Shoreline Change Rate Estimates

Flagler County

July 1999

Prepared by:
Emmett R. Foster[1]
Darren L. Spurgeon[2] and Jenny Cheng[2]

[1] Office of Beaches & Coastal Systems
Florida Dept. of Environmental Protection
Tallahassee, FL

[2] Beaches and Shores Resource Center
Florida State University
Tallahassee, FL

Report No. BCS-99-02
Florida Department of Environmental Protection
Office of Beaches and Coastal Systems

FOREWORD

This report was prepared to provide shoreline change rate estimates to assist in regulatory programs and beach management planning efforts. In particular, there is a need to assist project managers within the Office of Beaches and Coastal Systems in ranking proposed beach management projects for State of Florida funding support. Efforts were made in developing the rate estimates to consider and take into account the influences of coastal structures and sand fill placements on shoreline change. However, these influences can be very complex and extensive analysis and consideration of such influences was beyond the scope of this work.

Shoreline change analyses performed for other specific purposes, such as for establishing 30-year erosion projections pursuant to paragraph 161.053(6), F.S., should be developed in accordance with appropriate and applicable procedures for that specific purpose, although these reports may be relevant in that regard.

This report was prepared by Emmett Foster, P. E., of the Office of Beaches and Coastal Systems and Darren Spurgeon and Jenny Cheng of the Beaches and Shores Resource Center. The shoreline change rate estimates are based on the best available data at the time of report preparation. Updates to the report will be performed as new data becomes available and as staff workload allows.

APPROVED BY

Alfred B. Devereaux, Jr., Director
Office of Beaches and Coastal Systems

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 EXECUTIVE SUMMARY

Flagler County is located in northeast Florida about mid-way between Georgia and Cape Canaveral. Devoid of inlets or embayments, the county's moderately developed coastline is part of a barrier island and mainland complex that extends from Matanzas Inlet in southern St. Johns County to Ponce de Leon Inlet in Volusia County.

There has been very little human influence in Flagler County. No renourishment projects have been conducted. There are two relatively small sections of coastal armoring, at Marineland and Flagler Beach, respectively. Scattered along Flagler's shores, however, are natural beachrock outcroppings which essentially act as hardened structures or areas which are more resistant to erosion.

The large amount of broken shell gives the beach sand a notable reddish-orange coloration and a relatively steep beachface. This is in sharp contrast with beaches to the north and south, which are largely composed of fine white quartz with a much smaller percentage of shell. Apparently the finer material is selectively moved through Flagler County and most of the shell remains in place.

Shoreline change rates have been and are expected to remain small, on the order of -1 feet per year overall.

2 INTRODUCTION

This work is part of an ongoing project to develop up-to-date shoreline erosion rate estimates for the Florida sandy beach coastline. The shoreline referred to is the approximate Mean High Water (MHW) elevation contour. The information compiled and analyses conducted are intended to provide quantitative and qualitative information on a county-by-county basis that may be used to assist in beach management planning, coastal regulation, and general shoreline analysis work.

Quantitative erosion information will be focused on providing erosion estimates relative to currently active coastal processes in those places where no renourishment projects exist. Where renourishment or other similar sand fill projects of size exist, erosion rate estimates for the pre-project conditions will be attempted where possible. It is beyond the scope of these reports to analyze renourishment project performance. In such cases, erosion is a combination of initial onshore-offshore adjustments, lateral diffusion, structural interaction, and the "background erosion" process. Because the conditions that affect erosion are being frequently altered (e.g. inlets, shoals, and armoring additions/subtractions), pre-project erosion estimates are useful primarily in a historical sense and in showing what led to the need for the artificial nourishment.

The data used for this analysis is from the Office of Beaches and Coastal Systems Historical Shoreline Database. The database includes beach and offshore profile field surveys, digitized historical shoreline and bathymetric maps, aerial photographs from the Bureau files, and numerous graphical representations of the data, all within a common set of horizontal and vertical controls. This database was developed and quality controlled by engineers in the Research, Analysis and Policy Section and is continually updated as time and workload allows. Beach profiles were surveyed by the Coastal Data Acquisition Section and, in some cases, by private firms, the latter usually related to the monitoring of coastal erosion control projects.

It is beyond the scope of this report to investigate possible actions that may be necessary to prevent or curb shoreline erosion. Where appropriate, however, recommended actions may be suggested or previous, failed attempts may be pointed out in an effort to help guide the reader towards a better understanding of the dynamics of the coastline and future trends in shoreline change.

3 REGIONAL SETTING

3.1 Study Area

Flagler County is located in northeast Florida about mid-way between Georgia and Cape Canaveral (Figure 1). Fronted by the Atlantic Ocean, the Flagler County coast is part of a barrier island and mainland complex that extends from Matanzas Inlet in southern St. Johns County to Ponce de Leon Inlet in Volusia County.

Flagler County contains 100 DEP survey reference points, generally designated as "R" monuments, spaced approximately 1000 ft (300 m) apart. This report uses these reference points to locate various items within the county.

3.2 Coastal Setting

3.2.1 Waves and Tides

Tides along Flagler county are semi-diurnal and asymmetrical. National Ocean Service tide tables report a mean tidal range of 4.3 ft (1.3 m) with spring tides around 5.1 ft (1.6 m).

The dominant wave direction is out of the northeast and east directions, which also corresponds to the dominant wind direction. The most frequent wind speeds are between seven and sixteen knots (13-30 km/hr), according to the U. S. Naval Weather Service Command (BSRC, 1987). Wave heights of 3-4 ft (0.9-1.2 m) occur most frequently (30.1%), and waves with heights greater than 6 ft (1.8 m) occur with a frequency of 20.8 percent (BSRC, 1987). The prevailing wave periods are less than six seconds (53.3%) (BSRC, 1987).

3.2.2 Longshore Transport

Littoral transport is to the south. Estimates of sediment transport vary widely. There are no inlets or large artificial structures in Flagler county to interrupt the longshore transport, so littoral drift has been generally assumed to be relatively uniform throughout the county.

It is important to note that there are distinct transitions in shell content north and south of the county. Inside the county, the beach has a very high broken shell

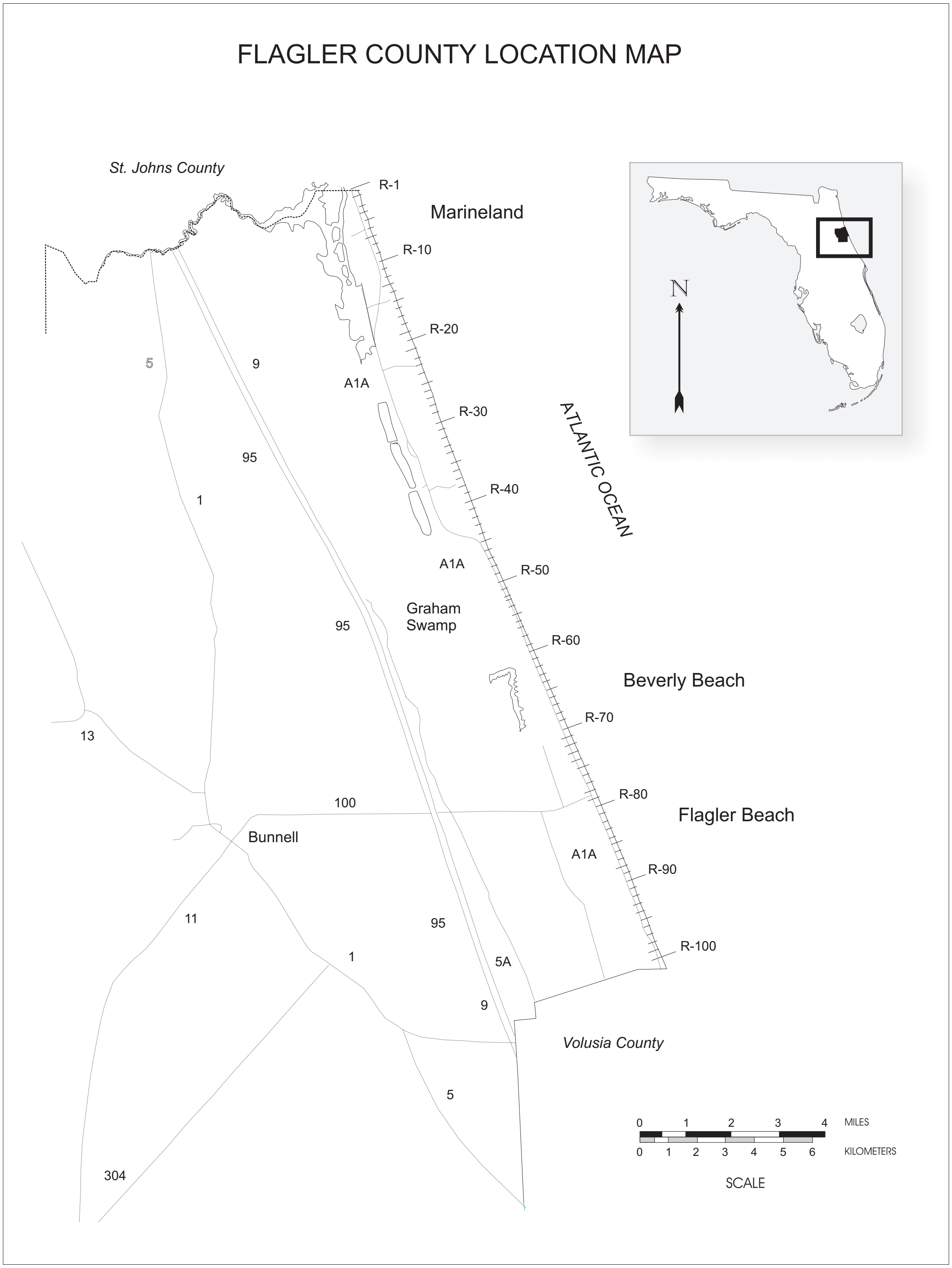


Figure 1. Study area showing Flagler County, Florida.

content, apparently from active shellfish populations and from the breakdown of beachrock and other similar features. This lends the beach a distinctive coloration and a relatively steep beachface. In St. Johns County to the north and Volusia County to the south, the relative abundance of fine quartz sand increases, so much so that driving on those beaches has had a long tradition. This suggests that the finer quartz sand is moved selectively through Flagler County, with the harder to move shell content mostly staying put or gradually dissolving and/or breaking down to finer fragments.

3.2.3 Storms

There have been numerous hurricanes and northeaster storms that have affected northeast Florida. Hurricane Dora in 1964, and northeasters in the 1960's and in November 1984 were probably the most intense in recent history. In general, winter storms or northeasters are thought to have a greater impact on shoreline change than hurricanes in this county because these winter storms occur with greater frequency and can remain in the area for longer periods of time. However, storms are just peaks in the total normal wind and wave climate record. Experience and observations indicate that severe storms can temporarily disrupt or obscure the longer term erosion pattern, perhaps for up to a decade. In some situations, if a major factor such as the sand supply is altered, or if an inlet is significantly changed, the coastal process and erosion pattern can be permanently changed by a storm. There are no indications of major storms changing the erosion pattern in Flagler County to date.

3.3 Engineering Projects / Hardened Features

Flagler County is devoid of any large-scale renourishment projects. Fronting the Marineland area, R-1 to R-3, is a 2,400 ft (730 m) rock revetment. A series of five small rock groins are also part of this armored length of shoreline. A large buried rock revetment exists along 6400 ft (2000 m) of Highway A1A in Flagler Beach, constructed or reconstructed in 1984 following the November northeaster.

Extending south of Marineland for about 2 mi (3.1 km) is a very pronounced outcrop of beachrock, R-3 to R-16. Although a natural feature, this rock acts essentially as a hardened structure, but becomes less pronounced in the last 3000 feet (900 m). Another significant, yet patchy exposure of beachrock exists between approximately R-20 and R-43. This segment is occasionally visible in the field and both segments are visible on a set of 11/21/72 aerial photography. Additional beachrock likely exists elsewhere in the county but lies buried beneath sand. In particular, the data suggests significant rock outcrops probably occur between approximately R-65 to R-71, and R-79 to R-92. The presence of such features would affect beach erosion, as can be seen in the results of this report.

There are also extensive nearshore hard-bottom rock outcrops along the whole length of the county. These exposures, which are evident on aerial photographs as well as from shore during calm wave conditions, appear similar in nature to rock observed on the beach. These nearshore features undoubtedly affect wave refraction and can be a major factor in maintaining the overall shoreline shape or curvature.

4 METHODS

A shoreline change analysis to satisfy the report objectives was performed using the methodology initially developed by Foster and Savage (1989) and Foster (1992). In brief, within the often nonlinear total time record, segments are identified in which the erosion is relatively constant or can reasonably be approximated as such. Three different rate calculation methods are applied to these near-linear time segments: the rate averaging, least squares, and end-point methods. These results are first averaged alongshore and then averaged across the three calculation methods to achieve a concensus average, not dependent on any single rate calculation method. This is because each calculation method has relative advantages and disadvantages. If time segments are selected reasonably well, the differences between rate methods will be minimal. In certain simplified situations it may be better to use a single rate calculation method, such as the end-point method, as necessity and reason dictate. If the averaging is done properly it will achieve results representative of the unaveraged data but will not be overly affected by individual point variability.

In many cases rates from longer and shorter time periods are calculated for comparison purposes (e.g., to show possible progression of an erosion pattern over time or to show that the use of more recent data, which is generally of higher accuracy, yields essentially the same results as the data in a comparative longer time period).

Visual tools used for analysis generally include plan views of shorelines oriented and scaled to emphasize shoreline width changes as well as subtle but important shoreline orientation differences or geologic features within a county or reach. This analysis also used distance versus time plots with overlapping axes, known as "stack plots" because several data plots are stacked in sequence to better see a pattern in the data (Appendix B). There are also representative beach profile plots (Appendix C).

5 SHORELINE CHANGE RESULTS

The first modern shoreline, linearly comparable and related to the most recent shoreline, appears to be the 1952-56 USGS shoreline. Earlier shorelines in this county are either suspected of being relatively inaccurate (1923-24) or are not obviously part of the same approximately linear time sequence (1872-73). The approximate linearity of the selected post 1950's period is illustrated in the stack plots of Appendix B.

Comparative rates have been calculated for the 1952-56 to 1986-87,93 (most recent data) time periods, and the 1972 (first DEP field data) to 1986-87,93 time periods. The most recent data is a mix of 1993 data (approximately every third range) and 1986-87 data. The latter 1986-87 data set may put a negative bias on the results because it is close in time to a major storm in 1984. However, slightly overestimating erosion is better than underestimating in this case of generally mild erosion. It would have been better to work with a more complete survey from 1993 or later as a consistent end point for our time segments, but such is not available. A later survey, when available, can be used to verify the results from this analysis.

The rate calculation results are listed in Table A-1 (Appendix A) and are shown graphically in Figure 2. It can be seen that the rates from the two selected time periods are very similar and complementary. The later, shorter time period (1972 to 1986-87,93) contains primarily more accurate data but still shows essentially the same erosion pattern. Slight differences between the two periods, especially at the very south end (where a pocket between headlands appears to have started eroding), may indicate that a progressive erosion pattern is at work. Consequently, rates of the later period are recommended for use as best estimates of recent conditions.

Comparisons of respective shorelines for the same time periods are shown in plan view in Figures 3 and 4. These figures highlight (by choice of scale and baseline) several important facts. Firstly, the Flagler County coastline is not straight. Extending southward from Matanzas Inlet, the shoreline has a distinct concave curvature, which is easily observable from the air. This concavity eventually transitions into a headland feature at the south end of the county at Flagler Beach. There are also irregularities along the entire coastline, known in certain areas to be rock exposures, and suspected of being the same in others (normally buried within the beachface).

The physics of longshore transport, described very well by the longshore transport equation, predicts that irregularities in the shoreline will be smoothed out if possible. Consequently, one can expect nature to wear down or fill in between irregularities over time in order to present a smoother shoreline overall. How it does this is affected by the amount of sand supply, wave climate, shoreline orientation, roughness and hardness of the rock exposures, refraction patterns, and other local conditions. In Flagler County, the net effect has been mild erosion in the northern half and a filling in between suspected rock outcrops along the southern half (Figure 2 and Table A-1). In the north/central part of the county, where known rock exposures exist, the shoreline is mildly eroding at about -0.5 ft/yr. Immediately south (downdrift) of these, the erosion is slightly higher, about -1 ft/yr. Along the leading face of the Flagler Beach headland, there has been mild accretion of about +1 ft/yr, apparently a result of infilling between suspected rock units and partly due to a pier (R-79), which acts as a permeable groin. South of the suspected underlying rocks along the headland, starting at about R-93, an erosion pocket exists between this headland and another farther south in Volusia County (not shown in these plots). The data indicates that this pocket first filled up but later began to erode. This pocket erosion may be temporary or permanent.

The patterns of erosion discussed above can be explained as being part of the long term smoothing of irregularites along this coast in a north to south net sand transport situation. There is no obvious indication of a sand supply deficit from the north. However, the large island to the north has been generally accretionary (e.g., at Crescent Beach) over the entire historic record and Matanzas Inlet may be an additional sediment sink. It is a possibility that this has resulted in a lesser supply of finer quartz sand gradually making its way southward to Flagler County, and/or an irregular supply of finer quartz sand across Matanzas Inlet.

Given the uncertainties in the sand supply situation and future climatic conditions such as sea level rise, a reasonably cautious approach of using -1 ft/yr throughout Flagler County is suggested for planning purposes.

A review of bluff erosion (average elevations of 17.6, 15.0, and 9.9 ft) yielded results consistent with shoreline erosion (i.e., between 0.0 and -1.0 ft/yr), but did not follow any obvious pattern.

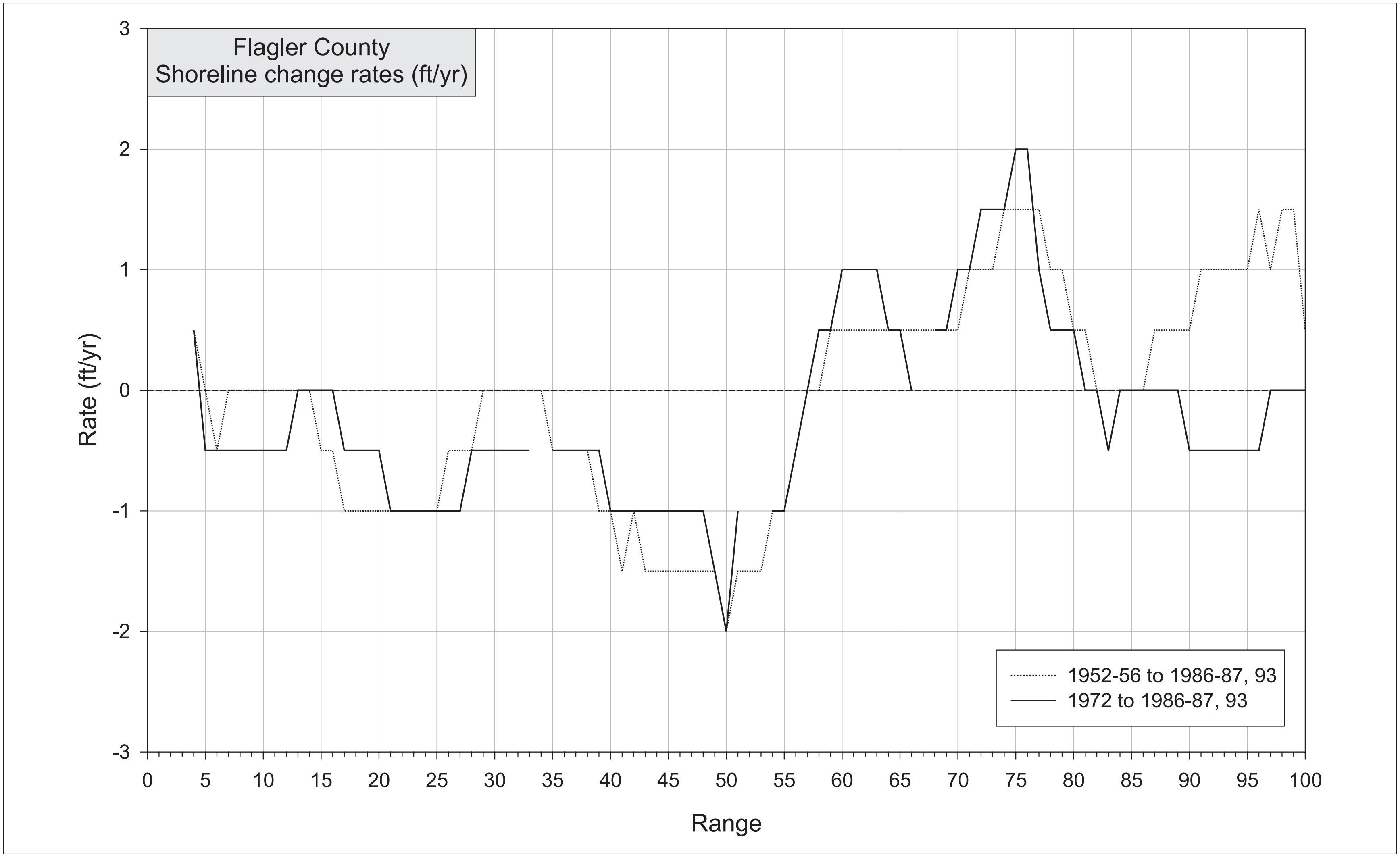


Figure 2. Shoreline rates of change for Flagler County, Florida.

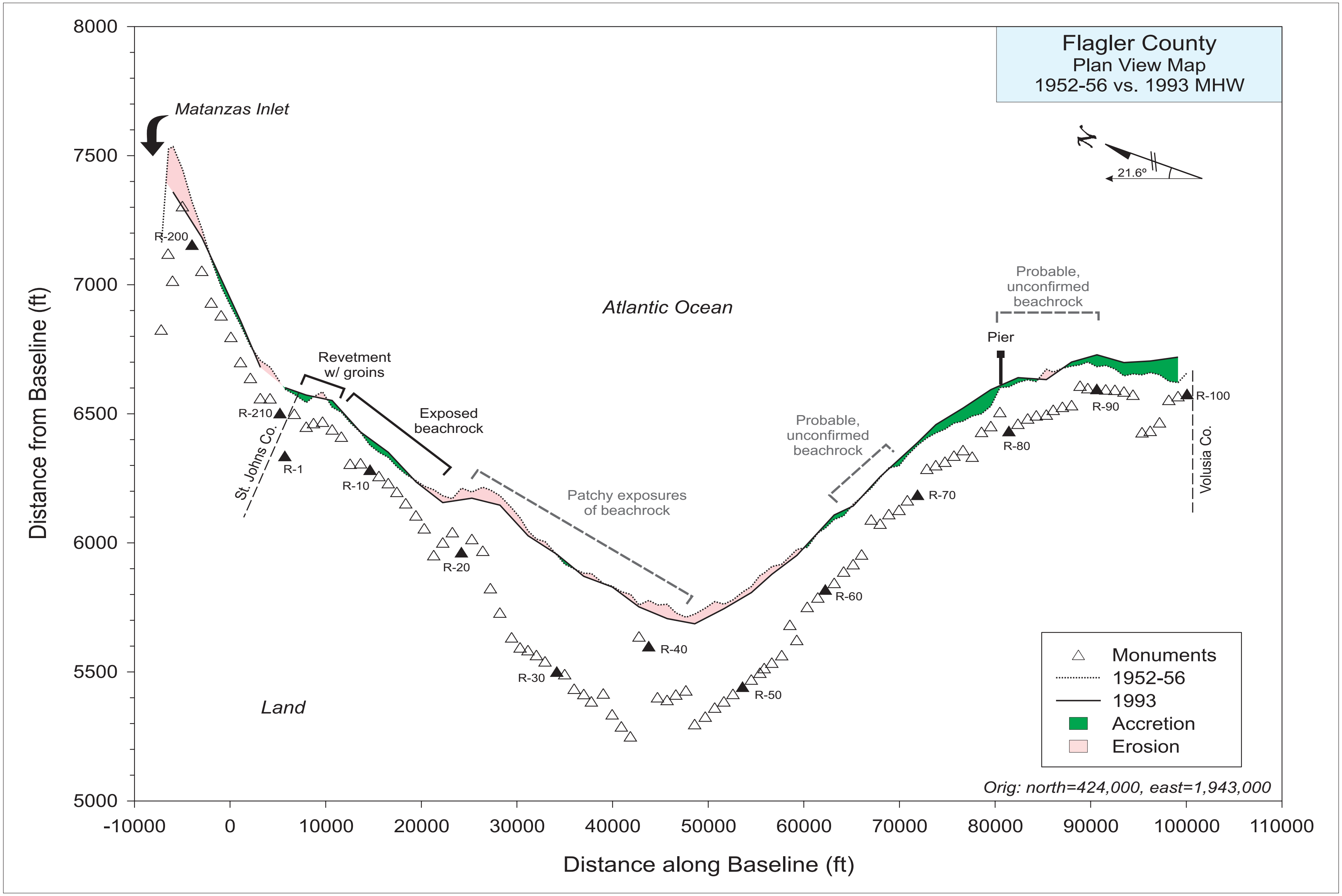


Figure 3. Plan view map of Flagler County comparing shorelines from 1952/56 and 1993.

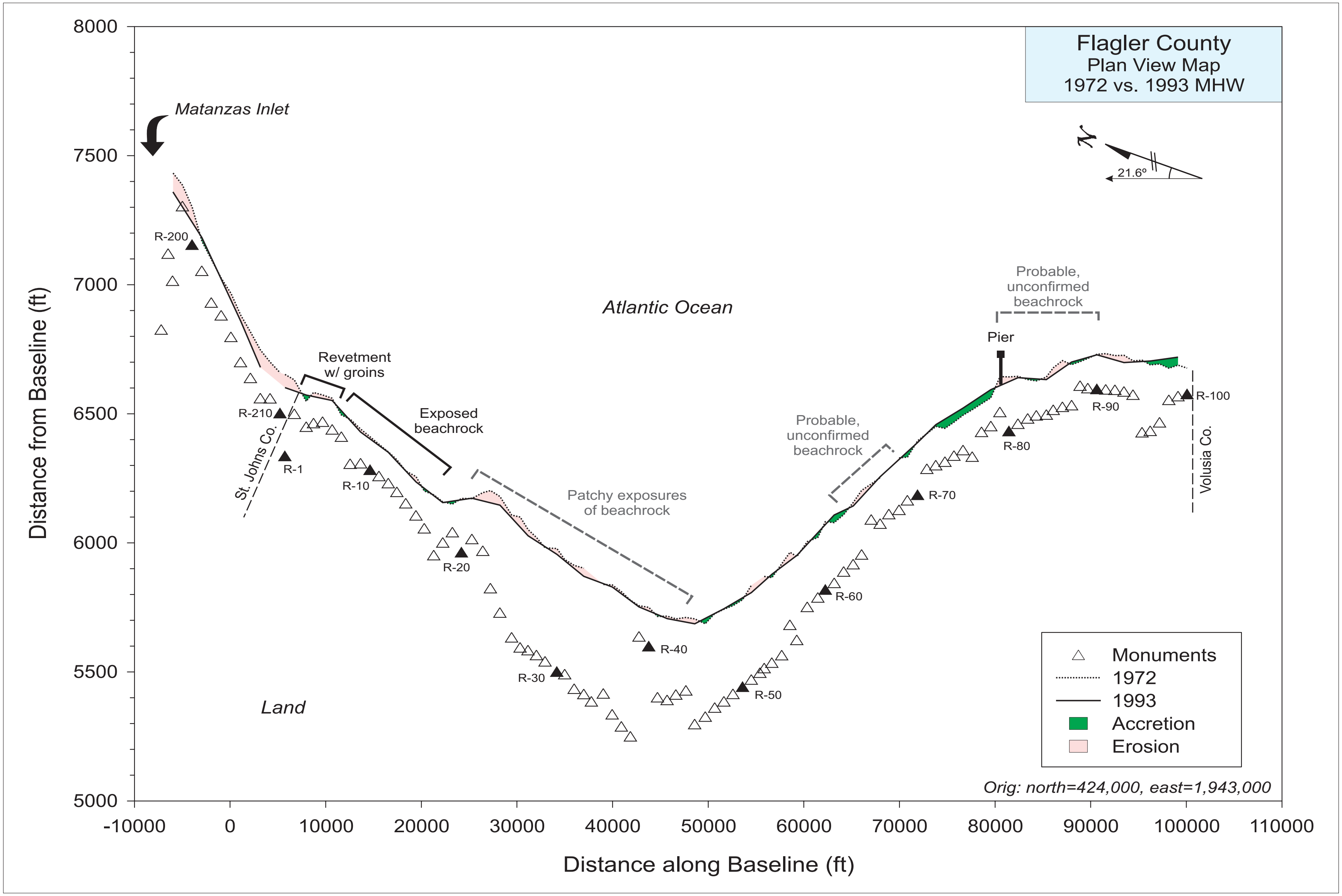


Figure 4. Plan view map of Flagler County comparing shorelines from 1972 and 1993.

6 SUMMARY

Review and analysis of the available survey data record leads to the conclusion that survey data comparisons most appropriate for shoreline erosion rate estimates are the 1952-56 to 1986-87, 93 time periods and the most recent 1972 to 1986-87, 93 time periods. In the 1952-56 to 1986-87, 93 time periods, Flagler County had a mildly eroding to mildly accreting shoreline, north to south. Essentially, the same pattern exists when examining the more recent 1972 to 1986-87, 93 time periods. Known and suspected rock exposures appear to have influenced shoreline erosion as well as contribute to the sand composition. The shoreline orientation is not straight but rather has a concave curvature in the north, transitioning toward a headland at Flagler Beach. The primary coastal process appears to be a smoothing of irregularities along the overall curvature, with net transport to the south. Erosion is generally between 0.0 and -1.0 ft/yr. Caution in future planning is recommended, as is the verification of these results via future surveys.

There can be daily (tidal), seasonal, and storm induced fluctuations in shoreline width that are much larger than the -1 ft/yr longer-term change rate. These factors should be considered when planning any construction activities or when developing any management strategies along the Flagler County coast.

7 REFERENCES

Beaches and Shores Resource Center, 1987. Coastal Construction Control Line Review and Reestablishment Study for Flagler County. Tallahassee, FL: Florida State University, Institute of Science and Public Affairs, 40 p.

Foster, Emmett R., 1992. Thirty Year Erosion Projections in Florida: Project Overview and Status. *In*: Proceedings of the 23rd International Conference on Coastal Engineering, Venice, Italy, ASCE, NY, Vol. 2, p. 2057-2070.

Foster, Emmett R. and Savage, Rebecca J., 1989. Methods of Historical Shoreline Analysis. Coastal Zone '89, American Society of Civil Engineers (ASCE), NY, Vol. 5, p. 4434-4448.

8 APPENDICES

8.1 Appendix A: Shoreline Change Rates

Table A-1: This table provides rates based on the method described in Section 4.

Table A-1. Rates of shoreline change for Flagler County, Florida.

Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
1	RA	0.2	-3.5	0.0	revetment
	LS	-0.2	-2.3		
	EP	0.2	-2.4		
2	RA	0.1	-3.9	0.0	revetment
	LS	0.2	-4.0		
	EP	0.1	-3.9		
3	RA	1.0	1.0	0.0	revetment
	LS	1.1	1.3		
	EP	0.8	1.1		
4	RA	0.8	0.6	0.5	no average
	LS	0.0	0.2		
	EP	0.8	0.6		
5	RA	-1.3	-1.5	-0.5	3 pt average
	LS	-1.6	-1.7		
	EP	-1.1	-1.5		
6	RA	0.2	-0.4	-0.5	5 pt average
	LS	0.3	0.0		
	EP	0.7	-0.4		
7	RA	-0.3	0.0	-0.5	7 pt average
	LS	-1.1	-0.2		↓
	EP	-0.3	0.0		
8	RA	-0.2	-1.3	-0.5	
	LS	-1.4	-1.7		
	EP	-0.2	-1.3		
9	RA	0.1	-0.5	-0.5	
	LS	-0.6	-0.4		
	EP	0.1	-0.5		
10	RA	0.5	0.1	-0.5	
	LS	0.2	-0.3		
	EP	1.1	0.1		
11	RA	0.7	-0.7	-0.5	
	LS	-0.2	-1.0		
	EP	0.7	-0.7		
12	RA	0.5	-0.1	-0.5	
	LS	0.1	0.3		
	EP	0.5	-0.1		
13	RA	0.9	0.1	0.0	
	LS	0.0	-0.1		
	EP	0.9	0.1		
14	RA	0.3	-0.3	0.0	
	LS	-0.4	-0.6		
	EP	0.3	-0.3		
15	RA	-0.1	-1.0	0.0	

Table A-1. Rates of shoreline change for Flagler County, Florida.

Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
	LS	-0.9	-0.3		
	EP	-0.1	-1.0		
16	RA	-0.2	0.9	0.0	
	LS	-1.6	0.6		
	EP	-0.2	0.9		
17	RA	-0.7	-0.1	-0.5	
	LS	-2.1	0.0		
	EP	-0.7	-0.1		
18	RA	-0.4	-0.1	-0.5	
	LS	-1.3	0.2		
	EP	-0.7	-0.1		
19	RA	-0.7	0.0	-0.5	
	LS	-1.2	0.0		
	EP	-0.7	0.0		
20	RA	-2.0	-2.1	-0.5	
	LS	-2.1	-2.2		
	EP	-2.3	-2.1		
21	RA	-0.7	0.1	-1.0	
	LS	-0.8	0.1		
	EP	-0.7	0.1		
22	RA	-0.9	-0.9	-1.0	
	LS	-1.7	-1.3		
	EP	-1.1	-0.9		
23	RA	-0.7	-1.3	-1.0	
	LS	-1.7	-1.8		
	EP	-0.7	-1.3		
24	RA	-0.9	-2.2	-1.0	
	LS	-1.0	-1.1		
	EP	-1.0	-1.6		
25	RA	-0.6	-0.4	-1.0	
	LS	-1.1	0.1		
	EP	-1.1	-0.4		
26	RA	-0.8	-1.9	-1.0	
	LS	-1.4	-2.4		
	EP	-0.8	-1.9		
27	RA	-0.5	-1.0	-1.0	
	LS	-0.4	-0.3		
	EP	-0.5	-1.1		
28	RA	0.1	-0.3	-0.5	
	LS	-0.3	-0.7		
	EP	0.1	-0.3		
29	RA	-0.4	0.8	-0.5	
	LS	-0.9	0.3		

Table A-1. Rates of shoreline change for Flagler County, Florida.

Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
	EP	-0.4	0.8		
30	RA	0.1	-1.4	-0.5	
	LS	0.1	-0.2		
	EP	0.1	-1.1		
31	RA	0.3	-0.7	-0.5	
	LS	-0.1	-1.2		
	EP	0.3	-0.7		
32	RA	0.3	-0.3	-0.5	
	LS	0.0	-0.8		
	EP	0.3	-0.3		
33	RA	-0.3	-1.7	-0.5	
	LS	-0.4	-0.5		
	EP	-0.3	-1.5		
34	RA	-0.3	n/a		
	LS	-0.6	n/a	n/a	1972 data unavailable
	EP	-0.3	n/a		
35	RA	-0.1	0.1	-0.5	
	LS	-0.1	0.6		
	EP	-0.1	0.1		
36	RA	-0.1	-0.4	-0.5	
	LS	0.0	0.1		
	EP	-0.1	-0.4		
37	RA	-0.1	-0.2	-0.5	
	LS	-0.3	-0.6		
	EP	-0.1	-0.2		
38	RA	-1.2	-1.4	-0.5	
	LS	-1.3	-1.6		
	EP	-1.4	-1.4		
39	RA	-0.2	-0.2	-0.5	
	LS	-0.3	0.1		
	EP	-0.2	-0.2		
40	RA	-1.5	-1.9	-1.0	
	LS	-2.0	-2.2		
	EP	-1.8	-1.9		
41	RA	-0.8	-0.2	-1.0	
	LS	-1.7	-0.3		
	EP	-1.5	-0.2		
42	RA	-0.9	-0.5	-1.0	
	LS	-1.4	0.1		
	EP	-1.5	-0.5		
43	RA	-1.8	-2.0	-1.0	
	LS	-1.9	-2.0		
	EP	-1.7	-2.0		

Table A-1. Rates of shoreline change for Flagler County, Florida.

Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
44	RA	-1.4	-2.5	-1.0	
	LS	-0.8	-2.6		
	EP	-1.2	-2.5		
45	RA	-1.1	-0.9	-1.0	
	LS	-1.0	-0.5		
	EP	-1.0	-0.9		
46	RA	-0.8	0.5	-1.0	
	LS	-2.1	0.4		
	EP	-1.7	0.5		
47	RA	-2.7	-2.1	-1.0	
	LS	-2.8	-2.3		
	EP	-2.5	-2.1		
48	RA	-0.5	0.1	-1.0	↑
	LS	-0.9	0.4		7 pt average
	EP	-0.5	0.1		
49	RA	-1.7	-1.8	-1.5	5 pt average
	LS	-2.1	-1.9		
	EP	-1.6	-1.8		
50	RA	-1.4	-1.5	-2.0	3 pt average
	LS	-1.8	-1.6		
	EP	-1.7	-1.5		
51	RA	-0.6	-2.9	-1.0	3 pt average of
	LS	-1.6	-1.4		R-50, R-51, & R-54
	EP	-0.6	-1.4		
52	RA	-1.8	n/a		
	LS	-2.4	n/a	n/a	1972 data unavailable
	EP	-1.6	n/a		
53	RA	-2.2	n/a		
	LS	-2.9	n/a	n/a	1986-87,93 data unavailable
	EP	-3.2	n/a		
54	RA	-0.1	0.6	-1.0	3 pt average of
	LS	-1.2	0.7		R-51, R-54, & R-55
	EP	-0.8	0.6		
55	RA	-0.5	-1.2	-1.0	3 pt average
	LS	-1.0	-1.3		
	EP	-0.5	-1.2		
56	RA	-0.6	-2.2	-0.5	5 pt average
	LS	-1.2	-2.4		
	EP	-0.6	-2.2		
57	RA	-0.6	0.2	0.0	7 pt average
	LS	-0.7	0.8		↓
	EP	-0.6	0.2		
58	RA	0.9	0.4	0.5	

Table A-1. Rates of shoreline change for Flagler County, Florida.

Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
	LS	0.1	0.2		
	EP	0.9	0.4		
59	RA	0.4	2.0	0.5	
	LS	-0.4	1.8		
	EP	0.4	2.0		
60	RA	1.3	1.1	1.0	
	LS	0.4	0.9		
	EP	1.4	1.1		
61	RA	0.5	1.8	1.0	
	LS	0.6	2.3		
	EP	0.5	1.4		
62	RA	1.5	1.9	1.0	
	LS	0.1	1.8		
	EP	1.1	1.9		
63	RA	-0.2	-0.7	1.0	
	LS	-0.4	0.4		
	EP	-0.2	-0.7		
64	RA	0.8	0.5	0.5	
	LS	0.2	0.3		
	EP	1.1	0.5		
65	RA	0.7	0.4	0.5	
	LS	0.1	0.2		
	EP	0.7	0.4		
66	RA	0.1	0.1	0.0	
	LS	-0.4	0.5		
	EP	0.1	0.1		
67	RA	0.6	n/a		
	LS	-0.1	n/a	n/a	1972 data unavailable
	EP	0.6	n/a		
68	RA	0.9	-0.2	0.5	
	LS	0.6	-0.2		
	EP	0.9	-0.2		
69	RA	0.5	0.9	0.5	
	LS	0.4	1.3		
	EP	0.5	1.5		
70	RA	0.3	-0.3	1.0	
	LS	0.7	-0.1		
	EP	0.3	-0.3		
71	RA	1.1	1.2	1.0	
	LS	0.7	1.3		
	EP	1.1	1.2		
72	RA	0.6	0.3	1.5	
	LS	0.6	1.3		

Table A-1. Rates of shoreline change for Flagler County, Florida.

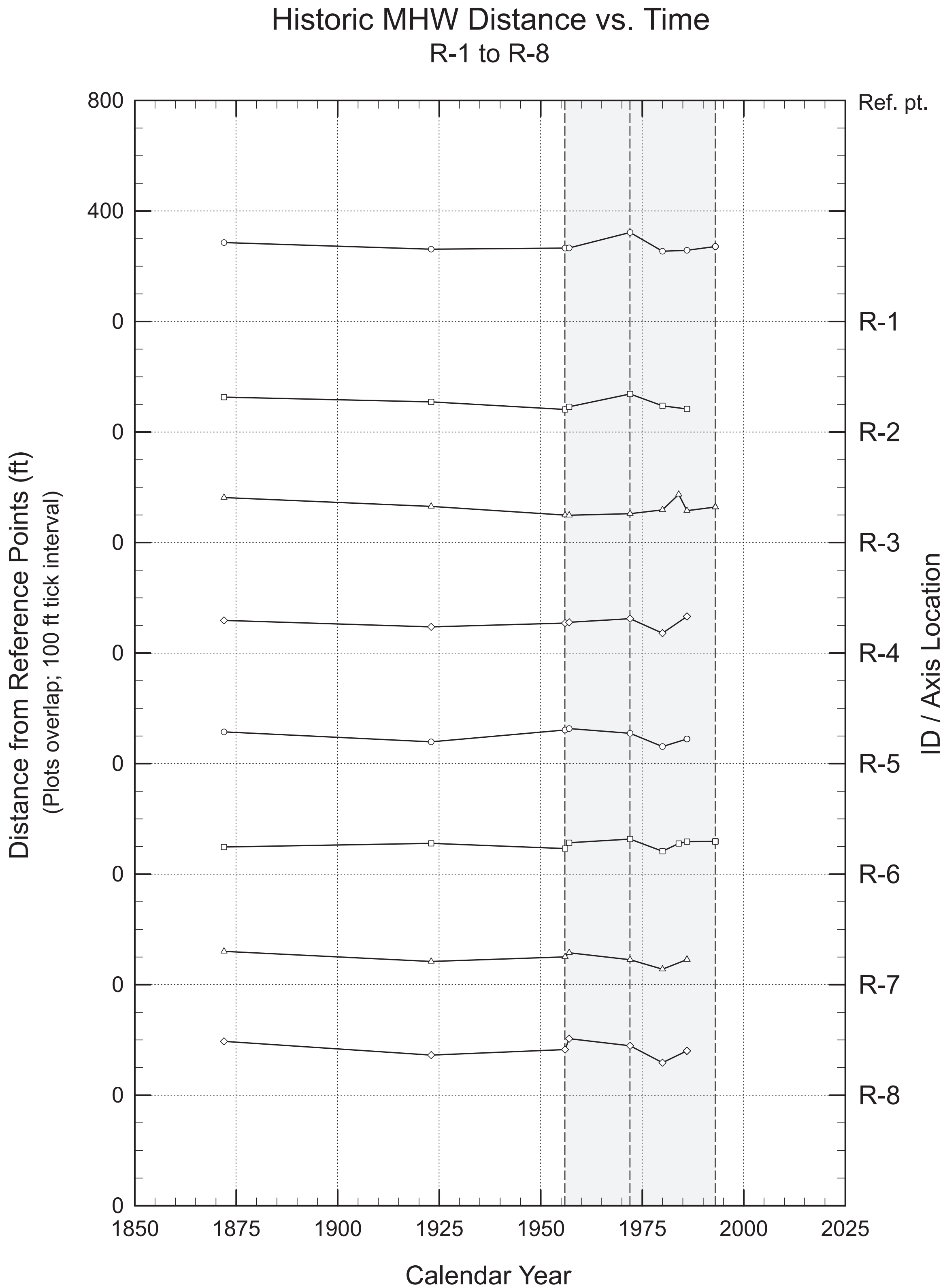
Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
	EP	0.9	0.3		
73	RA	1.8	2.5	1.5	
	LS	1.1	3.0		
	EP	1.5	2.8		
74	RA	1.9	2.7	1.5	
	LS	0.9	2.8		
	EP	1.4	2.7		
75	RA	1.9	2.0	2.0	
	LS	1.7	2.0		
	EP	1.4	1.3		
76	RA	1.4	1.0	2.0	
	LS	1.3	1.1		
	EP	1.3	1.0		
77	RA	1.5	1.6	1.0	
	LS	1.7	1.8		
	EP	2.0	1.6		
78	RA	2.1	1.9	0.5	
	LS	2.0	2.1		
	EP	1.7	1.5		
79	RA	1.1	0.4	0.5	
	LS	0.8	0.6		
	EP	1.5	0.4		
80	RA	0.3	-1.9	0.5	
	LS	0.2	-1.8		
	EP	0.3	-1.9		
81	RA	0.5	-0.2	0.0	
	LS	0.0	0.1		
	EP	0.5	-0.2		
82	RA	-0.3	-0.8	0.0	
	LS	-0.6	-0.7		
	EP	-0.3	-0.8		
83	RA	0.4	0.6	-0.5	
	LS	-0.2	0.7		
	EP	0.4	0.6		
84	RA	-0.5	-0.5	0.0	
	LS	-0.8	0.1		
	EP	-1.1	-0.5		
85	RA	0.8	0.5	0.0	
	LS	0.3	0.7		
	EP	0.8	0.5		
86	RA	0.5	0.0	0.0	
	LS	0.4	0.2		
	EP	1.0	0.0		

Table A-1. Rates of shoreline change for Flagler County, Florida.

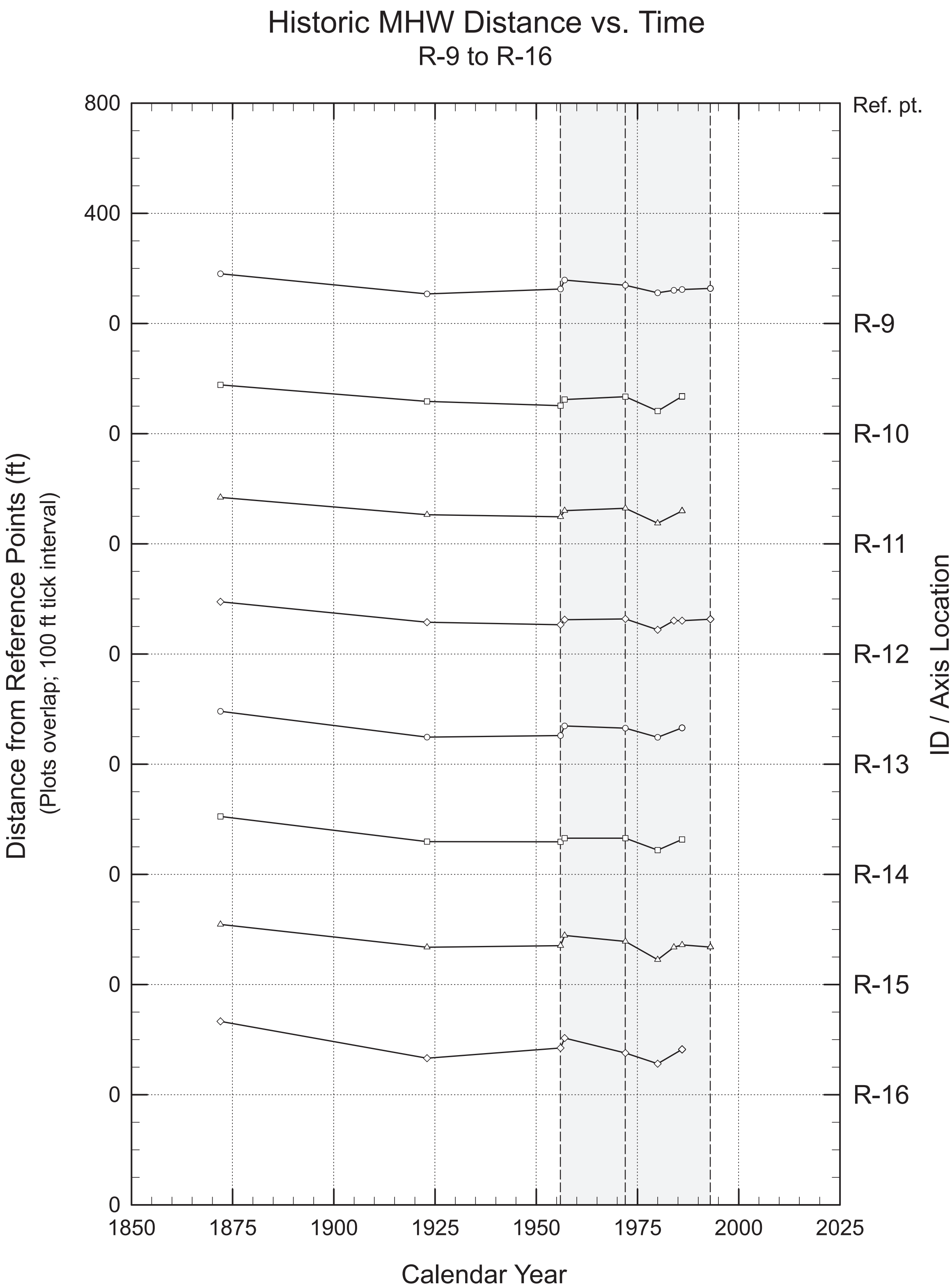
Range	Method	Original Rate Estimates (ft/yr)		Concensus Rate Average Estimates	
		Secondary Rates 1952 to 1986-87,93	Primary Rates 1972 to 1986-87,93	Rate (ft/yr)	Comments
87	RA	0.4	0.5	0.0	
	LS	0.6	1.5		
	EP	0.4	0.5		
88	RA	0.0	-0.9	0.0	
	LS	0.0	-0.9		
	EP	0.0	-0.9		
89	RA	0.2	-0.5	0.0	
	LS	-0.6	-0.5		
	EP	0.2	-0.5		
90	RA	1.2	-0.1	-0.5	
	LS	1.5	0.3		
	EP	1.2	-0.1		
91	RA	0.6	-0.6	-0.5	
	LS	0.7	-0.4		
	EP	1.2	-0.6		
92	RA	1.1	-0.2	-0.5	
	LS	1.2	0.0		
	EP	1.6	-0.2		
93	RA	0.6	-1.2	-0.5	
	LS	1.2	-0.4		
	EP	1.4	-1.3		
94	RA	1.0	-0.2	-0.5	
	LS	1.2	-0.1		
	EP	1.5	-0.2		
95	RA	0.6	-1.0	-0.5	
	LS	1.0	-0.9		
	EP	1.3	-1.0		
96	RA	1.7	0.7	-0.5	
	LS	1.9	1.3		
	EP	1.2	0.7		
97	RA	0.7	-1.4	0.0	↑
	LS	0.6	-1.3		7 pt average
	EP	0.7	-1.4		
98	RA	1.0	-0.5	0.0	5 pt average
	LS	1.6	-0.4		
	EP	1.4	-0.5		
99	RA	2.0	0.1	0.0	3 pt average
	LS	2.1	1.7		
	EP	2.7	1.5		
100	RA	0.6	0.0	0.0	no average
	LS	0.4	0.1		
	EP	0.6	0.0		

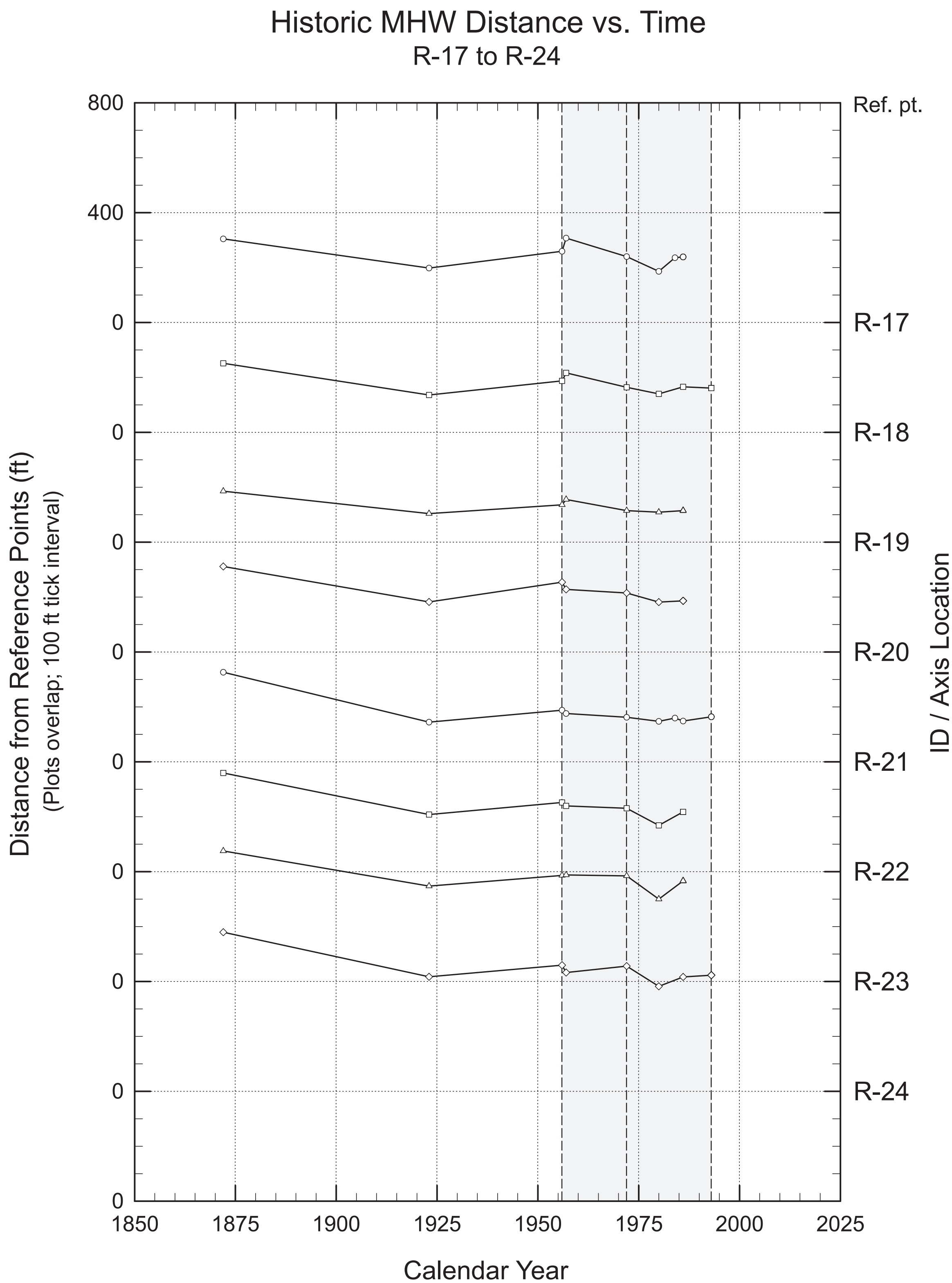
8.2 Appendix B: Stack Plots

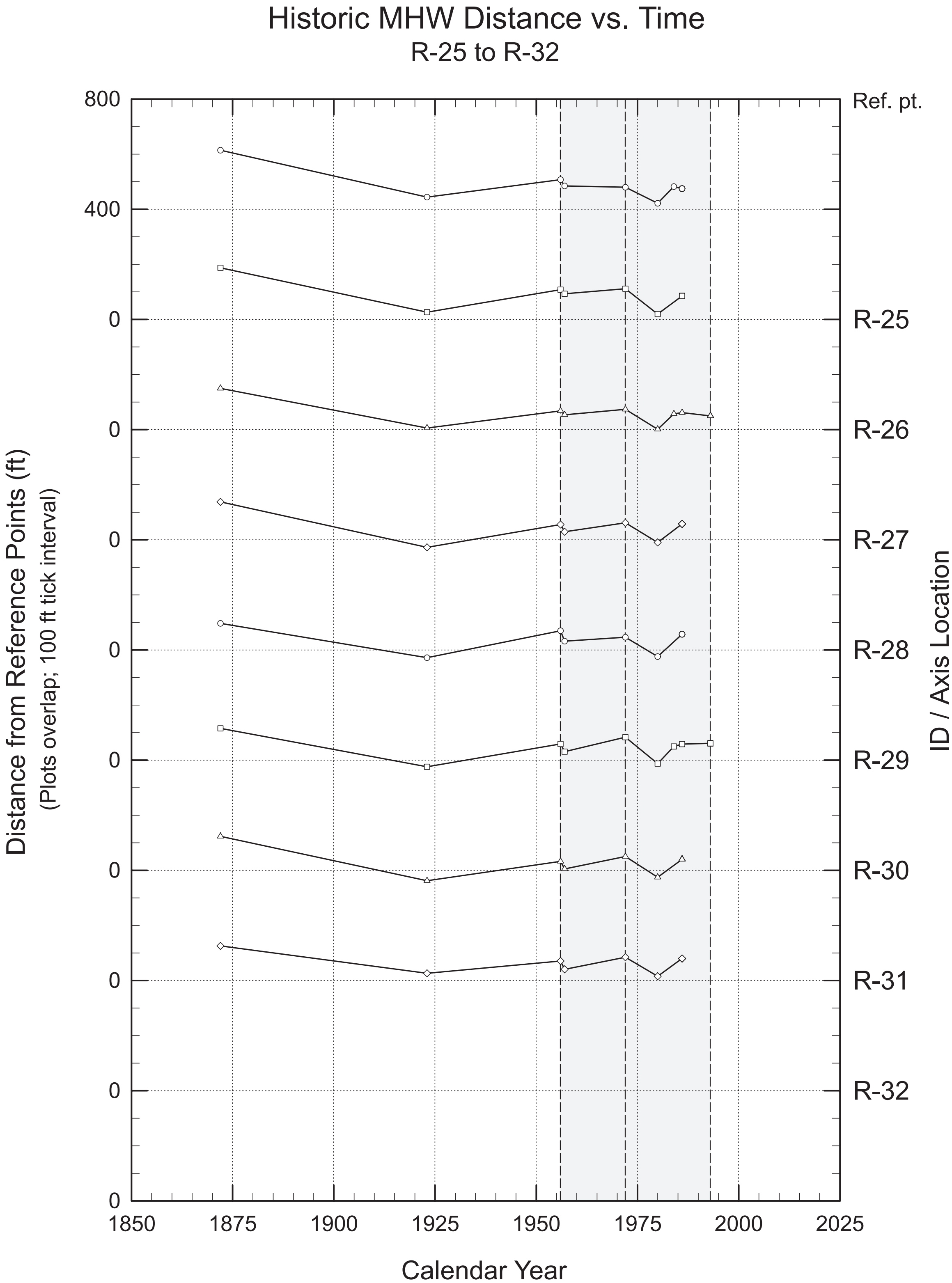
Stack plots from Historic Shoreline Database, Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems; slightly modified by authors.

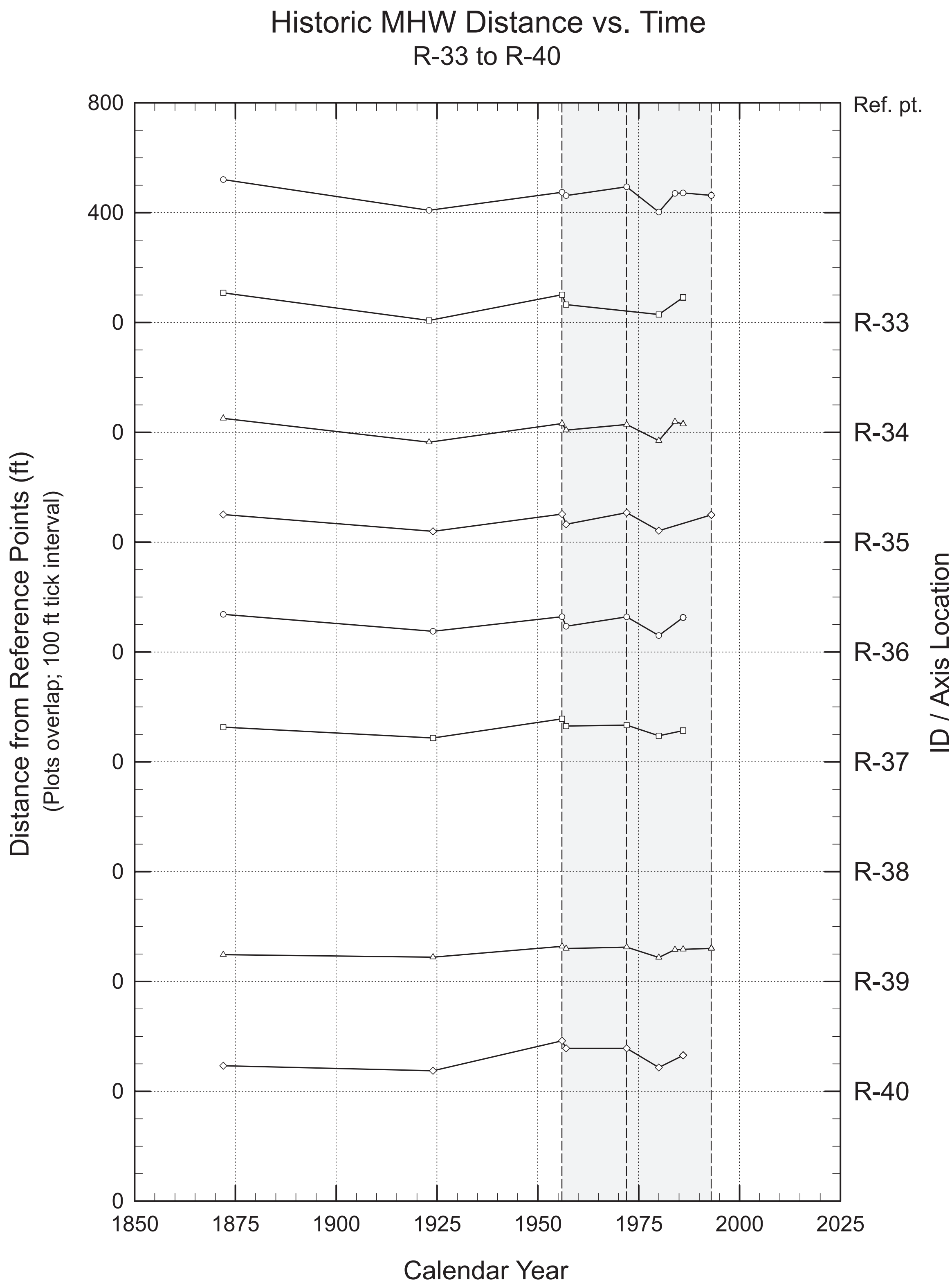


Historic MHW Distance vs. Time
R-1 to R-8
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-1
R-2
R-3
R-4
R-5
R-6
R-7
R-8
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year

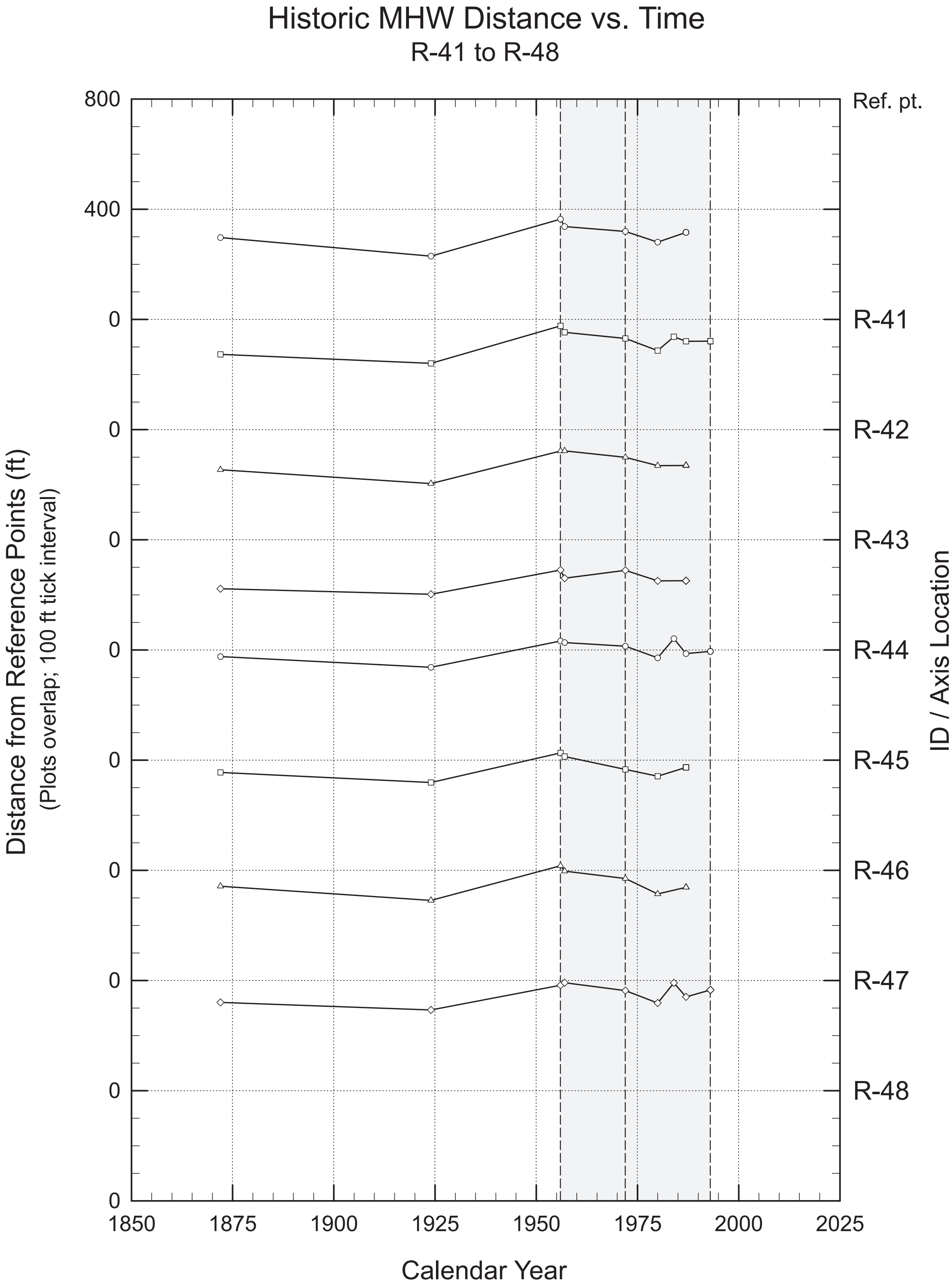

Historic MHW Distance vs. Time
R-9 to R-16
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-9
R-10
R-11
R-12
R-13
R-14
R-15
R-16
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year


Historic MHW Distance vs. Time
R-17 to R-24
800
400
0
0
0
0
0
0
0
0
0
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year
Ref. pt.
R-17
R-18
R-19
R-20
R-21
R-22
R-23
R-24
ID / Axis Location

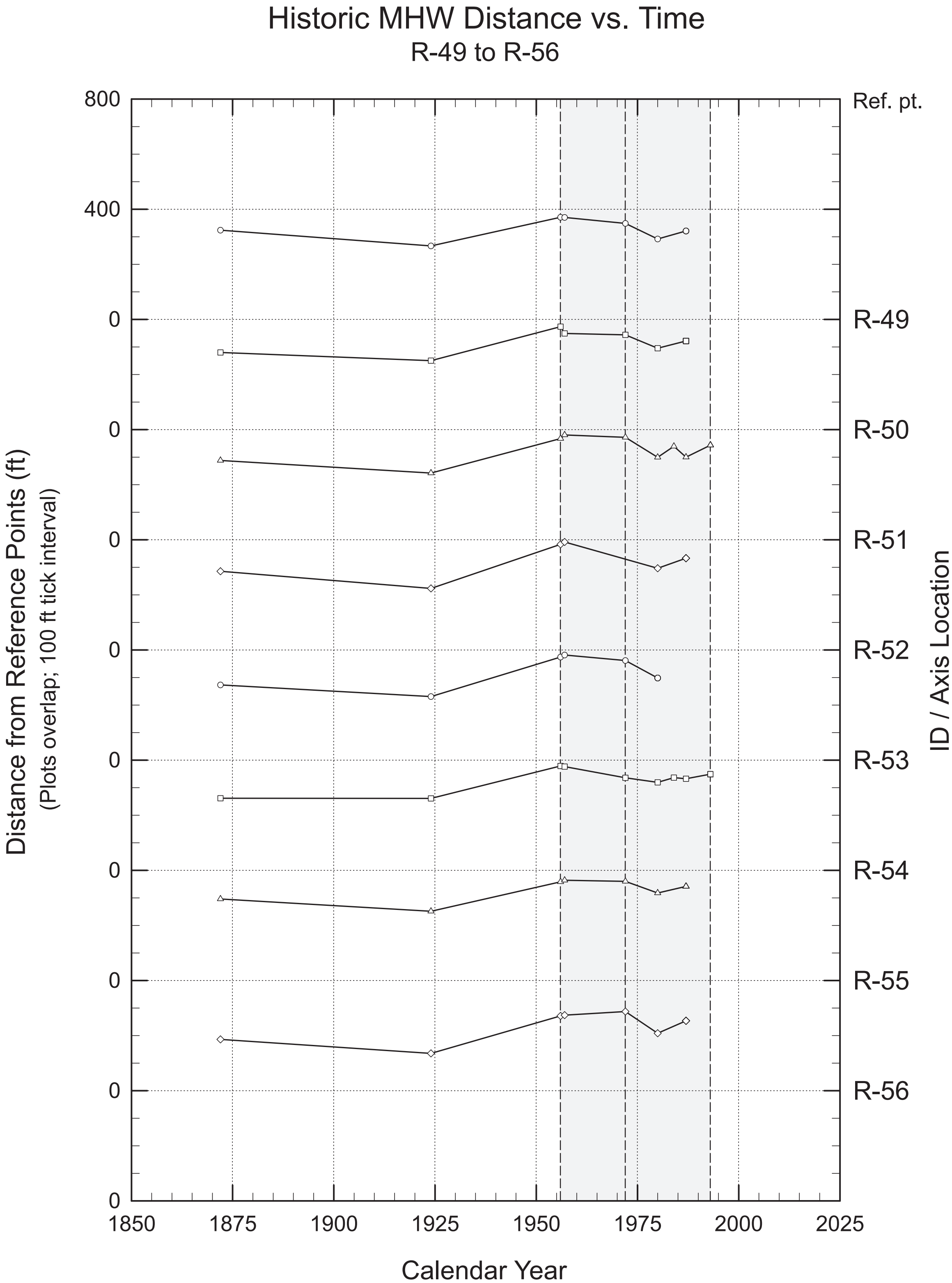

Historic MHW Distance vs. Time
R-25 to R-32
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
800
400
0
Ref. pt.
R-25
R-26
R-27
R-28
R-29
R-30
R-31
R-32
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year



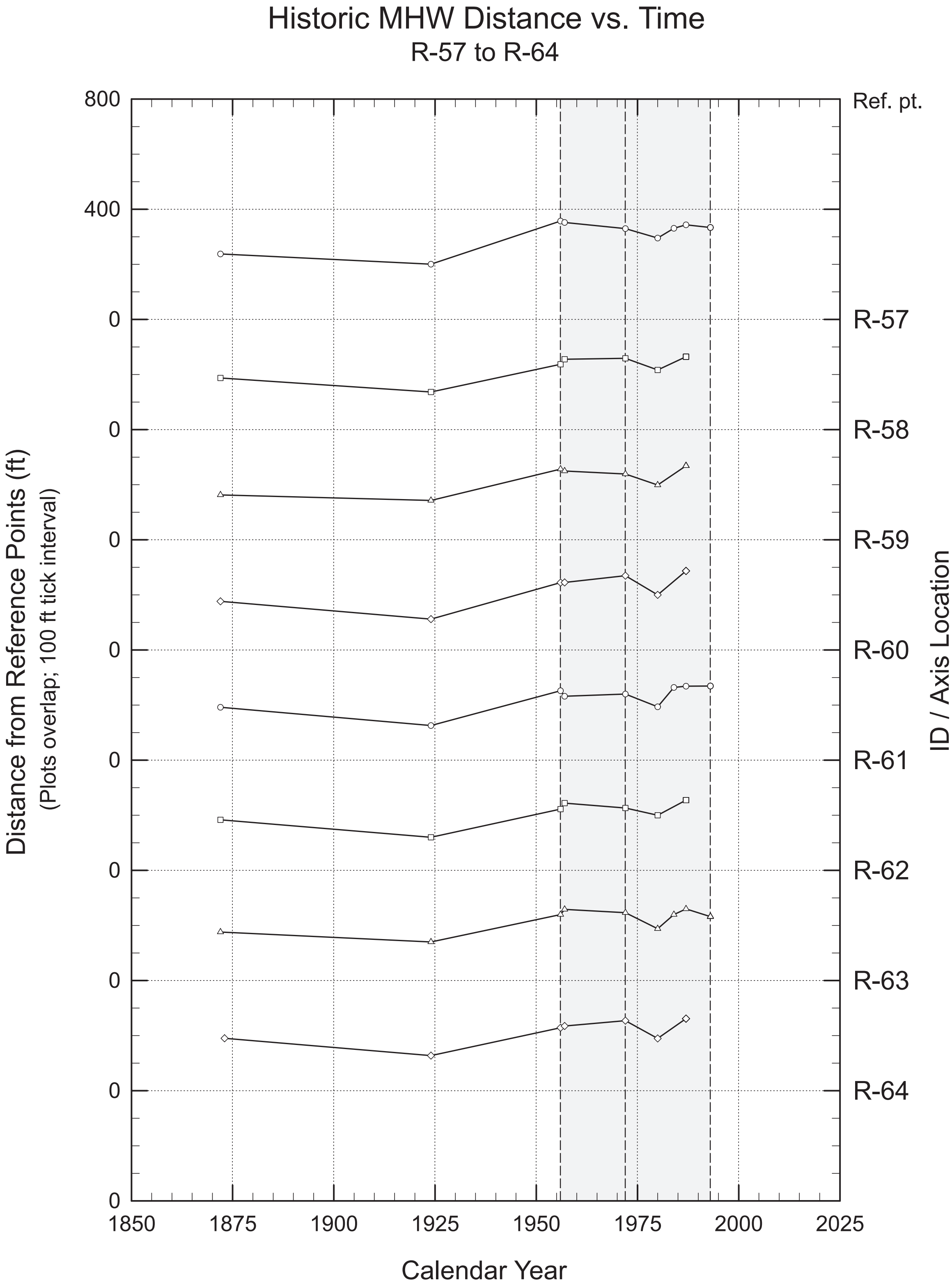
Historic MHW Distance vs. Time
R-33 to R-40
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-33
R-34
R-35
R-36
R-37
R-38
R-39
R-40
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year



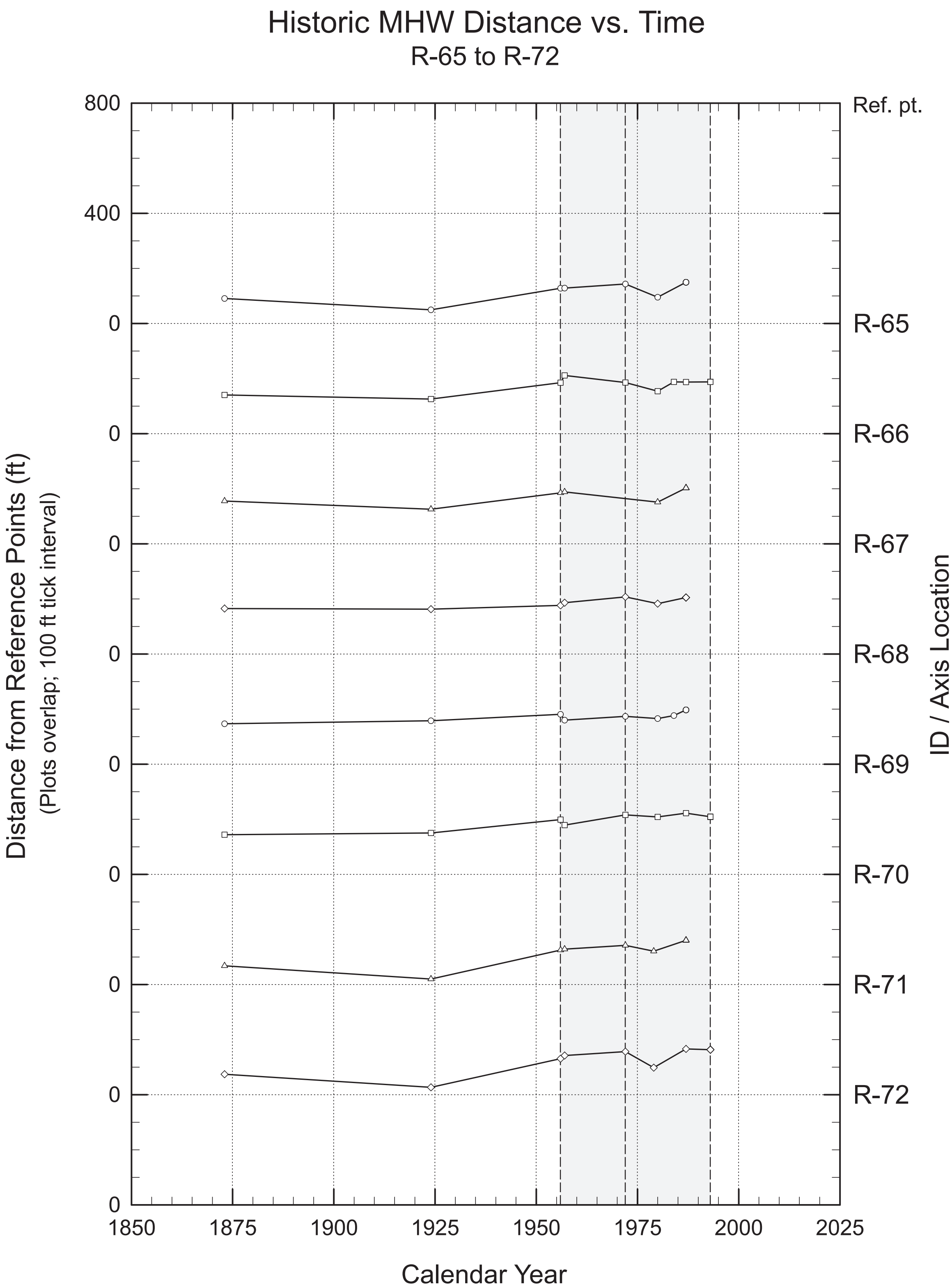
Historic MHW Distance vs. Time
R-41 to R-48
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
800
400
0
0
0
0
0
0
0
0
0
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year
Ref. pt.
R-41
R-42
R-43
R-44
R-45
R-46
R-47
R-48
ID / Axis Location



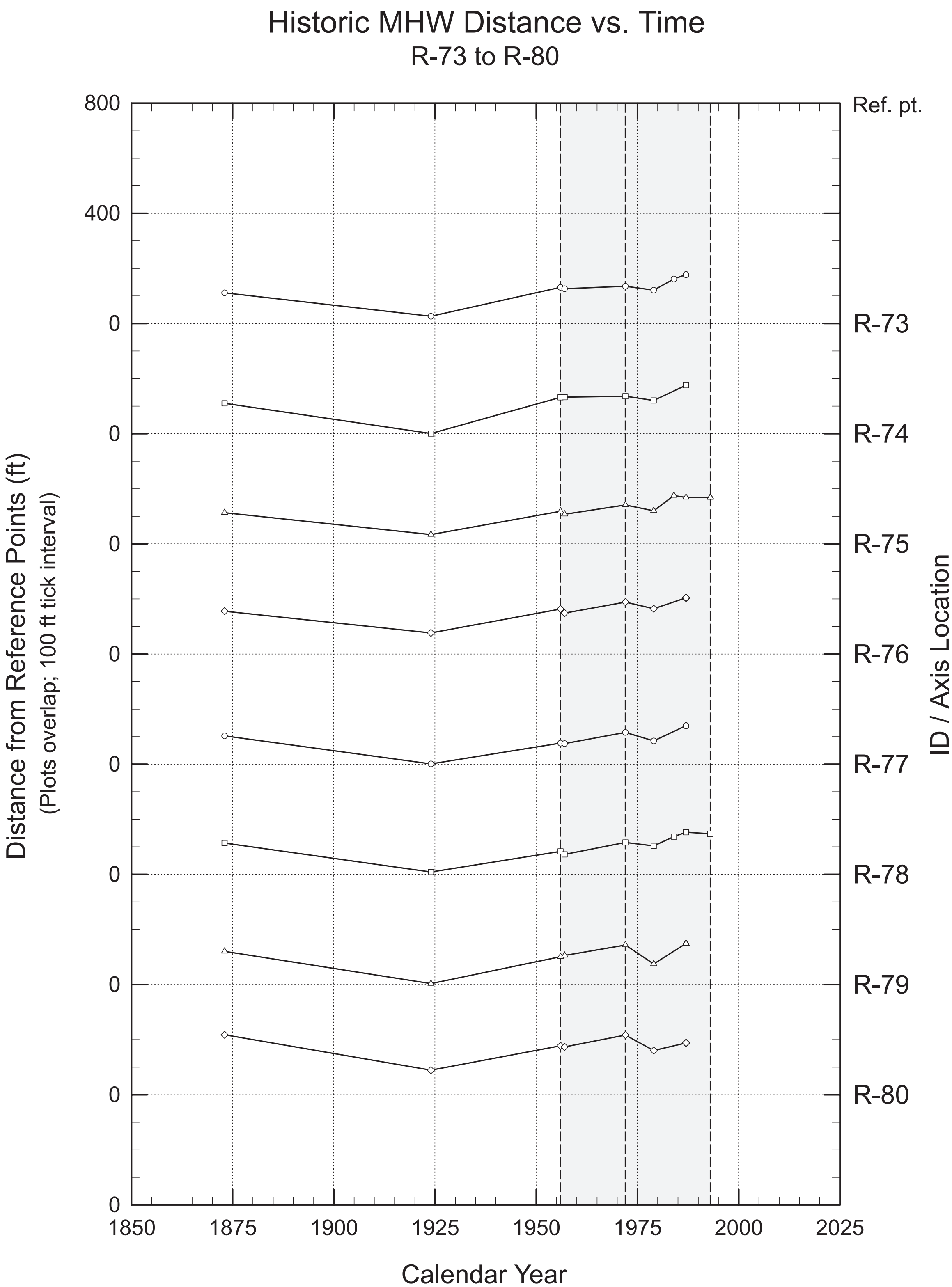
Historic MHW Distance vs. Time
R-49 to R-56
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-49
R-50
R-51
R-52
R-53
R-54
R-55
R-56
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year



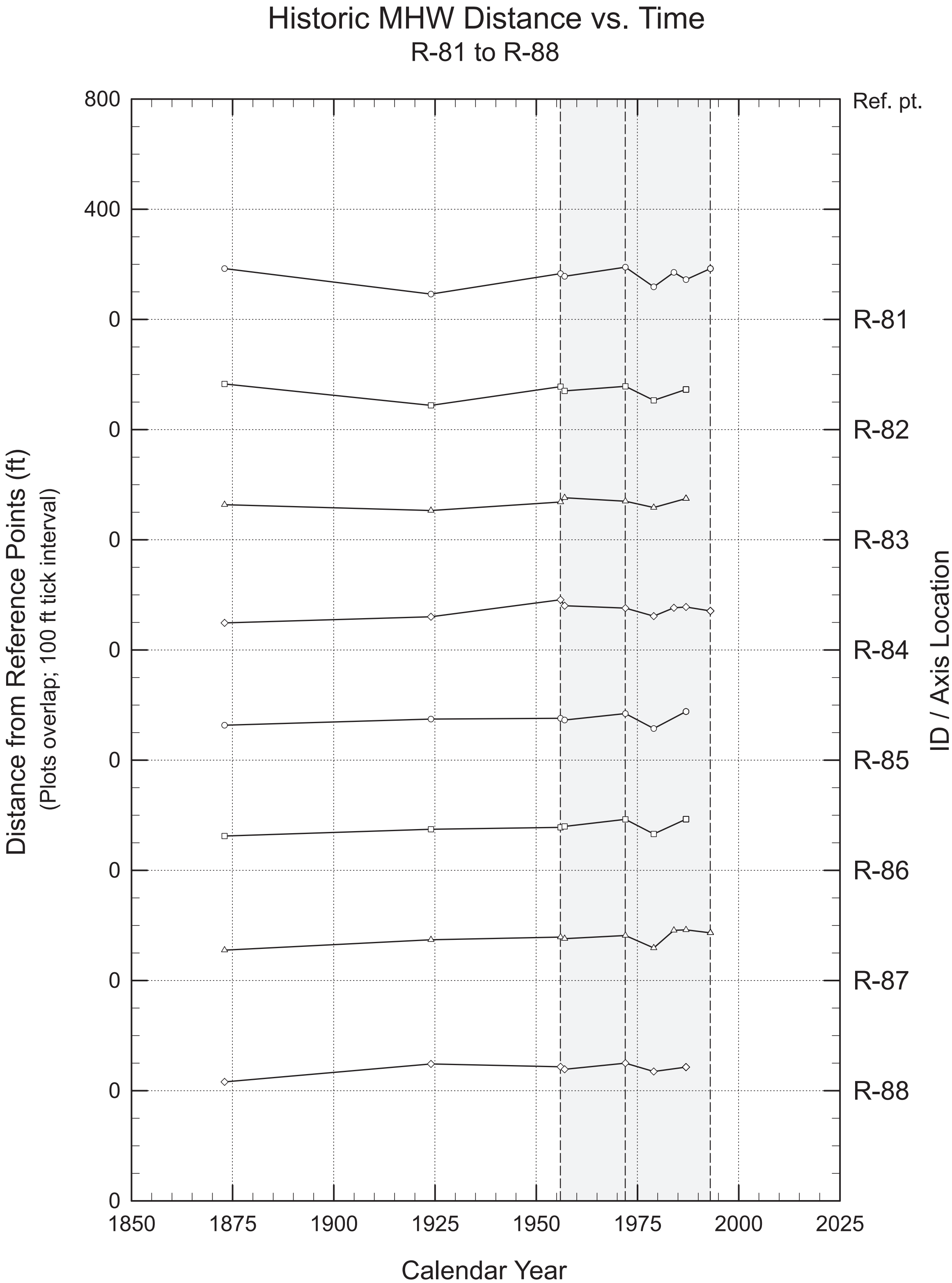
Historic MHW Distance vs. Time
R-57 to R-64
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-57
R-58
R-59
R-60
R-61
R-62
R-63
R-64
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year

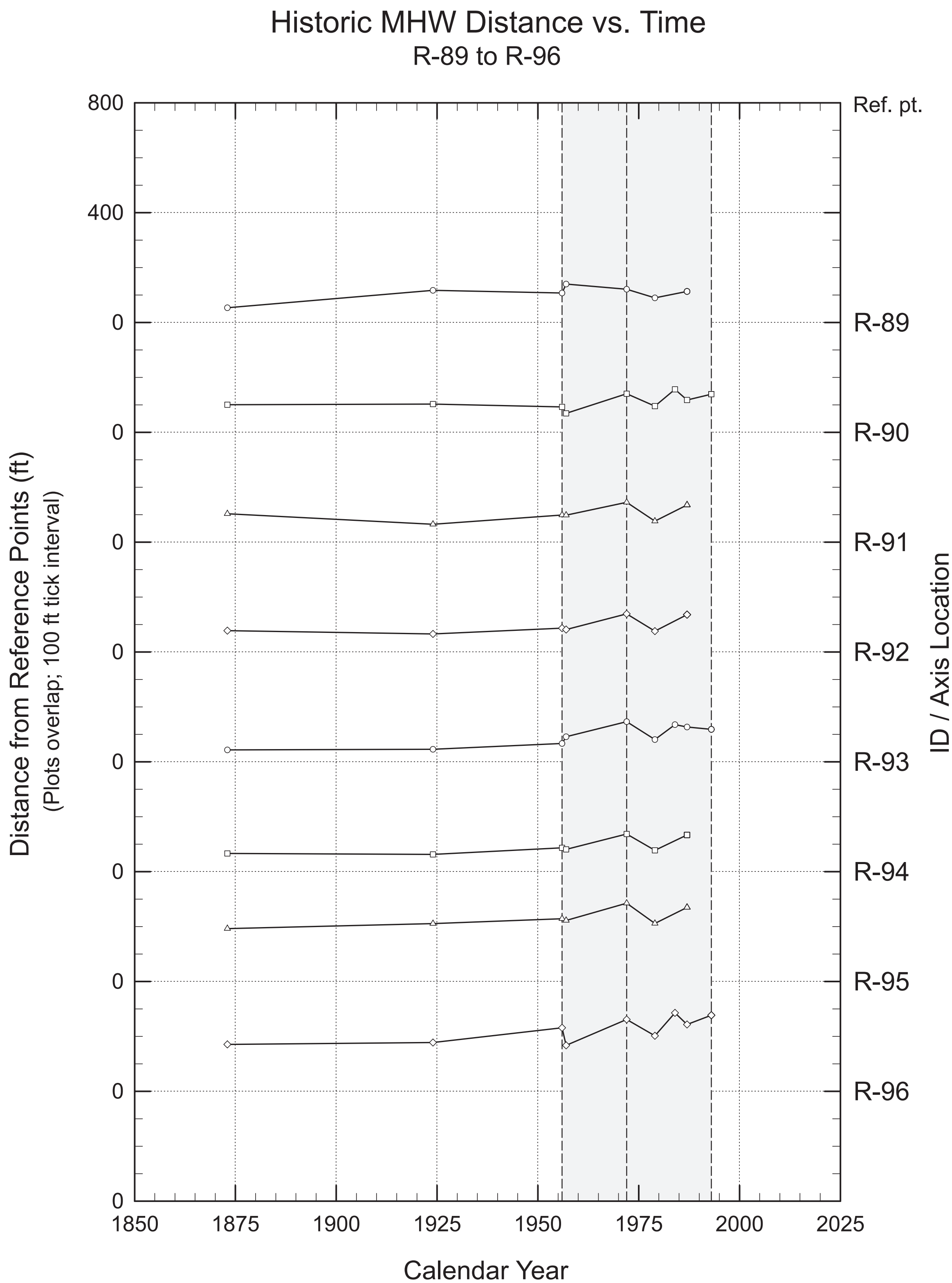


Historic MHW Distance vs. Time
R-65 to R-72
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
800
400
0
Ref. pt.
R-65
R-66
R-67
R-68
R-69
R-70
R-71
R-72
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year



Historic MHW Distance vs. Time
R-73 to R-80
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-73
R-74
R-75
R-76
R-77
R-78
R-79
R-80
ID / Axis Location
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year

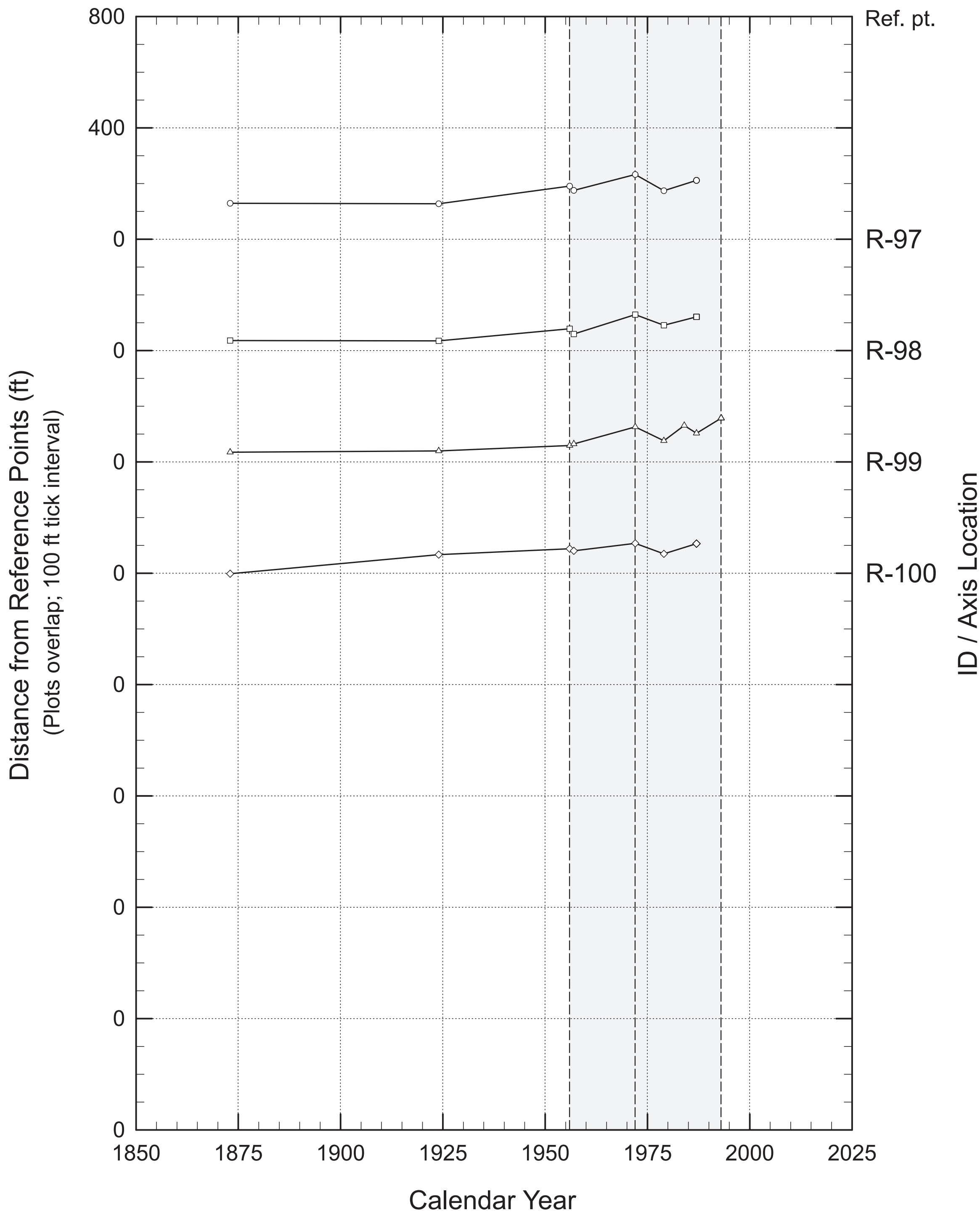

Historic MHW Distance vs. Time
R-81 to R-88
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-81
R-82
R-83
R-84
R-85
R-86
R-87
R-88
ID / Axis Location
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year



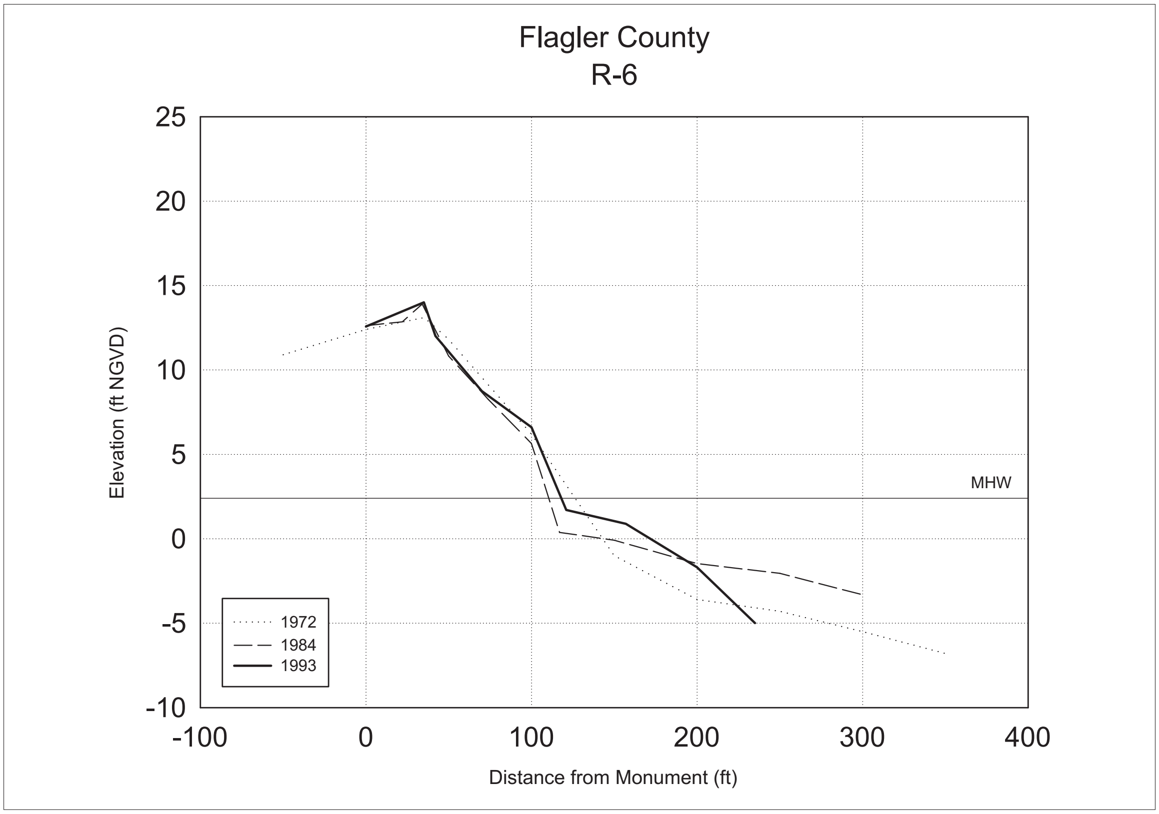
Historic MHW Distance vs. Time
R-89 to R-96
800
400
0
0
0
0
0
0
0
0
0
Ref. pt.
R-89
R-90
R-91
R-92
R-93
R-94
R-95
R-96
ID / Axis Location
Distance from Reference Points (ft)
(Plots overlap; 100 ft tick interval)
1850
1875
1900
1925
1950
1975
2000
2025
Calendar Year

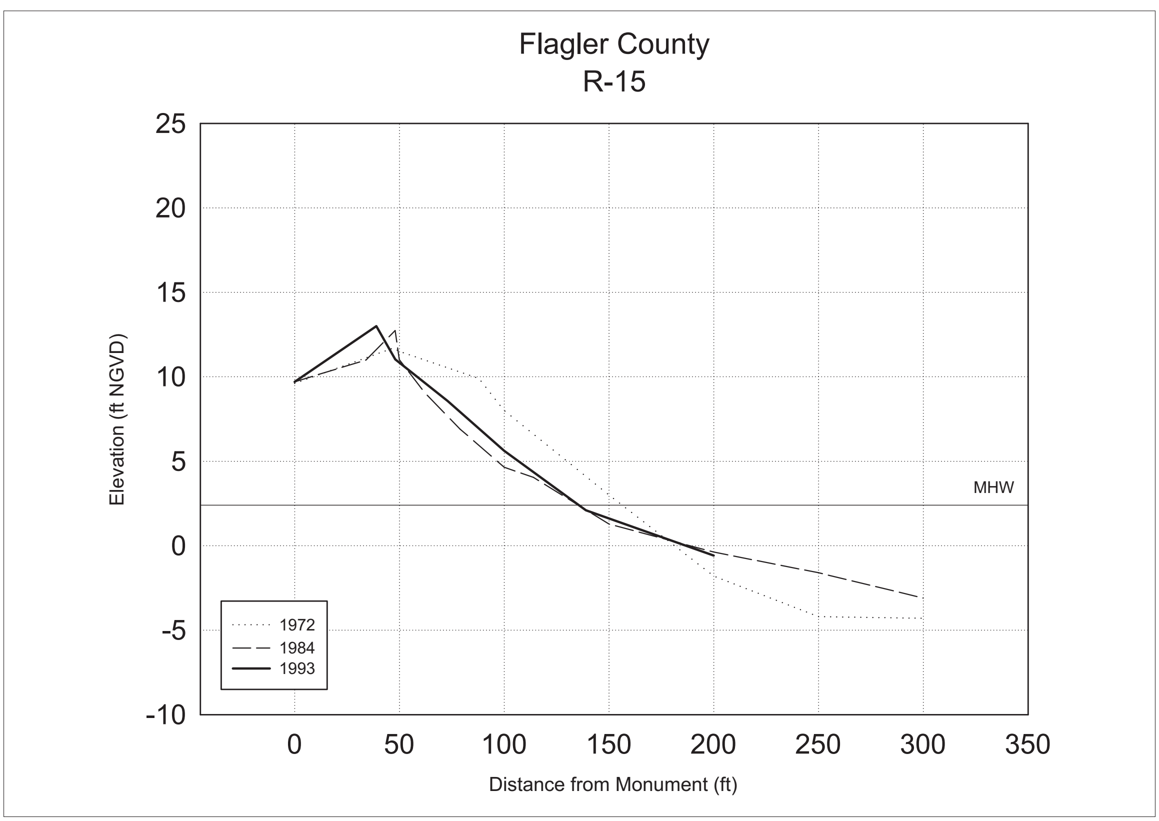
Historic MHW Distance vs. Time

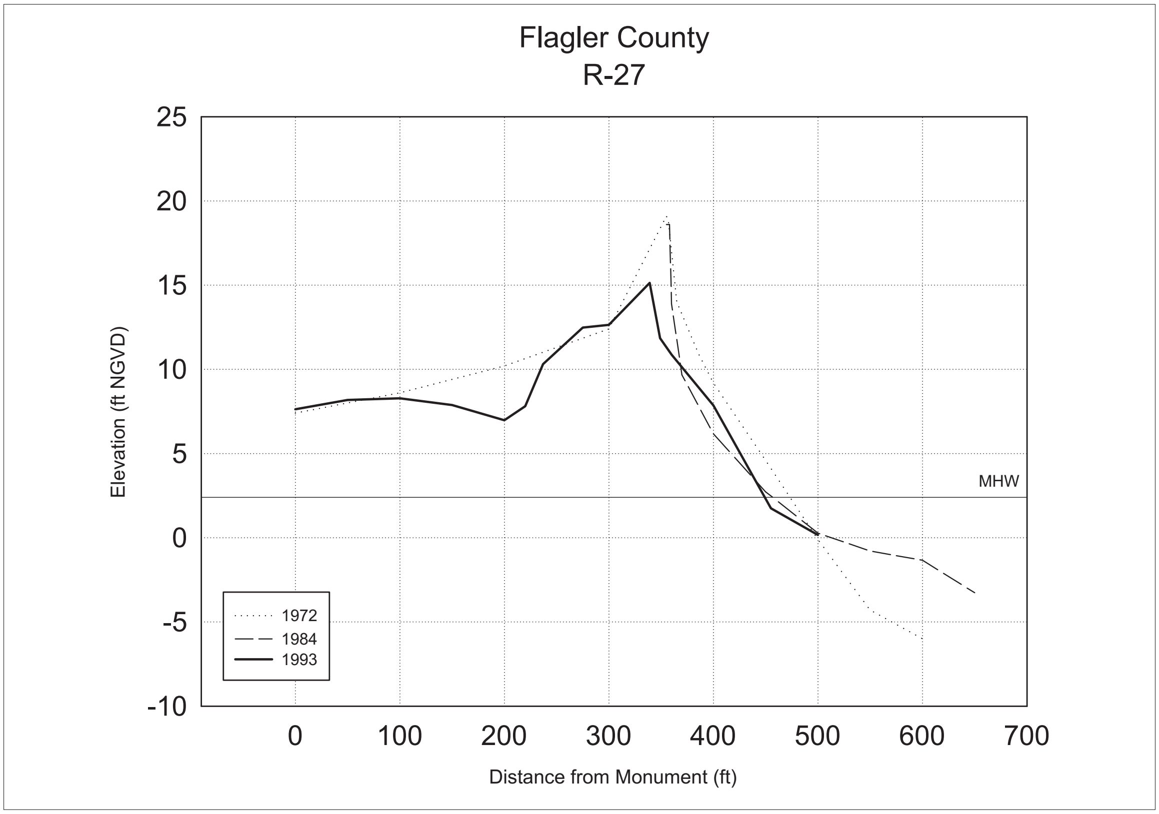
R-97 to R-100



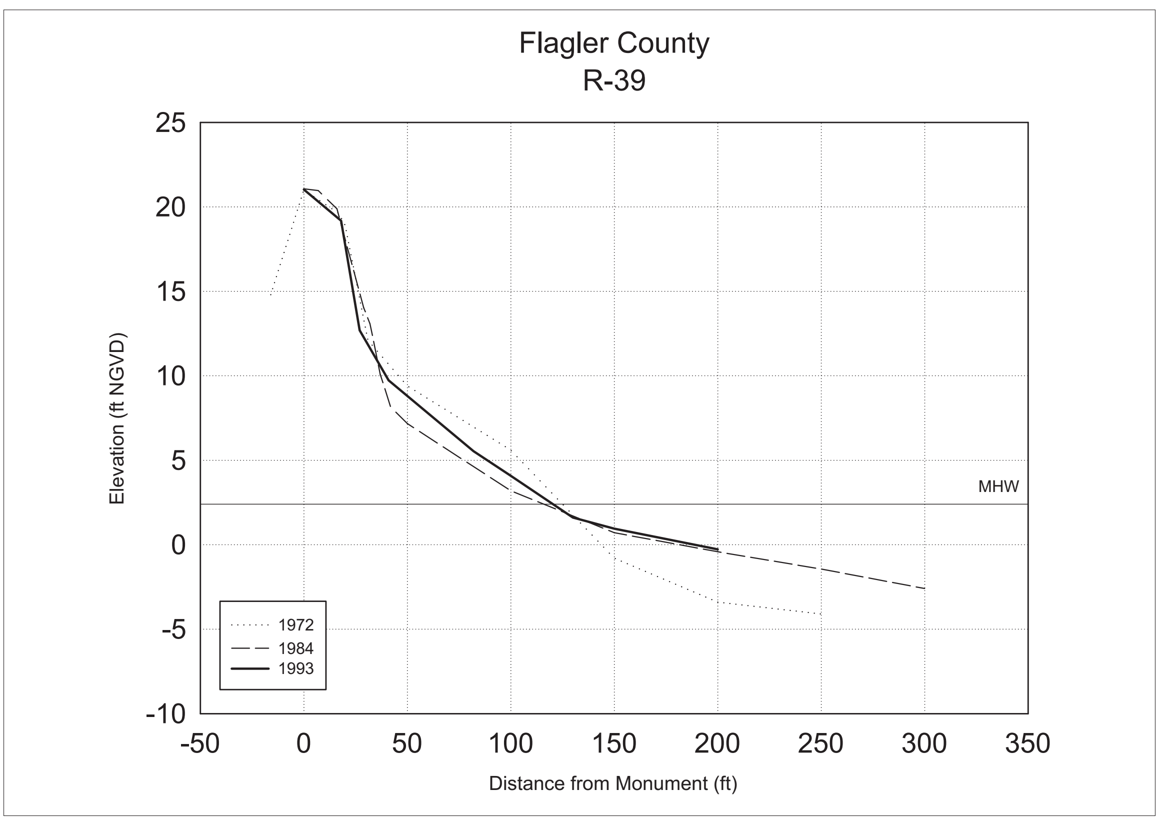
8.3 Appendix C: Profile Plots


Flagler County
R-6
25
20
15
10
5
0
-5
-10
-100
0
100
200
300
400
Elevation (ft NGVD)
Distance from Monument (ft)
MHW
1972
1984
1993

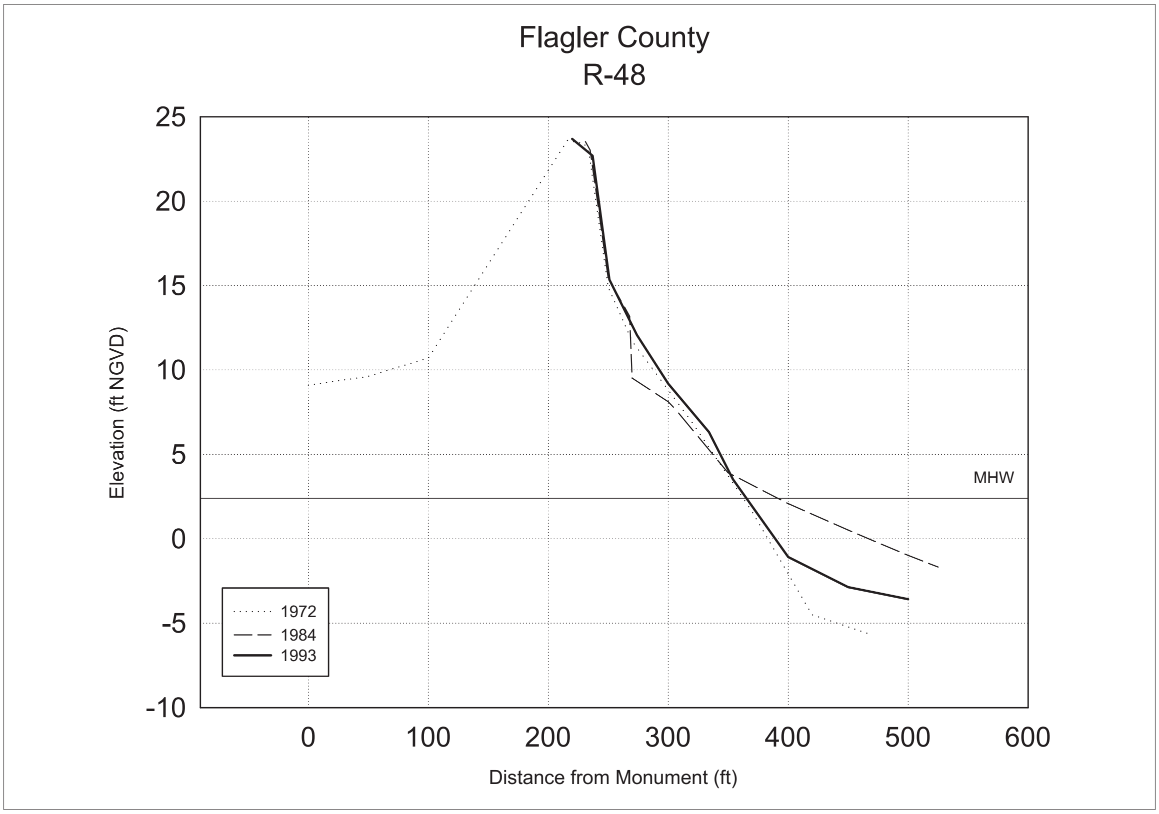

Flagler County
R-15
25
20
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
Elevation (ft NGVD)
Distance from Monument (ft)
MHW
1972
1984
1993



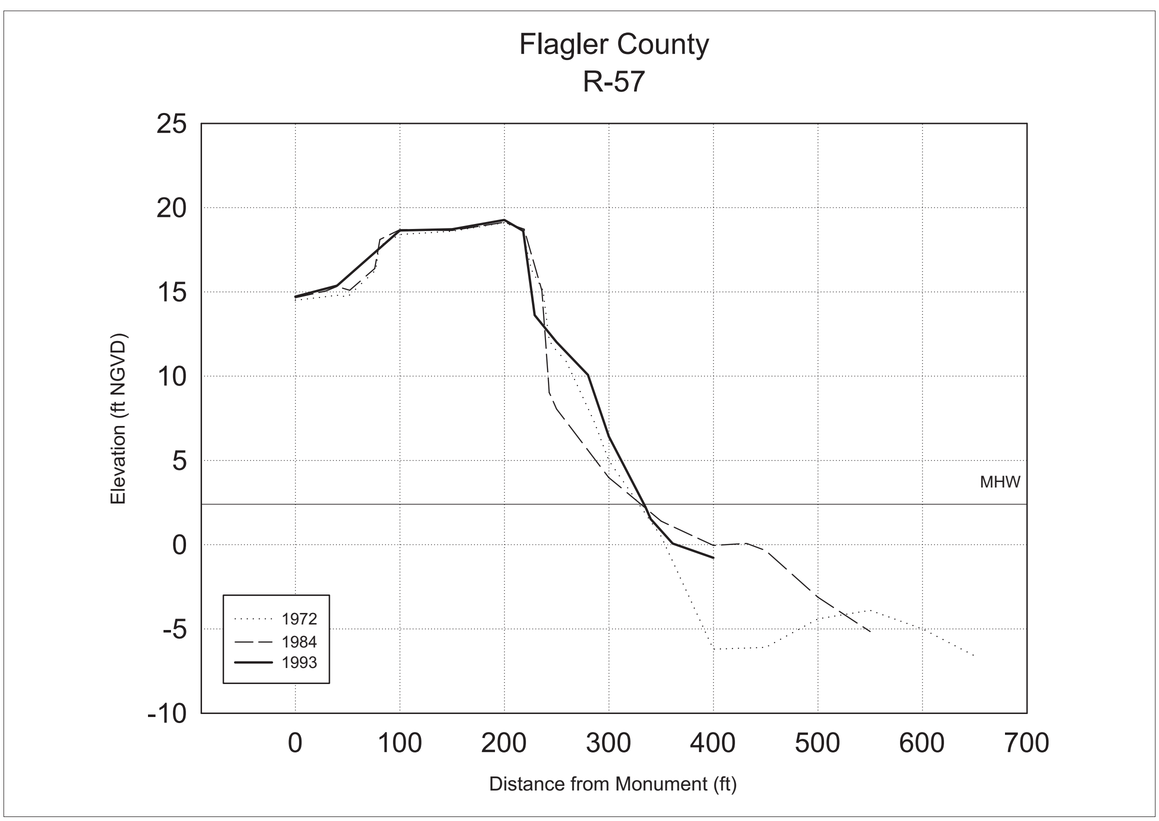
Flagler County
R-27
Elevation (ft NGVD)
25
20
15
10
5
0
-5
-10
MHW
1972
1984
1993
0
100
200
300
400
500
600
700
Distance from Monument (ft)



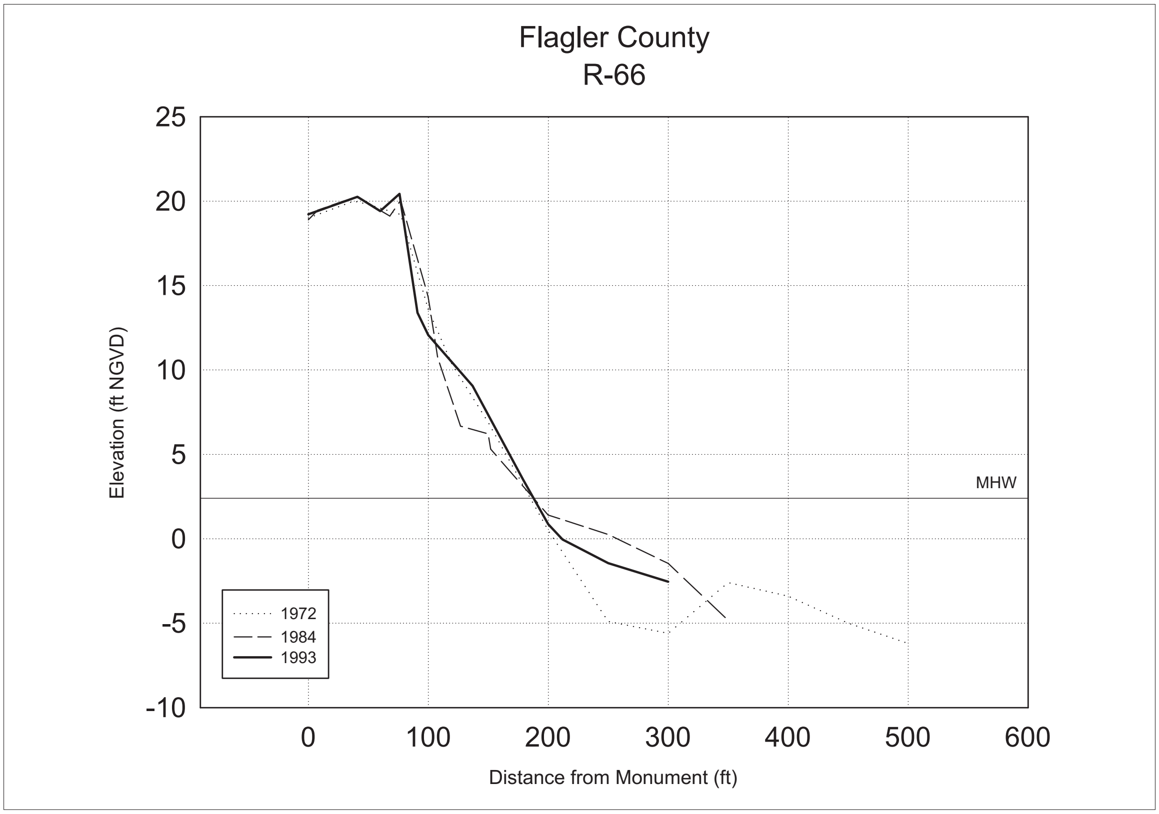
Flagler County
R-39
Elevation (ft NGVD)
25
20
15
10
5
0
-5
-10
MHW
1972
1984
1993
-50
0
50
100
150
200
250
300
350
Distance from Monument (ft)

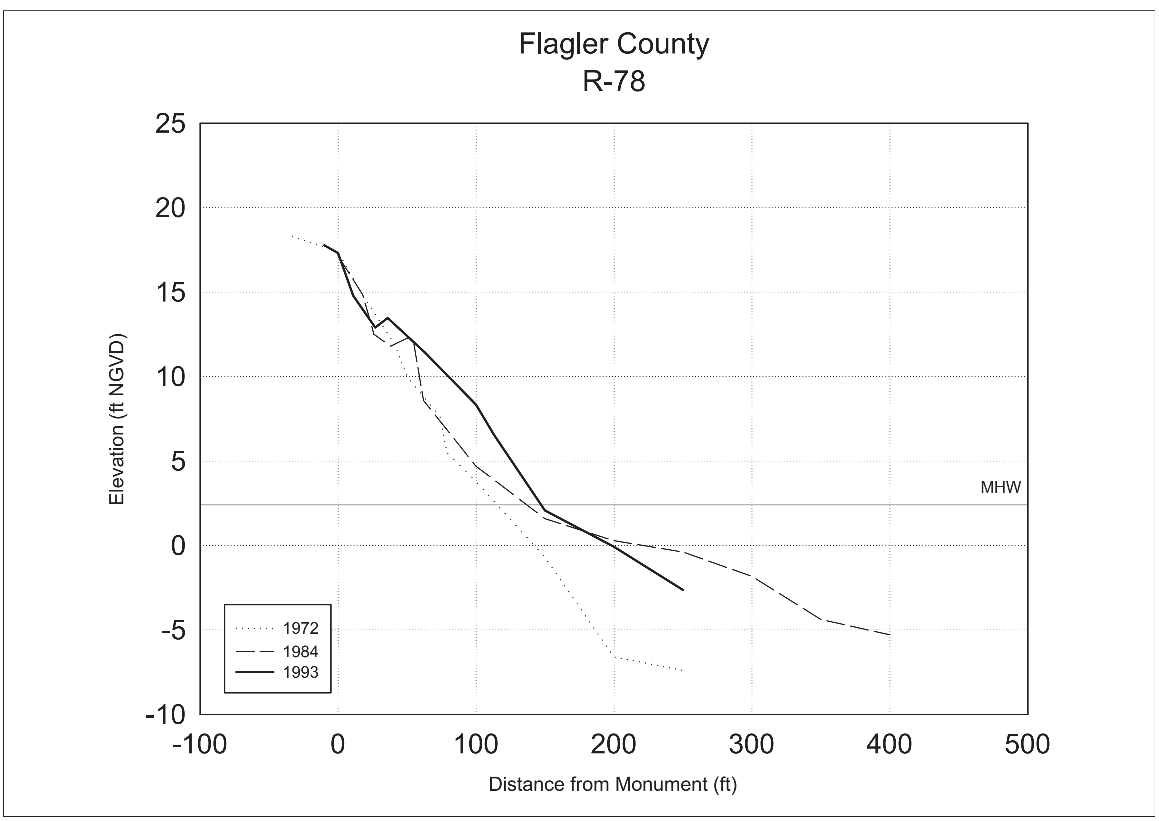


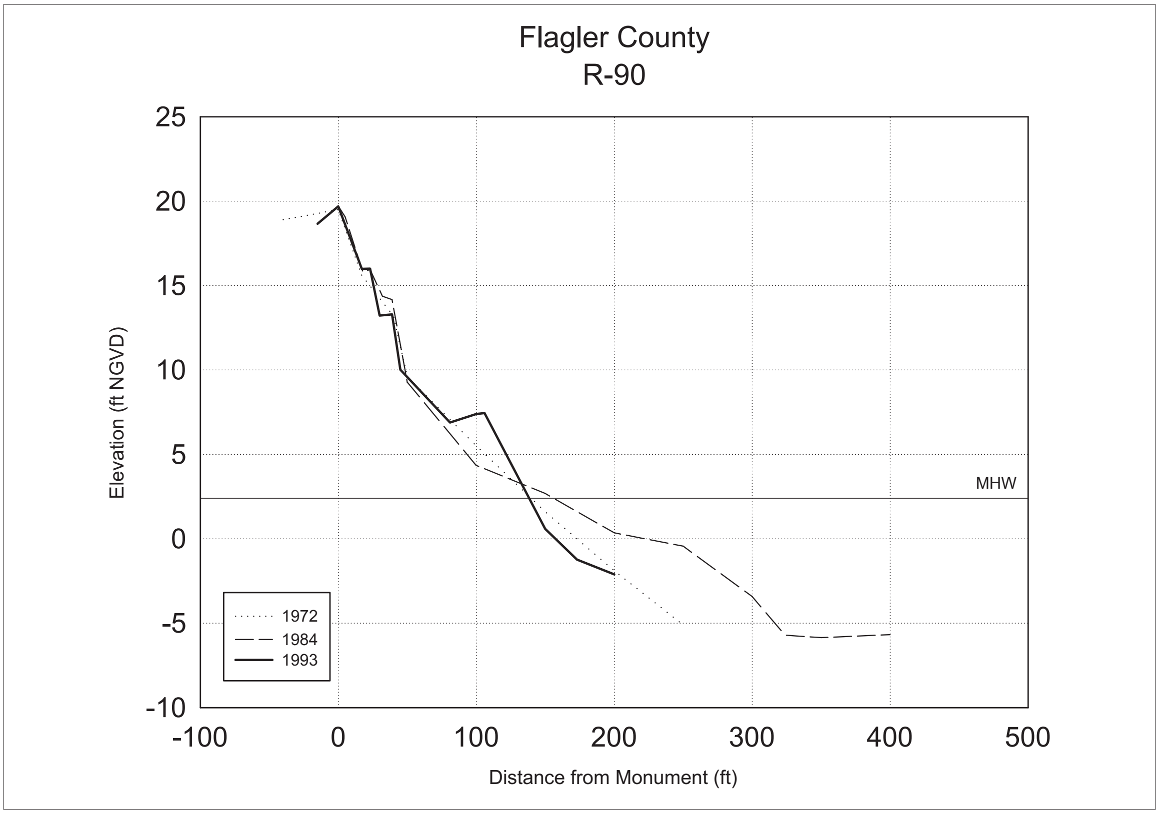
Flagler County
R-48
Elevation (ft NGVD)
Distance from Monument (ft)
MHW
1972
1984
1993

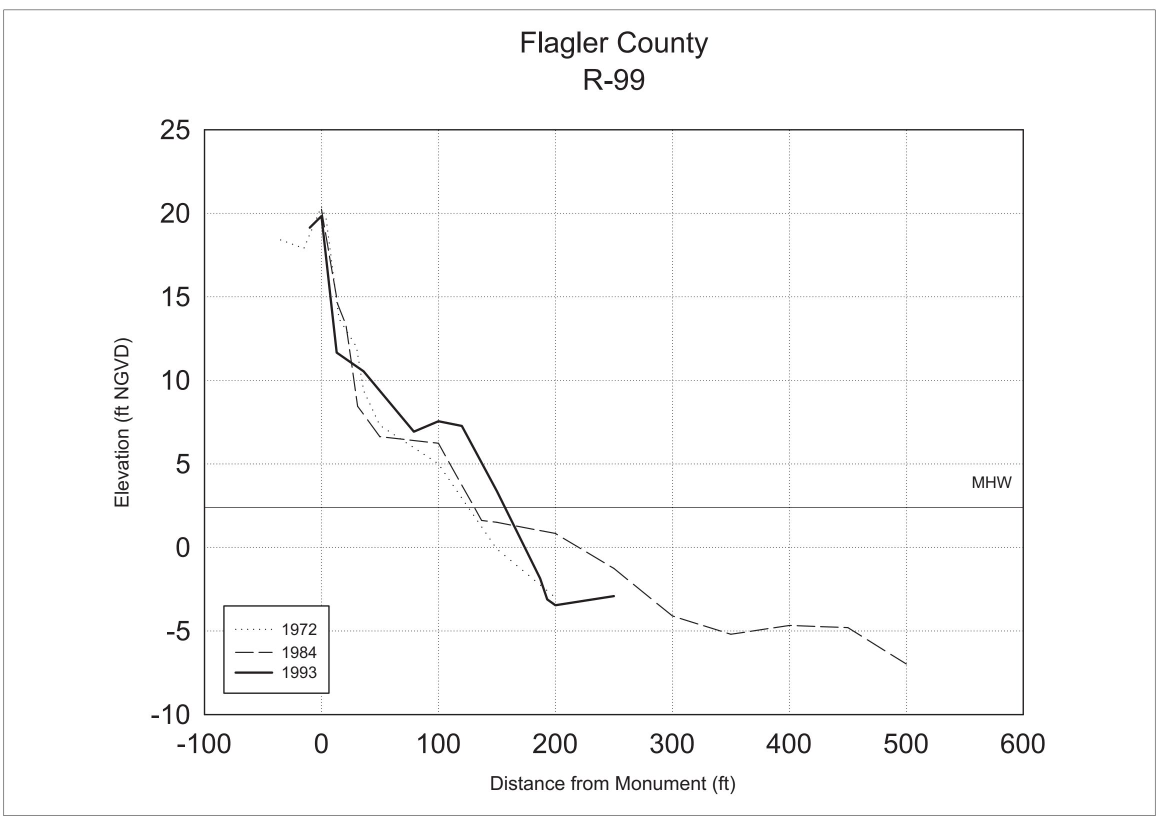


Flagler County
R-57
Elevation (ft NGVD)
Distance from Monument (ft)
MHW
1972
1984
1993


Flagler County
R-66
25
20
15
10
5
0
-5
-10
Elevation (ft NGVD)
MHW
1972
1984
1993
0
100
200
300
400
500
600
Distance from Monument (ft)


Flagler County
R-78
25
20
15
10
5
0
-5
-10
Elevation (ft NGVD)
MHW
1972
1984
1993
-100
0
100
200
300
400
500
Distance from Monument (ft)


Flagler County
R-90
25
20
15
10
5
0
-5
-10
Elevation (ft NGVD)
MHW
1972
1984
1993
-100
0
100
200
300
400
500
Distance from Monument (ft)


Flagler County
R-99
25
20
15
10
5
0
-5
-10
Elevation (ft NGVD)
MHW
1972
1984
1993
-100
0
100
200
300
400
500
600
Distance from Monument (ft)