SBEACH High-Frequency Storm Erosion Model Study for Franklin County

By

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1. Background

High-Frequency storm tide studies have been conducted by the Beaches and Shores Resource Center (BSRC) and the Division of Water Resource Management (DWRM) for 20 of the 24 CCCL studied counties since 2009. Hydrographs with return intervals of 15- and 25-year were developed for the application of dune erosion models. Due to increased usage of SBEACH (Storm-Induced BEAch CHange) by coastal engineers for coastal projects in Florida, the Bureau of Beaches and Coastal Systems (BBCS) of Florida Department of Environmental Protection (FDEP) contracted with the BSRC to conduct the model calibration and application on a county by county basis. A total of eight counties: Walton, Okaloosa, Brevard, St. Johns, Volusia and Indian River by Leadon and Nguyen (2009 and 2010), Sarasota, Palm Beach by Wang and Manausa (2013), were completed. Since 2014, the SBEACH study has been conducted by the Engineering, Hydrology and Geology Program (EHG) of the DWRM and Lee County was completed (Wang and Manausa, 2015) before the current Franklin County study. The SBEACH model, Version 4.03, for high-frequency storm event is used in verification for armoring project and shore/dune protection project permit application.

The SBEACH model developed by the U.S. Army Corps of Engineers (USACE), is an empirically based numerical model for predicting short-term profile response to storms. The SBEACH model calculates beach profile changes with emphasis on beach and dune erosion and bar formation and movement. It is a cross-shore sediment transport model so the longshore processes are considered to be uniform and neglected in the calculation of profile changes. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements and sensitivity testing (Larson and Kraus, 1989).

To accurately apply the SBEACH model for a high-frequency storm event, it is essential to have the model calibrated in the project area under similar storm conditions. This requires detailed pre- and post-storm beach profile surveys that represent a storm's effects upon cross-shore beach change, and coincident information regarding the wind, wave and water level conditions. This study presents eroded dune and beach profiles due to high frequency storm events with return intervals of 15 years and 25 years in Franklin County using the latest version of the SBEACH model. All data resources for calibration and input files required to run the SBEACH model are documented.

2. Model Calibration

Searches for available surveyed beach profiles associated with a tropical storm or hurricane for Franklin County resulted in a limited data set with sufficient completeness and quality for model calibration. A set of beach profiles in part of Franklin County were surveyed before and after Hurricane Dennis of 2005. The model calibration became possible with the help of BSRC's 2-D Storm Surge Model to make up for the lack of measured storm tides on the open coast.

2.1 Storm Data

Tropical storms and hurricanes since 1900 that passed within 80 n.m. radius from the center of Franklin County shoreline with a pressure deficit larger than 0.3 in. Hg are listed in Table 1. Hurricane Dennis of 2005, which was 96 n.m. away from the center of Franklin County, was not among the 29 listed storms, but was selected for the model calibration due to the available pre- and post-storm surveys. The other reason was the measured storm tide levels in the Dog Island area classified Hurricane Dennis as a high frequency storm for Franklin County.

Table 1 A Sampling of Historical Storms near Franklin County

No.	Date	Name
1	6/11/1901	
2	6/12/1902	
3	9/9/1903	
4	6/8/1906	
5	8/8/1911	
6	8/31/1915	
7	9/27/1924	
8	9/11/1926	
9	8/7/1928	
10	7/19/1929	
11	9/9/1932	
12	7/27/1936	
13	8/24/1937	
14	8/7/1939	
15	10/3/1941	
16	9/14/1953	
17	6/4/1966	ALMA
18	6/14/1972	AGNES
19	5/21/1976	
20	8/28/1985	ELENA
21	11/15/1985	KATE
22	6/3/1995	ALLISON
23	7/31/1995	ERIN
24	10/14/1996	JOSEPHINE
25	8/3/2004	BONNIE
26	8/25/2004	FRANCES
27	6/10/2006	ALBERTO
28	8/15/2008	FAY
29	6/23/2012	DEBBY

Dennis traversed a long section of western Cuba before emerging into the Gulf of Mexico just east of Havana around 0900 UTC 9 July. Dennis weakened significantly over Cuba, with the maximum sustained winds decreasing to 75 kt by the time the center left the island.

Dennis gradually intensified for the next 6-12 h over the Gulf of Mexico, then began another cycle of rapid intensification near 1800 UTC 9 July, accompanied by a turn toward the north-northwest. During this intensification, the central pressure fell 37 mb in 24 h, including 20 mb in 6 h and 11 mb in 1 h 35 min. Maximum sustained winds reached a third peak of 125 kt near 1200 UTC 10 July. Thereafter, weakening occurred, likely due to mid/upper-level dry air from the western Gulf of Mexico entrained into the hurricane. The maximum sustained winds decreased to 105 kt and the central pressure rose to 946 mb before Dennis made landfall on Santa Rosa Island, Florida, between Navarre Beach and Gulf Breeze, about 1930 UTC 10 July (Beven 2014). The "best track" chart of Dennis' path is given in Figure 1

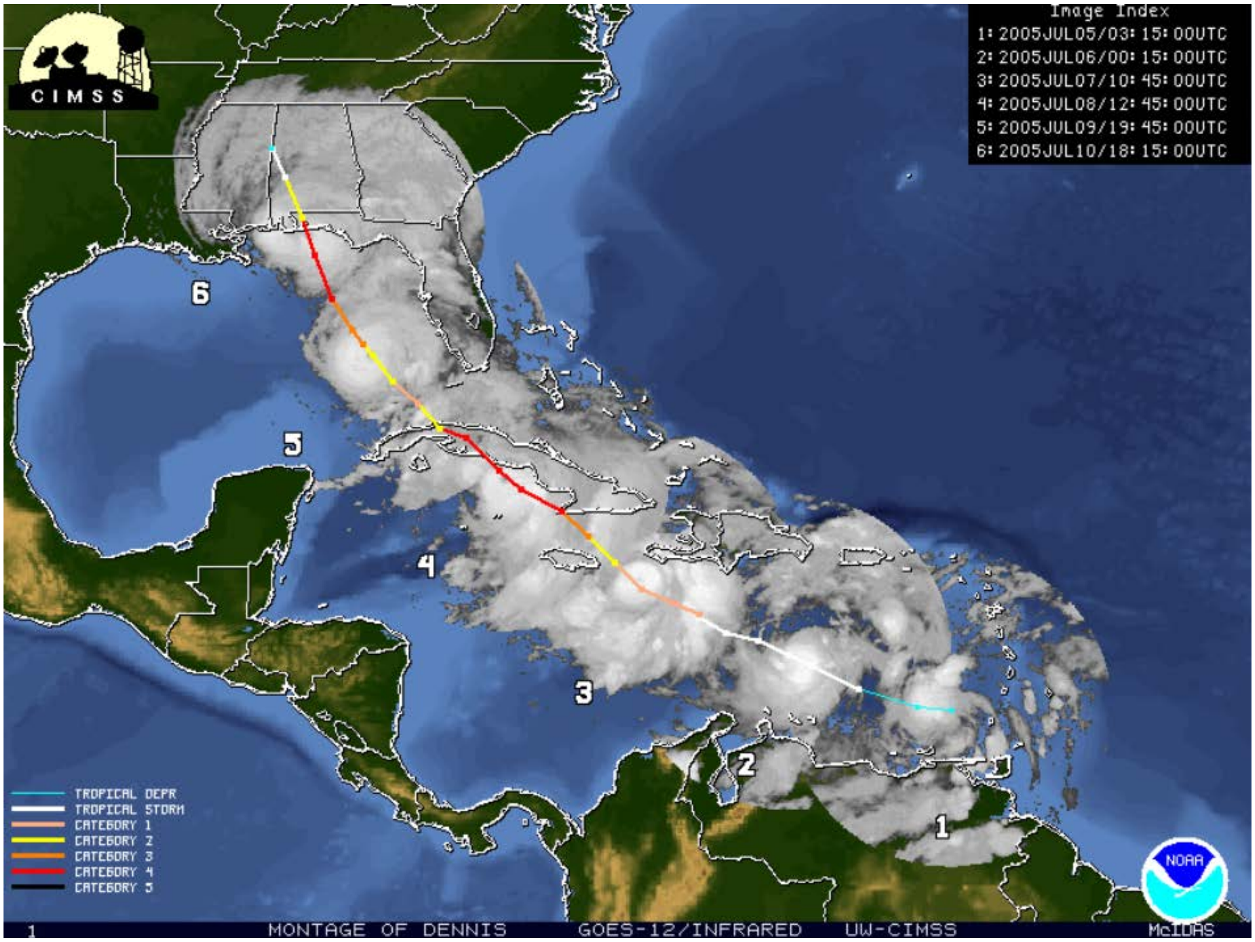

Figure 1. Hurricane Dennis track, 5-10 July 2005. (Source: CIMSS, UW-Madison).

2.1a Storm Tide Data

For the purpose of model calibration, the measured storm tide and wave data generated by Hurricanes Dennis are essential. The URS Group, Inc. was contracted by the Federal Emergency Management Agency (FEMA) to collect and survey Coastal High Water Marks (CHWMs) in the Dennis Impacted areas. For the purpose of Storm Tide calibration, only the interior High Water Mark (HWM) data from beach areas were selected to evaluate the storm tide associated with Hurricane Dennis. Two inside HWM observations for the Dog Island area in Franklin County were available and the HWM data and location descriptions are listed in Table 2 (FEMA, 2015). To verify those measured HWM data and to provide the additional areas with predicted storm tides, the 2-D Storm Surge Model was employed to calculate the total storm tide, i.e. surge generated from barometric pressure and wind stress plus dynamic wave setup and astronomical tide. Hurricane track, pressure deficit, radius to the maximum wind (RMW) of Dennis for 36 hours were input to the 2-D Storm Surge Model. The Model then ran and calculated the total storm tide for 3 locations in Franklin County. Figure 2 displays the results of model calculated total storm tides and the measured HWM. The 2-D Storm Surge Model calculated peak storm tide by Hurricane Dennis agree closely with the measured HWM. Table 3 gives the storm tide values and corresponding return periods for Franklin County.

Table 2 High Water Marks data in Franklin County during Hurricane Dennis

Location/HWM ID	Peak Surge (ft.-NAVD)	Lat.(N)	Lon.(W)	HWM Object
Dog Island/DFLC-14-06	8.5	29.792051	84.617760	Water line on door jamb
Dog Island/DFLC-14-07	8.4	29.782297	84.664133	Water line on door jamb

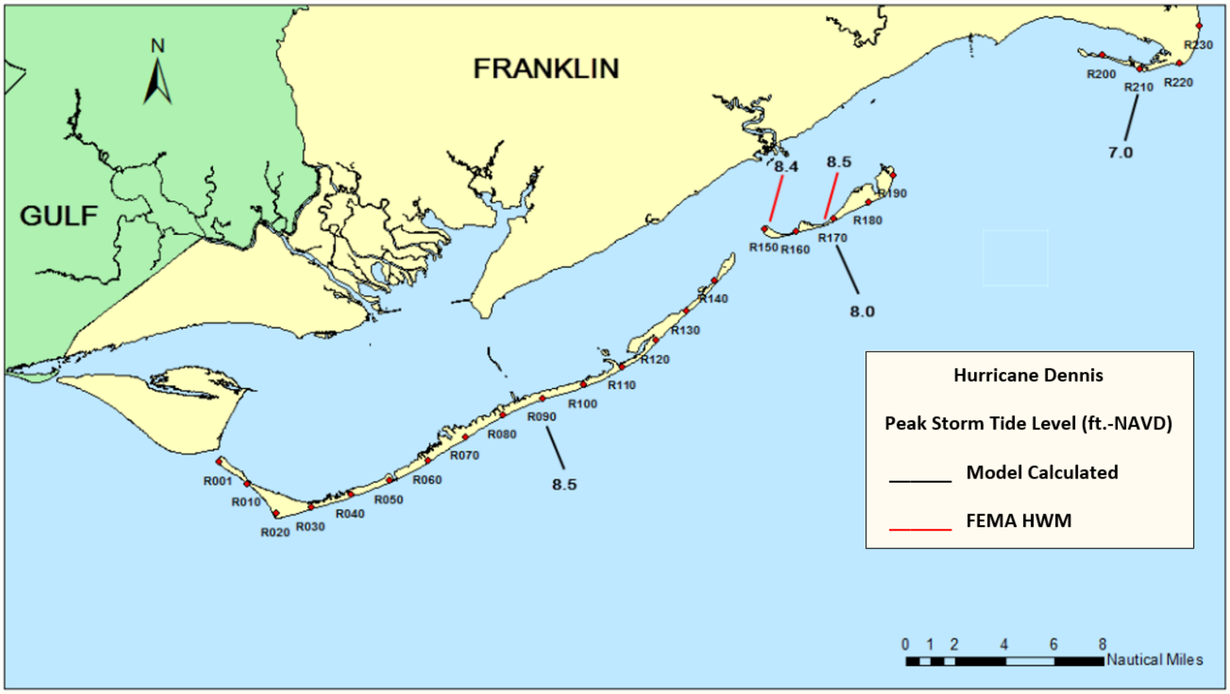

Figure 2. Peak Surge Levels in Franklin County for Hurricane Dennis.

Table 3 Storm Tide Values* (ft.-NAVD) for Various Return Periods

Return Period, (years)	R-25	R-90	R-130	R-170	R-210
50	9.5	9.7	10.2	10.4	10.6
30	8.3	8.6	8.7	8.9	8.8
25	7.9	8.1	8.2	8.4	8.4
20	7.4	7.6	7.7	7.8	7.7
15	6.9	6.9	7.1	7.0	6.9
10	5.9	5.9	6.0	5.9	5.8
5	3.9	3.8	3.9	4.0	3.6

*Includes contributions of: wind stress, barometric pressure, dynamic wave set-up and astronomical tide.

By comparing the 2 measured HWM and the 3 calculated storm tides with the Storm Tide Values for Various Return Periods listed in Table 3, it shows that Hurricane Dennis generated storm tides ranging between 15 and 30 years return period for Franklin County area. Therefore, Hurricane Dennis is qualified as a high frequency storm and its hydrograph generated by the 2-D Storm Surge Model is applied for the SBEACH Model calibration.

2.1b Wind and Wave Data

There are no wave measurements available over the northern West Florida Shelf (WFS) during Hurricane Dennis. Young's model (Young 1988) for fetch-limited waves was used to estimate the deep-water wave height (H_0) and the spectral peak period of the wave (T_0) by Dukhovskoy and Morey (2010) for a study to simulate the Hurricane Dennis storm surge in the Apalachicola Bay area:

$$H_0 = 0.0016\, W^2_{10} / g\, (gF / W^2_{10})^{0.5}$$

$$T_0 = 0.045\, (2\pi\, W_{10} / g)\, (gF / W^2_{10})^{0.33}$$

where W_{10} is 10-m wind speed and F is wind fetch.

Wind fields used in the model reveal that the maximum sustained wind over the WFS during Hurricane Dennis were in the range 20–25 m s-1, which is in agreement with the data collected by Clark and LaGrone (2006). The maximum sustained wind measured in this area (NOAA NDBC, Buoy 42036, 28.500N 84.517W, location about 75 miles south of Franklin county) was 23.5 m s-1. Surface wind fields as shown in Figure 3 indicated that wind speeds were between 40 and 50 kt. (20.6 and 25.7 m s-1) in the Franklin County area. Therefore, deep-water wave height in the studied region is in the range from 3.2 to 4.04 m and wave period is from 7.6 to 8.2 m s-1.

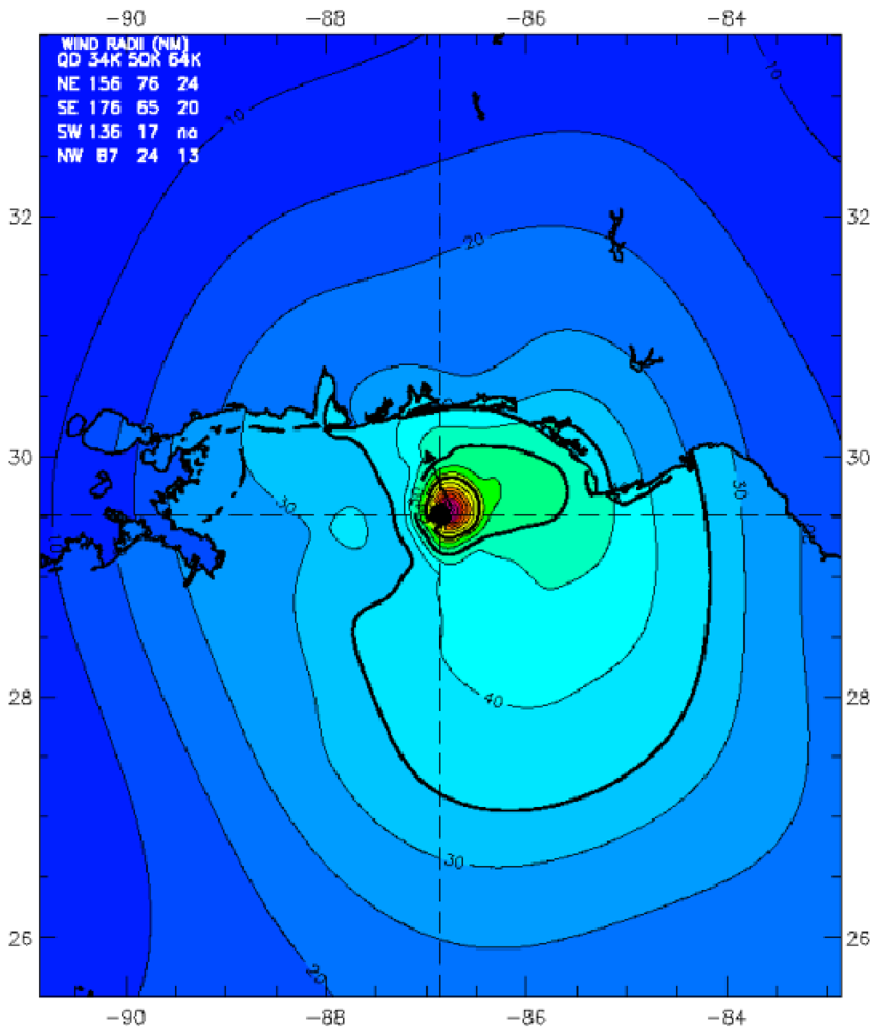

Figure 3. Surface Wind Fields Associated with Hurricane Dennis before landfall (HWind Scientific).

2.1c Hydrographic Survey Data

University of Florida and USACE conducted Pre-and Post-Dennis LiDAR surveys for Dog Island in November 2004 and July 2005, respectively. Pre-Dennis Beach profiles extracted from the LiDAR data were combined with 2006 offshore data for SBEACH input. A total of 13 profiles from R-172 to R-183, all of which are located at the windward side of Hurricane Dennis and show consistent erosion were selected for the model calibration. The map in Figure 4 shows the location of the profiles selected for the SBEACH model calibration and the storm tide calculated with the 2-D Storm Surge Model.

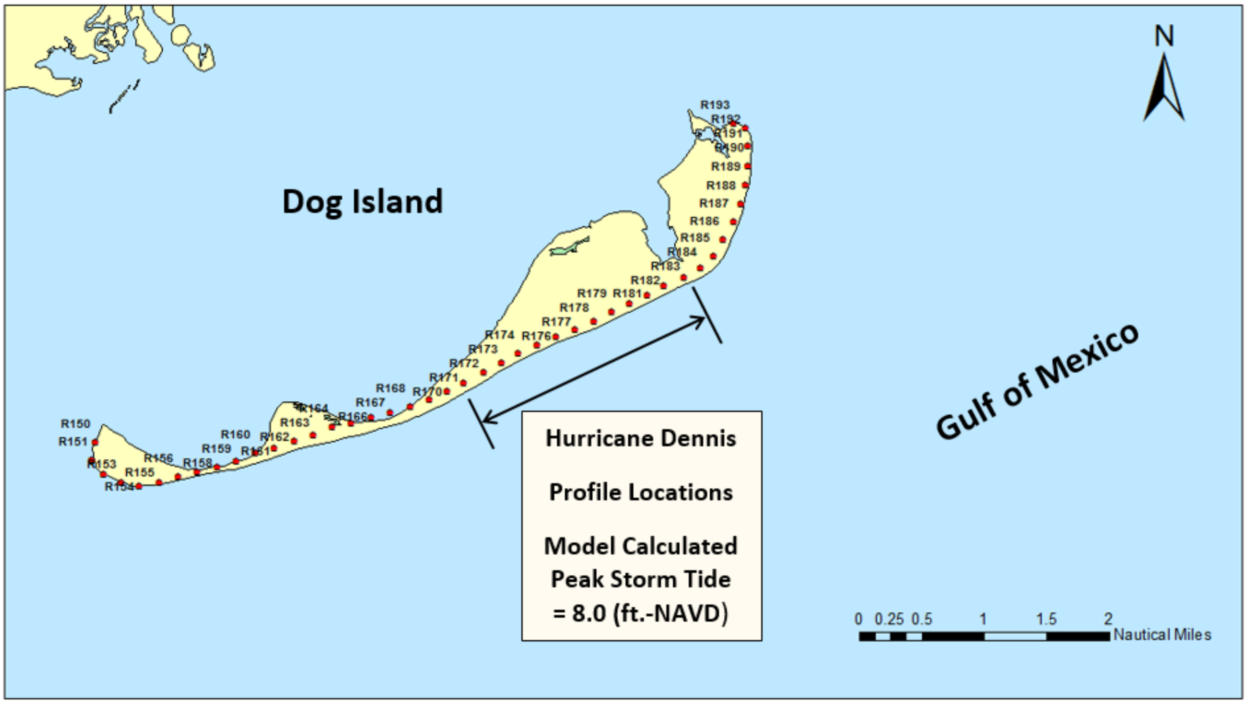

Figure 4: Locations of profiles and the calculated storm tide used in SBEACH calibration.

2.2 Model Input Parameters

The SBEACH model's primary input includes profile, storm and sediment data. Profile data are selected based on the segment of shoreline being modeled. Mean grain size of the beach material is one of the primary sediment data required. Other inputs include model parameters such as grid size, time step, and the transport rate coefficient.

The beach profiles were represented in the model using a constant grid scheme with grid cell spacing of 5 feet in order to generate a detailed result. Each reach was approximately 3,400 feet long and had about 680 cells of 5 feet across, well below the 1,000 cell limit allowed by the SBEACH model. Sediment data was obtained from the beach sediment survey in the Florida's northwest coast (Daniel et al, 2011). For the model calibration area, R-171 to R-183 of Dog Island, carbonate material averaged 0.1 percent of the sample sediments and the average mean grain size was 0.32 mm.

The default values for SBEACH are shown in Table 4. A series of model runs were conducted within the range of recommended values to achieve the best fit between measured and SBEACH calculated erosion profiles.

Table 4 Listing of SBEACH Input Parameters

Parameters	Unit	Default Value	Range of Recommended Values
Transport rate coefficient, *K*	m^4 /N	1.75 e^{-006}	0.25 e^{-006} - 2.5 e^{-006}
Overwash transport parameter		0.005	0.002 - 0.008
Coefficient for slope dependent term, ε	m^2/s	0.002	0.001 - 0.005
Transport rate decay coeff. multiplier, λ	m^{-1}	0.5	0.1 - 0.5
Landward surf zone depth	ft.	1.0	0.5 - 1.6
Effective grain size (mean D_{50})	mm	0.35	0.15 – 1.0
Maximum slope prior to avalanching	degree	45	15 - 90 deg.
Water temperature	degree, C	20	0 - 40

2.3 Model Calibration Results

The sensitivity evaluation resulted in initially setting most of the model input parameters at or near the default values as described above. Wind speed and direction, available as options during the model input were not included due to its insignificant effect in the model results. For each SBEACH run, only the hydrographs without wave setup that were generated by 2-D Storm Surge Model were entered, the SBEACH model then calculated and added the wave setup internally to reach the desired final water level. The hydrographs without wave setup were then adjusted for the 13 selected profiles, such that the peak water elevation output from SBEACH were in agreement with the peak storm tide values calculated by the 2-D Storm Surge Model for Hurricane Dennis.

The average measured versus the SBEACH calculated erosion distance for contours from 3 to 15 feet above NAVD 88 of the 13 profiles were used as the principle basis for determining the calibration parameters setting. Since a constant wave height and period will be used for the purpose of practical county wide application of SBEACH, different constant wave heights and periods were tested to generate a comparison between the model calculated erosion profiles and the measured post-storm profiles. It was found that a constant deep water wave with 12 foot wave height and 8 second wave period calculated by Dukhovskoy and Morey (2010) matched well with the calculated results from the measured ones.
Starting with the default values, a series of values for each calibration parameter were tested. The transport rate coefficient, *K,* the transport rate decay coefficient, the coefficient for slope dependent term, ε, and the maximum slope prior to avalanching were found to be significant to the calibration results, so they were adjusted individually until reasonable agreement with the measured erosions were achieved.

The final parameter values were determined as those providing the best presentation of measured erosions for the 13 selected profiles. The final parameter values resulting from the model calibration are summarized in Table 5. Figure 5 shows comparisons of average contour recessions between the measured and SBEACH model computed for Hurricane Dennis based on the final model parameters described above. Plots of pre-storm, post-storm, and SBEACH model predicted profiles with the final calibration parameters for each of the 13 profiles are presented in Appendix A.

Table 5 SBEACH Model Calibration Parameters for Franklin County

Parameters	**Unit**	**Values**
Transport rate coefficient, K	m^4 /N	2.5 e^{-006}
Overwash transport parameter		0.005
Coefficient for slope dependent term, ε	m^2/s	0.003
Transport rate decay coeff. multiplier, λ	m^{-1}	0.1
Landward surf zone depth	ft.	1.0
Effective grain size (mean D_{50})	mm	0.32
Maximum slope prior to avalanching	degree	30
Water temperature	degree, C	27
Wave Input Conditions		
Wave Height, H	ft.	12
Wave Period, Tp	Sec.	8
Wave Direction, α	degree	0 (shore-normal)

The 13 selected profiles were used as inputs to the SBEACH model in order to compare erosion differences that were due to the parameter sensibility. Average erosion distances above 3 foot NAVD88 at each foot contour were compared between the model predicted and measured so the best SBEACH model parameters could be achieved.

Differences of average erosions between model predicted with constant waves and pre- and post-storm measured were within 10 feet at all contours. The SBEACH model predicted erosions with the calibrated parameters (Table 5) came to a close agreement with the measured ones, especially for contours between 5 and 8 feet, which were impacted the most by the given 8 foot storm tide.

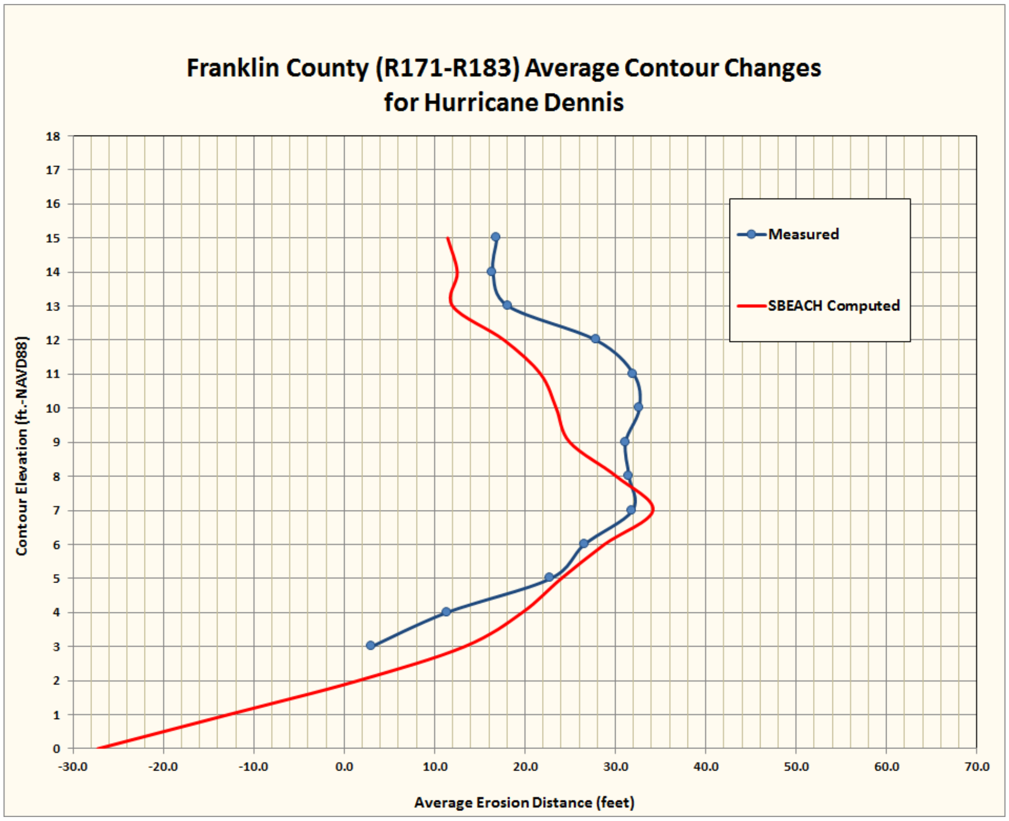

Figure 5: Comparisons of average contour changes between measured and SBEACH model computed for Hurricanes Dennis.

3. Franklin County SBEACH Application

3.1 Model Configuration

Application of the SBEACH model in Franklin County for high-frequency storm erosion will be primarily based on the model calibration results, as shown in Table 5 of the previous section. Countywide sediment data was obtained from the beach sediment survey in the Florida's southwest coast and Keys (Daniel et al, 2011). Figure 6 presents the mean grain size distribution throughout Franklin County. The wave height was set as 10 ft., which was averaged from the wave heights applied in the other counties for a typical high frequency storm, as listed in Table 6. A 10 foot wave height with a 10 second wave period were chosen as reasonable approximations for a generic high frequency storm that would impact this area. Franklin County storm tides developed by Wang and Manausa (2013) for 15- and 25-year storms are shown in Table 7.

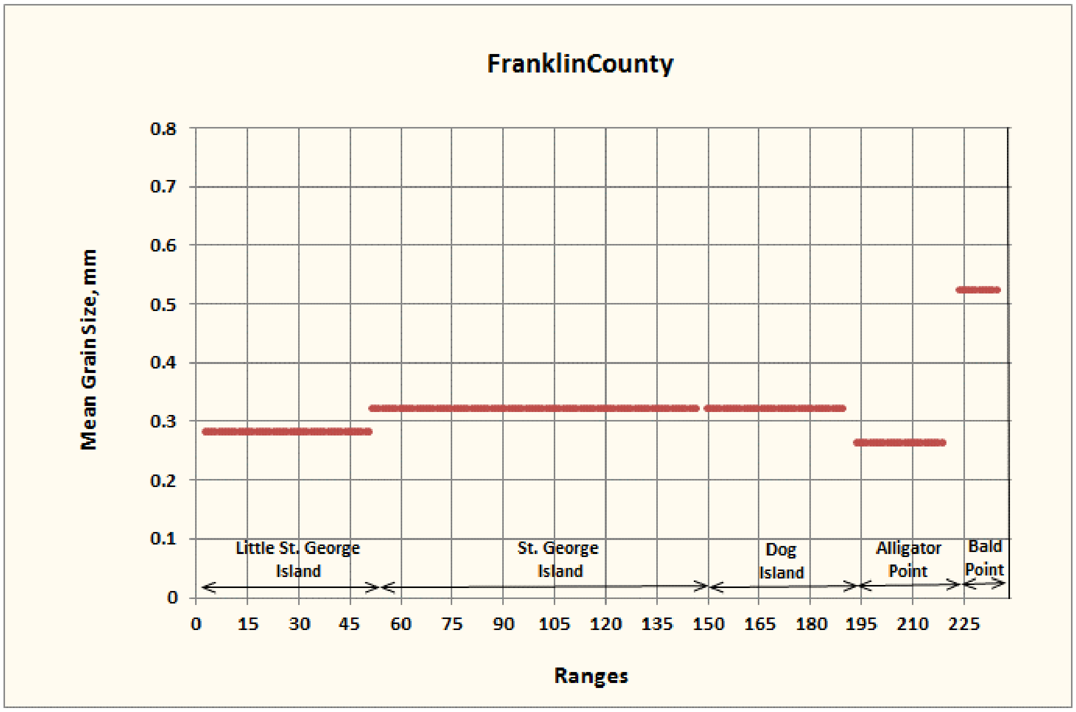

Figure 6: Sediment data distributions in Franklin County.

Table 6 Wave Heights Used in Florida Counties for SBEACH Applications

County	Wave Height (ft.)	Reference
Brevard	12	Leadon and Nguyen, 2010
Indian River	12	Leadon and Nguyen, 2010
Palm Beach	15	Wang and Manausa, 2013
Pensacola Beach, Escambia	10	Olson Associates, 2014
St. Johns	10	Leadon and Nguyen, 2010
Sarasota	7	Wang and Manausa, 2013
Volusia	10	Leadon and Nguyen, 2010
Walton	10	Leadon and Nguyen, 2009

Table 7 High-Frequency Storm Tides Level* (ft.-NAVD) for Franklin County

Ranges	15-year Return Period	25-year Return Period
R-1 to R-20	5.8	6.8
R-21 to R-51	6.9	7.9
R-52 to R-110	6.9	8.1
R-111 to R-149	7.1	8.2
R-150 to R-193	7.0	8.4
R-194 to R-239	6.9	8.4

* Includes contributions of: wind stress, barometric pressure, dynamic wave set-up and astronomical tide.

As mentioned in the Model Calibration Results (Section 2.3), only the hydrographs without wave setup were applied since the SBEACH model calculated and added the wave setup internally to reach the final water level. The final model output water levels did not always agree with the desired 15- or 25-year storm tides at first run, therefore, the input hydrographs were then adjusted so the resultant SBEACH model peak water levels were equivalent to the predicated storm tides for each profile. Recommended Reach and Storm input values to be used in 15- and 25-year storm erosion calculations by SBEACH are listed in Appendix B. Time series values for the adjusted hydrographs without wave setup for each reach are shown in Figures 7 and 8 and are tabulated in Appendix C.

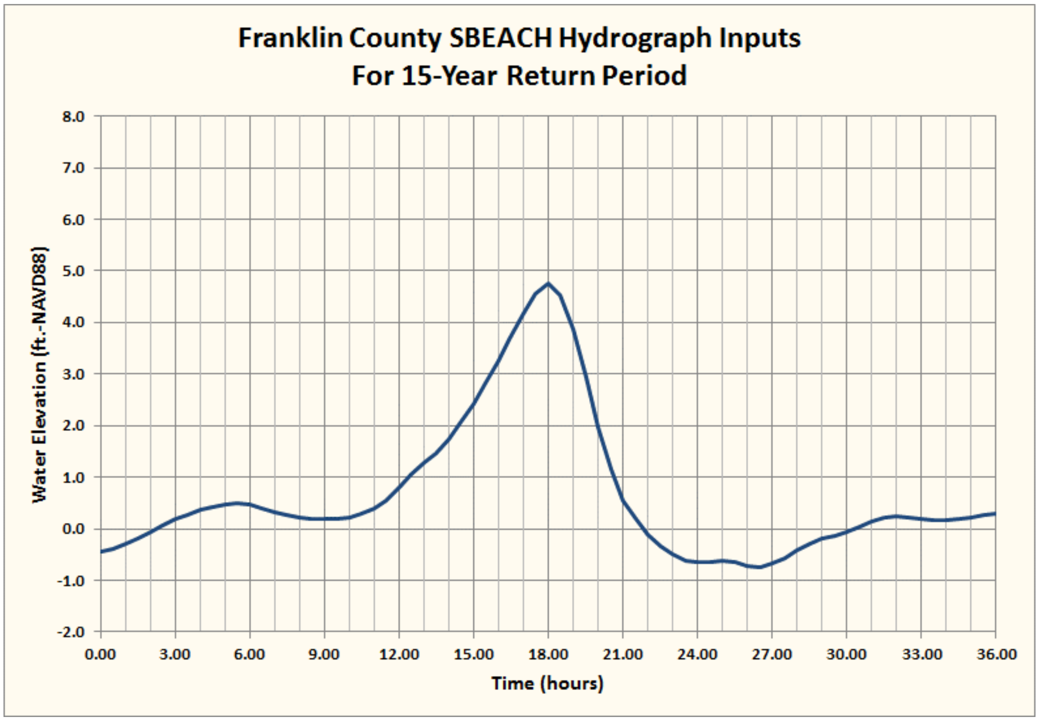

Figure 7: 15-year hydrographs for Franklin County profiles in SBEACH application.

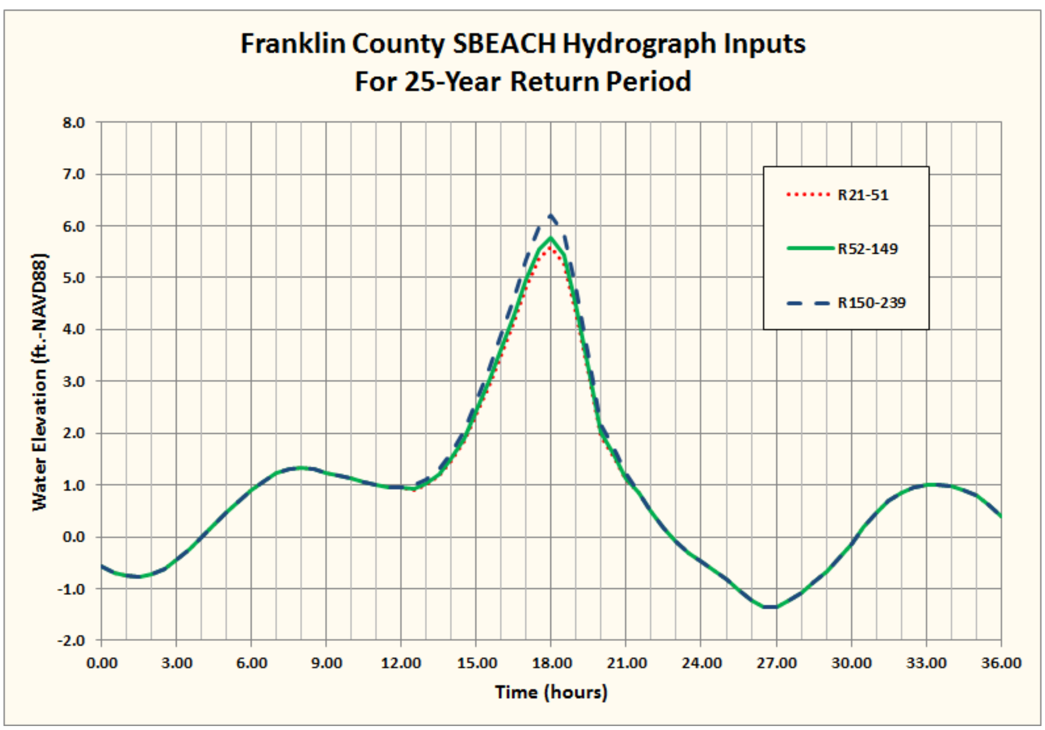

Figure 8: 25-year hydrographs for Franklin County profiles in SBEACH application.

3.2 Model Application and Results

Representative plots of surveyed profiles and their associated eroded profiles generated from SBEACH for the 15- and 25-year return periods for Franklin County are provided in Appendix D. Profiles at R-1 to R-20 and R-194 to R-239 were not included due to the lack of recent survey data. The most updated profiles available for Franklin County at present for SBEACH application are listed in Table 8.

Table 8 Profiles Used in SBEACH Application for Franklin County

Range	Beach Profile Date	Offshore Profile Date
21-50	Nov. 2008	Oct. 2008
51-81	Oct. 2008	Sep. 2008
82-85	Oct. 2008	Jan. 2009
86-149	Nov. 2008	Jan. 2009
150-193	April 2009	Jan. 2009

The plots in Appendix D are shown in the NAVD88 vertical datum. The map in Figure 9 below depicts the FDEP profile range locations along the Franklin County shoreline.

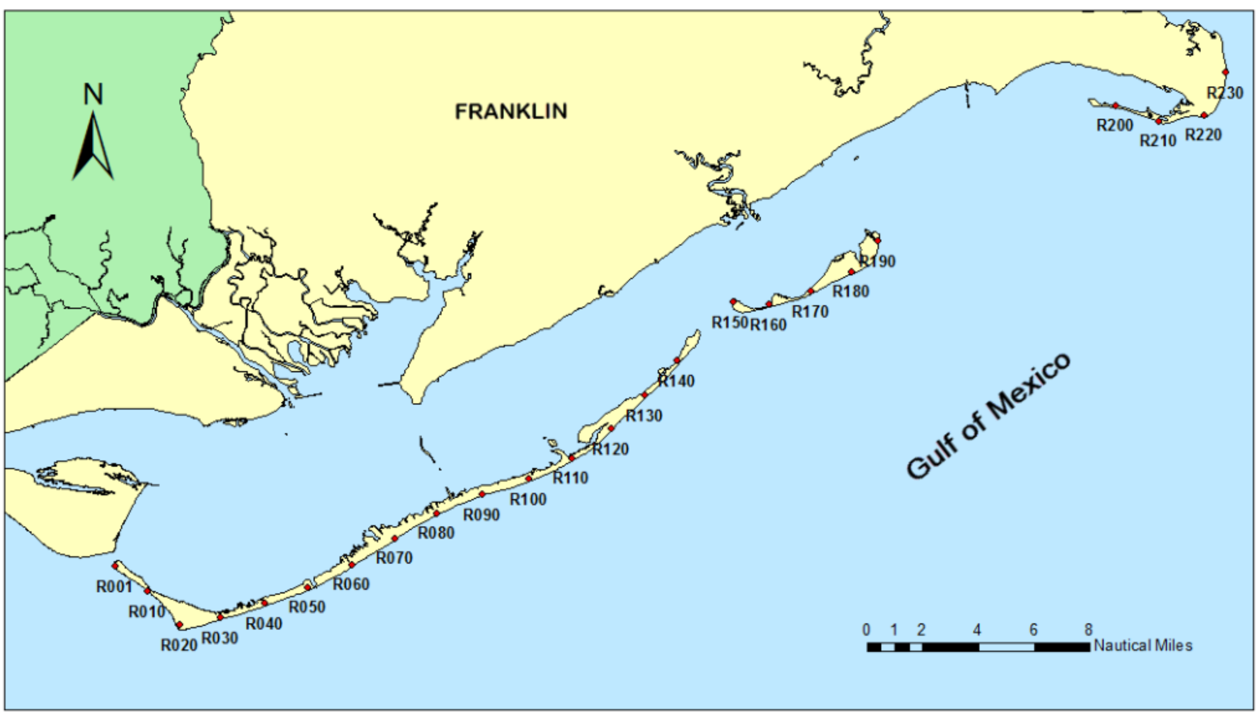

Figure 9: FDEP profile range locations along the Franklin County shoreline.

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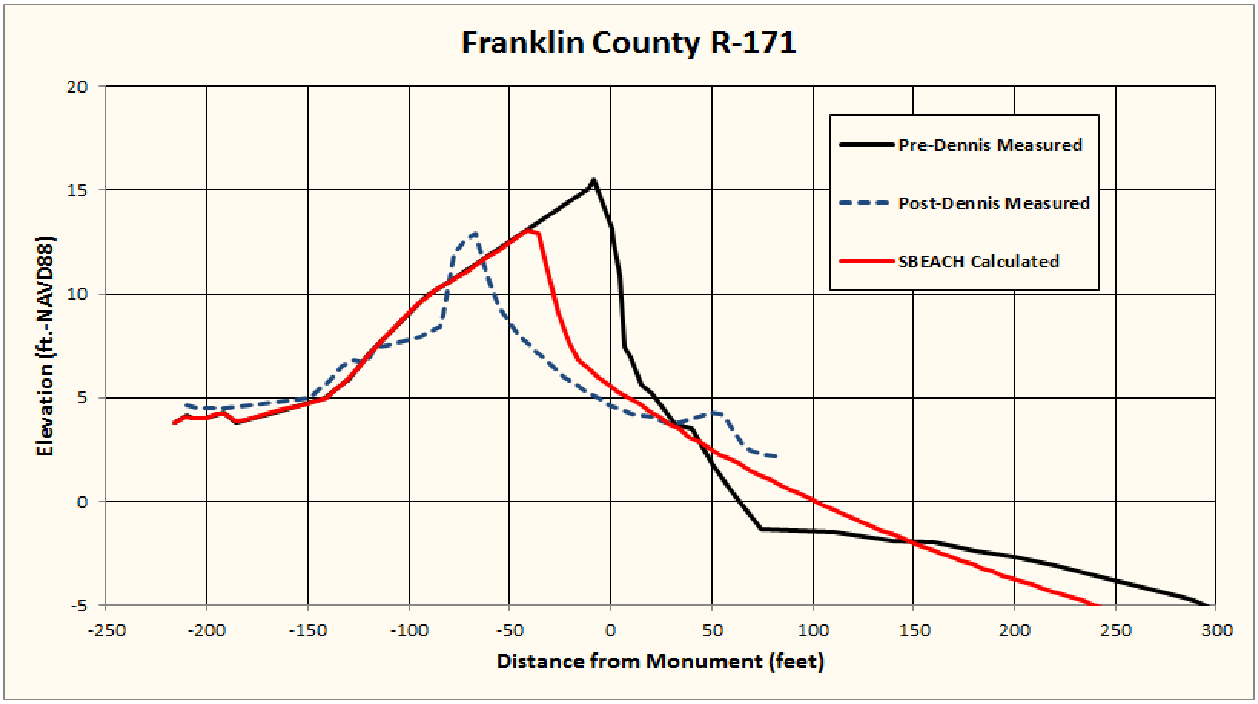
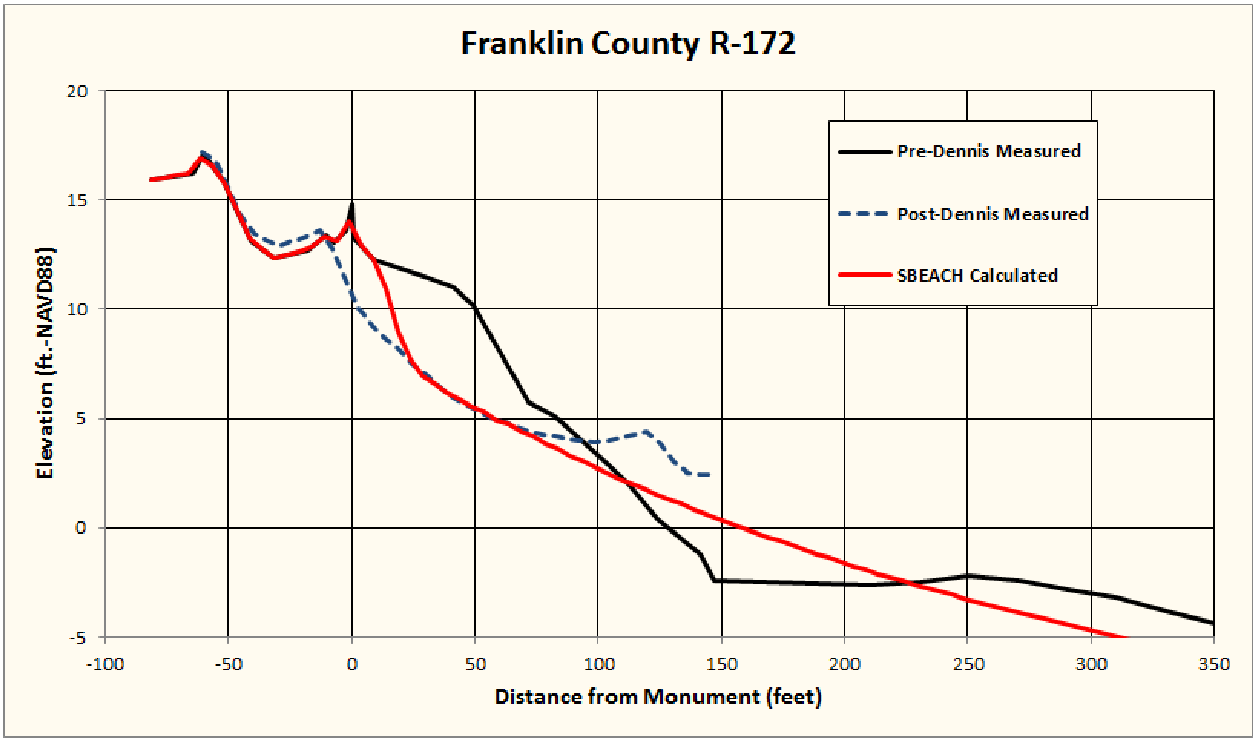
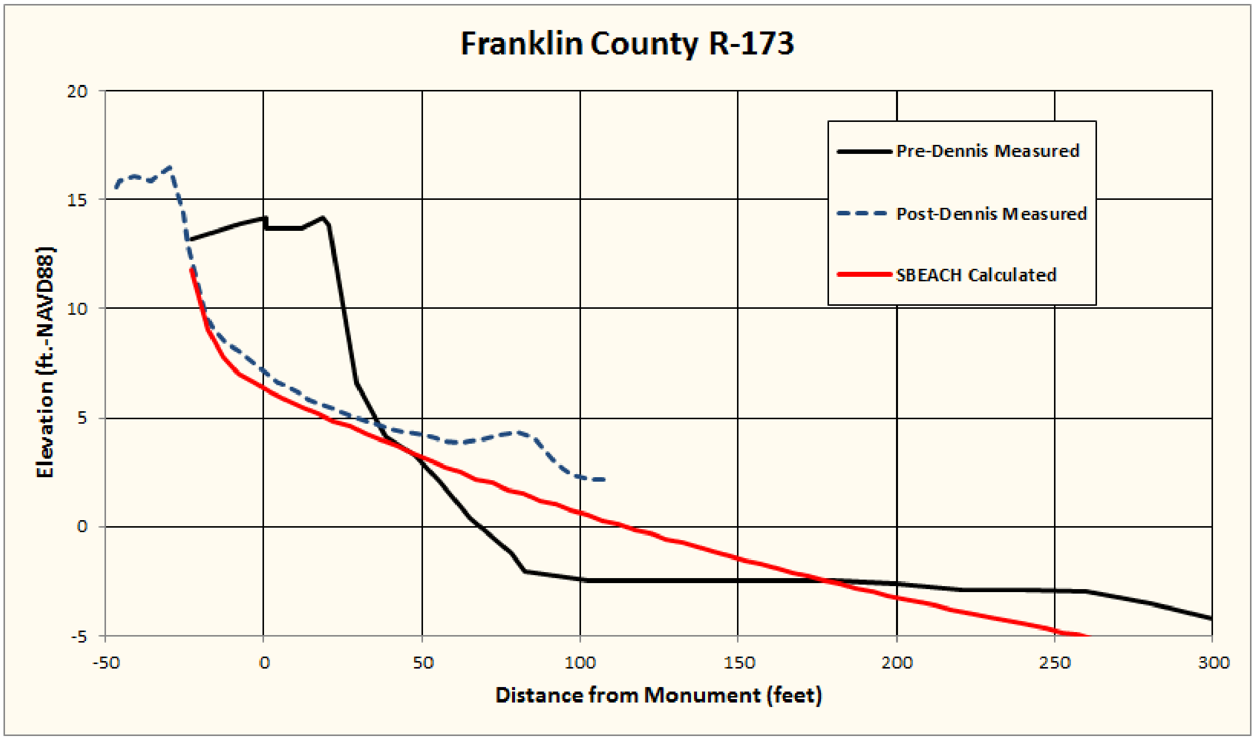
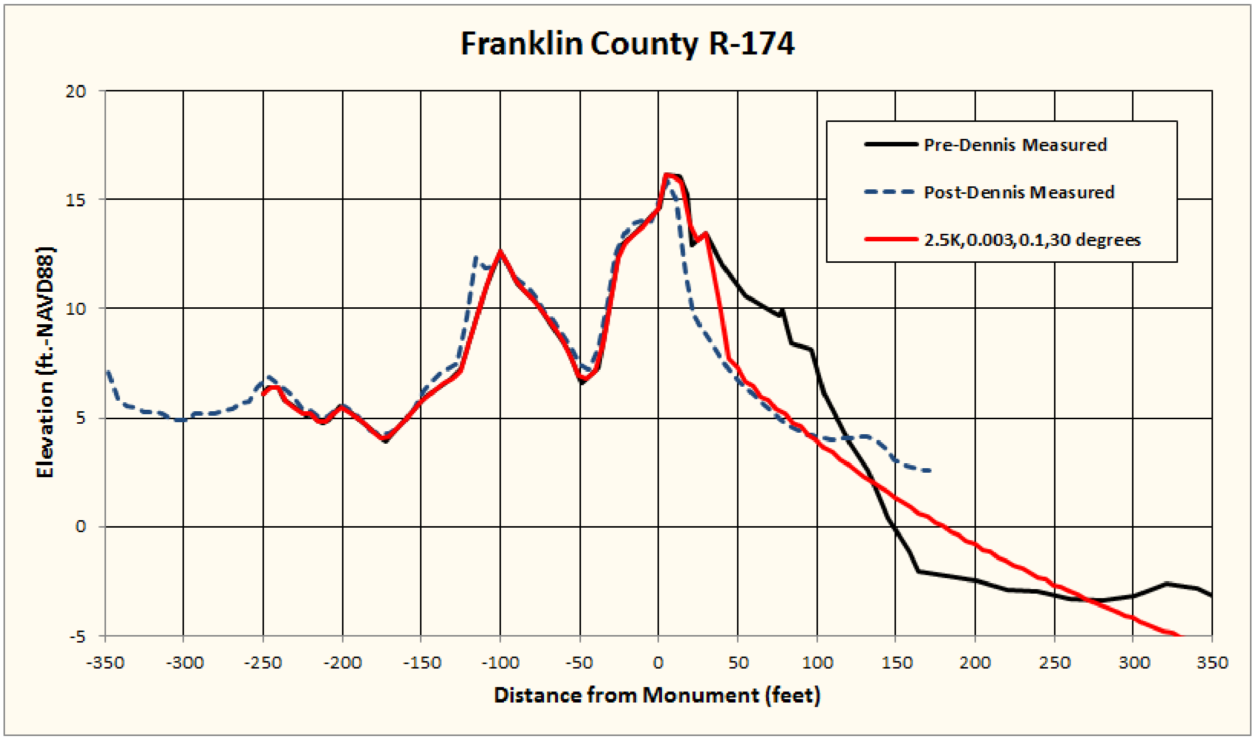
APPENDIX A

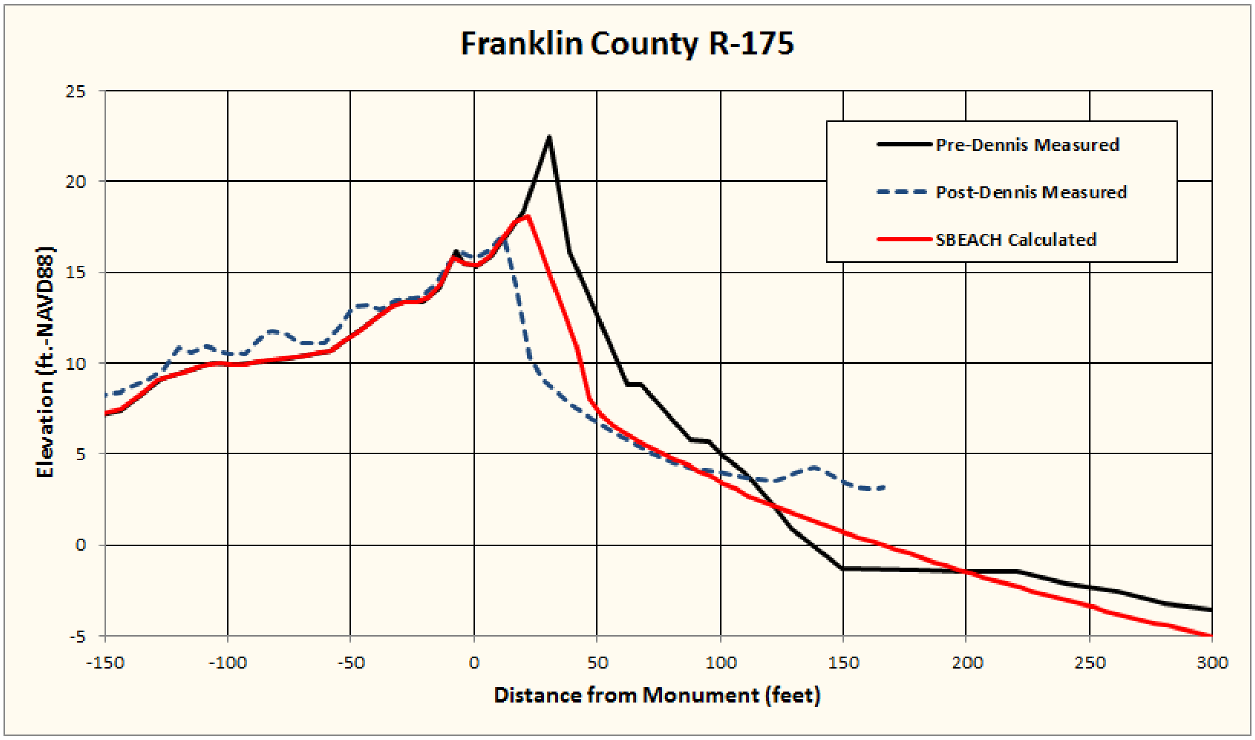
SBEACH Calibration Profiles for Franklin County


Franklin County R-171
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-250
-200
-150
-100
-50
0
50
100
150
200
250
300

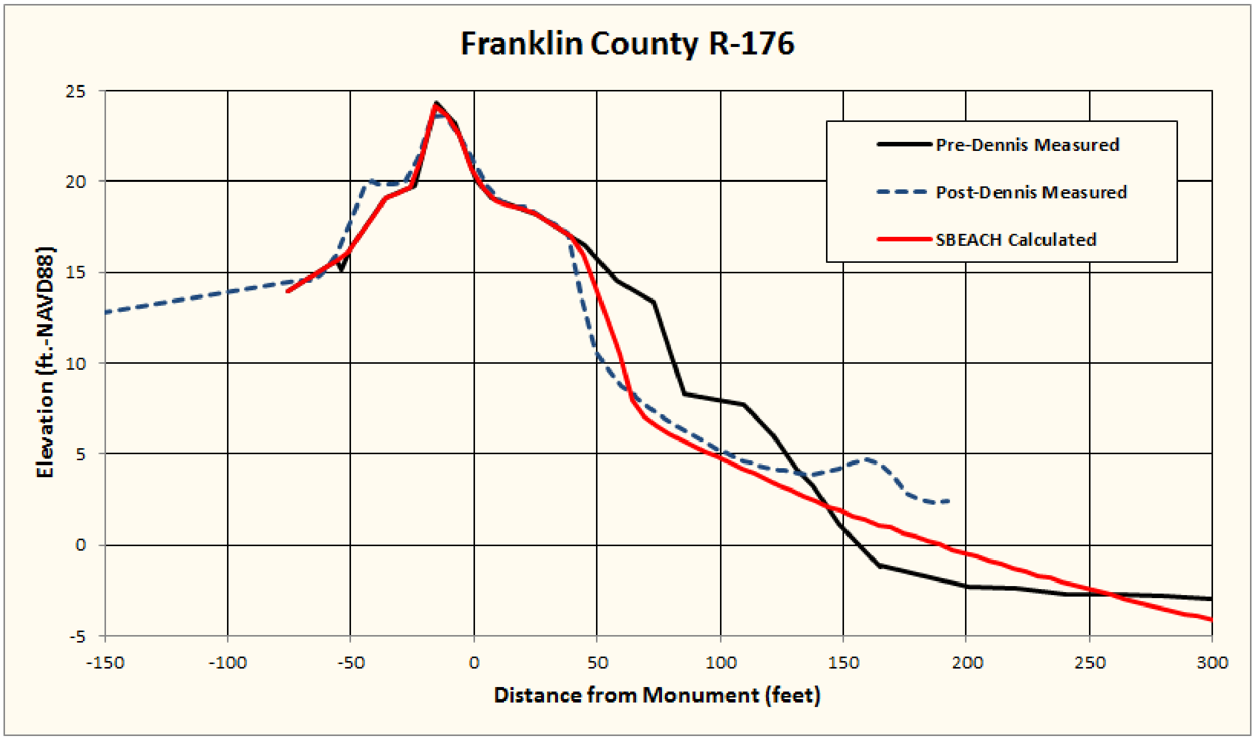

Franklin County R-172
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-100
-50
0
50
100
150
200
250
300
350


Franklin County R-173
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)

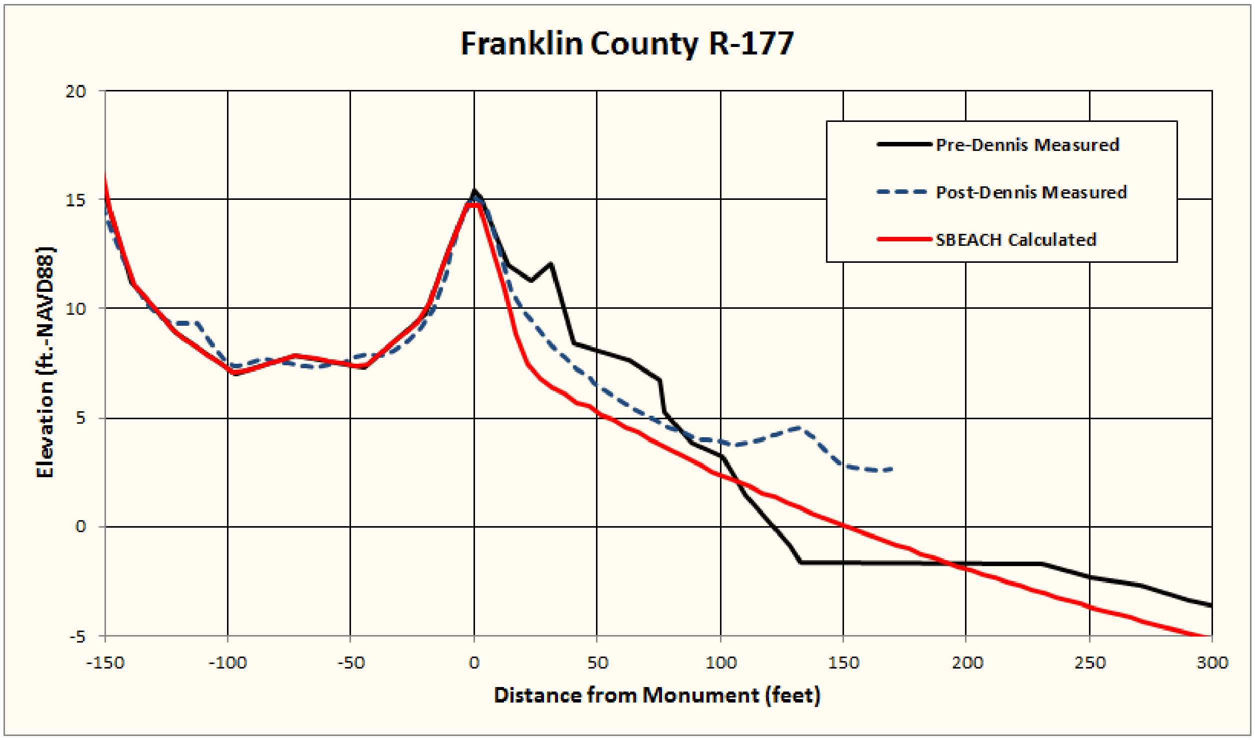

Franklin County R-174
Pre-Dennis Measured
Post-Dennis Measured
2.5K,0.003,0.1,30 degrees
Elevation (ft.-NAVD88)
Distance from Monument (feet)

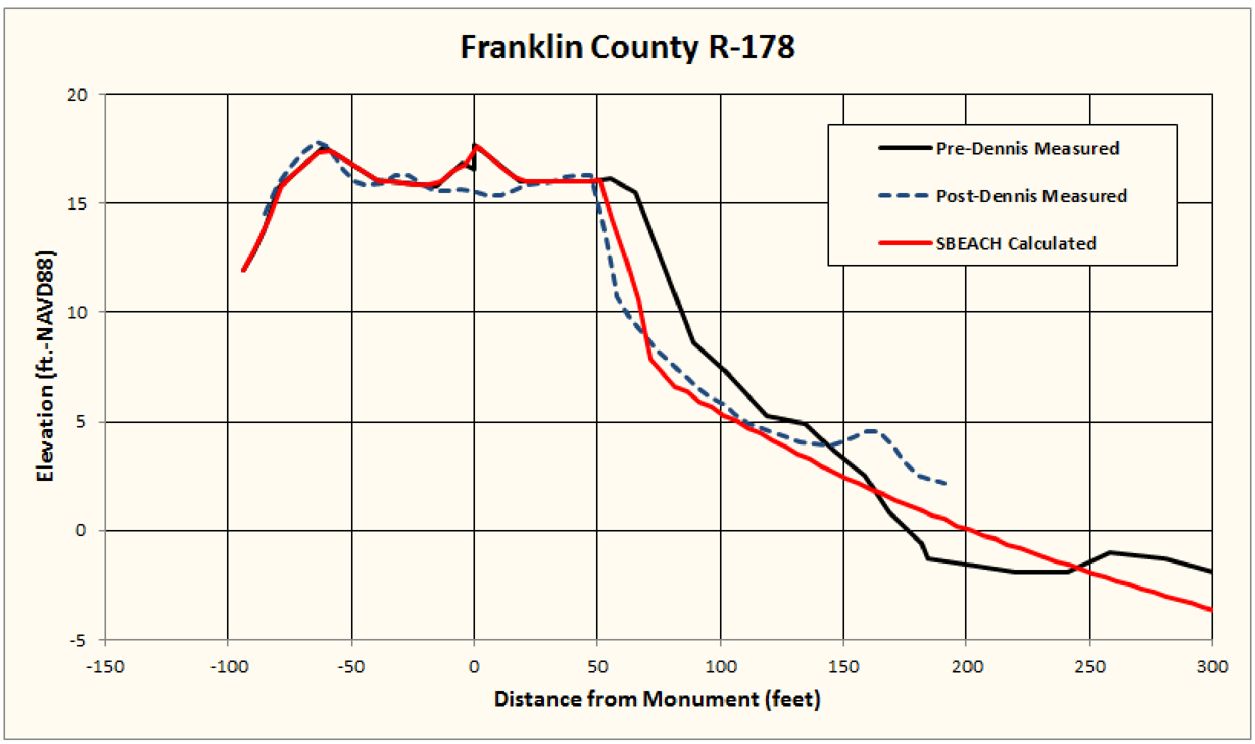


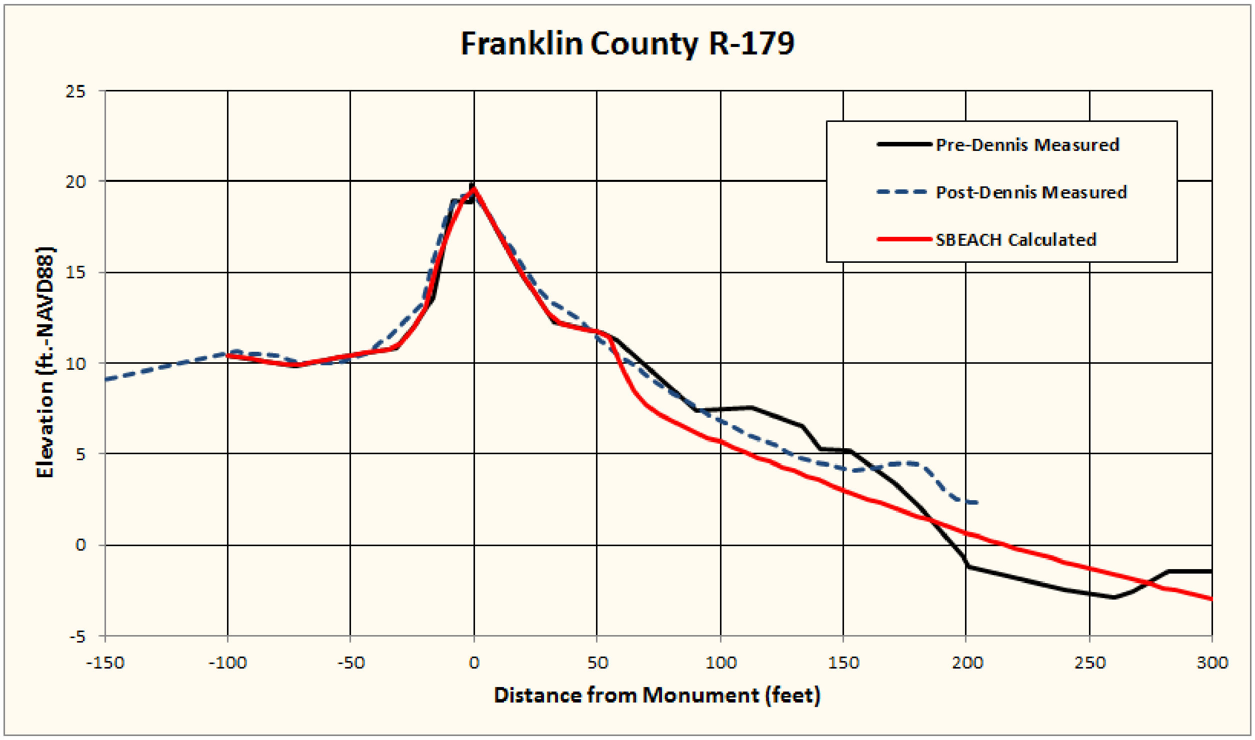
Franklin County R-175
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
25
20
15
10
5
0
-5
-150
-100
-50
0
50
100
150
200
250
300

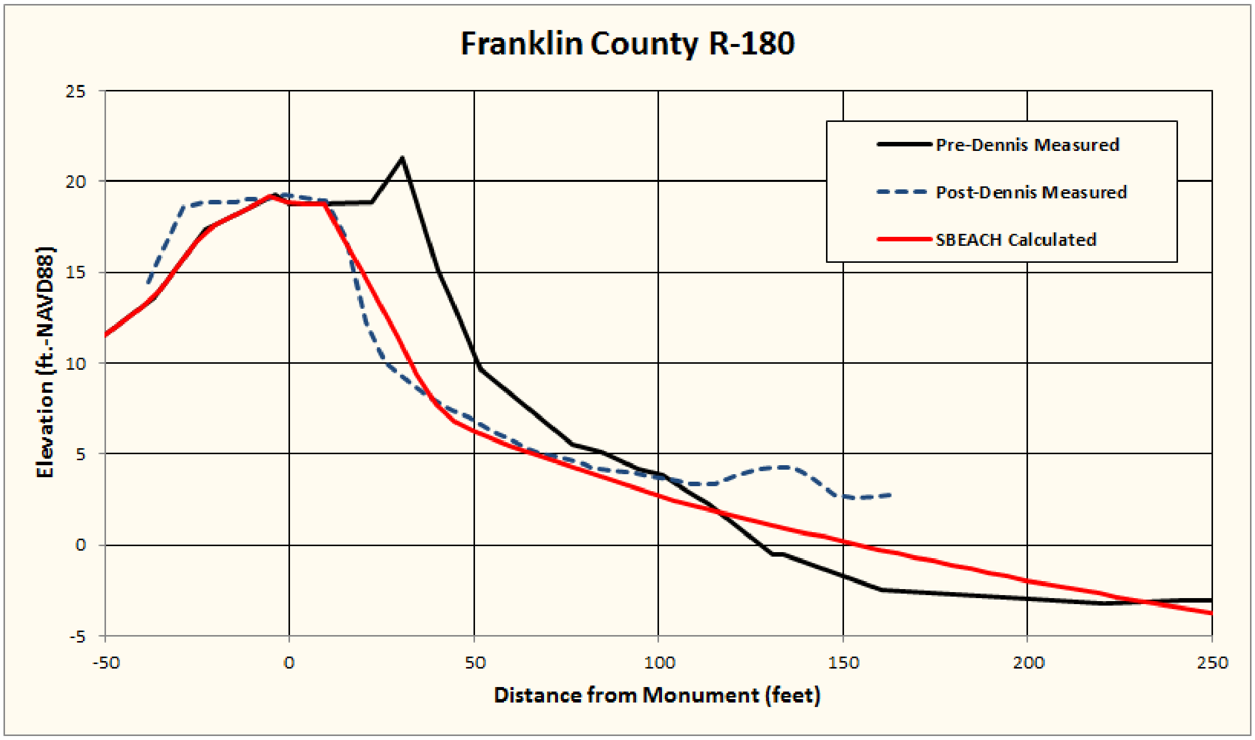


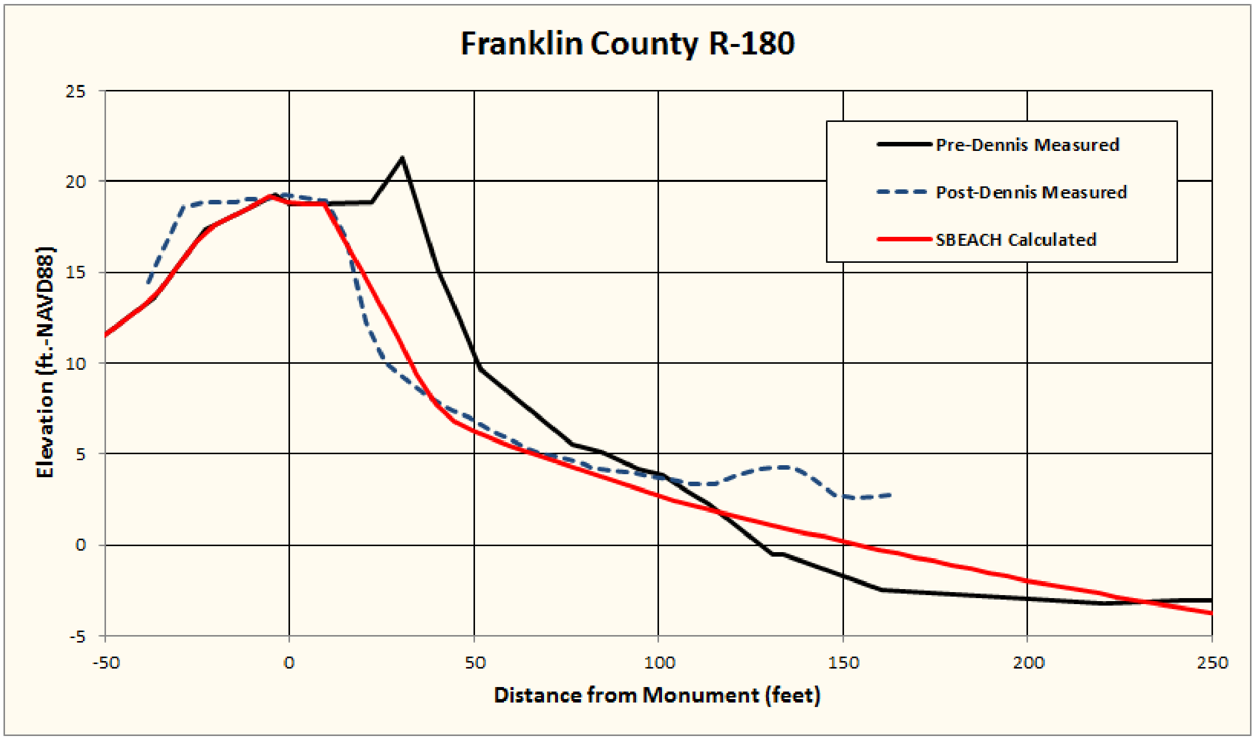
Franklin County R-176
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
25
20
15
10
5
0
-5
-150
-100
-50
0
50
100
150
200
250
300


Franklin County R-177
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
20
15
10
5
0
-5
-150
-100
-50
0
50
100
150
200
250
300
Distance from Monument (feet)

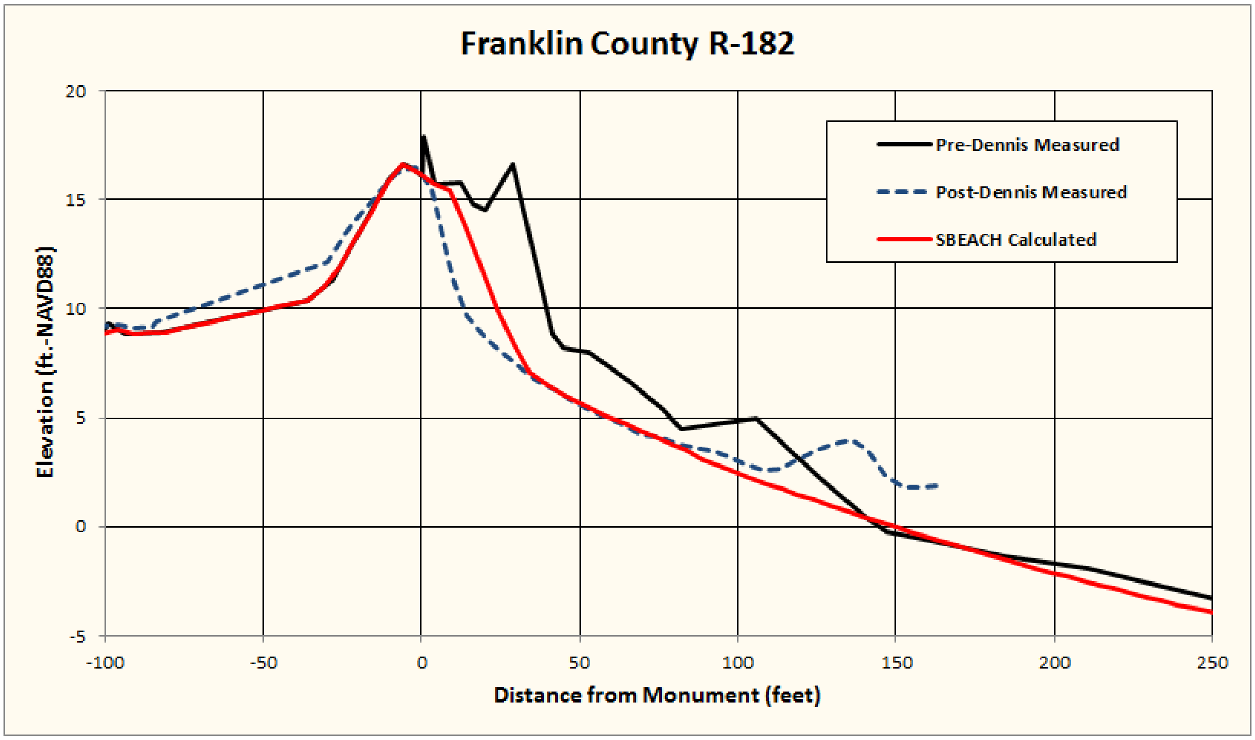

Franklin County R-178
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
20
15
10
5
0
-5
-150
-100
-50
0
50
100
150
200
250
300
Distance from Monument (feet)


Franklin County R-179
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
25
20
15
10
5
0
-5
-150
-100
-50
0
50
100
150
200
250
300
Distance from Monument (feet)

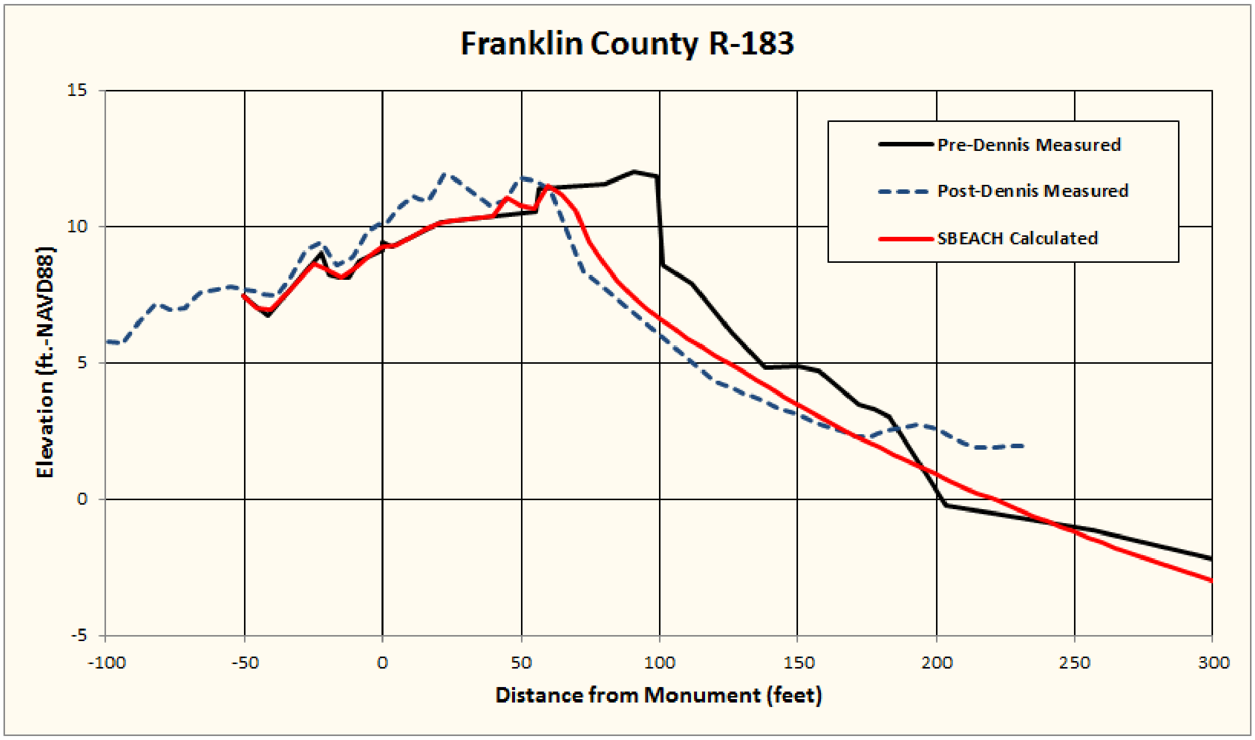

Franklin County R-180
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
Distance from Monument (feet)



Franklin County R-180
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250



Franklin County R-182
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-100
-50
0
50
100
150
200
250


Franklin County R-183
Pre-Dennis Measured
Post-Dennis Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-100
-50
0
50
100
150
200
250
300

APPENDIX B

Recommended SBEACH Input Values

Final SBEACH Input Settings – for 15- and 25-year storm erosions in Franklin County.

For all Storm Tide Hydrographs - Use 15- and 25-year hydrographs without wave setup adjusted proportionally to peak elevation shown for each range location segment shown below; storm duration for all cases is 36 hrs. All elevations listed below are in NAVD88 vertical datum. All wave input depth values were set as deep water with no wave randomization. All storm time steps were set at 5 minutes. Water temperature is set at 27 degrees. Grid cell width is 5 feet.

Range Segments	**R21 – R51**	**R52 - R149**	**R150 - R239**
Transport Rate Coefficient, *K*	2.5 e^{-006}	2.5 e^{-006}	2.5 e^{-006}
Overwash Transport Parameter	0.005	0.005	0.005
Coefficient for Slope Dependent Term, ε	0.003	0.003	0.003
Transport Rate Decay Coeff. M ultiplier, λ	0.1	0.1	0.1
Landward Surf Zone Depth (ft.)	1.0	1.0	1.0
Maximum Slope Prior to Avalanching	30	30	30
Constant Wave Height (ft.)	10	10	10
Constant Wave Period (sec.)	10	10	10
15-year Hydrograph Peak Elevation (ft.)	4.8	4.8	4.8
25-year Hydrograph Peak Elevation (ft.)	5.6	5.8	6.2

Range	Mean Grain Size (mm)
21 - 51	0.28
52 - 190	0.32
194 -219	0.26
224 - 239	0.52

APPENDIX C

Adjusted 15- and 25-year Hydrograph Tables for Franklin County

Franklin County - Adjusted 15-year Hydrograph (ft.-NAVD) for SBEACH

Time (hour)	R21 – R239
0.00	-0.44
0.50	-0.39
1.00	-0.30
1.50	-0.19
2.00	-0.07
2.50	0.07
3.00	0.18
3.50	0.27
4.00	0.36
4.50	0.43
5.00	0.48
5.50	0.49
6.00	0.47
6.50	0.40
7.00	0.32
7.50	0.28
8.00	0.22
8.50	0.19
9.00	0.18
9.50	0.19
10.00	0.23
10.50	0.30
11.00	0.40
11.50	0.56
12.00	0.80
12.50	1.05
13.00	1.28
13.50	1.46
14.00	1.74
14.50	2.07
15.00	2.43
15.50	2.82
16.00	3.26
16.50	3.72
17.00	4.18
17.50	4.56
18.00	4.75
18.50	4.53
19.00	3.86
19.50	2.92

Time (hour)	R21 – R239
20.00	1.97
20.50	1.15
21.00	0.54
21.50	0.18
22.00	-0.11
22.50	-0.33
23.00	-0.50
23.50	-0.61
24.00	-0.65
24.50	-0.64
25.00	-0.62
25.50	-0.65
26.00	-0.72
26.50	-0.75
27.00	-0.68
27.50	-0.56
28.00	-0.42
28.50	-0.30
29.00	-0.20
29.50	-0.13
30.00	-0.06
30.50	0.05
31.00	0.14
31.50	0.21
32.00	0.24
32.50	0.22
33.00	0.19
33.50	0.16
34.00	0.16
34.50	0.18
35.00	0.22
35.50	0.26
36.00	0.30

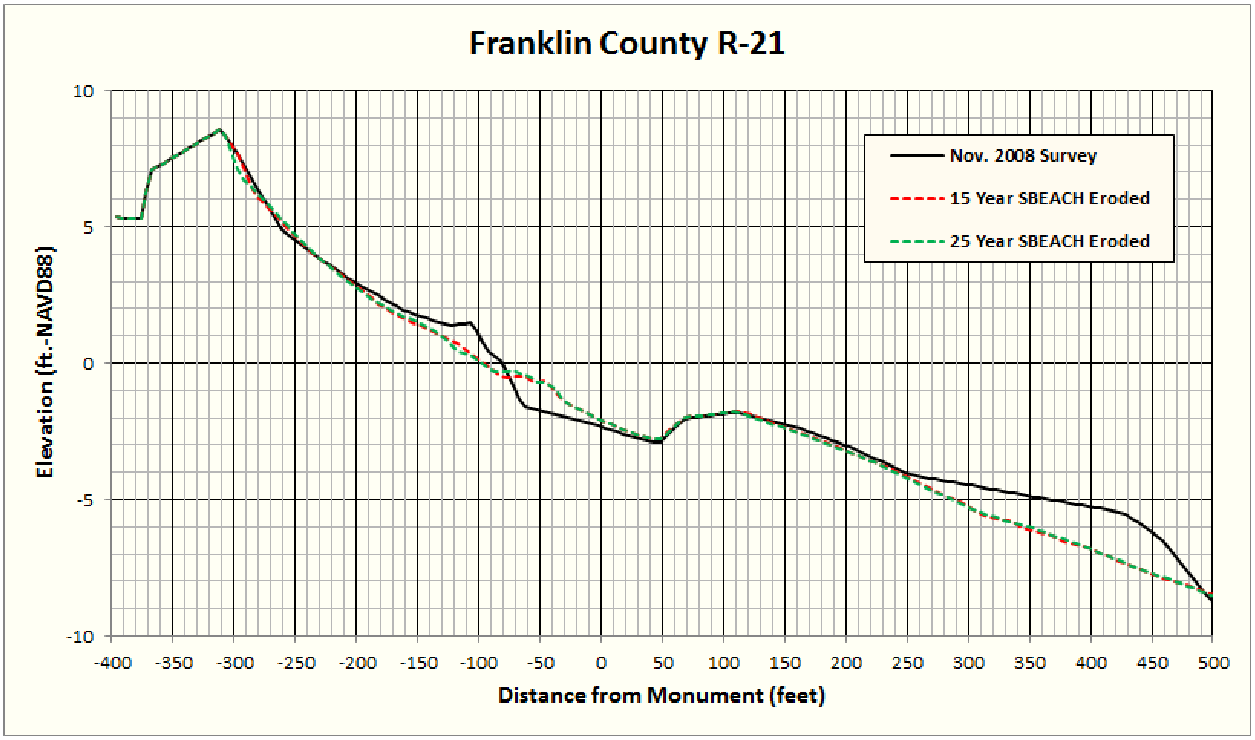
Franklin County - Adjusted 25-year Hydrograph (ft.-NAVD) for SBEACH

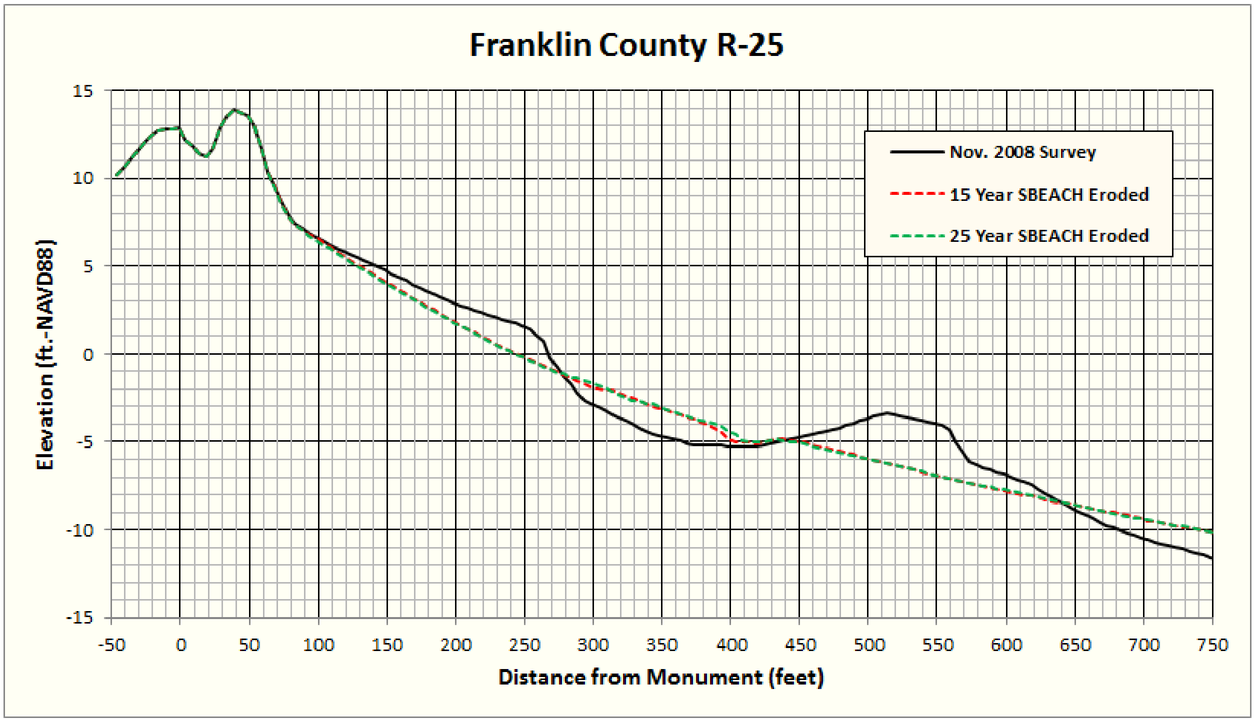
Time (hour)	R21 – R51	R52 - R149	R150 – R239
0.00	-0.57	-0.57	-0.57
0.50	-0.69	-0.69	-0.69
1.00	-0.75	-0.75	-0.75
1.50	-0.77	-0.77	-0.77
2.00	-0.73	-0.73	-0.73
2.50	-0.61	-0.61	-0.61
3.00	-0.44	-0.44	-0.44
3.50	-0.23	-0.23	-0.23
4.00	0.00	0.00	0.00
4.50	0.25	0.25	0.25
5.00	0.48	0.48	0.48
5.50	0.70	0.70	0.70
6.00	0.91	0.91	0.91
6.50	1.09	1.09	1.09
7.00	1.22	1.22	1.22
7.50	1.30	1.30	1.30
8.00	1.34	1.34	1.34
8.50	1.31	1.31	1.31
9.00	1.24	1.24	1.24
9.50	1.19	1.19	1.19
10.00	1.13	1.13	1.13
10.50	1.06	1.06	1.06
11.00	1.00	1.00	1.00
11.50	0.95	0.95	0.95
12.00	0.94	0.94	0.94
12.50	0.90	0.93	1.00
13.00	1.00	1.04	1.11
13.50	1.17	1.21	1.31
14.00	1.45	1.50	1.61
14.50	1.83	1.89	2.03
15.00	2.34	2.42	2.60
15.50	2.91	3.01	3.23
16.00	3.50	3.61	3.89
16.50	4.14	4.28	4.60
17.00	4.81	4.97	5.34
17.50	5.37	5.55	5.97
18.00	5.59	5.78	6.21
18.50	5.26	5.43	5.84
19.00	4.33	4.48	4.81
19.50	3.10	3.21	3.45

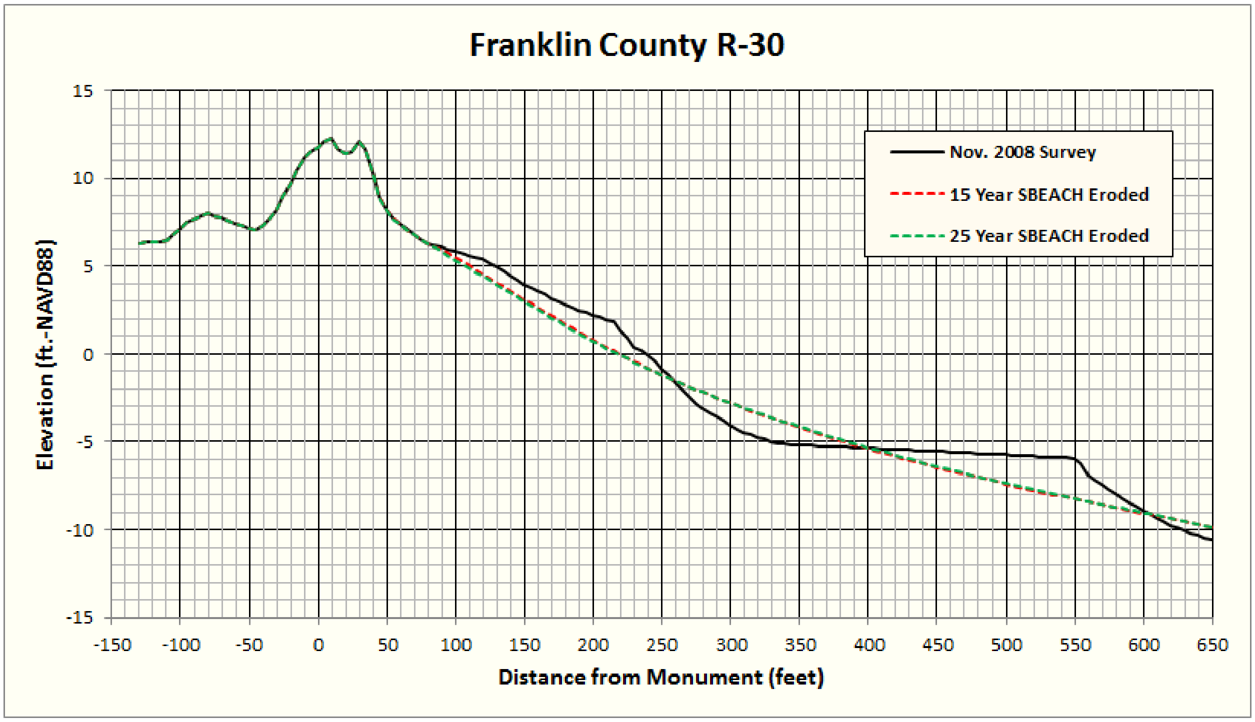
Time (hour)	**R21 – R51**	**R52 - R149**	**R150 – R239**
20.00	1.94	2.01	2.16
20.50	1.53	1.58	1.70
21.00	1.10	1.14	1.23
21.50	0.85	0.85	0.85
22.00	0.50	0.50	0.50
22.50	0.16	0.16	0.16
23.00	-0.10	-0.10	-0.10
23.50	-0.32	-0.32	-0.32
24.00	-0.48	-0.48	-0.48
24.50	-0.65	-0.65	-0.65
25.00	-0.82	-0.82	-0.82
25.50	-1.03	-1.03	-1.03
26.00	-1.24	-1.24	-1.24
26.50	-1.36	-1.36	-1.36
27.00	-1.35	-1.35	-1.35
27.50	-1.24	-1.24	-1.24
28.00	-1.07	-1.07	-1.07
28.50	-0.88	-0.88	-0.88
29.00	-0.66	-0.66	-0.66
29.50	-0.41	-0.41	-0.41
30.00	-0.13	-0.13	-0.13
30.50	0.18	0.18	0.18
31.00	0.47	0.47	0.47
31.50	0.70	0.70	0.70
32.00	0.86	0.86	0.86
32.50	0.95	0.95	0.95
33.00	1.00	1.00	1.00
33.50	1.00	1.00	1.00
34.00	0.98	0.98	0.98
34.50	0.91	0.91	0.91
35.00	0.80	0.80	0.80
35.50	0.61	0.61	0.61
36.00	0.40	0.40	0.40

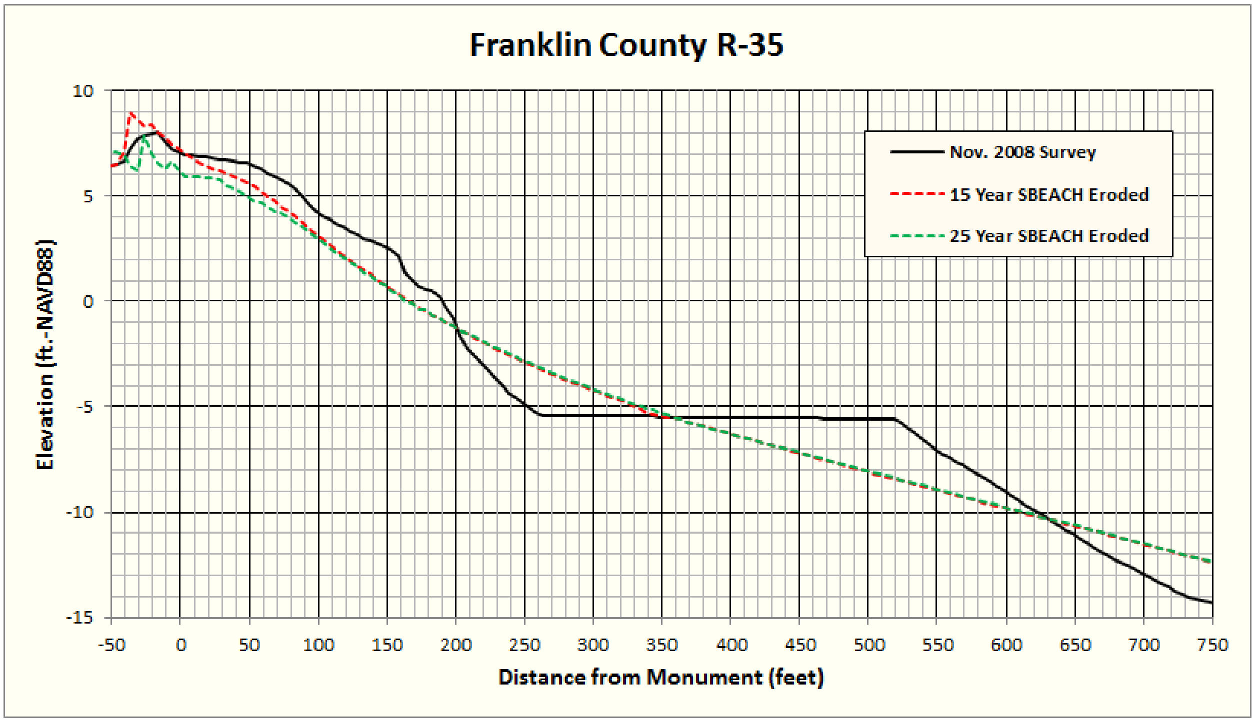
APPENDIX D

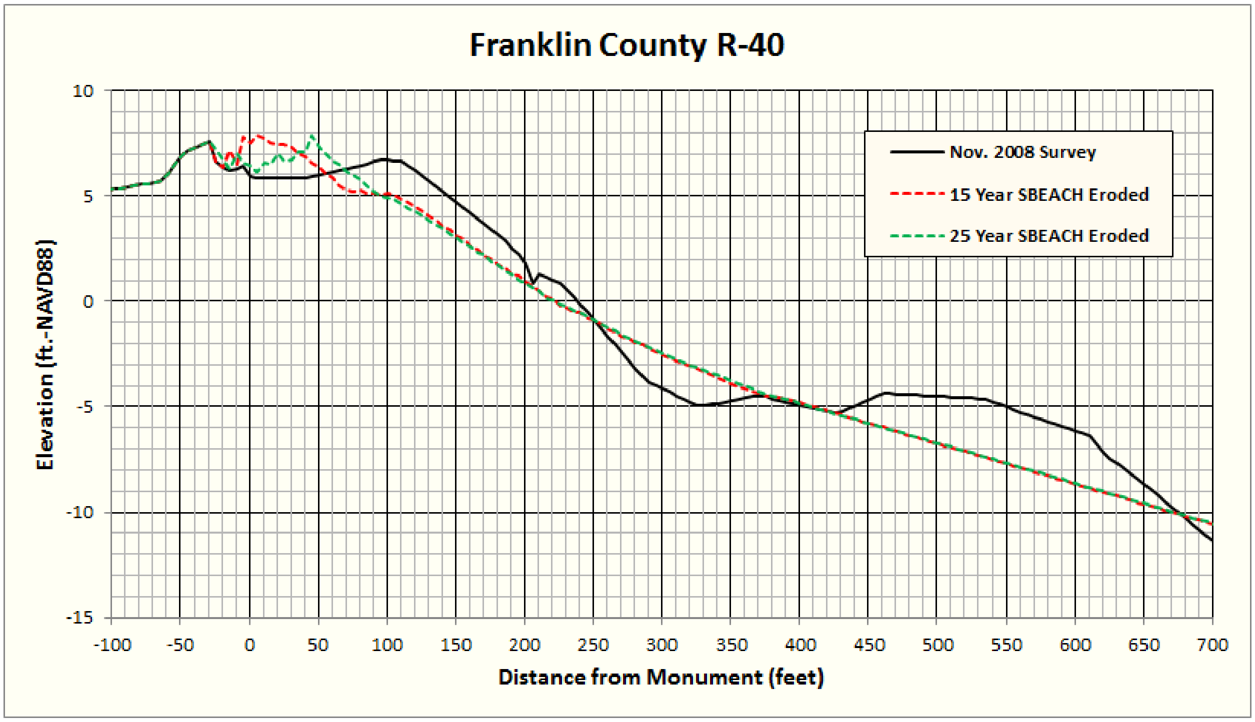
Franklin County SBEACH 15- and 25-year Storm Erosion Profiles

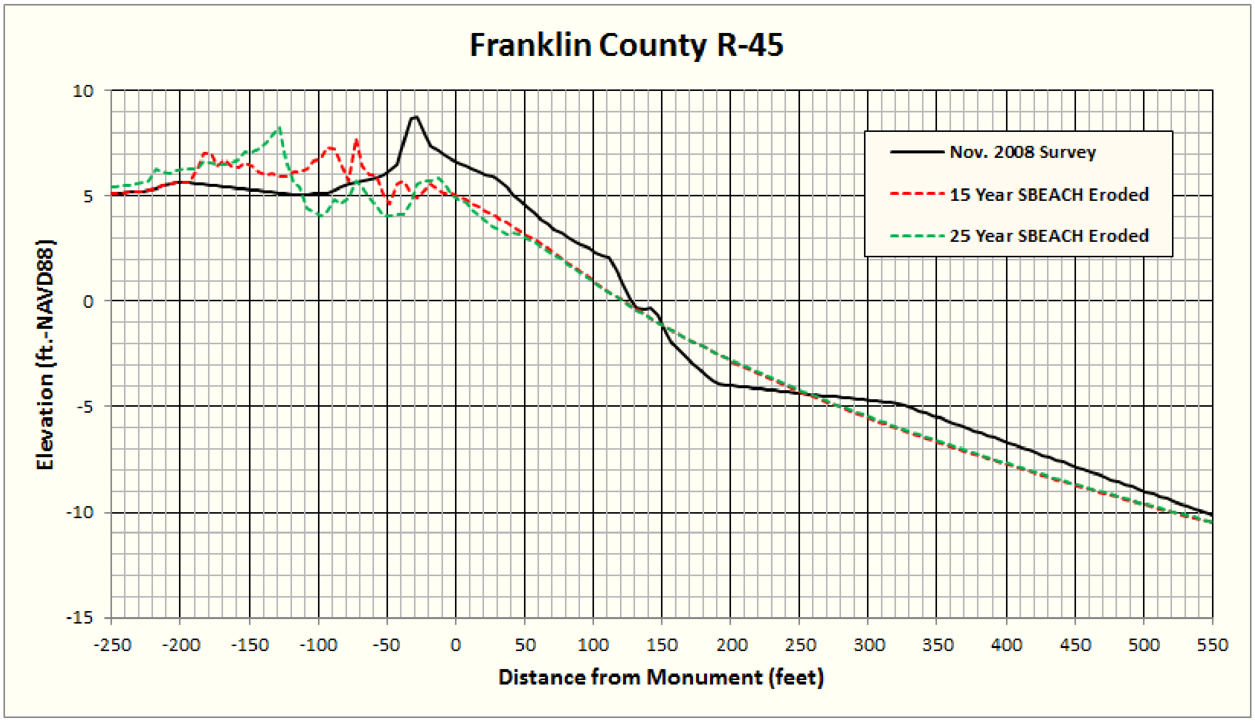

Franklin County R-21
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
10
5
0
-5
-10
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
Distance from Monument (feet)

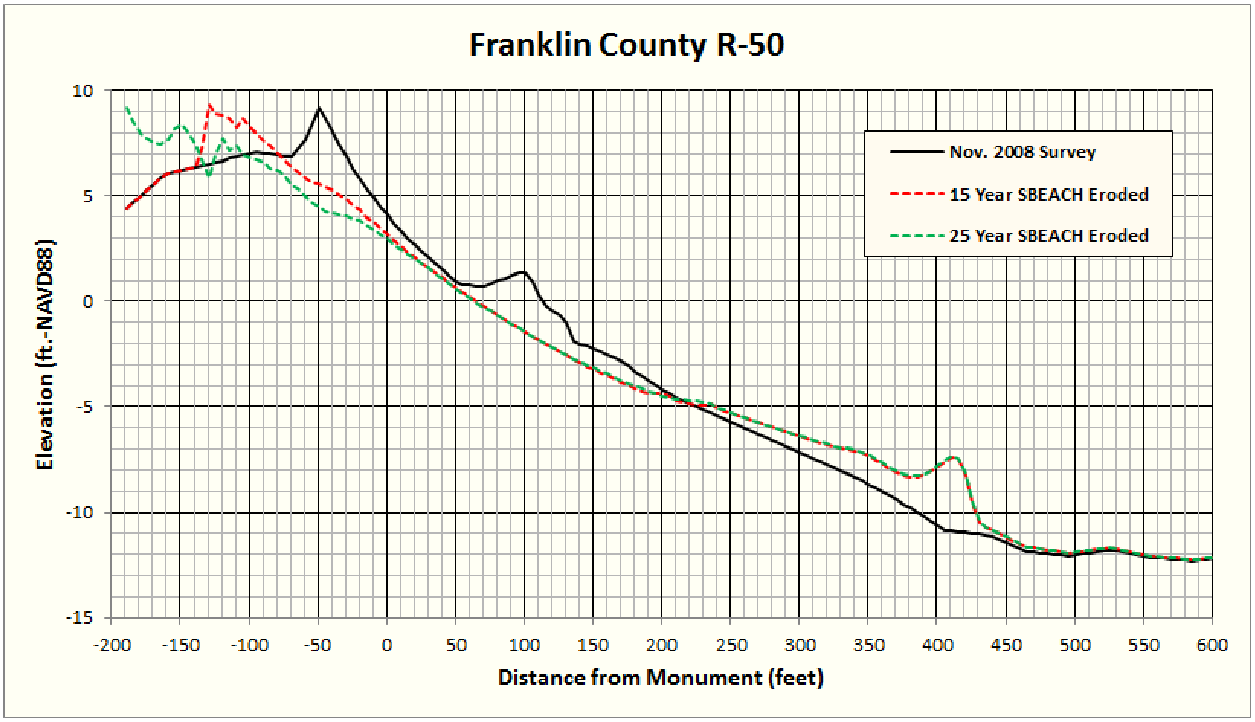

Franklin County R-25
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
Distance from Monument (feet)

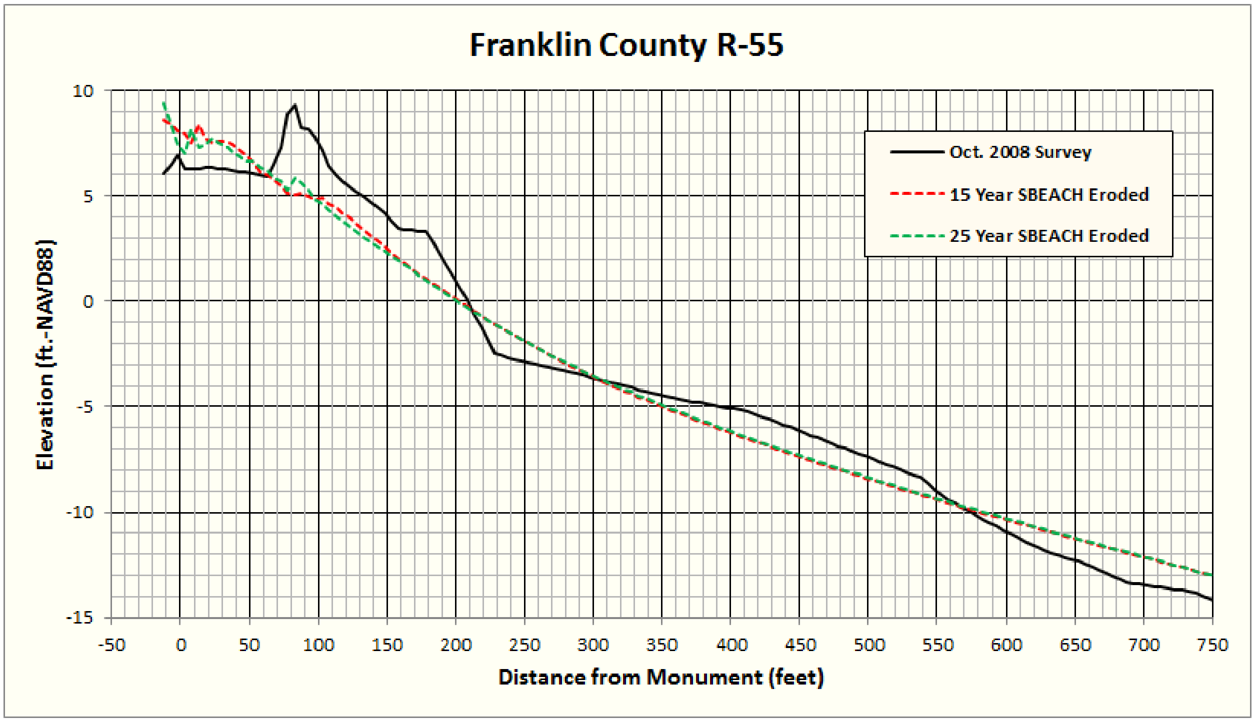

Franklin County R-30
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
-15
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance from Monument (feet)

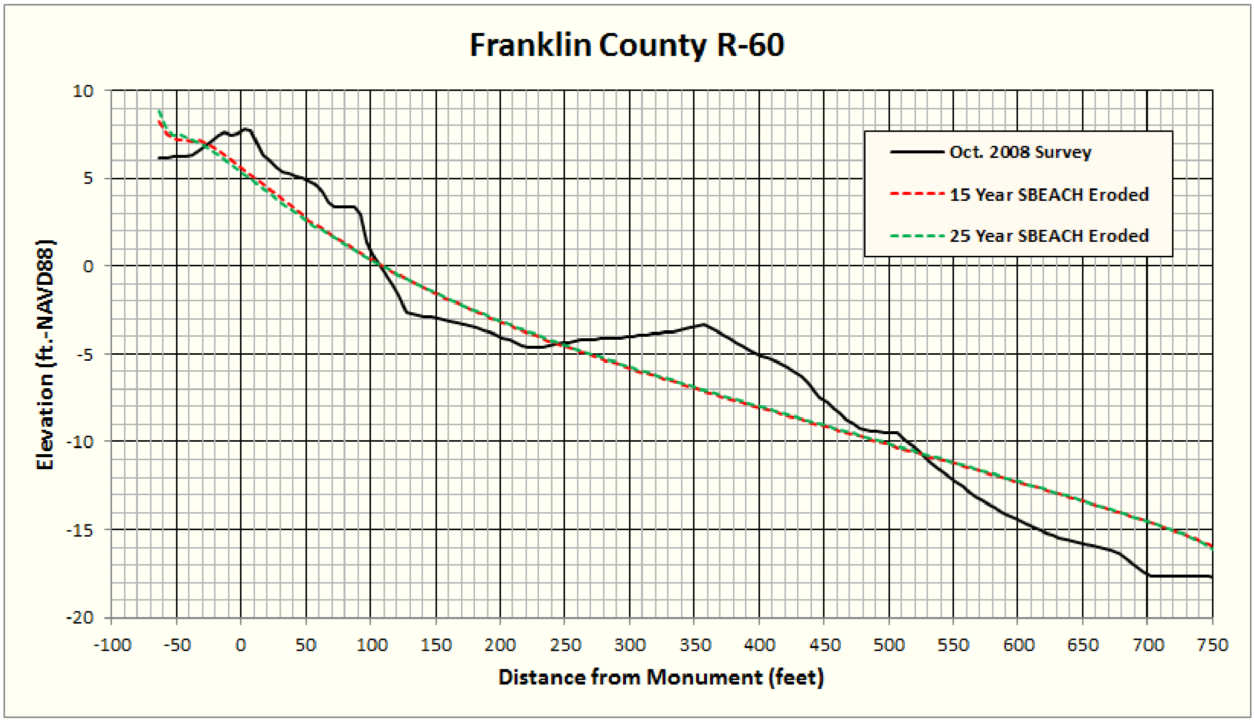

Franklin County R-35
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
Distance from Monument (feet)

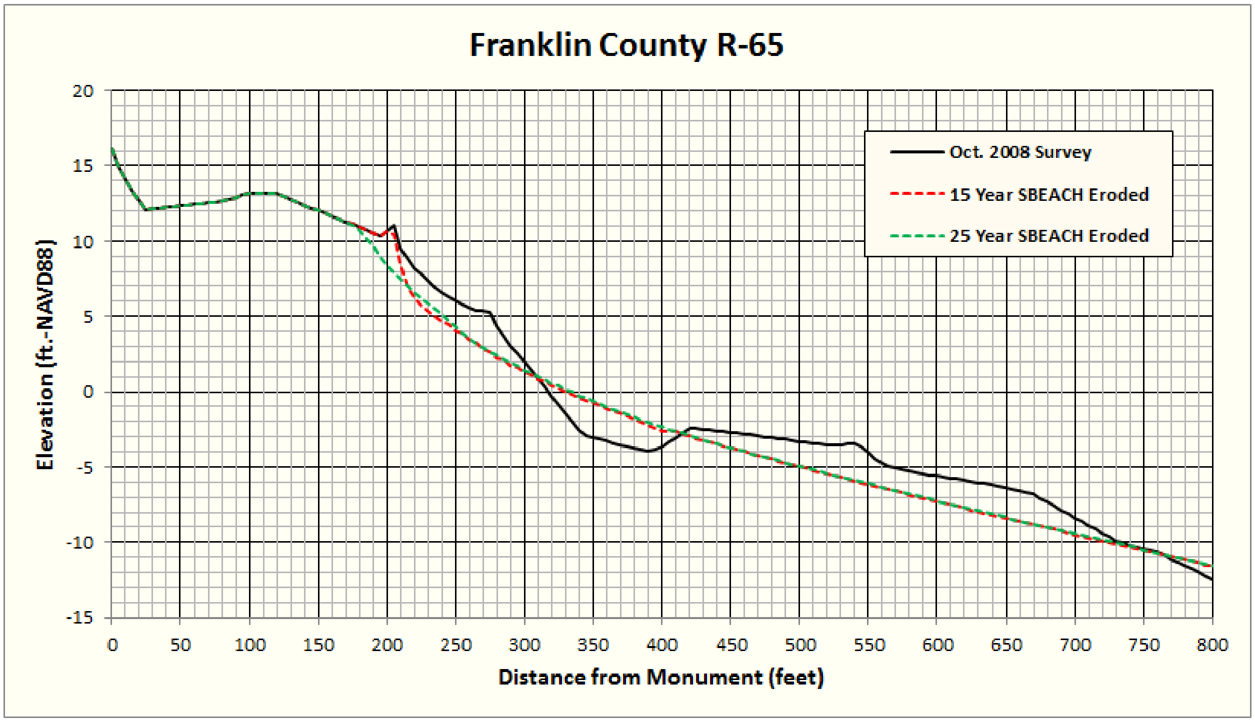

Franklin County R-40
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700

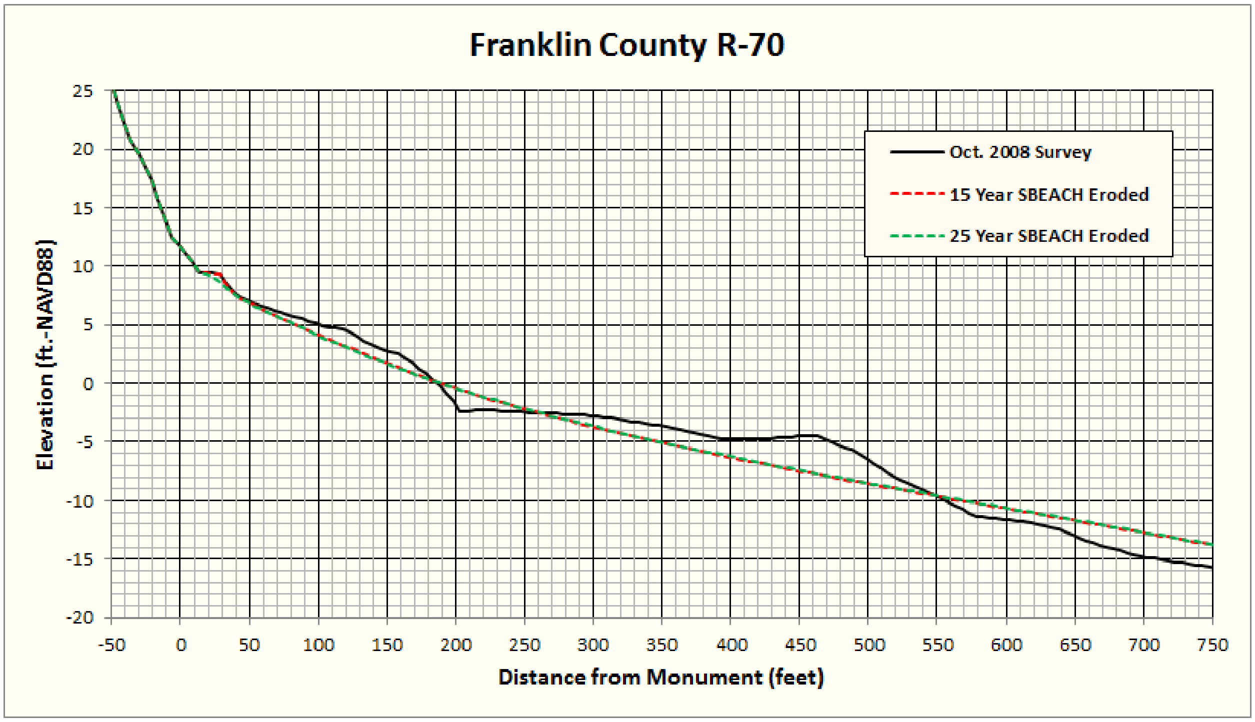

Franklin County R-45
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550

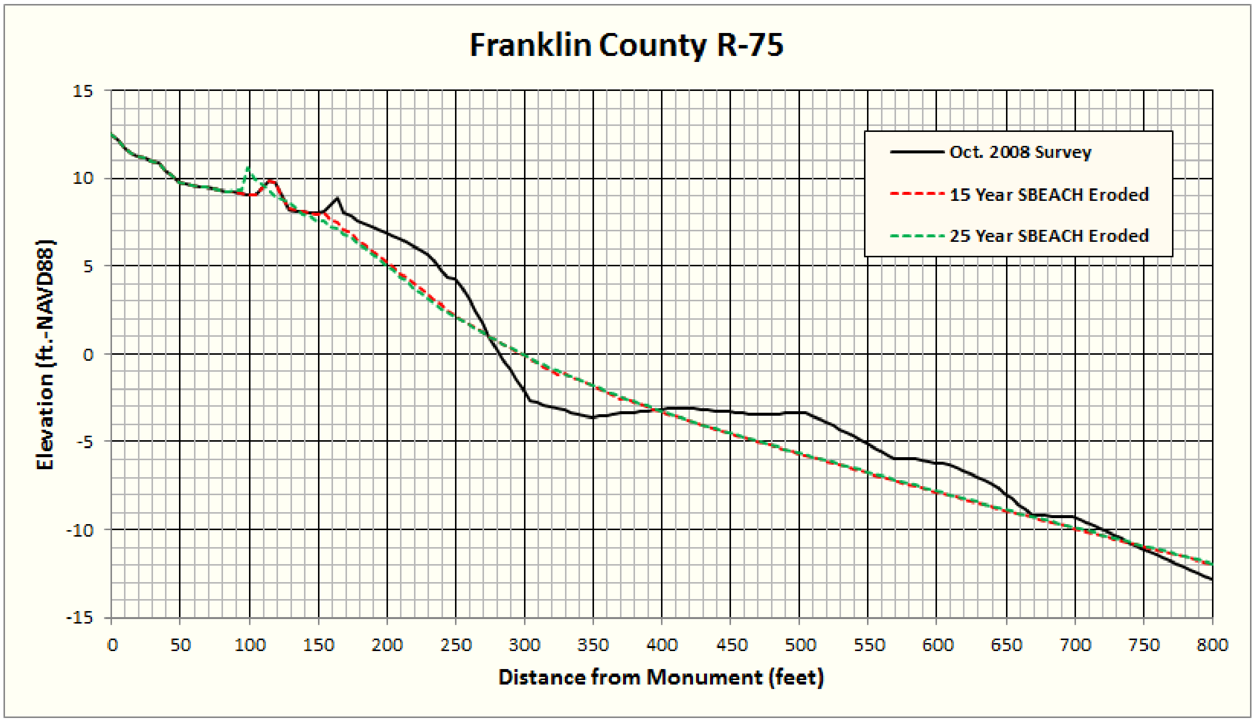

Franklin County R-50
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Nov. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600

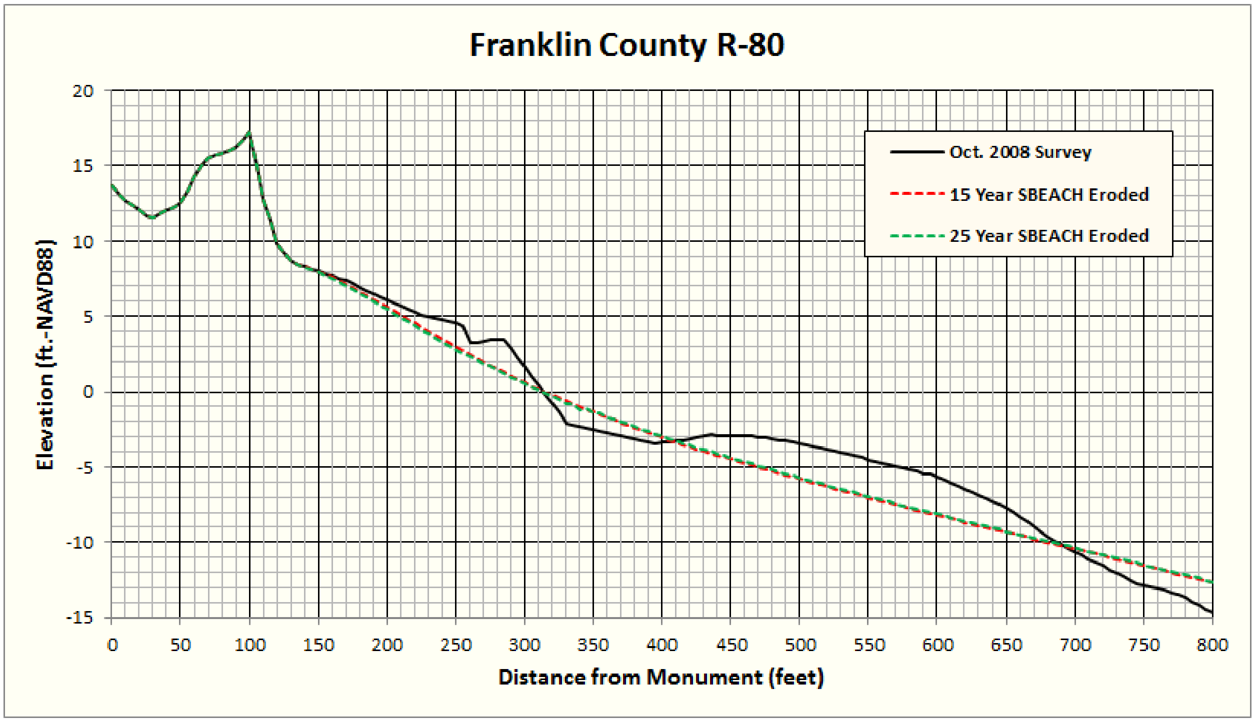

Franklin County R-55
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Oct. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750

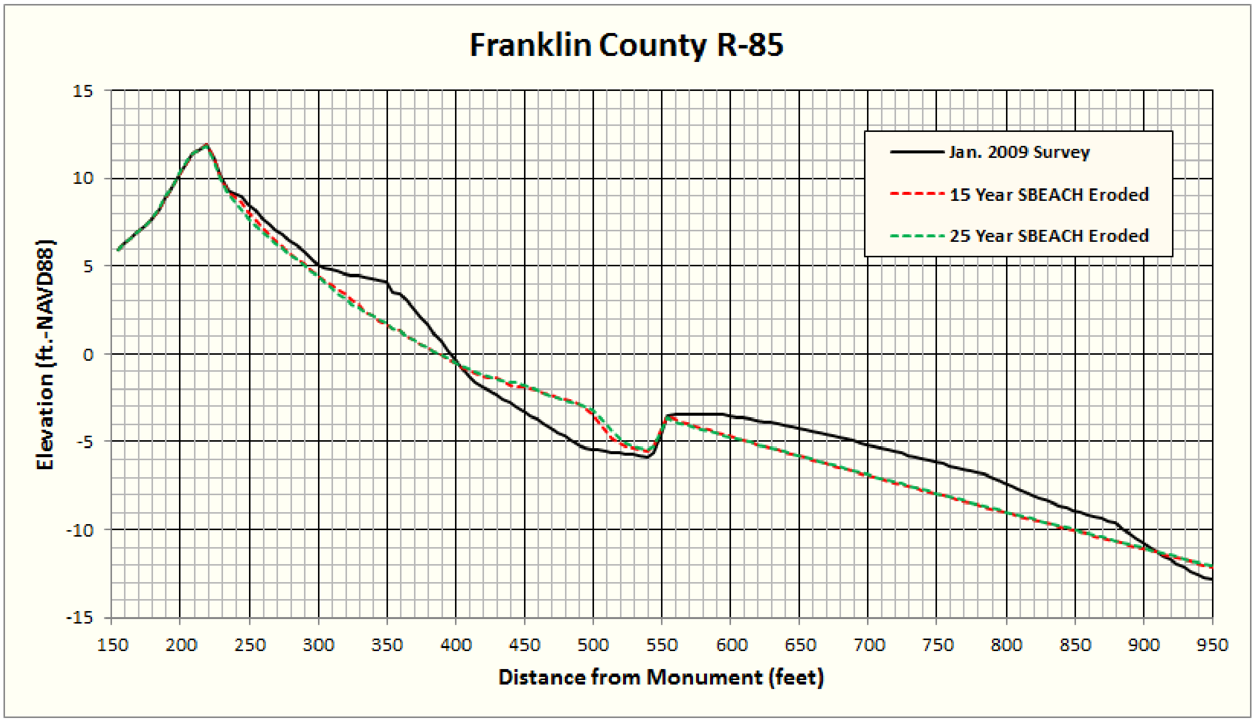

Franklin County R-60
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Oct. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-20
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750

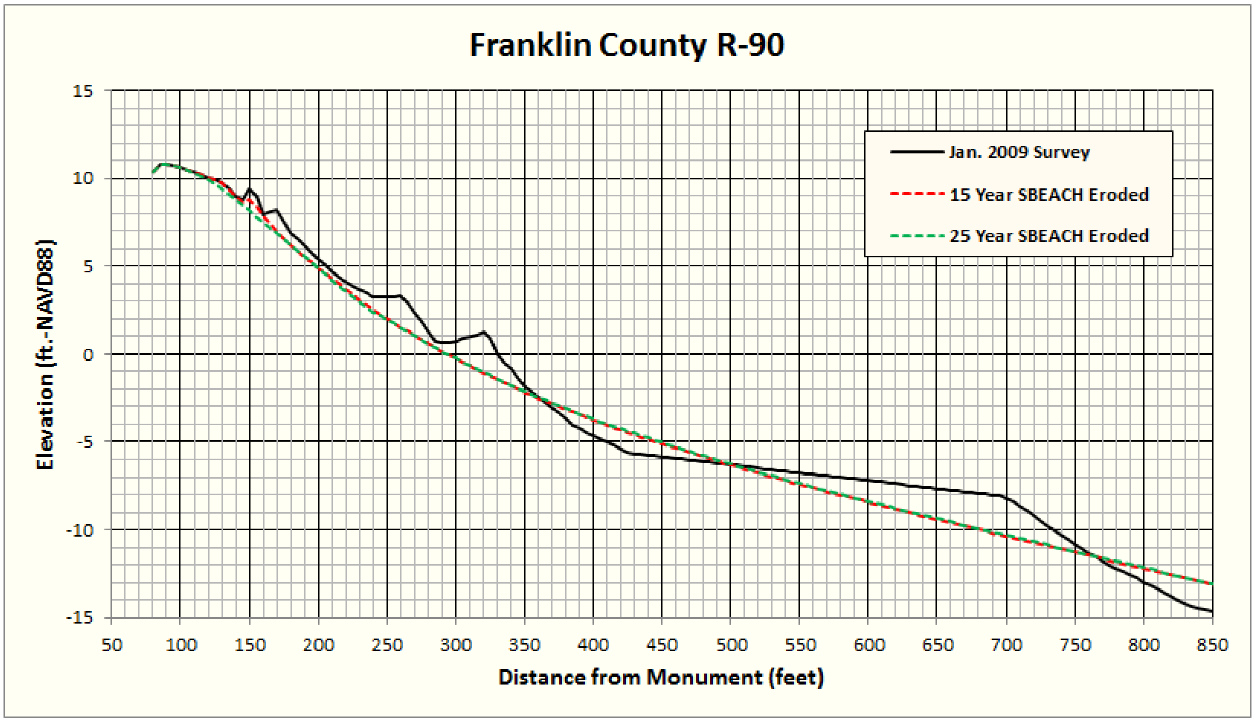

Franklin County R-65
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Oct. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
20
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800

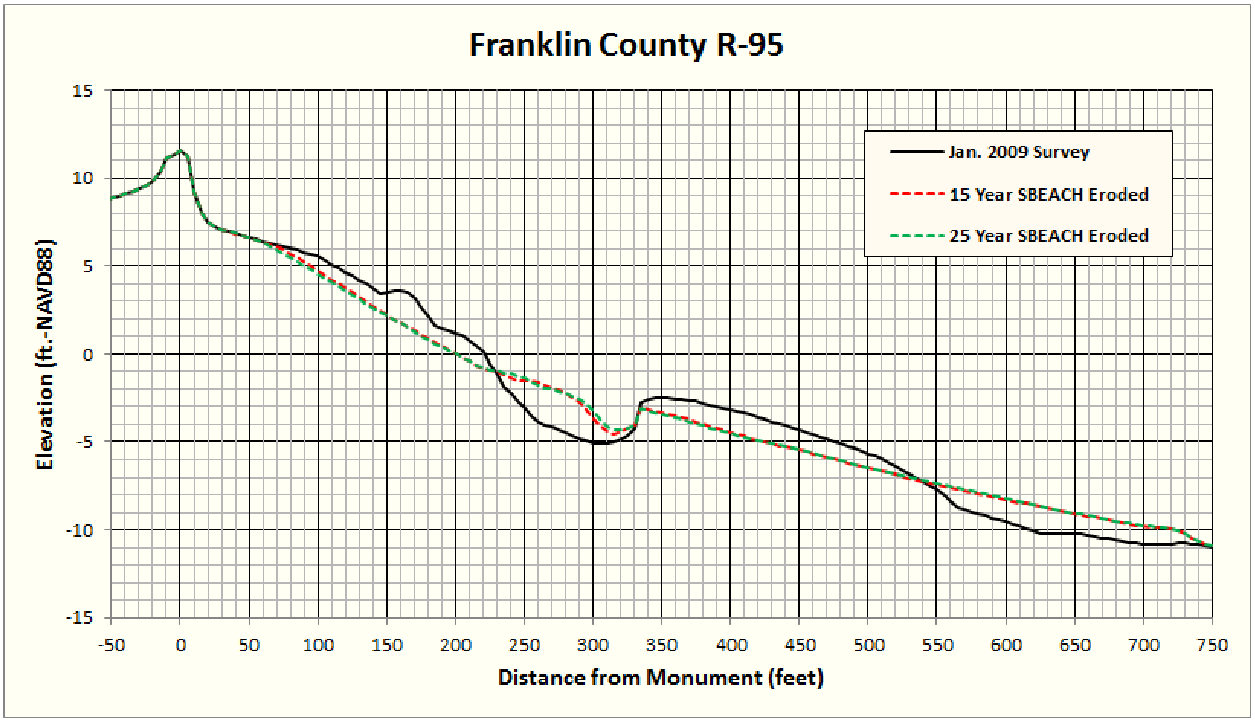

Franklin County R-70
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Oct. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
25
20
15
10
5
0
-5
-10
-15
-20
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750

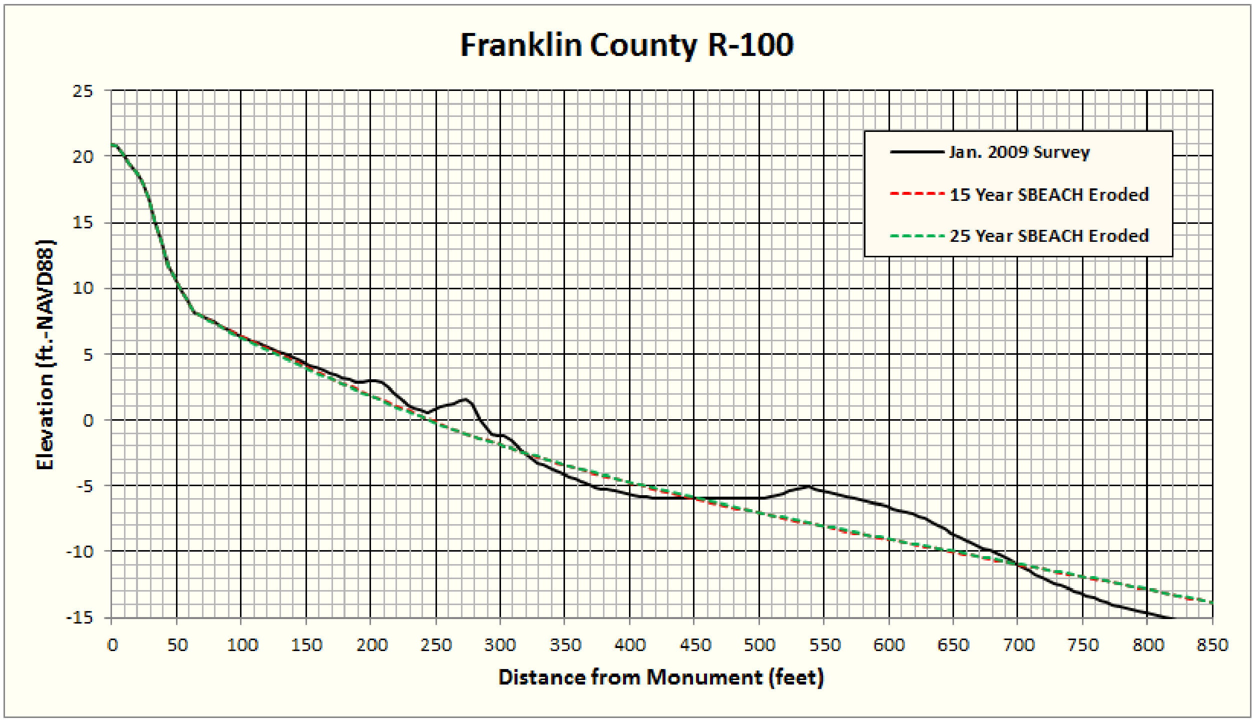

Franklin County R-75
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Oct. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800

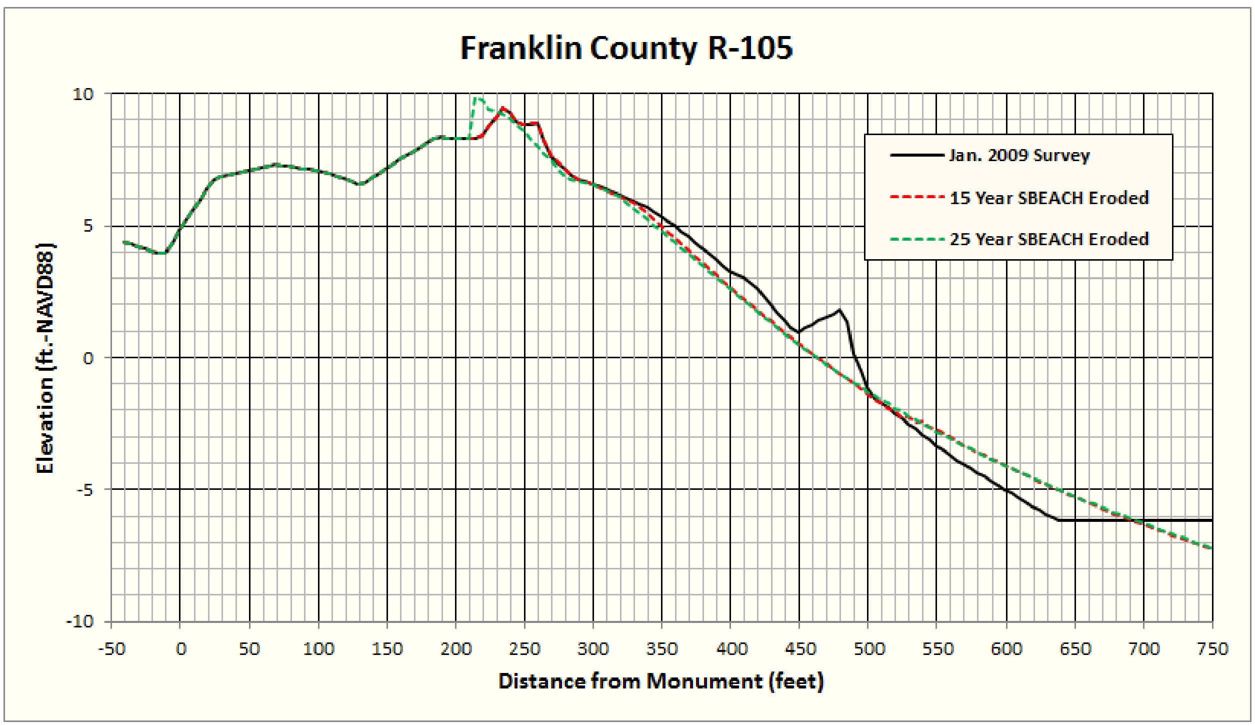

Franklin County R-80
Oct. 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800

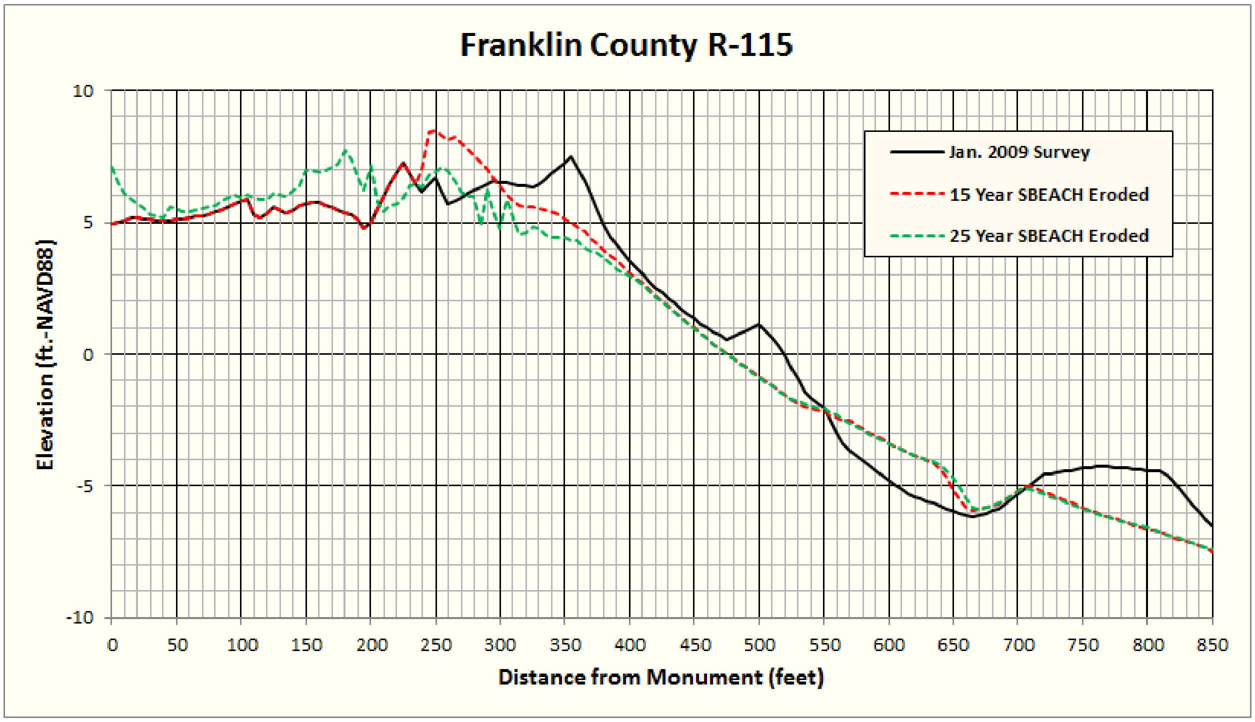

Franklin County R-85
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
-15
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950

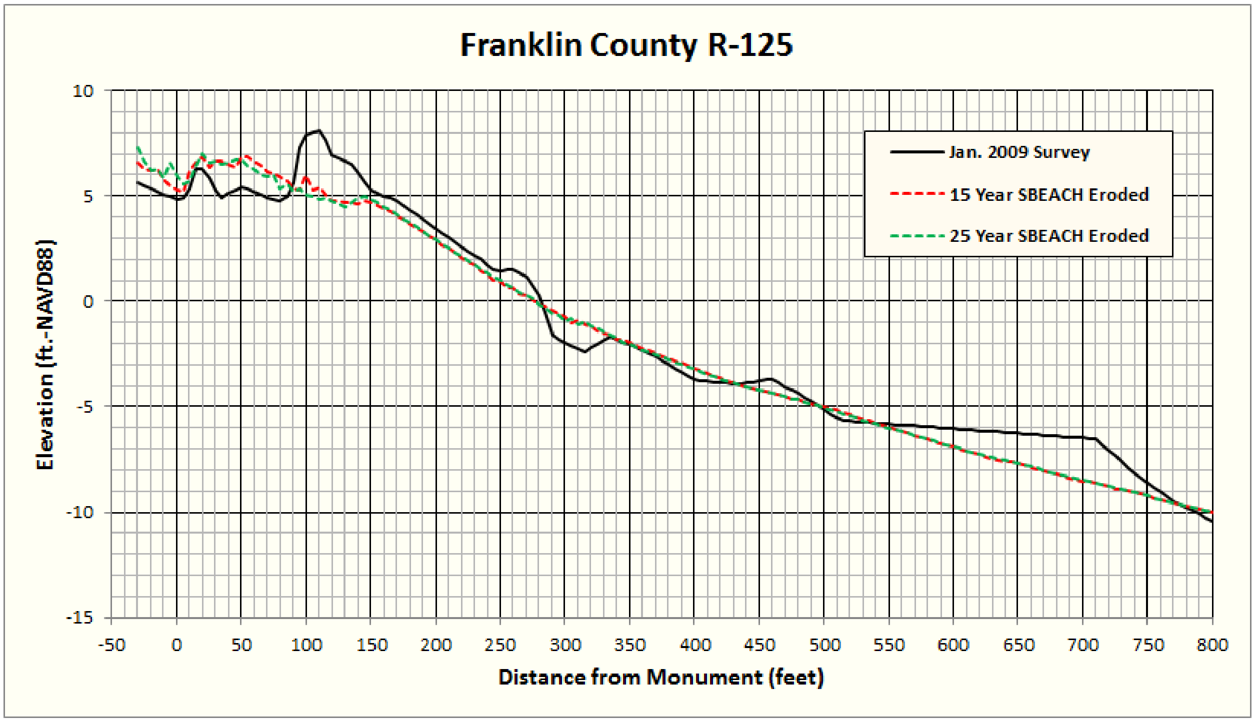

Franklin County R-90
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
-15
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850

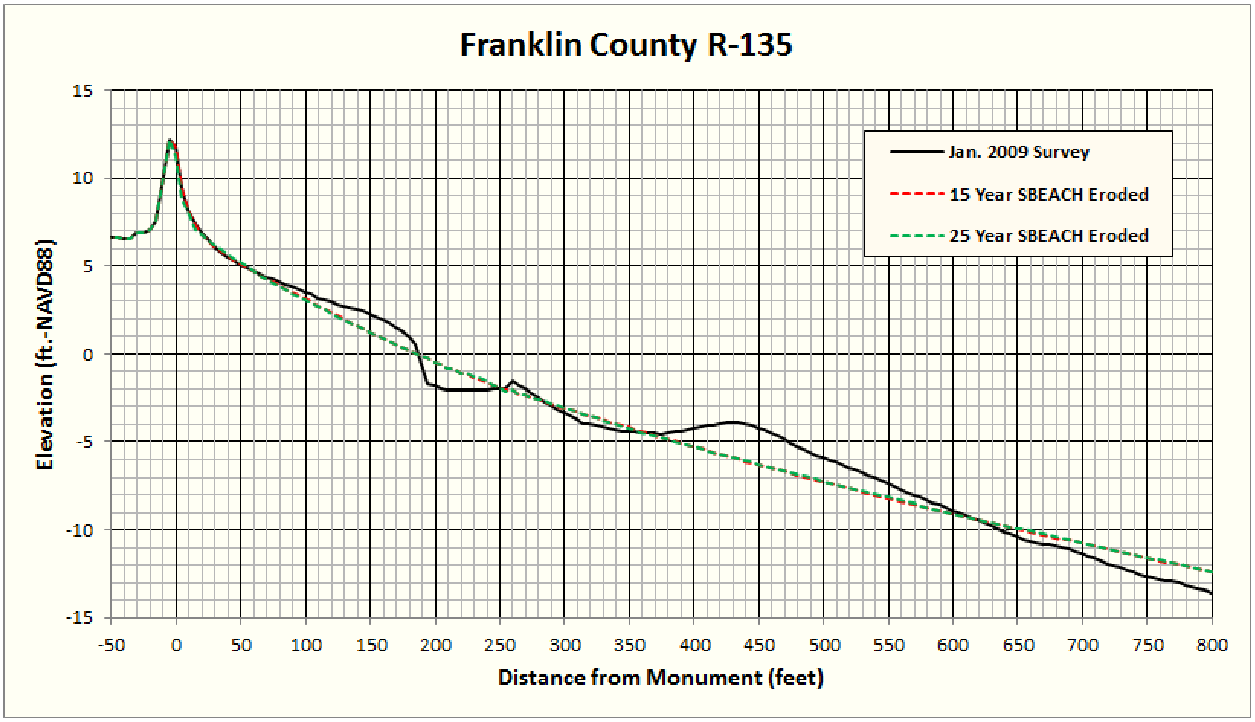

Franklin County R-95
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750

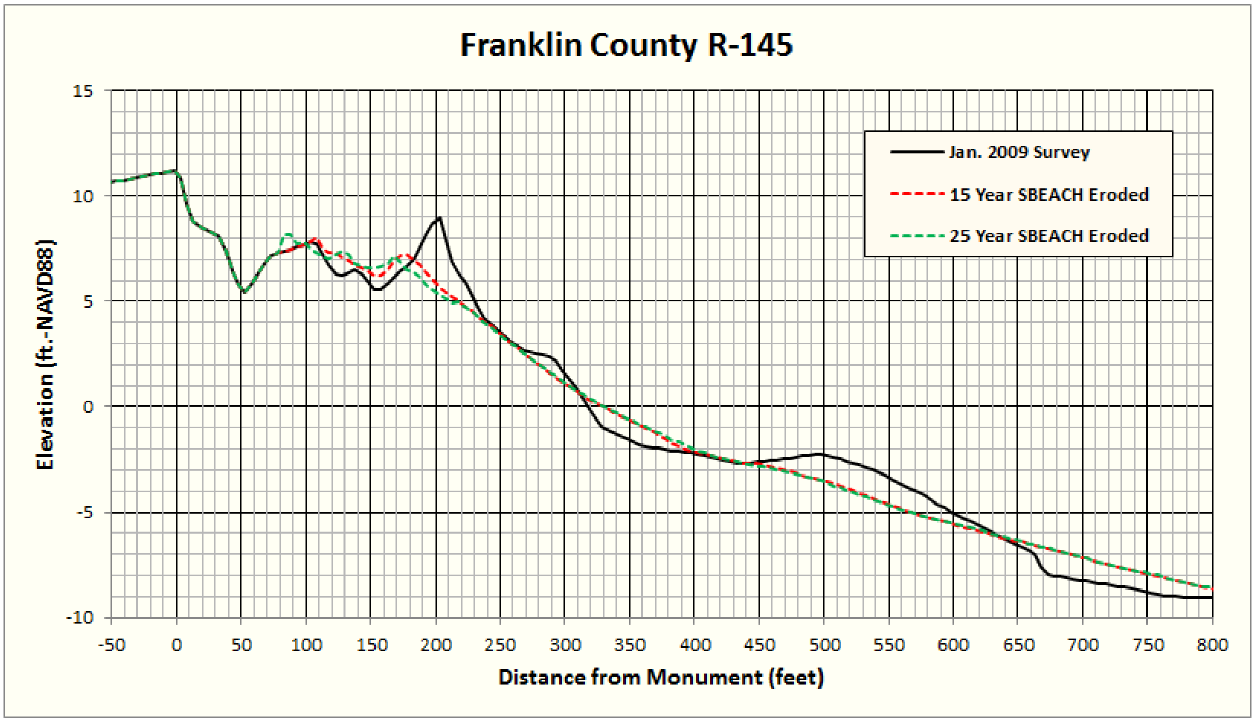

Franklin County R-100
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
25
20
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850

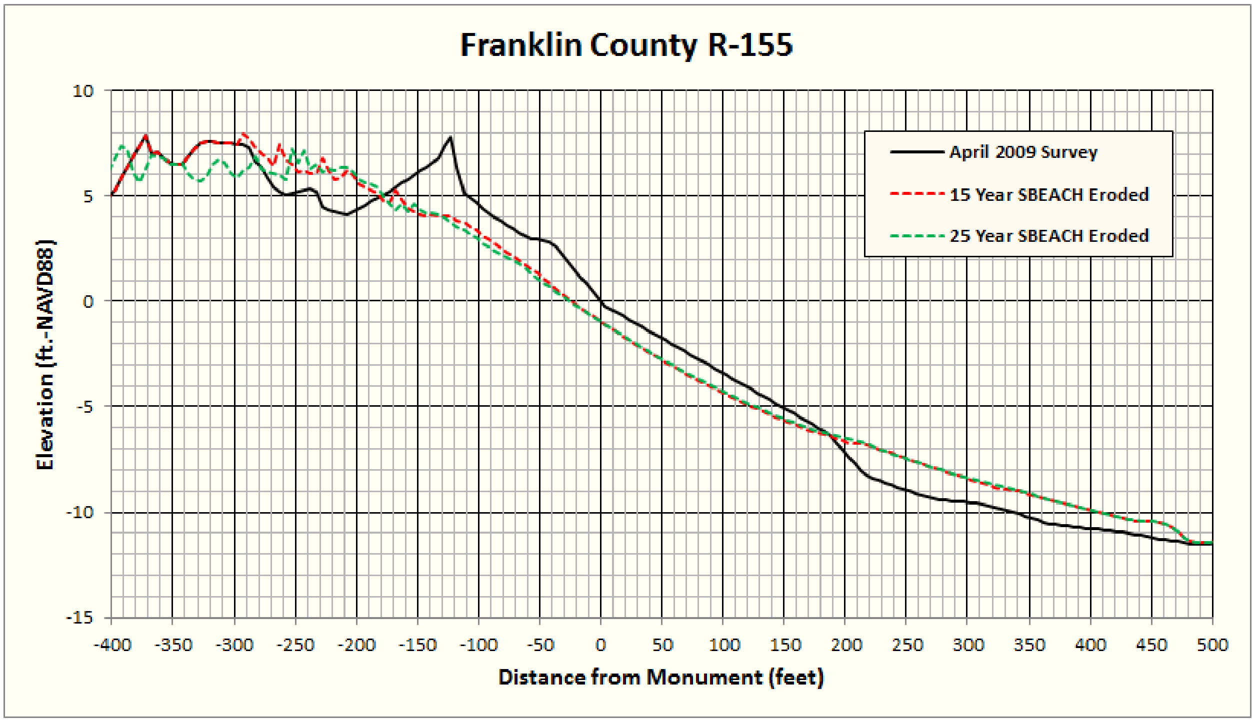

Franklin County R-105
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750

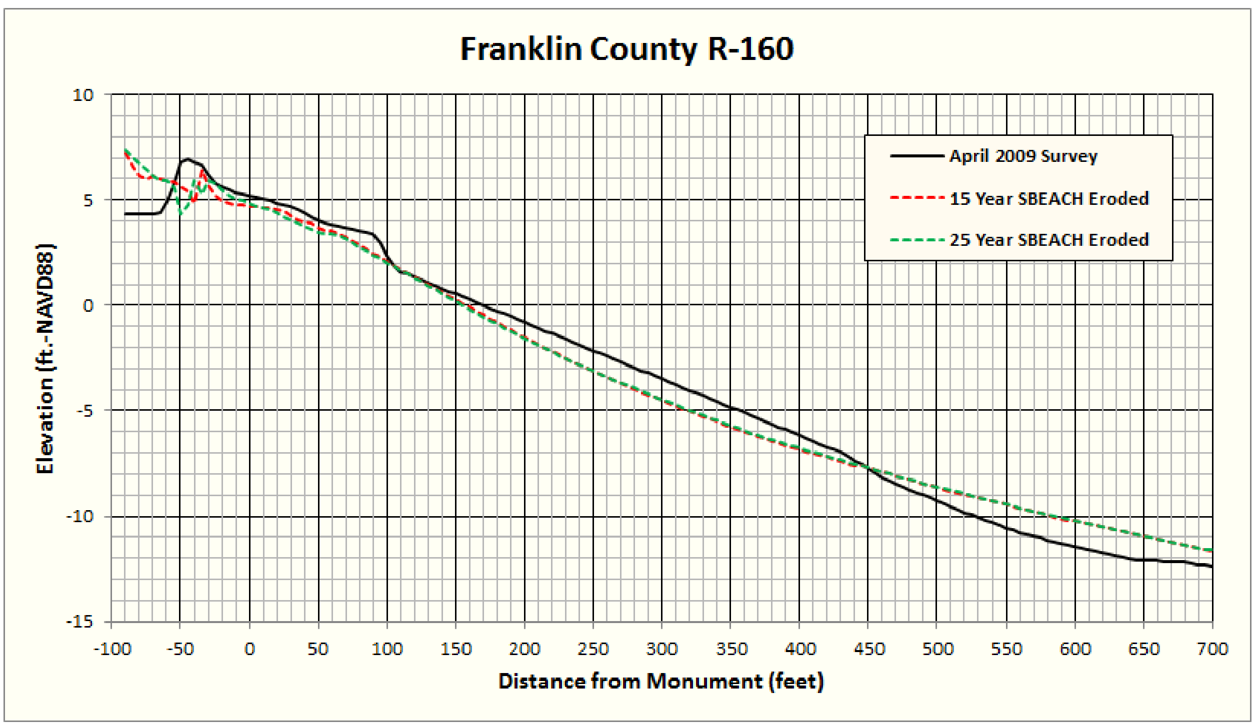

Franklin County R-115
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850

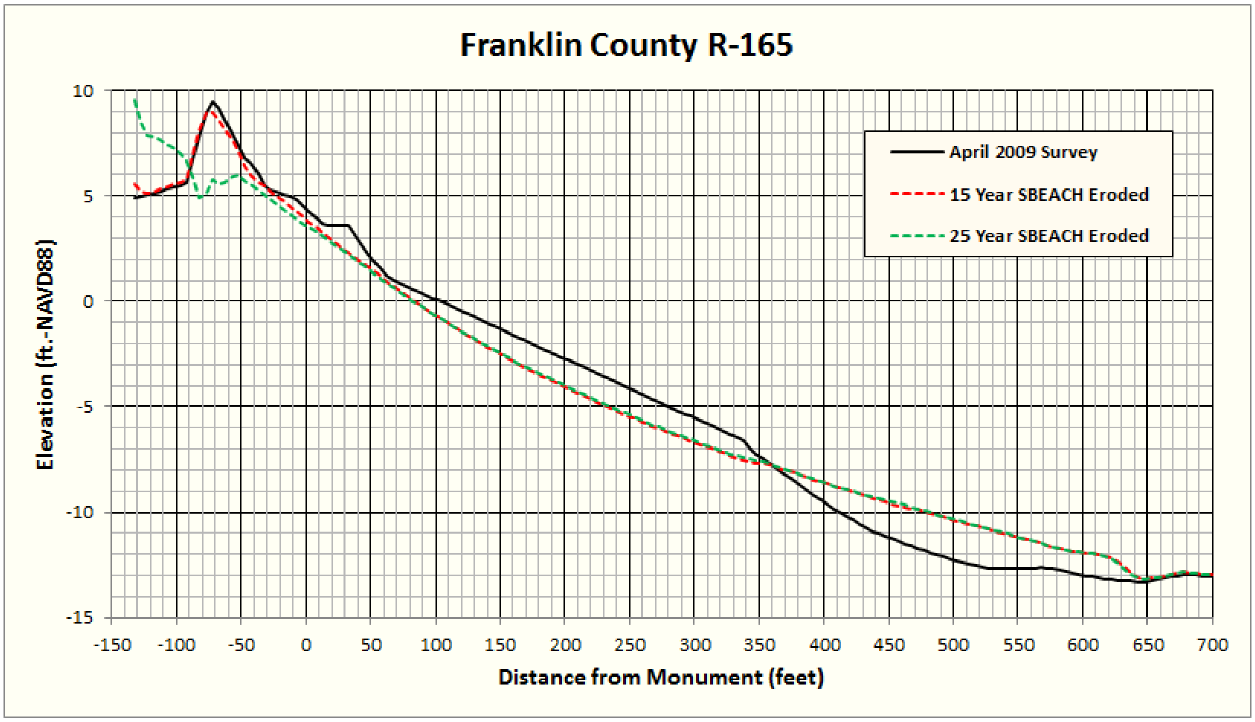

Franklin County R-125
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800

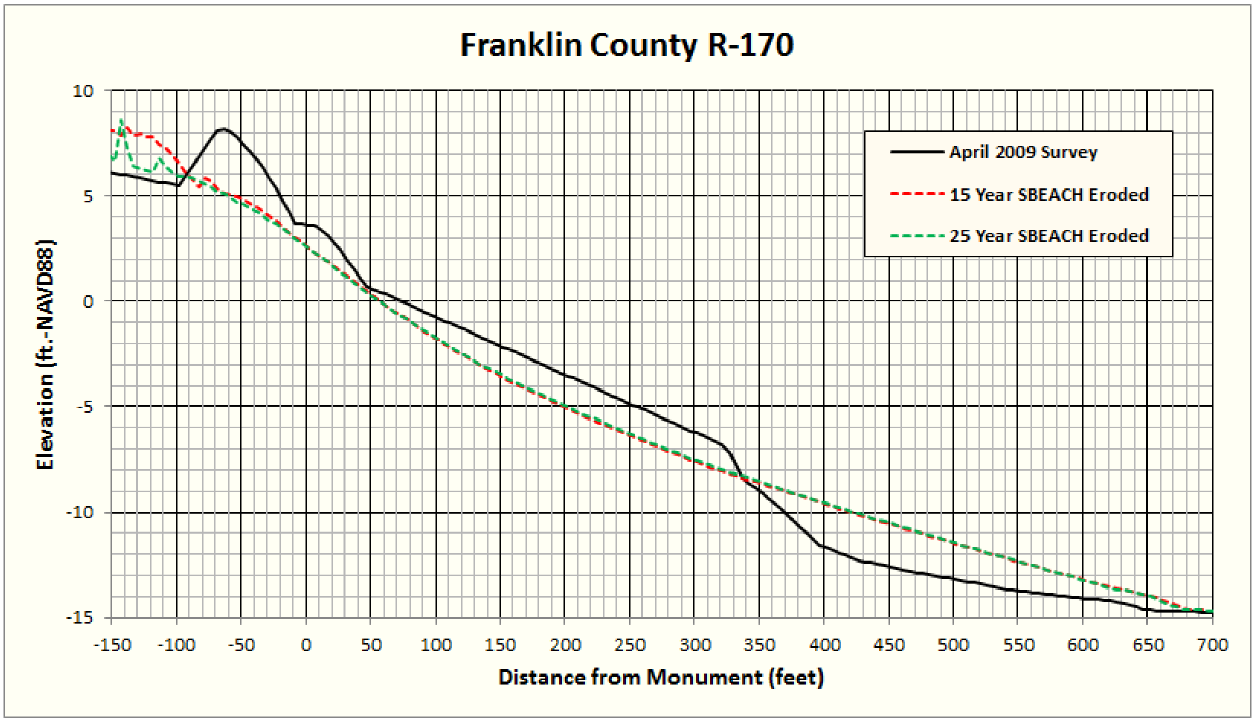

Franklin County R-135
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance from Monument (feet)
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded

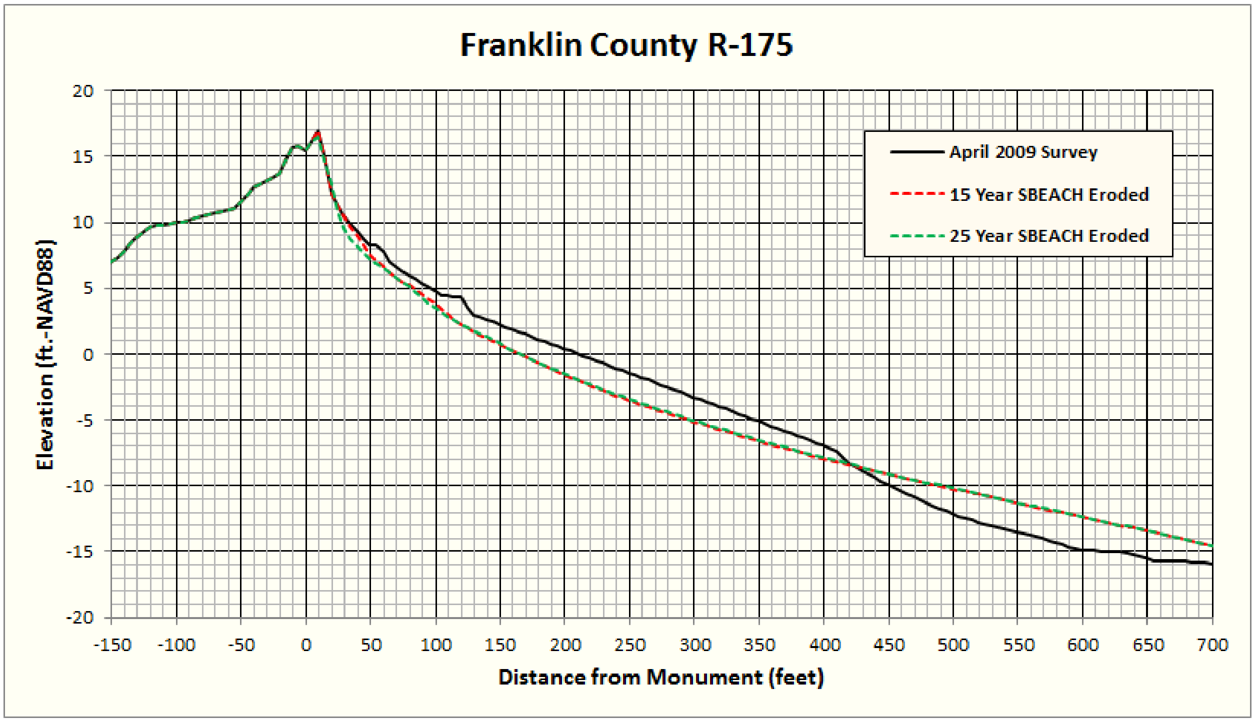

Franklin County R-145
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance from Monument (feet)
Jan. 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded


Franklin County R-155
Elevation (ft.-NAVD88)
Distance from Monument (feet)
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500

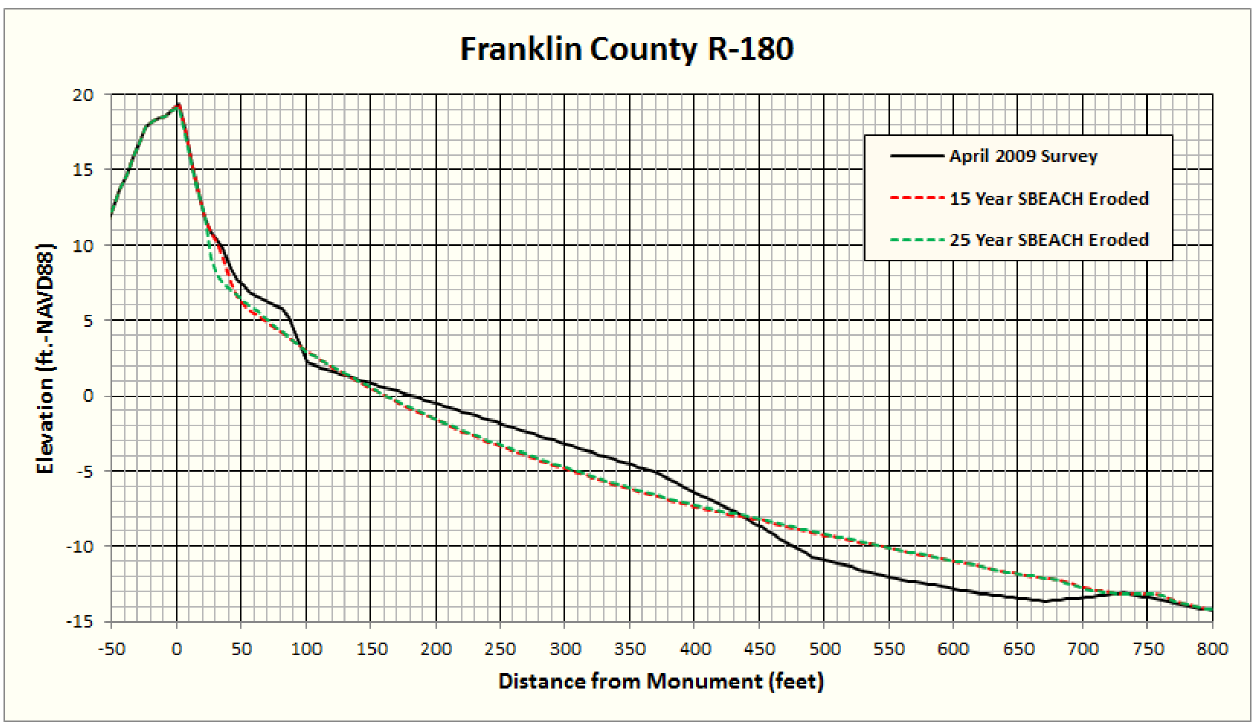

Franklin County R-160
Elevation (ft.-NAVD88)
Distance from Monument (feet)
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700


Franklin County R-165
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700

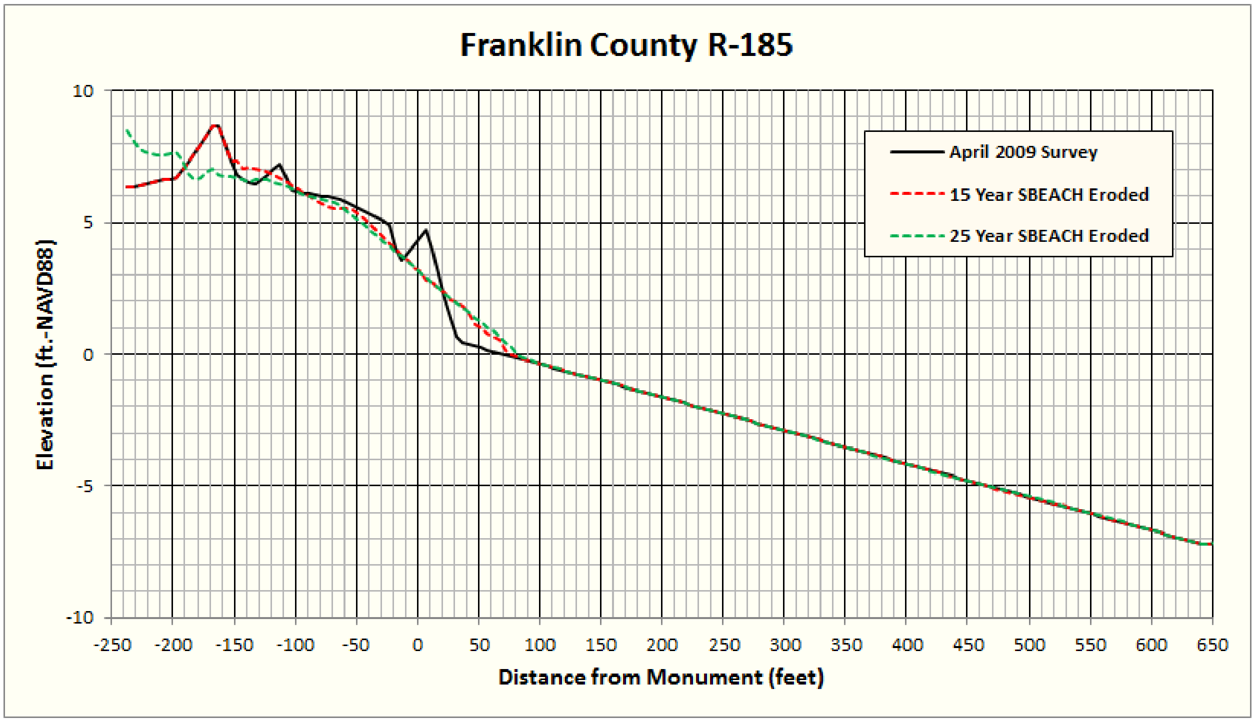

Franklin County R-170
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700



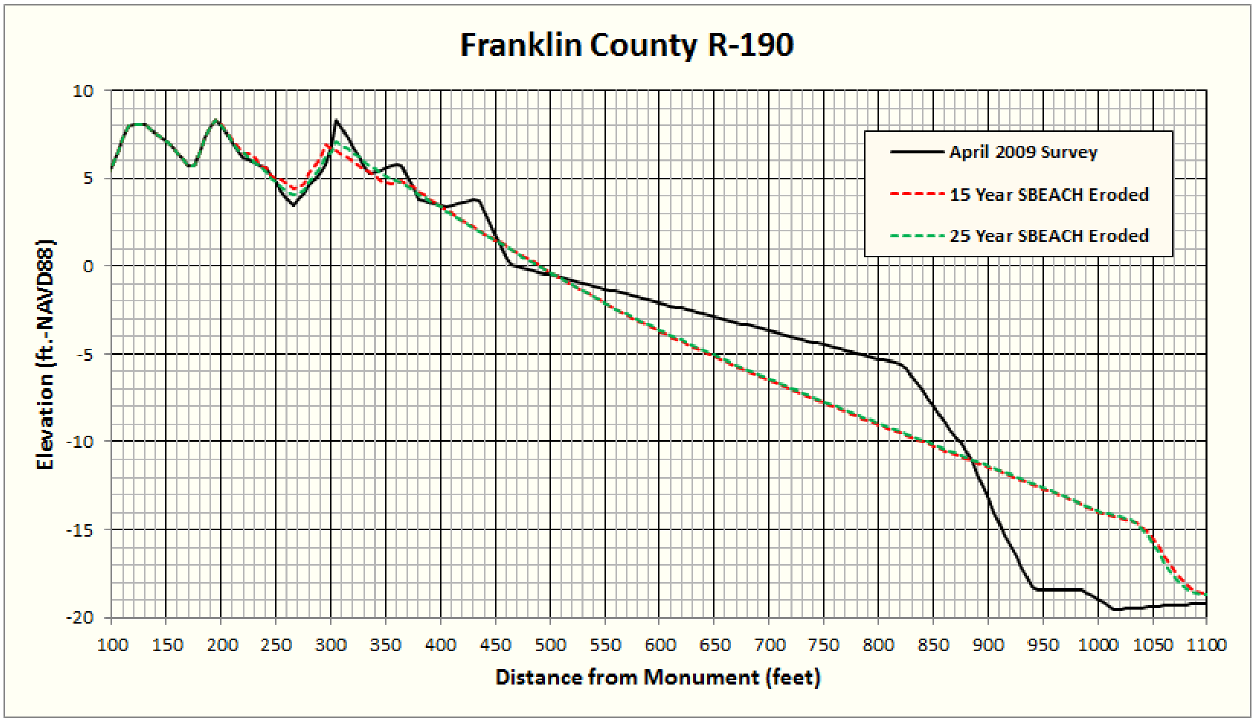
Franklin County R-175
Elevation (ft.-NAVD88)
Distance from Monument (feet)
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
20
15
10
5
0
-5
-10
-15
-20
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700



Franklin County R-180
Elevation (ft.-NAVD88)
Distance from Monument (feet)
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
20
15
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800



Franklin County R-185
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
10
5
0
-5
-10
-250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400 450 500 550 600 650
Distance from Monument (feet)



Franklin County R-190
April 2009 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
10
5
0
-5
-10
-15
-20
100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100
Distance from Monument (feet)