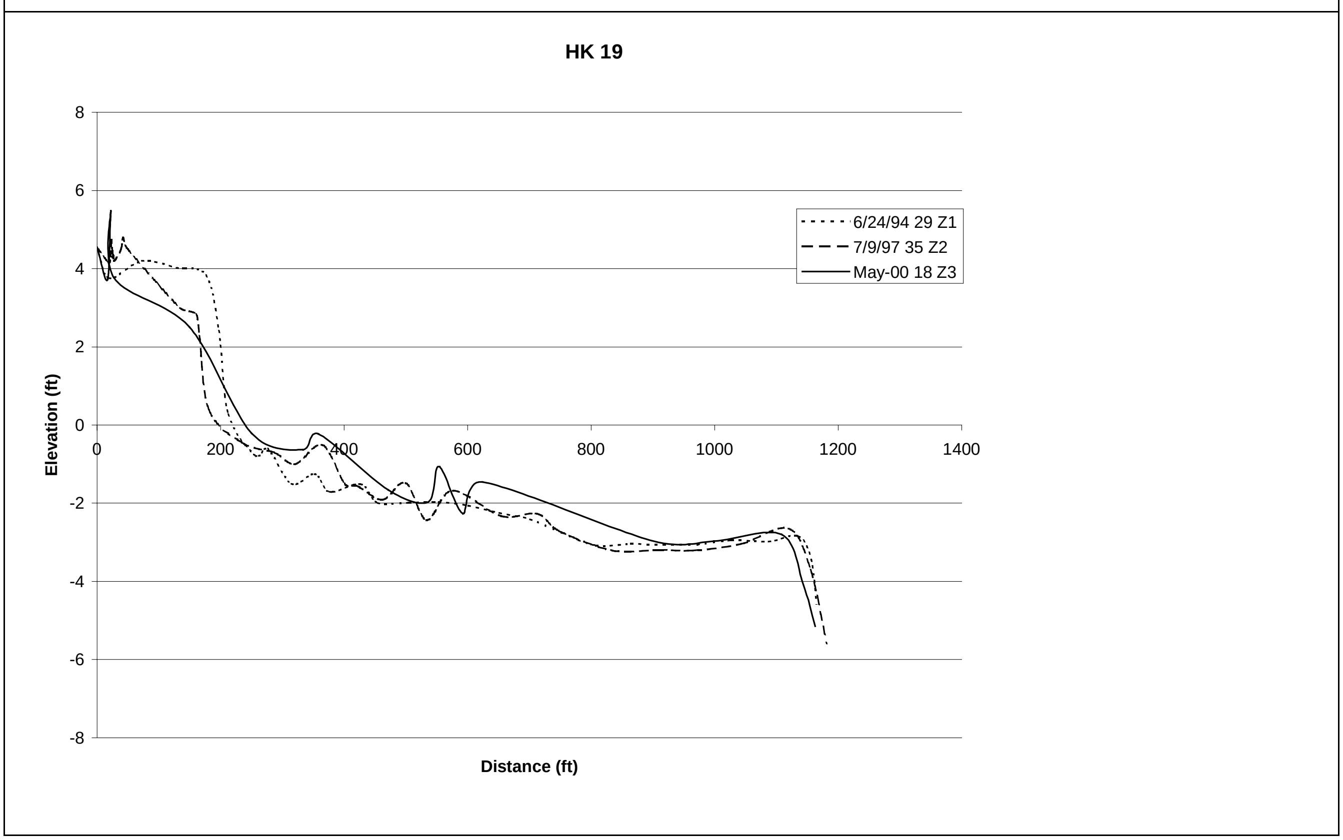
-6
0
200
400
600
800
1000
1200
1400
94 36 Z1
97 34 Z2
7/18/01 36 Z3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Elevation (ft)
Distance (ft)
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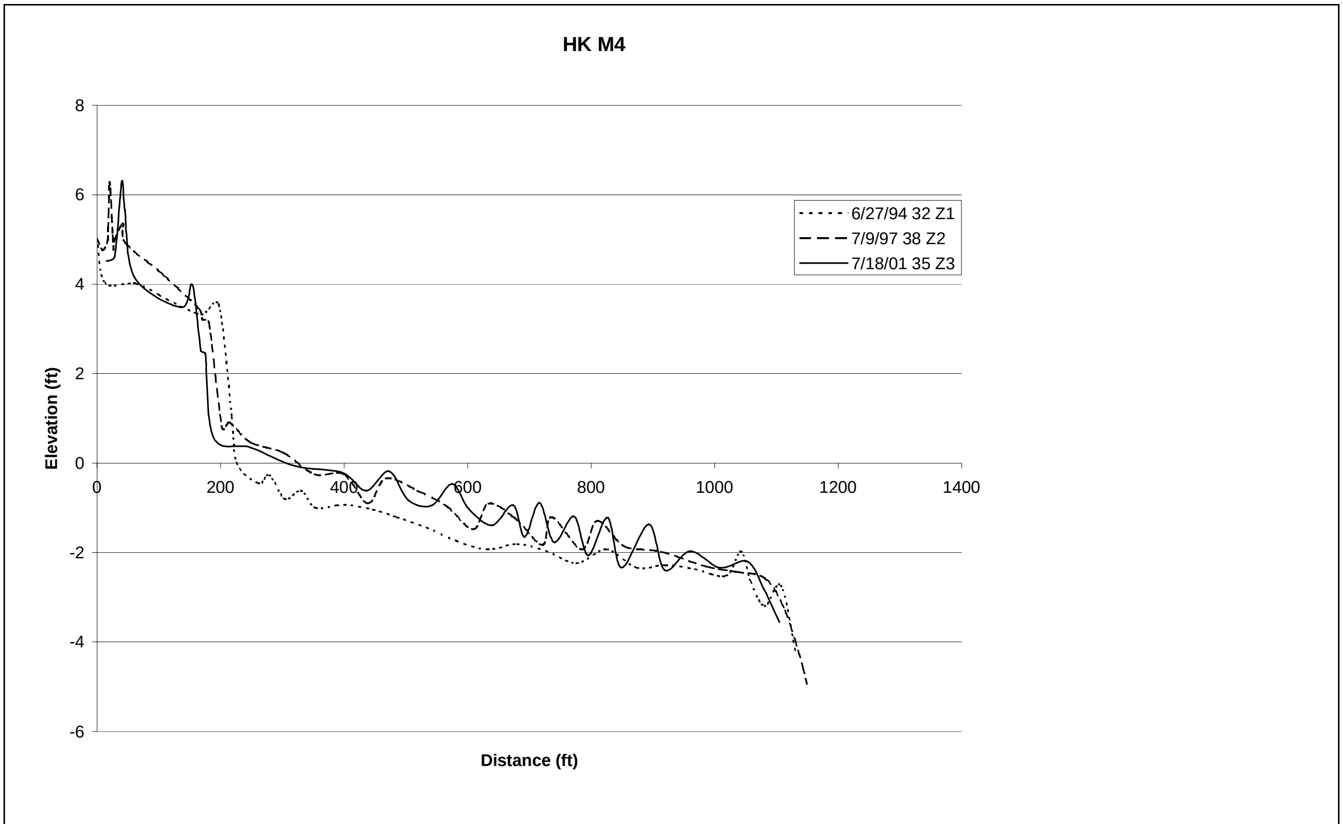
6
4
2
0
-2
-4
-6
-8
0
200
400
600
800
1000
1200
1400
6/24/94 29 Z1
7/9/97 35 Z2
May-00 18 Z3


HK M4
Elevation (ft)
Distance (ft)
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7/9/97 38 Z2
7/18/01 35 Z3
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6
4
2
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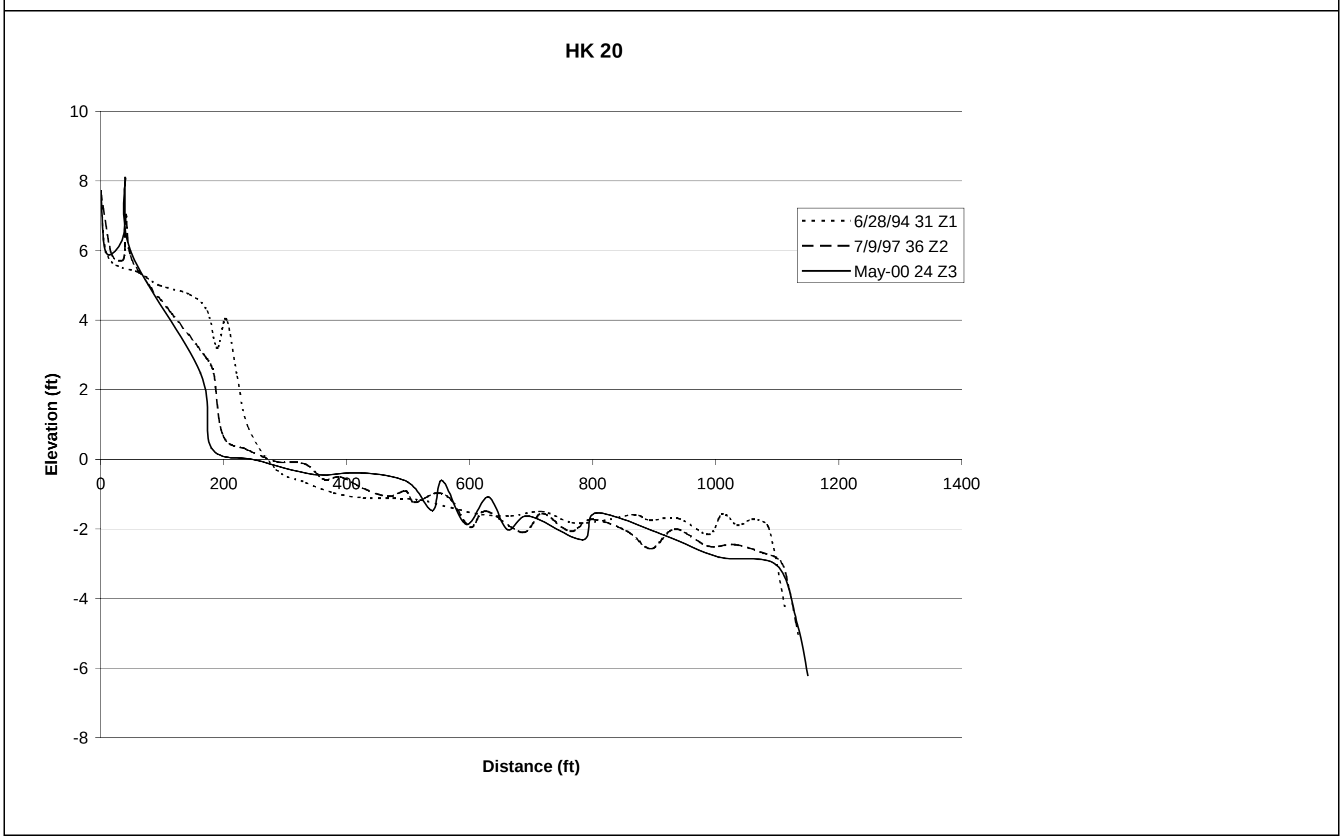
-2
-4
-6
0
200
400
600
800
1000
1200
1400


HK 20
Elevation (ft)
Distance (ft)
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7/9/97 36 Z2
May-00 24 Z3
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-2
-4
-6
-8
0
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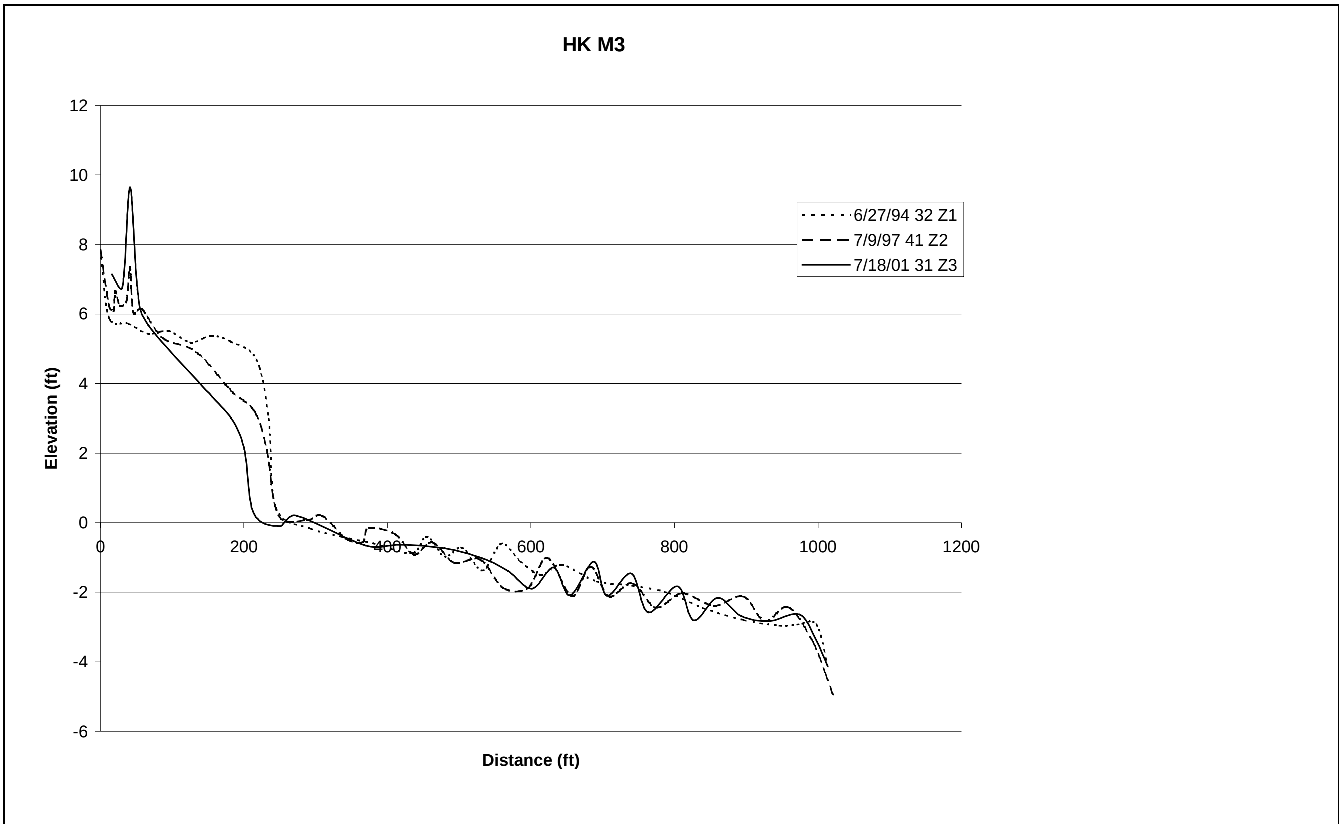
600
800
1000
1200
1400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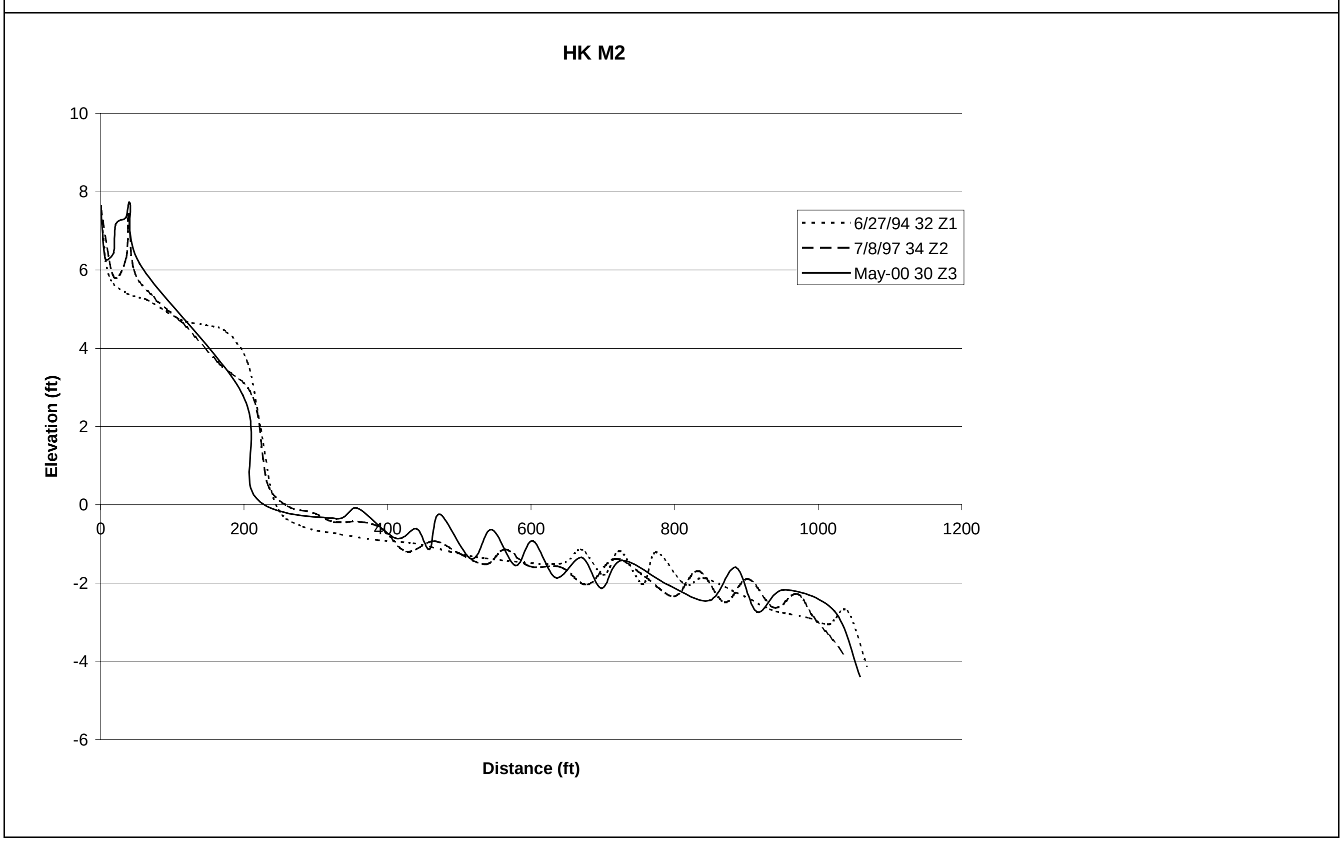
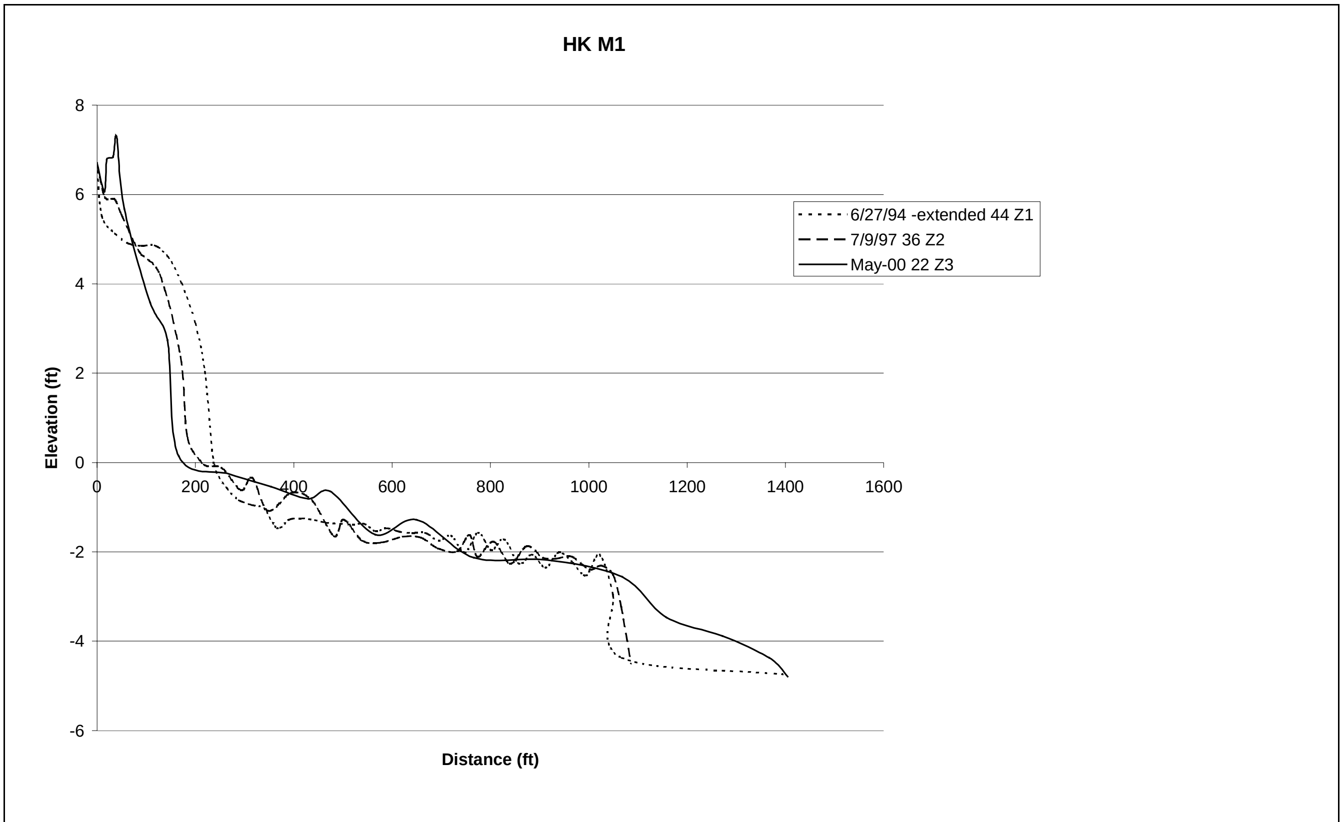
10
8
6
4
2
0
-2
-4
-6
0
200
400
600
800
1000
1200
Elevation (ft)
Distance (ft)
6/27/94 32 Z1
7/9/97 41 Z2
7/18/01 31 Z3


HK M2
10
8
6
4
2
0
-2
-4
-6
0
200
400
600
800
1000
1200
Elevation (ft)
Distance (ft)
6/27/94 32 Z1
7/8/97 34 Z2
May-00 30 Z3


HK M1
Elevation (ft)
Distance (ft)
6/27/94 -extended 44 Z1
7/9/97 36 Z2
May-00 22 Z3
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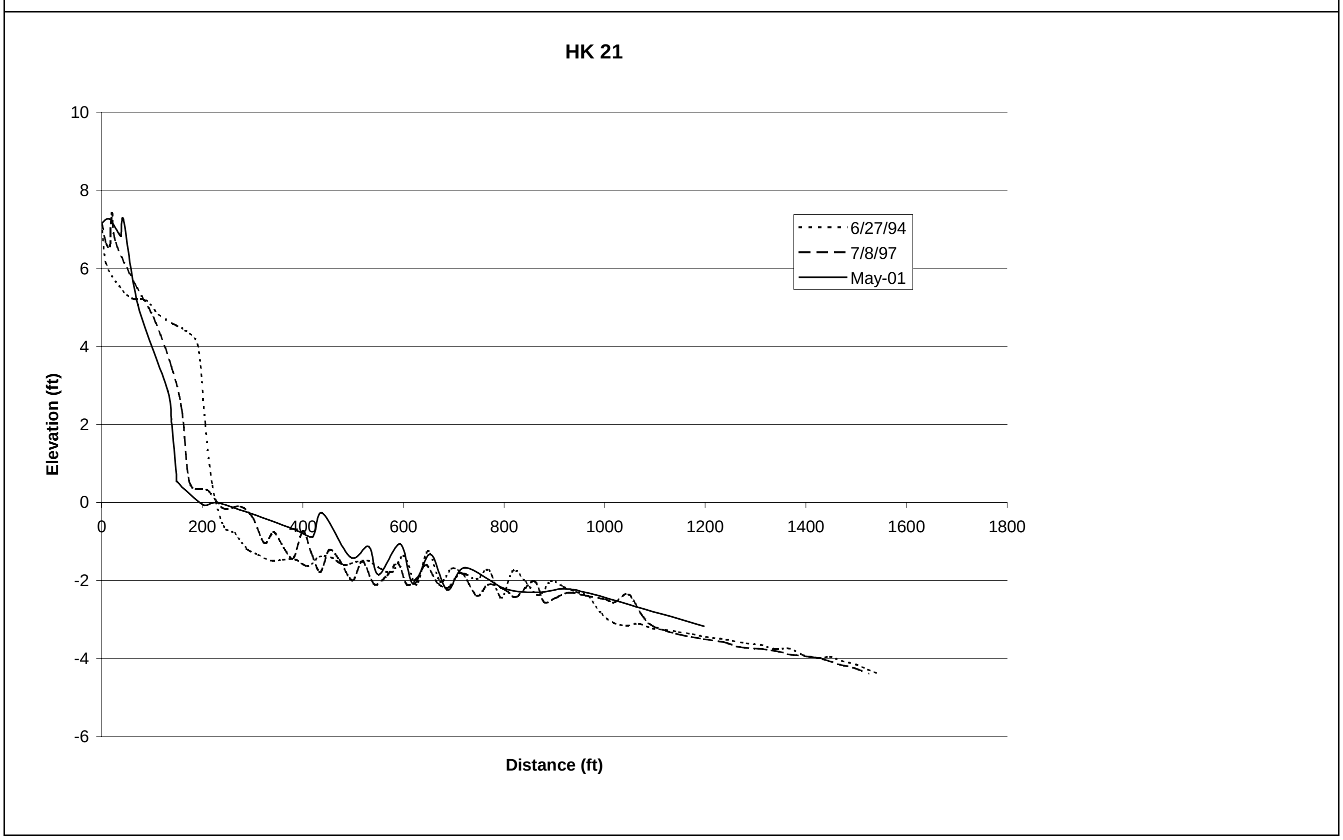
4
2
0
-2
-4
-6
0
200
400
600
800
1000
1200
1400
1600


HK 21
Elevation (ft)
Distance (ft)
6/27/94
7/8/97
May-01
10
8
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-2
-4
-6
0
200
400
600
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1000
1200
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1600
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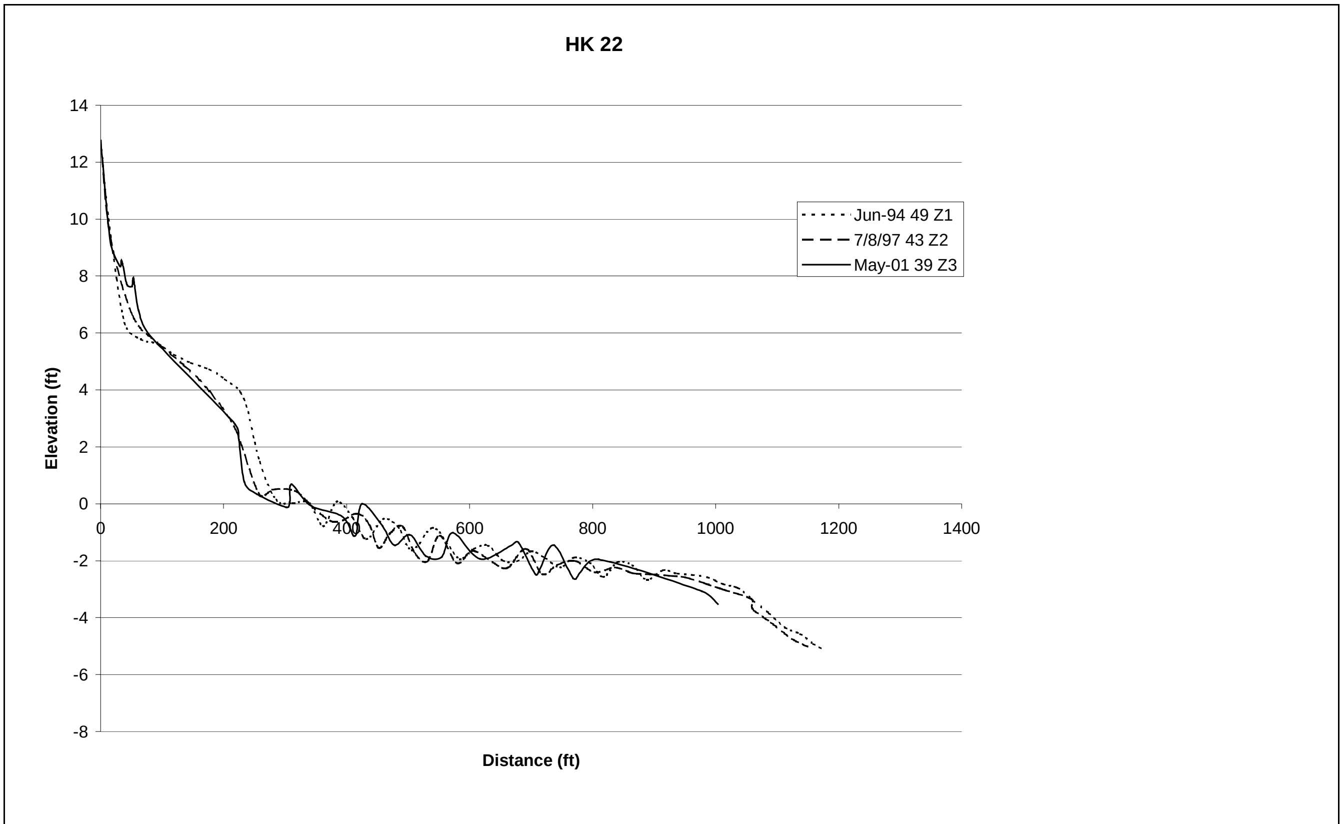
HK 22
Elevation (ft)
Distance (ft)
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10
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6
4
2
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-2
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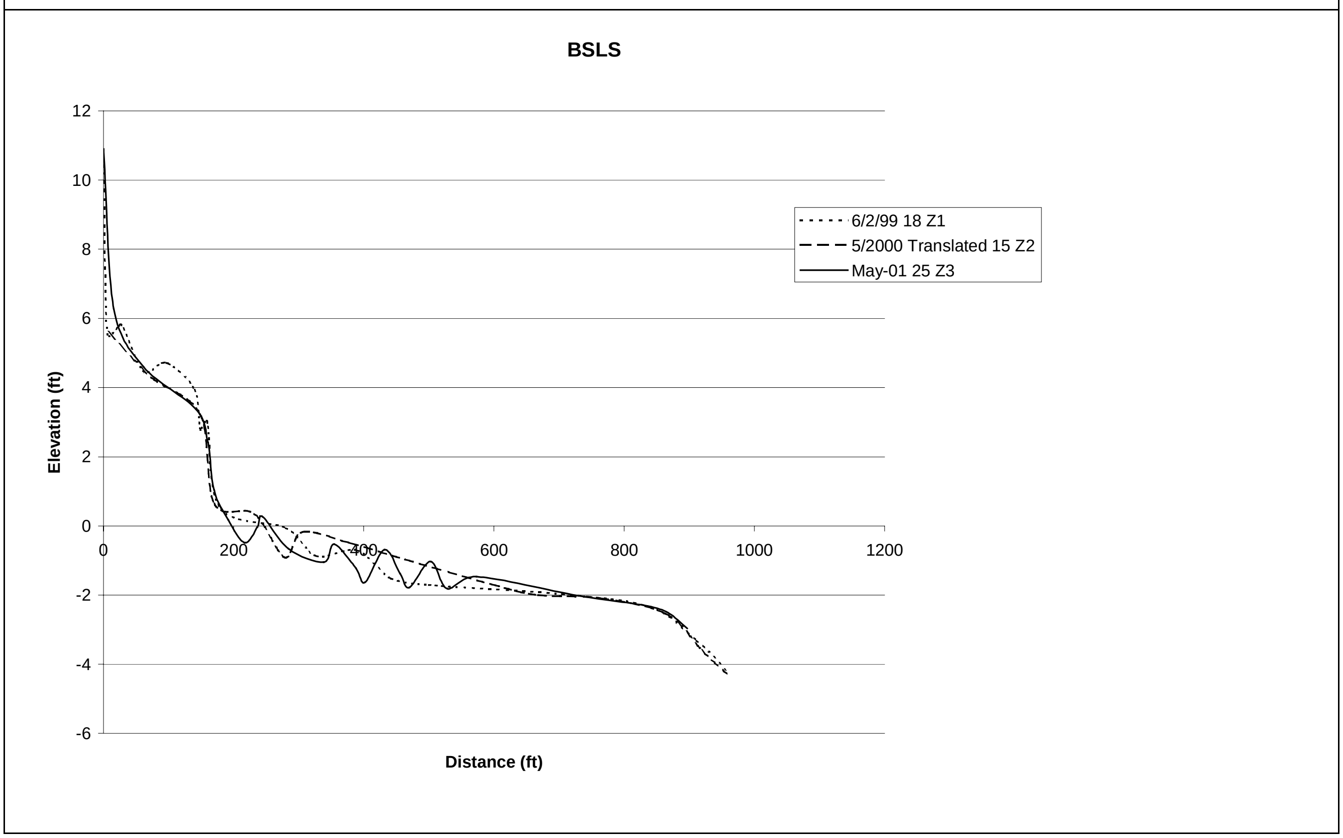
200
400
600
800
1000
1200
1400
Jun-94 49 Z1
7/8/97 43 Z2
May-01 39 Z3


BSLS
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Distance (ft)
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4
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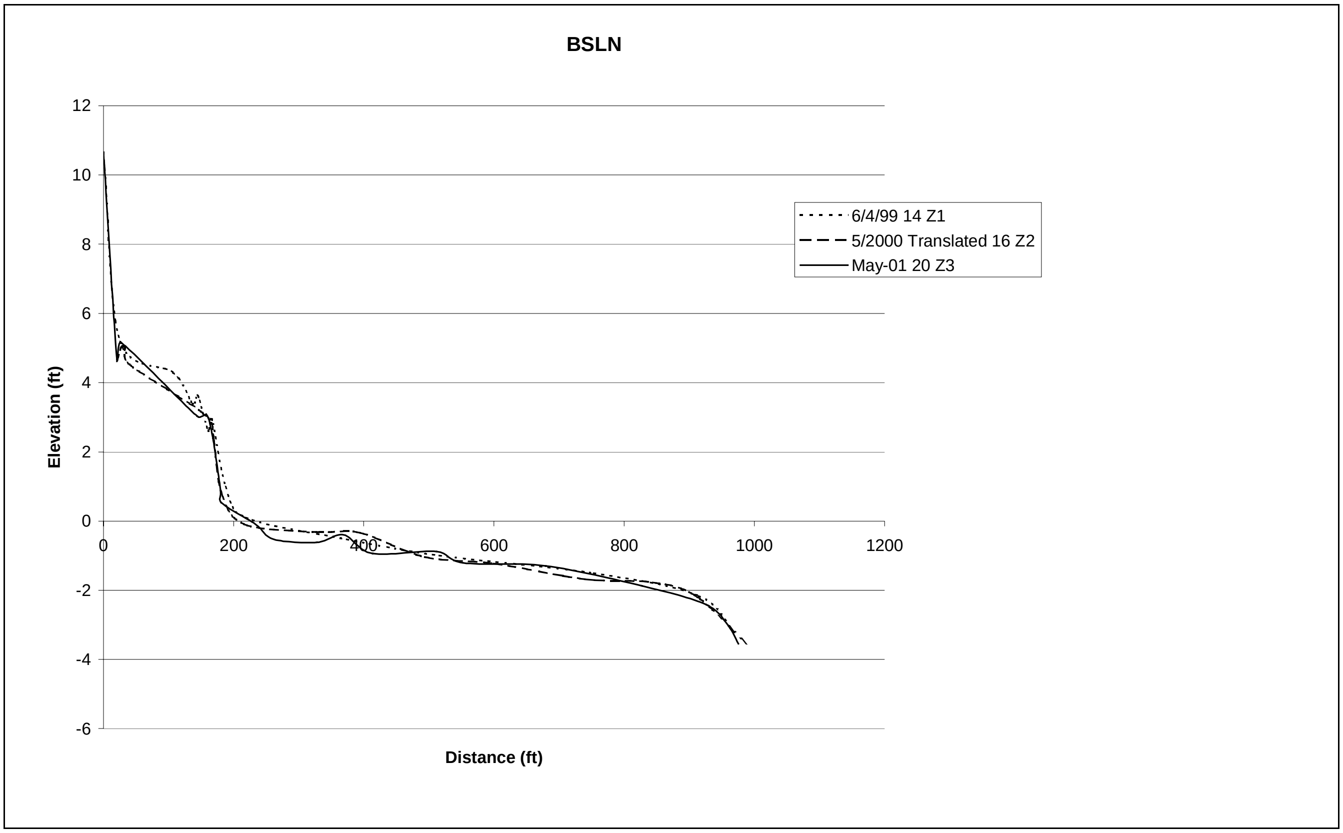
600
800
1000
1200
6/2/99 18 Z1
5/2000 Translated 15 Z2
May-01 25 Z3


BSLN
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4
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-2
-4
-6
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200
400
600
800
1000
1200
Distance (ft)
6/4/99 14 Z1
5/2000 Translated 16 Z2
May-01 20 Z3