Dead Neck Beach Nourishment Monitoring and Data Analysis - 2010

Osterville, Massachusetts

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Osterville, MA

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1. Background

Since the completion of a 225,000 cubic yard nourishment in the first quarter of 2000, the movement of the Dead Neck shoreline has been monitored annually through the use of Differentia GPS (DGPS) shoreline surveys and cross-shore profile measurements. These two data sets were used to determine shoreline change rates and volume loss in the 1999-2000 nourishment area, as well as shoreline change rates for the entire seaward shoreline of the island.

In order to enhance the storm protection capability of the eastern end of Dead Neck, two major beach nourishments have been place on the island, adjacent to West Bay inlet. This segment of the Dead Neck shoreline has historically been the most erosive area of the island, due to it proximity to West Bay inlet. The inlet, with its jetties, effectively interrupts littoral transport from updrift beaches. This has been the case since the opening of the inlet in the first half of the 20th century. Net transport along the Dead Neck shoreline is directed toward the Cotuit Bay entrance from the West Bay entrance. Therefore, as it is cut off from the natural source of sediment to the east, the east end of the island continues to erode (as evidenced by shoreline retreat and lowering of the island), further inhibiting its ability to adequately serve as storm protection for the area directly landward of the island (in the Seapuit River) and in West Bay.

1.A 1985 Nourishment

For the first nourishment in 1985, 120,000 cubic yards of sand were placed along the section of beach starting at West Bay inlet and extending 2,400 feet westward (Wood, et al., 1996). Beach compatible material dredged from the West Bay inlet entrance channel was the source of sand used for this project. The design template of the nourishment had a berm elevation of +12.0 ft NGVD and a width of 100 ft. On average, the fill template required 50 to 60 cubic feet of sand per foot length of beach and had a stated design life of 10 years.

The performance of the 1985 nourishment was monitored on a semi-annual basis up to 1993. In 1993 approximately 7% of the nourishment volume remained in the template area. The average volume loss rate for the 7.5-year monitoring period is 14,880 cubic yards per year. Erosion rates along the template were higher than average at the completion of the nourishment as the beach fill profile equilibrated. Toward the end of the monitoring period, erosion rates were again accelerated due to a series of severe storms which impacted this shoreline during this time, including Hurricane Bob (August, 1991), the “no-name” northeast storm of October, 1991 and the Blizzard of 1993.

1.B 1999 Nourishment

The second nourishment project commenced in the first half of 1999 and was completed in winter 2000 (Woods Hole Group, 2001). The fill template for this nourishment had an elevation of +13 MLW, and a berm crest width of 150 feet. The sand used for the fill was available from channel maintenance dredging at Cotuit and West Bay Inlets. For this nourishment, 187,300 cubic yards were initially placed along a 2,000 foot-length of the Dead Neck shoreline, starting at the West Bay inlet. This

resulted in an average fill volume of 95 cubic yards per foot of shoreline. In 2000, the fill was supplemented with an additional 25,100 cubic yards of sand, placed over the easternmost 1,000 feet of the island. The total volume of sand for the 1999-2000 nourishment project was therefore 212,400 cubic yards. Figures 1 and 2 show before and after views of the nourishment area.

Monitoring of this nourishment is an ongoing effort. As of November 2007, ten cross-shore and ten GPS shoreline surveys have been performed on Dead Neck. The following sections present an analysis of the survey data, and performance of the 1999 fill to date. In January 2009, an emergency nourishment event placed 12,000 cubic yards along the eastern section of Dead Neck.

Figure 1. The eastern portion of Dead Neck in 1999, showing at least two locations where the beach had significant storm overwash areas.

Figure 2. Dead Neck Beach immediately following the beach nourishment in 2000, where the beach width had been increased significantly to prevent breaching of the barrier.

2. GPS Shoreline Surveys

Annual monitoring of the Dead Neck shoreline was started in November of 2002. Along-shore shoreline surveys are performed as an adjunct to the cross-shore profile surveys. GPS shoreline surveys are a relatively easy method to monitor shoreline trends between measured cross-shore survey transects and also well beyond the alongshore limits of the 1999 beach fill. These surveys are carried out using a Trimble DGPS unit carried in a purpose-built backpack (Figure 3). As the surveyor walks along the Mean High Water (MHW) line of the beach, position data are collected at one-second intervals and recorded in a hand-held data logger. After the survey, the data are uploaded to a desktop PC and imported into a shoreline analysis extension created for the ESRI ARC-MAP GIS software program.

Figure 3. Collecting Dead Neck shoreline position data using a Trimble Backpack DGPS unit.

At the time of the first shoreline survey in November 2002, the filled beach profile already had eroded noticeably. This was made most evident by the steep scarp-face of the filled area and also by the failure of sections of sand fencing that had been placed on the crest of the fill at the time of the nourishment (Figure 4). By the time of the January 2006 survey, all of the sand fencing was gone, though the scarp face remained.

Figure 4. At the time of the November 2002 shoreline survey of Dead Neck, sand fencing set-up in the nourishment area had begun to fail due to erosion of the beach fill.

Plots showing nine measured shorelines overlaid on aerial photographs are presented in Figures 5 through 8, for both the western end (Sampsons Island) and Eastern end (the nourishment area) of Dead Neck. In Figure 5, it can be seen clearly that since the time of the 1994 photographs, the westernmost 1,000 feet of the island have been largely accretional; however there has been some recent erosion at the western tip. Between 1994 and 2005 the Sampsons Island spit grew approximately 80 feet into Cotuit Bay Inlet. Between 2006 and 2010 (Figure 6), the spit has eroded by approximately 25 feet, making the total growth of the spit roughly 55 feet in the 16 year time span.

Utilizing the more recent analysis from 2006 to 2010 (Figure 6), it appears that portions of shoreline in the Sampsons Island area of Dead Neck are clearly erosional, within the recent four-year span of available shoreline survey data. The section of shoreline about 1,250 feet from the inlet to Cotuit Bay had been erosional from 2005-2010 but the erosion rate has been reduced in recent years. Another section about 2,500 feet from the inlet has eroded more than 60 feet between 1994 and 2002. However, since the 2002 shoreline survey there has been much less change in the position of the shoreline, with only about 10 feet of recession between 2005 and 2010.

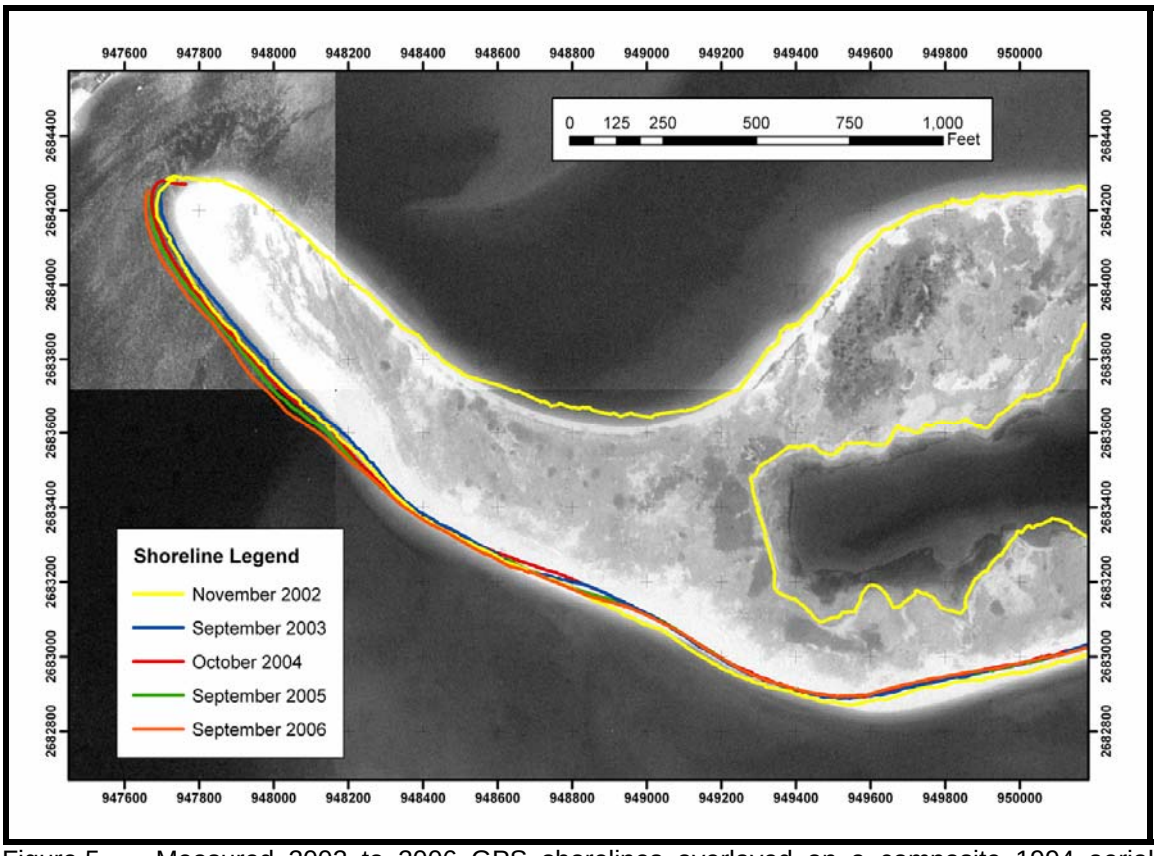

Figure 5. Measured 2002 to 2006 GPS shorelines overlayed on a composite 1994 aerial orthophoto (MassGIS, 2005) of the Sampsons Island region of Dead Neck. Cotuit Inlet is seen in the upper left portion of the photo. Positions are given in Massachusetts State Plane (NAD83, feet).

In the shoreline plots of the eastern end of Dead Neck (Figures 7 and 8), there has been a substantial reduction in beach width within portion of shoreline that was nourished in 1999. For the more recent period (Figure 8), the 2010 shoreline is

approximately 80 feet landward of the 2005 shoreline. The 2009 and 2010 shorelines show modest accretion along the eastern 500 feet of the beach, while the erosional trend continues for the remained of this shoreline. This is due to the January 2009 nourishment event that placed sediment excavated fro the Cotuit Bay entrance channel along the region adjacent to the West Bay west jetty.

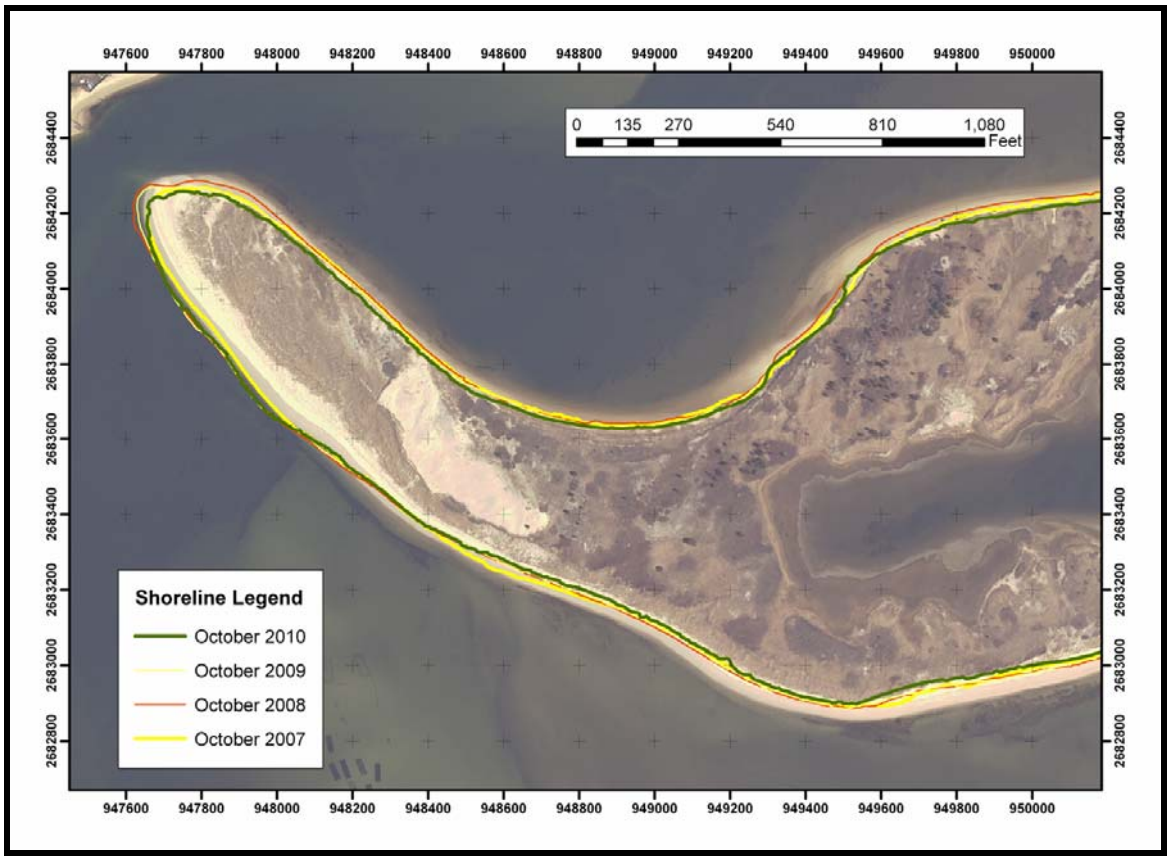

Figure 6. Measured recent GPS shorelines overlayed on a composite 2005 aerial orthophoto (MassGIS, 2005) of the Sampsons Island region of Dead Neck. Cotuit Inlet is seen in the upper left portion of the photo. Positions are given in Massachusetts State Plane (NAD83, feet).

Shoreline erosion rates were computed for the entire seaward shoreline of Dead Neck. The 2002 and 2010 shorelines were used for this analysis. These two survey years where chosen because the change rates resulting from the shoreline analysis are likely more representative of longer term rates, as opposed to the shorter time periods that are possible using the 2003 through 2009 shorelines. The results of the change analysis are presented in Figure 9 and 10.

In Figure 9, shoreline erosion rates are indicated by color bars along the Dead Neck shoreline, computed using the 2002 and 2010 shorelines. For the whole seaward facing shoreline the maximum erosion rate was computed to be -14.2 feet per year (ft/yr). This maximum rate occurred about 1,200 feet west of the West Bay Inlet. The average change rate over the 2,000 foot length of the 1999 nourishment was -13.2 feet per year during this period. At the western end of Sampsons Island, the westernmost 1,000 feet of shoreline from Cotuit Inlet was accretional, with an average change rate of

+9.1 ft/yr. The maximum rate of accretion was computed to be +9.2 feet per year, which occurs at the western tip of the Sampsons Island spit.

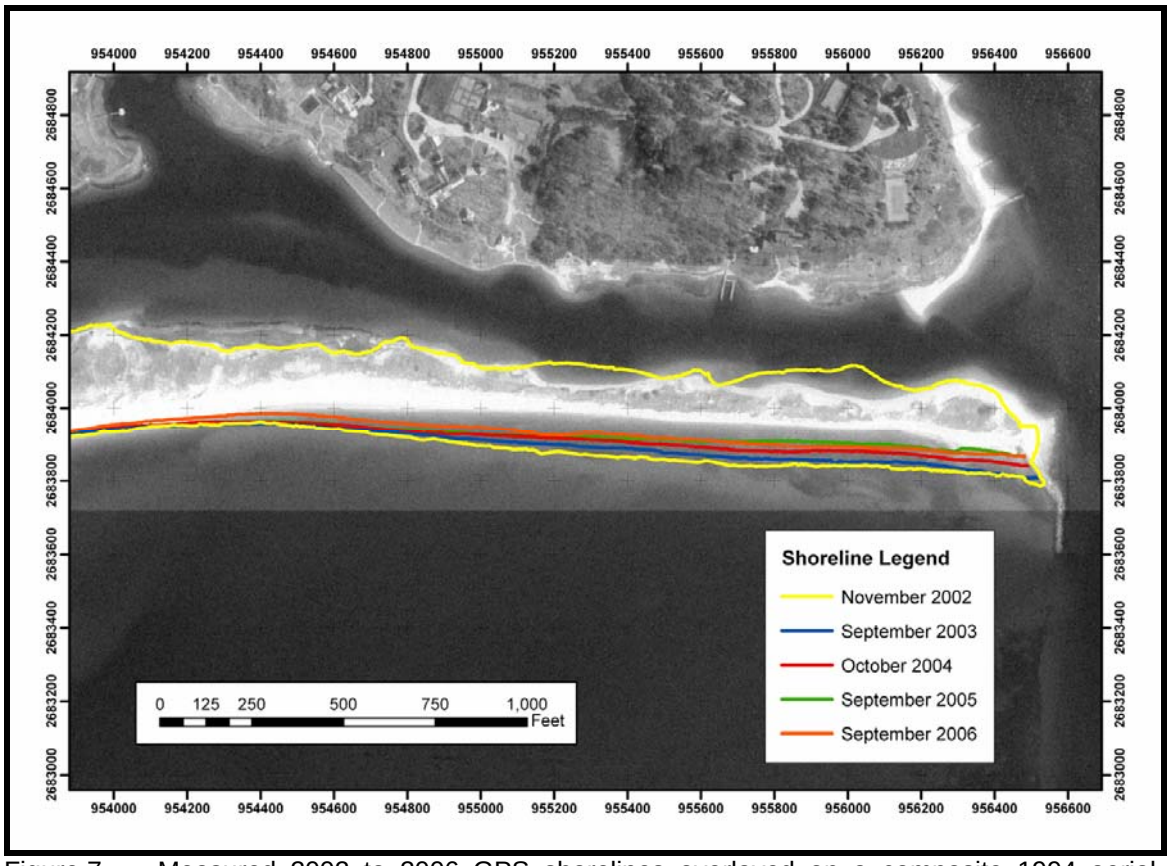

Figure 7. Measured 2002 to 2006 GPS shorelines overlayed on a composite 1994 aerial orthophoto (MassGIS, 2005) of the eastern end of Dead Neck. West Bay Inlet and its western jetty are seen in the right side of the photo. Positions are given in Massachusetts State Plane (NAD83, feet).

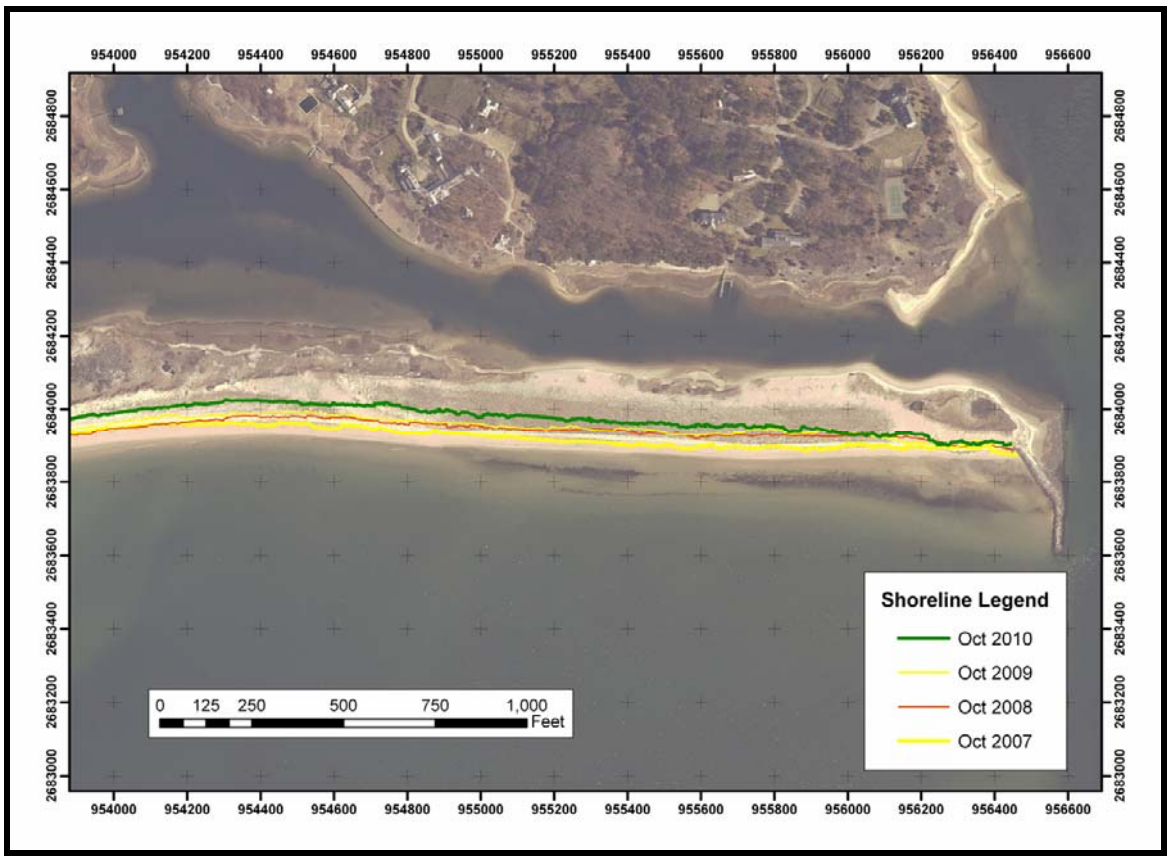

Figure 8. Measured recent GPS shorelines overlayed on a composite 2005 aerial orthophoto (MassGIS, 2005) of the eastern end of Dead Neck. West Bay Inlet and its western jetty are seen in the right side of the photo. Positions are given in Massachusetts State Plane (NAD83, feet).

Shoreline change statistics for the entire Dead Neck shoreline are presented in Figure 10. In this figure, a histogram plot of shoreline change rates shows the frequency distribution of rates for the entire seaward shoreline. Between 2002 and 2010, the mean change rate was -4.1 ft/yr, indicating that on average, the Dead Neck shoreline was erosional. These results are based on the analysis of shore-normal transects spaced between100 feet and 200 feet along the shoreline.

Figure 9. Results of shoreline change analysis using the 2002 and 2010 GPS shorelines. Color bars indicate a range of shoreline change computed along Dead Neck. Negative rates indicate erosion, and are represented by the colors green, yellow, orange and red. Areas of accreting shoreline are indicated by light and dark blue.

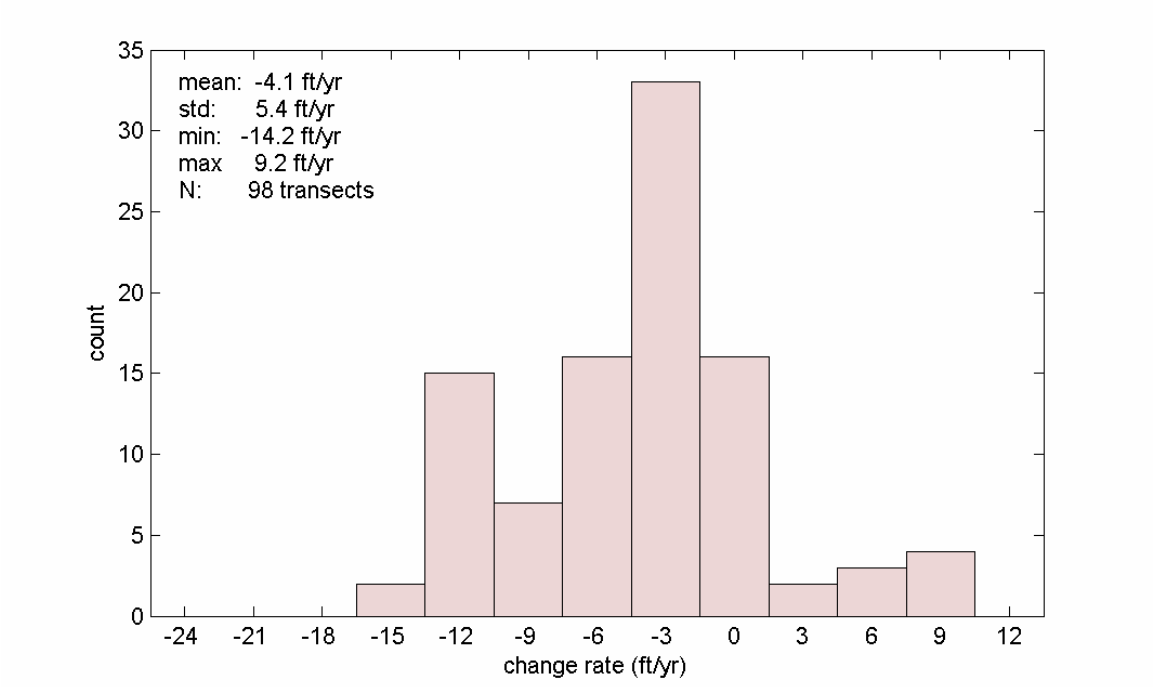

Figure 10. Histogram plot of annualized shoreline change rates between 2002 and 2010 GPS shorelines. Rates were computed along the entire seaward shoreline of Dead Neck, determined using a total of 102 shoreline transects.

3. Cross-shore Profile Surveys

Cross-shore profile surveying of the Dead Neck shoreline has been the principal method of monitoring the performance of both the 1985 and 1999 nourishments. In contrast to the more recent GPS monitoring efforts, cross-shore surveys have been limited to the easternmost 2,400 feet of Dead Neck. For the 1985 nourishment, profiles were measured semi-annually up to 1993. Since the completion of the 1999 nourishment, profiles generally have been surveyed annually, although no survey was performed in 2003 or 2009.

The extent and spacing of each profile survey are presented in Table 1. Up until the 2004 survey, profiles were measured by CapeSurv at 100 foot intervals, and to a distance offshore limited by the wading depth of a person. In September 2004, 200-foot transect spacing was used by the surveyor, GBA. The land-based profile survey was supplemented with a boat-based bathymetry survey. The boat extended the land survey seaward approximately 2,800 feet from the survey baseline by following the same transect lines of the land survey. The boat and land surveys overlapped near the shoreline, so the result was continuous cross-shore profile measurements that extend far offshore to depth of approximately -8 ft MLW. The most recent survey was performed by Applied Coastal staff in October of 2010. The survey was performed with 200-foot spacing, and transects were recorded from the survey baseline to the limiting wading depth offshore.

It should be noted that some of the baseline stakes have been lost, broken or are no longer firmly fixed in the dune. Specifically, the back stake at STA 0+00 has been washed out and was not located, the back stake at STA 2+00 is loose, the front stake at STA 4+00 is bent, the front stake at STA 18+00 is broken off at ground level and the front stake at STA 20+00 is bent. An effort should be made to record the exact GPS location of all baseline stakes and to replace them as soon as is convenient so that no stations are lost. Some thought must be given regarding the replacement of the back stake at STA 0+00 as the rear section of that dune has been gradually eroding. At some point, the location corresponding to this stake will likely be in the water. Temporary replacement stakes were placed by Applied Coastal staff during the October 2010 survey.

Table 1. Available Dead Neck cross-shore survey data sets, since the 1999 nourishment. Station 24+00 is 2,400 feet from west of West Bay inlet, along the survey baseline.

Survey	Shoreline coverage (stations)	Transect spacing
construction template	00+00 to 20+00	100 ft
pre-nourishment	00+00 to 14+00	100 ft
March 1999, post	00+00 to 20+00	100 ft
May 2000	00+00 to 24+00	100 ft
April 2001	00+00 to 24+00	100 ft
March 2002	00+00 to 24+00	100 ft
September 2004	00+00 to 24+00	200 ft
January 2006	00+00 to 20+00	200 ft
October 2006	00+00 to 20+00	200 ft
November 2007	00+00 to 20+00	200 ft
November 2008	00+00 to 20+00	200 ft
October 2010	00+00 to 20+00	200 ft

Plots of the profile data from the data listed in Table 1 are presented in the Appendix of this report. The construction template, pre-nourishment template and March 1999 survey profile data were digitized from plans created by GBA (1999). All other profile data sets were available in processed tabular formats.

Using the available profile data, volume change rates were computed along the length of the 1999 nourishment, between stations 00+00 (at West Bay inlet) and 20+00 (2,000 feet west of West Bay inlet). The results of these computations are shown in Figure 11. In this plot, the first three survey periods indicate accretion at the east end of Dead Neck. This accretion is due to the addition of 25,100 cubic yards of dredged sand in early 2000 on the first 1,000 feet of the beach (i.e., between stations 00+00 and 10+00).

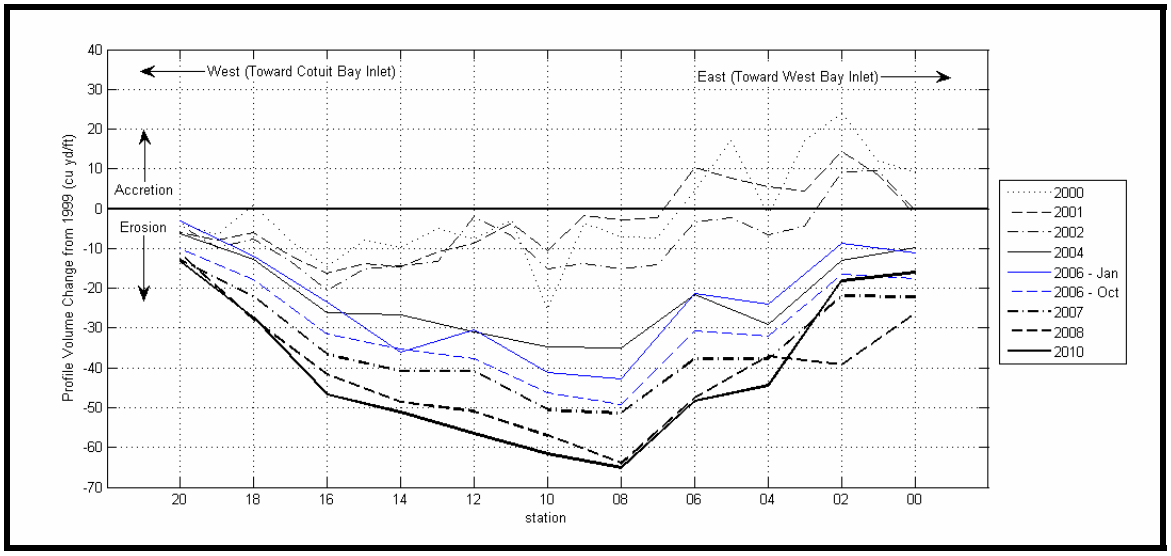

Figure 11. Profile volume loss from the 1999 measured profiles computed for each cross-shore survey transect in the nourishment area. The results from 2004 to 2010 are based on 200-ft transect spacing, while results from all other years are based on 100-ft transect spacing.

The September 2004 survey is the first time that all profiles were indicating volume loss. The trends of loss across from Stations 0+00 to 20+00 are similar over the past 3 years. The greatest volume loss had occurred in the reach between Station 08+00 to Station 10+00, where more than 50 cubic yards per foot length of beach (yd^3/ft) of fill material have been lost from the profile. Volume losses are smaller at both ends of the nourishment. At the west end of the nourishment, losses are likely mitigated due to the availability of sand from the updrift (eastern) portion of the nourishment area. At the eastern end, volume losses only appear to be less than toward the center of the nourishment, again due to the additional 25,100 yd^3 of sand placed on this end of the beach in early 2000. The recent accretion from Stations 0+00 to 0+03 is due to a nourishment event in January 2009 of approximately 12,000 yd^3.

The largest volume loss continues to be in the center of the 1999 nourishment (Stations 06+00 to 15+00) with the greatest losses occurring again in the area of Station 08+00. The eastern (Stations 0+00 to 4+00) and western (Stations 16+00 to 20+00) ends of the survey show minor loses when compared to 2007, while the more significant volume loss occurs in the center of the area. The eastern section of the 2010 survey (Stations 0+00 to 6+00) shows the largest change from the 2008 Survey due to the nourishment event mentioned above. The volume loss in the central and western reaches is smaller, with some areas showing near-stability.

From the profile volume computations, the total nourishment volume remaining within the nourishment template area (stations 00+00 to 20+00) at the time of each profile survey can be determined. Figure 12 presents the nourishment volume remaining as a function of time. At the time of the October 2010 survey, there were 99,100 yd^3 of sand remaining. By this volume loss determination, and knowing that the total nourishment volume was 212,400 cubic yards, the percent remaining of the original volume is computed to be 47%. Expressed in another way, 53% of the fill volume has been lost from the nourishment area over the last ten years.

Finally, the total volume loss rate for the nourishment between each cross-shore profile survey is presented in Table 2. The volume loss rate is shown to vary over time, with the maximum rate occurring in the first year after the nourishment. This is expected as the nourishment template profile equilibrated during this initial period. Over the approximate ten-year period since the bulk of the 1999 nourishment was completed, the average rate of volume loss has been -9,900 yd^3/yr.

In order to ensure that volume calculations are consistent when comparing surveys from different years, the shortest survey for a giving transect is used for the volume calculations. The January 2006 survey proved to be the limiting survey on many transects, due to the fact that each transect stopped at cross-shore position 0 feet while previous surveys had extended further towards Seapuit River. The result of these new limiting transects is that the calculations of volume change over the previous survey years have changed slightly, when compared to the values reported in February 2005 monitoring report (Applied Coastal Research and Engineering, Inc., 2005). These updated values are essential so that the older data can be directly compared to the 2006 data. The 2010 survey data continues this trend so that all survey years can be accurately compared.

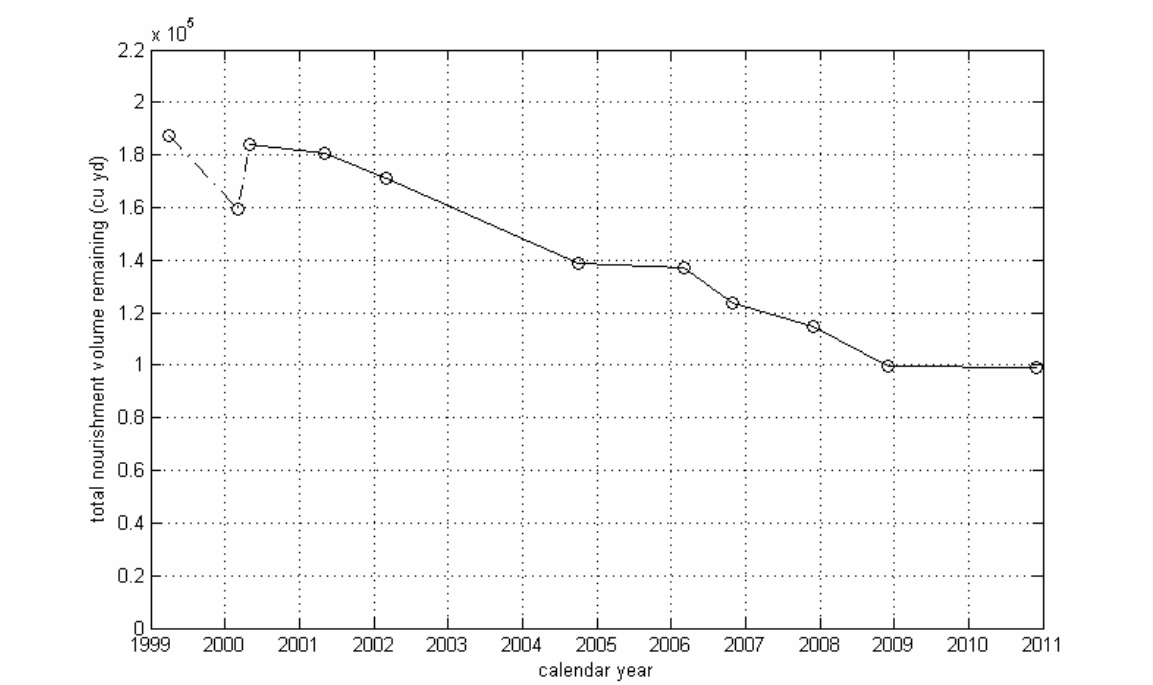

Figure 12. Volume of the Dead Neck nourishment remaining as a function of time. The first point is the nourishment volume as completed in 1999. The second point indicates the total volume of the nourishment before the addition of 25,100 cubic yards of sand in winter 2000.

Table 2. Total volume loss and resulting volume loss rate for the 1999 Dead Neck nourishment, between surveys and for the entire span of time between 1999 and 2004.

period	net volume loss (cu yd)	volume loss rate (cu yd/yr)
1999 to 2000[a]	-27,700	-30,400
2000 to 2001[b]	-4,200	-4,000
2001 to 2002	-9,500	-11,500
2002 to 2004	-33,200	-13,100
2004 to Jan 2006	-1,500	-1,200
Jan 2006 to Oct 2006	-14,100	-18,800
Oct 2006 to 2007	-9,800	-9,000
2007 to 2008	-14,200	-14,100
2008 to 2010	-400	-210
1999 to 2010	*-114,600*	*-9,900*

[a] to just prior to addition of 25,100 cubic yards in winter 2000
[b] from just after the completion of the nourishment in 2000

4. References

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Gahagen and Bryant Associates (1999). “West Bay and Cotuit Bay Dredging, Dead Neck Beach Nourishment”. Cross-section plan.

Wood, Jon D., John S. Ramsey, and Lee L. Weishar (1996). “Beach Nourishment Along Nantucket Sound: A Tale of Two Beaches.” Proceedings of the 9th Annual National Conference on Beach Preservation Technology. Florida Shore and Beach Preservation Association.

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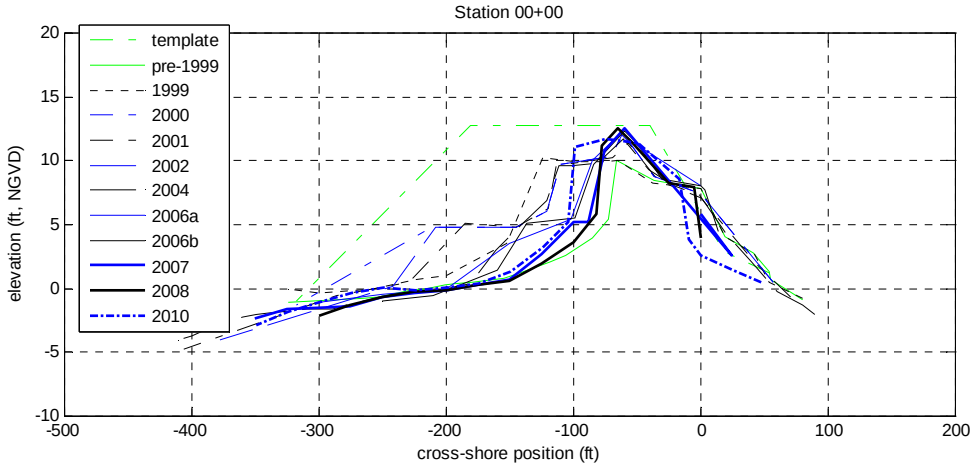
Appendix: Cross Shore Profile Plots


Station 00+00
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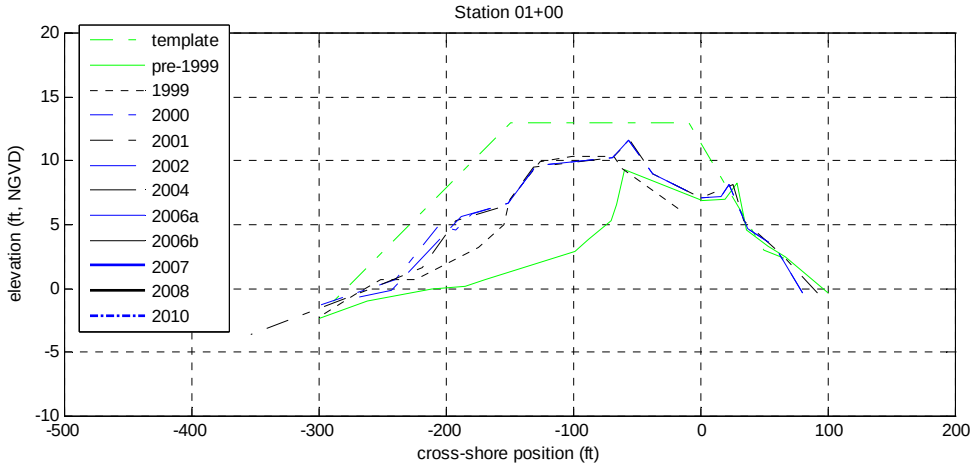
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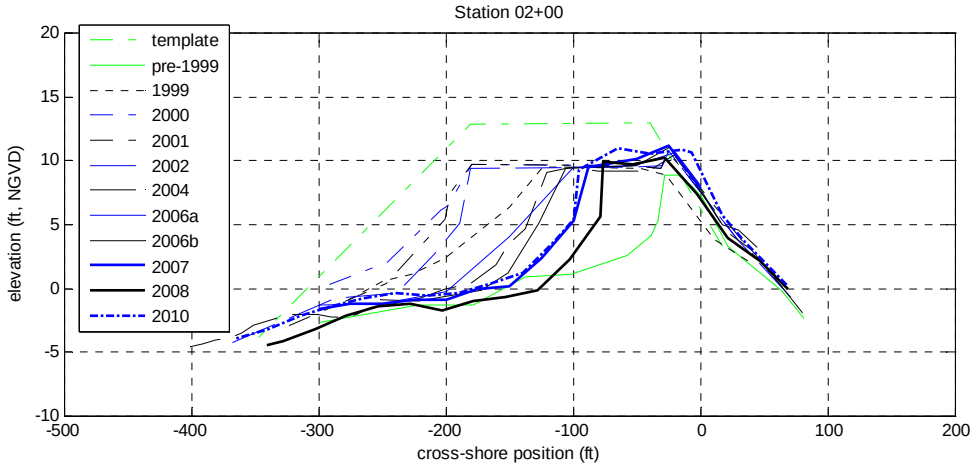
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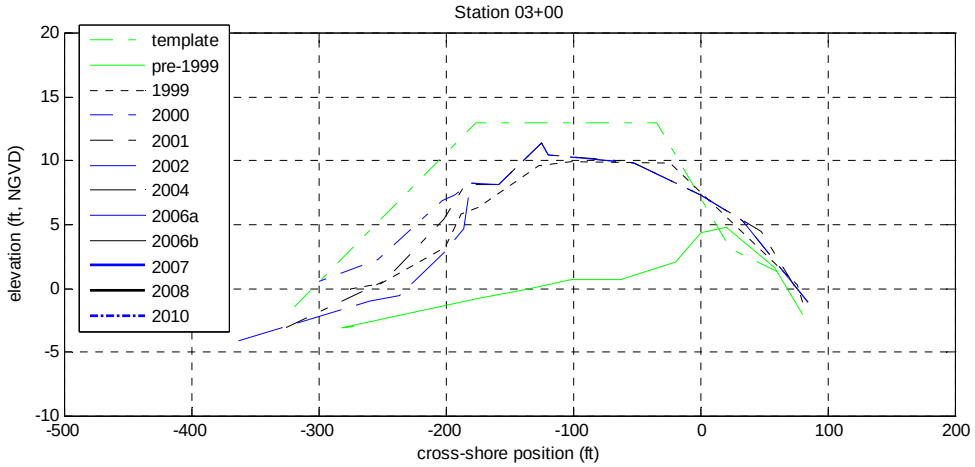
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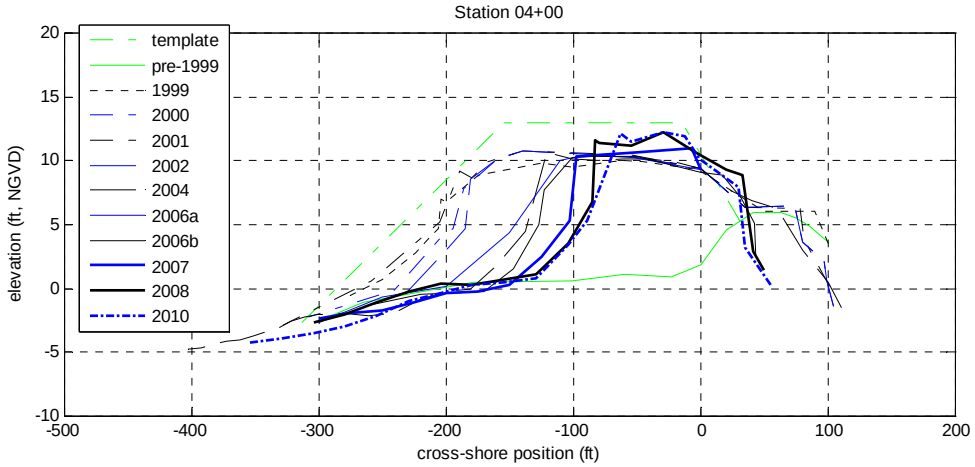
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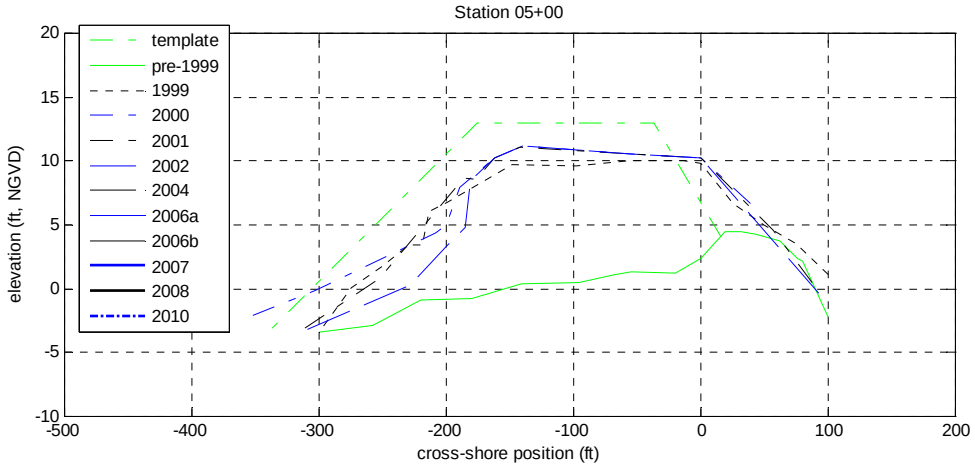
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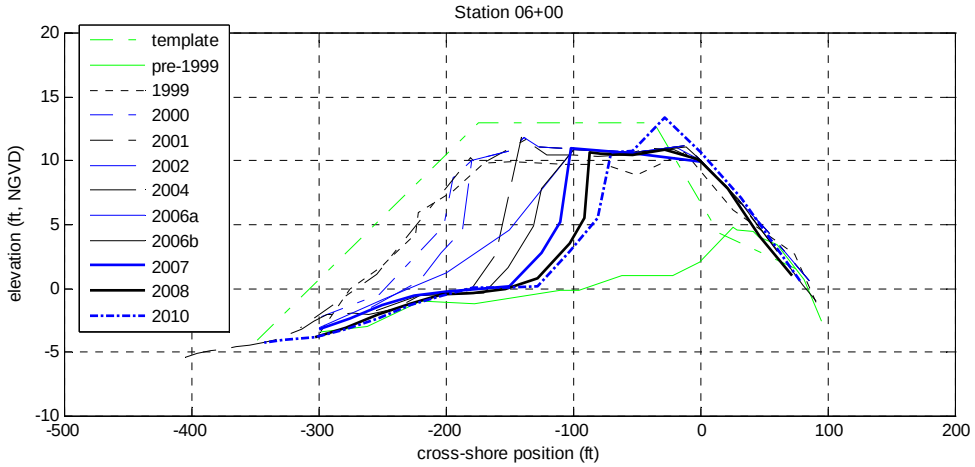
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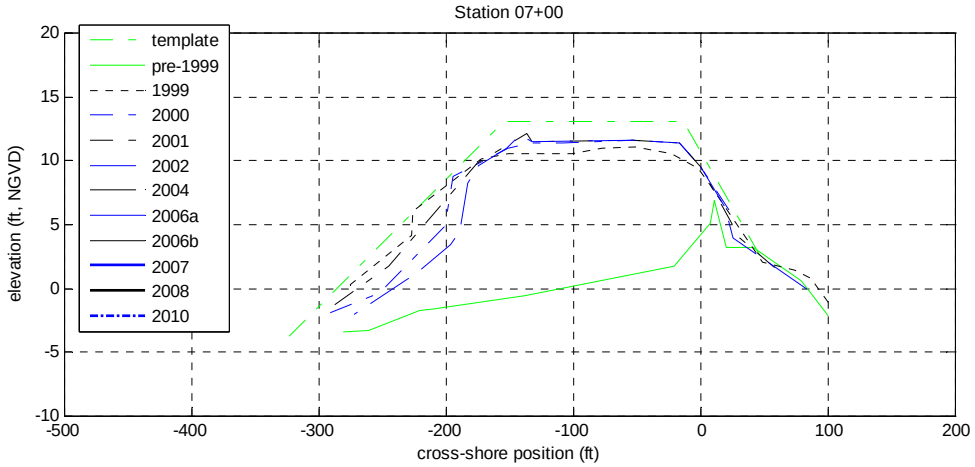
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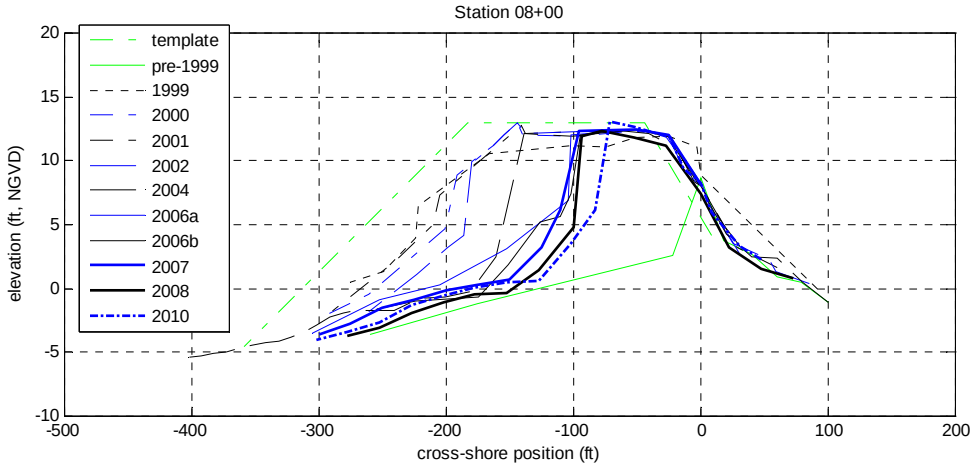
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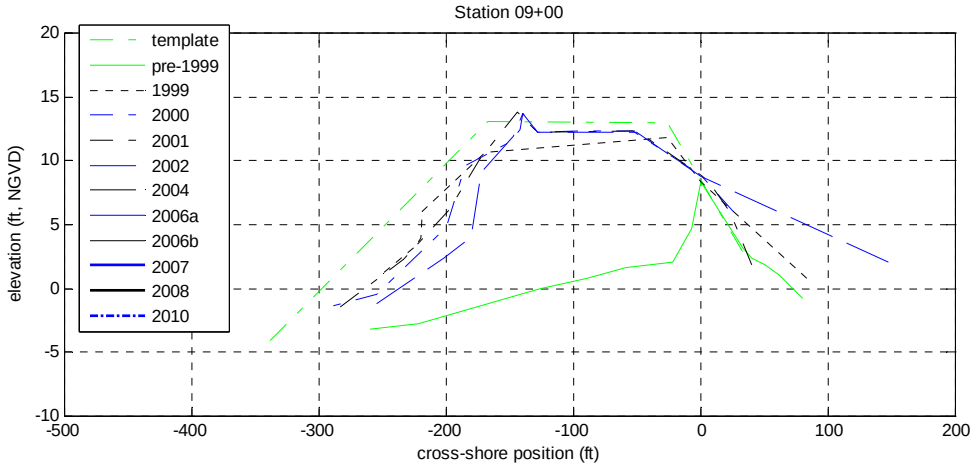
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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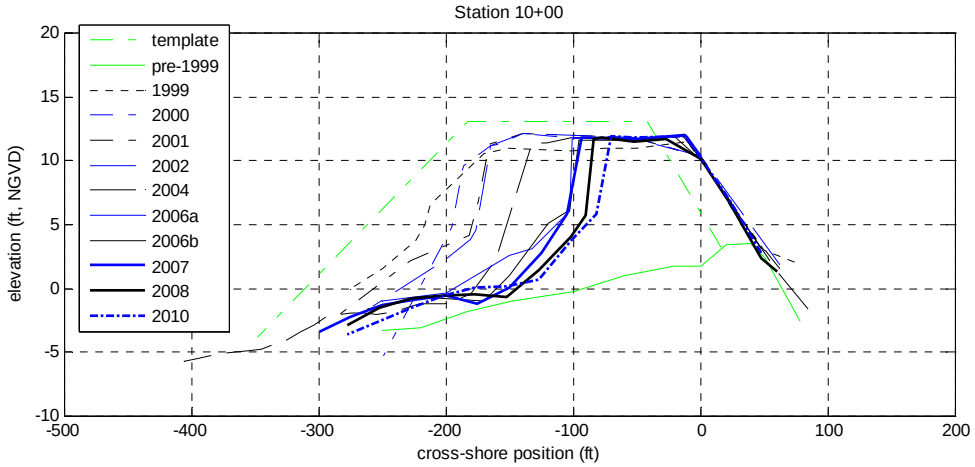
Station 10+00
template
pre-1999
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2006a
2006b
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2008
2010
elevation (ft, NGVD)
cross-shore position (ft)
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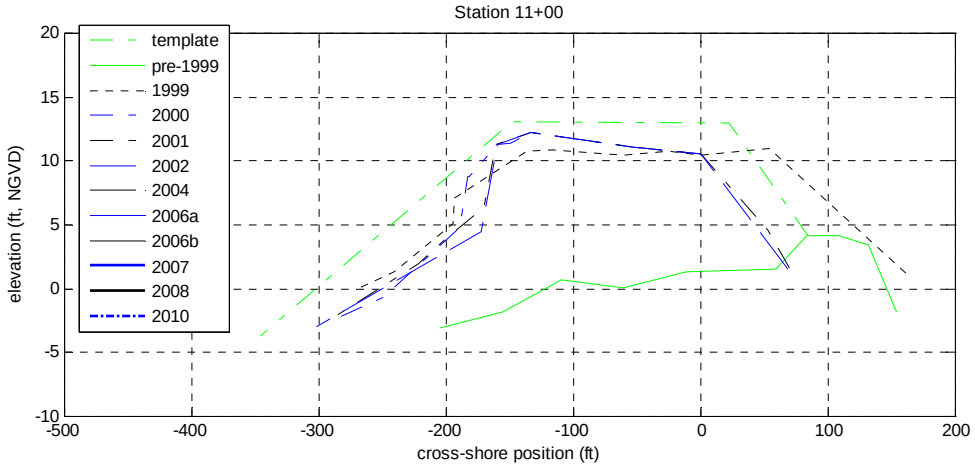
Station 11+00
template
pre-1999
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2004
2006a
2006b
2007
2008
2010
elevation (ft, NGVD)
cross-shore position (ft)
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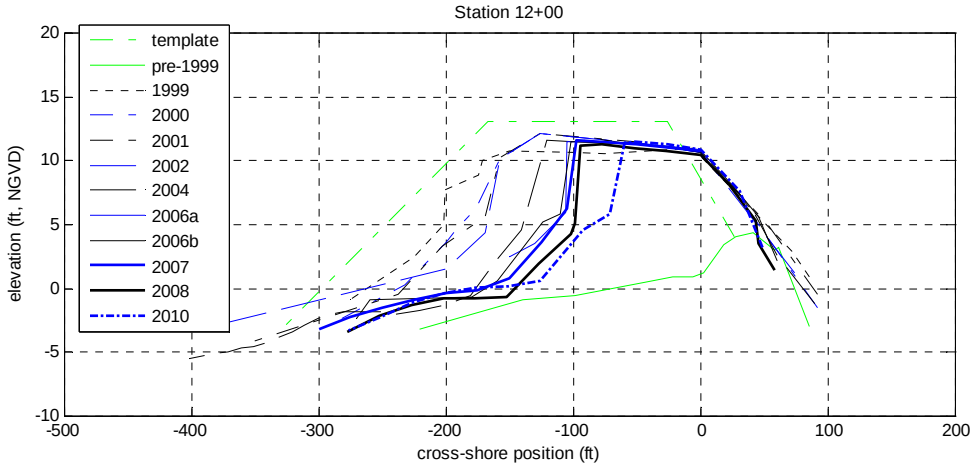
Station 12+00
template
pre-1999
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2004
2006a
2006b
2007
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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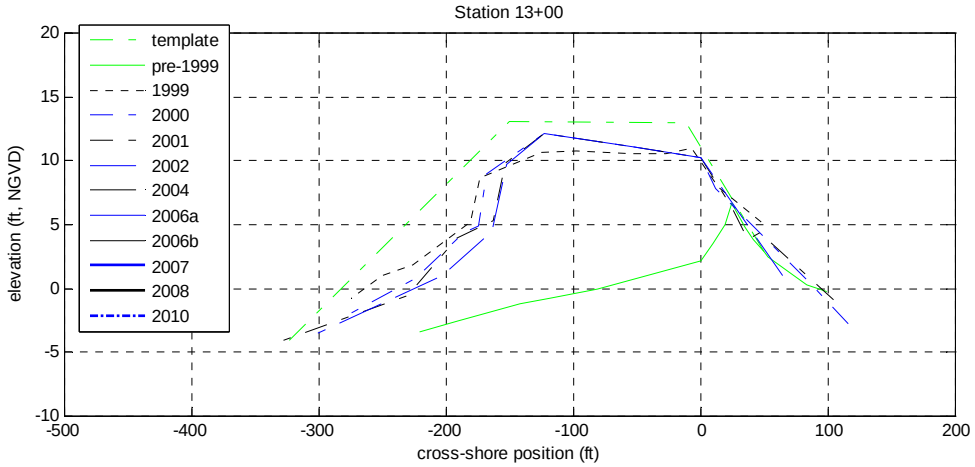
Station 13+00
template
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2006a
2006b
2007
2008
2010
elevation (ft, NGVD)
cross-shore position (ft)
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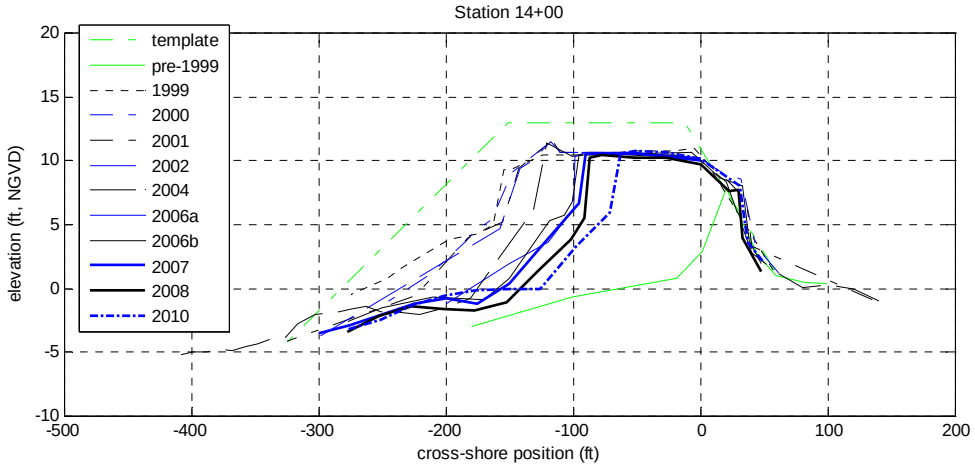
Station 14+00
template
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2006a
2006b
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2008
2010
elevation (ft, NGVD)
cross-shore position (ft)
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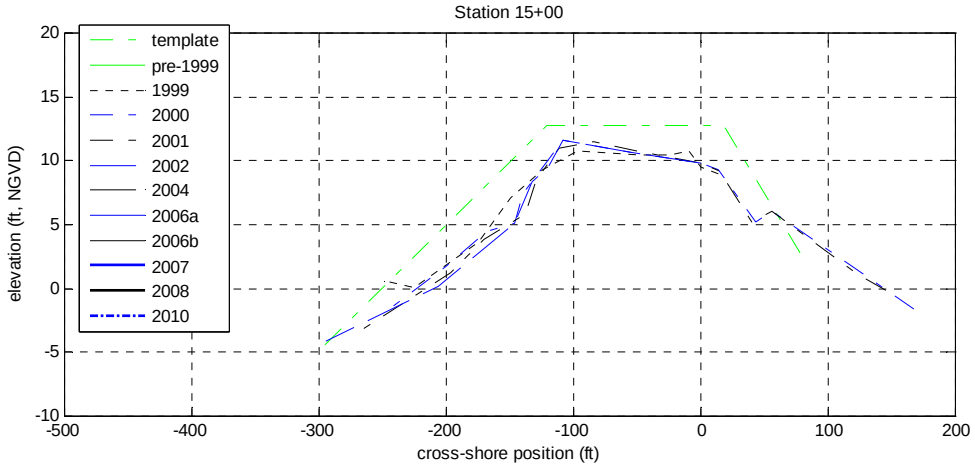
Station 15+00
template
pre-1999
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2006a
2006b
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2008
2010
elevation (ft, NGVD)
cross-shore position (ft)
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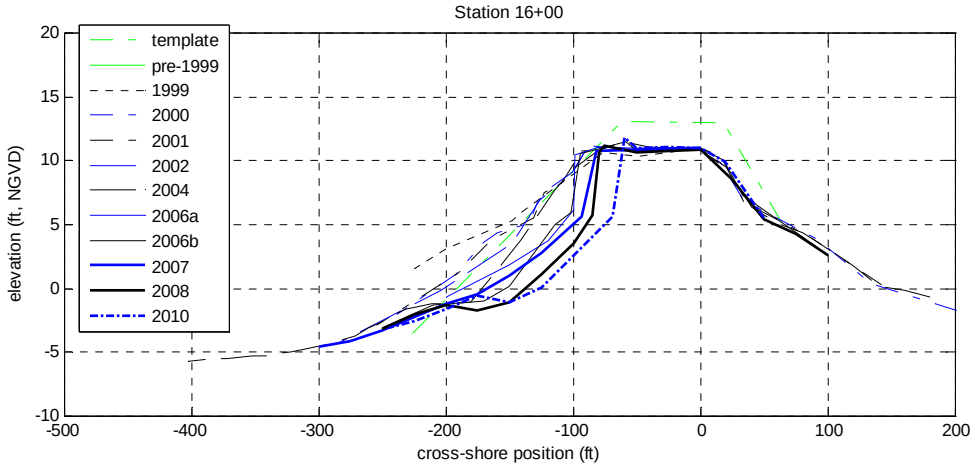
Station 16+00
template
pre-1999
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2006a
2006b
2007
2008
2010
elevation (ft, NGVD)
cross-shore position (ft)
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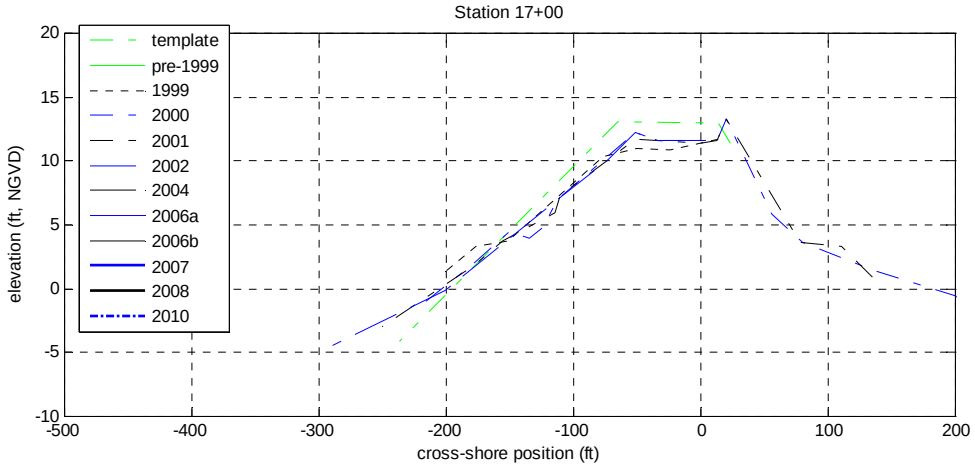
Station 17+00
template
pre-1999
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2006a
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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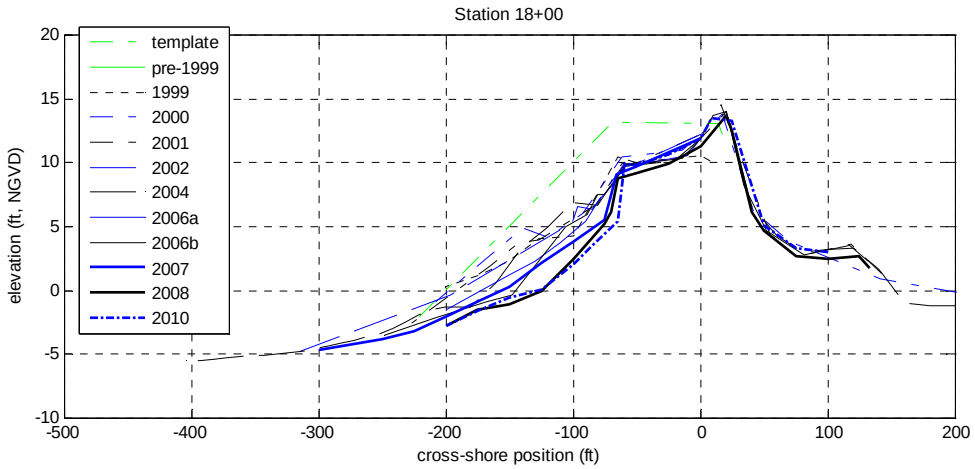
Station 18+00
template
pre-1999
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2006a
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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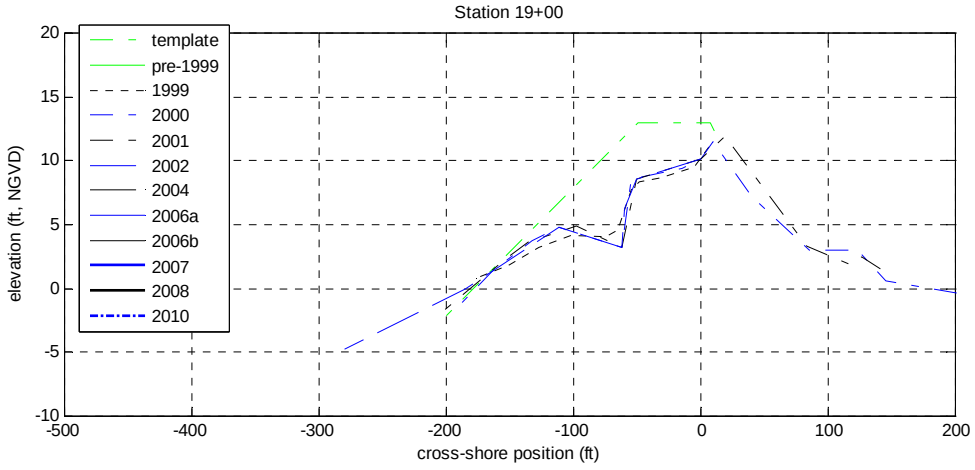
Station 19+00
template
pre-1999
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2006a
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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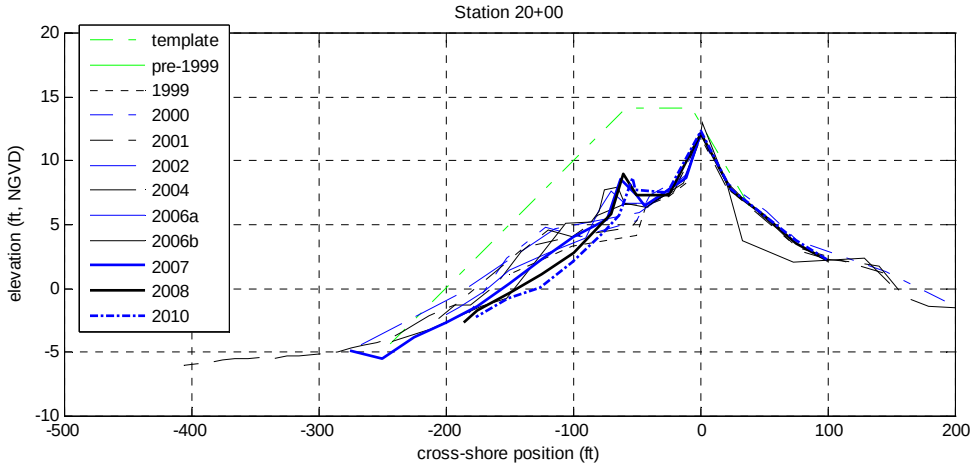
Station 20+00
template
pre-1999
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2006a
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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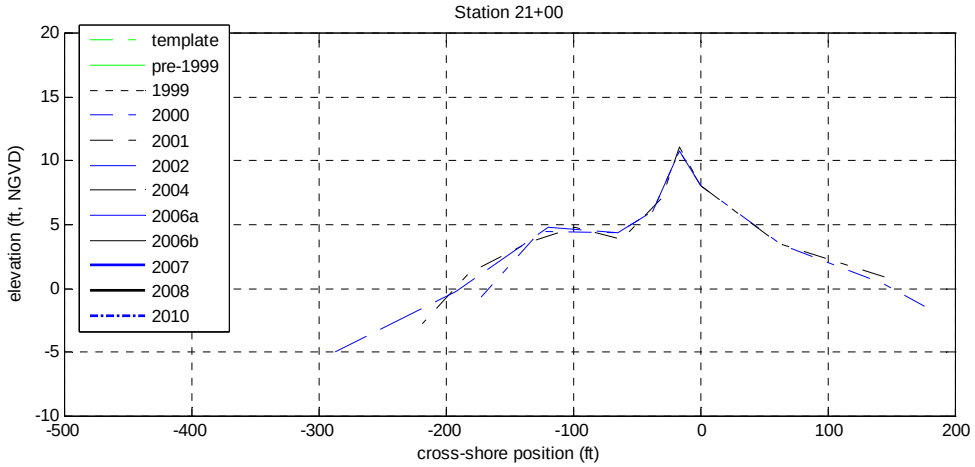
Station 21+00
template
pre-1999
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2006a
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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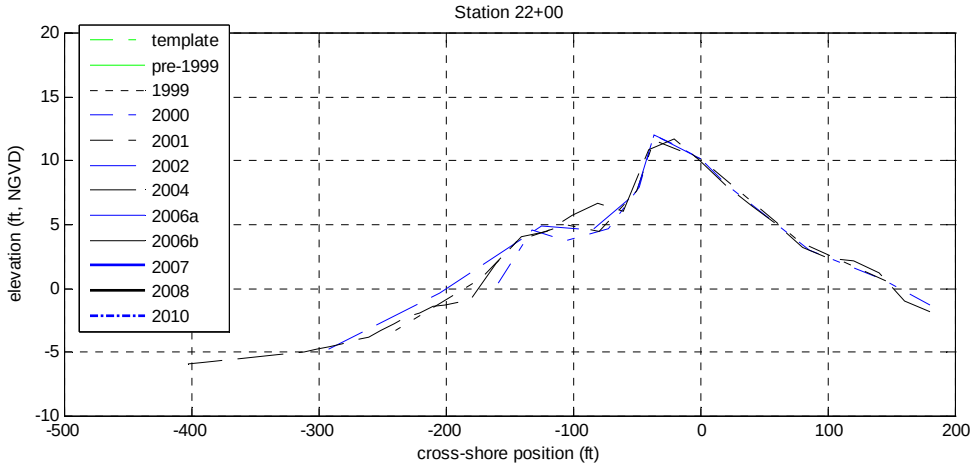
Station 22+00
template
pre-1999
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elevation (ft, NGVD)
cross-shore position (ft)
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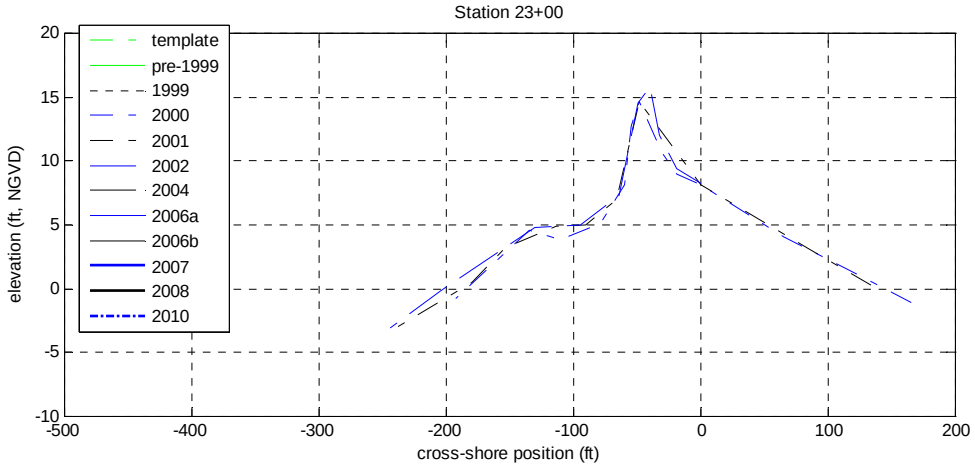
Station 23+00
template
pre-1999
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2006a
2006b
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2010
elevation (ft, NGVD)
cross-shore position (ft)
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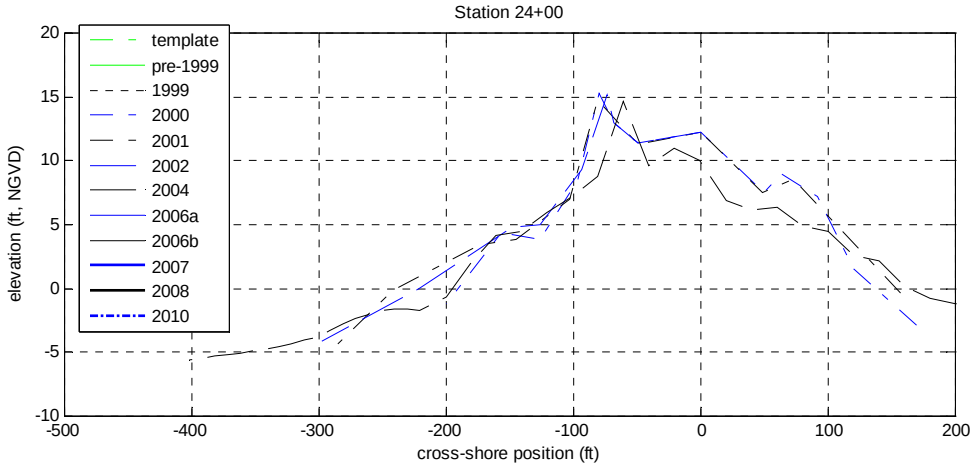
Station 24+00
template
pre-1999
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elevation (ft, NGVD)
cross-shore position (ft)
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