HIGH FREQUENCY SHORELINE CHANGES FOR THE PANHANDLE AREA OF FLORIDA

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EXECUTIVE SUMMARY

In addition to the long-term trends of shoreline change, the shorter-term or "high frequency" changes can pose a threat to coastal construction. These high frequency changes are due to storms and other unknown effects, although in the Florida Panhandle, the subject area of this report, it is well known that large scale cuspate features contribute substantially to the changes.

There are two approaches to predicting high frequency shoreline changes. The approach that has been applied previously is to quantify the storm hydrographs and waves associated with various storm return periods of interest and to input these into a beach and dune erosion model. The second approach, recommended here, is to base the high frequency shoreline changes on the variability in the shoreline data base, i.e. the deviations form the trend line.

A simple method is presented based on the variability in the shoreline position data base maintained by the Office of Beaches and Coastal Systems of the Florida Department of Environmental Protection. Tables are provided for the following four Panhandle counties: Escambia (and Santa Rosa), Okaloosa, Walton and Bay. The application of the method is illustrated with an example from Escambia County.

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HIGH FREQUENCY SHORELINE CHANGES FOR THE PANHANDLE AREA OF FLORIDA

1. INTRODUCTION

Shorelines change on a variety of time scales, ranging from seconds to millennia. Of primary concern to the stewardship of the State's beaches by the Office of Beaches and Coastal Systems (OBCS) of the Florida Department of Environmental Protection (FDEP) are the long-term changes that can be determined as a trend through analysis of the extensive historical shoreline position data base maintained by the OBCS. While these results capture the trend of shoreline changes, it is evident from the data that other time scales of shoreline change are also relevant to construction along the shoreline. Consider the idealized case in which the shoreline change trend is zero, yet there can be substantial fluctuations about the average shoreline position due to storms and other natural variability components of the shoreline position. The causes and interrelationships of some of these components are unknown at present. This is especially the case in the Panhandle area where large cuspate features occur and may migrate along the shoreline (Sonu, 1968; Miselis and Dean, 1993). The cause(s) of these features is unknown; however, their amplitudes can be on the order of 100 to 150 feet; thus they can represent a considerable threat to coastal construction, especially along a shoreline where there is an erosional trend such that the beach becomes narrower with time.

The purpose of the study described in this report was to develop a methodology that can be applied to represent the high frequency shoreline changes along the Florida Panhandle. "High frequency" as used in this report represents the deviations from the trend line as shown in Figure 1. As will be discussed and quantified in detail later, these deviations can be either reasonably coherent along the shoreline or can occur relatively locally in which case, they may be the result of the large scale cuspate features described above.

2. GENERAL BACKGROUND

2.1 General

Consider a storm that occurs affecting a coastal location in the Panhandle area. The resulting beach and dune recession depends on the detailed storm surge levels and wave heights and local factors including the three-dimensional topography, vegetation, and other local causes some of which may not be well understood. Beach and dune erosion models developed to date are two-dimensional representing only the cross-shore sediment transport. Additionally these models do not account for local effects which may influence the cross-shore sediment transport. Yet it is well known from inspecting the erosional scarp that the recession can vary substantially along the shoreline. Dean, et al (1998) have found in a study of the shoreline changes around the State of Florida that the average standard deviation of the variability about the shoreline change trend line is approximately 30 ft to 40 ft except in proximity to inlets where the variability is much greater. Zheng and Dean (1997) have examined contour changes resulting from five different storms and

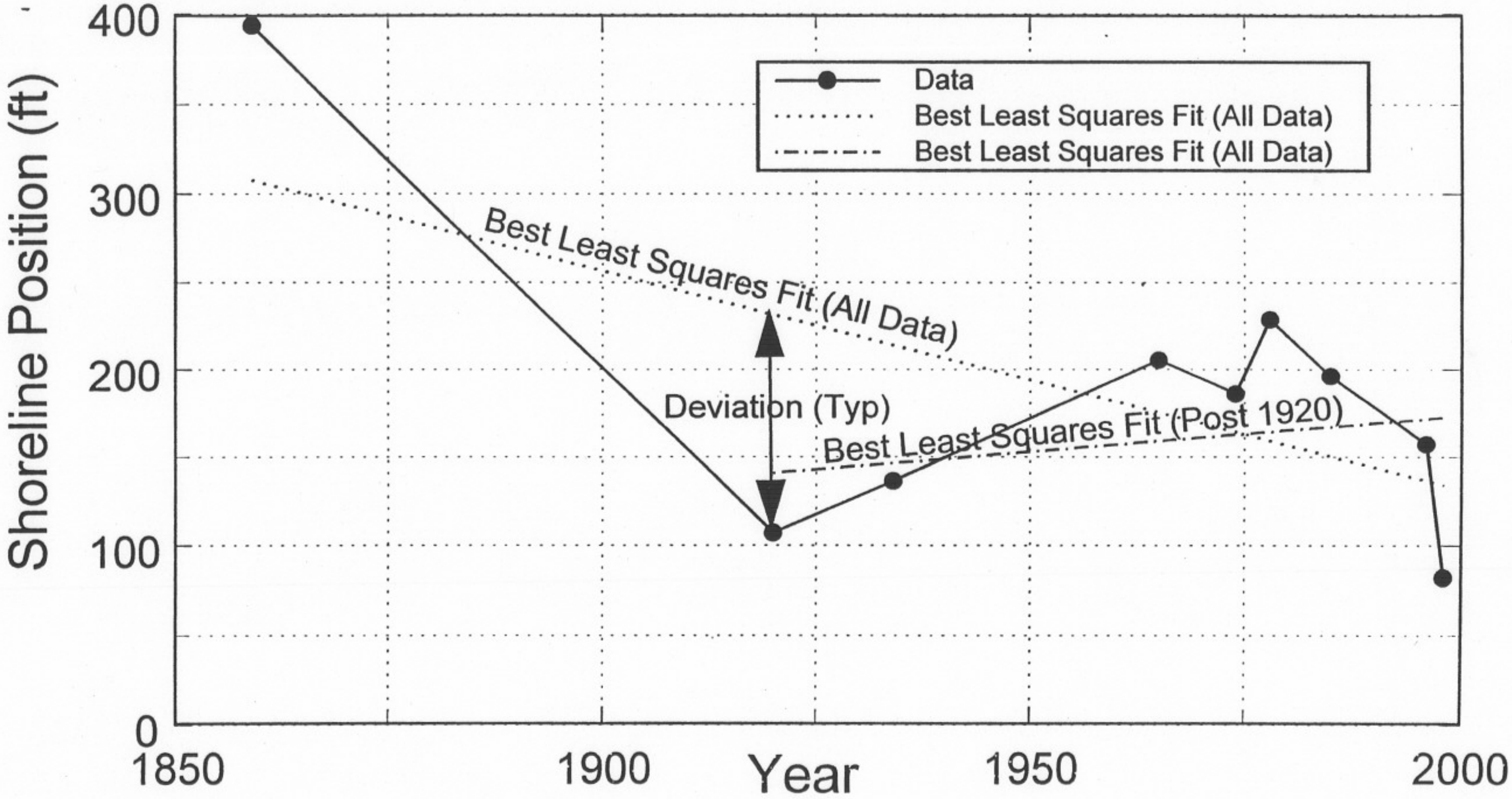

Figure 1. Shoreline Positions For Monument R-125, Escambia County

locations and found that the variability can vary from an average of 30% to 100% of the average change.

Part of the variability from the average change may be a result of irregular longshore topography prior to the storm and the tendency of the storm to straighten the shoreline. As noted, the available models are not sufficiently detailed to account for these features. In summary, the problem of concern here consists of both deterministic and probabilistic components with the deterministic component which could be predicted by a beach and dune erosion model if the related processes were understood adequately and the probabilistic component which is due to unknown and/or unpredictable processes and causes and thus must be determined empirically.

One approach to many problems which include deterministic and probabilistic components is to account for the deterministic component through calculation procedures and to represent the probabilistic component statistically. Wind forces are an example of such a phenomenon. For a given atmospheric pressure field and surface roughness, it is possible to calculate the distribution of the average wind speed with elevation above ground level; however, the temporal variability of the wind speed about its mean at a particular elevation can only be quantified by empirical approaches through the statistics of this variation. Dune erosion is similar. The two dimensional beach and dune erosion models can predict only the deterministic component of the beach and dune recession. Thus, some other realistic empirical approach must be developed and applied to account for the non-deterministic component. It is clear that with our present level of understanding, this non-deterministic component must be based on measured shoreline changes. One approach that has been applied in the establishment of the recommended position of the Coastal Construction Control Line (CCCL) is to apply a factor to the deterministic component (Chiu and Dean, 1984). Earlier efforts to predict high frequency shoreline changes employed similar approaches (Dean and Malakar, 1995). A second approach and the one that will be recommended here is to represent the total component (deterministic and non-deterministic components) from results of analysis of historical position change. However, first the relationships of these two components will be reviewed in the framework of shoreline change statistics.

2.2 Statistics of Shoreline Change

2.2.1 General

The statistics of shoreline change are considered in a manner which represents the structure of changes consistent with the causes and also consistent with the interest in predicting these high frequency changes. Consider the shoreline position, $y_{i,j}$ at the i^{th} location and j^{th} time as follows

$$y_{i,j} = y_{oi} + m_i(t - t_o) + \delta_{i,j} \tag{1}$$

in which y_{oi} is the predicted shoreline location at time t_o, m_i is the shoreline change rate at the i^{th}

location and $\delta_{i,j}$ is the deviation at t_j at the i^{th} location from the predicted location based on the trend line, see Figure 1. This deviation from the predicted value, $\delta_{i,j}$, can be decomposed further into two components as

$$\delta_{i,j} = \overline{\delta_{i,j}} + \delta_{i,j}^{\prime} \tag{2}$$

where the term $\overline{\delta_{i,j}}$ represents the <u>local spatial average</u> of the deviations from the predictions and the term $\delta_{i,j}^{\prime}$ represents the deviation from this local average. The local average is defined as

$$\overline{\delta_{i,j}} = \frac{1}{2k+1}\sum_{i-k}^{i+k} \delta_{i,j} \tag{3}$$

with the value k = 5 such that the local average is based on a shoreline length of approximately 10,000 feet based on a nominal DEP monument spacing of 1,000 feet.

To summarize, the shoreline position, $y_{i,j}$, at the i^{th} location and j^{th} time is represented as

$$y_{i,j} = \underbrace{y_{oi} + m_i(t - t_o)} + \overline{\delta_{i,j}} + \delta_{i,j}^{\prime} \tag{4}$$

Trend line

The interpretation of Eq.(4) in terms of our interest is that the first two terms on the right hand side of Eq. (4) represent the trend, that is, the long term predictable shoreline position. The next term, $\overline{\delta_{i,j}}$, is the local spatial average and the term representing storm or other longshore coherent effects and the component that should be predicted from a beach and dune erosion model if all of the processes were understood adequately. The final term, $\delta_{i,j}^{\prime}$ represents the local deviation from the predicted storm effects. Note that by definition, there will be deviations which exceed the predicted storm effects and deviations which are less than the predicted storm effects.

The following sections discuss the manner in which the various components, $\overline{\delta_{i,j}}$, and $\delta_{i,j}^{\prime}$ can be determined.

2.2.2 Determination of $\overline{\delta_{i,j}}$

At any time and location, this term represents the longshore coherent component of the deviation of the shoreline position from the predicted shoreline position based on analysis of the long term data. One approach to determining $\overline{\delta_{i,j}}$ is to utilize the most recent available beach profile available and to consider this profile in equilibrium. With the increased water levels and wave heights due to the storms, the shoreline will retreat by a maximum amount which depends on the temporal variations of these two variables and which could be predicted by a beach and dune erosion model. A second approach is to simply determine the quantity empirically as will be discussed and recommended later in this report.

2.2.3 Determination of $\delta'_{i,j}$

This quantity must be determined empirically through application of Eqs.(3) and (4). Figure 2 presents for 1996, plots of $\delta'_{i,j}$ (termed "delprime" in Figure 2) and $\overline{\delta_{i,j}}$ (termed "Delbar" in Figure 2) for a portion of the Escambia County shoreline . It is seen that the relative magnitudes of these two components vary considerably and that $\overline{\delta_{i,j}}$ (Delbar) is predominantly negative for 1996 over this section of shoreline.

2.2.4 Determination of $\delta_{rms}(j)$

The discussion in the preceding sections has been presented to provide a framework for the statistics of shoreline change. The recommended method will employ the root-mean-square value of $\delta_{i,j}$ (= $\delta_{rms}(j)$) as determined by a least squares fit to the data over all times considered accurate at each monument. Because the earlier surveys are not considered as valid as the later surveys, the earliest dates included in the analysis and results to be recommended here are: Escambia (and Santa Rosa) Counties: 1920; Okaloosa County: 1934; Walton County: 1932; and Bay County: 1932. Figure 3 presents a plot of the alongshore variation of $\delta_{rms}(j)$ over the same portion of Escambia County as portrayed in Figure 2.

3. RECOMMENDED METHOD

The total variance from the trend line includes both the variance due to storms (the predictable or deterministic component) and the variance representing the non-deterministic component. Thus, the recommended method is to simply apply this total variance as follows. The total variance at one monument is defined as $\overline{\delta_{i,j}^2}$, i.e.

$$\overline{\delta_j^2} = (\delta_{rms}(j))^2 = \overline{\delta_{i,j}^2} = \overline{\overline{\delta_{i,j}}^2 + \delta'^2_{i,j}} \tag{5}$$

in which the averaging is over time, i.e. the i^th subscript. In the application of the results, it is assumed that the variance is representative for all deviations and that, similar to the application to other predictions of natural events, one event occurs per year. Finally, it is assumed that the distribution to which the variance pertains is a normal distribution. Thus deviations can occur which are either negative or positive.

In accordance with a normal probability distribution, the recognition that the deviation from the trend line can be either positive or negative (we are only interested in recessions which are negative deviations) and that one extreme (positive or negative) shoreline deviation occurs per

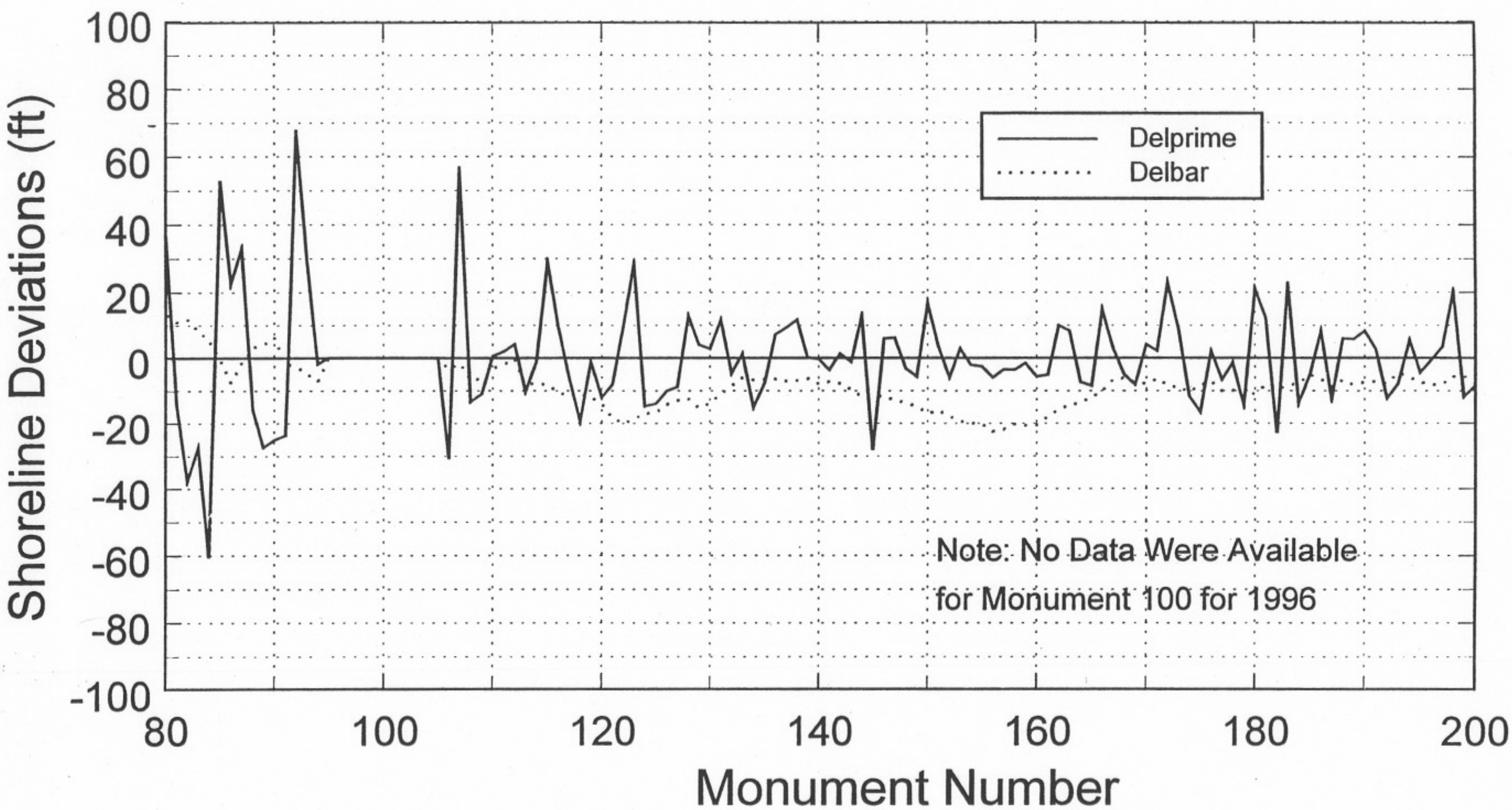

Figure 2. Shoreline Change Characteristics Along Portions of Escambia County, 1996

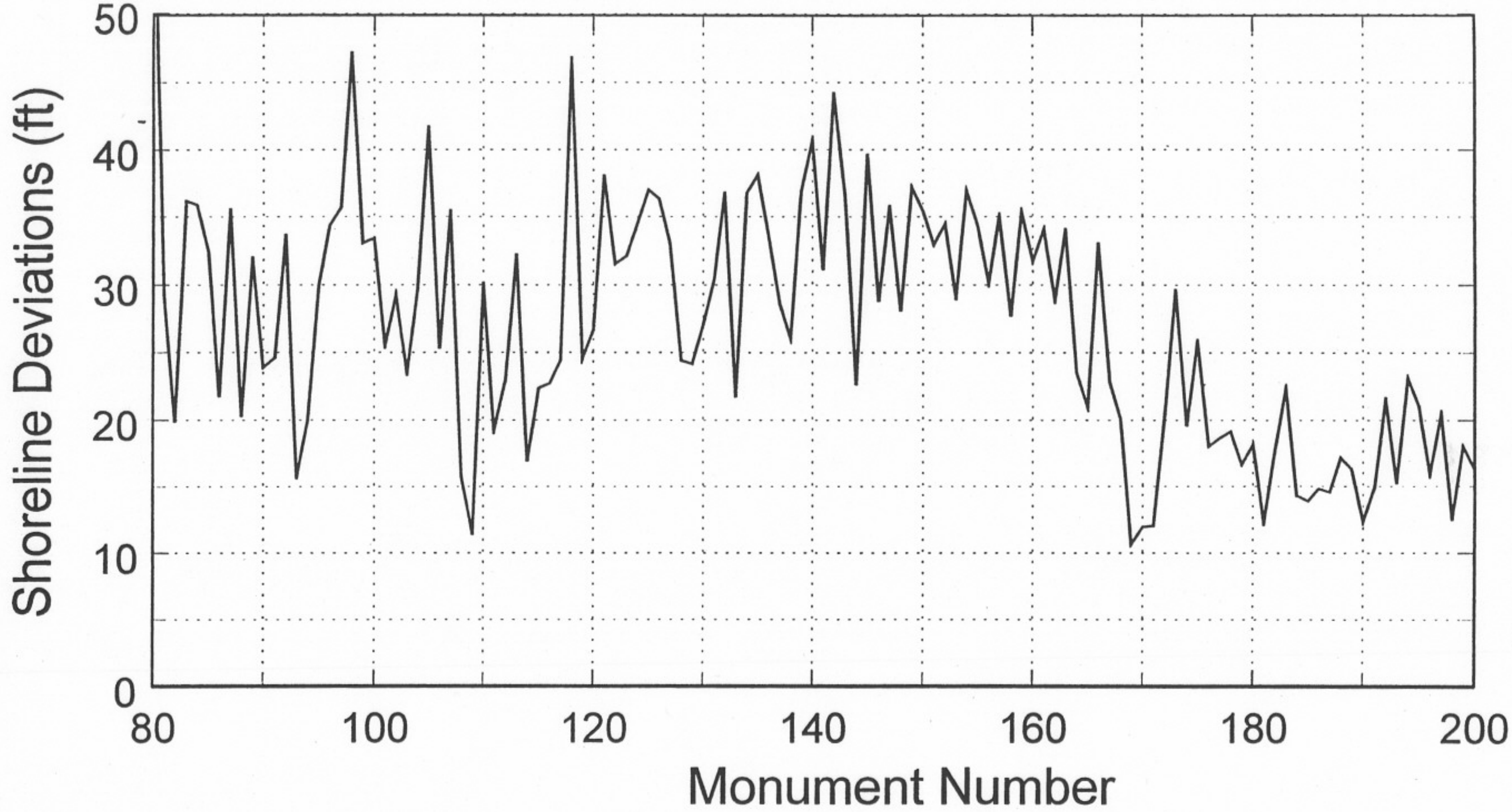

Figure 3. Variation of del(j) Along Portions of Escambia County

year, it can be shown that the recession, R_{TR}, associated with a particular return period, TR, is

$$R_{TR}(j) = F_{TR}\,\delta_{rms}(j) \qquad (6)$$

where $\delta_{rms}(j) = \sqrt{\overline{\delta_j^2}}$ and the values of F_{TR} as determined from a normal distribution are presented in Table 1. Because of the alongshore variability in $\delta_{rms}(j)$, in application, it may be desirable to employ a running average, see Figure 3.

Table 1
Values of the Factor F_{TR} for Various Return Periods, TR

	F_{TR} for Return Periods, TR (years)						
Return Periods, TR (years)	5	10	15	20	25	30	35
F_{TR}	0.97	1.40	1.61	1.75	1.86	1.96	2.00

Appendices A - D presents the recommended values of $\delta_{rms}(j)$ on a monument-by-monument basis for Escambia (and Santa Rosa) Counties: Appendix A; Okaloosa County: Appendix B: Walton County: Appendix C; and Bay County: Appendix D.

4. EXAMPLE OF APPLICATION

The methodology will be illustrated with an example for Escambia County. Suppose that the shoreline recessions are desired for return periods of 5, 10, 15, 20, 25, 30 and 35 years, for Monument 125 in Escambia County. The value of $\delta_{rms}(j)$ from Page A-1 of Appendix A is 37.0 feet. Thus applying Eq. (6) and the F_{TR} values in Table 1, the shoreline recessions for the various return periods are presented in Table 2.

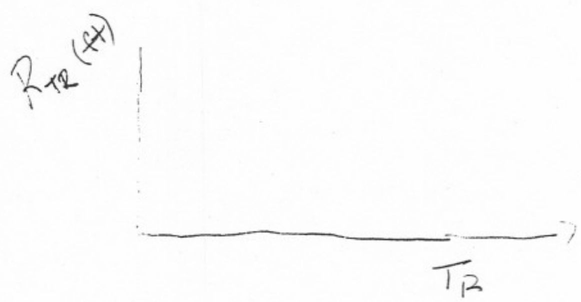

Table 2
Predicted Values of Shoreline Recession for Various Return Periods, TR
Monument 125 in Escambia County

	Shoreline Recessions (ft) for Return Periods, TR (years)						
Return Periods, TR (years)	5	10	15	20	25	30	35
Shoreline Recessions, R_{TR} (ft)	35.9	51.8	59.6	64.8	68.8	72.5	74.0

5. SUMMARY

A simple and direct method is developed and illustrated with an example for estimating the high frequency shoreline changes for the four county Panhandle shoreline of Florida. The method is based on the statistics of the deviations of measured shoreline positions from the long-term trend of the data in the shoreline position data base. In part this method is recommended over the previous method developed for estimating high frequency shoreline changes due to the documented contributions of non-deterministic large scale cuspate features along the Panhandle shoreline and thus the need to augment any predictions based on numerical modeling.

6. REFERENCES

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Zheng, J. and R. G. Dean (1997) "Shoreline and Dune Recession Variability and Cross-shore Modeling", Proceedings of the 10th National Conference on Beach Preservation Technology, Compiled by L. S. Tait, Florida Shore and Beach Preservation Association, Tallahassee, FL, pp.151 - 166.

APPENDIX A

ESCAMBIA (AND SANTA ROSA) COUNTY

TABULATIONS OF $\delta_{rms}(j)$ ON A MONUMENT-BY-MONUMENT BASIS

LISTING OF MONUMENT-BY-MONUMENT DELTA VALUES FOR ESCAMBIA COUNTY

MON. NO.	DELTA(j)	MON. NO.	DELTA(j)	MON. NO.	DELTA(j)
1	22.95	2	29.71	3	25.97
4	27.52	5	23.58	6	32.15
7	13.32	8	33.10	9	25.19
10	17.55	11	24.32	12	16.57
13	25.54	14	24.55	15	33.21
16	14.04	17	22.37	18	14.76
19	24.25	20	24.44	21	30.81
22	35.67	23	31.00	24	18.20
25	33.37	26	24.09	27	35.02
28	33.99	29	35.65	30	41.37
31	38.93	32	43.38	33	52.59
34	35.34	35	48.70	36	49.88
37	31.23	38	25.60	39	31.72
40	32.55	41	38.63	42	72.00
43	64.37	44	99.13	45	101.86
46	98.11	47	95.91	48	118.69
49	93.68	50	94.53	51	105.74
52	96.70	53	94.67	54	115.70
55	106.73	56	122.14	57	133.52
58	118.53	59	101.55	60	131.20
61	135.23	62	170.78	63	181.15
64	172.19	65	88.25	66	73.99
67	75.82	68	189.26	69	118.08
70	57.83	71	111.95	72	107.44
73	96.10	74	61.03	75	61.21
76	34.60	77	52.37	78	67.60
79	90.78	80	61.57	81	29.22
82	19.87	83	36.18	84	35.89
85	32.40	86	21.76	87	35.64
88	20.27	89	32.09	90	23.91
91	24.62	92	33.73	93	15.69
94	20.03	95	30.02	96	34.36
97	35.71	98	47.23	99	33.07
100	33.43	101	25.59	102	29.34
103	23.52	104	29.73	105	41.79
106	25.29	107	35.53	108	15.82
109	11.47	110	30.20	111	19.25
112	23.05	113	32.30	114	16.93
115	22.39	116	22.74	117	24.44
118	46.90	119	24.57	120	26.68
121	38.15	122	31.53	123	32.14
124	34.48	125	37.02	126	36.35
127	33.08	128	24.40	129	24.16
130	27.11	131	30.47	132	36.88

LISTING OF MONUMENT-BY-MONUMENT DELTA VALUES FOR ESCAMBIA COUNTY
(continued)

MON. NO.	DELTA(j)	MON. NO.	DELTA(j)	MON. NO.	DELTA(j)
133	21.73	134	36.80	135	38.14
136	33.65	137	28.66	138	26.07
139	36.92	140	40.74	141	31.12
142	44.29	143	36.62	144	22.63
145	39.68	146	28.82	147	35.83
148	28.10	149	37.24	150	35.45
151	32.95	152	34.50	153	29.09
154	36.97	155	34.33	156	30.18
157	35.10	158	27.77	159	35.42
160	31.79	161	34.09	162	28.93
163	34.06	164	23.55	165	21.02
166	33.09	167	22.83	168	20.08
169	10.67	170	11.94	171	12.02
172	20.28	173	29.71	174	19.61
175	25.90	176	18.03	177	18.67
178	19.14	179	16.66	180	18.18
181	12.28	182	17.94	183	22.48
184	14.28	185	13.90	186	14.82
187	14.55	188	17.19	189	16.28
190	12.37	191	14.90	192	21.58
193	15.32	194	23.15	195	21.11
196	15.97	197	20.54	198	12.62
199	18.07	200	16.35	201	11.63
202	18.63	203	17.16	204	20.59
205	20.08	206	12.89	207	18.68
208	33.49	209	22.57	210	16.77
211	18.75	212	23.16	213	38.34
214	32.14				

APPENDIX B

OKALOOSA COUNTY

TABULATIONS OF $\delta_{rms}(j)$ ON A MONUMENT-BY-MONUMENT BASIS

LISTING OF MONUMENT-BY-MONUMENT DELTA VALUES FOR OKALOOSA COUNTY

MON. NO.	DELTA(j)	MON. NO.	DELTA(j)	MON. NO.	DELTA(j)
1	26.94	2	22.97	3	24.17
4	18.05	5	22.67	6	29.44
7	19.98	8	11.97	9	28.31
10	18.92	11	14.10	12	22.76
13	10.90	14	25.95	15	19.98
16	19.44	17	198.37	18	207.44
19	201.45	20	164.12	21	143.56
22	178.75	23	37.11	24	33.84
25	28.10	26	40.48	27	37.69
28	38.19	29	42.46	30	41.34
31	32.07	32	39.43	33	26.14
34	38.84	35	25.92	36	26.12
37	28.29	38	35.40	39	29.84
40	32.77	41	34.27	42	32.77
43	37.09	44	24.85	45	37.20
46	30.57	47	26.67	48	29.40
49	14.25	50	18.67		

APPENDIX C

WALTON COUNTY

TABULATIONS OF $\delta_{rms}(j)$ ON A MONUMENT-BY-MONUMENT BASIS

LISTING OF MONUMENT-BY-MONUMENT DELTA VALUES FOR WALTON COUNTY

MON. NO.	DELTA(j)	MON. NO.	DELTA(j)	MON. NO.	DELTA(j)
1	34.78	2	18.98	3	42.58
4	25.44	5	15.91	6	31.99
7	23.43	8	28.97	9	19.48
10	42.43	11	37.64	12	27.06
13	15.09	14	23.09	15	23.26
16	34.85	17	61.85	18	42.47
19	47.15	20	55.42	21	45.48
22	46.21	23	40.32	24	28.71
25	28.58	26	28.86	27	32.20
28	28.22	29	28.76	30	25.40
31	47.85	32	17.20	33	29.10
34	19.75	35	31.11	36	31.41
37	18.78	38	20.08	39	29.68
40	24.40	41	37.14	42	50.16
43	64.37	44	34.42	45	44.00
46	22.51	47	33.87	48	25.03
49	29.22	50	18.28	51	29.86
52	20.81	53	24.88	54	22.12
55	22.01	56	22.26	57	25.81
58	28.48	59	26.58	60	25.34
61	19.95	62	17.57	63	32.97
64	18.42	65	20.02	66	28.34
67	23.67	68	31.09	69	30.15
70	23.65	71	31.31	72	33.53
73	16.67	74	19.81	75	39.67
76	34.74	77	49.34	78	39.38
79	40.00	80	14.97	81	34.44
82	22.01	83	21.17	84	21.21
85	15.55	86	19.08	87	21.51
88	20.33	89	25.03	90	23.96
91	18.35	92	20.99	93	36.18
94	30.39	95	24.29	96	26.11
97	25.07	98	29.31	99	24.16
100	12.36	101	28.77	102	28.23
103	20.76	104	21.82	105	27.40
106	28.17	107	23.96	108	14.58
109	20.10	110	16.02	111	29.49
112	27.02	113	20.39	114	22.95
115	16.48	116	17.98	117	30.78
118	18.36	119	15.74	120	23.49
121	21.35	122	16.32	123	24.94
124	17.90	125	24.35	126	25.02
127	25.02				

APPENDIX D

BAY COUNTY

TABULATIONS OF $\delta_{rms}(j)$ ON A MONUMENT-BY-MONUMENT BASIS

LISTING OF MONUMENT-BY-MONUMENT DELTA VALUES FOR BAY COUNTY

MON. NO.	DELTA(j)	MON. NO.	DELTA(j)	MON. NO.	DELTA(j)
1	22.64	2	31.26	3	38.09
4	32.61	5	24.40	6	27.32
7	29.26	8	38.22	9	26.37
10	43.92	11	30.53	12	21.02
13	36.93	14	22.88	15	43.62
16	42.39	17	37.43	18	36.98
19	53.77	20	43.55	21	38.71
22	41.91	23	31.70	24	27.55
25	30.65	26	35.35	27	34.16
28	37.46	29	39.64	30	48.56
31	39.66	32	36.65	33	44.91
34	42.11	35	39.26	36	50.54
37	32.56	38	28.60	39	27.80
40	41.67	41	39.84	42	63.35
43	21.02	44	26.83	45	26.34
46	34.85	47	19.35	48	27.83
49	36.97	50	20.20	51	20.79
52	22.07	53	15.51	54	20.41
55	25.29	56	27.15	57	22.72
58	21.06	59	14.12	60	35.78
61	21.45	62	18.66	63	29.24
64	16.18	65	21.20	66	22.25
67	41.77	68	24.42	69	19.70
70	27.41	71	23.55	72	17.34
73	25.54	74	30.24	75	18.37
76	22.18	77	21.55	78	23.17
79	19.39	80	18.91	81	23.60
82	23.00	83	15.88	84	32.52
85	29.32	86	26.89	87	27.39
88	42.66	89	25.99	90	33.91
91	49.77	92	39.89	93	44.27
94	52.85	95	76.52	96	96.32
97	65.08	98	49.27	99	64.12
100	58.45	101	50.12	102	26.15
103	35.52	104	22.73	105	42.10
106	33.88	107	30.94	108	53.30
109	36.17	110	27.08	111	19.75
112	60.69	113	29.05	114	41.44
115	19.32	116	30.35	117	31.01
118	65.92	119	41.07	120	41.67
121	54.18	122	41.36	123	33.44
124	39.48	125	41.81	126	32.78
127	62.20	128	37.31	129	44.16
130	29.99	131	9.41	132	16.65

LISTING OF MONUMENT-BY-MONUMENT DELTA VALUES FOR BAY COUNTY
(continued)

MON. NO.	DELTA(j)	MON. NO.	DELTA(j)	MON. NO.	DELTA(j)
133	9.39	134	10.73	135	13.66
136	20.88	137	36.96	138	22.40
139	21.15	140	29.21	141	21.74
142	22.45	143	13.58	144	13.29