STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Suite 965, 800 NE Oregon St., #28
Portland, Oregon 97232

OPEN-FILE REPORT O-93-10

Pilot Erosion Rate Data Study of the Central Oregon Coast Lincoln County

By
George R. Priest, Ingmar Saul, and Julie Diebenow
Oregon Department of Geology and Mineral Industries

1993

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Suite 965, 800 NE Oregon St., #28
Portland, Oregon 97232

OPEN-FILE REPORT O-93-10

PILOT EROSION RATE DATA STUDY OF THE CENTRAL OREGON COAST, LINCOLN COUNTY

FINAL REPORT
TO THE
FEDERAL EMERGENCY MANAGEMENT AGENCY

By

George R. Priest, Ingmar Saul, and Julie Diebenow
Oregon Department of Mineral Industries

1993

Funded by the Federal Emergency Management Agency
Cooperative Agreement No. EMW-92-K-3576

DISCLAIMER AND INSTRUCTIONS FOR USE OF THIS REPORT

This report was prepared with the support of the Federal Emergency Management Agency (FEMA), Cooperative Agreement No. EMW-92-K-3576. However, any options, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of FEMA.

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, camera-ready copy submitted by the editor has not been edited by the staff of the Oregon Department of Geology and Mineral Industries.

The erosion rates listed in this report should be considered preliminary and subject to revision when additional, higher quality data become available. The data quality was limited by the time and resources available for the study, and the nature of the investigation which is regional in scope. Many listed rates are average values or values from nearby, geologically similar areas that may or may not be applicable to individual sites. These rates should be used as general guidelines only; not as a substitute for detailed, site-specific estimates.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
INTRODUCTION 3
OBJECTIVE AND TASKS 5
INVESTIGATION METHOD 5
Tasks 1 and 2 (digital shorelines on historical maps and air photos) 5
Task 3 (analysis of tax lot and permit records) 11
Task 4 (analysis of bluff retreat by field measurements) 11
Task 5 (analysis of historical oblique photos) 11
Task 6 (analysis of the 1868 Topographic Map of Agate Beach-Newport) 12
Task 7 (Best estimate of erosion rate in each segment and transect0 13
Task 8 (Peer review of the investigation methods) 13
Task 9 (Cost and time itemization) 14
Task 10 (Final report and documentation) 14
RESULTS 14
Tasks 1 and 2 14
Task 3 15
Task 4 15
Task 5 16
Task 6 16
Task 7 16
Segment 1 (Salmon River Spit) 16
Segment 2 (Resistant Tertiary Sandstone and Mudstone Bluff Next to Mouth of the Salmon River) 18
Segment 3 (Basalt Flanked Pocket Beach in Tertiary Sandstone/Mudstone) 18
Segment 4 (Headlands and Small Pocket Beaches Composed of Basalt) 18
Segment 4.5 (Tertiary Sandstone/Mudstone Next to Basalt Headland) 18
Segment 5 (Roads End Area) 22
Segment 6 (Lincoln City Area) 22
Segment 7 (North Side of Siletz Bay - Wide Bluffed Beach of the Taft Area 27
Segment 8 (Siletz Spit) 27
Segment 9 (Gleneden Beach to Fishing Rock - Bluffed Beach) 31
Segment 10 (Fishing Rock) 35
Segment 11 (Pocket Beach at Fogarty Creek) 35
Segment 11.2 (Government Point to Depoe Bay) 35
Segment 11.3 (Depoe Bay Area) 35
Segment 11.4 (Depoe Bay to Cape Foulweather) 40
Segment 11.5 (Otter Crest) 40
Segment 12 (Pocket Beach on the South Side of Otter Crest) 43
Segment 13 (Devils Punch Bowl Headland) 43

TABLE OF CONTENTS (continued)

Segment 14 (Beverly Beach Area) 46
Segment 15 (Active Landslide Areas of Moolack Beach) 49
Segment 16 (Yaquina Head) 51
Segment 17 (Agate Beach) 51
Segment 18 (Landslide Areas of Newport, including Jumpoff Joe) 52
Segment 19 (Newport Area South of the Jumpoff Joe Landslides) 57
Segment 20 (Wide Beach on the North Side of the North Yaquina Bay Jetty) 59
Segment 21 (South Beach Area at the Southern Jetty of Yaquina Bay(.......................... 59
Segment 22 (Lost Creek State Wayside - Narrow Bluffed Beach) 61
Segment 21.5 (Duned River Mouth at Lost Creek) 63
Segment 23 (Duned River Mouth at Beaver Creek) 63
Segment 24 (Bluffed Beach South of the Ona Beach-Beaver Creek Area) 63
Segment 25 (Pleistocene Terrace Sand Bluffs with Basalt Sea Stacks) 65
Segment 26 (Tertiary Sandstone Bluffs with Basalt Sea Stacks) 65
Task 8 (Peer Review) 66
Task 9 (Cost Itemization) 67
DISCUSSION 68
RECOMMENDATIONS 72
BIBLIOGRAPHY 74
APPENDIX A Error Analysis of Digital Shoreline Data 75
Appendix A1 Generation of the 1991 Digital Shorelines 102
Appendix A2 Trial Tests of Shoreline Depiction Error 113
APPENDIX B Shoreline Measurements Using Historical Aerial Photographs 118
APPENDIX C Erosion Rate Database 125
APPENDIX D Graphs of Erosion Rate Vs. Transect Number 149
APPENDIX E Coastal Erosion Database Development Project 181
APPENDIX F Photographic Evidence for Sea Cliff Erosion and Beach Changes along the Oregon Coast 203

TABLE OF CONTENTS (continued)

FIGURES

Figure 1. Study area 4
Figure 2. Shoreline segments 7
Figure 3. Salmon River spit 17
Figure 4. Segments 2,3,4 (in part) 19
Figure 5. Segments 2,3,4 (in part) 20
Figure 6. Basaltic headland Segment 4 21
Figure 7. Segment 5 bluffs 23
Figure 8. Segment 6 at Roads End 24
Figure 9. Segment 6 typical bluffs 25
Figure 10. Pleistocene terrace in Segment 6 26
Figure 11. Beaches of Segment 7; Siletz Spit 28
Figure 12. Siletz Spit 29
Figure 13. Circulation within Siletz Bay 30
Figure 14. Siletz Spit/Gleneden Beach 32
Figure 15. Gleneden Beach - Segment 9 33
Figure 16. Coronado Shores 34
Figure 17. Fishing Rock 36
Figure 18. Fogarty Creek 37
Figure 19. Segment 11.2/Depoe Bay Segment 11.3 38
Figure 20. Segments 11.2 and 11.4 basalt hyaloclastite .. 39
Figure 21. Hyaloclastic basalt breccia Segment 11.3 41
Figure 22. Segment 11.4 - Little Whale Cove area 42
Figure 23. Otter Crest - Segment 11.5 44
Figure 24. Devils Punch Bowl/Beverly Beach 45
Figure 25. Segment 14 sandstone/mudstone 47
Figure 26. Beverly Beach 48
Figure 27. Moolack Beach, Segment 15 50
Figure 28. Jumpoff Joe 53
Figure 28a. Yaquina Head/Jumpoff Joe 54
Figure 29. Jumpoff Joe landslide area 56
Figure 30. Segment 19, Sylvania Beach 58
Figure 31. Segment 20, Yaquina Bay jetty 60
Figure 32. Segment 22 near Lost Creek 62
Figure 33. Segment 24 bluff 64

TABLES

Table 1 - Geomorphic Delineations 8
Table 2 - Personnel salaries and subcontracts 67
Table 3 - Time and cost itemization 68

STATE OF OREGON - PILOT EROSION RATE DATA STUDY

EXECUTIVE SUMMARY

Erosion rates for bluffed beaches of the Oregon coast are in general less than -1 ft/yr, except where there are weak rocks prone to landslides or where beach characteristics promote episodic wave attack on poorly consolidated rocks. The accuracy of digital shorelines was, in general, inadequate to determine rates less than -1 ft/yr.

Digital shorelines determined from 1939, 1967, and 1991 aerial photos had errors on the order of 1 ft/yr. Digital shorelines determined from 1927 and 1928 T-maps could not generally resolve rates less than about 2 ft/year. 1868 and 1884 T-maps had surveying errors on the order of 18-20% and thus could not be digitized.

Rates of less than 1 ft/yr were accurately determined by comparing house-to-bluff distances measured in the field to the same distances on historical photos. Unfortunately, many areas lacked houses or other landmarks that could serve to estimate rates by this method. Rates for areas without house-to-bluff data were estimated by analogy to geologically similar areas with this data. Mapping the geology of the bluffs at a scale of 1" = 400' was critical to estimates by analogy. The house-to-bluff technique did not work for areas with landslides, because of the long intervals between landslide events and the short available observation time (54 years) for available vertical air photos. Active landsliding in dipping Tertiary sedimentary units was generally limited to areas where all of the following conditions occur:

1. Tertiary sedimentary rock is at least 75% mudstone and forms at least 10 ft of the base of the sea cliff.

2. The rocks dip seaward at 14-28^{o}.

3. The angle between the strike of Tertiary sedimentary rock and the trend of the sea cliff (cliff-strike angle) is less than or equal to approximately 7^{o}.

Fault zones that weaken the Tertiary sedimentary rocks also caused small, very localized landslides and areas of severe rock fall erosion.

When any of the above conditions prevail, bluffs retreat by catastrophic failure over variable time intervals of up to 50 years. Achieving a meaningful average rate of retreat requires an observation time on the order of 100 years. This observation time was available only in the Moolack Beach-Yaquina Bay area where an 1868 1:10,000 scale T-map was available. The 1886 T-map had surveying errors that precluded digitization without expensive resurveying of landmarks; however, "rubber sheeting" of 1990 historical photos to small parts of the T-map using a Zoom Transfer

Stereoscope allowed crude erosion rates to be measured in landslide areas. A headwall retreat rate of 0.68 ± 0.34 ft/yr was determined from the 1868 T-map for a fault induced landslide on the south side of Yaquina Head. The mean, weighted for length of shoreline involved, is 1.77-1.90 ± 0.34 ft/yr for two areas with seaward dipping mudstone (Moolack Beach and the Jumpoff Joe area in Newport). A lower rate of about 1 ± 0.7 ft/yr was determined in a similar area in south Newport where sandstone is interbedded in the mudstone.

Other areas with erosion rates exceeding 1 ft/yr have all of the following conditions:

1. Bluffs composed of poorly indurated Pleistocene sandstone or sand dunes.

2. Coarse sand

3. Steeply sloping beaches.

4. Deep rip embayments.

These areas are subject to rapid removal of sand from the beaches, focusing wave attack from unusually severe storms on the rip embayments. Unfortunately, like the landslide areas, these areas are subject to highly episodic attack that requires long observation times for accurate erosion rate estimation. The observation time (25-54 years) available from the house-to-bluff and digital shoreline techniques may not be adequate to produce accurate rate estimates. However, there is no way of testing this hypothesis without the large scale, Nineteenth Century T-maps. A mean erosion rate of -0.62 ± 0.76 ft/yr was determined by the house-to-bluff method for bluffs of Pleistocene sandstone at Gleneden Beach which is known to be subject to these episodic erosion events. However, local areas of this beach have experienced rates as high as -2.3 ft/yr. The bluffs of the Lincoln City area have identical bluff geology but gently sloping beaches, fine sand, and few deep rip embayments. The mean bluff retreat rate there is -0.27 ± 0.34 ft/yr.

Bluffs composed of basalt or solidly cemented volcaniclastic rock had negligible (mean of -0.09 ± 0.16 ft/year) erosion rates. Even measurements by the house-to-bluff method failed to adequately resolve these very low rates. These rocks formed nearly all headlands in the area. In one case, individual basalt sea stacks mapped on a 1:10,000 scale reconnaissance map in 1868 could still be recognized today with little modification.

The fluctuation of non-bluffed soft sand beaches at the mouths of major rivers was large enough to show through the "noise" of the positional error in the digital shoreline method. Erosion and accretion rates in these areas were typically on the order of several feet per year which was generally greater than the standard error in the digital shoreline data. The digital shoreline mapping technique should probably be restricted to use in these geomorphic settings. There are, in fact, large stretches of the southern Oregon Coast that are composed of dune fields without a near shore bluff, so the digital shoreline technique could be profitably used in these areas. Caution should be taken in picking a final erosion rate, since most of these areas are not actually eroding landward any faster than the slowly weathering bluffs or jetties that lie adjacent to them. They do, however, fluctuate back and forth, accreting one year and eroding the next. In some cases, such as jetty beaches still in the process of adjusting to jetty construction, net accretion can be measured, but this will decrease progressively as the jetty beaches reach an equilibrium configuration (e.g. South Beach at Segment 21). Set backs should be based on the maximum predicted landward position of the active beach based on expected variability within the time interval of interest. Where there is a unidirectional change in rate from one observation interval to the next, the rate from the last interval should probably be used, if there has been some progressive change in sand supply or other factors. In the case of the unarmored end of Siletz Spit, it eroded in all time intervals but at a decreased rate in 1967-1991, as the rest of the spit became covered in rip rap. Presumably armoring of the main trunk of the spit stabilized the changes at the end.

It is not cost effective to precisely determine the erosion rates of all bluffs that have only slow (less than -1 ft/yr) erosion rates. These slow weathering rates can only be determined by relatively expensive high-precision techniques such as the house-to-bluff method or by rectification of historical photos. This study, because of a limited budget, lists erosion rates for these bluffs, but most rates were determined by analogy to the few areas where high-precision house-to-bluff measurements have been made. The analogy method is not scientifically satisfying, being fraught with potential errors, since no area is exactly like another. However, these estimates will improve as a state-wide database of high precision rates and geologic observations grows.

In any case, this project points out the need for careful geologic mapping in order to judge whether areas are vulnerable to landslides or episodic wave attack. Most bluff erosion rates greater than or equal to -1 ft/year involved landslides. Noting the geologic conditions that promote landslide-induced erosion should be a high priority in all future studies. Mapping beach conditions that promote episodic high erosion rates (coarse sand, steep beach profiles, and deep rip embayments), is also necessary to delineate areas of high erosion rate.

INTRODUCTION

This report summarizes a pilot study of erosion rates along the Oregon Coast for the Federal Emergency Management Agency (FEMA). The study area (Figure 1) was chosen to be representative of the many coastal environments of Oregon. It includes bluffed beaches, hard rock headlands, sand spits, and river mouth beaches.

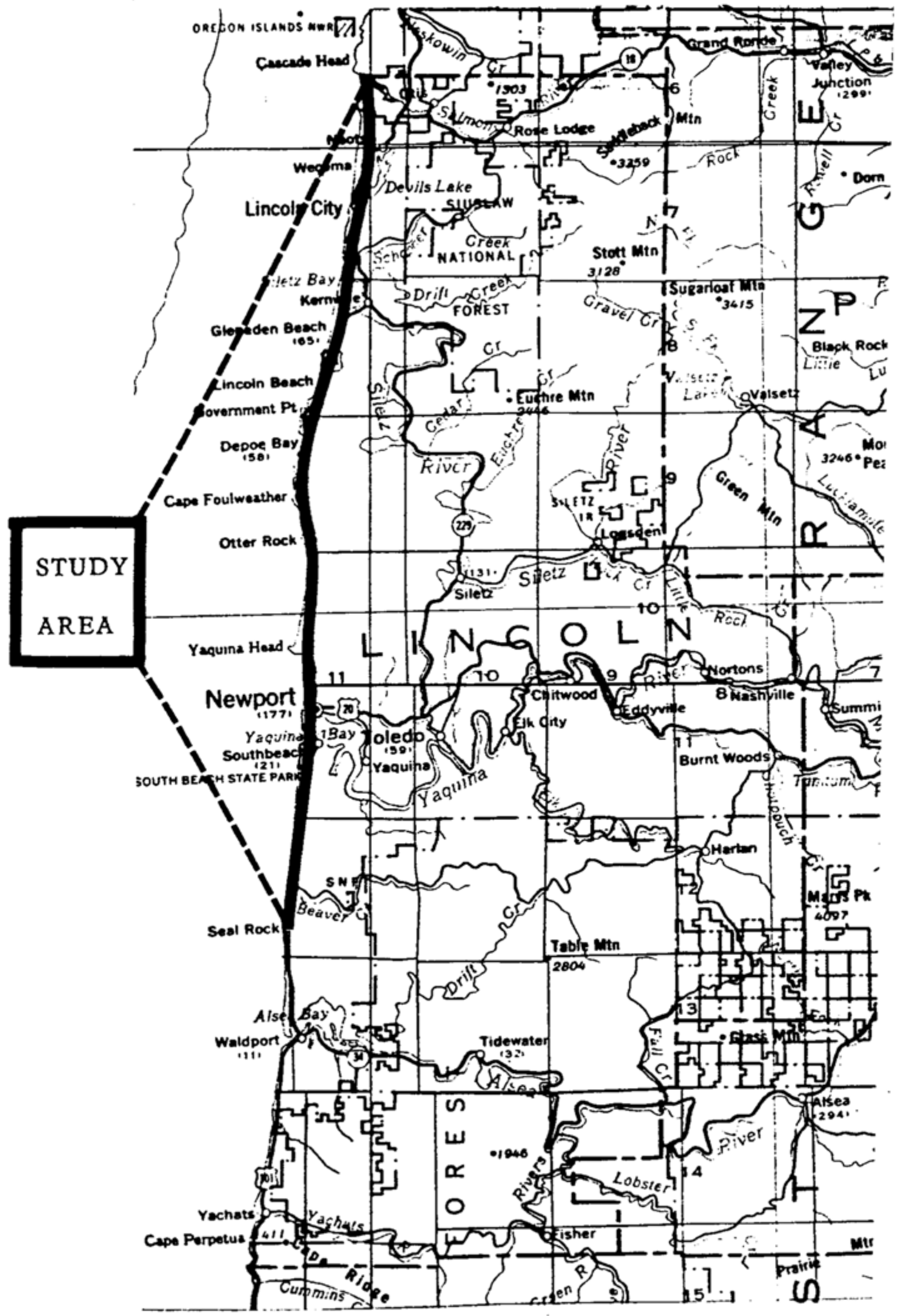


Figure 1. Study area for this investigation.

The study was undertaken to support the Federal Flood Insurance Program. The goal is to explore ways of measuring erosion rates so that bluff and shoreline positions can be accurately predicted up to 60 years in the future. These erosion rates could then be used to set flood insurance rates. Details of the program sponsorship for the study are summarized in Appendix A.

OBJECTIVE AND TASKS

The primary objective of this study is to find a scientifically defensible, and economically feasible method for estimating coastal erosion rates in Oregon. To meet this objective, the following tasks were completed:

1. Analysis of digitized shorelines on historic maps.

2. Analysis of three digitized shorelines on historic vertical air photos taken in 1939, 1967, and 1991.

3. Analysis of tax lot and building permit records.

4. Measurement of house-to-sea cliff distances in the field (1992), and comparing those same measurements to the distances in 1967 and 1939 air photos.

5. Examination of historical oblique photos gleaned from various collections to estimate changes in sea cliffs and beaches.

6. Production of bluff and landslide headwall recession rates from the 1:10,000 scale topographic maps produced for the Newport area in 1868.

7. Analysis of the data for best estimates of erosion rate in each geomorphic segment and each digital transect.

8. Peer review of the investigation methods.

9. Cost and time itemization to determine the cost of completing an erosion rate study of the entire Oregon coast.

10. Final report and documentation.

INVESTIGATION METHOD

<u>Tasks 1 and 2 (digital shorelines on historical maps and air photos)</u>

Two computer data bases were created from historical maps and photos, a historical shoreline location database (HSLD) with historical and current shoreline positions in digital format, and a historical shoreline positional change database (HSPCD). The latter was produced by running a transect program on the first database, calculating distances from an arbitrary offshore baseline to crossing points on transects drawn perpendicular to the shore. Transects were spaced at 150 ft intervals along the shoreline.

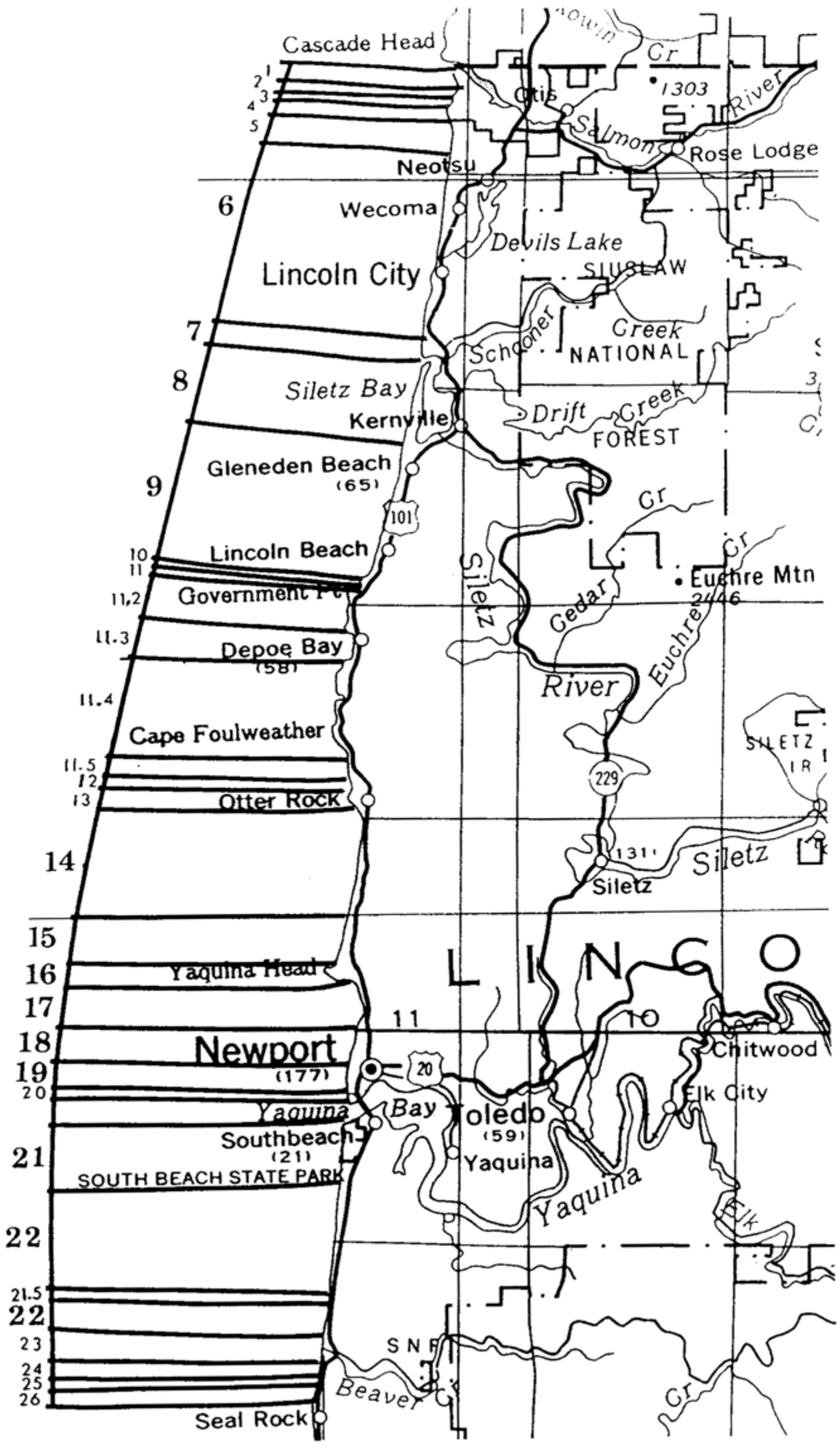
Rates of shoreline change were calculated by subtracting the shoreline positions such that a positive difference is indicative of accretion and a negative value is an erosion rate. This calculation was done only for the data from historical air photos taken in 1939, 1967, and 1991. Digital shorelines from historical maps were insufficiently accurate to utilize by standard digital technology. Details of the shoreline mapping method and associated errors are summarized in Appendices A and B.

The storm surge penetration line (SSPL) was digitized on 1939 and 1991 vertical air photos. This line corresponds to the furthest that major storm waves reach in a typical two year period. Its location is subjective, generally taken to be either the oceanward edge of flotsam accumulations or, lacking these, the "storm berm." The storm berm represents the current active shoreline since the 1982-1983 'el Ninno' event. On relatively narrow (< 100') bluffed beaches the SSPL was generally located at or near the base of the sea cliff. On wider beaches it was generally located on the seaward edge of foredune complexes.

The rectified, 16 ft contour was utilized as a proxy for the SSPL on the 1967 photography produced by the Oregon Department of Transportation. This line and other associated reference markers and beach contours were extremely useful, because they were produced by digital stereo plotting utilizing ground survey control. This provided a highly accurate reference frame for all other data. Unfortunately, the 16 ft contour did not always correspond exactly to the SSPL, as estimated visually on the 1939 and 1991 air photos. Lack of rectification on the 1939 and 1991 photos (other than spot checks by radial line triangulation on the 1991 photos) and uncertainty in picking the SSPL, were additional sources of error (Appendix A).

Digital shorelines were produced for most sandy beaches in the area, excluding public park areas where there was no digital contour data from the 1967 photos. There was also no digital contour data from 1967 photogrammetry for the cliffy headlands, so no digital data was produced for those areas. Most of the cliffy headlands are composed of extremely resistant rock with negligible cliff recession, so this was not considered a major problem for the study. Of the total 31 miles of coast, 66.6% has digital data from 1939 photos, 73.2% has digital data from 1967 and 1991 photos, and 26.8% has no digital shoreline data. The resulting shoreline change rates are summarized in Appendix C.

The study area was divided into geologically and geomorphically related segments (Figure 2). The segment boundaries and reason for their selection are summarized in Table 1.



SHORELINE SEGMENTS

Figure 2

Table 1

GEOMORPHIC DELINEATIONS (SEGMENTS)
Cascade Head to Seal Rock, Lincoln County, Oregon

SEGMENT	AREA	TRANSECTS	REASON FOR DELINEATION
1	Mouth of Salmon River	B1-22	Sand spit
2	SS bluff at mouth of Salmon River	B23-37	Sand spit to north; cliffs to the south with basalt plus SS.
3	Pocket beach south of Salmon River	B38-43	Basalt-flanked pocket beach composed of sandstone.
4	Headlands N of Roads End	B44-61	Basaltic headlands with minor patches of SS; SS-dominated bluffs N and S.
4.5	High cliffs N of Roads End	B62-67	Nestucca MS plus SS with low bluffs of Pleistocene debris flows to the S; basalt to the north.
5	Roads End area	B68-96	Low bluffs of Pleistocene colluvial deposits with bluffs of Pleistocene SS to the south and Tertiary SS and MS to the north.
6	Lincoln City	B97-283	Bluffs of Pleistocene SS with the mouth of Siletz Bay to the S and bluffs of Pleistocene colluvium N.
7	N side of Siletz Bay	B284-311	Separated from Segment 6 because of a wide bay mouth beach with foredunes.
8	Silez Spit	C1-97	Sand spit
9	Gleneden Beach	C98-200	Bluffs of Pleistocene SS bounded N by Siletz Spit and S by basalt at Fishing Rock.
10	Fishing Rock	C201-210	Basalt headland with SS bluffs north and south.
11	Fogarty Creek State Park	C211-223	SS pocket beach bounded N and S by basalt headlands.

11.2	Government Point to Depoe Bay	C224-313	Basaltic headlands bounded N by a pocket beach and S by Depoe Bay.
11.3	Depoe Bay	C314-335	Local areas of SS and basalt bounded N and S by basalt headlands.
11.4	Depoe Bay to Cape Foulweather	C336-475	Headlands of basaltic rocks bounded N and S by faulted SS.
11.5	Otter Crest	C476-484	Headland of Tertiary SS capped by Pleistocene SS; bounded N by faulted basalt, and S by landslides in SS and MS.
12	Pocket beach S of Otter Crest	C485-489	Landslide-backed pocket beach bounded on the N and S by SS headlands.
13	Devils Punch Bowl headland	C490-506	Headland of SS bounded on N and S by landslide-prone MS and SS reentrants.
14	Beverly Beach	C507-551; D1-98	Bay of SS and MS bluffs bounded on the N by a SS headland; bounded on the S by landslide-prone bluffs.
15	Moolack Beach	D99-124	Landslide-prone bluffs bounded on the N by bluffs with few landslides; bounded on the S by Yaquina Head.
16	Yaquina Head	D125-177	Basaltic headland bounded on N and S by SS and MS bluffs.
17	Agate Beach	D178-220	SS and MS bluffs bounded on the N by Yaquina Head; bounded on the S by landslide-prone bluffs.
18	Newport area landslides	D221-258	Active landslide areas bounded N and S by bluffs with fewer and smaller landslides.
19	S Newport	D259-297	Bluffs of MS and minor SS with few landslides bounded on the N by bluffs with large landslides; bounded

			on the S by change in bluff trend and no landslides.
20	N side of Yaquina Bay	D298-311	Landslide-free bluffs fronted by a wide, duned beach next to N jetty.
21	South Beach	E3-55	Wide duned beach on S side of S jetty, Yaquina Bay; bounded on S by narrow bluffed beach.
22	Lost Creek State Wayside	E56-170 E174-201	SS bluffs bounded on N and S by duned beaches.
21.5	Lost Creek	E171-173	Duned beach bounded on N and S by bluffed beaches
23	Beaver Creek	E202-227	Duned beach bounded on N and S by bluffed beaches
24	Beach N of Seal Rock sea stacks	E228-264	Narrow bluffed beach bounded on the N by duned beach and on the S by beach with sea stacks off shore.
25	Bluffs N of Seal Rock	E265-272	Bluffs composed of Pleistocene SS with offshore sea stacks; bounded on N by similar bluffs without sea stacks; bounded on the S by bluffs composed mostly of Tertiary SS.
26	Bluffs adjacent to Seal Rock	E273-282	Bluffs of Tertiary SS with offshore sea stacks; bounded on S by basalt headland; bounded on N by bluffs of Pleistocene SS.

A series of graphs were produced showing transect number on the X axis and positional change rate of digital shorelines and bluffs on the Y axis (Appendix D). The extent of armoring of the shoreline by shoreline protection structures (SPS) is also shown on the graphs.

Error bars on the histograms reflect the precision of the shoreline position. For the rates based on mapping of digital shorelines from historical photos, visual spot checks of the uncertainty in picking the storm surge penetration line were made at 1000' intervals utilizing the 1967 photo based maps at a scale of 1" = 100' (Appendix A). These uncertainties are probably conservative (high), because, unlike the 1939 and 1991 shorelines, in parts of the 1967 shoreline anomalous log accumulations were present that created somewhat greater uncertainties in the position of the storm surge penetration line. A detailed discussion of the digital shoreline errors is given in Appendix A.

Transects with SPS probably have erosion rates approaching zero, while the SPS is intact, but these structures can sometimes fail and are usually installed in areas vulnerable to erosion. The future erosion rate in these areas is therefore ambiguous and is not determined for transects crossing these structures.

TASK 3 (analysis of tax lot and permit records).

The highly variable, low accuracy and small amount of data available from this method precluded its use in this study. Details of the method are summarized in Appendix E. Data are in file GOOD on disk A.

TASK 4 (analysis of bluff retreat by field measurements)

Individual houses were located on 1967 and, in rare cases, 1939 photos and in the field. The 1992 or 1993 house-to-bluff-edge distance was then measured with a 100 ft. tape for calculation of the 25 or 26 year erosion rate. The local photo scale was determined by field measurement between points located on the 1967 and 1939 photos. Utilizing a local house next to the bluff for a tie point eliminated much of the operator error and error introduced from radial distortion of the non-rectified photos (distortion affected the reference point nearly the same as the nearby bluff edge).

The error of individual measurements was calculated by estimating the amount of each individual error source (bluff edge uncertainty, width of ink line on photo, and field taping error) and taking the square root of the sum of squares of these errors.

Estimated uncertainties for the rate of bluff erosion in each segment are listed on the histograms. In most cases the error in the measurements was too small to show graphically on the histograms.

Erosion rates and locations of the data from this method are in the digital file labeled BLUFF on the disk A. The rates are plotted on the histograms of Appendix D.

TASK 5 (Analysis of historical oblique photos)

Oblique historical photos in private collections and museums were searched. Emphasis was on pre-1939 photos, since a digital shoreline was available for much of the study area from 1939 air photos. Modern views and photos were then compared to the historical photos to ascertain changes to beaches and bluffs. Details of the method and results are summarized in Appendix F. No digital database was produced, owing to the small amount and qualitative nature of the erosion rate data.

Data was collected for a large portion of the northern Oregon Coast, although the effort was concentrated in the study area. The hope was that areas analogous to the study area would yield useful data for comparison.

Task 6 (Analysis of the 1868 Topographic Map of Agate Beach-Newport)

Although T-maps for the study area had inherent positional inaccuracies that precluded their use for digital shoreline analysis, using a zoom transfer scope (ZTS), it is possible to plot the 1990 bluff edge from 1:12,000 scale air photos onto the 1:10,000 scale 1868 T-map available for the Agate Beach-Newport area. The bluff edge and the headwalls of landslides are generally visible on the contoured 1868 map as a change in slope. Inaccuracies in surveying and scale on the T-map were overcome by carefully scaling, over distances of a few inches of map scale, to local geographic features that appear both on the 1990 photos and the T-map. In some cases the detail on the T-map was good enough to recognize individual basalt sea stacks that are still present at Yaquina Head. Plotting the 1990 position of the sea stacks onto the 1868 maps revealed a minimum positional error of approximately 0.05 inches which translates to an erosion rate of $\pm$ 0.34 ft/yr for the 122 year interval. In areas with less geographic control for scaling of the air photo to the T-map, the error was somewhat larger. Scaling was only a problem in Segment 19, where the southern part of the segment has few landmarks on the T-map that correspond to the air photo. Inherent error at this location is on the order of $\pm$0.1 inches, which causes a rate error of $\pm$0.68 ft/yr. The error in this case was determined by two independent trials, "rubber sheeting" the 1990 bluff edge to the 1868 map. Errors of 0.34-0.68 ft/yr are as large or larger than the typical bluff weathering rates, but smaller than most rates of bluff retreat by landsliding.

The 1868 T-map covered extensive areas of landsliding and provided an invaluable database for analysis of landslide erosion. Approximately 11.6% of the total study area was analyzed by this technique.

It may be that establishing a series of surveyed control points that can be recognised on the 1868 map would allow digital correction of the map for inherent errors. This might be worth exploring in future work.

Rates for transects crossing bluffed areas of the 1868 T-map are listed in file TRATENEG.dbf on disk A. The mean, weighted for length of shoreline, of the headwall erosion rate of landslides on the 1868 map was used as the "Best" rate for many transects crossing landslides in geologically similar rocks.

TASK 7 (Best estimate of erosion rate in each segment and transect)

Transects crossing shoreline protection structures were not assigned an erosion rate for the reasons explained above. For transects without SPS, the mean erosion rate and standard deviation was established for each segment in order to determine which transects had unusually high or low values (outliers). Outliers were defined as rate measurements at greater than one standard deviation from the mean within each geomorphic segment.

Outliers from the digital shoreline analysis were examined to determine the underlying cause of the unusual rate. Outliers caused by inherent inaccuracies in the digital shoreline technique were discarded.

An alternative estimate of the rate (e.g. house-to-bluff measurement) was sought where (1) an outlier was discarded, (2) standard error of the digital shoreline technique greatly exceeded the probable rate at a transect, (3) digital shoreline data was lacking. If no alternative estimate was available at a transect, a best estimate of rate was determined based on analogy to nearby, geologically similar areas with high precision rate estimates.

Where standard error of the digital shoreline technique was significantly smaller than the measured rates at a transect, the accuracy of the individual rate measurements for 1967 to 1939, 1991 to 1967, and 1991 to 1939 was examined. The main test of accuracy was the likelihood that the measurement could be extrapolated into the future to estimate erosion or accretion for the next 60 years. The geomorphic and oceanographic setting, overall history of shoreline change, and locational inaccuracies were taken into account to choose a best rate or range of rates. The final rates are summarized in the data field labeled BEST in file TRATENEG on disk A. An estimated root mean square error is listed next to each rate estimate.

This task depended heavily on an accurate understanding of the geology of bluffs. A detailed (1" = 400') geologic map of the bluffs and shoreline protection structures was produced. Previous work by Schlicker and others (1973), Rholeder and others (1978), and Gentile (1978) was also utilized.

TASK 8 (Peer review of the investigation methods)

As the project progressed, the principal investigator conferred with experts on coastal studies, including Dr. John Beaulieu of DOGAMI, Dr. Curt Peterson of Portland State University, Dr. Paul Komar and Dr. Jim Good, both of Oregon State University, to determine whether the techniques used were valid. These scientists served as an informal, ad hoc technical advisory committee for the project. On July 8, 1992 chronic hazard mapping and erosion rate analysis for this and a related study was discussed by the Technical Advisory Committee (TAC) to the Coastal Hazards Policy Working Group (PWG).

The PWG is an ad hoc advisory group sponsored by the Oregon Department of Land Conservation and Development, Oregon State University Sea Grant Extension, the Oregon Parks and Recreation Department, and DOGAMI. It includes members from local and county government. The TAC membership is as follows:

Jim Good, Oregon State University Oceanography
Rob Holman, Oregon State University Oceanography
Paul Komar, Oregon State University Oceanography
Mark Lorang, Oregon State University Oceanography
Phil Jackson, Oregon State University Oceanography
Jon Kimerling, Oregon State University Geosciences
Charles Rosenfeld, Oregon State University Geosciences
Curt Peterson, Portland State University
John Marra, Department of Land Conservation and Development

Preliminary results of the project were also presented orally to the PWG to get feed back from local and state planners and coastal zone managers.

Technical reviewers of the final report are:

Mark Crowell, Federal Emergency Management Agency
Jim Good, Oregon State University Oceanography
Jim Stembridge, Coast Environmental Resources Institute

Their advice and criticisms greatly improved the report and are deeply appreciated.

TASK 9 (Cost and time itemization)

Salaries and position classifications of all personnel were compiled together with their hours spent on each work element. Costs for work, supplies, and travel were then calculated. The total cost was then divided by 31 miles to produce a cost per mile for the pilot study area. Costs were divided into two categories, actual amount spent and recommended expenditure for additional studies. The second value is less, because it takes into account the learning curve from this pilot study.

TASK 10 (Final report and documentation)

A report was written outlining the results and analysis procedures and estimating cost of a statewide assessment.

RESULTS

Tasks 1 and 2

Digital shoreline positions from historical topographic maps were not accurate enough to be useful for erosion rate analysis (Appendix A). Digital shorelines produced from the 1939, 1967, and 1991 photos were of some value for bluffs and beaches in bays with erosion exceeding 8-11' between photography dates. The erosion rates estimated from the photos were plagued with inherent errors caused by scale, radial distortion (the photos were not rectified), operator error in picking the SSPL, and lack of exact correspondence between the SSPL and the 16 ft contour from the 1967 photos. The 16' contour, derived by previous stereoplotting by the Oregon Department of Transportation, was the only rectified datum at a scale (1" = 100') large enough to utilize for this study. Even this datum exists only for the sandy beaches that are not publically owned (i.e. not park lands, etc.). This lack of a rectified modern base at scales larger than 1:24,000 was a major hardship for the investigation.

Estimation of the very low erosion rates on hard rock headlands was found to be infeasible without very expensive photogrammetric and field survey methods. Rectification of the photo sets to eliminate radial distortion is a very expensive but possibly unavoidable step, if this technique is to be made highly reliable for bluffed beaches.

Wide duned beaches not backed by bluffs have very large erosion and accretion rates that can be seen even by comparison of non-rectified photos. Erosion and jetty-induced accretion are clearly evident in data from north and south of the Yaquina Bay jetties (Segments 20 and 21, Appendices C and D). Likewise, large fluctuations of unarmored parts of Siletz Spit also show up clearly in the photo data (Segment 8, Appendices C and D).

Task 3

Use of tax lot changes and erosion estimates in building permits was of variable and largely unknown accuracy. The data collection was very time consuming and therefor expensive. This technique is not being pursued further.

Task 4

Measurement of bluff retreat by comparison of house-to-bluff distances in the field to historical vertical photos was by far the most precise method. It was free of most errors plaguing the digitized shorelines (i.e. radial distortion and operator error in picking the datum).

The bluff retreat technique is not generally useful on non-bluffed beaches, and suffers from the following shortcomings:

1. The need for an identifiable landmark for measurement generally limited use of the technique to areas with works of man old enough to be on the 1967 photos. Using the 1939 photos, which have markedly fewer works of man correlatable to 1992-1993, proved to be even more difficult.

2. The 25-52 year span is a very small sample of the erosion history.

3. The need for field measurements may make the technique relatively time consuming for rapid reconnaissance work. However a full-scale mapping effort now underway will demonstrate whether or not this is true.

Task 5

Examination of historical oblique photos yielded only seven fairly accurate determinations of erosion rate in the study area. However, these few observations were the only photographic evidence to reach back before 1939. The photos also revealed other information about maximum storm wave height and the effect on erosion of vegetation and jetty construction (see Appendix F).

Task 6

Analysis of the 1868 1:10,000 scale T-map of the Agate Beach-Newport area was invaluable for determination of landslide erosion rates. It became apparent that the episodic nature of landslide erosion demands an observation time greater than 70 years. This large-scale T-map, when compared to the 1990 photos, yielded an unprecedented 122 year observation time. Even with inherent errors of $\pm$ 0.34 ft/yr, the large changes wrought by landslides were generally apparent with this technique. The database so developed served as a means of estimating landslide erosion rates in geologically similar areas throughout the study area.

Task 7

The following narrative analyzes the shoreline rate data for each segment, picking preferred rates in each case. Rates in the digital shoreline database exceeding one standard deviation from the mean are examined individually, if appropriate. Refer to the corresponding histograms in Appendix D as you read each section. Unless otherwise explicitly stated, all areas with shoreline protection structures (SPS) have not been assigned a preferred rate.

Segment 1 (Salmon River Spit): This is a roadless sand spit at the mouth of the Salmon River (Figure 3). The low slope of the beach led to high uncertainties in digitized location of the SSPL on photos. The resulting 5-6 ft/yr of uncertainty in the rate approximates the range of measured rate variation along the spit. I conclude that the digitized shorelines are not accurate enough to determine usable erosion or accretion rates.

By analogy to nearby Siletz Spit (Segment 8), the shoreline change rate on this spit should be relatively high, on the order of a few feet of accretion or erosion per year. The net change over a long period of time is probably near zero, since the spit is anchored to a resistant headland and is free of modification by anthropomorphic factors. High, vegetated dune areas are probably relatively safe for development, but the active dune area could be rapidly eroded on a 10 year time frame. Any erosion episode would likely be repaired by a

Figure 3. Salmon River spit, Segment 1.

period of accretion, as the spit oscillates about the stable headland to the south.

Segment 2 (Resistant Tertiary Sandstone and Mudstone Bluff Next to Mouth of the Salmon River): This area of resistant Tertiary mudstone and sandstone (Figure 4) lacks significant landslides that are associated with moderately high erosion rates in these rocks to the south. It adjoins an area of basaltic rocks to the south which forms a headland shielding the bluff from some of the winter waves.

The likely rate of bluff erosion should approximate the mean rate of 0.08 ft ± 0.08 ft/yr determined by the house-to-bluff method for similar geologic settings in (Task 4) in similar bluff-beach settings (Segments 11, 11.4, and 26). The 0.6-0.7 ft/yr of uncertainty in the erosion rate from digital shorelines for this segment is larger than this likely erosion rate, so the available erosion rate data is not usable. A default rate of ft/yr is assumed for all transects in this segment.

Six rates determined by the digital shoreline method are more than one standard deviation from the mean of the data. Four are accretion rates and two are erosion rates of about 1 ft/year. Detailed examination of the photos revealed that these rates are apparently caused by fluctuations in the soft sand beach, not the bluff itself.

Segment 3 (Basalt Flanked Pocket Beach in Tertiary Sandstone/Mudstone): The likely rate of erosion on this pocket beach (Figure 4) is near zero, based on analogy to similar areas to the south with high precision measurements. The 0.7-0.8 ft/yr of uncertainty in the erosion rate from digital shorelines is larger than the likely erosion rate, so the available erosion rate data is not usable. A default rate of -0.08 ft ± 0.08 ft/yr is assumed, based on the mean rate determined from more precise rates measured (Task 4) in the similar geologic settings (Segments 11, 11.4, and 26).

Segment 4 (Headlands and Small Pocket Beaches Composed of Basalt): This segment is composed chiefly of basaltic rocks with minor patches of sandstone cut by complex dikes of basalt (Figures 4 and 5). There are several very small pocket beaches where sandstone or fractured basalt create less resistant areas. There are no digital shorelines for this segment. A possible default rate of -0.09 ft ± 0.16 ft/yr could be assumed, based on house-to-bluff data (Task 4) from areas with basalt bluffs.

Segment 4.5 (Tertiary Sandstone/Mudstone Next to Basalt Headland): This segment is bounded on the north by a basaltic headland and on the south by a low bluff composed principally of Quaternary colluvial units (Figure 6). The Nestucca mudstone and sandstone that form the high (100 ft) cliffs of the segment strike nearly perpendicular to the bluff trend. There are no house-to-bluff data, but the erosion rate is likely low, since there is little landsliding. The most similar segment with high precision house-to-bluff data is Segment 17 where the mean rate is -0.25 ± 0.36 ft/yr. The 0.8 ft/yr of

Figure 4. Segment 2 bluff in foreground; Segment 3 pocket beach in background (on south side of the Salmon River spit). Segment 4 headlands at the top of the picture.

Figure 5. Segment 2 bluff in foreground; Segment 3 pocket beach in background (on south side of the Salmon River spit). Segment 4 headlands at the top of the picture.

Figure 6. Basaltic headland bounding Segment 4 on left. Segment 4.5 cliffs transition southward to lower elevation, developed bluffs of Segment 5 (Roads End area).

uncertainty in the erosion rate from digital shorelines is larger than this rate and the range of measured erosion rates, so the available erosion rate data is not usable. All transects are provisionally assigned a rate of -0.25 ± 0.36 ft/yr.

Segment 5 (Roads End Area): This segment is bounded on the north by high cliffs of Nestucca mudstone and sandstone and on the south by a change in bluff rock type to Pleistocene terrace sand. The segment is composed of a low rampart of Tertiary sandstone and mudstone overlain by post-80,000 year colluvial and debris flow deposits. The bluff is only about 30 ft or so high (Figure 7) except where it meets the high cliffs of Segment 4.5 to the north (Figure 6). There it rises in height where the colluvial units are in steep, seaward dipping contact with the underlying Nestucca rocks. In this transition zone the poorly indurated colluvial units form local landslides. The low bluff area is almost entirely developed and is armored with SPS. The usable (unarmored) rate data from digital shorelines is therefore from only a few places lacking SPS.

The 1.1 ft/yr of uncertainty in the digital shoreline measurements is far in excess of the total range of digital shoreline rates for this segment. Two higher precision measurements from Task 4 give a mean erosion rate of -0.27 ± 0.34 ft/yr in this segment. Analysis of historical photos (Task 5) reveals a 70-year rate near zero (Appendix F). Unarmored transects without local house-to-bluff data are assigned an erosion rate of -0.27 ± 0.34 ft/yr rate. Other unarmored transects are assigned local house-to-bluff rates.

Segment 6 (Lincoln City Area): This segment is bounded on the north by the change in bluff rock type from Pleistocene terrace sand to Quaternary colluvial units (Figure 8) and on the south by the dune-fronted bluffs next to Siletz Bay. The bluffs are composed of Pleistocene terrace sands that are generally free of large bedrock landslides, eroding backward mainly by gradual weathering (Figures 8, 9, and 10). Wave attack is infrequent on the fine grained, low profile dissipative beaches (Komar and Shih, 1991).

Development is very heavy with many areas armored with SPS, but a large percentage of the bluff remains unarmored. Considering the poorly consolidated nature of the terrace sands, the bluffs show surprisingly little evidence of erosion during the last 52 years. The histogram of rates from digital shorelines (Appendix D) show clustering about a zero rate. The data from historical digital shorelines has an uncertainty on the order of 1.2-1.4 ft/year. This is a large uncertainty compared to the mean rate of -0.27 ± 0.34 ft/yr determined from 14 measurements of the more precise house-to-bluff technique (see database BLUFF). Unusually high rates of -2.4 ft/yr (transect b128) and -2.5 ft/yr (transect b127) were measured from digital shorelines, but detailed examination of the photos revealed that these rates are apparently caused by fluctuations in the soft sand beach, not the bluff itself. A rate of -0.27 ± 0.34 ft/yr was assigned to all transects without SPS or bluff-to-house data.

Figure 7. Segment 5 bluffs of armored colluvial deposits.

Figure 8. North boundary of Segment 6 at Roads End. Note that the Pleistocene terrace sand composing the cliff is better indurated than the colluvial deposits of Segment 5, so there is less armoring of the bluff.

Figure 9. Typical bluffs of Segment 6 in the Lincoln City area.

Figure 10. Pleistocene terrace sand that forms most of the bluff in Segment 6.

Segment 7 (North Side of Siletz Bay - Wide Bluffed Beach of the Taft Area): This segment has the same bluff lithology as Segment 6, but is fronted by a wide beach and by relatively stable dunes interwoven with buried logs at the mouth of Siletz Bay (Figure 11). The rate of retreat of the bluffs is caused entirely by weathering rather than by wave attack (Komar and Shih, 1991).

The low slope of the beach and wide occurrence of flotsam made picking the storm surge penetration line on photos somewhat difficult. This led to uncertainties of 7.4-8.6 ft/year in rates determined by the digital shoreline technique. Examination of photos taken in the 1920's revealed less than 3 ft of bluff retreat in one area (Komar and Shih, 1991; Appendix F, Taft area). Three house-to-bluff rates of -0.09 ± 0.08 ft/yr, 0.00 ± .08 ft/yr , and -0.07 ± 0.08 ft/yr were measured in this area. A default rate of -0.05 ± 0.08 ft/yr is assigned to all transects not located at a high-precision measurement of Task 4 or 5.

Segment 8 (Siletz Spit): This segment consists of the a north-directed sand spit at the mouth of Siletz Bay (Figure 11). The segment boundary to the south is the contact with bluffs of Pleistocene terrace sands. According to Komar and Rea (1976) and Komar (1983), the spit has steep reflective beaches composed of coarse sands that tend to erode into deep rip embayments. These embayments can deepen quickly during winter storms.

Reference to the histogram of Appendix D shows the extreme variability of digital shorelines on this spit. Whereas the uncertainty in the rate of change is ± 3.2-3.7 ft/yr, the rates of erosion and accretion are generally larger than this. Prior to development in the last 25 years, the spit was not armored with SPS, and rates of change were 0-6 ft/yr (accretion) in the south half and -0-18 ft/yr (erosion) in the north half.

Most of the spit was armored during the 1970's and 1980's, following severe erosional episodes in 1972, 1973, and 1976 (Komar and Rea, 1976; Komar and McKinney, 1977). The greatest erosion on the ocean side of the spit is highly episodic, occurring during winter storms and focused in rip current embayments (Komar and Rea, 1976; Komar and McKinney, 1977). These eroded embayments generally fill back in, and long-term erosion of ocean side of unarmored spit has been occurring at a decreasing rate as the rest of the spit became armored (Appendix D).

The bay side of the north half of the spit has suffered almost continuous erosion where the Siletz River channel banks up against the spit. The narrowest part of the spit occurs where the Siletz River channel first hits the middle of the spit (Figures 12 and 13). The width decreased at this point from 330 ft to 170 ft between 1939 and 1976 (Komar and Rea, 1976; Komar and McKinney, 1977). No digital shorelines were produced for the bay side, so no rates of erosion are assigned in the database.

Figure 11. Wide duned beaches of Segment 7 on left. Tip of Siletz Spit (Segment 8) on the right side of Siletz Bay.

Figure 12. Siletz Spit where Siletz River (upper right) strikes the back side, narrowing the spit.

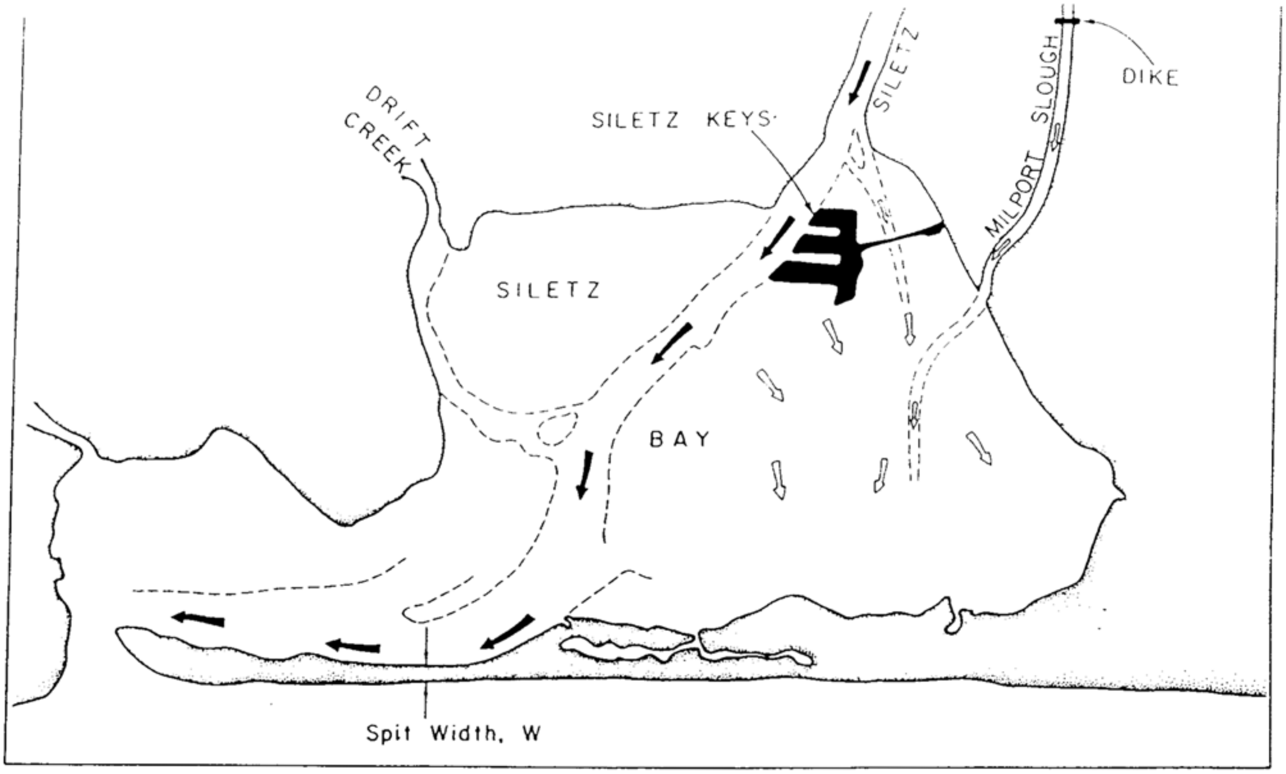


Figure 13. Circulation within Siletz Bay, modified by the presence of a dike on Milport Slough and the Siletz Keys landfill. Previously the flood waters of the Siletz River were able to spill over into the south Bay as shown by the white arrows. With the fills the river flood waters are jetted against the back-side of the spit as shown by the black arrows, aggrevating erosion of the spit at its thinnest point (taken from Komar and Rea, 1976).

The south half of the spit is almost entirely armored, and unarmored parts have rates of change similar to the uncertainty in the measurements. Since armoring of the spit has apparently reduced the overall positional variability of the ocean side, the 1967 to 1991 rates are used in preference to the 1939 to 1967 rates. The seaward side of the spit in unarmored areas is therefore assigned the rate of change for the 1991 to 1967 digital shorelines plus or minus the 3.7 ft/yr of uncertainty. However, it should be noted that the dynamics of this spit could produce locally higher erosion or even accretion as wave conditions and sand supply vary.

Segment 9 (Gleneden Beach to Fishing Rock - Bluffed Beach): This segment is bounded by Siletz Spit on the north (Figure 14) and the basaltic headland of Fishing Rock on the south. Like the Lincoln City and Taft areas (Segments 6 and 7), the bluffs are composed of Pleistocene terrace sands. Like Siletz Spit (Segment 8), this is a steep reflective beach with rip embayments and coarse sands that can be removed quickly during severe winter storms (Figure 15). Erosion of the bluffs is therefore caused by both slow weathering and direct wave attack. Erosion rates should be higher than those on the low-sloping, dissipative beaches of Lincoln City.

Uncertainty in the shoreline position is relatively high at 1.5-1.7 ft/yr, and rates cluster about a zero value on the histograms (Appendices C and D). The mean erosion rate from house-to-bluff rates is -0.62 ± 0.76 ft/yr. This rate is, in fact, higher than the mean rate for the Lincoln City area (-0.27 ± 0.34 ft/yr).

Two high-precision measurements of -2.33 ± 0.11 ft/yr at the Coronado Shores area in the middle of the segment were chiefly caused by 30 or more feet of erosion from a severe storm in 1982. Areas a few hundred feet north and south of these points did not experience such large losses of sea cliff. The highly eroded areas are now armored with extensive rip rap (Figure 16).

High rates of -1.4-2.8 ft/yr were measured from digital 1967 to 1991 shorelines in transects c113, c114, c172, c176-178, and c182-184. In six cases where there were nearby high precision bluff retreat rates, it was apparent that the actual bluff retreat was less than half of these rates. Detailed examination of the photos revealed that none of these rates were caused by bluff retreat, rather, they were the result of removal of beach sand near the base of the bluffs.

Accretion rates of 1 to 3.1 ft/yr were measured from digital data in transects c100-c140, c180-172, and c182-183. In every case these rates were caused by shifts in the soft sand beach. Unusually wide accumulations of drift logs are present on the 1967 beaches relative to the 1939 and 1991 beaches. This factor, combined with somewhat poorer recognition of drift logs on the lower quality images on the 1939 and 1991 photos, produced apparent accretion rates.

The digital shoreline rates are discarded because of the high uncertainty in the data relative to the likely bluff retreat as determined by the house-to-bluff erosion data. House-to-bluff data

Figure 15. Gleneden Beach (Segment 9) is a steep, reflective beach with rip embayments.

Figure 14. Contact of Siletz spit (Segment 8) with bluffs of Gleneden Beach (Segment 9).

Figure 15. Gleneden Beach (Segment 9) is a steep, reflective beach with rip embayments.

Figure 16. Coronado Shores development with rip rap on areas attacked by waves in winter storms of the early 1980s (Segment 9).

are used for transects that have it. For other transects the mean of the house-to-bluff rates, -0.62 ± 0.76 ft/yr ft/yr, is used.

Segment 10 (Fishing Rock): This is a basaltic headland (Figure 17) and lacks any digital shoreline data. A possible default rate of -0.09 ft ± 0.16 ft/yr could be assumed, based on the mean of house-to-bluff data from basalt in other parts of the study area (Task 4).

Segment 11 (Pocket Beach at Fogarty Creek): This segment is bounded on both the north (Figure 17) and south (Figure 18) by small basaltic headlands. The bluff is composed principally of well indurated Tertiary sandstone and mudstone without landslides. The contact of the sandstone and basalt in the cliff on the south end of the segment is faulted and jointed in such a way that it is subject to failure by sliding and toppling of blocks.

The digital shorelines can be unambiguously located on this pocket beach, the uncertainty in location producing errors of about 0.1 ft/yr. However, of the 13 rates determined from the digital shorelines all but two are accretion rates. The two erosion rates are -0.34 ft/yr (transect c212) and -1.17 ft/yr (transect 211), located on the north side of the segment. The mean value of the 13 rates is 0.34 ± 0.63.

The accretion rates are caused by accumulation of beach sand and talus at the base of the bluffs and have no relevance to the bluff retreat rate. The -1.17 ft/yr seems large compared to the one house-to-bluff measurement in the area of 0.00 ± 0.07 ft/yr, and the mean of -0.08 ft ± 0.08 ft/yr determined by the house-to-bluff method in similar settings. Radial distortion in the 1991 photos may have caused an error in this rate.

All transects in this small pocket beach are provisionally assigned the value of the one precise measurement, 0.00 ± 0.07 ft/yr.

Segment 11.2 (Government Point to Depoe Bay): This segment is bounded by the Fogarty Creek pocket beach on the north and by the cliffy reentrant at Depoe Bay on the south (Figure 19). The segment is entirely composed of cliffs of basalt and basaltic hyaloclastites (Figure 20). Cementation by alteration minerals causes the hyaloclastite to be as resistant as basalt.

There are no digital shorelines for this segment. House-to-bluff rates determined in the area range from -0.2 ft/yr to 0.00 ft/yr. Those rates are assigned to the appropriate transects. The rest of the transects are assigned the mean basalt value of -0.09 ft ± 0.16 ft/yr.

Segment 11.3 (Depoe Bay Area): This segment is bounded by basaltic headlands on the north (Figure 19) and south. The bluffs are composed of local areas of well indurated Tertiary sandstone and mudstone in complex faulted or depositional contact with coarse basaltic breccias. There is essentially no beach in front of the

Figure 17. Fishing Rock is a basalt headland bounding Segment 9 on the left and the Fogarty Creek pocket beach (Segment 11) on the right.

Figure 18. Fogarty Creek pocket beach (Segment 11)
with basaltic headland on right.

Figure 19. Segment 11.2 headlands on left. Mixed basalt and sandstone of Depoe Bay (Segment 11.3) on the right.

Figure 20. Typical basalt hyaloclastite of Segments 11.2 and 11.4.

highly resistant bluffs. A coarse hyaloclastic basalt breccia (Figure 21) is the dominant rock type in the area.

A house-to-bluff rate of -0.07 ± 0.1 ft/yr was measured on a narrow, basalt-bounded segment of Tertiary sandstone. Another rate of -0.03 ± 0.06 was measured on coarse, well cemented basaltic breccias. Transects at or near these two locations are assigned corresponding rates. Other transects chiefly cross basaltic rocks and are assigned the mean basalt rate of -0.09 ft ± 0.16 ft/yr..

Segment 11.4 (Depoe Bay to Cape Foulweather): This segment is bounded by Depoe Bay on the north and by the Tertiary sandstone headland of Otter Crest on the south. It is composed almost entirely of basalt flows, invasive basalt intrusions, and local areas of basaltic hyaloclastite in fault contact with pockets of sandstone (Figure 22). On the south end of the segment this rock is locally in complex fault contact with highly indurated Tertiary sandstone and moderately indurated Pleistocene terrace sands. The basalt is in the footwall on the oceanward side of this fault and thus protects the softer sandstones from direct wave attack. These faulted areas show up as small reentrants in the cliffy, beach-free bluffs.

Five house-to-bluff rates ranging from -0.56 ± 0.14 ft/yr 0.00 ± .08 ft/yr were measured and are assigned to the appropriate transects. Other transects are assigned the mean basalt rate of -0.09 ft ± 0.16 ft/yr.

Segment 11.5 (Otter Crest): This segment is bounded on the north by a small pocket beach armored with basalt. It is bounded on the south by a pocket beach composed of Tertiary sandstone and mudstone with extensive active landslides (Figure 23). The headland is composed of seaward-dipping Tertiary sandstone capped by several feet of poorly indurated Pleistocene terrace sand.

The digital shoreline technique is not suited to cliffy areas with no beach, because the cliff frequently obscures the storm-surge penetration line, if the air photo flight line is at all landward of the cliff. This situation is the case for the Otter Crest area, so the erosion rates of 0.0 ft/yr to -2.6 ft/yr are suspect.

This resistant sandstone headland is essentially identical to the Devils Punch Bowl headland (Segment 13). The one house-to-bluff measurement from that headland is assigned to the transects at this headland, since all cross similar unfaulted rock.

However, the north and south sides of Otter Crest, where the headland contacts the pocket beaches have a large fault zone that breaks up the rocks. The retreat rate in these areas is not known, but about 15 ft of the south flank of the headland was lost to catastrouphic rock falls of the fault zone in the winter of 1992-1993. A similar faulted sandstone bluff at the south side of Yaquina Head (northernmost part of Segment 17) has a 122-year erosion rate of 0.68 ± 0.34 ft/yr. No transect crosses the fault zone, but this erosion hazard should be recognised.

Figure 21. Coarse hyaloclastic basalt breccia of Segment 11.3, Depoe Bay.

Figure 22. Typical Segment 11.4 basalt headlands and local pocket beaches composed of sandstone bluffs. Little Whale Cove area.

Segment 12 (Pocket Beach on the South Side of Otter Crest): This segment is bounded on the north by Otter Crest (Figure 23) and on the south by the resistant headland of Devils Punch Bowl. The small pocket beach is backed by a bluff composed of seaward-dipping Tertiary mudstone and sandstone capped by several feet of poorly indurated Pleistocene terrace sand. The bluff has extensive active landslides, so much of the material at the wave line is composed of disaggregated slide debris and small (10-20 ft) slide blocks. The beach is partially protected by the nearby headlands and by a wave cut platform extending about 100-150 ft from the base of the cliff. However, the beach is very narrow and waves strike the base of the bluff at most high tides.

The uncertainty in the position of the digital shorelines gives an error in the erosion rate of ± 0.8-1.0 ft/yr. This uncertainty is approximately equal to the total range of erosion rates determined by this method (-0.2 to + 1.8) in the segment. These rates only measure the location of the toe of the landslide debris which is continuously fed to the eroding waves. The rate of erosion of the foot of the landslides is therefore only imperfectly related to the rate of retreat of the main bluff at the head of the landslide.

The 1868-1990 headwall retreat in identical rock for Segments 15 and 18 has a mean rate of -1.45 ± 0.34 ft/yr, weighted for length of shoreline affected. Much of the erosion in Segments 15 and 18 occurred by catastrophic failure involving 50 to 200 feet of the cliff at a time. Such failures occur any time conditions are favorable. Favorable conditions include unusually prolonged heavy rains, erosion of previously fallen blocks from the base of the cliff, and earthquake shaking. Without a long (100 yr) observation time, it is not possible to determine whether the pocket beach at Otter Crest has experienced block failures of this magnitude. The protection offered by the adjacent headlands may reduce the ability of waves to remove slide debris from the base of the cliff, thus reducing the rate of failure by landsliding. Using the mean rate for Segments 15 and 18 for Segment 12 may therefore overestimate the potential hazard somewhat. However, one of the digital shoreline rates had a value of -1.8 ± 1.0 ft/yr, the same order of magnitude as the mean rate for Segments 15 and 18. Until additional data become available, the mean rate of -1.45 ft/yr is assigned to all transects in this segment.

Segment 13 (Devils Punch Bowl Headland): This segment is a headland composed of well indurated Tertiary sandstone (Figure 24). It is bounded on the north and south by the contact of the Tertiary sandstone with a sequence of Tertiary mudstones and interbedded sandstones. All of the Tertiary units are capped by several feet of poorly indurated Pleistocene terrace sands, and all dip seaward. The seaward dip produces some landsliding on either side of Segment 13 where mudstone is exposed in the cliff faces.

Figure 23. Ottercrest headland (Segment 11.5) with landslide-dominated pocket beach of Segment 12 on right.

Figure 24. Sandstone headland of Devils Punch Bowl (Segment 13) with Beverly Beach (Segment 14) in the background.

Only 1967 and 1939 shorelines were digitized and the resulting rates gave accretion values which are obviously in error. There is therefore no reliable rate data for this segment. A single house-to-bluff rate of -0.09 ft/yr was determined and is assigned to all transects.

Segment 14 (Beverly Beach Area): This segment is bounded on the north by the Devils Punch Bowl headland and on the south by the extensive active landslide area at Moolack Beach. The entire segment is composed of seaward dipping mudstone and lesser sandstone with some landsliding (Figures 25 and 26). The landslide areas are not extensive, but some large blocks are locally active. The geology of the area is similar to that of landslide-prone areas like Segments 15 and 18, but the angle between the strike of the seaward dipping beds and the bluff trend is slightly higher except in local areas of highly variable bedding strike. This may account for the lesser development of landslides. Local areas with highly active landsliding may be places where the strike of the beds becomes more parallel to the bluff. Landslides obscure the outcrops where strike and dip data might have been collected to test this hypothesis.

The relocation of Oregon Coast Highway 101 since 1939 to a position next to the edge of the sea cliffs necessitated dumping of considerable fill which artificially prograded the shoreline by up to 40 feet in some areas (Stembridge, 1975). This introduced error in the digital shoreline data and made it difficult to find unmodified landmarks for direct measurement of bluff retreat in the field.

A 1967 digital shoreline was available only for the northern and southern part of the segment, leaving a large data gap in the middle where the coast highway comes near the edge of the bluff. This middle area is public land unlikely to see private development. Uncertainty in shoreline position generated rate errors of ± 1.1-1.3 ft/yr with most data clustering about a zero rate of erosion (Appendix D).

A number of rates that are more than ± 1.3 ft/yr from the approximate mean of 0.0 ft/yr have been discarded and all negative (accretion) rates are considered inaccurate. Since the bluffs cannot grow without works of man, all negative rates resulted from changes in the soft sand beach, fill, or operator error in placing the shorelines. A number of negative rates were caused by a large accumulation of logs on the 1967 photos that were not present on the 1939 photos. Removal of these logs between the 1967 and 1991 photography dates resulted in several anomalously high erosion rates unrelated to bluff retreat. Anomalous negative rates caused by the log effect include 1939-1967 rates at transects d66-65, d74, d84-d98, c515, c517, and c520. The same effect causes anomalous positive rates for the 1967-1991 transects d61, d62, d66-68, d75, d100, and c522-524. An anomalous rate of -1.7 ft/yr at transect c511 is apparantly caused by changes in the soft sand beach rather than bluff retreat. A rate of -2.4 ft/yr erosion between 1939 and 1967 at transect d75 resulted from local erosion of a narrow septum of the cliff to a barely connected sea stack. The sea stack is nearly gone in the 1991 photo.

Figure 25. Segment 14 seaward dipping sandstone and mudstone. (Paula Priest in the foreground).

Figure 26. Beverly Beach with steep cliffs of Tertiary sandstone capped by Pleistocene terrace sand (Segment 14).

This rate is not considered valid for the sea cliff as a whole at this locality. Extensive fill at a bridge installed across Moloch Creek between 1939 and 1967 caused an accretion rate at transect d61. The effects of this fill and of normal depositional processes at the creek mouth produced an anomalous accretion rate at transect d61 for the 1967-1991 interval as well.

Transects c519-526 cross a giant slide block that is actively moving seaward. This block penetrates for several hundred feet inland, crossing Highway 101. Offsets of a few feet are apparent in the highway, but the rate of movement is not known. The effect of this movement on the shoreline positions cannot therefore be evaluated, so the digital shoreline rate data for this segment is discarded.

Lack of significant development in the area makes it difficult to get precise house-to-bluff measurements. There is also no coverage from large-scale T-maps from the 1800's. Two house-to-bluff rates of -1.0 $\pm$ 0.13 ft/yr and -0.38 $\pm$ 0.14 ft/yr were measured from 1967 photos. The former rate is on a small landslide block but appears to be a weathering rate for the block.

Areas with active landslides are provisionally assigned the mean 122 year rate of landslide-prone areas in Segments 15 and 18 (-1.45 $\pm$ 0.34 ft/yr), until better data become available. The angle between the bluff trend and average strike of the dipping Tertiary rocks is larger in much of this segment than in Segments 15 and 18, so the tendency to form landslides is in general diminished. Some areas lacking landslides also have less than 75% mudstone in Tertiary units of the cliff face. Other areas have old, apparently stable landslide blocks that probably only move during unusual events like great earthquakes. Active landslide areas are at bluffs with more than 75% mudstone that have local bedding strikes only 6-8^{o} away from the bluff trend. This general observation is true also for Segments 15 and 18 where the bluff-to-bedding strike angle is generally $\leq 7^{o}$.

Areas without landslides or local house-to-bluff data are tentatively assigned the mean of the two weathering rates, -0.69 $\pm$ 0.34 ft/yr. This mean is not a satisfying value, based on only two rates, but no other house-to-bluff data comes from areas truly analogous to this one. The closest analogue is the mixed landslides and solid bluffs of Segment 19 which has a 122 year bluff erosion rate of -1.02 $\pm$ 0.68 ft/yr over most of its length.

Segment 15 (Active Landslide Areas of Moolack Beach): This segment is bounded on the north by the contact of an area of active landslides (Figure 27) with a more stable bluff. Yaquina Head bounds the segment on the south. Bluffs are composed of seaward dipping mudstone capped by several feet of poorly indurated Pleistocene terrace sands. The strike of the Tertiary rocks is almost exactly parallel to the trend of the bluff. Extensive active landslides and slide blocks affect the entire area. This segment is a geologic analogue of the Jumpoff Joe landslide area of Segment 18. However, it has not had significant development until very recent times, so precise data from the house-to-bluff method is lacking.

Figure 27. Back-tilted slide blocks of Moolack Beach (Segment 15).

The erosion rate data from digital shorelines is quite variable, ranging from 2 to -1.6 ft/yr (Appendix D). The uncertainty in the location of shoreline positions led to estimated errors of 0.9-1.1 ft/yr in the rates.

All of the digital shoreline data is suspect, because it may be affected by seaward motion of the extensive landslides and slide blocks. Some of these blocks can be very resistant to erosion. In one case, an isolated, stabilized slide block of mudstone at the mouth of Schooner Creek has suffered no more than a few inches of erosion since the 1939 photography. This seaward advance of blocks may be responsible for some of the negative rates in the database.

Using a zoom transfer scope, it is possible to plot part of the 1990 headwall from 1:12,000 scale air photos onto the 1:10,000 scale 1868 T-map which covers the southern part of this area. As previously explained, the error in headwall retreat rate by this method is ± 0.34 ft/yr. Headwall retreat rates range from -0.68 to -3.73 ft/yr, and the mean, weighted for shoreline length affected, is -1.90 ± 0.34 ft/yr. This is very similar to the mean rate of -1.77 ± 0.34 ft/yr for the geologically identical Jumpoff Joe area (Segment 18).

The 1868-1990 rates are assigned to the corresponding transects with this data. For transects in the northern part of the area lacking this data, the northernmost retreat rate is assigned to adjacent transects crossing the same landslide mass. Transects north of that mass are assigned the weighted mean of -1.90 ft/yr.

Transects d120-124 next to Yaquina Head appear to have less than 42 ft of bluff change, based on comparison of the 1868 T-map to the 1990 photos. Those transects are therefore assigned a rate of >-0.34 ft/yr.

Segment 16 (Yaquina Head): This segment is a prominent basaltic headland, the boundaries being drawn at the contact with mudstone of Segment 15 and the sandstones and mudstones of Segment 17. The headland is largely devoid of development, other than some gravel operations and use as a park.

House-to-bluff data for one area at the lighthouse give a best value of -0.17 ± 0.13 ft/yr. Plotting by zoom transfer scope of the 1990 bluff edge onto the 1:10,000 scale 1868 T-map revealed less change than the error of the technique (i.e. 0.34 ft/yr). In fact many modern sea stacks were clearly identifiable on the 1868 T-maps even though these rocks are exposed to direct attack by storm waves. The mean basalt erosion rate of -0.09 ft ± 0.16 ft/yr is assigned to all transects lacking local house-to-bluff data.

Segment 17 (Agate Beach): This segment is bounded by Yaquina Head on the north and by the active landslide area of Jumpoff Joe on the south. It is composed of bluffs of Tertiary sandstone and mudstone that strike at relatively high angles to the trend of the bluff. This strike, combined with the fair induration of the Tertiary rocks cause much of the segment to be nearly devoid of active landslides with one exception. A small area immediately adjacent to Yaquina Head has an active landslide that destroyed three homes in the 1960's (Stembridge, 1975). It is not for certain why this landslide occurred. The rocks in the bluff are not well enough exposed to investigate the problem directly; however, a large fault zone, exposed a few hundred feet to the north, trends toward this area.

Positional uncertainties in the digital shorelines led to errors of ± 1.5-1.7 ft/yr. All but two rates range between ± 1.6 ft/yr of the mean rates of -0.3-0.5 ft/yr. In general, all of the negative rates are probably caused by foredune shifts combined with inherent positional errors. The highest accretion and erosion rates (1939-1967 transects d180, d189, d202, and d214-215) were caused by shifting foredunes, not bluff retreat. Eliminating these rates and all negative rates, the means of the 1939-1967 and 1967-1991 rates are -0.49 ± 0.25 ft/yr and -0.43 ± 0.28 ft/yr (errors figured on the sample deviation of data only). The same calculation for the 1939-1991 rate gives a mean of 0.28 ± 0.21 ft/yr. As previously explained, the means of picking the 1991 and 1939 shorelines was somewhat different than that used for the 1967 shoreline. This similarity is probably the reason that there is less scatter of the data about the mean of the 1939-1991 rates. However, the positional error of 1.5-1.6 ft/yr makes it difficult to use these rates.

Four house-to-bluff measurements give rates of -0.88 ± 0.15 ft/yr to 0.00 ± 0.08 ft/yr. The mean of-0.25 ± 0.36 ft/yr is assigned to all transects without local house-to-bluff data..

Plotting the 1991 bluff edge onto the 1:10,000 scale 1868 T-map (zoom transfer scope method explained above) revealed that the part of the segment without landsliding retreated at a rate lower than the error in this technique (i.e. 0.34 ft/yr). This adds credibility to the above mean rate.

A headwall retreat rate for the small landslide area next to Yaquina Head (Transects d178 and d179) was determined by plotting the 1990 headwall onto the 1868 T-map. The resulting rate of -0.68 ± 0.34 ft/yr is assigned to these transects.

Segment 18 (Landslide Areas of Newport, Including Jumpoff Joe): This segment is bounded on the north and south by the contact of this massive area of landsliding with normal sea cliffs. The area lies at the contact between two seaward dipping Tertiary formations, the Astoria Sandstone and the underlying Nye Mudstone which are in turn capped by a 20-30 ft of Pleistocene terrace sands (Figure 28). In 1868 a large promontory called Jumpoff Joe was composed of the resistant Astoria Sandstone and formed a major landmark in the area. All that remains of this feature today is a small sandstone promontory immediately south of the old one (Figure 28a). Even that promontory is now sliding seaward as a block. The rest of the segment has Nye Mudstone in the lower part of the sea cliff. Jumpoff Joe was destroyed by massive landslides as erosion exposed the contact with the underlying Nye Mudstone. When this seaward dipping

Figure 28. Horizontal Pleistocene terrace sands cap seaward dipping Astoria sandstone over darker Nye mudstone at Jumpoff Joe (Segment 18).

Figure 28a. Yaquina Head basalt in background; Jumpoff Joe landslide area in foreground; headwall near the railing on the right (Segment 18).

contact is exposed, or when mudstone interbeds in the Astoria Sandstone become exposed in the sea cliff, erosion occurs primarily by massive, episodic landslides.

Many areas in the northern part of the segment have experienced numerous slide events in the recent past but show little evidence of movement in the last few decades. In contrast, the southern (Jumpoff Joe) half of the segment has experienced massive slides that show evidence of very recent movements.

The digital shoreline retreat rates and the house-to-bluff rates cover short time intervals which, in many parts of the segment, have not had the large (100-200 ft) slide block failures that characterize known slide failures over the last 122 years. For example, most of the 1967-1992 house-to-bluff rates at the headwall of the Jumpoff Joe landslide are lower than the corresponding 122 year rates (see data files for transects d242 to d246). The house-to-bluff rates represent slow weathering of the headwall and are not representative of the long-term rate of erosion.

Aside from covering an insufficiently long time interval, the digital shoreline changes are only indirectly related to the rate of headwall retreat, the essential issue for planning. Shoreline retreat rates are prone to variations caused solely by landslide movement and by erosion at the toe of the landslides. Indeed, casual inspection of the change in shoreline and headwall positions in Figure 4 reveals the lack of equality of rates so derived.

The rate of erosion of this segment is so large that it is noticeable by comparison of even the highly inaccurate topographic maps of the last century to modern shoreline positions. Studies of historical photos, plat maps, and the old topographic maps allowed Stembridge (1975) to map the 1868 headwall of the slide area and compare it with the position of the 1939 and 1967 headwall (Figure 29). However, he does not explain his techniques nor how large are the positional errors. As explained above in Task 6, an 1868 to 1990 headwall retreat rate was measured with an error of ± 0.34 ft/yr. The measured rates are, with one exception, greater than this. The mean, weighted for length of shoreline involved, is -1.77 ± 0.34 ft/yr.

Transects in the main database are assigned the appropriate 1868-1990 rate for that shoreline location, unless the rate falls below the 0.34 ft/yr error. Only one area has a retreat rate below the 0.34 ft/yr. Transects d240-d241 cross a large coherent slide block with substantial downward displacement. The block and headwall, albeit hard to delineate precisely on the 1868 T-map, have apparently not changed position (within the ± 42 ft of uncertainty) in 122 years. Field examination of a paved driveway crossing the headwall fault revealed no evidence of cracking or landslide-caused repair of the road. The driveway was installed between the 1967 and 1991 photos and is at least several years old. This block probably stabilizes the headwall and is itself quite stable, barring some unusual event such as an earthquake. 1939-1991 house-to-bluff weathering rates of -0.45 ± 0.29 ft/yr and -0.51 ± 0.29 ft/yr were measured at the

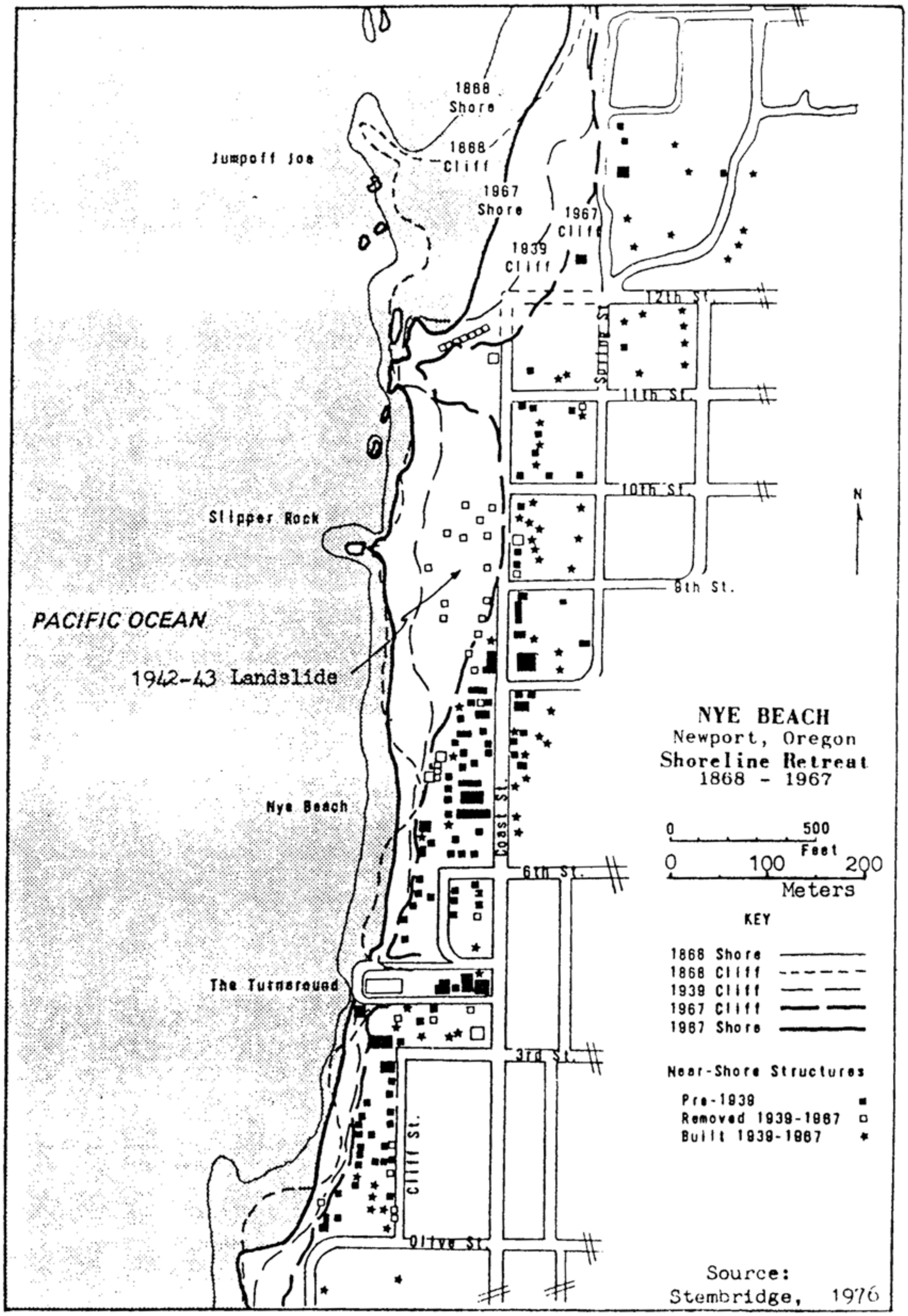


Figure 29. Jumpoff Joe landslide area (taken from Stembridge, 1976).

headwall above this block. These rates are assigned to the appropriate transects. The erosion rate of the block itself is unknown, but must be equal to or less than the error of 0.34 ft/yr in the 1868-1990 data.

Segment 19 (Newport Area South of the Jumpoff Joe Landslides): This segment is bounded on the north by the Jumpoff Joe landslide area and on the south by a change in the trend of the sea cliff. The area is geologically similar to Segment 18 with seaward dipping Nye mudstone capped by 20-30 ft of Pleistocene terrace sands; however, there are fewer landslide areas. The change in sea cliff trend at the south end of the segment eliminates the tendency to landslide altogether, since the beds south of there do not strike parallel to the bluff.

Digital shoreline data has positional uncertainties that cause errors on the order of ± 1.6-1.9 ft/yr. These errors are clearly too large to resolve the actual erosion rates. Apparant accretion rates from the digital shoreline technique were caused by shifts in the foredune, and, in one area (transect d271) by sand accretion south of a groin. High (-1.8-2.8 ft/yr) apparent erosion rates at transects d298 and d301-302 were caused by foredune shifts rather than bluff retreat.

Historical oblique photos from 1917 reveal that a low part of the bluff at the mouth of a drainage (d263-266) has less than 5 ft of bluff retreat since that time (Figure 30; see comments on the Sylvania Beach Hotel in Appendix F). Five 1967-1993 house-to-bluff rates from somewhat higher, steeper bluffs range from 0.00 ± 0.07 ft/yr to -0.76 ± 0.09 ft/yrof 0.15 ± 0.02 ft/yr. However, these data do not specifically cover the areas within the segment that have currently active landsliding. In fact, it is not entirely clear why more of the segment does not have landslides as extensive as those of Jumpoff Joe. The trend of the cliff is nearly parallel to strike of the seaward dipping mudstones, so landsliding should be an important form of erosion. Some areas do, in fact, have more interbedded fine grained sandstone than the Jumpoff Joe sea cliffs, so this may be the reason.

Zoom transfer scope (ZTS) plots of the bluff edge from 1:12,000 scale 1990 photos onto the 1:10,000 scale 1868 T-map for this area revealed a rather uniform erosion rate of 1.02 ± 0.68 ft/yr for the 122 year interval. The rather high positional error is caused by the lack of many distinctive geographic features for scaling the 1868 map to the 1990 photos. In spite of the high error, it is notable that this rate is about half of the mean rate of headwall retreat in the Jumpoff Joe area (Segment 18). The interbedded sandstone in this segment may retard landslide erosion enough to make it difficult to observe the erosion in periods of less than 100 years.

The rate of 1.02 ± 0.68 ft/yr is assigned to all transects in the segment except the area at transects d263-d264 that lacks a high sea cliff. That area showed less bluff retreat in 122 years than the error (0.68 ft/yr) of the ZTS technique. The above observations of no erosion in the last 70 years confirm the low erosion rate. These

Figure 30. Segment 19 showing well vegetated bluffs at the Sylvania Beach Hotel (left). This area has an anomalously low erosion rate for the segment.

transects are therefore assigned a zero erosion rate, even at the area with a concrete sea wall. This sea wall protects a building at beach level at the mouth of the drainage. No bluff retreat is likely there since there is essentially no bluff.

Segment 20 (Wide Beach on the North Side of the North Yaquina Bay Jetty): This segment is bounded on the north by a sharp change in trend of the bluff and on the south by the north jetty at Yaquina Bay. A wide accretionary beach (Figure 31) was created by installation of jetties in 1830 and later extensions between 1940 and 1974 (Komar and others, 1976). The beach is quite wide next to the jetty because of sand accumulation during the summer, but general growth of the jetty beach is prevented by the obtuse angle that the jetty has with the mainland (Stembridge, 1975). This orientation exposes the beach to the vigorous storm waves that come in from the southwest in winter (Komar and others, 1976). The beach is backed by a bluff of seaward-dipping mudstone capped by Pleistocene terrace sands. This bluff is heavily vegetated and, because the cliff not parallel to the strike of the dipping mudstone, it is free of landslides. All development is on top of the bluff, the beach being accessible only for recreation.

The bluff weathering rate is therefore the most important quantity to measure. Pictures of the Yaquina Bay Lighthouse taken near the turn of the century reveal less than 5 ft of bluff retreat there (Appendix F). Using a zoom transfer scope, the bluff position was transferred to the 1:10,000 scale 1868 T-map. There was clearly no significant change in bluff position within the limits of the error ($\pm$ 0.34 ft/yr). The protection from wave attack afforded by the wide beach combines with the high angle between bluff trend and bedding strike of the Tertiary mudstones to cause ththe low rate of retreat.

Uncertainties in the digital shoreline position on this wide beach caused rate errors on the order of $\pm$ 7-8 ft/yr. These data are clearly of no use for estimation of bluff retreat. The erosion rate of <0.05 ft/yr estimated from the lighthouse pictures is assigned to all transects.

Segment 21 (South Beach Area at the Southern Jetty of Yaquina Bay): This segment is bounded on the north by the south jetty of Yaquina Bay and on the south by the narrow bluffed beaches of Segment 22. An extremely wide accretionary beach was created by installation of jetties in 1830 and later extensions between 1940 and 1974 (Komar and others, 1976). This beach is much wider and longer than the one north of the jetties because of the acute angle that the jetties make with the mainland at this point. The jetties effectively protect the beach from summer waves arriving from the northwest and trap the northward migrating sand driven by the southwesterly winds of winter (Komar and others, 1976).

There is a low irregular bluff area several hundred feet behind the shoreline, although part of the segment lacks any bluff, being backed by the alluvial deposits of the Yaquina River. The low bluffed area is composed principally of stabilized, heavily vegetated dunes with

Figure 31. Wide duned beach of Segment 20 next to the north Yaquina Bay jetty (background).

minor development. No erosion rate data is available for these low bluffs, but the rate of erosion must be insignificant, since they are totally protected from any wave attack. Wind erosion is inhibited by the vegetation. Sand accretion is a possibility, but no evidence of bluff accretion was found.

The digital shoreline data for this segment show many interesting variations in the shore, mostly from accretion of sand (Appendices C and D), but these rates are mostly irrelevant to erosion in the developable, bluffed part of the beach. Accretion rates on the order of 1 to 12 ft/yr are typical for the 1967-1991 period. Larger rates prevailed in the 1939-1967 interval, owing to jetty extension.

Owing to the complete protection from wave attack, all transects are assigned a zero erosion rate until precise house-to-bluff data is available.

Segment 22 (Lost Creek State Wayside - Narrow Bluffed Beach): This segment is bounded on the north by the wide accretionary beach of South Beach and on the south by the wide river mouth beach at Beaver Creek. The area has a narrow beach backed by bluffs composed of 20-30 feet of Pleistocene terrace sands underlain by 8-12 feet of seaward-dipping Tertiary mudstone and minor sandstone (Figure 32). The ratio of terrace sand to underlying Tertiary rocks in the cliff face is much higher south of Yaquina Bay than north, because of tectonic offset of Pleistocene terraces down to the south at the bay (Ticknor, 1993).

The large proportion of Terrace sand in the cliff face inhibits, but does not entirely stop, the formation of landslides in the seaward dipping mudstones. Some local landslides and slide blocks are present but are generally of small extent. There is no evidence that these landslide areas are eroding at rates similar to the Jumpoff Joe area to the north, so headwall retreat rates from that area cannot be used.

The area is only sparsely populated, so there is little opportunity to utilize the house-to-bluff method. Two house-to-bluff erosion rates of -0.93 $\pm$ 0.09 and -1.67 $\pm$ 0.09 ft/yr were measured in an area free of landslides.

The digital shoreline data suffered from uncertainties in the shoreline position that caused erosion rate errors of $\pm$ 1.0-1.2 ft/yr. Negative rates were generally caused by the high positional error coupled with shifts in the foredune and log accumulations. The uncertainties in this data are similar or larger than the measured house-to-bluff rates, so the digital shoreline data is not useful.

The large proportion of Pleistocene terrace sand in the bluffs makes it likely that the erosion rates are similar to areas with high proportion of this same unit. The bluffs of Segment 6 are also dominated by Pleistocene terrace sands. The low slope and narrowness of the beach in Segment 22 is very similar to the beach of Segment 6. house-to-bluff data for Segment 6 is therefore combined with the data

Figure 32. Thick Pleistocene terrace sand on Tertiary sandstone and mudstone. Typical bluff of Segment 22 near Lost Creek.

from Segment 22 to calculate a mean erosion rate of -0.36 ± 0.45 ft/yr for transects without local house-to-bluff data.

This rate is not assigned to transects crossing local, small-scale landslides. There is no house-to-bluff data for these small landslides and no data from analogues in other segments. No erosion rates are assigned to these transects.

Segment 21.5 (Duned River Mouth at Lost Creek): This segment is a small area of dune-covered alluvium at the mouth of Lost Creek. It occurs in the middle of Segment 22, but is separated from that area because it lacks a significant bluff.

Digital shoreline data for this segment has an error of ± 0.9-1.0 ft/yr, but rates measured with this method vary from -3 to +3 ft/yr, so changes in the storm surge penetration line are large enough to be resolved from the "noise" in the data. The two transects in the middle of the segment show erosion of -2-3 ft/yr in 1967-1991 but accretion of 2-3 ft/yr in 1939-1967. These rates reflect the shifting of the foredune in response to changing wave and storm conditions. The 1967-1991 erosion rate is probably the result of unusual erosion during the last El Nino in the early 1980's. The 1939-1991 rate is near zero in all transects and probably represents the best long-term rate. The 1939-1991 rate is provisionally assigned to each transect.

Segment 23 (Duned River Mouth at Beaver Creek): This segment is bounded on the north and south by narrow bluffed beaches on either side of the mouth of Beaver Creek. The area is composed of wide, duned beaches overlying Quaternary alluvium from Beaver Creek. There is only a low (6-10 ft) bluff composed of the alluvial material and local areas of fill for Highway 101. The area has no development, so there is no house-to-bluff data.

All rates measured with the digital shoreline technique lie within the positional uncertainty error of ± 1.9-2.2 ft/yr. The shoreline data show rates of accretion and erosion of up to ± 2 ft/yr, but these values reflect shifts in the foredune rather than the low bluff. The protection offered by the wide beach and dune system probably reduces the retreat rate of the low bluff to near zero. No geological analogue to this area has high-precision data for a bluff rate estimate, so no erosion rates are assigned. .

Segment 24 (Bluffed Beach South of the Ona Beach-Beaver Creek Area): This segment is bounded on the north by the wide beaches at the mouth of Beaver Creek and on the south by a similar beach with basaltic sea stacks offshore. The bluffs are composed of less than 6 feet of seaward-dipping Tertiary mudstone and sandstone surmounted by 20-30 ft of Pleistocene terrace sands (Figure 33). One small landslide penetrates only a few tens of feet into the bluff; all other bluff retreat is by slow weathering and wave erosion. The area is sparsely populated, so there is little opportunity to utilize the house-to-bluff technique.

Figure 33. Segment 24 bluff. Note that there is only a few feet of Tertiary mudstone at the base of the softer Pleistocene sands; also typical of Segment 25.

There is no precise house-to-bluff data in this segment, and the positional uncertainty in the digital shoreline data (± 1.0-1.2 ft/yr) is greater than the likely erosion rates. The closest analogues to these bluffs are the sea cliffs dominated by of Pleistocene terrace sands in Segment 6 and 22. The mean of precise house-to-bluff rates in these areas is -0.23 ± 0.45 ft/yr. That rate is assigned to all transects except the one crossing the small active landslide (e255). No precise erosion data is available for geological analogues to this slide, so no rate is assigned.

Segment 25 (Pleistocene Terrace Sand Bluffs with Basalt Sea Stacks): This segment is defined by the bluff rock type combined with the presence of basalt sea stacks about 100 feet offshore from the narrow bluffed beach. Segment 24 lacks the sea stacks, and Segment 26 to the south has a different rock type in the bluff.

The bluffs are composed of Pleistocene terrace sands with less than 3 feet of seaward dipping Tertiary mudstone and sandstone at the base. There are no landslides and all erosion is caused by weathering combined with wave attack that is partially dissipated by the sea stacks and submarine rocks.

There is only one house-to-bluff measurement in this sparsely populated segment. The value of -1.53 ± 0.07 ft/yr (near e265) seems high compared to rates in similar bluffs of Segments 22 and 6 (mean of -.36 ± 0.45 ft/yr). In fact, the rate for approximately the same time interval (1967 to 1991) from digital shoreline data gives a rate of -0.44 ± 0.7 ft/yr at e255. It is likely that the bluff retreat rate is not representative of the segment as a whole but represents a single, recent (1992) sloughing event at this one site.

The positional errors associated with the digital shoreline data (0.7-0.8 ft/yr) are as large or larger than the likely erosion rate. The digital data is therefore not very likely to yield accurate erosion rates.

There is no exact geologic analogue to Segment 25 in other parts of the study area, but the area is geologically transitional between the bluffs of Segment 24 and 26. A reasonable mean erosion rate can therefore be calculated by adding the mean rates for these two segments together and dividing by two. The resulting rate of -0.23 ± 0.45 ft/yr is assigned to all transects except the one with a local rate determination.

Segment 26 (Tertiary Sandstone Bluffs with Basalt Sea Stacks): This segment is bounded on the north by an increase in the proportion of Tertiary sedimentary rock in the cliff face from less than 3 ft in Segment 25 to more than 3 ft in this segment. The amount of Pleistocene terrace sand likewise decreases as a proportion of the cliff face, so erosion is governed by the well indurated Tertiary sandstones that make up a larger and larger proportion of the cliff as one proceeds south. On the south the segment terminates against the small basalt-armored headland of Seal Rocks. The segment is characterized by a narrow beach that is increasingly well protected from wave attack as the basaltic sea stacks offshore merge to form a nearly continuous wall next to the small headland. The sea stacks and headland are part of a large, nearly shore-parallel basalt dike. Talus from the dike forms steeply dipping layers within the Pleistocene terrace sands that bank up against it. It is apparent that the dike had relief at least as high as the thickness of the terrace sands during the late Pleistocene. It still crops out at the headland as high as the top of the Pleistocene sands, so the dike is a very long lived feature unlikely to undergo much erosional modification in the short (52 year) observation time available here.

The digital shoreline data has positional uncertainties which lead to errors of ± 0.5 ft/yr. As mentioned previously, the 1939 and 1991 digital shorelines were picked in the most directly comparable manner and give erosion rates 0-0.4 ft/yr. Accretion and erosion rates as large as -1 ft/yr to +1.1 ft/yr were measured from comparison of the 1967 shoreline position to these two shorelines. In each case these anomalous rates were caused by local topographic highs on the beach. These highs are generally resistant erosional remnants of the Tertiary sandstones. These subtle variations in elevation affect the 1967 shoreline, because it is an elevation contour, whereas the other shorelines were picked to correspond with the furthest reach of storm waves, which generally bank up against the base of the bluff.

Discarding all negative values from the 1939-1991 digital shoreline data, the mean erosion rate is 0.16 ft/yr. This rate is subject to errors of ± 0.5 ft/yr of average positional uncertainty and a sample standard deviation of ± 0.1 ft/yr. This rate is very similar to one precise house-to-bluff rate of -0.11 ± 0.08 ft/yr located between transects e278 and e279 near the center of the segment. The central part of the segment also has a cliff face lithology and geologic setting that is an approximate average. The high precision rate of -0.11 ft/yr is probably representative for the segment as a whole and is assigned to all transects without house-to-bluff data.

Task 8 (Peer Review)

The general methodology for this study was discussed by an ad hoc technical advisory panel in the Fall of 1992. Preliminary results and general methods were presented to the Coastal Natural Hazard Policy Working Group this winter. This preliminary draft has been sent for review to Dr. Curt Peterson of Portland State University and Dr. James Good of Oregon State University.

The technical advisory panel recommended that beach morphology factors be studied in addition to the positional data. They pointed out that narrow beaches with little sand, steep slopes, or coarse sand tend to develop rip current embayments where waves can attack the sea cliff. In contrast, low sloping beaches composed of fine sand dissipate wave energy, leading to lower erosion rates. It was beyond the scope of this investigation to study the effect of these factors independent of variations in lithology of sea cliffs. The effects are, however, quite dramatic in some cases such as the previously mentioned Coronado Shores area (Segment 9) where a steep reflective beach in one small area produced an erosion rate nearly an order of magnitude greater than the normal rate for this segment.

Task 9 (Cost Itemization)

Salaries and position classifications of all personnel are shown in Table 2. The time, in hours, of all personnel is listed in Table 3 for Phases I and II (first year's work) and for Phase III (second year's work). The cost of generating the final report was estimated together with direct costs for supplies (Table 3). These data were used to produce a rough estimate of the cost per mile to produce erosion rate data in this 31-mile stretch of the coast. The "recommended" column of Table 3 shows the estimate of cost based on lessons learned during this investigation.

Table 2. Personnel salaries and subcontracts.

Position/Subcontract	$/mo.	$/hr.	Subcontract $
Geologist 4	3715	21.44	
Geologist 1	2096	12.09	
Cartographer 3	2415	13.94	
Rosenfeld, OSU (1991 shoreline)			6191
Rosenfeld, OSU (1939 shoreline)			4799
Good, OSU (Point rates)			4336
Komar, OSU (Historical photos)			9880

Table 3. Time and cost itemization.

Item	Hours	$/hr	$ Cost	$ Recommended
Phases I and II				
Literature/map/photo search	58	13.94	808	513
Data preparation, maps	242	13.94	3,372	0
Data preparation, photos	19	13.94	265	168
Digitize, maps	79	13.94	1,101	0
Digitize, 1967 photos	193	13.94	2,690	284
Digitize, 1991 photos (Rosenfeld)			3,691	590
Data manipulation	79	13.94	1,101	176
Transect program	79	13.94	1,101	176
Training (technician)	28	13.94	390	0
Management	144	21.44	3,087	494
Report preparation/analysis	256	21.44	5,488	878
Mylar T-Sheets			1,014	1,014
1991 photos (flown - Rosenfeld)			2,500	7,000
Paper copies, 1967 photos			158	158
USGS quadrangles			70	70
Subtotal, Phases I and II	1,177	154	26,836	11,521
Indirect costs (16.9%)			4,535	1,947
Subtotal (with indirect costs)	1,177		31,371	13,468
Phase III				
Field mapping (SPS + geology)	347	21	7,430	7,430
Compile field mapping	130	21	2,786	2,786
Analysis and report	520	21	11,145	7,430
House-to-bluff (Geologist 1)	347	12	4,192	6,288
Compile house-to-bluff data	130	12	1,572	2,358
Digital data manipulation	260	14	3,623	5,434
Travel (car rental)			2,700	3,300
Travel (per diem)			4,252	5,315
Historical photo analysis (Komar)			9,880	5,000
Digitize 1939 photos (Rosenfeld)			4,799	767
Test point rate methods (Good)			4,336	0
Purchase stereo air photos			1,000	1,000
Subtotal, Phase III	1,733		57,715	47,108
Indirect costs (16.9%)			9,754	7,961
Subtotal (with indirect costs)			67,469	55,069
TOTAL PHASES I, II, AND III	**2,910**		**98,839**	**68,538**
COST PER MILE FOR 31 MILES	**94**		**3,188**	**2,211**

DISCUSSION

The most important lesson learned from this investigation is that mapping of digital shorelines is not, in general, precise enough to measure erosion rates on bluffed beaches of the Oregon Coast. Rates on these beaches are typically less than 1 foot per year which is comparable to the standard error for the digital shoreline method. In approximately 20 per cent of the area there were no significant beaches, and therefore no way of mapping a digital shoreline. It is possible that additional refinement of the method could make it more useful. Possibilities include:

1. More care could be taken in picking the shorelines in comparable ways. Using the same operator for all shorelines and picking the base of the bluff rather than the flotsam line would greatly reduce the uncertainties in shoreline position, provided the photography allows a view of the bluff base. For sand spits and other non-bluffed beaches, the seaward-most line of stable beach grass or other vegetation may prove to be the most consistent, unambiguous shoreline. In any case, this is the line of most interest to development, since it defines the active beach.

2. Photogrammetric rectification of the 1967 photos and of a modern set of air photos would yield superior bases for use in direct measurement of bluff and shoreline retreat. This would eliminate errors caused by imperfect adjustment of the digitized shorelines by radial line triangulation. In many cases these adjustments were not possible because the photo centers fell in the ocean. This technique would also allow direct measurement of bluff retreat in the 20 per cent of the area without significant beaches.

It is unlikely that careful picking of shorelines could achieve much better precision than $\pm$ 0.5 ft/yr, based on the best precision achieved on some segments with extraordinarily unambiguous shorelines (e.g. narrow pocket beaches). Rectification and production of orthophotos from two sets of air photos is likely to cost on the order of $25,000-40,000 for each set. This $50,000-80,000 cost prior to digitization and analysis is probably prohibitively expensive. Even if this money were expended, only two data points in time could be used, since there is not enough positional control to rectify the 1939 photos. As mentioned previously, the 1967-present time interval may not be representative of the long-term erosion rate of many areas that, like the Jumpoff Joe landslide, are subject to infrequent but large erosion events. 100 years or more of data are necessary to see the true erosion rate in these episodically eroding bluffs.

In the case of the Jumpoff Joe landslide area, the landslide is located within the City of Newport which has been settled since the mid-1800's. This served as an incentive to produce a crude topographic map in 1868, prior to construction of a jetty. This extraordinary situation is not likely to be repeated for other landslide areas on the Oregon Coast. Use of the Jumpoff Joe area as an analogy to other areas is warranted only for areas with an identical sequence of mudstones dipping seaward in an open coast setting. Many landslides in the study area do not match these conditions. Headwall retreat rates in these areas could not be accurately measured. In these cases anecdotal data from local residents or measurements by the house-to-bluff technique for short (1939-present or 1967-present) time spans may be all that can be done. Where the house-to-bluff technique is impossible, analogy to similar areas with this data must be used.

Estimating erosion rates by analogy was completely dependent on an accurate map of the lithology of the sea cliffs. No map of sufficient accuracy is available for the Oregon Coast, so this had to be generated by field mapping over a 2 month period. The resulting map also outlined in detail areas with shoreline protection devices. In some cases dumped or naturally deposited sand covered rip rap, making identification of armored areas difficult, but this was a minor source of error when mitigated by interviews with local residents. No rates are listed for armored areas because there is no way of estimating the effectiveness of these structures short of an engineering analysis. Rip rap on duned areas on Siletz Spit appears to have stopped erosion, but this area has only been tested by one or two high erosion events (e.g. Komar and Rea, 1976).

No shoreline protection was encountered in areas with extensive landsliding. It is unlikely that surficial armoring of these areas would stop slope failure. In areas with small, shallow landslides these devices may be effective, if well engineered. Proper draining of the landslide is particularly important for stabilization. Based on reconnaissance mapping, no area in this study could be assumed to have adequate shoreline engineering to stabilize bedrock landslides.

The fluctuation of non-bluffed soft sand beaches at the mouths of major rivers was large enough to show through the "noise" of the positional error in the digital shoreline method. Erosion and accretion rates in these areas were typically on the order of several feet per year which was generally greater than the standard error in the digital shoreline data. The technique should probably be restricted to use in these geomorphic settings. There are, in fact, large stretches of the southern Oregon Coast that are composed of dune fields without a near shore bluff, so the digital shoreline technique could be profitably used in these areas. Caution should be taken in picking a final erosion rate, since most of these areas are not actually eroding landward any faster than the bluffs or jetties that lie adjacent to them. They do, however, fluctuate back and forth, accreting one year and eroding the next. In some cases, such as jetty beaches still in the process of adjusting to jetty construction, net accretion can be measured, but this will decrease progressively as the jetty beaches reach an equilibrium configuration (e.g. South Beach at Segment 21). Set backs should be based on the maximum predicted landward position of the active beach based on expected variability within the time interval of interest. Where there is a changing but unidirectional change in rate for all observation intervals, the rate from last interval should probably be used, if there has been some progressive change in sand supply or other factors. This was the case on the unarmored end of Siletz Spit which showed erosion in all time intervals but a decreased rate in 1967-1991, as the rest became covered in rip rap.

The most precise method for determination of weathering rates of bluffs is measurement of the current distance from the bluff edge to a house or other permanent feature. Comparison of this distance with the same distance measured on the 1939 or 1967 photos gave erosion rates with positional errors 5-10 times less than errors of the digital shoreline technique. The technique suffered from uncertainties in the definition of the bluff edge and a dependence on permanent geographic features for reference. It is also a field-based, moderately time consuming technique.

Field measurements can be eliminated if each photo is carefully scaled by measuring between fixed points in the field; then house-to-bluff distances on the photos near these scaling points are measured. However, trial tests of this technique revealed that the error rate was increased by about 300% versus measuring the house-to-bluff distance in the field. The resulting errors were typically on the order of 0.3 ft/yr, which is similar to many bluff erosion rates. Error was principally from measurement of house-to-bluff distances on 1991 photos (1" = 400') versus the highly accurate field measurements.

Eliminating field measurements also eliminates field inspection and interviews with residents. These interviews and inspections are useful in eliminating errors caused by moved houses and remodeling. Anecdotal data from older residents can also be a valuable check on the erosion rates.

Using a zoom transfer scope to plot the bluff edge from 1990 photos onto a 1:10,000 scale 1868 T-map was the most accurate method for measuring headwall retreat rates in landslide areas. Unfortunately, T-maps with this large of a scale are rare on the Oregon Coast. The episodic nature of landslide erosion necessitates observation times in excess of 70 years. Short term (52-25 years) observation times yielded highly variable rates in landslide terrain, whereas highly consistent erosion rates averaging about 1.45 $\pm$ 0.34 ft/yr were determined for the 122 year time interval. This rate is weighted for length of coastline affected by various rates over the 2.4 miles of landslide-prone coastline. The long observation time revealed the full lateral extent of landsliding.

Bedrock landsliding with this average rate of headwall recession occurs in sea cliffs that meet the following conditons:

1. Tertiary sedimentary rock composed of at least 75% mudstone that dips seaward at 14-28^{o}.

2. The Tertiary sedimentary rock forms at least 10 ft of the base of the sea cliff.

3. The angle between the strike of Tertiary sedimentary rock and the trend of the sea cliff (cliff-strike angle) is less than or equal to approximately 7^{o}.

These observations were invaluable in estimating headwall recession rate by analogy where the 122 year observation time was not possible.

Minor landsliding and even some large but small-displacement slide blocks occurred in areas that had a cliff-strike angle of 7-23^{o} and that met the first two conditions above. It was difficult to estimate headwall retreat rates in these areas, because they did not occur extensively in cliffy areas covered by the 1868 1:10,000 scale T-map. Additional work in other study areas may yield a database that could serve as analogy for these areas.

One interesting aspect of the areas with cliff-strike angles in this 27-7^{o} range was the occurrance of large stable landslide blocks that are outlined by major shore-parallel drainages. These drainages appear to mark the back facing grabens and fissures at the headwalls of these large, stable blocks. Similar large stable slide blocks and shore-parallel drainages occur landward of the active slide areas at cliff-strike angles of less than 7^{o}. It may be that these blocks only become active during great earthquakes.

All of the mudstones in this study had dips of 14-28^{o}, so it was not possible to explore the effect on landsliding of other seaward dips. This limits the use of this database in areas outside the study area.

In many areas, such as uninhabited, roadless bluffs without significant beaches, there was no way to accurately map positional changes of bluff edges. In these cases the only way of estimating erosion rate is to do so by analogy. Analogy to areas with house-to-bluff rates or with rates determined utilizing 1868 1:10,000 scale T-maps was found to be the most useful and precise method. The accuracy of this technique is questionable, since no area is exactly like another. Care must be taken to find matching cliff lithology and geomorphic setting. Geologic mapping at scales of 1" = 400' or greater is critical to application of this technique. Attention to the nature of the beach morphology in front of the bluff is particularly critical. Wide ($\geq$100 ft) low sloping beaches or beaches guarded by nearby headlands or offshore sea stacks dissipate wave energy. Narrow (<100 ft) beaches with steep slopes and coarse sand form deep rip current embayments which can focus wave attack on bluffs and foredunes (Komar, 1991).

RECOMMENDATIONS

Erosion rates on the Oregon Coast are best measured with a combination of techniques, depending on the geographic and geologic setting. On bluffed beaches without landslides bluff retreat should be measured by comparing the distance of the bluff edge to fixed points identifiable on vertical air photos taken in 1939, 1967, and at present. Field measurements between fixed points should be utilized to establish the scale of all photos as near as possible to the intended bluff retreat measurements. Ideally, the modern bluff-to-fixed-point distance should be measured in the field to minimize measurement error and to determine whether the point itself is, in fact, fixed.

On bluffed beaches without fixed points for reference, erosion rates should be estimated by analogy to well studied areas of similar geomorphology and bluff lithology. Detailed maps of the bluff lithology should be produced to facilitate this method. Comparison, utilizing the zoom transfer scope, of the bluff position and shape in historical air photos to modern ones is also useful to determine whether large changes have occurred.

In landslide areas headwall retreat should be measured over time spans greater than 70 years. Using a zoom transfer scope to transfer the modern landslide headwall position (from air photos) to a pre-1900 topographic map of 1:10,000 or larger scale is the only effective method found in this study. Areas without this long-term observational data should be assigned erosion rates based on geologic analogy to areas with this data. A large database of detailed geologic mapping is therefore essential. Where there is no long-term data from geologic analogues to a landslide-prone bluff, erosion must be estimated from comparison of the modern headwall position to that on historical photos such as the 1939 air photos.

Transferal of the landslide headwall from 1:12,000 scale air photos in the Moolack Beach-Newport area to a 1:10,000 scale 1868 T-map revealed that the mean landslide headwall retreat rate there is 1.45 $\pm$ 0.34 ft/yr, weighted for shoreline length affected. This 122 year rate should be applied to sea cliffs with all of the following attributes:

1. Tertiary sedimentary rock composed of at least 75% mudstone dipping 14-28^{o} seaward.

2. Tertiary sedimenary rock forming at least 10 ft of the base of the sea cliff.

3. Angle between the strike of Tertiary sedimentary rock and the trend of the sea cliff (cliff-strike angle) less than or equal to approximately 7^{o}.

A concerted effort should be made to determine headwall retreat rates in areas with landsliding but which do not match the above conditions. Areas of this kind in the present study lacked a >70 year observation time, so headwall retreat could not be accurately determined. Until these rates are determined, measurement of local house-to-bluff rates is the only available method in these areas.

In addition to allowing estimation of erosion rates by analogy, detailed geologic mapping of the sea cliffs allows simultaneous mapping of shoreline protection devices. Areas armored by these devices have ambiguous, probably lower, erosion rates than is typical of the rest of the area.

Application of these techniques to erosion rate analysis for the Oregon Coast should cost on the order of $2,200 per mile of coastline. Two to three times this cost would need to be expended in order to rectify available historical vertical air photos and thereby increase significantly the accuracy of erosion rate measurements. This expense is probably not justified unless site-specific data is desired.

BIBLIOGRAPHY

Gentile, J.R., 1978, The delineation of landslides in the Lincoln County, Oregon coastal zone: Corvallis, Oreg., Oregon State University master's, thesis, 24 p.

Komar, P.D., 1983, The erosion of Siletz Spit, Oregon, in Handbook of Coastal Processes and Erosion, CRC Press, Boca Raton, Florida, p. 65-76.

Komar, P.D., 1991, Ocean processes and hazards along the Oregon coast: Paper presented orally and in written form at the Coastal Natural Hazards Conference and Workshop, October 2, 1991, Newport, Oregon, 39 p.

Komar, P.D., and McKinney, B.A., 1977, The Spring 1976 erosion of Siletz Spit, Oregon: Oregon State University Sea Grant College Program Publication no. ORESU-T-77-004.

Komar, P.D., and Rea, C.C., 1976, Erosion ofSiletz Spit, Oregon: Shore and Beach, v. 4, no. 1, p. 9-15.

Komar, P.D., Lizarraga, J.R., and Terich, T.a., 1976, Oregon coast shoreline changes due to jetties: Journal of Waterways, Harbors and Coastal Engineering Division, American Society of Civil Engineers, v. 102, no. WW1, paper 11933, p. 13-30.

Komar, P.D., and Shih, S., 1991, Sea-Cliff erosion along the Oregon coast: Report for Oregon Sea Grant No. ORESU-R-91-008 R/CM-36; June 25-27, 1991 Proceedings Specialty Conference/WR Div./ASCE, Seattle, Washington, p. 1558-1570.

Rholeder, J.P., Northam, R.M., Kimmerling, A.J., and Rosenfeld, C.L., 1978, Environmental hazard inventory: unpublished report of RNRK Associates to Lincoln County, 67 p.

Schlicker, H.G., Deacon, Olcutt, G.W., and Beaulieu, J.D., 1973, Environmental geology of Lincoln County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 81, 171 p.

Stembridge, J.E., 1975, Shoreline changes and physiographic hazards on the Oregon coast: Eugene, Oreg., University of Oregon Ph.D. dissertation, 202 p.

Ticknor, R., 1993, Late Quaternary crustal deformation on the central Oregon coast as deduced from uplifted wave-cut platforms: Bellingham, Wash., Western Washington University masters thesis, 70 p.

APPENDIX A

ERROR ANALYSIS OF DIGITAL SHORELINE DATA

PHASES I AND II, FEMA COASTAL EROSION STUDY, OREGON

(WITH ANALYSIS OF 1939 AND 1868 DATA FROM PHASE III)

TABLE OF CONTENTS - APPENDIX A

INTRODUCTION 77
- Background 77
- Scope of Work and Objectives 77

EQUIPMENT 78
- Hardware 78
- Software 78

DATA SOURCES 79

PROCEDURES 80
- Shoreline Location Database 80
- Historic Shoreline Positional Change Database 87

COST AND TIME ITEMIZATION 90

ERROR DISCUSSION 91
- Error Inherent to Data Sources and Techniques 91
- Consistency of Shoreline Depiction 94
- Summary of Error Analysis 96

DISCUSSION 98

ACKNOWLEDGEMENTS 100

REFERENCES 100

APPENDIX A1: Generation of the 1991 Digital Shoreline 102
- Analytical Photogrammetry 104
- ZTS Photo-Interpretation 104
- Stereo Video Interpretation 104
- Digital Videogrammetry 105
- Summary of Costs 105

APPENDIX A2: Trial tests of shoreline depiction error 113

INTRODUCTION

Background

The Housing and Community Development Act of 1987 was enacted into law on February 5, 1988. Section 544 of this law (commonly referred to as the Upton/Jones Amendment to the National Flood Insurance Act) allows for the payment of flood insurance claims under the National Flood Insurance Program for undamaged structures that are threatened by erosion and subject to imminent collapse. The Upton/Jones Amendment also includes a setback provision for property that is the subject of a claim payment. In implementing this amendment, the Federal Emergency Management Agency (FEMA) has established criteria for determining whether a structure is subject to imminent collapse based on the rate of erosion at the site. In addition, the determination of the setback requirements at a site also requires the use of erosion rate data. FEMA will be required to develop erosion rate data where such data do not exist or is of an unacceptable level of detail and accuracy.

Following the guidelines of the National Research Council (NRC, 1990), FEMA developed a pilot procedure for estimating coastal erosion rates, termed the Erosion Rate Data Study (ERDS). ERDS entails the creation of two computer databases. The first database, the Historic Shoreline Location Database, contains historic and current shoreline positions in digital format. The second database, the Historic Shoreline Positional Change Database, is created by digitizing the intersection points of a series of perpendicular transects with the historic and current shorelines. These spacial and temporal data are then used to compute rates of shoreline erosion.

ERDS is being tested in a number of different coastal environments in a series of pilot studies throughout the United States. This report summarizes the ERDS pilot study completed by the Oregon Department of Geology and Mineral Industries (DOGAMI) for the coast of Oregon.

FEMA and DOGAMI entered into Cooperative Agreement EMW-91-K-3576 in February of 1991 to complete an ERDS pilot study of 50 km of the central Oregon Coast. This report summarizes the results of the first two phases of the pilot study.

Scope of Work and Objectives

The principal objective of this study is to create the previously mentioned Historic Shoreline Location Database and Historic Shoreline Positional Change Database. Natural (hurricanes, storms, etc.) and man-induced (groin and jetty construction/reconstruction) phenomena that have significantly changed the shoreline configuration are also evaluated.

A cost estimate for the various tasks in the study was required. This estimate is important in order to perform cost-benefit analyses.

This first phase of the pilot study will also allow a preliminary evaluation of the applicability of the ERDS technique to the bluffed shorelines typical of the West Coast of the U.S. A more detailed analysis of geological and oceanographic factors controlling the shoreline changes will be pursued in a second phase of the study.

EQUIPMENT

Hardware

For this project, we used an AST Premium 486/33 DOS-based computer with dual screens, super-VGA graphics on one and Hercules compatible on the other, to allow up to eight views of our map area to be shown in detail. Digitizing was done on a Summagraphics Microgrid III, 36" by 48" digitizer with 16-button cursor. Plotting was done on a Hewlett Packard Draftmaster RX, E-size, 8-pen plotter.

Software

Intergraph's MicroStation PC 4.0 is a high-end computer aided drafting (CAD) package that we used for digitizing the shorelines and determining coordinates of selected points. The typical CAD capabilities of color, line weight, line style, and layers were utilized to create the Historic Shoreline Location Database. Up to seventeen control points at a time can be used to register maps on the digitizer to the drawing. We also wrote user commands, which are programs utilizing a "macro" capability to combine MicroStation drawing commands, to automate repetitive tasks such as transect creation and coordinate recording of intersection points.
To process coordinate information and distance files outside of MicroStation, we wrote programs using Microsoft Quickbasic 4.5. These programs were used to compute the distances between baseline and shorelines, format the data to the proper style, and combine various files into the Historic Shoreline Positional Change Database.

For entry of control points where we only had latitude and longitude values, we had planned to use BLMSPC27 and CORPSCON, two programs supplied by the Bureau of Land Management (BLM), to convert the coordinates to state plane values. This could be done automatically for multiple points in batch mode, or for individual points in interactive mode. BLMSPC27 is a compiled BASIC program that was written for the BLM. CORPSCON is an U.S. Army Corps of Engineers enhancement to the National Ocean Service NADCON program.

The original project contract called for the shoreline database to be expressed in latitude/longitude and, again, we had planned to use the conversion programs to obtain the proper format. However, because FEMA later decided that state plane coordinates were better for database purposes, we did not need to convert our distance/coordinate database after all.

DATA SOURCES

FEMA wanted four shorelines digitized at evenly spaced time intervals over as long a time period as possible. For our study area, the earliest year that a National Ocean Survey (NOS) T-sheet is available was 1887, giving us a 104 year time span. The next T-sheets for this area are from 1927 and 1928. All of these T-sheets were surveyed and constructed in the field. For more recent shorelines, we used a 1967 map made from the Oregon Department of Transportation (ODOT) photos, and a 1991 map made from Oregon State University (OSU) aerial photographs. Shown below are the dates, names, and scales of the source materials.

1887 shoreline:
Source: 1887 NOS T-sheets
Name: Topographical Reconnaissance charts, nos. 1776 and 1809
Scale: 1:40,000
Coverage: 100% of study area

1927-1928 shoreline:
Source: 1927 NOS T-sheets
Name: Charts nos. 4338 and 4339
Scale: 1:20,000
Coverage: 67% of study area

Source: 1928 NOS T-sheets
Name: Chart no. 4411
Scale: 1:20,000
Coverage: 26% of study area

Source: 1928 NOS T-sheets
Name: Chart no. 4412
Scale: 1:10,000
Coverage: 7% of study area

1967 shoreline:
Source: ODOT beach bill photos
Name: Ocean Shores series
Nestucca Bay - Lincoln City section, photos 14 to 29.
Lincoln City - Newport section, photos 1 to 39.
Newport - Waldport section, photos 2 to 15.
Scale: 1:1,200
Coverage: Photos for 100% and photogrammetric data for 80% of study area

1991 shoreline:
Source: Oregon State University Professor Chuck Rosenfeld
Name: OSU photos
Scale: Unknown
Coverage: Photos for 100% and digital shoreline for 80% (same 80% as photogrammetric data of 1967 photos)

PROCEDURES

Shoreline location database

Design file set up

The MicroStation CAD software refers to an electronic drawing as a 'design file', and uses a typical x-y coordinate system for the basis of its design file. For this project, we set the grid units to represent tenths of feet. Since state plane coordinates are measured in feet, we were able to easily register points with known coordinates into our drawing. We were also able to extract state plane coordinates of any point on the map. This permitted direct measurement or computation of distances between points of interest, such as transect-shoreline intersections.

The basic MicroStation package does not have the direct ability to convert between different map projections. Therefore, in the event we wished to register maps using latitude and longitude tick marks, we needed to have a graticule superimposed over our design file. The University of Oregon Geography Department has MicroStation workstations that have the capability of converting projections, so we asked them to set up our initial design file using the Oregon state plane coordinates north zone as the base grid, and overlay lines showing quadrangle boundaries using the Lambert conformal conic projection. This permitted us to register USGS 7 1/2' quadrangles, or any other maps that had lat/long lines drawn on them, directly to a quadrangle grid.

MicroStation allows one design file to be attached to another design file as a "reference file". These reference files are visible "beneath" the active design file, and act similarly to layers of the drawing. This permitted us to enter each year's shoreline in its own design file, and still have them all registered to one another and viewable at all times. After all the digitizing was done, we copied the desired features to a master design file and made a DXF file from that file for FEMA.

Data capture

T-sheets

T-sheets have the Mean High Water line drawn on them as heavy, solid lines. On the mylar copies we received from NOS, the quality of the image was not good. In addition, the image was on the top side of the mylar. This meant that when the mylar was laid on the digitizing table, the image was further degraded due to light refraction within the mylar. This led to a solid mass of black in many places where contours were closely spaced, such as headlands and cliffs. This required us to first put the mylar on a light table and trace the shoreline with a thin, blue pencil. This blue line was then digitized. One way to avoid this extra effort, and the almost certain introduction of errors due to tracing the line multiple times, is to use a back-lit digitizer, which we did not have.

<u>1887 T-sheets</u>: There were two base maps used for the 1887 shoreline. The northern one, no. 1776, has a marking "N. Am. Datum, Aug. 1918". The southern one, no. 1809, has a marking "N. Am. Std. Oct. 1914". To register them to the NAD 27 used for this project, apparant control points on the maps were registered to the drawing using NAD 27 coordinates.

Register no. 1776, the northern map, Cascade Head to Yaquina Head, has azimuth and position lines drawn from points on prominent features, but these points are not named. However, they are situated on basaltic headlands which are highly resistant to erosion. There are modern day triangulation stations at these same locations, so we used the coordinates for each of these points. Listed are the points and their values:

Register no. 1776:

Map name	Database name	Northing	Easting
Penacle	PENACLE 1927	524357.442	1092153.124
Bald	BALD	444702.984	1075588.608
Train	TRAIN	432787.009	1073088.698
Yaquina Head Lighthouse	YAQUINA HEAD LIGHTHOUSE	388916.358	1069530.346

In addition to the triangulation stations above, we used two other points marked on the map. The T-sheet indicated that one sighting from the Bald station was "tangent to Cascade Head". The 1984 topographic 7 1/2′ Neskowin quadrangle was registered to the drawing and a line drawn that duplicated the azimuth sighting. The point of tangency on Cascade Head was used as a registration point.

The 1984 topographic 7 1/2′ Newport North quadrangle was registered to the drawing and the middle of an island called Otter Rock was recorded in the drawing. This point was also located on the 1887 T-sheet and used as an additional registration point.

Register no. 1809, the southern map, Yaquina Point to Alsea Bay (south of the study area), has lines drawn from named control points. We used NAD 27 coordinates to register these points, and their values are:

Register no. 1809:

Map name	Database name	Northing	Easting
Yaquina Head Lighthouse	YAQUINA HEAD LIGHTHOUSE	388916.358	1069530.346
Old light house	YAQUINA OLD LIGHTHOSE	369573.085	1072951.299
Seal Bluff	SEAL ROCK	323438.884	1065185.231

<u>1927 T-sheets</u>: The 1927 T-sheets are at a scale of 1:20,000 except for the Newport area, which is at a scale of 1:10,000. The grid and map features were originally drawn on the North American Datum (NAD), although a later notation shows the offset to adjust for NAD 27. We used named control stations on the maps to register them to the drawing. We would "datapoint" with the digitizer cursor on a known point, and input NAD 27 coordinates to register the map. Listed are the points and their coordinates:

North portion of 4338:

Map name	Database name	Northing	Easting
Dry	DRY	475687.927	1088888.821
Spit	SPIT	477388.549	1087312.060
Lone Tree	LONE TREE	477623.418	1090190.823
Taft	TAFT	480734.280	1088317.375
Cot	COT 1927	483973.011	1088051.065
Beach	BEACH	487677.817	1088351.648
Delake	DELAKE	491659.153	1089756.585
Wood	WOOD	497301.530	1090178.546
Coma	COMA	502813.363	1091811.564
Wick	WICK	502923.231	1094112.602
Salmon	SALMON	512912.733	1095228.831
River	RIVER	516058.241	1093743.287
Penacle	PENACLE 1927	524357.442	1092153.124
Center	CENTER 1927	529721.959	1092703.041
Hart	HART 1927	535292.180	1094871.459
Cascade	CASCADE	527720.319	1104405.257

South portion of 4338:

Map name	Database name	Northing	Easting
Barn	BARN	464995.570	1084847.793
Dry	DRY	475687.927	1088888.821
Lone Tree	LONE TREE	477623.418	1090190.823
Spit	SPIT	477388.549	1087312.060
Taft	TAFT	480734.280	1088317.375
Grave	GRAVE	482966.147	1088300.095
Surf	SURF 1927	483432.206	1087450.265
Cot	COT 1927	483973.011	1088051.065
Rock	ROCK 1927	487758.461	1087827.679
Beach	BEACH	487677.817	1088351.648
Nel	NEL 1927	489504.708	1089132.327
Delake	DELAKE	491659.153	1089756.585
Wood	WOOD	497301.530	1090178.546
Wick	WICK	502923.231	1094112.602
Coma	COMA	502813.363	1091811.564
Salmon	SALMON	512912.733	1095228.831
River	RIVER	516058.241	1093743.287

North portion of 4339:

Map name	Database name	Northing	Easting
Whale	WHALE	419042.350	1074216.771
Weather	WEATHER	423701.465	1072133.199
Cave	CAVE	428267.914	1072633.569
Depot	DEPOT	432727.562	1073245.576

Bald	BALD	444702.984	1075588.608
Mud	MUD	450156.622	1079464.670
Barn	BARN	464995.570	1084847.793

South portion of 4339:

Map name	Database name	Northing	Easting
Yaquina Head Lighthouse	YAQUINA HEAD LIGHTHOUSE	388916.358	1069530.346
Iron	IRON	394443.816	1076663.678
Otter	OTTER	399357.721	1074813.850
Whale	WHALE	419042.350	1074216.771
Weather	WEATHER	423701.465	1072133.199
Cave	CAVE	428267.914	1072633.569
Depot	DEPOT	432727.562	1073245.576

North portion of 4411:

Map name	Database name	Northing	Easting
Rise	RISE	360126.741	1071803.573
Schoolhouse Yaquina	YAQUINA SCHOOLHOUSE CUPOLA	363150.680	1086654.088
Port Nye	PORT NYE	372883.673	1073455.838
Monterey	MONTEREY	381326.956	1074838.347
Yaquina Head Lighthouse	YAQUINA HEAD LIGHTHOUSE	388916.358	1069530.346

South portion of 4411:

Map name	Database name	Northing	Easting
Schoolhouse Yaquina	YAQUINA SCHOOLHOUSE CUPOLA	363150.680	1086654.088
Rise	RISE	360126.741	1071803.573
Dodge	DODGE	350126.334	1070780.565
Bunch	BUNCH	341255.374	1077188.035
Buck	BUCK	336266.881	1068289.098
Seal	SEAL ROCK	323438.884	1065185.231
Smithy Ranch	SMITHY RANCH	316639.080	1066076.036

4412:

Map name	Database name	Northing	Easting
Life	LIFE	356350.183	1071316.667
Rise	RISE	360126.741	1071803.573
Schoolhouse Yaquina	YAQUINA SCHOOLHOUSE CUPOLA	363150.680	1086654.088
Hint 2	HINT 2	365556.719	1082083.576
Jetty	JETTY	366704.838	1070769.602
Mack 2	MACK 2	370341.147	1080049.815
Jumpoff	JUMP OFF	377060.020	1073558.016
Monterey	MONTEREY	381326.956	1074838.347

1967 ODOT photos

In 1967, the whole coast of Oregon was photographed by the Oregon Department of Transportation (ODOT) in preparation for delineating a line to indicate public ownership of the beaches. Using accepted photogrammetric methods, Mean Sea Level (National Geodetic Survey datum) and various elevation contours were plotted on a state plane grid drawn on mylar sheets. The scale of these maps is 1:1,200.

The photos were also reproduced as enlarged halftone film positives. These halftones were laid on the mylars, and with a bit of minor shifting due to the unrectified nature of the photos, the shoreline and contours were transferred from the mylars to the film positives. Diazo prints which show the shoreline and contours can be made from these films.

We purchased diazo print coverage of the study area to determine what line to use as the 1967 shoreline.

The "log line" or storm surge penetration line (SSPL) was apparant on nearly all of the 1967 aerial phtotos and roughly corresponds approximately to the 16' contour (referenced to Mean Sea Level) on the 1967 photogrammetry data (e.g. Figure 6). The SSPL corresponds to the furthest that major storm waves reach in a typical two year period. Its location is subjective, generally taken to be either the oceanward edge of flotsam accumulations or, lacking these, the "storm berm." The storm berm represents the current active shoreline since the 1982-1983 'el Ninno' event. On relatively narrow (< 100') bluffed beaches the SSPL was generally located at or near the base of the sea cliff. On wider beaches it was generally located on the seaward edge of foredune complexes.

For analysis of digital shorelines, the 1967 SSPL was assumed to correspond to the 16 ft contour on the ODOT photographic base maps. This contour line is somewhat higher in elevation than the Extreme High Tide defined by Oregon Division of State Lands (1973). For the Oregon coast the Extreme High Tide is defined as the sum of the highest predicted tide and the highest recorded storm surge and has an elevation of 14.5' above Mean Lower Low Water (Oregon Division of State Lands, 1973) and about 11.5' above the Mean Sea Level of the National Geodetic Survey (NGS; Gonor, 1967). The difference in elevation reflects the difference in the elevation of waves versus the mean tidal level. The lateral separation of the Extreme High Tide and SSPL is approximated by the separation of the 12' and 16' contours on the 1967 photos and averages 29' $\pm$ 55' (Appendix A.2).

We could not use the "dark wet sand line" method popular on the east coast to specify the high water line, because the same wet sand line did not always appear on adjacent photos. Upon closer examination of the 1967 photos, we realized that the differing shadow directions on the photos meant that they were not all taken at the same tidal period. The west coast has two high tide levels differing in elevation by 0.1-2.9 feet, so the "dark wet sand" technique described by Dolan and others (1979) did not yield consistent results for photos flown at differing times. These problems caused the horizontal uncertainty in the position of the dark wet sand line to be approximately twice that of the SSPL (see error analysis section below).

Because the diazo prints were not rectified and had no control points marked on them, they could not be used for digitizing. Instead, we obtained the original mylar contour maps from ODOT and used them. The mylars have the 1,000 foot state plane grid marked on them, so we used that to register the mylars to our drawing. We used a minimum of four registration points for each section we wished to digitize. After fastening the mylar to the digitizer, we digitized a grid intersection, and keyed in the corresponding coordinates to register that point to the drawing. After the registration points were entered, digitizing of that section began. The mylars are too big to fit on the digitizer all at once, so after one section was done, they were moved and re-registered, and digitizing continued until the area was completed.

The Oregon Revised Statutes list the state plane coordinates of the points that define the public beach ownership line. These points lie on the 16 foot contour and were chosen at critical break points. To check our work, we entered the coordinates and connected them with a line. We found that line to be consistently to the southwest of our digitized shoreline. When queried about this, ODOT informed us that the mylars had been drawn at 'local datum' and we needed to apply a correction factor to adjust them to 'sea level datum'. For the area from Cascade Head, at the north end of the project, to Boiler Bay, we needed to multiply the values by .9998982. For the rest of our study area, the correction factor is .9999632. This shifted our digitized shoreline to the southwest approximately 140 feet.

Unfortunately, any state-owned, oceanfront land and any rocky headlands where no sand beach existed were not photo-interpreted in 1967, so there are no mylars for these sections. However, aerial photo coverage is available for these areas, although expensive photogrammetric processing ($400/km) would be necessary to achieve the precision of the mylar data. Such processing was not within budget constraints.

1991 photos

Dr. Chuck Rosenfeld (Oregon State University) produced the 1991 digital shoreline. His team flew the project area in a light aircraft at an altitude of 4,000', photographed the shore, photo-interpreted the desired shoreline, and digitized this line. They tried to match, as closely as possible, the same SSPL represented by the 16' contour on the 1967 map. They used a zoom transfer scope to provide stereo viewing of their photos and outlined the shoreline on the 1967 diazo prints, checking the shoreline position for radial distortion using radial line triangulation. The diazo prints were then aligned with the 1967 mylars and the line transferred to the mylars. They were then able to digitize the line from the mylars which had the state plane grid on them for registration to our database. Like the 1967 shoreline, areas of headlands and public-owned beach are missing, but could be added at additional cost. See Appendix A.1 for a summary of Rosenfeld's work.

1939 photos

The small scale (1" = 800-950') of the 1939 photos made "rubber sheeting" to the 1967 photos impossible, since the maximum scale change for a ZTS is 1:7. Instead, the 1939 photo scales were established for each negative from ground references on the 1991 and 1967 imagery. The SSPL on the 1939 photos was then transferred to the 1967 imagery by scaling points at 100 m intervals to corresponding points on the 1967 photos. Attempts to check the SSPL on the 1939 photos for radial line distortion failed because principal points could not be located.

A number of factors combined to make the 1939 digital shoreline incomplete. Many of the 1939 photos covering the shoreline were not available from the Corps of Engineers, because the prints were lost and the negatives were in the hands of a contractor for duplication. These negatives will be available in a year or two. In other cases the SSPL corresponded with a bluff base that was masked from view because the photo was inland of the bluff.

Historic Shoreline Positional Change Database

Baseline

An arbitrary baseline was drawn just seaward of, and parallel to, the general orientation of the shorelines. The purpose of this baseline was to provide a reference point from which to draw perpendicular transects through the shorelines in order to measure the distances from the baseline to the different shorelines.

We had to disregard the 1887 shoreline in places when paralleling the shoreline, as the 1887 line had some extreme variances to it that did not conform to the other lines. This may have been caused by the scale factor, or by the fact that the 1887 map was a "reconnaisance survey" and not of the required accuracy. Either way, for a few places, the 1887 line lies seaward of the baseline, and the distances from the baseline to the 1887 line are shown as a negative numbers in those cases in the final database. Where negative numbers occur, the absolute value must be added to the other years' figures for the particular transect in order to compute distances between years.

We chose to draw the baseline in five individual segments, usually ending them at a bay or river mouth. This allowed easier handling of the data and permitted us to stay within MicroStation's limitation on the number of points that can define a linestring.

The five baselines are labeled "a" through "e", from north to south, and have from 31 to 551 transects apiece. Each of these transects are identified by a unique code made up from the baseline letter, such as "a", and the transect number, such as "23" (see enclosed index maps).

Transects

Once a baseline was in place, transects perpendicular to the baseline were drawn through the shorelines. The transect spacing along the baseline is 150 feet, producing 1,488 transects. We wrote a User Command that measured along the baseline the desired distance and drew a transect at a 90 degree angle to the baseline. Due to the mathematics involved in the User Command, occasionally a transect was drawn seaward from the baseline. The errant lines were easily corrected by extending the lines to the proper side of the baseline. Another User Command placed the transect identifier a short distance from the baseline-transect intersection.

Coordinates

Since the design file was originally set up in state plane coordinates, it was a matter of writing a user command that would read the coordinates of a desired point and save them to a file. To create a file for each year, we had to digitize a point at each transect-shoreline (T-S) intersection. We always picked the seaward T-S intersection if the transect crossed the shoreline multiple times. Where the transect did not cross the desired year's shoreline, we digitized a dummy point with coordinates of 0:0:0. This occured where we had incomplete coverage for the year or where the baseline curved around headlands and the transect did not pick up each shoreline.

The User Command recorded the transect identifier and east/north coordinates in an ASCII file on our hard disk. After some manipulation in a word processor, the file was written in a cleaner, rearranged format that is shown below with the transect identifier, the north coordinate, and the east coordinate.

#b210, 493284.5, 1089936.0

Distances

Because our coordinates were stored in feet (state plane), it was a simple procedure to compute the distance along a transect from the baseline to the different shorelines. We wrote a Quickbasic program that read the baseline coordinate file, read the proper year's shoreline coordinate file, calculated the distance for each transect, and created a file of the distances. Where the coordinate was the dummy point "0:0:0", the distance for that year was recorded as "-----". Another program read the four distance files and combined them into one file. For the few transects where the 1887 shoreline was seaward of the baseline, we opened the file and added a minus sign with a text editor. A sample from a transect with missing shorelines and one with all four shoreline distances are shown.

```
#a1  ,    7.6,   45.6,  -----,  -----
#b210, 306.6,   46.8,  260.4,  271.7
```

Final Database

Another Quickbasic program read the coordinate and distance files and combined them into the form requested by FEMA: transect code, north/east coordinates of baseline-transect intersection, shoreline year, distance to shoreline, north/east coordinates of transect-shoreline intersection. A sample list appears below.

```
#b210, 493362.7, 1089639.5, 1887,   306.6, 493284.5, 1089936.0
#b210, 493362.7, 1089639.5, 1927,    46.8, 493350.8, 1089684.8
#b210, 493362.7, 1089639.5, 1967,   260.4, 493296.3, 1089891.3
#b210, 493362.7, 1089639.5, 1991,   271.7, 493293.4, 1089902.2
```

COST AND TIME ITEMIZATION

The FEMA contract calls for itemization of cost and time spent on this pilot project. The following matrices summarize this information.

Table 1. Summary of DOGAMI personnel time for production of the 1887, 1927-28, and 1967 digital shorelines. Costs may be evaluated from salary rates as follows: Cartographer = $24.63 /hr.; geologist = $37.88 /hr (includes 3% cost of living raise as of 1-1-92, 46.95% overhead and 20.3% indirect costs). Cost per km of coastline may be approximated by dividing by 50 km length of the study area. Production of the 1991 shoreline was subcontracted to Dr. Charles Rosenfeld of Oregon State University; see Appendix A.1 for more detail on costs of the 1991 shoreline.

	Technician (hrs.)	Geologist (hrs.)
Source data collection	58	
Data prep., maps	242	
Data prep., photos	19	
Digitization, maps	79	
Digitization, photos	193	
Data manipulation	79	
Transect program	79	
Training (technician)	28	
Management		144
Report preparation and analysis		256

Table 2. Summary of direct costs.

	Total Cost ($)	Cost ($/km)
Mylar T-sheets	1,014	8
1991 aerial photos (flown)*	250	5
Paper copies, 1967 photos	158	3
USGS quadrangles	70	0.14

*) See Appendix A.1 for more detail on costs for production of the 1991 aerial photo source material.

ERROR DISCUSSION

Error inherent to data sources and techniques

The quality of the T-sheets received from NOS was very poor. They are mylar sheets with a poor quality black image depicting the shoreline and selected physical features. Copies of T-sheets used to be "contacted" full size from the original mylar map. The quality of the customer's copy was dependant on the quality of the original manuscript. Now, the original maps have all been photographed on 8 1/2" by 11" film at an 8:1 reduction. When a T-sheet is requested, the mylar copy is produced by making an enlargement from this film.

If the camera equipment in either of these steps is even slightly out of adjustment, the resulting image can be degraded severely. This usually means fuzzy lines and filled-in areas where there were closely drawn lines, making interpretation very difficult.

Due to the generalization of smaller scale maps and the resultant loss of detail, the project was not supposed to use any materials with a scale smaller than 1:20,000. However, ninteenth century T-sheets for the study area, and many other areas of the Oregon coast, are only available at 1:40,000 (i.e. the 1887 series). The only exception was one 1886 1:10,000 sheet (Register No. 1086) that covers the Yaquina Head-Yaquina Bay area, but that map had numerous notes from 1914 and 1916 surveyors warning of major errors. When the distance between lighthouses at Yaquina Head (mislabeled Cape Foulweather) and Yaquina Bay was compared to the same distance on the more accurately surveyed 1928 1:20,000 scale T-map, the 1868 map had a distance, using the listed scale, 20.6% larger than the 1928 map. The same test for the 1887 map revealed a distance 18.1 % larger.

Probably the biggest problem associated with the T-maps of the nineteenth century is the fact that they are "topographical reconnaissance" maps. According to Shalowitz (1964):

"A reconnaissance survey is a hasty, preliminary survey of a region made to provide advance information regarding the area, which may be useful pending the execution of more complete surveys. Such a survey is made in a rapid manner, usually covers an extensive area on a comparatively small scale, and may or may not be controlled by triangulation. The resulting survey is frequently no more than a sketch of the area, and if soundings are made they sparsely cover the area and give only the most general idea of hydrographic conditions.

"Such charts were published in the early years for exploratory purposes and as a preliminary to the making of detailed surveys."

The positional errors resulting from the reconnaissance nature of these maps precluded their use for digitizing shorelines. In the

Even if the maps had been adequately surveyed and quality controlled, there would still be possible errors due to line weights on the small scale maps. On the 1:40,000 scale maps, such as the 1887 maps, the shoreline was shown by a line varying in width from .005" to .012". This represents an area on the ground of 17' to 33' wide. Added to this is the unquantifiable error of the person interpreting the shoreline from the mass of black lines caused by the reproduction process. Also add any error caused by the unsteadiness of the digitizer's hand when entering this line into the computer. Errors of 50' to 60' are quite possible for the 1887 T-sheets. Owing to the larger scale, the corresponding error on the 1:10,000 scale 1868 maps is probably about four times smaller.

Another possible error is with the assumption wasmade when the 1887 T-sheets were registered. The northern map, Register no. 1776, had azimuth lines drawn from unnamed points. It was assumed that the points correspond to modern day triangulation stations. Even though the 1887 T-sheets were topographic surveys, it seems unlikely that the surveyors in 1887 did not place markers that were also used for subsequent surveys. Either way, the rocky outcrops used for sightings are not wide enough that more than perhaps 80 ft. difference in equipment location could be possible. This would influence the headland shoreline position a bit, but not significantly affect shoreline location farther away. However, the errors due to scale and lack of accuracy of the 1887 T-sheets far outweigh any question of error caused by incorrect location of the survey points.

The 1927 1:20,000 scale T-sheets had line weights varying from .008" to .012", or 13' to 20' on the ground. The 1927 1:10,000 T-sheets had lines half that width, corresponding to 7' to 10' of ground coverage. The 1967 1:1,200 scale maps had pencil lines from .010" to .020" thick, which means the shoreline varied 1' to 2' from actual ground location. The 1991 1:4,800 scale photos had corresponding errors of 4-8'.

The 1939 1:9,600 to 1:1,140 scale photos had errors of 6-11' from line weights. However, unlike the 1991 photos, the 1939 digital shoreline could not be checked for radial distortion, because the principal points could not be accurately located. The only way of transferring a shoreline was to scale individual points at 100 m intervals to the same points on the 1967 and 1991 photos. This introduced additional error equal to at least the width of a line on these photos (1-8 ft) plus the uncertainty in the scale of the 1967 and 1991 photos. The scale variations are probably minimal for the 1967 and 1991 photos, because the flights are at constant elevation directly over the beach.

In order to determine the error for the 1939 shoreline due to scaling from the 1967 and 1991 photos, a search was made for unique areas that had (1) no erosion between 1939 and 1991, and (2) no significant error in picking the 1991 and 1939 SSPL. The 1991 shoreline was used because the SSPL was picked in the same way as the 1939 SSPL. Five areas met the above condition, 3 with basalt bluffs and one with a small stable mudstone slide block that had undergone no modification since 1939. Careful examination of this slide block revealed no positional change relative to adjacent features and no change in even subtle geomorphic features on the seaward edge of the block. All of these areas also had very unambiguous SSPL'^{s}. The root mean square error for the five measurements is 8 ft. The total digitizing error is therefore 8-11 ft (square root of sum of squares of line width error and scaling error).

To summarize, errors inherent to the data sources and transfer techniques are as follows:

1886 T-sheets:	13-15' plus variable, large survey errors
1887 T-sheets:	50-60' plus variable, large survey errorss

1927-1928 T-sheets: 7-20'

1939 photos: 8-11'

1967 photos: 1- 2'

1991 photos: 4-8'

Consistency of shoreline depiction

Rates from Comparison of T-map to Photo Shorelines on Headlands

The photogrammetric data for the photos were only available for sandy beaches with one exception, the Fishing Rock area in the northern part of the study area (Figure 6). This is a small basalt headland with a protected narrow beach to the north. Bluff retreat on this feature is probably negligible, so it affords an opportunity to evaluate the potential errors between the photogrammetric and T-map data.

It is apparant that the photogrammetric shoreline is a much more accurate representation of the shoreline than the T-map data (Figure 6). The combined errors discussed above have produced lateral differences on the order of 85-100' relative to the highly accurate photogrammetric shoreline for the 1967 photo.

Rates from Comparison of T-map to Photo Shorelines on Sandy Beaches

Sandy beach shorelines on the T-maps are clearly not the same features digitized from aerial photos. This problem is a large source of error between these two fundamentally different data sets.

The T-maps have shorelines that are supposed to correspond to Mean High Water (Shalowitz, 1964). According to the Oregon Division of State Lands (1973), mean high water in Oregon is at an elevation of about 4.6' (NGS datum; elevation = 7.62' using the Mean Lower Low Water datum). These shorelines were digitized, but it is apparant that they bear little relation to shorelines that could be mapped on the photos without photogrammetry.

The two identifiable shorelines available from the 1991 photos, the dark wet sand line (generally 6-10' elevation) and the SSPL (roughly 16' elevation) are both above the 4.6' elevation (Mean High Water) on the 1967 photos (e.g. Figure 6). The 4.6' elevation was not available from photogrammetry on the 1967 photos, the lowest elevation contour being 5.7'. There was therefore no cost effective way of estimating accurately where the T-map shoreline would be on the photos.

To obtain a measure of the uncertainty in shoreline depiction on the the air photos, we examined random transects across all sandy shorelines at 1000' intervals on the 1967 photos (1" = 100'), cataloguing uncertainties in the lateral position of the SSPL and dark wet sand line. Means and standard deviations (68 per cent of the population) were calculated for the 173 transects (Appendix A.2). These photos have photogrammetric elevation contours for 90 per cent of the sandy beaches, so absolute elevations could be compared to the SSPL and dark wet sand line (Appendix A.2). A simple mean rather than the root mean square was used, because the latter overemphasizes areas with anomalously large error which only occur on wide (400-850 ft) beaches.

The mean lateral uncertainty of the dark wet sand line (67') was much higher than the SSPL (41'). However, the standard deviations of these mean values, generally approach 100 per cent of the mean, owing principally to the dependence of uncertainty magnitude on beach width (Appendix A.2).

The uncertainty in position of both the dark wet sand line and SSPL is anomalously high for sand spits and river mouth beaches because of the low slope, large width, and large amount of flotsam. When the data set is analyzed without the 24 transects on these wide beaches, the mean uncertainty for the dark wet sand line and SSPL is 61' and 32', respectively, . The uncertainty of lateral position of the dark wet sand line is therefore nearly twice that of the SSPL for bluffed sandy beaches that typify most of the study area.

The main source of error in the SSPL is the dependence on finding an identifiable flotsam line on the 1991 and 1939 photos that corresponded to the 16' photogrammetric contour on the 1967 photos. In some areas, such as river mouths and spits, large log accumulations throughout and buried in the beach sands complicated identification of the flotsam line. Also, the 16' elevation contour utilized from the 1967 photos for the SSPL did not consistently correspond to either the landward or seaward limit of the flotsam, so the uncertainty for picking the SSPL on the 1991 and 1939 photos essentially equaled the width of the flotsam. Log-rich river mouth beaches thus produced a very large uncertainty. The lateral uncertainty could probably be reduced by consistently picking either the seaward or landward limit of flotsam in multiple photo sets, where photogrammetry is not available.

Other areas lacked sufficient flotsam to unambiguously identify the SSPL. In these areas the base of the bluff or margin of stable vegetation growth was utilized.

Most of the study area consists of bluffed sandy beaches with consistent, relatively narrow flotsam accumulations. The above factors did not seriously contribute to uncertaintly in the SSPL in those areas.

On sandy beaches the dark wet sand line was seaward an average of 117' from the SSPL (e.g. Figure 6; Appendix A.2), a value much larger than the mean uncertainties in shoreline position on the photos. Therefore, even if the shorelines depicted on the T-maps represent a estimation of shoreline recession/accretion rates slowly receding bluffed coastlines of the Pacific Northwest.

The photo data sets are better than T-maps for study of historic shoreline recession. However, shoreline changes between photography sets must exceed the mean uncertainty of the data, which is 32' on the bluffed shorelines typical of most of the study area. On average erosion rates on wide, low sloping beaches such as dune-dominated sand spits can only be determined if the shoreline positions change by more than about 100'. Lateral changes on narrow (<100') beaches must exceed about 8-11' between photography dates in order to be observed.

Table 3 summarizes the average errors expected for shoreline depiction with T-maps and photos.

Table 3

ESTIMATED ERROR IN DIGITIZING THE STORM SURGE PENETRATION LINE (IN FEET ON THE GROUND)

DATA SOURCE	SCALE	LINE WIDTH	SSPL PICK	T-MAP SURVEY	(estimated) DIGITIZING	ROOT MEAN SQUARE
1886 T-map	1:10K	7-10	117[1]	20.6%[2]	8	117-118
1887 T-Map	1:40K	17-33	117[1]	18.1%[2]	30	122-125
1927 T-Map	1:20K	7-16	117[1]	minor	15	117-119
1928 T-Map	1:10K	7-10	117[1]	minor	8	117-118
1928 T-Map	1:20K	7-16	117[3]	minor	15	117-119
1939 photo	1:10K	6-11	40	n.a.	8[4]	41-42
1967 photo	1:1.2K	1-2	40[3]	n.a.	<1	41
1991 photo	1:4.8K	4-8	40[3]	n.a.	<1	41-42

1) Actual error is unknown. The listed value assumes that the SSPL on T-maps corresponds to the dark wet sand line on the photos. If this assumption is valid, the T-map shoreline is seaward of the photo-interpreted SSPL a mean distance of 117 ± 101 ft for all sandy beaches in the study area. Magnitude of error correlates positively with beach width.

2) Estimated by comparing the high quality surveyed distance from Yaquina Head Lighthouse to Yaquina Bay Lighthouse on the 1928 1:20,000 T-map to the same distance on the older maps. In each case the estimated distance on the older maps, utilizing the listed map scale, was larger than the actual distance by 18-20% of the actual distance. These errors precluded use of the older maps for digitizing.

dark wet sand line observed by surveyors at the time, then the T-map shorelines were signficantly seaward of the contemporary SSPL on sandy beaches. If the T-map shoreline approximates the 4.6' elevation (Oregon Mean High Water), then the T-map shorelines are probably even further seaward of the SSPL, since the lowest mapped elevation, 5.7', is generally seaward of the dark wet sand line on the 1967 photos. This error makes it impossible to compare the photo and T-map data for calculation of erosion rate, except on very narrow (<70') beaches. Since the erosion rates on these very narrow beaches are generally low, owing to close proximity of resistant headlands, it is unlikely that the erosion rates will be less than measurement error.

Rates from Comparison of 1887 T-Maps to 1927-1928 T-maps

If Shalowitz's (1964) analysis of T-maps is valid, then the two sets of maps use a consistent shoreline depiction method. The above discussion of the dark wet sand technique suggests shoreline depiction errors of about 67', being larger on wide, low sloping beaches such as sand spits (mean uncertainty of 107'). Combining this error with the 50-60' error caused by the scale of the 1887 T-maps versus the 1927-1928 maps (7-20' error), the root mean square error is probably on the order of 90-120'. This is unacceptable for erosion rate analysis.

Rates from Comparison of Shorelines on 1967 Photos versus the 1939 and 1991 Photos

There may be inconsistencies between the 1939, 1967, and 1991 photo-interpreted shorelines, but the total error is far less than the disparities between T-maps and photos. Different operators produced the 1939 and 1991 shorelines by digitizing the SSPL, and, unlike the 1967 data, no photogrammetry was available for the 1939 and 1991 data to specify the 16' contour as a proxy for the SSPL.

The 173 trial transects discussed above (Appendix A.2) show that the average uncertainty for picking the SSPL is probably on the order of 32-46' for moderately wide (150-350') sandy beaches (Table 1). The uncertainty in the SSPL is least on narrow (<100') beaches (i.e. mean value of 8' in the 9 transects of Appendix A.2 meeting this criteria). The uncertainty is as high as 150-430' (mean of 100') on large sand spits and river mouth beaches (beach width on the order of 400-850').

Summary of Error Analysis

The historic T-map data is not useful for analysis of shoreline recession/accretion unless the horizontal change exceeds approximately 100' over the time interval separating the data sets. Therefore the T-map data is probably not generally useful for

3) Mean uncertainty in picking SSPL for all sandy beaches in the study area. Standard deviation is 46 ft. Magnitude of the uncertainty varies positively with beach width.

4. Determined by measuring the difference in position between digitized 1991 and 1939 shorelines in five places where other sources of error are negligible. Locations are 50 ft N of transect D99, 50-100' N of transect B25, transect B25, B26, and 75 ft south of transect C210. Error is calculated by summing the squares of the five error estimates, dividing by 4, and taking the square root.

DISCUSSION

Owing to scale and other errors, the digital T-map shorelines for the Oregon coast were generally not useful for study of shoreline recession/accretion rate. The three photo-controlled shorelines (1939, 1967, and 1991) may be useful, but only if, on average, erosion exceeds 40-41 feet between photography dates.The storm surge penetration line, approximated by the 16' elevation contour, was the most precisely located feature on aerial photos. Nearly all development on the open coast of Oregon is shoreward of this line, so it is a particularly useful datum for planning. If historic shoreline analysis can yield useful data for prediction of shoreline changes, study of this datum will likely yield the most useful information for the least cost.

Photogrammetric control will be expensive, on the order of $400/km of coastline for each historic shoreline, so it is essential to evaluate whether it is needed. Given costs for the Phase I and II pilot study (without photogrammetry) on the order of $800/km for one photo-controlled shoreline, adding photogrammetry for 2-3 shorelines could make historic shoreline analysis prohibitively expensive ($1600-2000/km).

Recession rates at the highly resistant headlands are very low (on the order of 0.17'/year, according to Rohleder and others [1978]) and the high relief causes high radial distortion on aerial photos. Historical shoreline mapping at these sites is therefore challenging, even with precise photogrammetry. For example, the largest time span between available photos, the 1939 to 1991 sets, yields only about 9' of recession at 0.17'/yr (i.e. 60 year set back = about 10'). It may be that historic shoreline analysis of basaltic headlands in the Pacific Northwest is not cost effective.

Utilizing the technique of this study, the position of the dark wet sand line and the storm surge penetration line on wide (>400') low-sloping sandy beaches has uncertainties on the order of 100'. Producing accurate recession/accretion rate data for these dune-dominated shorelines in the Pacific Northwest will require either tracking a photogrammetrically controlled elevation through time, or some other technique. Historic shoreline analysis for the two most common types of these beaches, sand spits and jetty-bounded beaches, may be inappropriate. The known tendency for sand spits to both accrete and recede at various times (e.g. Komar, 1991) suggests that two or three historic "snapshots" may seriously misrepresent the actual fluctuation of the shoreline on spits. Wide sandy beaches next to jetties on the Oregon coast are relatively stable, having formed from rapid accretion north and south of the jetty shortly after construction (Komar and others, 1976). Barring changes in the jetties themselves, historic shoreline analysis of these beaches is probably not a useful exercise for the National Flood Insurance Program.

Photogrammetry may not be essential for analysis of changes of the storm surge penetration line on sandy beaches of small to moderate width (<400'). Recession/accretion rates should be higher than at headlands and relief on the beaches is low, so there is little radial distortion. For these bluffed beaches, use of a zoom transfer scope with some positional control by radial line triangulation is adequate for detection of lateral shoreline changes of greater than about 11-32', being lowest for narrow (x<100') beaches. Good correlation between the photogrammetric data from the 1967 photos and the data from the 1991 photos (e.g. Figure 6) supports this observation.

ACKNOWLEDGEMENTS

This study was supported by FEMA and has received much valuable technical guidance from the FEMA personnel, Michael Buckley and Mark Crowell. Critical reviews by Paul Komar and James Good of Oregon State University and by Curt Peterson of Portland State University greatly improved the paper.

REFERENCES

Dolan, R.B., Hayden, B., Rea, C., and Heywood, J., 1979, Shoreline erosion rates along the middle Atlantic coast of the United States: Geology, v. 7, p. 602-606.

Gonor, J., 1967, Chart showing 1967 Beach Bill elevation boundary relative to maximum high tide, mean high water, mean sea level, and mean lower low water: June 20, 1967 article in the Newport News & Times.

Komar, P.D., 1983, The erosion of Siletz Spit, Oregon, in Handbook of Coastal Processes and Erosion, CRC Press, Boca Raton, Florida, p. 65-76.

Komar, P.D., 1991, Ocean processes and hazards along the Oregon coast: Paper presented orally and in written form at the Coastal Natural Hazards Conference and Workshop, October 2, 1991, Newport, Oregon, 39 p.

Komar, P.D., Lizarraga, J.R., and Terich, T.a., 1976, Oregon coast shoreline changes due to jetties: Journal of Waterways, Harbors and Coastal Engineering Division, American Society of Civil Engineers, v. 102, no. WW1, paper 11933, p. 13-30.

Komar, P.D., and Shih, S., 1991, Sea-Cliff erosion along the Oregon coast: Report for Oregon Sea Grant No. ORESU-R-91-008 R/CM-36; June 25-27, 1991 Proceedings Specialty Conference/WR Div./ASCE, Seattle, Washington, p. 1558-1570.

National Research Council, 1990, Managing coastal erosion: National Academy Press, Washington, D.C., 182 p.

Oregon Division of State Lands, 1973, Tidal Elevations on the Oreon Coast: Infomation brochure, State of Oregon Division of State Lands.

Rholeder, J.P., Northam, R.M., Kimmerling, A.J., and Rosenfeld, C.L., 1978, Environmental hazard inventory: unpublished report of RNRK Associates to Lincoln County, 67 p.

Schlicker, H.G., Deacon, Olcutt, G.W., and Beaulieu, J.D., 1973, Environmental geology of Lincoln County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 81, 171 p.

Shalowitz, A.L., 1964, Shore and sea boundaries, Volume 2: U.S. Department of Commerce, Publication 10-1, U.S. Government Printing Office, Washington, D.C., 749 p.

Vincent, P., 1989, Geodetic deformation of the Oregon Cascadia margin: Eugene, Oreg., University of Oregon master's thesis, 86 p.

Wilson, B.W., and Torum, A., 1972, Runup heights of the major tsunami on North American coasts, in The Great Alaska Earthquake of 1964: Oceanography and Coastal Engineering: National Academy of Sciences, Washington, D.C., p. 158-180.

Weldon, R., 1991, Deformation of the Oregon coast from geodetics and tidal records: Unpublished oral and poster presentation, March 18, 1991 Wordshop on Oregon Earthquake Source Zones.

APPENDIX A.1

GENERATION OF THE 1991 DIGITAL SHORELINE

A COMPARATIVE STUDY OF SHORELINE CHANGE DETECTION TECHNIQUES: REMOTE SENSING

by:

Charles L. Rosenfeld
Associate Professor
Department of Geosciences
Oregon State University

A short term demonstration project was conducted for the Oregon Department of Geology and Mineral Industries (DOGAMI) on behalf of the Federal Emergency Management Agency (FEMA) for the purpose of comparing the accuracy and costs of complimentary techniques remote sensing techniques for shoreline mapping. The study concentrated on four basic technologies:

(a) Analytical photogrammetry using the radial line triangulation method,

(b) Photointerpretive 'rubber sheeting' employing a Zoom Transfer Scope (ZTS),

(c) Stereo Video Interpretation using video editing equipment, and

(d) Digital videogrammetry on a microcomputer with a 'frame grabber' capability.

The study area selected for the project was a stretch of the Oregon coast for Cascade Head (45°04') to Seal Rock (44°29'), which includes a wide variety of coastal landforms form basaltic headlands to sand spits, and contains both structurally controlled and naturally evolving shoreline segments. The shoreline was imaged using a light aircraft platform equipped with both a 70mm Hasselblad 500 EL/M camera and a Cannon A-1 Digital Camcorder. The photography was acquired on Kodak 2402 (Tri-X) panchromatic film using a Wratten 15 (minus blue) filter and a metric Zeiss 50mm lens. The video images were acquired on Hi-8 videotape using the Super VHS format. Images were simultaneously acquired from an altitude of 4000 feet MSL.

Two shoreline features were interpreted and mapped using the above imagery: (1) the base of shoreline erosion bluffs, and (2) the lowest consistent line of flotsom on the upper beach. Each of these features has interpretation characteristics of its own, and each is related to rates of marine erosion and potential flooding. Most of the shoreline bluffs interpreted are actively washed by marine processes at least during annual peak storm events (2 year return interval events), although in some cases recent flotsom lies several meters seaward of the cliff bases. These sites require additional ground verification to determine if the cliff base reflects a modern erosional shoreline, or if recent littoral accumulation or neotectonic events have isolated it from present processes. The recent flotsom line was often difficult to interpret, as the quantity of large debris objects varied considerably along several segments of the study area. In several cases the 'storm berm' was interpreted in stereo images as a substitute for the flotsom line. This line represents the current active shoreline since the 1982-83 'el Ninno' event, and gives a more accurate representation of the sand distribution on beaches within the littoral cells, but may misrepresent the long term shoreline (especially events with > 10-year return intervals).

ANALYTICAL PHOTOGRAMMETRY

This technique promises the greatest finite accuracy, however at a cost considerably greater than the alternative methods. Metric photography may be used to construct a stereo 'model' in an analytical plotter, or used to produce a planimetric line by the radial line triangulation technique. Cost of the stereoplotter method was estimated by the Oregon Department of Transportation, Photogrammetry Unit at $700.00 per kilometer- cost prohibitive for this study, but capable of producing three foot contour lines. The radial line triangulation method was used in this study to verify points along the shoreline at approximately 100 meter intervals. Using a standard positional error of 0.002 inches, the accuracy checks were valid to a resolution of +/- 40 inches. Figure 1 shows the simple instruments used to perform these accuracy checks manually. The procedure can be enhanced through the use of a KEK Radial Line Plotter, a manual instrument that can produce a continuous line from two photo prints adjusted to form a stereo model in the plotter. Such an instrument was not available during this study. Cost of the radial line verification was about $35.00 per kilometer. Photo acquisition cost with the 70mm system is about $5.00/km, and is applicable to both systems.

ZTS PHOTO-INTERPRETATION

The Zoom Transfer Scope is a photomechanical devise used to adjust scale and make unidirectional stretches in image geometry. This device is easy to use and to train interpreters, but is limited to the resolution of either the source image (new photo) or the target image (map or earlier photo) whichever is less. The accuracy checks done with the X method described in the previous section indicates that the ZTS method had a general resolution of +/- 1.4 meters (57 inches). This method should provide sufficient accuracy to examine shoreline change on at least a decade interval basis, and can be used to monitor major storm effects as well.

STEREO VIDEO INTERPRETATION

Stereo videography was obtained by 'freeze-framing' a video image, then subsequently 'freeze-framing' a subsequent image with sufficient image overlap to produce a stereo image when simultaneously displayed on adjacent video monitors and viewed through a stereoscope device. Figure 3 shows an image from the study area displayed on adjacent monitors using standard Hi-8 editing equipment, the stereo attachment is shown in the lower left of the photo. Figure 4 shows an interpreter viewing the images in stereo, the digital camera is shown in the lower right of the photo. The Super-VHS format has 420 pixels of horizontal resolution, this equates to 21 inches at the acquisition scale of the imagery. With a +/- 2 pixel resolution this reflects an accuracy roughly equivalent to that of the ZTS locations. The principal advantage of this technique is the low acquisition cost of the color images: $2.10 /km, including aircraft time.

DIGITAL VIDEOGRAMMETRY

Our experiment in the use of this technique were unfortunately interrupted by the death of our video technician. We intend to continue to pursue the viability of this technique in several steps, using the imagery from this project as examples. Results of future progress will be reported to DOGAMI as they occur. Two specific techniques are being investigated: image digitizing of aerial photos, and digital 'frame grabbing' of video imagery.

Figure 5 shows the Eiknoix image digitizer focused on the 70mm photos from the project area. With an array size of 1048x1048 with 256 grey levels, this device provides an excellent digital file for both spatial rectification and interpretation through digital image enhancement. the digital files of photo overlap areas are displayed on a high resolution graphics monitor and viewed with a stereoscope, figure 6. An afine transformation technique is used to digitally 'rubbersheet' the photos. The shoreline is interpreted and the digital file is sent to a plotter.

The video 'frame grabber' is installed in a 386-based microcomputer, and IDRISI software is used to display color images from the video record in stereo. A stereoscope is fitted to the monitor for geometric rectification and interpretation. IDRISI merges image processing software with a raster bases GIS. This system is limited to VGA graphics standards, so only part of a scene may be analyzed at one time. Although this technology uses low cost video imagery and low cost computer system, its limited image area may prove costly in a large project area.

SUMMARY OF COSTS

The following is a list of the costs incurred by the following methods:

Light Aircraft (Cessna 172)	$50-$75 /hour
70mm Film and Processing	$1.00-$1.45/km
Hi-8 Video	$0.50-$0.70/km
Photo Interpreter	$20.00/hour
Video Editor	$30.00/hour
PC (IDRISI)	$6.00/hour
Eikonix/Raster Tech System	$25.00/hour

At this point I feel that he ZTS procedure is the most cost-effective technique for the results desired. However, once the software procedures are perfected, I feel that he microcomputer bases interpretation/GIS system will have the most overall utility, and probably better cost-effectiveness.

Figure 1:

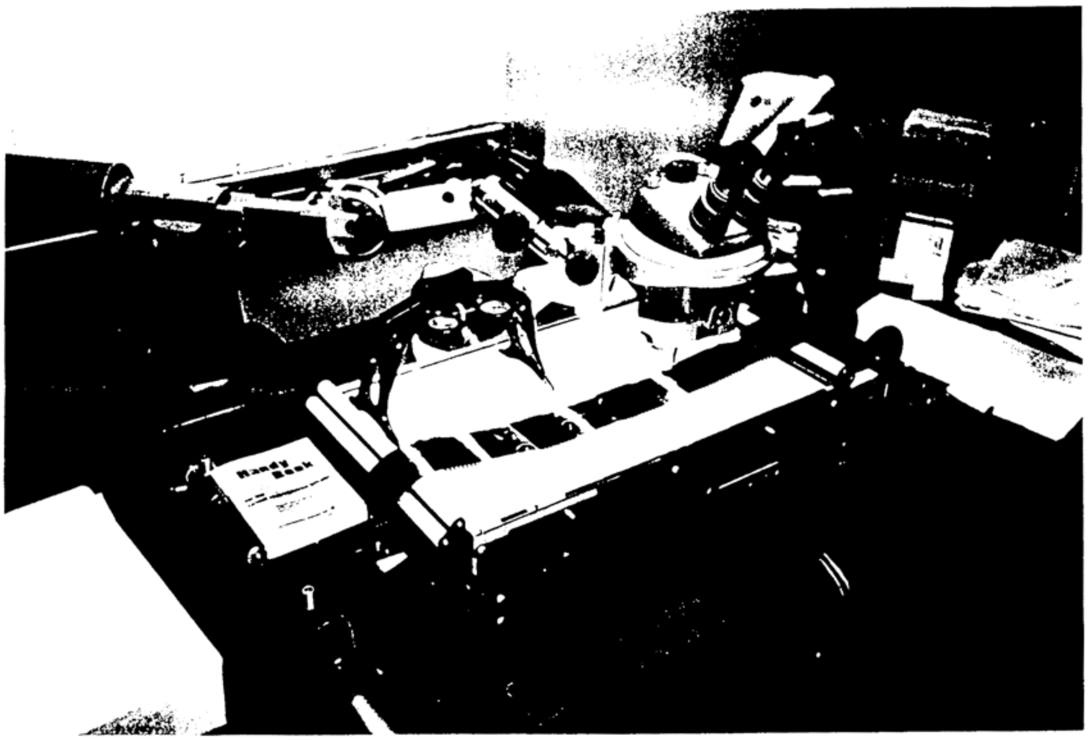


PHOTO INTERPRETER'S WORKSTATION FOR RADIAL LINE TRIANGULATION METHOD.

FIGURE 2:

INTERPRETER USING A ZOOM TRANSFER SCOPE FOR PLOTTING SHORELINES.

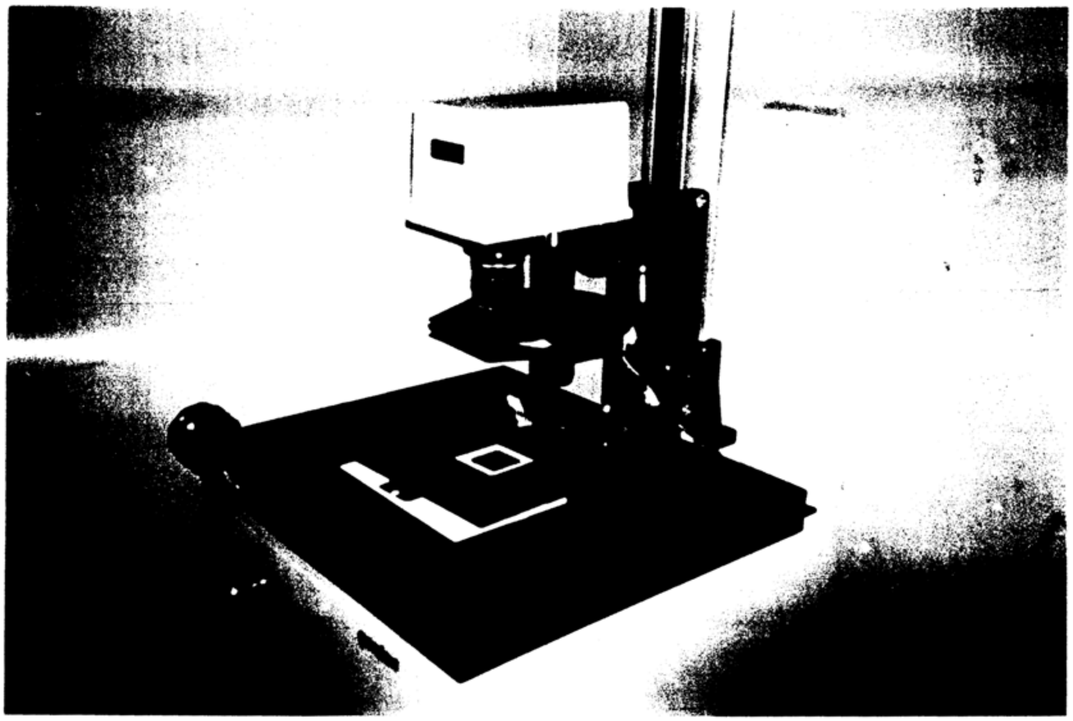
FIGURE 3:

VIDEO EDITING EQUIPMENT WITH STEREOSCOPE (LOWER LEFT).

FIGURE 4:

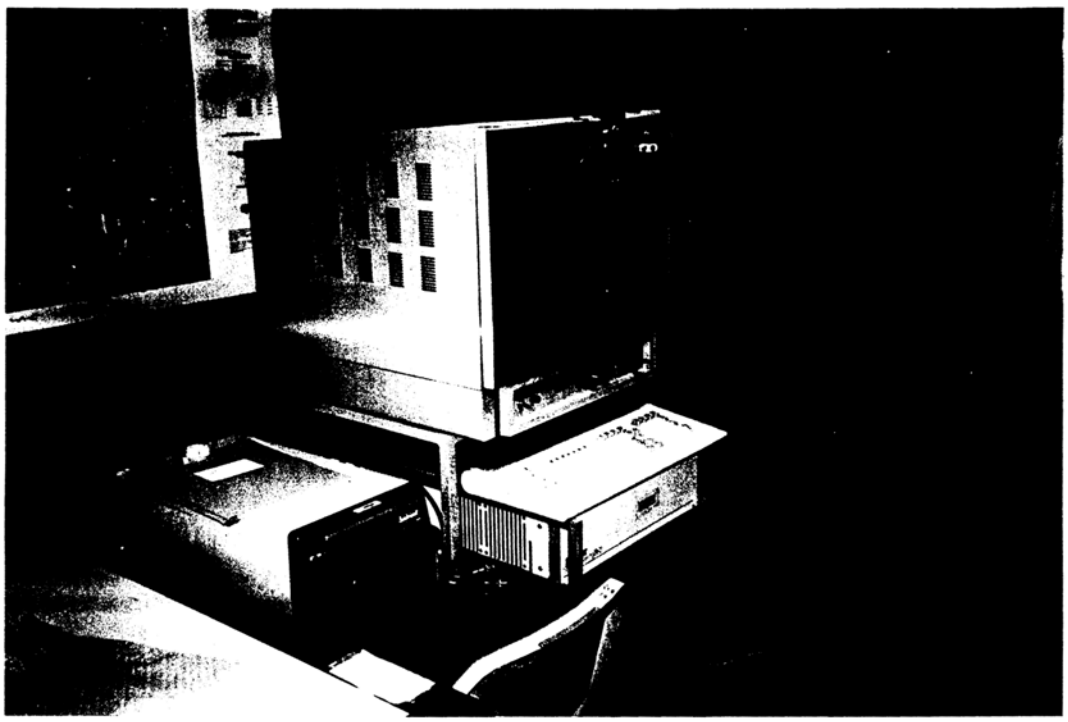
INTERPRETER USING VIDEO EDITING SYSTEM FOR STEREO VIDEO TRACKING.
DIGITAL CAMCORDER AT LOWER LEFT.

FIGURE 5:



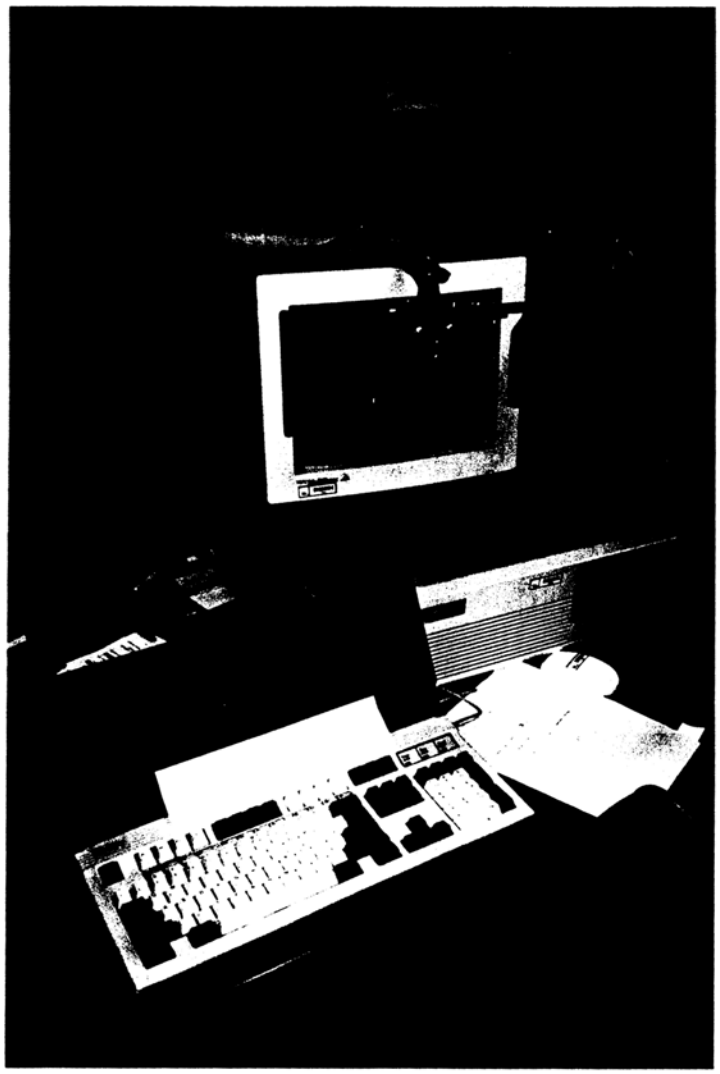
EIKONIX IMAGE DIGITIZER AND 70mm NEGATIVES.

FIGURE 6:



RASTER TECH MONITOR AND STEREO VIEWER ATTACHMENT FOR 'SPLIT SCREEN' STEREO VIDEO. FILM RECORDER AND DIGITIZER PAD AT LOWER LEFT.

FIGURE 7: MICRO-COMPUTER WITH VGA SCREEN AND STEREO VIEWER FOR INTEGRATED IMAGE ENHANCEMENT AND GIS MAPPING USING THE IDRISI SOFTWARE PACKAGE.



APPENDIX A2

APPENDIX A2 Trial tests of shoreline depiction error; elevations relative to Mean Sea Level

SSPL = Storm Surge Penetration Line

DWSL = dark wet sand line

GEOGRAPHIC AREA	Beach Width in ft	Uncertainty DWSL in ft	Uncertainty Logline in ft	SSPL to 12 ft elev.	SSPL to 10 ft elev.	SSPL to DWSL in ft
Salmon River Spit End	850	60	130	120	190	730
Salmon River Spit Side	450	92	100	68	85	330
Pocket Beach N of Cascade Head	120	52	20	n.d.*	54	72
" "	70	30	20	19	60	50
Roads End Beach	140	80	25	15	n.d	95
" " "	45	30	12	10	33	15
" " "	250	5	7	12	66	90
D River area	230	90	75	15	98	187
Lincoln city area	215	100	25	20	32	35
Siletz spit	300	90	40	85	148	240
" "	300	60	115	25	40	90
Gleneden Beach	290	80	5	30	60	140
" "	325	150	50	88	130	170
Gleneden Beach/Schoolhouse Cr.	320	5	25	67	134	240
Lincoln Beach	180	105	20	66	95	120
Fogarty Cr. Beach	178	60	5	5	5	92
Otter Rock/Crest Beach	52	33	5	<5	30	25
Beverly Beach	380	47	60	12	30	155
Moloch Beach	190	120	45	20	19	140
" "	350	185	45	10	15	165
Agate Beach	250	35	20	7	25	120
S. of Yaquina Head	320	20	10	10	20	80
" " "	270	70	40	18	42	110
" " "	190	5	20	5	10	20
Jump Off Joe	<5	<5	<5	<5	<5	<5
Beach S. of Jump Off Joe	130	30	<5	<5	<5	25
Beach N of Yaquina Jetty	390	100	5	7	35	130
Beach S. of Yaquina Jetty	265	80	90	27	102	170
Near Henderson Cr.	190	95	30	5	10	145
Holiday Beach	240	80	25	12	37	130
Lost Cr. State Park area	265	80	<5	5	13	115
Immed. N. of Seal Rocks	215	100	20	10	20	110
Seal Rocks Area	150	60	15	8	15	70
Salmon River Spit	460	150	115	135	190	210
" "	480	140	160	50	110	160
N. of Roads End	65	15	15	10	20	30
Roads End	100	20	20	5	12	25
" "	110	40	22	17	27	35
" "	140	60	30	40	80	90
" "	160	45	30	7	15	125
" "	210	20	20	15	30	90
" "	190	50	40	40	50	105
" "	340	120	28	25	36	78
" "	210	38	28	10	26	60

GEOGRAPHIC AREA	Beach Width in ft	Uncertainty DWSL in ft	Uncertainty Logline in ft	SSPL to 12 ft elev.	SSPL to 10 ft elev.	SSPL to DWSL in ft
Wecoma Beach	240	100	25	40	65	158
" "	340	40	20	27	70	110
" "	200	40	30	30	110	135
" "	210	20	10	<5	<5	22
" "	240	5	30	30	43	85
" "	250	25	<5	5	40	40
Ocean Lake Area	65	<5	10	8	20	20
" "	110	38	10	45	96	84
" "	220	10	30	20	70	40
N. of D River	240	80	15	25	85	92
" "	280	20	20	65	100	120
S. of D River	270	50	40	30	63	63
Delake area	250	30	47	47	70	68
" "	320	187	40	10	47	65
" "	315	140	35	35	75	48
S. of Delake area	370	15	90	70	220	212
" "	222	170	35	15	30	35
Nelscott	220	45	40	27	52	90
"	190	95	25	10	61	115
"	202	15	10	12	35	40
"	220	80	10	10	35	40
"	240	25	20	18	30	30
"	250	70	120	30	158	155
Taft	360	30	230	230	278	280
"	310	60	160	90	210	260
"	380	130	187	10	12	203
Siletz Spit	260	60	175	38	170	190
" "	405	70	150	125	274	370
" "	280	60	70	45	65	210
" "	225	100	35	30	55	160
" "	330	60	80	107	202	263
" "	295	100	20	78	102	225
" "	227	82	60	30	60	170
" "	350	110	10	42	128	230
" "	382	115	40	58	92	165
" "	300	135	90	42	78	210
" "	330	40	25	55	192	230
" "	220	130	35	24	55	90
Gleneden Beach	230	115	30	61	71	128
" "	200	65	60	40	98	115
" "	275	190	<5	15	65	110
Coronado Shores	256	130	10	5	37	50
" "	280	140	15	35	60	82
" "	215	60	10	51	82	146
S. of Coronado Shores	330	130	5	35	57	190
" "	230	88	30	72	142	130
" "	229	70	32	60	103	90
Lincoln Beach	365	40	50	65	148	185
" "	370	70	110	116	175	215
Fogarty Creek	85	<5	<5	<5	12	<5
Whale Cove	100	5	80	32	53	53
Otter Crest area	180	55	40	15	35	50

GEOGRAPHIC AREA	Beach Width in ft	Uncertainty DWSL in ft	Uncertainty Logline in ft	SSPL to 12 ft elev.	SSPL to 10 ft elev.	SSPL to DWSL in ft
Beverly Beach	180	30	45	17	27	130
" "	190	40	10	n.d.	n.d.	100
" "	300	60	30	n.d.	n.d.	100
" "	300	90	20	n.d.	n.d.	108
" "	260	100	50	n.d.	n.d.	120
" "	85	<5	<5	n.d.	n.d.	<5
" "	110	<5	<5	n.d.	n.d.	<5
" "	175	90	20	n.d.	n.d.	60
" "	151	30	30	n.d.	n.d.	45
" "	200	20	40	n.d.	n.d.	15
" "	152	28	20	n.d.	n.d.	20
" "	100	<5	<5	n.d.	n.d.	<5
" "	262	10	10	n.d.	n.d.	10
" "	250	20	10	n.d.	n.d.	60
Moloch Creek	225	15	32	13	20	70
Moloch Beach	250	180	42	20	32	70
" "	220	50	60	10	15	40
" "	215	60	10	10	20	185
" "	188	40	20	<5	10	95
" "	135	20	10	<5	7	15
Agate Beach N	330	50	20	12	20	120
" "	190	50	30	20	30	60
" "	110	30	20	8	52	65
" "	110	40	10	18	32	50
Agate Beach S	330	75	30	20	30	38
" "	310	50	70	43	66	112
" "	380	110	25	12	38	140
Big Creek	570	430	180	30	80	290
Agate Beach S	245	60	30	5	13	100
" "	286	45	10	6	10	20
Newport Beach	269	60	20	n.d.	n.d.	100
" "	70	5	10	8	12	20
" "	322	65	20	13	22	88
" "	280	10	25	18	63	100
" "	240	40	30	30	35	40
" "	240	50	90	22	87	140
" "	270	60	10	7	10	85
N. Yaquina Bay Beach	735	220	130	130	210	480
" "	690	70	252	102	220	470
South Beach	430	60	80	n.d.	n.d.	130
" "	460	60	200	n.d.	n.d.	370
" "	410	80	110	n.d.	n.d.	320
" "	255	70	80	n.d.	n.d.	240
" "	300	70	70	n.d.	n.d.	200
" "	250	40	90	45	120	200
" "	285	80	80	30	60	160
" "	340	60	130	30	120	200
" "	325	70	80	35	55	150
" "	250	70	35	15	28	60
" "	290	60	35	17	45	32
" " (Grant Cr.)	400	30	30	9	15	110
" "	230	97	5	<5	9	110
" "	290	60	20	9	15	130
" "	230	60	20	8	20	100
" " (Thiel Cr.)	250	60	50	15	80	160
" "	270	45	50	20	50	170
" "	150	40	<5	<5	10	40

GEOGRAPHIC AREA	Beach Width in ft	Uncertainty DWSL in ft	Uncertainty Logline in ft	SSPL to 12 ft elev.	SSPL to 10 ft elev.	SSPL to DWSL in ft
Lost Cr. State Park	150	35	<5	n.d.	n.d.	50
" " "	230	90	10	n.d.	n.d.	25
" " "	275	100	5	n.d.	n.d.	5
" " "	235	100	22	n.d.	n.d.	5
" " "	230	100	20	n.d.	n.d.	100
" " " (Lost Cr.)	380	120	25	n.d.	n.d.	120
" " "	255	70	<5	n.d.	n.d.	90
Ona Beach	262	120	<5	5	12	10
" "	345	50	<5	5	52	115
" "	235	40	<5	3	48	80
" " State Park	270	50	15	n.d.	n.d.	105
" " " "	255	70	5	n.d.	n.d.	150
Beaver Creek	590	30	50	n.d.	n.d.	485
" "	320	70	75	n.d.	n.d.	240
Ona Beach	218	60	20	9	30	155
" "	285	70	30	12	30	110
" "	210	100	30	15	30	140
" "	190	60	30	21	30	115
" "	295	80	10	5	22	120
Seal Rocks State Park	200	60	10	12	22	10

Total # data points	173	173	173	144	144	173
Mean	250	65	40	29	61	117
Sigma	123	51	46	55	55	101

VALUES WITHOUT SAND SPIT AND RIVER MOUTH DATA

Total # data points	160	160	160	128	128	160
Mean	235	61	32	24	52	98
Sigma	86	41	34	29	48	69

VALUES FOR SAND SPIT AND RIVER MOUTHS ONLY

Total # data points	26	26	26	24	24	26
Mean	373	98	90	61	121	237
Sigma	182	80	66	39	39	151

* n.d. = no data

APPENDIX B

SHORELINE MEASUREMENTS
USING HISTORCAL AERIAL PHOTOGRAPHS:
AN EXAMPLE FROM THE OREGON COAST

By

Charles L. Rosenfeld and Jerry Clinton

Oregon State Unversity

During June and July of 1992, an effort to use historical aerial photography to determiine the erosional rates of retreat along the Cascade Head to Seal Rock portion of the coast was undertaken by the Department of Geosciences at Oregon State Universiity. This research was done in support of a comprehensive study of the mechanics of shoreline change being conducted by the Oregon Department of Geology and Mineral Industres (DOGAMI), sponsored by the Federal Emergency Management Agency (FEMA).

The historical aerial photos were taken for the U.S. Army Corps of Engineers in 1939. The principal task was to identify features on the 1939 photos which could serve as reliable 'bench marks' for shoreline change detection measurements, and to ascertain the accuracy to which these measurements are reliable. The interpretation task had numerous pitfals- structures had often been 'remodelled, changing their rooflines or foundation outlines, and some had been moved due to recession of the shore bluff. Both 1967 Oregon Department of Transportation photos and 1991 phtography, acquirred for this project, were used.

For consistency with a previous project, the measured photo distances were compared with those measured from equivalent features on the 1967 and 1939 photos. In addition, radial line triangulation was uased to determine the relative accuracy of the 1939 photos for quantitative linear measurements.

Of the eighty photographs used in thiis study, seventy-four were useful for shoreline measurement. the remaining photos either missed the shoreline, showed excessive tilt, or 'masked' the base of the shore bluff due to perspective (i.e. the photocenter was inland from the bluff). Since the actual principal points of the original aerial negatives could not be ascertained on the copies, the results f the radial line triangulations (Table 2) was inconclusive. A cost-effective Zoom-Transfer Scope (ZTS) method, described in our previous study, was not applicable to these photos due to the extreme scale difference, the average scale for the 1939 photos is 1:10,000 and the adjusted scale for the 1967 photos is 1:1200, the maximum scale difference for the ZTS is 1:7.

Since the scale of the 1939 photos varied from 1:9.600 to 1:10,800, each photo was referenced to the 1:1200 photos from 1967. Table 1 lists the 1967 photo frames, and the corresponding

1939 photos referenced to each. Once a finiite scale was determined for each of the 1939 photos (using ground references from the 1967 photos) a series of shoreline measurements were made using corresponding features.

An attempt to locate corresponding photo points at 100 meter intervals, each scaled to the measured scale of the individual negative as made. These points were then digitized using Intergraph Microstation software and were delivered to DOGAMI in July, 1992.

Table 1

1967	1939
2/24	2727
3/24	2728, 2729
4/24	2729
5/24	NA
6/24	2732
7/24	2732, 2733, 2734
8/24	2734
9/24	2734, 2735
10/24	2735, 2736
11/24	2736, 2737
12/24	2737, 2738
13/24	2738, 2739
14/24	2739, 2740
15/24	2740, 2741
16/24	2741, 2742
17/24	2744

1967	1939
1/39	10018, 10019, 2689, 2690
2/39	10019, 2690, 2691
3/39	10019, 10020, 10021, 10022, 2691, 2692, 2789, 2790
4/39	10022, 10023, 10024, 2693
5/39	10024
6/39	10025, 10026
7/39	10026, 10027, 10028
8/39	10028
9/39	10028, 10029
10/39	NA
11/39	10033, 10034
12/39	10034
13/39	10034
14/39	10038
15/39	10038
16/39	10038, 10039, 10040
17/39	10040, 10041
18/39	NA
19/24	NA
20/39	NA
21/39	NA
22/39	2710, 2711
23/39	NA
24/39	2713
25/39	2713, 2714
26/39	2714, 2715
27/39	2715
28/39	2716, 2717
29/39	2717
30/39	2718
31/39	2719
32/39	2719, 2720
33/39	2721
34/39	2721
35/39	2721, 2722
36/39	2722, 2723
37/39	2723, 2724
38/39	2724, 2725
39/39	2726

1967	1939
18/29	NA
19/29	NA
20/29	NA
21/29	NA
22/29	2682
23/29	2682
24/29	2682, 2683
25/29	2683, 2684
26/29	2686
27/29	2687, 2688
28/29	2688
29/29	2688, 2689

----

* 1939 photographs which show corresponding coverage with 1967 O.D.O.T. photos are listed, by photo number, in the column to the right of the appropriate 1967 photo number.

Table 2

Pairs	Max	Min	Avg
2710/2711	127	51	102
2713/1714	153	25	102
2714/2715	42	17	25
2715/2716	51	8.5	17
2716/2717	102	8.5	51
2732/2733	127	25.5	51

This list shows 1939 stereopairs of which radial line triangulations (RDL) were attempted, and the maximum, minimum, and average wing-point displacements--in feet--in columns to the right of each pair.

The proper photo registration markings used to perform tringulations were very poor or not present which renders the enclosed RDLs useless.

These have been provided only for your information regarding the 1939 photography.

Notes: 1939 aerial photographs

Of eighty photographs provided for coverage of Oregon coast shoreline between Cascade Head and Seal Rocks, seventy-four appear to be useable. Of the useable photos there is some overlapping of coverages as well as gaps in coverage, i.e., a gap in coverage from Salmon river estuary to Roads End.

Stereopairs are available among most of the 1939 coverages on hand, however most photos are lacking fiducial marks or corner registration marks with which to establish the principal point for each. Also, the end lap of most stereopairs prove insufficient to enable plotting conjugate principal points with any confidence; CPps do not occur in many stereopairs.

Approximate scale of 1939 photos is derived by comparing measured distances of and between natural and manmade landmarks identified in each corresponding 1967 Oregon Department of Transportation (ODOT) aerial photograph coverage, keeping in mind distortion factors of course. The best average ratio is usually about 8.5 to 1 and yields photo scale of 1:9,600 to 1:10,800 as calculated from the 1:1200 scale of the 1967 ODOT Photos.

Because of the large scale difference between the 1939 aerial photographs and the 1967 ODOT photos the use of zoom transfer scopes for translation of any features is not feasible.

By using the calculated scales of the 1939 photos and the 1967 ODOT coverages we proceeded to translate the 1939 data--shoreline and upper-bank line--from any features which were recognizable in both the 1939 and 1967 photography.

APPENDIX C

The following table lists the State Plane coordinates of the oceanward starting points a series of transects drawn perpendicular to the shoreline. A row in the table is assigned to each transect and rates of shoreline change are estimated from digital shorelines and house-to-bluff data. The column labels and their explanations are as follows:

TRANSECT: Transect number

NORTHING: State Plane coordinate north

EASTING: State Plane coordinate east

SEGMENT: Segment number

R67-39: Rate from digital shorelines aged 1967 and 1939

R91-67: Rate from digital shorelines aged 1991 and 1967

R91-39: Rate from digital shorelines aged 1991 and 1939

BEST: Best rate estimate for the transect

ERROR: Best estimate of error for the transect; mean rate estimates have an error listed that is the sample standard deviation of the population from the mean.

SPS: Shoreline protection structure present? Y = yes, N = no.

Note that a COMMENT field in the digital data base (TRATENEG.DBF) lists the origin of each BEST erosion rate.

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#a1	524515.0	1091639.0	CAS HD				NO DATA	NO DATA	N
#a2	524389.0	1091561.1	CAS HD				NO DATA	NO DATA	N
#a3	524240.9	1091539.3	CAS HD				NO DATA	NO DATA	N
#a4	524091.3	1091528.9	CAS HD				NO DATA	NO DATA	N
#a5	523941.7	1091518.4	CAS HD				NO DATA	NO DATA	N
#a6	523798.8	1091540.0	CAS HD				NO DATA	NO DATA	N
#a7	523698.7	1091651.5	CAS HD				NO DATA	NO DATA	N
#a8	523601.9	1091766.1	CAS HD				NO DATA	NO DATA	N
#a9	523508.9	1091883.6	CAS HD				NO DATA	NO DATA	N
#a10	523425.0	1092008.0	CAS HD				NO DATA	NO DATA	N
#a11	523361.5	1092143.9	CAS HD				NO DATA	NO DATA	N
#a12	523303.4	1092282.1	CAS HD				NO DATA	NO DATA	N
#a13	523252.2	1092423.0	CAS HD				NO DATA	NO DATA	N
#a14	523219.2	1092569.3	CAS HD				NO DATA	NO DATA	N
#a15	523143.6	1092682.2	CAS HD				NO DATA	NO DATA	N
#a16	523045.0	1092783.2	CAS HD				NO DATA	NO DATA	N
#a17	523050.9	1092932.2	CAS HD				NO DATA	NO DATA	N
#a18	523066.8	1093081.4	CAS HD				NO DATA	NO DATA	N
#a19	523068.1	1093231.0	CAS HD				NO DATA	NO DATA	N
#a20	523031.2	1093376.4	CAS HD				NO DATA	NO DATA	N
#a21	522996.2	1093522.3	CAS HD				NO DATA	NO DATA	N
#a22	522967.7	1093669.5	CAS HD				NO DATA	NO DATA	N
#a23	522955.3	1093817.6	CAS HD				NO DATA	NO DATA	N
#a24	522993.5	1093961.2	CAS HD				NO DATA	NO DATA	N
#a25	523076.3	1094084.2	CAS HD				NO DATA	NO DATA	N
#a26	523196.2	1094171.1	CAS HD				NO DATA	NO DATA	N
#a27	523249.0	1094297.8	CAS HD				NO DATA	NO DATA	N
#a28	523316.7	1094428.1	CAS HD				NO DATA	NO DATA	N
#a29	523301.1	1094547.1	CAS HD	−0.24			NO DATA	NO DATA	N
#a30	523212.6	1094666.8	CAS HD	0.03			NO DATA	NO DATA	N
#a31	523171.7	1094806.5	CAS HD	0.05			NO DATA	NO DATA	N
#b1	523016.6	1094752.6	1	8.53	0.22	4.70		5.50	N
#b2	522939.4	1094630.5	1					5.50	N
#b3	522807.1	1094571.3	1					5.50	N
#b4	522661.8	1094534.1	1					5.50	N
#b5	522516.5	1094496.8	1					5.50	N
#b6	522367.3	1094490.4	1					5.50	N
#b7	522217.3	1094490.4	1					5.50	N
#b8	522067.3	1094491.8	1		−0.11			5.50	N
#b9	521917.3	1094493.9	1		−1.66			5.50	N
#b10	521767.3	1094495.9	1	4.61	−0.42	2.29		5.50	N
#b11	521617.3	1094497.9	1	1.96	0.96	1.50		5.50	N
#b12	521467.3	1094500.0	1	1.03	1.96	1.46		5.50	N
#b13	521317.3	1094502.0	1	0.88	1.83	1.32		5.50	N
#b14	521167.3	1094504.0	1	1.63	2.35	1.96		5.50	N
#b15	521017.3	1094506.0	1	2.28	3.31	2.76		5.50	N
#b16	520867.3	1094508.1	1	2.68	2.91	2.78		5.50	N
#b17	520717.5	1094515.5	1	2.07	2.75	2.38		5.50	N
#b18	520567.7	1094523.4	1	2.42	0.91	1.72		5.50	N
#b19	520417.9	1094531.3	1	3.46	−0.93	1.43		5.50	N
#b20	520268.1	1094539.2	1	3.22	−1.13	1.22		5.50	N
#b21	520118.3	1094547.1	1	3.13	−1.08	1.19		5.50	N
#b22	519968.5	1094554.9	1	2.33	0.18	1.34		5.50	N
#b23	519819.2	1094557.1	2	1.49	−0.75	0.45	−0.08	0.08	N
#b24	519672.7	1094525.0	2	2.23	−0.01	1.20	−0.08	0.08	N
#b25	519570.5	1094419.5	2	−0.34	0.94	0.25	−0.09	0.16	N
#b26	519473.2	1094305.3	2	−0.51	0.92	0.15	−0.09	0.16	N
#b27	519375.9	1094191.2	2	−0.05	−0.59	−0.30	−0.09	0.16	N
#b28	519278.6	1094077.0	2	0.90	−0.61	0.20	−0.08	0.08	N
#b29	519181.3	1093962.9	2	0.68	−0.15	0.30	−0.08	0.08	N
#b30	519084.0	1093848.7	2	−0.80	−0.48	−0.65	−0.08	0.08	N
#b31	518986.7	1093734.6	2	−1.04	3.46	1.04	−0.09	0.16	N
#b32	518889.4	1093620.4	2	−0.53	0.85	0.11	−0.09	0.16	N
#b33	518792.1	1093506.3	2	−0.58	0.35	−0.15	−0.09	0.16	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#b34	518694.9	1093392.1	2				−0.09	0.16	N
#b35	518597.9	1093277.7	2				−0.09	0.16	N
#b36	518500.8	1093163.3	2			0.25	−0.09	0.16	N
#b37	518403.8	1093048.9	2			−0.41	−0.09	0.16	N
#b38	518270.8	1092981.3	3			0.21	−0.08	0.08	N
#b39	518135.3	1092916.9	3	−0.76	0.17	−0.33	−0.08	0.08	N
#b40	517999.8	1092852.5	3	−0.76	0.10	−0.36	−0.08	0.08	N
#b41	517864.3	1092788.1	3			−0.10	−0.08	0.08	N
#b42	517728.8	1092723.7	3			−0.71	−0.08	0.08	N
#b43	517585.7	1092678.8	3			−1.61	−0.08	0.08	N
#b44	517442.3	1092634.9	4				−0.09	0.16	N
#b45	517298.9	1092590.9	4				−0.09	0.16	N
#b46	517155.5	1092547.0	4				−0.09	0.16	N
#b47	517012.1	1092503.1	4				−0.09	0.16	N
#b48	516868.7	1092459.2	4				−0.09	0.16	N
#b49	516719.8	1092442.2	4				−0.09	0.16	N
#b50	516570.6	1092426.3	4				−0.09	0.16	N
#b51	516421.5	1092410.3	4				−0.09	0.16	N
#b52	516272.3	1092394.4	4				−0.09	0.16	N
#b53	516123.2	1092378.4	4				−0.09	0.16	N
#b54	515974.0	1092362.5	4				−0.09	0.16	N
#b55	515824.9	1092346.5	4				−0.09	0.16	N
#b56	515675.7	1092330.6	4				−0.09	0.16	N
#b57	515526.6	1092314.6	4				−0.09	0.16	N
#b58	515377.4	1092298.7	4				−0.09	0.16	N
#b59	515228.0	1092289.8	4				−0.09	0.16	N
#b60	515116.6	1092376.6	4				−0.09	0.16	N
#b61	515073.3	1092517.6	4				−0.09	0.16	N
#b62	515084.8	1092664.9	4.5		0.23		−0.25	0.36	N
#b63	514982.1	1092771.3	4.5		0.63		−0.25	0.36	N
#b64	514860.0	1092857.8	4.5		1.07		−0.25	0.36	N
#b65	514731.8	1092935.7	4.5		1.35		−0.25	0.36	N
#b66	514603.6	1093013.6	4.5		0.51		−0.25	0.36	N
#b67	514463.2	1093064.9	4.5		0.24		−0.25	0.36	N
#b68	514319.1	1093103.4	5		1.11		−0.27	0.34	N
#b69	514169.3	1093112.0	5		0.88		−0.27	0.34	N
#b70	514019.5	1093120.5	5		0.28		−0.27	0.34	N
#b71	513869.6	1093123.6	5		0.05		−0.27	0.34	N
#b72	513719.6	1093122.9	5		−0.08		−0.27	0.34	N
#b73	513569.6	1093122.2	5		−0.14		−0.27	0.34	N
#b74	513419.6	1093121.4	5		−0.50		−0.27	0.34	N
#b75	513269.6	1093120.7	5		−1.06		−0.27	0.34	N
#b76	513119.6	1093120.0	5		0.00				Y
#b77	512969.6	1093119.3	5		−0.21				Y
#b78	512819.6	1093118.6	5		−0.24				Y
#b79	512669.6	1093117.9	5		0.07				Y
#b80	512519.6	1093116.0	5		−0.46				Y
#b81	512369.7	1093109.4	5		−0.57				Y
#b82	512219.8	1093102.9	5		0.19				Y
#b83	512069.9	1093096.3	5		−0.46				Y
#b84	511920.0	1093089.7	5		−0.27				Y
#b85	511770.1	1093083.1	5		0.28				Y
#b86	511620.2	1093076.5	5		−0.12				Y
#b87	511470.3	1093069.9	5		−0.08				Y
#b88	511320.4	1093063.4	5		−0.16				Y
#b89	511170.5	1093056.8	5		−0.08				Y
#b90	511020.6	1093050.2	5		−0.30				Y
#b91	510870.7	1093043.6	5		−0.54				Y
#b92	510720.8	1093037.0	5		−0.55				Y
#b93	510571.3	1093026.2	5		0.02				Y
#b94	510422.5	1093007.3	5		−0.20				Y
#b95	510273.7	1092988.3	5		−0.15				Y
#b96	510124.9	1092969.4	5		0.25				Y
#b97	509976.1	1092950.5	6		−0.13		−0.27	0.34	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#b98	509827.3	1092931.6	6		0.08		−0.27	0.34	N
#b99	509678.5	1092912.7	6		0.04		−0.08	0.11	N
#b100	509529.7	1092893.7	6		0.40		−0.08	0.11	N
#b101	509381.4	1092871.8	6		−0.02		−0.27	0.34	N
#b102	509234.0	1092843.8	6		−0.78		0.00	0.07	N
#b103	509086.6	1092815.9	6		0.11		−0.27	0.34	N
#b104	508939.2	1092787.9	6		−1.50		−0.27	0.34	N
#b105	508791.8	1092759.9	6		0.36		−0.27	0.34	N
#b106	508644.4	1092731.9	6		0.42				Y
#b107	508497.0	1092703.9	6		0.00				Y
#b108	508349.6	1092675.9	6		0.35				Y
#b109	508202.2	1092648.0	6		0.05		−0.24	0.08	N
#b110	508054.8	1092620.0	6		0.17		−0.27	0.34	N
#b111	507908.3	1092587.9	6		0.53		−0.27	0.34	N
#b112	507762.1	1092554.5	6		0.18		−0.28	0.11	N
#b113	507615.9	1092521.2	6		−0.19		−0.27	0.34	N
#b114	507469.6	1092487.8	6		0.16		−0.27	0.34	N
#b115	507323.4	1092454.4	6		−0.23		−0.06	0.09	N
#b116	507177.1	1092421.1	6		−0.27		−0.20	0.09	N
#b117	507030.9	1092387.7	6		−0.04		−0.27	0.34	N
#b118	506884.6	1092354.4	6		−0.28		−0.27	0.34	N
#b119	506738.4	1092321.0	6		−0.53		−0.20	0.09	N
#b120	506592.2	1092287.7	6		−0.36		−0.20	0.09	N
#b121	506446.0	1092254.3	6		0.42		−0.27	0.34	N
#b122	506299.7	1092221.0	6		−0.08		−0.27	0.34	N
#b123	506153.5	1092187.6	6		−0.32		−0.27	0.34	N
#b124	506007.3	1092154.3	6		−0.58		−0.27	0.34	N
#b125	505861.1	1092120.9	6		−1.23		−0.27	0.34	N
#b126	505714.8	1092087.6	6		−1.66		−0.27	0.34	N
#b127	505568.2	1092055.7	6		−2.50		−0.27	0.34	N
#b128	505421.2	1092025.7	6		−2.38		−0.27	0.34	N
#b129	505274.2	1091995.6	6		−0.71		−0.27	0.34	N
#b130	505127.2	1091965.5	6		−0.83		−0.27	0.34	N
#b131	504980.2	1091935.5	6		−0.29				Y
#b132	504833.2	1091905.4	6		−0.26		−0.67	0.09	N
#b133	504686.2	1091875.3	6		0.19		−0.27	0.34	N
#b134	504245.3	1091785.2	6		0.03		−0.27	0.34	N
#b135	504098.3	1091755.1	6		−0.14		−1.64	0.07	N
#b136	503951.3	1091725.0	6		0.20		−1.64	0.07	N
#b137	503804.3	1091695.0	6		−0.11		−0.27	0.34	N
#b138	503657.3	1091664.9	6		−0.41		−0.27	0.34	N
#b139	503510.3	1091635.2	6		−0.17				Y
#b140	503657.3	1091664.9	6		−0.39				Y
#b141	503510.3	1091635.2	6		−0.59				Y
#b142	503362.5	1091609.5	6		0.13				Y
#b143	503214.7	1091583.8	6		−0.07				Y
#b144	503066.9	1091558.0	6		−0.53				Y
#b145	502919.1	1091532.3	6		0.02				Y
#b146	502771.3	1091506.6	6		0.54				Y
#b147	502623.5	1091480.9	6		−0.18				Y
#b148	502475.7	1091455.1	6	0.26	−0.43	−0.06			Y
#b149	502327.9	1091429.4	6	−0.11	−0.20	−0.15			Y
#b150	502180.1	1091403.7	6	−0.27	−0.67	−0.46			Y
#b151	502032.3	1091378.0	6	−1.31	0.24	−0.59	−0.43	0.02	N
#b152	501884.5	1091352.2	6	−0.43	0.21	−0.13			Y
#b153	501736.7	1091326.5	6	−0.39	0.16	−0.14			Y
#b154	501588.9	1091300.8	6	−0.11	0.37	0.11			Y
#b155	501441.1	1091275.0	6	−0.48	0.47	−0.04			Y
#b156	501293.3	1091249.3	6	0.25	0.24	0.24			Y
#b157	501145.5	1091223.6	6	0.16	0.19	0.17			Y
#b158	500997.6	1091198.4	6	0.91	0.29	0.63			Y
#b159	500849.5	1091174.4	6	0.46	−0.70	−0.08			Y
#b160	500701.4	1091150.5	6	0.19	0.07	0.13			Y
#b161	500553.3	1091126.6	6	0.13	0.36	0.24			Y
#b162	500405.2	1091102.7	6	0.30	−0.02	0.15			Y

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#b163	500257.1	1091078.8	6	0.39	−0.13	0.15			Y
#b164	500109.0	1091054.9	6	−0.06	−0.11	−0.08	−0.24	0.07	N
#b165	499960.9	1091030.9	6	−0.05	0.17	0.05	−0.27	0.34	N
#b166	499812.8	1091007.0	6	−0.51	−0.09	−0.31	−0.27	0.34	N
#b167	499664.7	1090983.1	6	−0.52	0.06	−0.25	−0.35	0.07	N
#b168	499516.6	1090959.2	6	−0.31	0.21	−0.07	−0.19	0.06	N
#b169	499368.5	1090935.3	6	−0.05	−0.18	−0.11	−0.17	0.06	N
#b170	499220.4	1090911.4	6	−0.27	−0.20	−0.24	−0.27	0.34	N
#b171	499072.3	1090887.4	6	−0.20	−0.17	−0.19	−0.27	0.34	N
#b172	498924.2	1090863.5	6	−0.17	−0.87	−0.49			Y
#b173	498776.1	1090839.6	6	−0.87	−0.33	−0.62	−0.27	0.34	N
#b174	498628.0	1090815.7	6	−1.86	−0.81	−1.38	−0.27	0.34	N
#b175	498480.1	1090790.8	6	−1.80	−0.14	−1.03	−0.27	0.34	N
#b176	498333.4	1090759.3	6	−1.90	0.29	−0.89	0.00	0.07	N
#b177	498186.7	1090727.8	6	−1.63	0.12	−0.82	0.00	0.07	N
#b178	498040.0	1090696.3	6	−1.42	0.18	−0.68	−0.27	0.34	N
#b179	497893.3	1090664.9	6	−2.29	0.19	−1.15	−0.27	0.34	N
#b180	497746.6	1090633.4	6	−0.90	−1.35	−1.11	−0.27	0.34	N
#b181	497599.9	1090601.9	6	−0.49	−1.13	−0.78			Y
#b182	497453.2	1090570.4	6	−0.81	−0.88	−0.84			Y
#b183	497306.5	1090538.9	6	−2.14	−0.18	−1.23	−0.25	0.08	N
#b184	497159.8	1090507.4	6	−1.25	0.57	−0.41	−0.25	0.08	N
#b185	497013.1	1090475.9	6	−0.25	1.02	0.34			N
#b186	496866.4	1090444.5	6	−0.04	0.62	0.26			Y
#b187	496719.8	1090413.0	6	0.16	1.27	0.67			Y
#b188	496573.1	1090381.5	6	0.43	0.17	0.31			Y
#b189	496426.4	1090350.0	6	0.57	−0.19	0.22			Y
#b190	496279.7	1090318.5	6	0.15	0.01	0.09	−0.27	0.34	N
#b191	496132.7	1090288.6	6	−0.02	−0.39	−0.19	−0.27	0.34	N
#b192	495984.9	1090263.0	6	−0.51	−0.88	−0.68	−0.27	0.34	N
#b193	495837.1	1090237.4	6	−0.14	−0.01	−0.08	−0.27	0.34	N
#b194	495689.3	1090211.8	6	−0.25	−0.39	−0.32	−0.27	0.34	N
#b195	495541.5	1090186.2	6	−0.15	−0.57	−0.34	−0.27	0.34	N
#b196	495393.7	1090160.6	6	1.32	−0.32	0.56			Y
#b197	495246.4	1090132.9	6	−0.58	0.22	−0.21			Y
#b198	495102.6	1090090.8	6	−1.28	0.60	−0.41			Y
#b199	494961.5	1090040.0	6	−1.22	−0.24	−0.77			Y
#b200	494820.4	1089989.2	6	−0.86	−0.72	−0.80			Y
#b201	494677.3	1089945.2	6	−0.73	−0.68	−0.71			Y
#b202	494530.8	1089913.0	6	−0.61	0.32	−0.18	−0.27	0.34	N
#b203	494384.3	1089880.9	6		0.15				Y
#b204	494237.8	1089848.8	6	0.65	0.03	0.37			Y
#b205	494091.3	1089816.7	6	−0.87	0.33	−0.32			Y
#b206	493944.8	1089784.5	6	−1.54	−0.80	−1.20			Y
#b207	493798.3	1089752.4	6	−0.53	1.45	0.38			Y
#b208	493652.8	1089716.0	6	−0.47	1.45	0.42			Y
#b209	493507.8	1089677.7	6	−0.65	−0.15	−0.42	−0.27	0.34	N
#b210	493362.7	1089639.5	6	−0.90	−0.47	−0.70	−0.27	0.34	N
#b211	493217.7	1089601.3	6	−0.68	0.24	−0.26	−0.27	0.34	N
#b212	493072.7	1089563.0	6	−0.79	0.43	−0.23	−0.14	0.09	N
#b213	492927.6	1089524.8	6	−0.66	−0.06	−0.38	−0.12	0.08	N
#b214	492782.6	1089486.5	6	−0.24	−0.14	−0.19	−0.12	0.08	N
#b215	492637.5	1089448.3	6	−0.58	−0.51	−0.55	−0.34	0.08	N
#b216	492492.5	1089410.1	6	−0.28	−0.56	−0.41	−0.42	0.10	N
#b217	492347.4	1089371.8	6	−0.43	−0.10	−0.28	−0.42	0.10	N
#b218	492202.4	1089333.6	6	−0.07	0.24	0.07	−0.27	0.34	N
#b219	492057.4	1089295.3	6	0.50	−0.68	−0.05	−0.27	0.34	N
#b220	491912.3	1089257.1	6	0.82	−0.91	0.02	−0.27	0.34	N
#b221	491767.3	1089218.8	6	0.23	−0.75	−0.22	−0.27	0.34	N
#b222	491622.2	1089180.6	6	−0.23	−0.67	−0.43	−0.14	0.07	N
#b223	491477.2	1089142.4	6	−0.26	−0.47	−0.36	−0.27	−0.27	N
#b224	491332.2	1089104.0	6	−0.04	−0.01	−0.03	−0.27	0.34	N
#b225	491187.9	1089063.0	6	0.38	0.20	0.30	−0.27	0.34	N
#b226	491043.6	1089021.9	6	−0.33	0.00	−0.18	−0.27	0.34	N
#b227	490899.3	1088980.8	6	0.17	−1.00	−0.37	−0.27	0.34	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#b228	490755.0	1088939.8	6	0.13	−1.45	−0.60	−0.27	0.34	N
#b229	490610.7	1088898.7	6	0.29	−1.07	−0.34	0.00	0.03	N
#b230	490466.4	1088857.6	6	0.31	−0.41	−0.02	0.00	0.03	N
#b231	490322.1	1088816.5	6	−0.13	−0.54	−0.32	−0.27	0.34	N
#b232	490177.8	1088775.5	6	0.15	−1.25	−0.50	−0.27	0.34	N
#b233	490032.7	1088737.7	6	0.17	−0.42	−0.10	−0.27	0.34	N
#b234	489886.9	1088702.5	6	0.03	−0.45	−0.19	−0.27	0.34	N
#b235	489737.8	1088690.8	6	0.31	−0.37	0.00	−0.34	0.20	N
#b236	489587.9	1088685.1	6	−0.51	0.40	−0.09	−0.34	0.20	N
#b237	489438.0	1088679.4	6	−0.90	−0.38	−0.66	−0.27	0.34	N
#b238	489288.1	1088673.7	6	0.77	−0.73	0.08	−0.27	0.34	N
#b239	489138.2	1088668.0	6	0.71	−0.16	0.31	−0.27	0.34	N
#b240	488988.3	1088662.3	6	0.80	−0.40	0.25	−0.27	0.34	N
#b241	488838.4	1088656.6	6	1.21	−0.98	0.20	−0.27	0.34	N
#b242	488693.5	1088630.7	6	0.13	−1.05	−0.41	−0.27	0.34	N
#b243	488558.2	1088565.9	6	0.02	−0.88	−0.40	−0.27	0.34	N
#b244	488422.9	1088501.1	6	−0.86	−0.05	−0.48	−0.27	0.34	N
#b245	488287.6	1088436.3	6	−0.12	−0.94	−0.50	−0.27	0.34	N
#b246	488158.1	1088361.6	6	−0.38	−0.07	−0.24	−0.27	0.34	N
#b247	488034.6	1088276.5	6	−0.74	−0.22	−0.50	−0.27	0.34	N
#b248	487911.0	1088191.5	6	0.07	−0.75	−0.31	−0.27	0.34	N
#b249	487787.5	1088106.4	6	0.42	−0.12	0.17	−0.27	0.34	N
#b250	487645.1	1088071.0	6	0.16	0.03	0.10	−0.16	0.08	N
#b251	487496.2	1088052.8	6	0.21	−0.12	0.06	−0.20	0.08	N
#b252	487347.3	1088034.6	6	0.39	−0.17	0.13	−0.21	0.08	N
#b253	487198.4	1088016.3	6	0.33	−0.08	0.14			Y
#b254	487049.5	1087998.1	6	−0.16	−0.33	−0.24	−0.27	0.34	N
#b255	486900.6	1087979.9	6	−0.16	−0.70	−0.41	−0.27	0.34	N
#b256	486751.7	1087961.6	6	−0.06	−0.73	−0.37	−0.27	0.34	N
#b257	486602.8	1087943.4	6	0.30	−0.71	−0.17	−0.27	0.34	N
#b258	486453.9	1087925.2	6	0.38	−1.13	−0.31	−0.27	0.34	N
#b259	486305.0	1087906.9	6	0.64	0.03	0.36	−0.27	0.34	N
#b260	486156.1	1087888.7	6	0.00	0.13	0.06	−0.09	0.08	N
#b261	486007.2	1087870.5	6	−0.23	0.51	0.11			Y
#b262	485858.3	1087852.2	6	−0.23	0.71	0.20			Y
#b263	485709.4	1087834.0	6	−0.37	0.45	0.01			Y
#b264	485560.5	1087815.8	6	−0.46	0.32	−0.10			Y
#b265	485411.6	1087797.5	6	−0.38	0.15	−0.13			Y
#b266	485262.7	1087779.3	6	−0.64	0.25	−0.23			Y
#b267	485113.8	1087761.1	6	−0.33	0.21	−0.08			Y
#b268	484964.9	1087742.8	6	−0.38	0.04	−0.19			Y
#b269	484816.0	1087724.6	6	−0.39	0.22	−0.11			Y
#b270	484667.1	1087706.4	6	−0.40	0.54	0.03			Y
#b271	484518.2	1087688.1	6	−0.16	0.58	0.18			Y
#b272	484369.3	1087669.9	6	−0.09	0.17	0.03	−0.27	0.34	N
#b273	484220.4	1087651.7	6	1.27	−0.81	0.31	−0.27	0.34	N
#b274	484071.5	1087633.4	6	0.85	−1.07	−0.04	−0.27	0.34	N
#b275	483922.6	1087615.2	6	−0.35	0.19	−0.10	−0.16	0.08	N
#b276	483773.7	1087597.0	6	−0.24	0.03	−0.12	−0.18	0.07	N
#b277	483624.8	1087578.7	6	−0.04	0.33	0.13	−0.27	0.34	N
#b278	483475.9	1087560.5	6	0.02	0.43	0.21	−0.27	0.34	N
#b279	483327.0	1087542.2	6	−0.38	0.28	−0.07	−0.27	0.34	N
#b280	483178.1	1087524.0	6	−0.37	0.49	0.03	−0.27	0.34	N
#b281	483029.2	1087505.8	6	0.12	0.34	0.22	−0.27	0.34	N
#b282	482880.3	1087487.5	6	−0.16	−0.06	−0.11			Y
#b283	482731.4	1087469.3	6	0.51	1.12	0.79			Y
#b284	482582.5	1087451.1	7	1.03	1.00	1.02			Y
#b285	482433.6	1087432.8	7	−0.26	0.43	0.06			Y
#b286	482284.7	1087414.6	7	−0.52	−0.02	−0.29			Y
#b287	482135.8	1087396.4	7	−0.51	−0.05	−0.30			Y
#b288	481986.9	1087378.1	7	−0.48	−0.38	−0.43			Y
#b289	481838.0	1087359.9	7	−0.19	−0.13	−0.16			Y
#b290	481689.1	1087341.7	7	0.01	0.00	0.01	−0.05	0.05	N
#b291	481540.2	1087323.4	7	0.20	0.18	0.19	−0.05	0.05	N
#b292	481391.3	1087305.2	7	0.08	0.23	0.15	−0.09	0.08	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#b293	481242.4	1087287.0	7	0.53	−0.03	0.27	−0.09	0.08	N
#b294	481092.9	1087276.6	7	0.82	−0.64	0.15	−0.07	0.08	N
#b295	480943.0	1087271.0	7	−0.30	−0.10	−0.21	−0.05	0.05	N
#b296	480793.1	1087265.5	7	−0.03	−0.32	−0.17	−0.05	0.05	N
#b297	480643.4	1087266.9	7	−0.31	−0.28	−0.30	−0.05	0.05	N
#b298	480493.9	1087279.2	7	−0.94	0.46	−0.29	−0.05	0.05	N
#b299	480344.4	1087291.5	7	−1.01	0.45	−0.33	−0.05	0.05	N
#b300	480199.4	1087323.8	7	−0.98	0.47	−0.31	−0.05	0.05	N
#b301	480059.1	1087376.8	7	−0.92	0.28	−0.37	−0.05	0.05	N
#b302	479926.8	1087445.0	7	−1.11	0.58	−0.33	−0.05	0.05	N
#b303	479803.4	1087530.3	7	−0.91	−0.05	−0.51	−0.05	0.05	N
#b304	479684.7	1087620.7	7	−0.93	−0.06	−0.53	−0.05	0.05	N
#b305	479588.0	1087735.3	7	−1.40	1.10	−0.25	0.00	0.08	N
#b306	479495.4	1087852.8	7	−1.46	1.36	−0.16	0.00	0.08	N
#b307	479420.4	1087982.7	7	−1.38	1.32	−0.13	−0.05	0.05	N
#b308	479345.3	1088112.6	7	−1.03	0.81	−0.18	−0.05	0.05	N
#b309	479287.9	1088250.9	7	−0.96	0.77	−0.16	−0.05	0.05	N
#b310	479249.1	1088393.9	7	−1.01	0.85	−0.15	−0.05	0.05	N
#b311	479243.0	1088543.8	7			0.21	−0.05	0.05	N
#c1	478919.2	1087905.9	8				NO DATA	NO DATA	N
#c2	478882.5	1087760.8	8				NO DATA	NO DATA	N
#c3	478814.4	1087627.2	8			−5.01	NO DATA	NO DATA	N
#c4	478742.1	1087496.3	8			−4.54	NO DATA	NO DATA	N
#c5	478646.2	1087380.9	8	−6.49	−0.09	−3.53	−0.09	3.70	N
#c6	478538.6	1087279.8	8	−6.19	−0.25	−3.44	−0.25	3.70	N
#c7	478406.3	1087209.1	8	−8.64	−0.18	−4.74	−0.18	3.70	N
#c8	478274.0	1087138.4	8	−11.28	−0.54	−6.32	−0.54	3.70	N
#c9	478141.6	1087067.9	8	−14.51	0.11	−7.76	0.11	3.70	N
#c10	477999.0	1087021.5	8	−17.86	0.90	−9.20	0.90	3.70	N
#c11	477856.4	1086975.1	8	−18.18	−2.91	−11.13	−2.91	3.70	N
#c12	477713.8	1086928.7	8	−18.86	−2.50	−11.31	−2.50	3.70	N
#c13	477570.1	1086885.7	8	−18.80	−2.34	−11.20	−2.34	3.70	N
#c14	477425.3	1086846.5	8	−18.30	−2.33	−10.93	−2.33	3.70	N
#c15	477280.5	1086807.3	8	−18.10	−1.27	−10.33	−1.27	3.70	N
#c16	477135.7	1086768.1	8	−15.83	−1.87	−9.38	−1.87	3.70	N
#c17	476990.9	1086728.9	8	−12.63	−3.15	−8.25	−3.15	3.70	N
#c18	476846.1	1086689.7	8	−11.92	−2.47	−7.56	−2.47	3.70	N
#c19	476701.3	1086650.5	8	−12.13	−1.84	−7.38	−1.84	3.70	N
#c20	476556.5	1086611.3	8	−11.58	−2.46	−7.37	−2.46	3.70	N
#c21	476411.7	1086572.1	8	−11.29	−3.33	−7.62	−3.33	3.70	N
#c22	476266.9	1086532.9	8	−11.05	−2.65	−7.18			Y
#c23	476122.1	1086493.7	8	−10.31	−3.63	−7.22			Y
#c24	475977.3	1086454.5	8	−9.95	−5.10	−7.71			Y
#c25	475831.6	1086419.1	8	−9.87	−5.17	−7.70			Y
#c26	475685.1	1086387.0	8	−9.09	−5.29	−7.33			Y
#c27	475538.6	1086354.9	8	−9.24	−5.07	−7.32			Y
#c28	475392.1	1086322.8	8	−10.04	−4.84	−7.64			Y
#c29	475245.6	1086290.7	8	−11.65	−1.85	−7.13			Y
#c30	475099.1	1086258.6	8	−11.37	−2.37	−7.22			Y
#c31	474952.6	1086226.5	8	−11.84	−1.74	−7.18			Y
#c32	474806.1	1086194.4	8	−11.92	−1.30	−7.02			Y
#c33	474659.6	1086162.4	8	−11.91	−1.93	−7.31			Y
#c34	474513.1	1086130.3	8	−11.58	−1.94	−7.13			Y
#c35	474366.6	1086098.2	8	−11.53	−0.86	−6.60			Y
#c36	474220.1	1086066.1	8	−11.95	−1.53	−7.14			Y
#c37	474073.6	1086034.0	8	−10.77	−2.27	−6.84			Y
#c38	473927.1	1086001.9	8	−8.95	−1.96	−5.72			Y
#c39	473780.6	1085969.8	8	−7.75	−1.67	−4.94			Y
#c40	473634.1	1085937.7	8	−5.98	−1.65	−3.98			Y
#c41	473487.6	1085905.6	8	−4.49	−0.70	−2.74			Y
#c42	473341.1	1085873.5	8	−3.82	−0.58	−2.32			Y
#c43	473194.6	1085841.4	8	−2.44	0.21	−1.22			Y
#c44	473048.1	1085809.4	8	−1.55	−0.68	−1.15			Y
#c45	472901.6	1085777.3	8	1.11	−3.04	−0.81			Y
#c46	472755.1	1085745.2	8	0.61	−1.71	−0.46			Y

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#c47	472608.6	1085713.1	8	0.85	−1.55	−0.26			Y
#c48	472462.1	1085681.0	8	1.02	−0.03	0.54			Y
#c49	472315.6	1085648.9	8	1.80	−2.00	0.05			Y
#c50	472169.1	1085616.8	8	1.95	−2.13	0.07			Y
#c51	472022.6	1085584.7	8	1.89	−2.21	−0.00			Y
#c52	471876.1	1085552.6	8	1.60	−1.42	0.21			Y
#c53	471729.6	1085520.5	8	1.41	−1.67	−0.01			Y
#c54	471583.1	1085488.4	8	2.59	−2.88	0.06			Y
#c55	471436.6	1085456.4	8	3.22	−3.65	0.05			Y
#c56	471290.1	1085424.3	8	3.86	−3.87	0.29			Y
#c57	471143.6	1085392.2	8	5.32	−5.41	0.37			Y
#c58	470997.1	1085360.1	8	5.81	−5.41	0.63			Y
#c59	470850.6	1085328.0	8	5.46	−4.99	0.64			Y
#c60	470704.1	1085295.9	8	5.13	−5.14	0.39			Y
#c61	470557.6	1085263.8	8	4.77	−5.07	0.23			Y
#c62	470411.1	1085231.7	8	3.25	−3.40	0.18			Y
#c63	470264.6	1085199.6	8	3.17	−3.15	0.26			Y
#c64	470118.1	1085167.5	8	1.86	−1.49	0.32			Y
#c65	469971.6	1085135.4	8	0.85	−0.33	0.30			Y
#c66	469825.1	1085103.4	8	0.74	−0.95	−0.04			Y
#c67	469678.6	1085071.3	8	2.76	−0.94	1.05			Y
#c68	469532.1	1085039.2	8	2.94	−0.85	1.19			Y
#c69	469385.6	1085007.1	8	2.36	−0.53	1.03			Y
#c70	469239.1	1084975.0	8	2.26	−0.63	0.92			Y
#c71	469092.6	1084942.9	8	1.47	−0.45	0.58			Y
#c72	468946.1	1084910.8	8	0.49	1.10	0.77			Y
#c73	468799.6	1084878.7	8	3.07	−0.88	1.25			Y
#c74	468653.1	1084846.6	8	2.48	−1.22	0.77			Y
#c75	468506.6	1084814.5	8	2.52	−1.71	0.57			Y
#c76	468360.1	1084782.4	8	3.91	−2.38	1.01			Y
#c77	468213.6	1084750.4	8	4.18	−3.36	0.70			N
#c78	468067.1	1084718.3	8	3.98	−2.50	0.99			N
#c79	467920.6	1084686.2	8	4.73	−3.93	0.74			Y
#c80	467774.1	1084653.8	8	4.73	−4.39	0.52			Y
#c81	467628.8	1084616.5	8	4.62	−3.85	0.71			Y
#c82	467483.5	1084579.2	8	5.01	−4.60	0.57			Y
#c83	467338.2	1084542.0	8	2.53	−2.18	0.36			Y
#c84	467192.9	1084504.7	8	4.59	−5.34	0.00			Y
#c85	467047.6	1084467.5	8	0.31	−0.78	−0.20			Y
#c86	466902.3	1084430.2	8	1.87	−1.46	0.33			Y
#c87	466757.0	1084392.9	8	0.46	−0.60	−0.02			Y
#c88	466611.7	1084355.7	8	2.47	−1.88	0.46			Y
#c89	466466.4	1084318.4	8	0.70	0.54	0.63			Y
#c90	466321.1	1084281.1	8	2.11	−1.05	0.65			Y
#c91	466175.8	1084243.9	8	1.04	0.05	0.58			Y
#c92	466030.5	1084206.6	8	0.73	−0.05	0.37			Y
#c93	465885.2	1084169.3	8	0.62	−0.46	0.12			Y
#c94	465739.9	1084132.1	8	1.46	−0.42	0.59			Y
#c95	465594.6	1084094.8	8	1.54	−0.61	0.54			Y
#c96	465449.3	1084057.6	8	1.74	−0.25	0.82			Y
#c97	465304.0	1084020.3	8	1.89	−1.01	0.55			Y
#c98	465158.7	1083983.0	9	1.36	−0.38	0.56	−0.12	0.03	N
#c99	465013.4	1083945.8	9	1.04	−0.47	0.34	−0.62	0.76	N
#c100	464868.1	1083908.5	9	0.04	0.41	0.21	−0.62	0.76	N
#c101	464722.8	1083871.2	9	0.57	−0.30	0.17	−0.62	0.76	N
#c102	464577.5	1083834.0	9	0.70	−0.09	0.34	−0.82	0.08	N
#c103	464432.2	1083796.7	9	0.41	−0.16	0.14	−0.82	0.08	N
#c104	464286.9	1083759.5	9	0.66	−0.22	0.26	−0.62	0.76	N
#c105	464141.6	1083722.2	9	0.27	−0.25	0.03			Y
#c106	463996.3	1083684.9	9	0.95	−0.35	0.35			Y
#c107	463851.0	1083647.7	9	0.51	−0.01	0.27	−0.62	0.76	N
#c108	463705.7	1083610.4	9	0.05	0.07	0.06	−0.62	0.76	N
#c109	463560.4	1083573.1	9	−0.24	0.55	0.13	−0.62	0.76	N
#c110	463415.1	1083535.9	9	0.39	0.25	0.32	−0.62	0.76	N
#c111	463269.8	1083498.6	9	1.11	−0.55	0.34	−0.05	0.07	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#c112	463124.5	1083461.3	9	1.81	−1.15	0.44	−0.05	0.07	N
#c113	462979.2	1083424.1	9	2.46	−1.49	0.64	−0.14	0.07	N
#c114	462833.9	1083386.8	9	3.45	−1.87	0.99	−0.62	0.76	N
#c115	462688.6	1083349.6	9	2.60	−1.08	0.90	−0.62	0.76	N
#c116	462543.3	1083312.3	9	2.88	−0.94	1.12	0.00	0.07	N
#c117	462398.0	1083275.0	9	2.45	−0.75	0.97			Y
#c118	462252.7	1083237.8	9	2.53	−2.53	0.20			Y
#c119	462107.4	1083200.5	9	2.26	−2.73	−0.04			Y
#c120	461962.1	1083163.2	9	1.11	−0.81	0.22			Y
#c121	461816.8	1083126.0	9		−1.31		−0.62	0.76	N
#c122	461671.5	1083088.7	9	0.84	−0.10	0.41	−0.62	0.76	N
#c123	461526.2	1083051.5	9	0.46	−0.56	−0.01	−0.62	0.76	N
#c124	461380.9	1083014.2	9	0.96	−1.33	−0.09	−0.62	0.76	N
#c125	461235.6	1082976.9	9	0.85	0.40	0.64	−0.62	0.76	N
#c126	461090.3	1082939.7	9	0.79	0.00	0.43	−0.62	0.76	N
#c127	460945.0	1082902.4	9	0.81	−0.46	0.22	−0.62	0.76	N
#c128	460799.7	1082865.1	9	0.04	0.84	0.41			Y
#c129	460654.4	1082827.9	9	−0.01	0.24	0.11	−0.14	0.07	N
#c130	460509.1	1082790.6	9	0.17	−0.01	0.09			Y
#c131	460363.8	1082753.3	9	0.73	−0.63	0.10	−0.12	0.07	N
#c132	460218.5	1082716.1	9	0.33	−0.67	−0.13	−0.12	0.07	N
#c133	460073.2	1082678.8	9		−0.44				Y
#c134	459927.9	1082641.6	9	−1.71	3.35	0.62			Y
#c135	459782.6	1082604.3	9	0.35	1.67	0.96			Y
#c136	459637.3	1082567.0	9	1.08	0.23	0.69			Y
#c137	459492.0	1082529.8	9	0.41	0.04	0.24			Y
#c138	459346.7	1082492.5	9	0.29	−0.12	0.10			Y
#c139	459201.4	1082455.2	9	0.54	−0.39	0.11			Y
#c140	459056.1	1082418.0	9	0.54	−0.39	0.11			Y
#c141	458910.8	1082380.7	9	0.55	−0.37	0.13	−0.62	0.76	N
#c142	458765.5	1082343.4	9	0.47	−0.71	−0.07			Y
#c143	458620.2	1082306.2	9	0.03	−0.50	−0.21			Y
#c144	458474.9	1082268.9	9	−0.26	−0.80	−0.51			Y
#c145	458329.6	1082231.7	9	−0.02	−0.33	−0.16			Y
#c146	458184.3	1082194.4	9	0.74	−0.10	0.35			Y
#c147	458039.0	1082157.1	9	5.11	−3.13	1.30			Y
#c148	457893.7	1082119.9	9	0.51	−0.31	0.13			Y
#c149	457748.4	1082082.6	9	0.72	0.14	0.46			Y
#c150	457603.1	1082045.3	9	0.93	−1.04	0.02			Y
#c151	457457.8	1082008.1	9	−0.06	0.38	0.14			Y
#c152	457312.5	1081970.8	9	0.19	0.21	0.20			Y
#c153	457167.2	1081933.6	9	0.27	−1.13	−0.38			Y
#c154	457021.9	1081896.3	9	0.66	−0.99	−0.10			Y
#c155	456876.6	1081859.0	9	−1.03	0.29	−0.42	−0.62	0.76	N
#c156	456731.3	1081821.8	9	0.24	0.00	0.13			Y
#c157	456586.0	1081784.5	9	0.31	−0.15	0.10			Y
#c158	456441.0	1081746.4	9	0.37	0.58	0.47			Y
#c159	456297.8	1081701.7	9	1.13	−0.35	0.44			Y
#c160	456154.6	1081657.0	9	0.94	0.50	0.73			Y
#c161	456011.4	1081612.4	9	1.29	−1.27	0.10			Y
#c162	455868.2	1081567.7	9	0.57	−0.35	0.14			Y
#c163	455725.0	1081523.1	9	0.41	−0.50	−0.01			Y
#c164	455581.8	1081478.4	9	1.75	−1.21	0.38			Y
#c165	455438.6	1081433.7	9	0.02	1.68	0.79			Y
#c166	455295.4	1081389.1	9	1.22	2.09	1.62			Y
#c167	455152.2	1081344.4	9	−0.22	0.55	0.13			Y
#c168	455009.0	1081299.8	9	0.52	0.40	0.46			Y
#c169	454865.8	1081255.1	9	1.07	−0.95	0.14	−0.62	0.76	N
#c170	454722.6	1081210.4	9	0.41	0.22	0.32	−0.62	0.76	N
#c171	454579.4	1081165.8	9	0.01	−0.14	−0.06	−0.62	0.76	N
#c172	454436.2	1081121.1	9	0.79	−2.13	−0.56	−0.62	0.76	N
#c173	454293.0	1081076.5	9	0.08	−0.35	−0.12	−0.44	0.04	N
#c174	454149.8	1081031.8	9	0.94	−0.57	0.24	−0.36	0.04	N
#c175	454006.6	1080987.1	9	2.58	−1.27	0.80	−0.62	0.76	N
#c176	453863.4	1080942.5	9	2.71	−1.66	0.69	−0.62	0.76	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#c177	453720.2	1080897.8	9	1.07	−1.82	−0.27	−0.62	0.76	N
#c178	453577.0	1080853.2	9	1.27	−1.92	−0.20	−0.62	0.76	N
#c179	453433.8	1080808.5	9	0.86	−0.80	0.09	−0.62	0.76	N
#c180	453290.6	1080763.8	9	2.18	−1.14	0.65	−0.62	0.76	N
#c181	453147.4	1080719.2	9	−0.67	0.15	−0.29	−0.62	0.76	N
#c182	453004.2	1080674.5	9	2.90	−2.55	0.38	−0.62	0.76	N
#c183	452861.0	1080629.9	9	2.59	−2.84	0.08	−0.62	0.76	N
#c184	452717.8	1080585.2	9	1.86	−1.69	0.22	−0.62	0.76	N
#c185	452574.6	1080540.5	9		−0.35		−0.62	0.76	N
#c186	452431.4	1080495.9	9		−1.38		−0.62	0.76	N
#c187	452288.2	1080451.2	9		0.57		−0.62	0.76	N
#c188	452145.0	1080406.5	9		−0.02		−0.62	0.76	N
#c189	452001.8	1080361.9	9		0.76				Y
#c190	451858.6	1080317.2	9		0.38		−1.07	0.10	N
#c191	451715.4	1080272.6	9		0.28		−0.62	0.76	N
#c192	451572.2	1080227.9	9		0.65		−0.62	0.76	N
#c193	451429.0	1080183.2	9		−0.46		−0.62	0.76	N
#c194	451285.8	1080138.6	9		−1.34		−0.62	0.76	N
#c195	451145.5	1080086.3	9		−4.41				Y
#c196	451009.5	1080023.1	9		0.45				Y
#c197	450873.5	1079959.9	9		−0.13				Y
#c198	450737.4	1079896.7	9		−0.75				Y
#c199	450601.4	1079833.5	9		−0.05				Y
#c200	450476.0	1079758.6	9		−0.29				N
#c201	450478.2	1079617.1	10				−0.09	0.16	N
#c202	450554.7	1079488.1	10				−0.09	0.16	N
#c203	450544.3	1079346.6	10				−0.09	0.16	N
#c204	450451.0	1079230.0	10				−0.09	0.16	N
#c205	450319.3	1079163.8	10				−0.09	0.16	N
#c206	450177.4	1079115.0	10				−0.09	0.16	N
#c207	450031.8	1079096.8	10				−0.09	0.16	N
#c208	449891.7	1079142.2	10				−0.09	0.16	N
#c209	449779.5	1079233.7	10				−0.09	0.16	N
#c210	449680.3	1079341.4	10				−0.09	0.16	N
#c211	449545.5	1079323.8	11	1.03	−1.17	0.02	0.00	0.07	N
#c212	449430.2	1079227.9	11	0.64	−0.34	0.19	0.00	0.07	N
#c213	449299.2	1079155.1	11	0.17	0.26	0.21	0.00	0.07	N
#c214	449161.4	1079100.6	11	0.50	0.19	0.36	0.00	0.07	N
#c215	449013.8	1079073.9	11	−0.03	0.28	0.12	0.00	0.07	N
#c216	448866.2	1079047.2	11	0.20	0.80	0.48	0.00	0.07	N
#c217	448717.1	1079031.3	11	0.31	0.61	0.45	0.00	0.07	N
#c218	448567.9	1079015.7	11	0.24	0.50	0.36	0.00	0.07	N
#c219	448418.7	1079000.1	11	0.01	0.36	0.18	0.00	0.07	N
#c220	448278.9	1078952.9	11		1.59		0.00	0.07	N
#c221	448188.4	1078841.6	11		0.66		0.00	0.07	N
#c222	448120.2	1078708.0	11		0.48		0.00	0.07	N
#c223	448052.1	1078574.4	11		0.60		0.00	0.07	N
#c224	447983.9	1078440.8	11.2				−0.09	0.16	N
#c225	447915.8	1078307.2	11.2				−0.09	0.16	N
#c226	447847.6	1078173.6	11.2				−0.09	0.16	N
#c227	447779.5	1078040.0	11.2				−0.09	0.16	N
#c228	447724.0	1077903.3	11.2				−0.09	0.16	N
#c229	447751.5	1077758.3	11.2				−0.09	0.16	N
#c230	447804.0	1077617.8	11.2				−0.09	0.16	N
#c231	447801.9	1077469.5	11.2				−0.09	0.16	N
#c232	447770.6	1077324.9	11.2				−0.09	0.16	N
#c233	447708.1	1077189.2	11.2				−0.09	0.16	N
#c234	447595.8	1077089.7	11.2				−0.09	0.16	N
#c235	447471.1	1077018.1	11.2				−0.09	0.16	N
#c236	447322.0	1077001.4	11.2				−0.09	0.16	N
#c237	447172.9	1076984.7	11.2				−0.09	0.16	N
#c238	447023.8	1076968.0	11.2				−0.09	0.16	N
#c239	446874.5	1076964.5	11.2				−0.09	0.16	N
#c240	446724.9	1076975.4	11.2				−0.09	0.16	N
#c241	446575.8	1076991.6	11.2				−0.09	0.16	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#c242	446426.8	1077008.6	11.2				-0.09	0.16	N
#c243	446277.8	1077025.5	11.2				-0.09	0.16	N
#c244	446128.8	1077042.5	11.2				-0.09	0.16	N
#c245	445979.8	1077059.5	11.2				-0.09	0.16	N
#c246	445830.8	1077076.5	11.2				-0.09	0.16	N
#c247	445686.9	1077049.1	11.2				-0.09	0.16	N
#c248	445545.6	1076998.8	11.2				-0.09	0.16	N
#c249	445460.2	1076883.3	11.2				-0.09	0.16	N
#c250	445388.8	1076751.4	11.2				-0.08	0.08	N
#c251	445317.5	1076619.4	11.2				-0.08	0.08	N
#c252	445246.2	1076487.4	11.2				-0.08	0.08	N
#c253	445174.8	1076355.5	11.2				-0.08	0.08	N
#c254	445115.4	1076221.8	11.2				-0.09	0.16	N
#c255	445145.3	1076074.8	11.2				-0.09	0.16	N
#c256	445187.0	1075932.1	11.2				-0.09	0.16	N
#c257	445258.6	1075800.3	11.2				-0.09	0.16	N
#c258	445330.2	1075668.5	11.2				-0.09	0.16	N
#c259	445339.3	1075530.9	11.2				-0.09	0.16	N
#c260	444895.7	1075516.8	11.2				-0.09	0.16	N
#c261	445225.9	1075257.4	11.2				-0.09	0.16	N
#c262	445126.9	1075144.7	11.2				-0.09	0.16	N
#c263	445027.8	1075032.1	11.2				-0.09	0.16	N
#c264	444928.8	1074919.4	11.2				-0.09	0.16	N
#c265	444786.0	1074875.9	11.2				-0.09	0.16	N
#c266	444641.8	1074834.7	11.2				-0.09	0.16	N
#c267	444497.6	1074793.5	11.2				-0.09	0.16	N
#c268	444353.4	1074752.3	11.2				-0.09	0.16	N
#c269	444209.2	1074711.2	11.2				-0.09	0.16	N
#c270	444065.0	1074670.0	11.2				-0.09	0.16	N
#c271	443920.8	1074628.8	11.2				-0.09	0.16	N
#c272	443776.6	1074587.6	11.2				-0.09	0.16	N
#c273	443632.4	1074546.4	11.2				-0.09	0.16	N
#c274	443488.2	1074505.2	11.2				-0.09	0.16	N
#c275	443344.0	1074464.1	11.2				-0.09	0.16	N
#c276	443199.8	1074422.9	11.2				-0.09	0.16	N
#c277	443051.4	1074408.9	11.2				-0.09	0.16	N
#c278	442901.5	1074404.4	11.2				-0.09	0.16	N
#c279	442751.6	1074399.9	11.2				-0.09	0.16	N
#c280	442601.7	1074395.4	11.2				-0.09	0.16	N
#c281	442451.8	1074390.9	11.2				-0.20	0.14	N
#c282	442301.9	1074386.4	11.2				-0.06	0.12	N
#c283	442152.0	1074381.9	11.2				-0.08	0.08	N
#c284	442002.1	1074377.4	11.2				0.00	0.11	N
#c285	441852.2	1074372.9	11.2				0.00	0.11	N
#c286	441702.3	1074368.4	11.2				0.00	0.11	N
#c287	441552.4	1074363.9	11.2				-0.09	0.16	N
#c288	441402.5	1074359.4	11.2				-0.09	0.16	N
#c289	441252.6	1074354.9	11.2				-0.09	0.16	N
#c290	441102.7	1074350.4	11.2				-0.09	0.16	N
#c291	440952.8	1074345.9	11.2				-0.09	0.16	N
#c292	440802.9	1074341.4	11.2				-0.09	0.16	N
#c293	440653.0	1074336.9	11.2				-0.09	0.16	N
#c294	440503.1	1074332.4	11.2				-0.09	0.16	N
#c295	440353.2	1074327.9	11.2				-0.09	0.16	N
#c296	440203.3	1074323.4	11.2				-0.09	0.16	N
#c297	440053.4	1074318.9	11.2				-0.09	0.16	N
#c298	439903.5	1074314.4	11.2				0.00	0.12	N
#c299	439753.6	1074309.9	11.2				0.00	0.12	N
#c300	439603.7	1074305.4	11.2				0.00	0.14	N
#c301	439453.8	1074300.9	11.2				-0.09	0.16	N
#c302	439303.9	1074296.4	11.2				-0.09	0.16	N
#c303	439154.0	1074291.9	11.2				-0.09	0.16	N
#c304	439004.1	1074287.4	11.2				-0.09	0.16	N
#c305	438856.9	1074292.0	11.2				-0.09	0.16	N
#c306	438734.4	1074378.6	11.2				-0.09	0.16	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#c307	438611.9	1074465.1	11.2				-0.09	0.16	N
#c308	438542.6	1074587.3	11.2				-0.09	0.16	N
#c309	438509.3	1074733.6	11.2				-0.09	0.16	N
#c310	438476.1	1074879.8	11.2				-0.09	0.16	N
#c311	438473.2	1075028.0	11.2				-0.09	0.16	N
#c312	438487.9	1075177.3	11.2				-0.09	0.16	N
#c313	438502.6	1075326.6	11.2				-0.07	0.10	N
#c314	438455.9	1075461.5	11.3				-0.07	0.10	N
#c315	438338.5	1075529.8	11.3				-0.09	0.16	N
#c316	438189.5	1075537.4	11.3				-0.09	0.16	N
#c317	438040.1	1075524.3	11.3				-0.09	0.16	N
#c318	437890.7	1075511.1	11.3				-0.09	0.16	N
#c319	437741.3	1075497.9	11.3				-0.09	0.16	N
#c320	437591.9	1075484.8	11.3				-0.09	0.16	N
#c321	437442.5	1075471.6	11.3				-0.09	0.16	N
#c322	437293.1	1075458.5	11.3				-0.09	0.16	N
#c323	437143.7	1075445.3	11.3				-0.09	0.16	N
#c324	436994.3	1075432.1	11.3				-0.09	0.16	N
#c325	436844.9	1075419.0	11.3				-0.03	0.06	N
#c326	436695.5	1075405.8	11.3				-0.03	0.06	N
#c327	436546.1	1075392.7	11.3				-0.09	0.16	N
#c328	436396.7	1075379.5	11.3				-0.09	0.16	N
#c329	436247.3	1075366.3	11.3				-0.09	0.16	N
#c330	436097.9	1075353.2	11.3				-0.09	0.16	N
#c331	435948.5	1075340.0	11.3				-0.09	0.16	N
#c332	435799.1	1075326.9	11.3				-0.09	0.16	N
#c333	435649.7	1075313.7	11.3				-0.09	0.16	N
#c334	435500.3	1075300.5	11.3				-0.09	0.16	N
#c335	435350.9	1075287.4	11.3				-0.09	0.16	N
#c336	435316.0	1075165.2	11.4				-0.09	0.16	N
#c337	435310.2	1075015.3	11.4				-0.09	0.16	N
#c338	435369.8	1074879.1	11.4				-0.09	0.16	N
#c339	435435.0	1074744.0	11.4				-0.09	0.16	N
#c340	435478.4	1074606.0	11.4				-0.09	0.16	N
#c341	435448.6	1074459.5	11.4				-0.09	0.16	N
#c342	435366.4	1074334.0	11.4				-0.09	0.16	N
#c343	435277.7	1074214.5	11.4				-0.09	0.16	N
#c344	435158.8	1074123.0	11.4				-0.09	0.16	N
#c345	435039.9	1074031.5	11.4				-0.09	0.16	N
#c346	434921.0	1073940.0	11.4				-0.09	0.16	N
#c347	434802.2	1073848.5	11.4				-0.09	0.16	N
#c348	434683.3	1073757.0	11.4				-0.09	0.16	N
#c349	434564.4	1073665.5	11.4				-0.09	0.16	N
#c350	434445.6	1073574.0	11.4				-0.09	0.16	N
#c351	434326.7	1073482.5	11.4				-0.09	0.16	N
#c352	434207.8	1073391.0	11.4				-0.09	0.16	N
#c353	434089.0	1073299.5	11.4				-0.09	0.16	N
#c354	433970.1	1073208.0	11.4				-0.09	0.16	N
#c355	433851.2	1073116.5	11.4				-0.09	0.16	N
#c356	433732.4	1073025.0	11.4				-0.09	0.16	N
#c357	433613.5	1072933.5	11.4				-0.09	0.16	N
#c358	433494.6	1072842.0	11.4				-0.09	0.16	N
#c359	433375.8	1072750.5	11.4				-0.09	0.16	N
#c360	433256.9	1072659.0	11.4				-0.09	0.16	N
#c361	433136.9	1072569.0	11.4				-0.09	0.16	N
#c362	433012.3	1072490.6	11.4				-0.09	0.16	N
#c363	432862.5	1072482.6	11.4				-0.09	0.16	N
#c364	432712.9	1072471.8	11.4				-0.09	0.16	N
#c365	432563.4	1072459.7	11.4				-0.09	0.16	N
#c366	432413.9	1072447.6	11.4				-0.09	0.16	N
#c367	432264.4	1072435.4	11.4				-0.09	0.16	N
#c368	432114.9	1072423.3	11.4				-0.09	0.16	N
#c369	431965.4	1072411.2	11.4				-0.09	0.16	N
#c370	431815.9	1072399.1	11.4				-0.09	0.16	N
#c371	431666.4	1072386.9	11.4				-0.09	0.16	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#c372	431516.9	1072374.8	11.4				-0.09	0.16	N
#c373	431367.4	1072362.7	11.4				-0.09	0.16	N
#c374	431217.9	1072350.6	11.4				-0.09	0.16	N
#c375	431068.4	1072338.4	11.4				-0.09	0.16	N
#c376	430918.9	1072326.3	11.4				-0.09	0.16	N
#c377	430769.4	1072314.2	11.4				-0.09	0.16	N
#c378	430619.9	1072302.1	11.4				-0.09	0.16	N
#c379	430470.4	1072289.9	11.4				-0.17	0.09	N
#c380	430320.9	1072277.8	11.4				-0.17	0.09	N
#c381	430171.4	1072265.7	11.4				-0.17	0.09	N
#c382	430021.9	1072253.6	11.4				-0.17	0.09	N
#c383	429872.4	1072241.4	11.4				-0.17	0.09	N
#c384	429722.9	1072229.3	11.4				-0.17	0.09	N
#c385	429573.4	1072217.2	11.4				-0.17	0.09	N
#c386	429423.9	1072205.1	11.4				-0.17	0.09	N
#c387	429274.4	1072192.9	11.4				-0.17	0.09	N
#c388	429124.9	1072180.8	11.4				-0.09	0.16	N
#c389	428975.4	1072168.7	11.4				0.00	0.08	N
#c390	428825.9	1072156.5	11.4				-0.02	0.08	N
#c391	428676.4	1072144.4	11.4				-0.56	0.14	N
#c392	428526.9	1072132.3	11.4				-0.09	0.16	N
#c393	428377.4	1072119.5	11.4				-0.09	0.16	N
#c394	428228.2	1072104.5	11.4				-0.09	0.16	N
#c395	428079.0	1072089.5	11.4				-0.09	0.16	N
#c396	427929.8	1072074.5	11.4				-0.09	0.16	N
#c397	427780.6	1072059.5	11.4				-0.09	0.16	N
#c398	427631.4	1072044.5	11.4				-0.09	0.16	N
#c399	427482.1	1072029.4	11.4				-0.09	0.16	N
#c400	427332.9	1072014.4	11.4				-0.09	0.16	N
#c401	427183.7	1071999.4	11.4				-0.09	0.16	N
#c402	427034.5	1071984.4	11.4				-0.09	0.16	N
#c403	426885.3	1071969.4	11.4				-0.09	0.16	N
#c404	426736.1	1071954.3	11.4				-0.09	0.16	N
#c405	426586.9	1071939.3	11.4				-0.09	0.16	N
#c406	426437.7	1071924.3	11.4				-0.09	0.16	N
#c407	426288.5	1071909.3	11.4				-0.09	0.16	N
#c408	426139.3	1071894.3	11.4				-0.09	0.16	N
#c409	425990.1	1071879.3	11.4				-0.09	0.16	N
#c410	425840.9	1071864.2	11.4				-0.09	0.16	N
#c411	425691.7	1071849.2	11.4				-0.09	0.16	N
#c412	425542.5	1071834.2	11.4				-0.09	0.16	N
#c413	425393.3	1071819.2	11.4				-0.09	0.16	N
#c414	425244.1	1071804.2	11.4				-0.09	0.16	N
#c415	425094.9	1071789.2	11.4				-0.09	0.16	N
#c416	424945.6	1071774.1	11.4				-0.09	0.16	N
#c417	424796.4	1071759.1	11.4				-0.09	0.16	N
#c418	424647.2	1071744.1	11.4				-0.09	0.16	N
#c419	424498.0	1071729.1	11.4				-0.09	0.16	N
#c420	424348.8	1071714.1	11.4				-0.09	0.16	N
#c421	424199.6	1071699.0	11.4				-0.09	0.16	N
#c422	424050.4	1071684.0	11.4				-0.09	0.16	N
#c423	423901.2	1071669.0	11.4				-0.09	0.16	N
#c424	423751.9	1071654.5	11.4				-0.09	0.16	N
#c425	423602.3	1071664.9	11.4				-0.09	0.16	N
#c426	423452.7	1071675.2	11.4				-0.09	0.16	N
#c427	423303.1	1071685.6	11.4				-0.09	0.16	N
#c428	423154.1	1071698.9	11.4				-0.09	0.16	N
#c429	423014.3	1071753.3	11.4				-0.09	0.16	N
#c430	422874.5	1071807.7	11.4				-0.09	0.16	N
#c431	422734.7	1071862.0	11.4				-0.09	0.16	N
#c432	422594.9	1071916.4	11.4				-0.09	0.16	N
#c433	422455.1	1071970.7	11.4				-0.09	0.16	N
#c434	422357.6	1072082.1	11.4				-0.09	0.16	N
#c435	422264.9	1072200.0	11.4				-0.09	0.16	N
#c436	422172.2	1072317.9	11.4				-0.09	0.16	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#c437	422079.4	1072435.8	11.4				−0.09	0.16	N
#c438	421986.7	1072553.7	11.4				−0.09	0.16	N
#c439	421894.0	1072671.6	11.4				−0.09	0.16	N
#c440	421801.3	1072789.5	11.4				−0.09	0.16	N
#c441	421708.6	1072907.4	11.4				−0.09	0.16	N
#c442	421610.4	1073019.2	11.4				−0.09	0.16	N
#c443	421482.7	1073097.9	11.4				−0.09	0.16	N
#c444	421355.1	1073176.7	11.4				−0.09	0.16	N
#c445	421227.4	1073255.4	11.4				−0.09	0.16	N
#c446	421099.7	1073334.2	11.4				−0.09	0.16	N
#c447	420956.5	1073360.7	11.4				−0.09	0.16	N
#c448	420806.5	1073364.4	11.4				−0.09	0.16	N
#c449	420656.5	1073368.0	11.4				−0.09	0.16	N
#c450	420506.5	1073371.7	11.4				−0.09	0.16	N
#c451	420356.5	1073375.3	11.4				−0.09	0.16	N
#c452	420206.5	1073378.9	11.4				−0.09	0.16	N
#c453	420056.5	1073382.6	11.4				−0.09	0.16	N
#c454	419906.5	1073386.2	11.4				−0.09	0.16	N
#c455	419756.5	1073389.9	11.4				−0.09	0.16	N
#c456	419606.5	1073393.5	11.4				−0.09	0.16	N
#c457	419456.5	1073397.2	11.4				−0.09	0.16	N
#c458	419306.5	1073400.8	11.4				−0.09	0.16	N
#c459	419156.5	1073404.4	11.4				−0.09	0.16	N
#c460	419021.5	1073464.8	11.4				−0.09	0.16	N
#c461	418889.2	1073535.5	11.4				−0.09	0.16	N
#c462	418756.9	1073606.2	11.4				−0.09	0.16	N
#c463	418624.6	1073676.9	11.4				−0.09	0.16	N
#c464	418497.2	1073756.0	11.4				−0.09	0.16	N
#c465	418370.5	1073836.3	11.4				−0.09	0.16	N
#c466	418243.8	1073916.6	11.4				−0.09	0.16	N
#c467	418117.1	1073996.8	11.4				−0.09	0.16	N
#c468	417985.9	1074064.3	11.4				−0.09	0.16	N
#c469	417836.9	1074081.7	11.4				−0.09	0.16	N
#c470	417687.9	1074099.1	11.4				−0.09	0.16	N
#c471	417538.9	1074116.5	11.4				−0.09	0.16	N
#c472	417389.9	1074133.9	11.4				−0.09	0.16	N
#c473	417240.9	1074151.3	11.4				−0.09	0.16	N
#c474	417091.9	1074168.7	11.4				−0.09	0.16	N
#c475	416942.9	1074186.1	11.4				−0.09	0.16	N
#c476	416796.1	1074192.7	11.5		−0.09		−0.09	N.D.	N
#c477	416665.9	1074118.4	11.5		−0.25		−0.09	N.D.	N
#c478	416535.5	1074044.1	11.5		−1.13		−0.09	N.D.	N
#c479	416393.5	1074017.3	11.5		−0.32		−0.09	N.D.	N
#c480	416243.6	1074022.7	11.5		−2.60		−0.09	N.D.	N
#c481	416093.7	1074028.2	11.5		−0.31		−0.09	N.D.	N
#c482	415954.4	1074064.8	11.5		−2.29		−0.09	N.D.	N
#c483	415832.2	1074151.9	11.5		−0.81		−0.09	N.D.	N
#c484	415725.5	1074255.0	11.5		−0.93		−0.09	N.D.	N
#c485	415609.8	1074326.6	12	−0.36	−0.20	−0.29	−1.45	0.34	N
#c486	415459.9	1074331.7	12	−0.15	0.02	−0.07	−1.45	0.34	N
#c487	415310.0	1074336.9	12	0.06	−0.11	−0.02	−1.45	0.34	N
#c488	415160.1	1074342.1	12	−0.15	−1.01	−0.55	−1.45	0.34	N
#c489	415010.2	1074347.2	12	0.03	−1.72	−0.78	−1.45	0.34	N
#c490	414930.6	1074230.4	13	1.36			−0.09	N.D.	N
#c491	414859.9	1074098.1	13	1.10			−0.09	N.D.	N
#c492	414789.2	1073965.8	13				−0.09	N.D.	N
#c493	414684.3	1073861.0	13	11.90			−0.09	N.D.	N
#c494	414542.2	1073823.6	13	9.66			−0.09	N.D.	N
#c495	414394.6	1073821.2	13	11.81			−0.09	N.D.	N
#c496	414247.4	1073849.8	13	8.41			−0.09	N.D.	N
#c497	414100.2	1073878.4	13	1.71			−0.09	N.D.	N
#c498	413953.0	1073907.1	13	3.79			−0.09	N.D.	N
#c499	413805.8	1073935.7	13				−0.09	N.D.	N
#c500	413690.2	1074012.7	13	7.79			−0.09	N.D.	N
#c501	413604.9	1074136.1	13	9.10			−0.09	N.D.	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#c502	413547.6	1074268.2	13				−0.09	N.D.	N
#c503	413547.6	1074418.2	13	0.28			−0.09	N.D.	N
#c504	413579.1	1074558.6	13				−0.09	N.D.	N
#c505	413662.9	1074683.0	13	0.56			−0.09	N.D.	N
#c506	413744.1	1074807.9	13				−0.09	N.D.	N
#c507	413712.4	1074954.5	14	−0.64	0.22	−0.24	−1.45	0.34	N
#c508	413588.3	1075037.6	14	−0.72	−1.08	−0.88	−0.69	0.36	N
#c509	413462.8	1075119.8	14	−0.85	0.37	−0.29	−0.69	0.36	N
#c510	413337.3	1075201.9	14	−0.97	−0.44	−0.73	−0.69	0.36	N
#c511	413211.8	1075284.0	14	−1.71	0.22	−0.82	−0.69	0.36	N
#c512	413086.3	1075366.1	14	−0.54	−0.25	−0.41	−0.69	0.36	N
#c513	412960.8	1075448.2	14	−1.37	0.13	−0.68	−0.69	0.36	N
#c514	412828.9	1075516.6	14	−0.16	−0.02	−0.09	−0.69	0.36	N
#c515	412685.2	1075559.6	14	0.36	−0.42	−0.00	−0.69	0.36	N
#c516	412541.5	1075602.6	14	−0.38	−0.06	−0.23	−0.69	0.36	N
#c517	412397.8	1075645.6	14	0.47	−0.05	0.23	−0.69	0.36	N
#c518	412254.1	1075688.6	14	0.08	−0.62	−0.25	−1.45	0.34	N
#c519	412110.4	1075731.6	14	−1.06	0.14	−0.51	NO DATA	NO DATA	N
#c520	411962.7	1075749.5	14	1.16	−0.80	0.26	NO DATA	NO DATA	N
#c521	411812.7	1075752.9	14	0.04	−0.75	−0.33	NO DATA	NO DATA	N
#c522	411662.7	1075756.4	14	0.68	−1.65	−0.40	NO DATA	NO DATA	N
#c523	411512.7	1075759.8	14	0.15	−1.42	−0.57	NO DATA	NO DATA	N
#c524	411362.7	1075763.3	14	0.03	−1.22	−0.55	NO DATA	NO DATA	N
#c525	411212.7	1075766.7	14			−0.25	NO DATA	NO DATA	N
#c526	411062.7	1075770.2	14				NO DATA	NO DATA	N
#c527	410914.6	1075748.9	14				−0.69	0.36	N
#c528	410766.8	1075723.1	14				−0.69	0.36	N
#c529	410619.0	1075697.3	14				−0.69	0.36	N
#c530	410471.2	1075671.5	14				−0.69	0.36	N
#c531	410323.4	1075645.7	14				−0.69	0.36	N
#c532	410175.6	1075619.9	14				−0.69	0.36	N
#c533	410027.8	1075594.1	14				−0.69	0.36	N
#c534	409880.0	1075568.3	14				−0.69	0.36	N
#c535	409732.2	1075542.5	14				−0.69	0.36	N
#c536	409584.4	1075516.7	14				−0.69	0.36	N
#c537	409436.6	1075490.9	14				−0.69	0.36	N
#c538	409288.0	1075470.5	14				−0.69	0.36	N
#c539	409139.4	1075450.4	14				−0.69	0.36	N
#c540	408990.8	1075430.2	14				−0.69	0.36	N
#c541	408842.2	1075410.1	14				−0.69	0.36	N
#c542	408693.6	1075389.9	14				−0.69	0.36	N
#c543	408544.6	1075372.9	14				−0.69	0.36	N
#c544	408395.4	1075357.0	14				−0.69	0.36	N
#c545	408246.2	1075341.2	14				−0.69	0.36	N
#c546	408097.0	1075325.3	14				−0.69	0.36	N
#c547	407947.8	1075309.4	14				−0.69	0.36	N
#c548	407798.6	1075293.6	14				−0.69	0.36	N
#c549	407649.4	1075277.7	14				−0.69	0.36	N
#c550	407500.2	1075261.9	14				−0.69	0.36	N
#c551	407351.0	1075246.0	14				−0.69	0.36	N
#d1	407182.8	1075228.2	14				−0.69	0.36	N
#d2	407033.6	1075212.3	14				−0.69	0.36	N
#d3	406884.4	1075196.4	14				−0.69	0.36	N
#d4	406735.2	1075180.6	14				−0.69	0.36	N
#d5	406586.0	1075164.7	14				−0.69	0.36	N
#d6	406436.8	1075148.9	14				−0.69	0.36	N
#d7	406287.6	1075133.0	14				−0.69	0.36	N
#d8	406138.4	1075117.2	14				−0.69	0.36	N
#d9	405989.2	1075101.3	14				−0.69	0.36	N
#d10	405840.0	1075085.5	14				−0.69	0.36	N
#d11	405690.8	1075069.6	14				−0.69	0.36	N
#d12	405541.6	1075053.8	14				−0.69	0.36	N
#d13	405392.4	1075037.9	14				−0.69	0.36	N
#d14	405243.2	1075022.1	14				−0.69	0.36	N
#d15	405094.0	1075006.2	14				−0.69	0.36	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#d16	404944.8	1074990.4	14				−0.69	0.36	N
#d17	404795.6	1074974.5	14				−0.69	0.36	N
#d18	404646.4	1074958.7	14				−0.69	0.36	N
#d19	404497.2	1074942.8	14				−0.69	0.36	N
#d20	404348.0	1074927.0	14				−0.69	0.36	N
#d21	404198.8	1074911.1	14				−0.69	0.36	N
#d22	404049.6	1074895.3	14				−0.69	0.36	N
#d23	403900.4	1074879.4	14				−0.69	0.36	N
#d24	403751.2	1074863.6	14				−0.69	0.36	N
#d25	403602.0	1074847.7	14				−0.69	0.36	N
#d26	403453.0	1074830.6	14				−0.69	0.36	N
#d27	403305.3	1074804.7	14				−0.69	0.36	N
#d28	403157.6	1074778.7	14				−0.69	0.36	N
#d29	403009.9	1074752.8	14				−0.69	0.36	N
#d30	402862.2	1074726.8	14				−0.69	0.36	N
#d31	402714.5	1074700.9	14				−0.69	0.36	N
#d32	402566.8	1074674.9	14				−0.69	0.36	N
#d33	402419.1	1074649.0	14				−0.69	0.36	N
#d34	402271.4	1074623.0	14				−0.69	0.36	N
#d35	402123.7	1074597.1	14				−0.69	0.36	N
#d36	401976.0	1074571.2	14				−0.69	0.36	N
#d37	401828.3	1074545.2	14				−0.69	0.36	N
#d38	401680.6	1074519.3	14				−0.69	0.36	N
#d39	401532.9	1074493.3	14				−0.69	0.36	N
#d40	401385.2	1074467.4	14				−0.69	0.36	N
#d41	401237.5	1074441.4	14				−0.69	0.36	N
#d42	401089.8	1074415.5	14				−0.69	0.36	N
#d43	400942.1	1074389.5	14				−0.69	0.36	N
#d44	400794.4	1074363.6	14				−0.69	0.36	N
#d45	400646.7	1074337.6	14				−0.69	0.36	N
#d46	400499.0	1074311.7	14				−0.69	0.36	N
#d47	400351.3	1074285.8	14				−0.69	0.36	N
#d48	400203.6	1074259.8	14				−0.69	0.36	N
#d49	400055.9	1074233.9	14				−0.69	0.36	N
#d50	399908.2	1074207.9	14				−0.69	0.36	N
#d51	399760.5	1074182.0	14				−0.69	0.36	N
#d52	399612.8	1074156.0	14				−0.69	0.36	N
#d53	399465.1	1074130.1	14				−0.69	0.36	N
#d54	399317.4	1074104.1	14				−0.69	0.36	N
#d55	399169.7	1074078.2	14				−0.69	0.36	N
#d56	399022.0	1074052.2	14				−0.69	0.36	N
#d57	398875.6	1074020.4	14				−0.69	0.36	N
#d58	398731.0	1073980.5	14				−0.69	0.36	N
#d59	398586.4	1073940.7	14		0.22		−0.69	0.36	N
#d60	398441.8	1073900.9	14		−0.67		−0.69	0.36	N
#d61	398297.2	1073861.1	14	2.42	1.98	2.22	−0.69	0.36	N
#d62	398152.6	1073821.2	14	0.05	0.31	0.17	−0.69	0.36	N
#d63	398008.0	1073781.4	14	−0.30	0.07	−0.13	−0.69	0.36	N
#d64	397863.4	1073741.6	14	0.70	−0.59	0.10	−0.69	0.36	Y
#d65	397718.8	1073701.8	14	0.76	−0.25	0.30	−0.69	0.36	N
#d66	397574.2	1073661.9	14	0.81	0.54	0.69	−0.69	0.36	N
#d67	397429.6	1073622.1	14	−0.05	0.40	0.16	−0.69	0.36	N
#d68	397285.0	1073582.3	14	−0.05	0.68	0.29	−0.69	0.36	N
#d69	397140.4	1073542.5	14	−0.33	−1.04	−0.66	−0.69	0.36	N
#d70	396995.8	1073502.7	14	−0.33	−0.03	−0.19	−0.69	0.36	N
#d71	396851.2	1073462.8	14	−0.13	−0.32	−0.22	−0.69	0.36	N
#d72	396706.6	1073423.0	14	−0.03	−0.28	−0.14	−0.69	0.36	N
#d73	396562.0	1073383.2	14	0.14	−0.46	−0.14	−1.45	0.34	N
#d74	396417.4	1073343.4	14	0.39	−0.09	0.17	−1.45	0.34	N
#d75	396272.8	1073303.5	14	−2.40	0.12	−1.24	−1.45	0.34	N
#d76	396128.2	1073263.7	14	0.19	0.18	0.19	−1.45	0.34	N
#d77	395983.6	1073223.9	14	0.27	0.00	0.15	−1.45	0.34	N
#d78	395839.0	1073184.1	14	−0.67	0.07	−0.33	−1.45	0.34	N
#d79	395694.4	1073144.3	14	−0.29	0.42	0.04	−1.45	0.34	N
#d80	395549.8	1073104.4	14	−0.19	−0.10	−0.15	−1.45	0.34	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#d81	395405.2	1073064.6	14	−1.24	0.18	−0.58	−1.45	0.34	N
#d82	395260.6	1073024.8	14	0.14	0.13	0.13	−1.45	0.34	N
#d83	395116.0	1072985.0	14	−0.23	0.03	−0.11	−1.45	0.34	N
#d84	394971.4	1072945.1	14	0.29	−0.60	−0.12	−1.45	0.34	N
#d85	394826.8	1072905.3	14	0.16	−0.16	0.01	−1.45	0.34	N
#d86	394682.2	1072865.5	14	1.83	−0.61	0.70	−0.69	0.36	N
#d87	394537.6	1072825.7	14	−0.16	−0.19	−0.17	−0.69	0.36	N
#d88	394393.0	1072785.8	14	0.55	−0.25	0.18	−0.38	0.14	N
#d89	394248.4	1072746.0	14	1.14	−0.83	0.23	−1.45	0.34	N
#d90	394103.8	1072706.2	14	0.47	−0.40	0.07	−1.45	0.34	N
#d91	393959.2	1072666.4	14	0.65	−0.45	0.14	−0.69	0.36	N
#d92	393814.6	1072626.6	14	0.74	−0.50	0.17	−0.69	0.36	N
#d93	393670.0	1072586.7	14	1.06	0.02	0.58	−0.69	0.36	N
#d94	393523.0	1072556.8	14	0.97	−0.63	0.23	−0.69	0.36	N
#d95	393375.8	1072528.3	14	0.25	−0.00	0.13	−0.69	0.36	N
#d96	393228.5	1072499.8	14	2.55	−0.88	0.97	−0.69	0.36	N
#d97	393081.2	1072471.2	14	2.13	−1.45	0.48	−0.69	0.36	N
#d98	392933.9	1072442.7	14	0.23	0.05	0.15			N
#d99	392786.6	1072414.1	15	0.03	−1.01	−0.45	−1.90	0.34	N
#d100	392639.3	1072385.6	15	0.89	−1.90	−0.40	−1.90	0.34	N
#d101	392492.0	1072357.0	15	0.43	0.02	0.24	−1.90	0.34	N
#d102	392344.8	1072328.5	15	0.54	−0.47	0.07	−1.90	0.34	N
#d103	392197.5	1072300.0	15	1.14	−0.75	0.27	−1.90	0.34	N
#d104	392050.2	1072271.4	15	1.57	−1.40	0.20	−1.90	0.34	N
#d105	391902.9	1072242.9	15	1.08	−0.63	0.29	−3.73	0.34	N
#d106	391755.6	1072214.3	15	0.22	−0.43	−0.08	−3.73	0.34	N
#d107	391610.8	1072176.1	15	−0.04	0.02	−0.01	−2.03	0.34	N
#d108	391467.7	1072131.3	15	−0.96	0.40	−0.33	−2.03	0.34	N
#d109	391324.6	1072086.5	15	−0.99	−0.67	−0.84	−0.68	0.34	N
#d110	391181.5	1072041.7	15	0.14	−0.90	−0.34	−1.02	0.34	N
#d111	391038.4	1071996.9	15	−0.12	−0.85	−0.46	−1.36	0.34	N
#d112	390895.3	1071952.1	15	0.61	−1.23	−0.24	−2.03	0.34	N
#d113	390752.2	1071907.3	15	−0.03	−0.47	−0.23	−1.36	0.34	N
#d114	390613.8	1071851.7	15	−0.13	−0.64	−0.36	−1.69	0.34	N
#d115	390483.8	1071776.8	15	−0.12	−0.12	−0.12	−1.02	0.34	N
#d116	390353.8	1071702.0	15	0.56	−0.21	0.20	−3.05	0.34	N
#d117	390223.8	1071627.1	15	−0.14	−1.55	−0.79	−2.37	0.34	N
#d118	390093.8	1071552.3	15	0.79			−2.03	0.34	N
#d119	389964.5	1071476.3	15	1.73			−1.36	0.34	N
#d120	389837.9	1071395.8	15	1.93			>−0.34	0.34	N
#d121	389711.3	1071315.4	15	0.58			>−0.34	0.34	N
#d122	389602.1	1071218.7	15	−0.64			>−0.34	0.34	N
#d123	389529.8	1071087.3	15	−0.74			>−0.34	0.34	N
#d124	389457.5	1070955.9	15	−0.59			>−0.34	0.34	N
#d125	389451.1	1070807.0	16	−0.39			−0.09	0.16	N
#d126	389448.5	1070657.0	16				−0.09	0.16	N
#d127	389463.3	1070508.1	16				−0.09	0.16	N
#d128	389484.2	1070359.6	16				−0.09	0.16	N
#d129	389505.1	1070211.1	16				−0.09	0.16	N
#d130	389526.0	1070062.6	16				−0.09	0.16	N
#d131	389543.7	1069914.0	16				−0.09	0.16	N
#d132	389528.1	1069764.8	16				−0.09	0.16	N
#d133	389512.4	1069615.6	16				−0.09	0.16	N
#d134	389496.7	1069466.4	16				−0.09	0.16	N
#d135	389457.1	1069324.5	16				−0.09	0.16	N
#d136	389386.7	1069192.1	16				−0.09	0.16	N
#d137	389280.1	1069090.7	16				−0.17	0.13	N
#d138	389160.0	1069000.8	16				−0.09	0.16	N
#d139	389023.0	1068953.1	16				−0.09	0.16	N
#d140	388874.0	1068935.4	16				−0.09	0.16	N
#d141	388725.0	1068917.7	16				−0.09	0.16	N
#d142	388576.0	1068900.0	16				−0.09	0.16	N
#d143	388436.1	1068924.1	16				−0.09	0.16	N
#d144	388307.7	1069001.7	16				−0.09	0.16	N
#d145	388187.5	1069089.9	16				−0.09	0.16	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#d146	388080.3	1069194.8	16				−0.09	0.16	N
#d147	387973.0	1069299.6	16				−0.09	0.16	N
#d148	387865.8	1069404.5	16				−0.09	0.16	N
#d149	387766.4	1069516.6	16				−0.09	0.16	N
#d150	387671.2	1069632.6	16				−0.09	0.16	N
#d151	387576.0	1069748.6	16				−0.09	0.16	N
#d152	387480.8	1069864.6	16				−0.09	0.16	N
#d153	387385.6	1069980.6	16				−0.09	0.16	N
#d154	387307.0	1070106.8	16				−0.09	0.16	N
#d155	387246.0	1070243.8	16				−0.09	0.16	N
#d156	387185.0	1070380.8	16				−0.09	0.16	N
#d157	387123.9	1070517.8	16				−0.09	0.16	N
#d158	387090.7	1070663.0	16				−0.09	0.16	N
#d159	387067.5	1070811.2	16				−0.09	0.16	N
#d160	387044.3	1070959.4	16				−0.09	0.16	N
#d161	387021.0	1071107.6	16				−0.09	0.16	N
#d162	387002.2	1071256.2	16				−0.09	0.16	N
#d163	386997.2	1071406.1	16				−0.09	0.16	N
#d164	386992.1	1071556.0	16				−0.09	0.16	N
#d165	386987.0	1071705.9	16				−0.09	0.16	N
#d166	386991.2	1071855.8	16				−0.09	0.16	N
#d167	386997.7	1072005.7	16				−0.09	0.16	N
#d168	387004.1	1072155.6	16				−0.09	0.16	N
#d169	387010.6	1072305.5	16				−0.09	0.16	N
#d170	387017.0	1072455.4	16				−0.09	0.16	N
#d171	387034.2	1072603.8	16				−0.09	0.16	N
#d172	387069.0	1072749.7	16				−0.09	0.16	N
#d173	387103.9	1072895.6	16				−0.09	0.16	N
#d174	387151.1	1073036.9	16				−0.09	0.16	N
#d175	387219.9	1073170.2	16				−0.09	0.16	N
#d176	387299.8	1073295.7	16				−0.09	0.16	N
#d177	387402.3	1073405.2	16				−0.09	0.16	N
#d178	387429.8	1073546.0	17	0.37	−0.10	0.15	−0.25	0.36	N
#d179	387361.5	1073677.8	17	−0.35	−0.16	−0.26	−0.25	0.36	N
#d180	387268.7	1073794.7	17	−0.33	0.67	0.13	0.00	0.08	N
#d181	387154.7	1073892.2	17	0.19	0.06	0.13	−0.25	0.36	N
#d182	387020.7	1073953.0	17	−0.40	0.49	0.01	−0.25	0.36	N
#d183	386877.0	1073995.9	17	−0.76	0.44	−0.21	−0.25	0.36	N
#d184	386733.3	1074039.0	17	−0.27	0.28	−0.01	−0.25	0.36	N
#d185	386590.9	1074086.0	17	−0.30	0.18	−0.08	−0.25	0.36	N
#d186	386448.5	1074133.0	17	−0.42	0.21	−0.13	−0.25	0.36	N
#d187	386306.1	1074180.0	17	−0.31	0.33	−0.02	−0.25	0.36	N
#d188	386163.7	1074227.0	17	−0.46	0.08	−0.21	−0.25	0.36	N
#d189	386019.1	1074266.8	17	−0.70	1.70	0.41	−0.25	0.36	N
#d190	385874.2	1074305.5	17	−0.18	0.24	0.02	−0.25	0.36	N
#d191	385729.3	1074344.3	17	−0.95	0.38	−0.33	−0.25	0.36	N
#d192	385584.4	1074382.9	17	−0.26	0.17	−0.06	−0.25	0.36	N
#d193	385435.3	1074399.4	17	−0.77	0.13	−0.36	−0.19	0.13	N
#d194	385286.2	1074415.9	17	−0.45	−0.48	−0.47	−0.19	0.13	N
#d195	385137.1	1074432.5	17	−0.87	0.11	−0.42	−0.25	0.36	N
#d196	384988.0	1074449.0	17	−0.33	−0.37	−0.34	−0.25	0.36	N
#d197	384838.9	1074465.5	17	−0.12	−0.43	−0.26	−0.88	0.15	N
#d198	384689.8	1074482.1	17	−0.50	−0.50	−0.50	0.00	0.14	N
#d199	384540.7	1074498.6	17	−0.90	0.09	−0.44	−0.25	0.36	N
#d200	384391.5	1074513.8	17	−0.55	−0.33	−0.45			Y
#d201	384241.5	1074514.3	17	−0.63	0.29	−0.20			Y
#d202	384091.5	1074514.7	17	−1.14	1.13	−0.09	−0.25	0.36	N
#d203	383941.5	1074515.1	17	−0.87	0.07	−0.43			Y
#d204	383791.5	1074515.6	17		−0.41				Y
#d205	383641.5	1074516.0	17	−0.92	−0.74	−0.84			Y
#d206	383491.5	1074516.5	17	−0.73	0.62	−0.10	−0.25	0.36	N
#d207	383341.5	1074516.9	17	−0.29	0.10	−0.11	−0.25	0.36	N
#d208	383191.5	1074517.3	17	−0.41	0.13	−0.16	−0.25	0.36	N
#d209	383041.5	1074516.2	17	−0.25	−0.11	−0.19	−0.25	0.36	N
#d210	382891.5	1074512.7	17	−0.40	0.20	−0.13	−0.25	0.36	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#d211	382741.5	1074509.1	17	-0.41	-0.72	-0.56	-0.25	0.36	N
#d212	382591.5	1074505.6	17	-0.17	-0.99	-0.55	-0.25	0.36	N
#d213	382441.5	1074502.0	17	-0.52	-1.30	-0.88	-0.25	0.36	N
#d214	382291.5	1074498.5	17	-2.79	-0.46	-1.72	-0.25	0.36	N
#d215	382141.6	1074494.3	17	-2.62	0.32	-1.26	-0.25	0.36	N
#d216	381995.5	1074460.5	17	-0.67	0.91	0.06	-0.25	0.36	N
#d217	381849.3	1074426.6	17	-1.48	0.32	-0.65			Y
#d218	381703.2	1074392.8	17	-1.96	0.38	-0.88			Y
#d219	381557.1	1074359.0	17	-1.35	0.20	-0.63			Y
#d220	381411.0	1074325.2	17	-1.63	-0.07	-0.91			Y
#d221	381264.9	1074291.4	18	-1.15	-0.14	-0.69	-0.24	0.12	N
#d222	381118.8	1074257.6	18	-0.35	0.13	-0.13	-0.24	0.12	N
#d223	380972.7	1074223.8	18	-0.57	-0.33	-0.46	-0.24	0.12	N
#d224	380826.6	1074190.0	18	-0.23	-0.28	-0.25	-0.23	0.08	N
#d225	380680.5	1074156.2	18	-0.51	-0.12	-0.33	-0.21	0.08	N
#d226	380534.4	1074122.4	18	-0.05	-0.30	-0.17	-0.15	0.08	N
#d227	380388.3	1074088.6	18	-0.30	-0.10	-0.21	-0.15	0.08	N
#d228	380242.7	1074052.5	18	-0.55	-0.89	-0.71	-0.44	0.08	N
#d229	380097.6	1074014.4	18	-0.08	-0.58	-0.31	>-1.02	0.34	N
#d230	379952.5	1073976.3	18	-0.32	-0.40	-0.36	>-1.02	0.34	N
#d231	379807.4	1073938.2	18	0.20	-0.55	-0.14	-0.68	0.34	N
#d232	379662.3	1073900.1	18	-0.40	-0.58	-0.48	-1.69	0.34	N
#d233	379517.2	1073862.0	18	-0.60	-0.24	-0.44	-2.03	0.34	N
#d234	379372.1	1073823.9	18	0.56	-0.66	-0.00	-2.03	0.34	N
#d235	379227.0	1073785.8	18	-0.77	-0.50	-0.65	-1.36	0.34	N
#d236	379081.9	1073747.7	18	-0.24	-0.13	-0.19	-1.02	0.34	N
#d237	378935.0	1073717.6	18	0.18	-0.07	0.06	-1.02	0.34	N
#d238	378787.9	1073688.2	18	0.39	-0.81	-0.16	-0.85	0.98	N
#d239	378640.8	1073658.8	18	-0.24	0.69	0.19	-0.85	0.98	N
#d240	378499.9	1073611.4	18	-1.54	-0.01	-0.83	-0.45	0.29	N
#d241	378365.7	1073544.4	18	-1.49	0.62	-0.52	-0.51	0.29	N
#d242	378231.4	1073477.5	18	-0.12	0.55	0.19	-0.68	0.34	N
#d243	378097.2	1073410.5	18	-2.06	-0.25	-1.22	-1.37	0.34	N
#d244	377956.4	1073359.9	18	-2.38	0.32	-1.13	-5.81	0.34	N
#d245	377813.3	1073314.9	18	-3.09	0.75	-1.32	-4.44	0.34	N
#d246	377670.2	1073269.9	18	-1.83	-0.35	-1.14	-2.73	0.34	N
#d247	377527.1	1073224.9	18	-2.15	-1.00	-1.62	-3.42	0.34	N
#d248	377384.0	1073179.9	18	-2.90	-6.65	-4.63	-3.42	0.34	N
#d249	377240.9	1073134.9	18	-2.54			-2.05	0.34	N
#d250	377097.8	1073089.9	18	-4.89	-0.08	-2.67	-2.05	0.34	N
#d251	376954.7	1073044.9	18	-1.09	-1.47	-1.27	-2.05	0.34	N
#d252	376805.4	1073033.2	18	-1.62	-1.84	-1.72	-2.05	0.34	N
#d253	376655.7	1073023.7	18	-0.98	-1.10	-1.04	-2.05	0.34	N
#d254	376506.0	1073014.3	18	-1.26	-0.06	-0.71	-2.05	0.34	N
#d255	376356.3	1073004.9	18	-0.88	-0.06	-0.50	-2.05	0.34	N
#d256	376206.6	1072995.5	18	-0.37	-0.15	-0.27	-1.71	0.34	N
#d257	376057.0	1072984.4	18	-0.73	0.14	-0.33	-1.71	0.34	N
#d258	375907.4	1072973.3	18	-0.22	-0.48	-0.34	-1.37	0.34	N
#d259	375757.8	1072962.2	19	-0.36	0.60	0.08	-1.37	0.34	N
#d260	375608.2	1072951.1	19	-0.65	0.53	-0.11	-1.02	0.68	N
#d261	375458.6	1072940.0	19	-0.48	0.40	-0.08	-1.02	0.68	N
#d262	375311.6	1072912.4	19	-0.47	0.35	-0.09	-1.02	0.68	N
#d263	375165.8	1072877.3	19	-0.33	0.03	-0.16			Y
#d264	375020.0	1072842.2	19	-1.65	1.48	-0.20	0.00	0.68	N
#d265	374874.2	1072807.2	19	0.11	0.33	0.21	0.00	0.68	N
#d266	374728.4	1072772.1	19	-0.01	0.57	0.26	0.00	0.68	N
#d267	374582.6	1072737.0	19	0.15	0.03	0.10	-1.02	0.68	N
#d268	374437.0	1072701.0	19	-0.25	0.44	0.07			Y
#d269	374291.5	1072664.5	19	-0.55	0.65	0.01			Y
#d270	374146.0	1072628.1	19	0.10	0.10	0.10			Y
#d271	374000.5	1072591.6	19	1.31	0.60	0.98	-1.02	0.68	N
#d272	373855.0	1072555.1	19	0.28	0.57	0.41	-1.02	0.68	N
#d273	373709.5	1072518.7	19	0.67	-0.52	0.12	-1.02	0.68	N
#d274	373564.0	1072482.2	19	0.68	0.02	0.37	-1.02	0.68	N
#d275	373418.5	1072445.8	19	0.76	-0.55	0.16	-1.02	0.68	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#d276	373273.0	1072409.3	19	-0.00	0.96	0.44	-1.02	0.68	N
#d277	373127.6	1072372.4	19	-0.86	0.37	-0.29	-1.02	0.68	N
#d278	372984.6	1072327.1	19	-0.59	0.40	-0.14	-1.02	0.68	N
#d279	372841.6	1072281.8	19	-0.53	1.16	0.25	-1.02	0.68	N
#d280	372698.6	1072236.5	19	-0.69	1.08	0.13	-1.02	0.68	N
#d281	372555.6	1072191.2	19	-0.71	1.01	0.08	-1.02	0.68	N
#d282	372412.6	1072145.9	19	-0.30	0.98	0.29	-1.02	0.68	N
#d283	372269.6	1072100.6	19	-0.75	0.51	-0.17	-1.02	0.68	N
#d284	372126.6	1072055.3	19	-0.10	0.63	0.23	-1.02	0.68	N
#d285	371983.6	1072010.0	19	-0.34	-0.03	-0.20	-1.02	0.68	N
#d286	371838.3	1071972.9	19	-0.56	0.14	-0.24	-1.02	0.68	N
#d287	371692.4	1071938.2	19	-0.67	0.32	-0.22	-1.02	0.68	N
#d288	371546.5	1071903.6	19	-0.83	0.96	-0.01	-1.02	0.68	N
#d289	371400.6	1071868.9	19	-0.88	0.85	-0.08	-1.02	0.68	N
#d290	371252.5	1071846.7	19	-1.26	1.28	-0.09	-1.02	0.68	N
#d291	371103.5	1071829.4	19	-1.29	0.40	-0.51	-1.02	0.68	N
#d292	370954.5	1071812.1	19	-1.17	-0.00	-0.63	-1.02	0.68	N
#d293	370805.5	1071794.8	19	-0.90	0.08	-0.45	-1.02	0.68	N
#d294	370656.5	1071777.5	19	-0.38	-0.09	-0.25	-1.02	0.68	N
#d295	370507.5	1071760.1	19	-0.56	-0.24	-0.41	-1.02	0.68	N
#d296	370358.5	1071742.8	19	-0.47	-0.17	-0.33	-1.02	0.68	N
#d297	370208.8	1071750.6	19	-0.60	0.08	-0.29	-1.02	0.68	N
#d298	370059.1	1071759.5	20	-2.85	-0.87	-1.94	>-0.05	0.05	N
#d299	369914.6	1071787.6	20	-1.22	-0.10	-0.70	>-0.05	0.05	N
#d300	369781.0	1071855.7	20	-0.80	0.19	-0.35	>-0.05	0.05	N
#d301	369647.4	1071923.8	20	-1.83	-0.34	-1.14	>-0.05	0.05	N
#d302	369513.8	1071992.0	20	-2.51	0.27	-1.23	>-0.05	0.05	N
#d303	369375.9	1072050.9	20	0.06	-1.79	-0.79	>-0.05	0.05	N
#d304	369235.5	1072101.4	20	-0.44	-1.00	-0.70	>-0.05	0.05	N
#d305	369086.2	1072116.0	20	8.79	-11.55	-0.60	>-0.05	0.05	N
#d306	368937.8	1072108.8	20				>-0.05	0.05	N
#d307	368790.1	1072082.5	20				>-0.05	0.05	N
#d308	368643.4	1072100.4	20				>-0.05	0.05	N
#d309	368497.0	1072133.0	20				>-0.05	0.05	N
#d310	368377.4	1072222.5	20				>-0.05	0.05	N
#d311	368259.0	1072314.6	20				>-0.05	0.05	N
#d312	368168.1	1072433.1	BAY					0.05	N
#d313	368080.8	1072555.1	BAY					0.05	N
#e1	365875.3	1071056.4	BAY					0.05	
#e2	365728.5	1071087.4	BAY					0.05	
#e3	365581.7	1071118.5	21	28.35	2.15	16.26	0.00	0.05	N
#e4	365434.9	1071149.5	21	19.44	4.35	12.48	0.00	0.05	N
#e5	365288.1	1071180.5	21	14.90	7.60	11.53	0.00	0.05	N
#e6	365139.0	1071188.7	21	9.38	10.50	9.90	0.00	0.05	N
#e7	364989.0	1071188.7	21	6.93	12.25	9.38	0.00	0.05	N
#e8	364839.0	1071188.7	21	6.54	12.58	9.33	0.00	0.05	N
#e9	364689.0	1071188.7	21	6.03	12.96	9.23	0.00	0.05	N
#e10	364539.0	1071188.7	21	6.24	12.37	9.07	0.00	0.05	N
#e11	364389.0	1071188.7	21	6.39	12.38	9.15	0.00	0.05	N
#e12	364239.0	1071188.7	21	6.91	10.25	8.45	0.00	0.05	N
#e13	364089.0	1071188.7	21	7.09	8.52	7.75	0.00	0.05	N
#e14	363939.0	1071188.7	21	7.04	7.33	7.17	0.00	0.05	N
#e15	363789.0	1071188.7	21	7.27	6.65	6.98	0.00	0.05	N
#e16	363639.0	1071188.7	21	7.24	5.65	6.51	0.00	0.05	N
#e17	363489.0	1071188.7	21	7.22	5.16	6.27	0.00	0.05	N
#e18	363339.0	1071188.7	21	7.49	4.44	6.08	0.00	0.05	N
#e19	363189.0	1071188.7	21	7.41	3.90	5.79	0.00	0.05	N
#e20	363039.0	1071188.7	21			5.60	0.00	0.05	N
#e21	362889.0	1071188.7	21				0.00	0.05	N
#e22	362739.4	1071181.5	21				0.00	0.05	N
#e23	362590.4	1071164.3	21				0.00	0.05	N
#e24	362441.4	1071147.2	21				0.00	0.05	N
#e25	362292.4	1071130.0	21				0.00	0.05	N
#e26	362143.4	1071112.8	21				0.00	0.05	N
#e27	361994.4	1071095.7	21				0.00	0.05	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#e28	361845.4	1071078.5	21				0.00	0.05	N
#e29	361696.4	1071061.3	21				0.00	0.05	N
#e30	361547.4	1071044.2	21				0.00	0.05	N
#e31	361398.4	1071027.0	21				0.00	0.05	N
#e32	361249.4	1071009.8	21	7.22	1.08	4.39	0.00	0.05	N
#e33	361100.4	1070992.7	21	6.52	1.88	4.38	0.00	0.05	N
#e34	360951.4	1070975.5	21	7.05	1.41	4.45	0.00	0.05	N
#e35	360802.4	1070958.3	21	6.14	1.99	4.23	0.00	0.05	N
#e36	360653.4	1070941.2	21	5.54	2.92	4.33	0.00	0.05	N
#e37	360504.4	1070924.0	21	5.94	2.03	4.13	0.00	0.05	N
#e38	360355.4	1070906.8	21	5.13	2.13	3.74	0.00	0.05	N
#e39	360206.4	1070889.7	21	5.59	2.00	3.93	0.00	0.05	N
#e40	360057.4	1070872.5	21	6.01	0.99	3.69	0.00	0.05	N
#e41	359908.4	1070855.3	21	5.43	−0.48	2.70	0.00	0.05	N
#e42	359759.4	1070838.2	21	4.90	−0.86	2.24	0.00	0.05	N
#e43	359610.4	1070821.0	21	4.81	−1.63	1.84	0.00	0.05	N
#e44	359461.4	1070803.8	21	4.65	−1.33	1.89	0.00	0.05	N
#e45	359312.4	1070786.6	21	3.84	−0.71	1.74	0.00	0.05	N
#e46	359163.4	1070769.5	21	3.27	−0.80	1.39	0.00	0.05	N
#e47	359014.4	1070752.3	21	2.89	−1.05	1.07	0.00	0.05	N
#e48	358865.4	1070735.1	21	1.64	−0.09	0.84	0.00	0.05	N
#e49	358716.4	1070718.0	21	−0.98	1.69	0.25	0.00	0.05	N
#e50	358567.4	1070700.8	21	−0.29	0.41	0.03	0.00	0.05	N
#e51	358418.4	1070683.6	21	0.36	−0.34	0.04	0.00	0.05	N
#e52	358269.4	1070666.5	21	−0.54	1.22	0.27	0.00	0.05	N
#e53	358120.4	1070649.3	21	−0.38	0.40	−0.02	0.00	0.05	N
#e54	357971.4	1070632.1	21	0.08	0.51	0.28	0.00	0.05	N
#e55	357822.4	1070615.0	21	−1.54	1.69	−0.05	0.00	0.05	N
#e56	357673.4	1070597.8	22	0.03	−0.03	0.01	−0.36	0.45	N
#e57	357524.4	1070580.6	22	−0.24	−0.07	−0.16	−0.36	0.45	N
#e58	357375.4	1070563.5	22	−0.10	0.03	−0.04	−0.36	0.45	N
#e59	357226.4	1070546.3	22	−0.46	0.10	−0.20	−0.36	0.45	N
#e60	357077.4	1070529.1	22	−0.01	0.33	0.15	−0.36	0.45	N
#e61	356928.4	1070512.0	22	−0.39	0.05	−0.19			Y
#e62	356779.4	1070494.8	22	−0.55	0.39	−0.12	−0.36	0.45	N
#e63	356630.4	1070477.6	22		0.61		−0.36	0.45	N
#e64	356481.4	1070460.5	22		0.33		NO DATA	NO DATA	N
#e65	356332.4	1070443.3	22		0.53		NO DATA	NO DATA	N
#e66	356183.4	1070426.1	22		0.45		NO DATA	NO DATA	N
#e67	356034.4	1070409.0	22		0.53		NO DATA	NO DATA	N
#e68	355885.4	1070391.8	22		0.59		NO DATA	NO DATA	N
#e69	355736.4	1070374.6	22		−0.07		NO DATA	NO DATA	N
#e70	355587.4	1070357.4	22		0.41		−0.36	0.45	N
#e71	355438.4	1070340.3	22		0.72		−0.36	0.45	N
#e72	355289.4	1070323.1	22		−0.38		−0.36	0.45	N
#e73	355140.4	1070305.9	22		−1.32		−0.36	0.45	N
#e74	354991.4	1070288.8	22		−0.77		−0.36	0.45	N
#e75	354842.4	1070271.6	22		0.06		NO DATA	NO DATA	N
#e76	354693.4	1070254.4	22		0.07		−0.36	0.45	N
#e77	354544.4	1070237.3	22		0.40		−0.36	0.45	N
#e78	354395.4	1070220.1	22		0.23		−0.36	0.45	N
#e79	354246.4	1070202.9	22		−0.09		−0.36	0.45	N
#e80	354097.4	1070185.8	22		0.13		−0.36	0.45	N
#e81	353948.4	1070168.6	22		−0.09		−0.36	0.45	N
#e82	353799.4	1070151.4	22		0.75		−0.36	0.45	N
#e83	353650.4	1070134.3	22		0.57		−0.36	0.45	N
#e84	353501.4	1070117.1	22	−0.11	0.15	0.01	−0.36	0.45	N
#e85	353352.4	1070099.9	22	−0.89	0.10	−0.44	−0.36	0.45	N
#e86	353203.4	1070082.8	22	−0.40	0.01	−0.21	−0.36	0.45	N
#e87	353054.4	1070065.6	22	−0.35	−0.13	−0.24	−0.36	0.45	N
#e88	352905.4	1070048.4	22	−0.70	−0.11	−0.43	−0.36	0.45	N
#e89	352756.5	1070030.4	22	−0.63	0.56	−0.08	NO DATA	NO DATA	N
#e90	352608.0	1070009.0	22	−0.44	0.05	−0.22	NO DATA	NO DATA	N
#e91	352459.5	1069987.6	22	−0.45	0.20	−0.15	NO DATA	NO DATA	N
#e92	352311.0	1069966.2	22	−0.34	−0.03	−0.20	NO DATA	NO DATA	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67-39	R91-67	R91-39	BEST	ERROR	SPS
#e93	352162.5	1069944.8	22	-0.51	0.25	-0.16	NO DATA	NO DATA	N
#e94	352014.0	1069923.4	22	-0.15	0.64	0.21	-0.36	0.45	N
#e95	351865.5	1069902.0	22	-0.31	0.85	0.23	-0.36	0.45	N
#e96	351717.0	1069880.6	22	-0.12	0.20	0.03	-0.36	0.45	N
#e97	351568.5	1069859.2	22	-0.06	0.00	-0.03	-0.36	0.45	N
#e98	351420.0	1069837.8	22	-0.25	0.08	-0.10	-0.36	0.45	N
#e99	351271.5	1069816.4	22	0.21	-0.01	0.11	-0.36	0.45	N
#e100	351123.0	1069795.0	22	0.02	-0.07	-0.02	-0.36	0.45	N
#e101	350974.5	1069773.6	22	-0.41	0.46	-0.01	-0.36	0.45	N
#e102	350826.0	1069752.3	22	-0.02	-0.10	-0.06			Y
#e103	350677.5	1069730.9	22	-0.15	-0.04	-0.10	-0.36	0.45	N
#e104	350529.0	1069709.5	22	-0.21	-0.47	-0.33	-0.36	0.45	N
#e105	350380.5	1069688.1	22	0.10	-0.50	-0.18	-0.36	0.45	N
#e106	350232.0	1069666.7	22	-0.01	-0.19	-0.09	-0.36	0.45	N
#e107	350083.5	1069645.3	22	-0.21	0.63	0.18	-0.36	0.45	N
#e108	349935.0	1069623.9	22	-0.46	0.60	0.03	-0.36	0.45	N
#e109	349786.5	1069602.5	22	-0.45	0.40	-0.05	-0.36	0.45	N
#e110	349638.0	1069581.1	22	-0.63	0.64	-0.05	-0.36	0.45	N
#e111	349489.5	1069559.7	22	-0.70	0.41	-0.19	-0.36	0.45	N
#e112	349341.0	1069538.3	22	-0.27	0.11	-0.09	-0.36	0.45	N
#e113	349192.5	1069516.9	22	-0.63	0.32	-0.19	-0.36	0.45	N
#e114	349044.0	1069495.5	22	-1.10	0.42	-0.40	-0.36	0.45	N
#e115	348895.5	1069474.2	22	-0.24	0.10	-0.08	-0.36	0.45	N
#e116	348747.0	1069452.8	22	-0.40	0.26	-0.09	-0.36	0.45	Y
#e117	348598.5	1069431.4	22	-0.50	0.19	-0.18	-0.36	0.45	N
#e118	348450.0	1069410.0	22	-0.40	0.31	-0.08	-0.36	0.45	N
#e119	348301.5	1069388.6	22	-0.55	1.24	0.28	-0.36	0.45	N
#e120	348153.0	1069367.2	22	0.16	0.43	0.28	-0.36	0.45	N
#e121	348004.5	1069345.8	22	-0.73	0.22	-0.29	-0.36	0.45	N
#e122	347856.0	1069324.4	22	-0.32	-0.43	-0.37	-0.36	0.45	N
#e123	347707.5	1069303.0	22	-1.10	0.07	-0.56	-0.36	0.45	N
#e124	347559.0	1069281.6	22	-0.20	-0.39	-0.29	-0.36	0.45	N
#e125	347410.5	1069260.2	22	-0.60	-0.34	-0.48	-0.36	0.45	N
#e126	347262.0	1069238.8	22	-0.38	0.27	-0.08	-0.93	0.09	N
#e127	347113.5	1069217.4	22	-0.70	0.07	-0.34	-0.93	0.09	N
#e128	346965.0	1069196.0	22	-1.03	1.47	0.13	-0.36	0.45	N
#e129	346816.5	1069174.7	22	-0.19	0.49	0.13	-1.67	0.09	N
#e130	346668.0	1069153.3	22	-0.17	-0.25	-0.21	-1.67	0.09	N
#e131	346519.5	1069131.9	22	-0.49	0.11	-0.21	-0.36	0.45	N
#e132	346371.0	1069110.5	22	-0.39	0.20	-0.12	-0.36	0.45	N
#e133	346222.5	1069089.1	22	-0.66	0.10	-0.31	-0.36	0.45	N
#e134	346074.0	1069067.7	22	-0.15	-0.11	-0.13	-0.36	0.45	N
#e135	345925.5	1069046.3	22	-0.29	-0.02	-0.17	-0.36	0.45	N
#e136	345777.0	1069024.9	22	-0.14	-0.04	-0.09	-0.36	0.45	N
#e137	345628.5	1069003.5	22	-0.56	0.49	-0.07	-0.36	0.45	N
#e138	345480.0	1068982.1	22	-0.39	0.49	0.02	-0.36	0.45	N
#e139	345331.5	1068960.7	22	-0.53	0.38	-0.11	-0.36	0.45	N
#e140	345183.0	1068939.3	22	-0.14	-0.33	-0.23	-0.36	0.45	N
#e141	345034.5	1068917.9	22	-0.02	-0.13	-0.07	-0.36	0.45	N
#e142	344886.0	1068896.5	22	-0.31	-0.14	-0.23	-0.36	0.45	N
#e143	344737.5	1068875.2	22	-0.68	0.29	-0.23	-0.36	0.45	N
#e144	344589.0	1068853.8	22	-0.26	0.27	-0.02	-0.36	0.45	N
#e145	344440.5	1068832.4	22	-1.58	0.60	-0.57	-0.36	0.45	N
#e146	344292.0	1068811.0	22	-0.79	0.32	-0.28	-0.36	0.45	N
#e147	344143.5	1068789.6	22	-0.60	0.96	0.12	-0.36	0.45	N
#e148	343995.0	1068768.2	22	0.07	0.15	0.11	-0.36	0.45	N
#e149	343846.5	1068746.8	22	-0.31	0.35	-0.01	-0.36	0.45	N
#e150	343698.0	1068725.4	22	-0.55	0.40	-0.11	-0.36	0.45	N
#e151	343549.5	1068704.0	22	-0.33	0.67	0.13	-0.36	0.45	N
#e152	343401.0	1068682.6	22	-0.17	-0.08	-0.13	-0.36	0.45	N
#e153	343252.5	1068661.2	22	-0.25	0.19	-0.05	-0.36	0.45	N
#e154	343104.0	1068639.8	22	-0.16	-0.24	-0.20	-0.36	0.45	N
#e155	342955.5	1068618.4	22	-0.31	0.20	-0.07	-0.36	0.45	N
#e156	342807.0	1068597.0	22	-0.26	0.01	-0.14	-0.36	0.45	N
#e157	342658.5	1068575.7	22	-0.42	0.03	-0.21	-0.36	0.45	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#e158	342510.0	1068554.3	22	−0.01	0.22	0.09	−0.36	0.45	N
#e159	342361.5	1068532.9	22	0.22	0.39	0.30	−0.36	0.45	N
#e160	342213.0	1068511.5	22	0.29	0.37	0.32	−0.36	0.45	N
#e161	342064.5	1068490.1	22	0.62	0.08	0.37	−0.36	0.45	N
#e162	341916.0	1068468.7	22	0.26	0.12	0.19	−0.36	0.45	N
#e163	341767.5	1068447.3	22	−1.44	1.48	−0.09	−0.36	0.45	N
#e164	341619.0	1068425.9	22	−0.25	−0.02	−0.14	−0.36	0.45	N
#e165	341470.5	1068404.5	22	−0.34	0.27	−0.06	−0.36	0.45	N
#e166	341322.0	1068383.1	22	−0.61	0.45	−0.12	−0.36	0.45	N
#e167	341173.5	1068361.7	22	−0.55	0.31	−0.15	−0.36	0.45	N
#e168	341025.0	1068340.3	22	−0.57	0.30	−0.17	−0.36	0.45	N
#e169	340876.5	1068318.9	22	−0.41	0.10	−0.18	−0.36	0.45	N
#e170	340728.0	1068297.5	22	−0.37	0.24	−0.09	−0.36	0.45	N
#e171	340579.5	1068276.2	21.5	−0.30	0.10	−0.11	−0.11	1.00	N
#e172	340431.0	1068254.8	21.5	−3.18	3.09	−0.29	−0.29	1.00	N
#e173	340282.5	1068233.4	21.5	−3.02	1.60	−0.89	−0.89	1.00	N
#e174	340134.0	1068212.0	22	−0.84	−0.02	−0.46	−0.36	0.45	N
#e175	339985.5	1068190.6	22	−0.28	−0.20	−0.24	−0.36	0.45	N
#e176	339837.0	1068169.2	22	−0.38	0.48	0.01	−0.36	0.45	N
#e177	339688.5	1068147.8	22	−0.17	0.12	−0.04	−0.36	0.45	N
#e178	339540.0	1068126.4	22	−0.34	0.14	−0.12	−0.36	0.45	N
#e179	339391.5	1068105.0	22	−0.25	−0.16	−0.21	−0.36	0.45	N
#e180	339243.0	1068083.6	22	−0.33	0.06	−0.15	−0.36	0.45	N
#e181	339094.5	1068062.2	22	−0.42	−0.06	−0.25	−0.36	0.45	N
#e182	338946.0	1068040.8	22	−0.35	−0.24	−0.30	−0.36	0.45	N
#e183	338797.1	1068023.0	22	−0.09	−0.30	−0.19	−0.36	0.45	N
#e184	338648.1	1068006.0	22	−0.34	−0.00	−0.18	−0.36	0.45	Y
#e185	338499.1	1067988.9	22	−0.13	−0.49	−0.29	−0.36	0.45	N
#e186	338350.1	1067971.9	22	−0.38	0.00	−0.21	−0.36	0.45	N
#e187	338201.1	1067954.9	22	−0.27	−0.21	−0.24	−0.36	0.45	N
#e188	338052.1	1067937.9	22	−0.25	−0.00	−0.13	−0.36	0.45	N
#e189	337903.1	1067920.8	22	−0.41	0.36	−0.06	−0.36	0.45	N
#e190	337754.1	1067903.8	22	−0.51	0.23	−0.17	−0.36	0.45	N
#e191	337605.1	1067886.8	22	−0.32	−0.12	−0.23	−0.36	0.45	N
#e192	337456.1	1067869.7	22	−0.45	0.22	−0.14	−0.36	0.45	N
#e193	337307.1	1067852.7	22	−0.31	0.04	−0.15	−0.36	0.45	N
#e194	337158.1	1067835.7	22	−0.54	−0.02	−0.30	−0.36	0.45	N
#e195	337009.1	1067818.7	22	−0.34	0.26	−0.06	−0.36	0.45	N
#e196	336860.1	1067801.6	22	−0.56	0.22	−0.20	−0.36	0.45	N
#e197	336711.1	1067784.6	22	−0.46	0.05	−0.22	−0.45	0.07	N
#e198	336562.1	1067767.6	22	−0.22	−0.13	−0.18	−0.36	0.45	N
#e199	336413.1	1067750.5	22	−0.26	−0.02	−0.15	−0.36	0.45	N
#e200	336264.1	1067733.5	22	−0.19	0.06	−0.07	−0.36	0.45	N
#e201	336115.1	1067716.5	22	−0.09	0.11	0.01	−0.36	0.45	N
#e202	335966.1	1067699.5	23	−0.21	0.06	−0.09	NO DATA	NO DATA	N
#e203	335817.1	1067682.4	23	−1.65	1.48	−0.20	NO DATA	NO DATA	N
#e204	335668.1	1067665.4	23	−0.06	0.02	−0.02	NO DATA	NO DATA	N
#e205	335519.1	1067648.4	23	−0.26	0.34	0.01	NO DATA	NO DATA	N
#e206	335370.1	1067631.3	23	−0.21	0.29	0.02	NO DATA	NO DATA	N
#e207	335221.1	1067614.3	23	−0.32	0.20	−0.08	NO DATA	NO DATA	N
#e208	335072.0	1067598.4	23	−0.09	−0.50	−0.27	NO DATA	NO DATA	N
#e209	334922.4	1067587.0	23	−0.26	−0.01	−0.15	NO DATA	NO DATA	N
#e210	334772.8	1067575.6	23	−0.23	−0.42	−0.32	NO DATA	NO DATA	N
#e211	334623.2	1067564.2	23	−0.23	−0.04	−0.14	NO DATA	NO DATA	N
#e212	334473.6	1067552.7	23	−0.26	−0.56	−0.40	NO DATA	NO DATA	N
#e213	334324.1	1067548.4	23	−0.16	−0.69	−0.40	NO DATA	NO DATA	N
#e214	334174.8	1067562.5	23	−0.39	0.04	−0.19	NO DATA	NO DATA	N
#e215	334025.5	1067576.7	23	−0.27	−0.73	−0.49	NO DATA	NO DATA	N
#e216	333879.2	1067601.6	23	−0.42	−0.12	−0.28	NO DATA	NO DATA	N
#e217	333743.7	1067666.0	23	−0.79	−0.13	−0.49	NO DATA	NO DATA	N
#e218	333608.2	1067730.4	23	−1.94	−0.13	−1.11	NO DATA	NO DATA	N
#e219	333472.8	1067794.9	23	−2.27	0.72	−0.89	NO DATA	NO DATA	N
#e220	333337.6	1067859.8	23	−2.17	1.55	−0.45	NO DATA	NO DATA	N
#e221	333202.4	1067924.7	23		1.82		NO DATA	NO DATA	N
#e222	333058.1	1067926.6	23				NO DATA	NO DATA	N

TRANSECT	NORTHING	EASTING	SEGMENT	R67−39	R91−67	R91−39	BEST	ERROR	SPS
#e223	332937.3	1067837.7	23				NO DATA	NO DATA	N
#e224	332816.5	1067748.8	23				NO DATA	NO DATA	N
#e225	332695.7	1067659.8	23				NO DATA	NO DATA	N
#e226	332564.9	1067586.9	23				NO DATA	NO DATA	N
#e227	332432.0	1067517.4	23			−0.67	NO DATA	NO DATA	N
#e228	332299.0	1067448.0	24	−0.77	0.09	−0.37	−0.36	0.45	N
#e229	332158.7	1067395.1	24	−0.30	−0.35	−0.32	−0.36	0.45	N
#e230	332018.3	1067342.3	24	−0.40	−0.53	−0.46	−0.36	0.45	N
#e231	331877.9	1067289.6	24	−0.70	0.35	−0.22	−0.36	0.45	N
#e232	331737.5	1067236.9	24	−1.54	−0.05	−0.85	−0.36	0.45	N
#e233	331597.1	1067184.1	24	−1.41	−0.80	−1.13	−0.36	0.45	N
#e234	331456.7	1067131.4	24	−1.33	−0.70	−1.04	−0.36	0.45	N
#e235	331316.0	1067079.5	24	−0.58	−1.09	−0.82	−0.36	0.45	N
#e236	331171.4	1067039.6	24	−0.47	−0.66	−0.56	−0.36	0.45	N
#e237	331026.8	1066999.7	24	−0.45	−0.20	−0.34	−0.36	0.45	N
#e238	330882.2	1066959.8	24	−0.68	0.04	−0.35	−0.36	0.45	N
#e239	330737.6	1066919.9	24	−0.73	−0.04	−0.41	−0.36	0.45	N
#e240	330593.0	1066880.0	24	−0.90	−0.18	−0.57	−0.36	0.45	N
#e241	330448.4	1066840.0	24	−0.51	−0.13	−0.33	−0.36	0.45	N
#e242	330303.8	1066800.1	24	−0.23	−0.24	−0.23	−0.36	0.45	N
#e243	330159.2	1066760.2	24	0.50	−0.36	0.10	−0.36	0.45	N
#e244	330014.6	1066720.3	24	−0.21	−0.50	−0.34	−0.36	0.45	N
#e245	329870.0	1066680.4	24	−0.07	−0.14	−0.10	−0.36	0.45	N
#e246	329725.4	1066640.5	24	−0.36	−0.47	−0.41	−0.36	0.45	N
#e247	329580.8	1066600.5	24	−0.16	−0.33	−0.24	−0.36	0.45	N
#e248	329436.2	1066560.6	24	−0.31	−0.53	−0.42	−0.36	0.45	N
#e249	329291.6	1066520.7	24	−0.18	−0.26	−0.22	−0.36	0.45	N
#e250	329147.0	1066480.8	24	−0.20	−0.42	−0.30	−0.36	0.45	N
#e251	329002.4	1066440.9	24	0.02	−0.60	−0.26	−0.36	0.45	N
#e252	328857.8	1066401.0	24	1.00	−0.10	0.49	−0.36	0.45	N
#e253	328713.2	1066361.1	24	0.44	0.20	0.33	−0.36	0.45	N
#e254	328568.6	1066321.1	24	0.45	−0.31	0.10	−0.36	0.45	N
#e255	328424.0	1066281.2	24	−1.22	0.05	−0.63	NO DATA	NO DATA	N
#e256	328279.4	1066241.3	24	−1.22	0.38	−0.48	−0.36	0.45	N
#e257	328134.8	1066201.4	24	−0.88	0.12	−0.42	−0.36	0.45	N
#e258	327990.2	1066161.5	24	−0.76	0.13	−0.35	−0.36	0.45	N
#e259	327845.6	1066121.6	24	−0.80	0.29	−0.30	−0.36	0.45	N
#e260	327701.0	1066081.6	24	−0.70	−0.18	−0.46	−0.36	0.45	N
#e261	327556.4	1066041.7	24	−0.35	−0.63	−0.48	−0.36	0.45	N
#e262	327411.5	1066002.8	24			−1.01	−0.36	0.45	N
#e263	327265.8	1065967.3	24	−0.88	−0.02	−0.48	−0.36	0.45	N
#e264	327120.0	1065931.9	24	−0.78	−0.17	−0.50	−0.36	0.45	N
#e265	326974.3	1065896.4	25	−0.77	−0.44	−0.62	−1.53	0.07	N
#e266	326828.6	1065860.9	25	−0.66	−0.32	−0.50	−0.24	0.45	N
#e267	326682.8	1065825.5	25	−0.63	0.38	−0.16	−0.24	0.45	N
#e268	326536.5	1065793.5	25	−0.49	0.34	−0.11	−0.24	0.45	N
#e269	326387.3	1065778.4	25	−1.27	0.98	−0.23	−0.24	0.45	N
#e270	326238.1	1065763.3	25	−0.70	0.02	−0.37	−0.24	0.45	N
#e271	326088.9	1065748.2	25	−0.80	0.57	−0.17	−0.24	0.45	N
#e272	325939.7	1065733.1	25	−0.40	0.09	−0.18	−0.24	0.45	N
#e273	325790.5	1065718.0	26	−0.44	0.17	−0.16	−0.11	0.08	N
#e274	325641.3	1065702.9	26	0.27	−0.47	−0.07	−0.11	0.08	N
#e275	325493.9	1065676.7	26	0.62	−0.75	−0.01	−0.11	0.08	N
#e276	325347.4	1065644.3	26	−0.66	0.06	−0.33	−0.11	0.08	N
#e277	325200.8	1065612.6	26	−1.06	0.85	−0.18	−0.11	0.08	N
#e278	325051.6	1065597.5	26	−0.63	0.95	0.10	−0.11	0.08	N
#e279	324902.4	1065582.5	26	−0.67	0.32	−0.22	−0.11	0.08	N
#e280	324768.8	1065521.8	26	−0.35	0.15	−0.12	−0.11	0.08	N
#e281	324641.8	1065441.9	26			0.08	−0.11	0.08	N
#e282	324514.8	1065362.1	26			−0.22	−0.11	0.08	N

APPENDIX D

GRAPHS OF EROSION RATE VERSUS TRANSECT NUMBER

The graphs show transect number on the X axis plotted against erosion rate measured by the digital shoreline technique. Available house-to-bluff erosion rates and rates derived from the 1868 T-map of the Newport-Agate Beach area are also shown. The transects are spaced at 150 ft intervals along the shoreline segments, so the graphs show geographic variation of erosion rate. Areas with shoreline protection devices (rip rap or sea walls) are shown by a graphic symbol on the X axis. The term SPS stands for shoreline protection structure on the graphs.

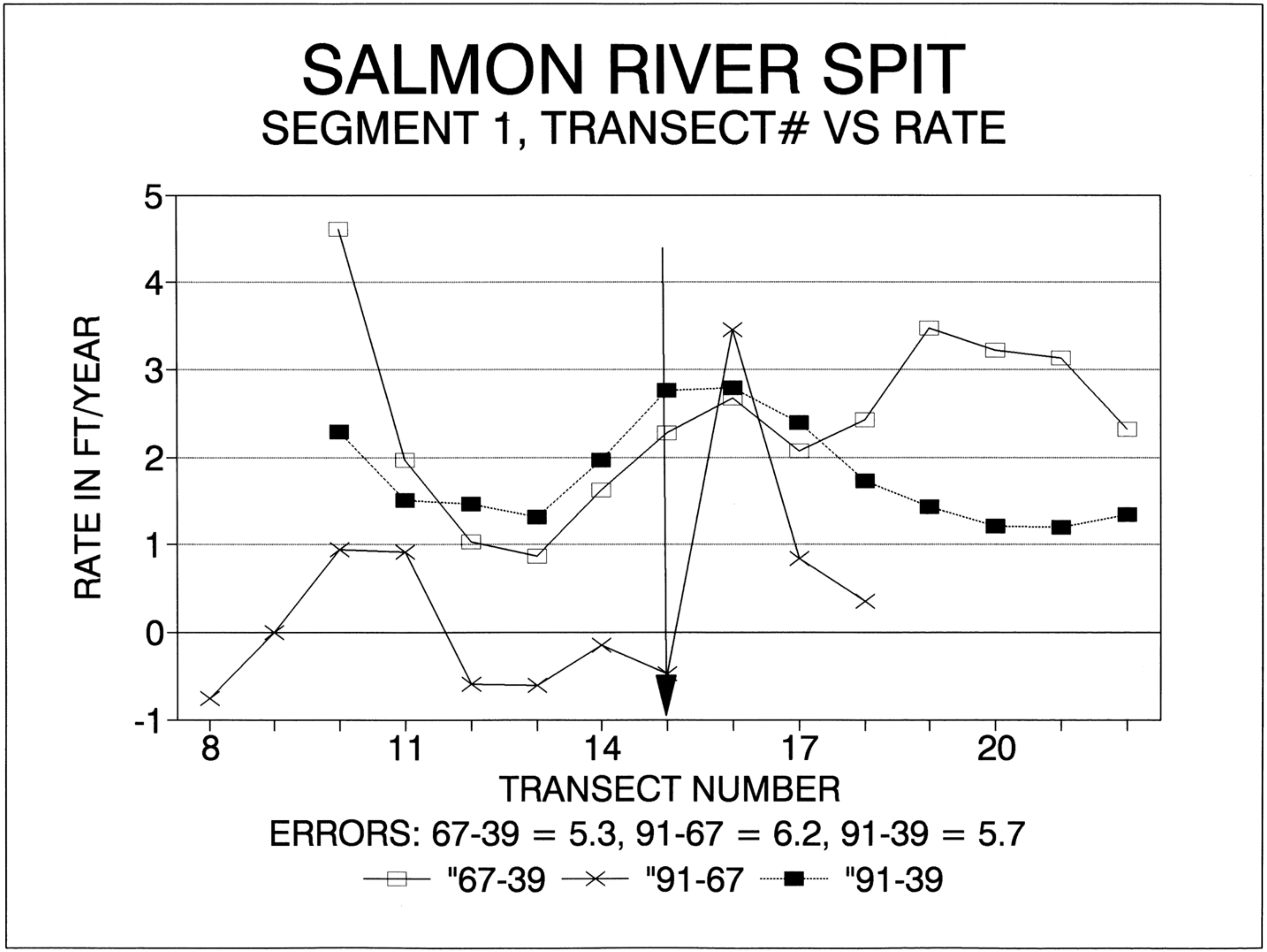
The data labeled "67-"39, "91-"67, and "91-"39 are, respectively, the rates obtained by the difference in spatial position of the 1967 versus the 1939 shoreline, the 1991 versus the 1967 shoreline, and the 1991 versus the 1939 shoreline. Measurements were done randomly every 150 feet along the shoreline.

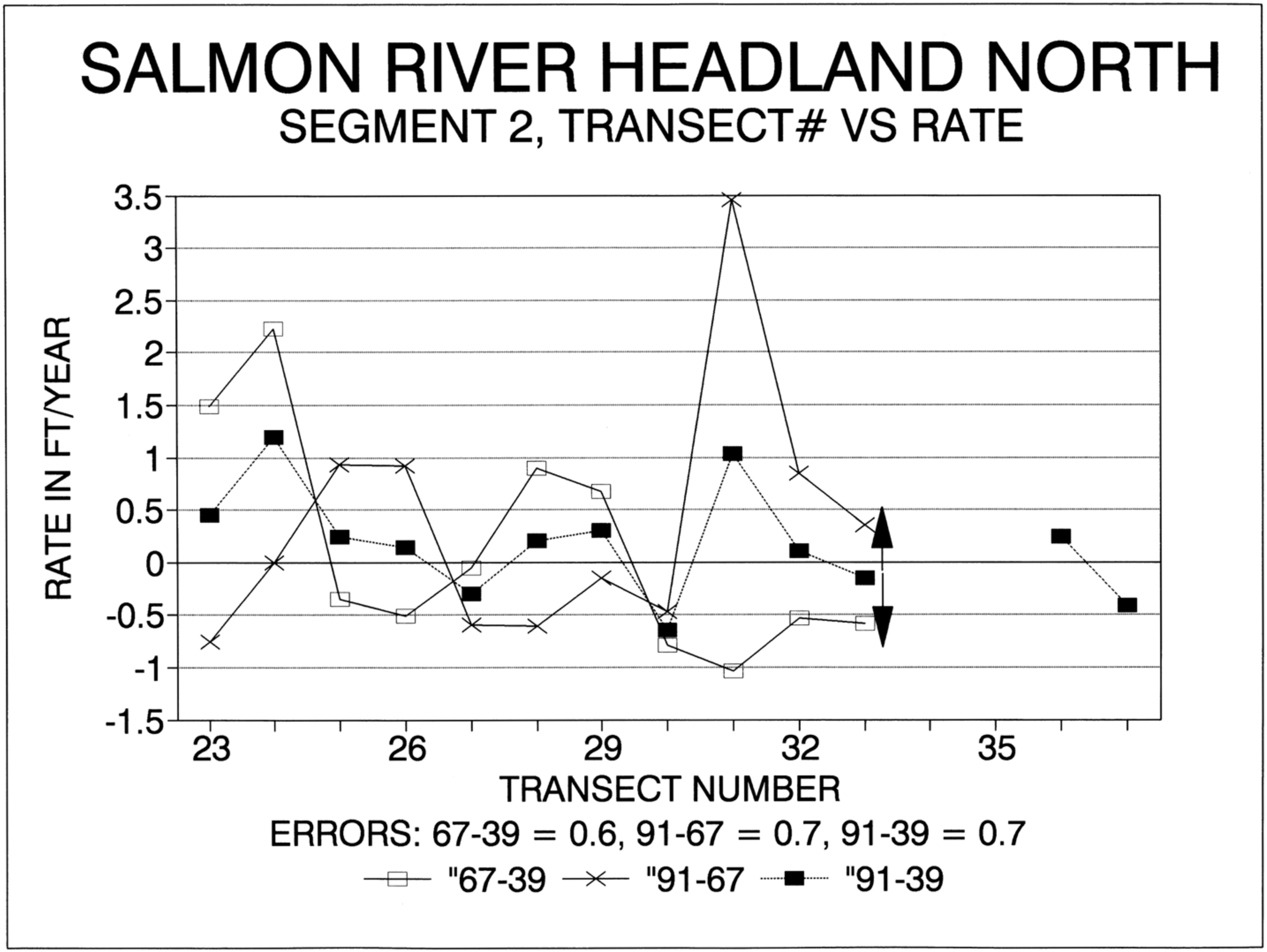
Data labeled 1868-"91 are rates obtained by transferring the bluff edge or landslide headwall from 1:12,000 scale air photos to a 1:10,000 scale map of the Newport-Agate Beach area produced by the Coast and Geodetic Survey in 1868.

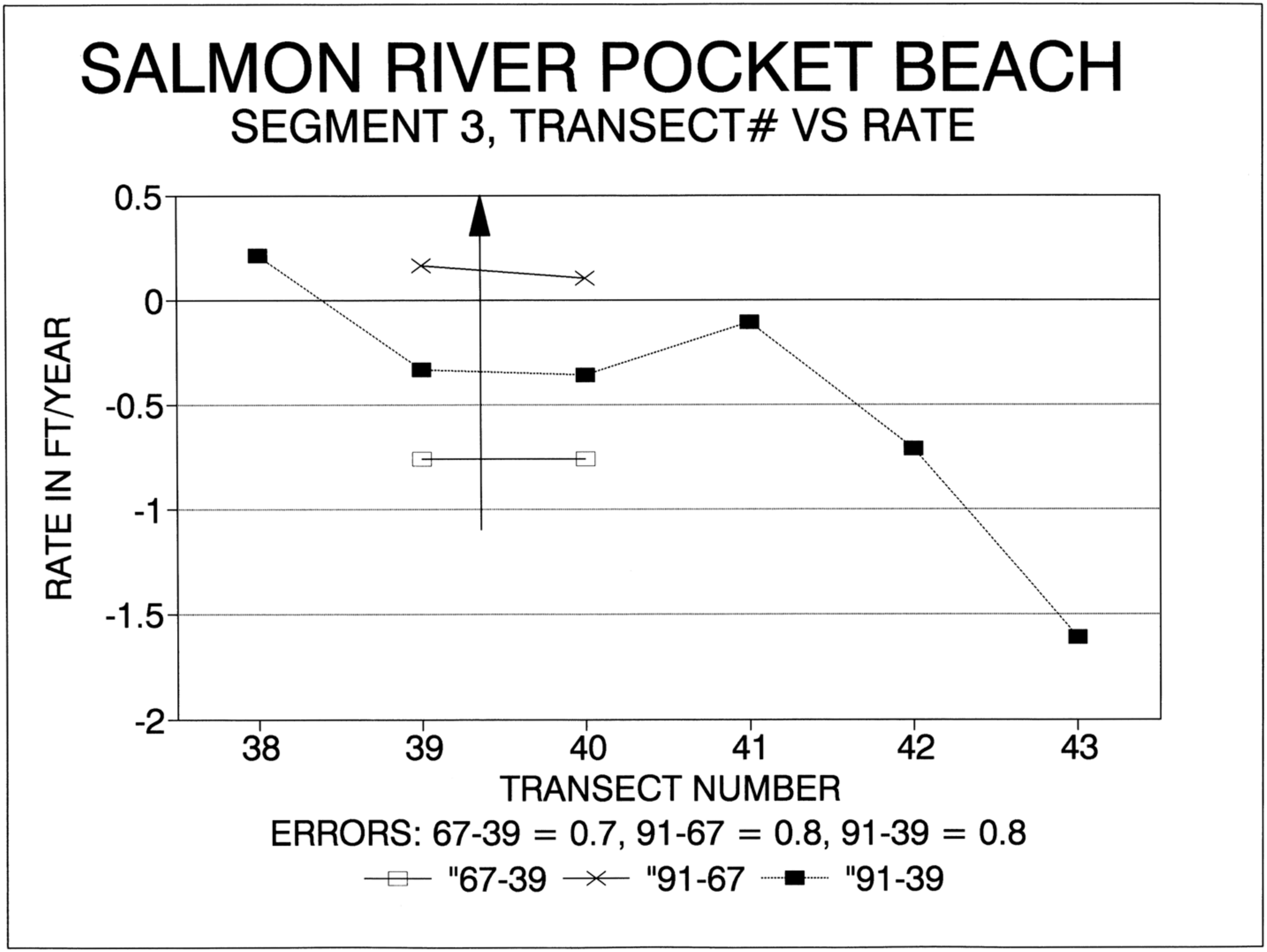
Data labeled "Bluff" are rates of bluff retreat obtained in most cases by comparing the distance between a house or other feature and the bluff edge to the same distance on 1967 Oregon Department of Transportation photo-based maps at a scale of approximately 1" = 100'. In a few rare cases the bluff rate is determined by comparison of field measurements to a 1939 Corps of Engineers air photo at a scale of approximately 1" = 900'.

The overall uncertainty in the measurements for each segment is listed in the legends as "ERRORS" and, if the uncertainty is significantly larger than the graphical symbols used to plot the data, a representative range of uncertainty is shown by horizontal arrows. For the rates based on mapping of digital shorelines from historical photos, visual spot checks of the uncertainty in picking the storm surge penetration line were made at 1000' intervals utilizing the 1967 photo based maps at a scale of 1" = 100'. These uncertainties are probably conservative (high), because, unlike the 1939 and 1991 shorelines, in parts of the 1967 shoreline log accumulations were present that created somewhat greater uncertainties in the position of the storm surge penetration line.

For the rates based on house-to-bluff measurements, the error of individual measurements was determined by estimating the amount of each individual error source (bluff edge uncertainty, width of ink line on photo, and field taping error) and taking the square root of the sum of squares of these errors. The overall uncertainty of digital shoreline rates and house-to-bluff rates for each segment was calculated by squaring the individual error estimates, dividing the sum of squares by the number of measurements minus 1, and taking the square root. Where there were three or fewer measurements of uncertainty (as in some small pocket beaches), a simple mean of the uncertainty measurements was utilized.

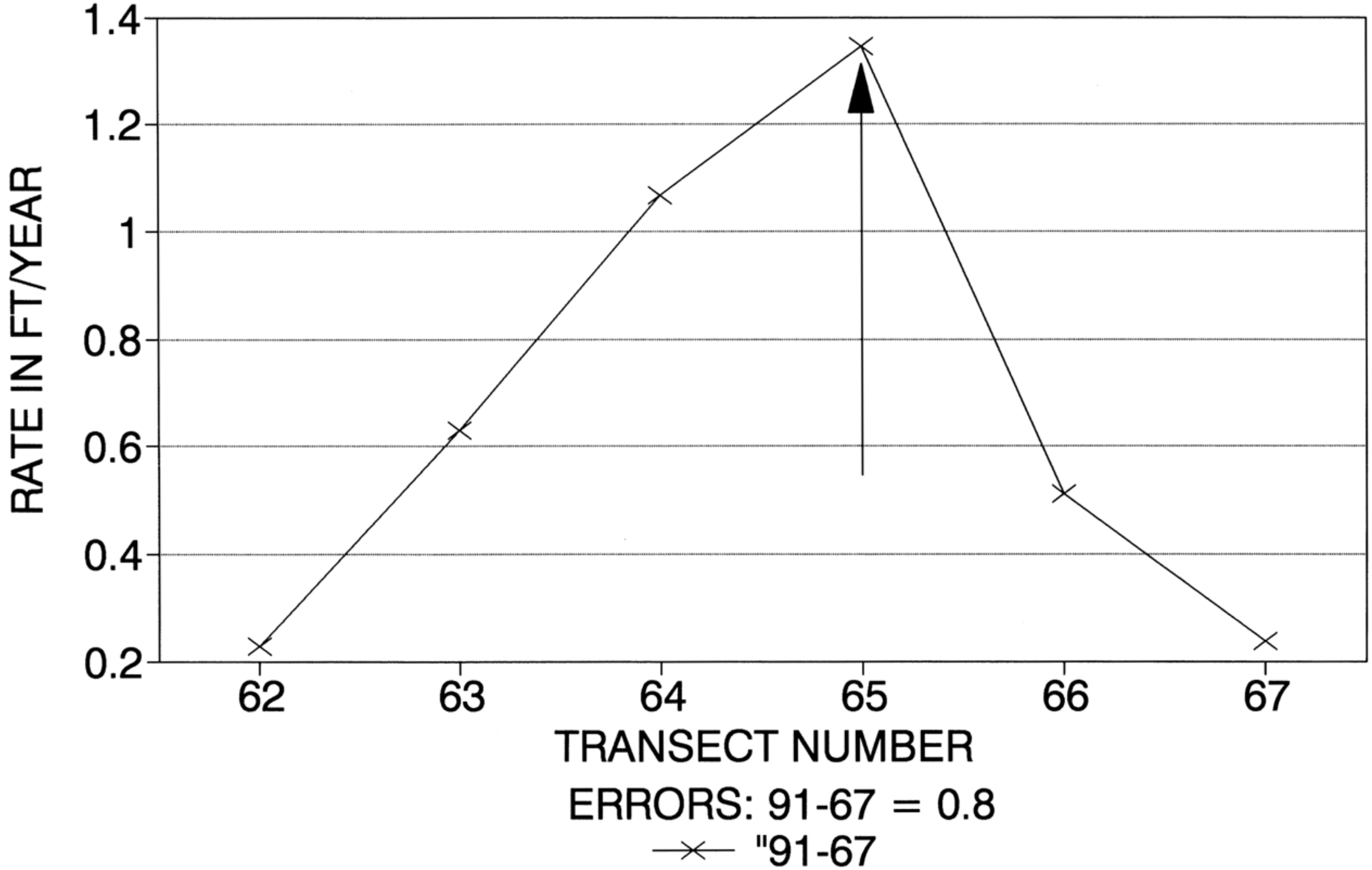

SALMON RIVER SPIT
SEGMENT 1, TRANSECT# VS RATE
RATE IN FT/YEAR
5
4
3
2
1
0
-1
8
11
14
17
20
TRANSECT NUMBER
ERRORS: 67-39 = 5.3, 91-67 = 6.2, 91-39 = 5.7
"67-39
"91-67
"91-39


SALMON RIVER HEADLAND NORTH
SEGMENT 2, TRANSECT# VS RATE
RATE IN FT/YEAR
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
23
26
29
32
35
TRANSECT NUMBER
ERRORS: 67-39 = 0.6, 91-67 = 0.7, 91-39 = 0.7
"67-39
"91-67
"91-39


SALMON RIVER POCKET BEACH
SEGMENT 3, TRANSECT# VS RATE
RATE IN FT/YEAR
0.5
0
-0.5
-1
-1.5
-2
38
39
40
41
42
43
TRANSECT NUMBER
ERRORS: 67-39 = 0.7, 91-67 = 0.8, 91-39 = 0.8
"67-39
"91-67
"91-39

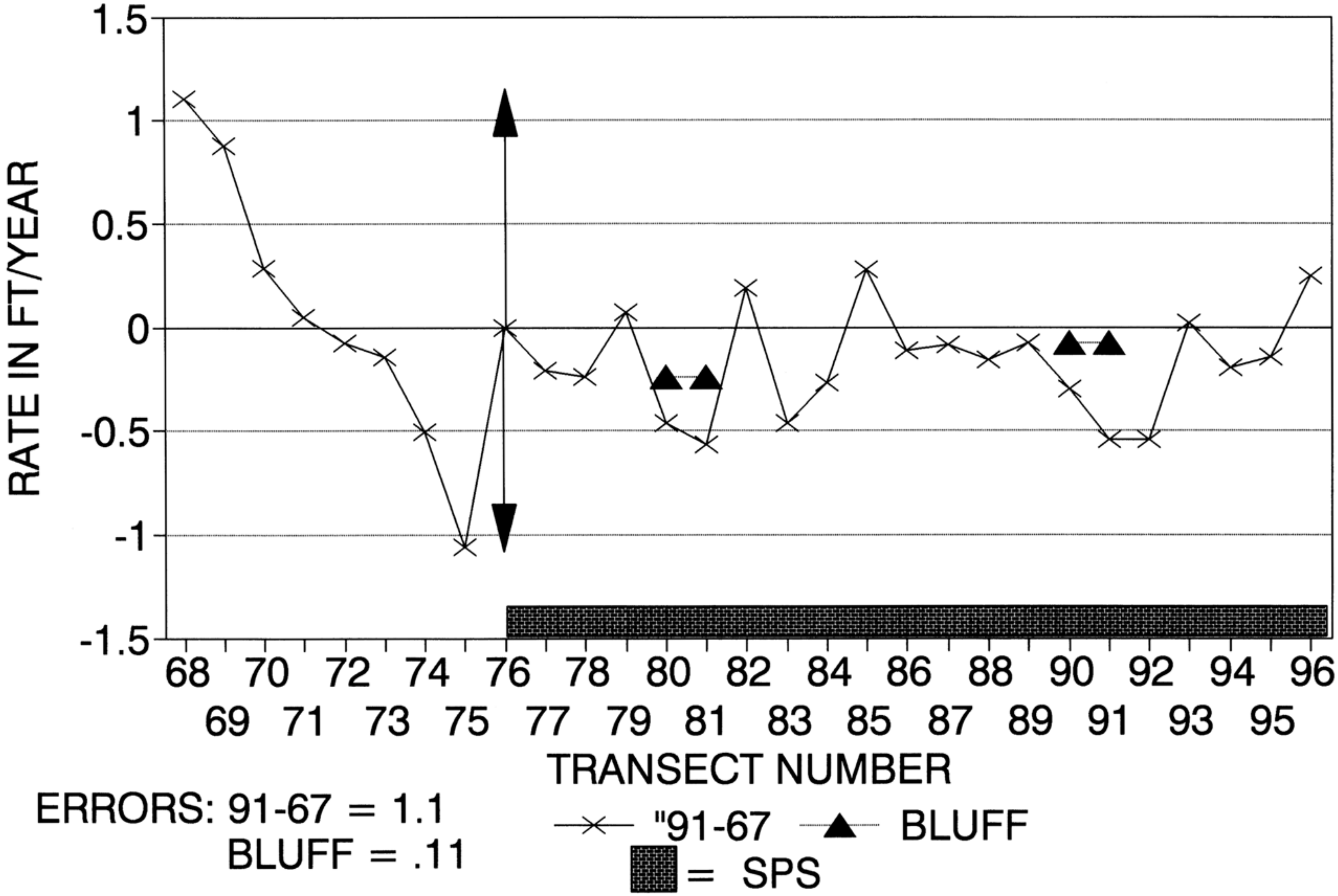
HIGH CLIFFS NORTH OF ROADS END

SEGMENT 4.5, TRANSECT# VS RATE



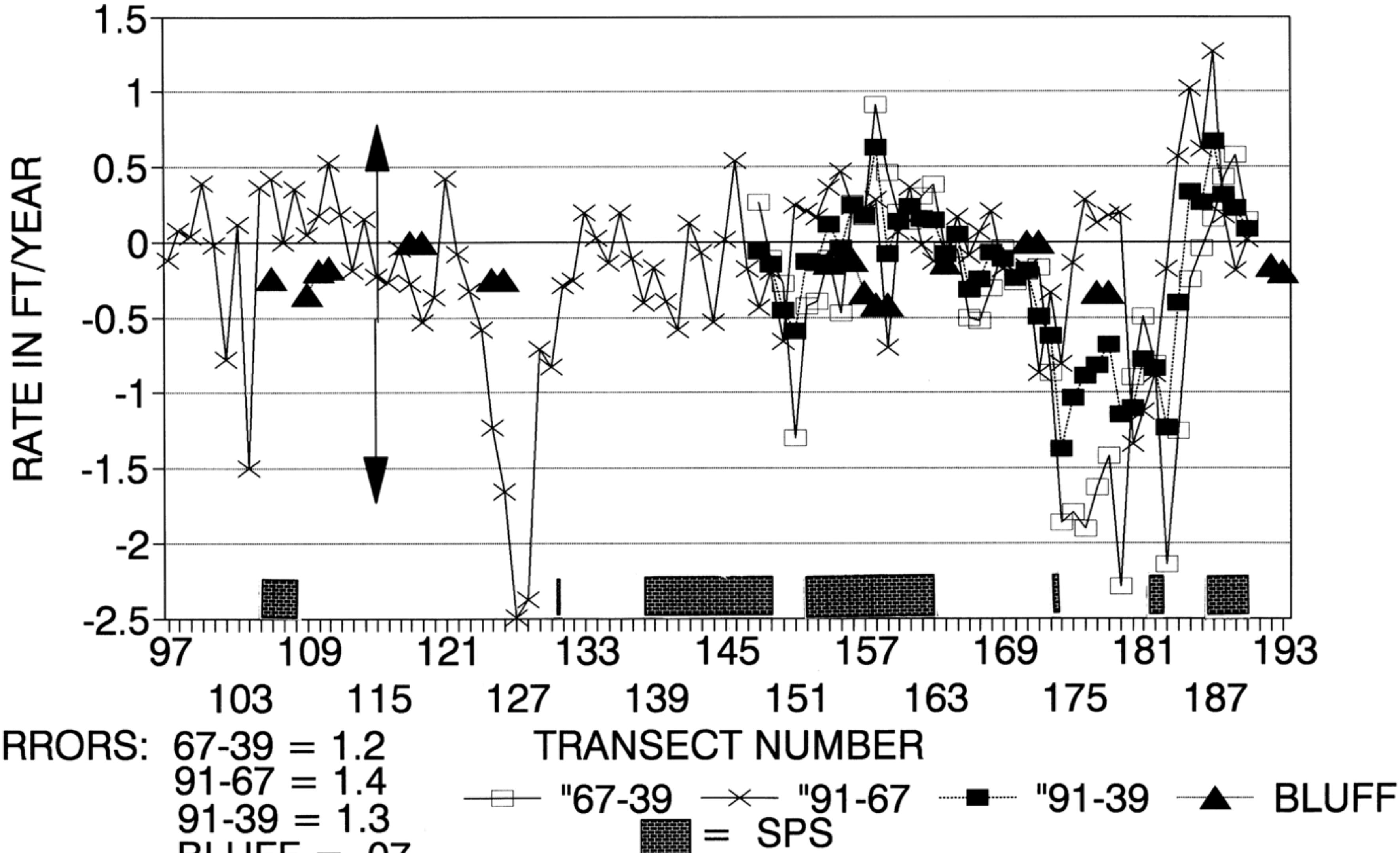
ROADS END

SEGMENT 5, TRANSECT# VS RATE

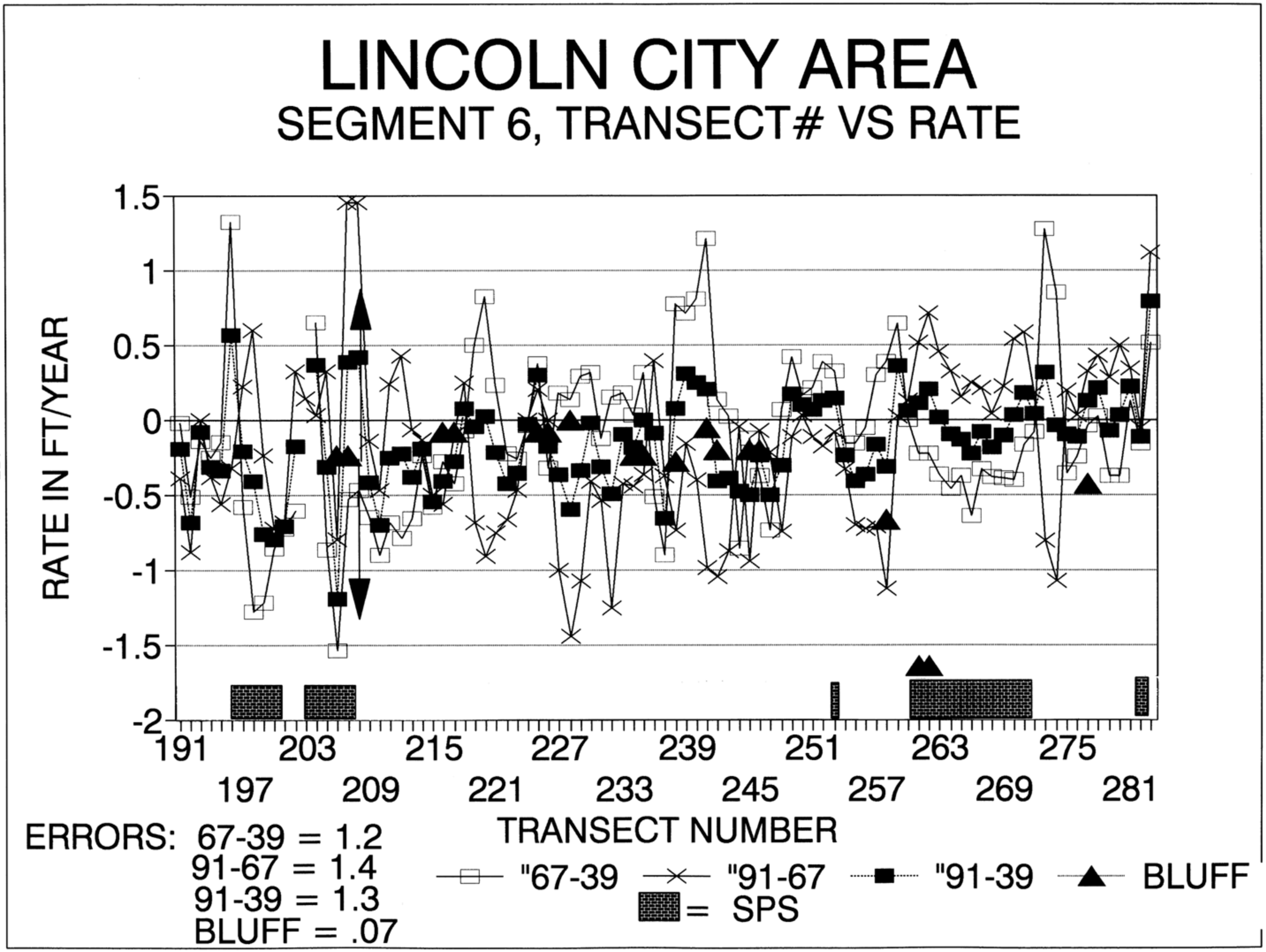


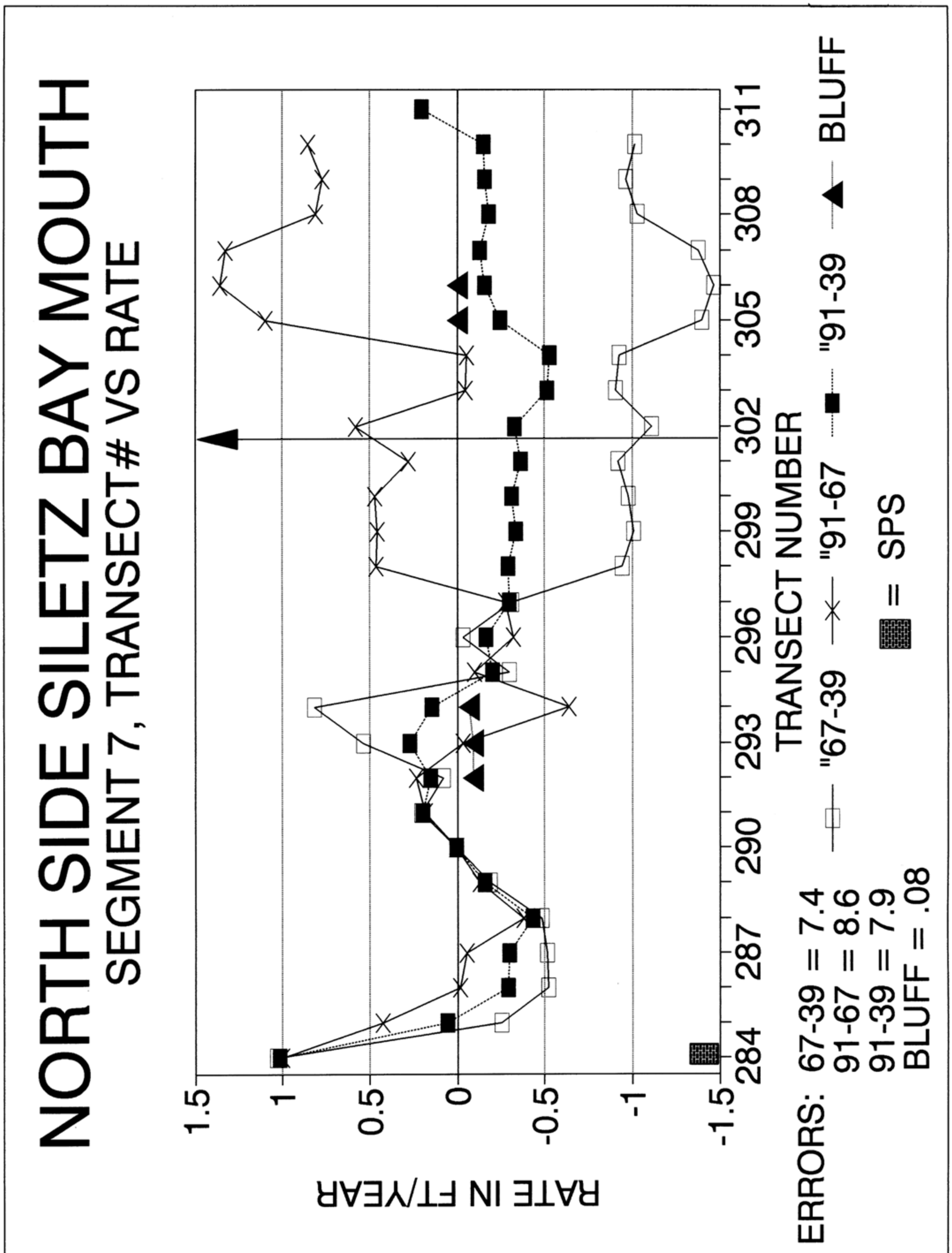
LINCOLN CITY AREA

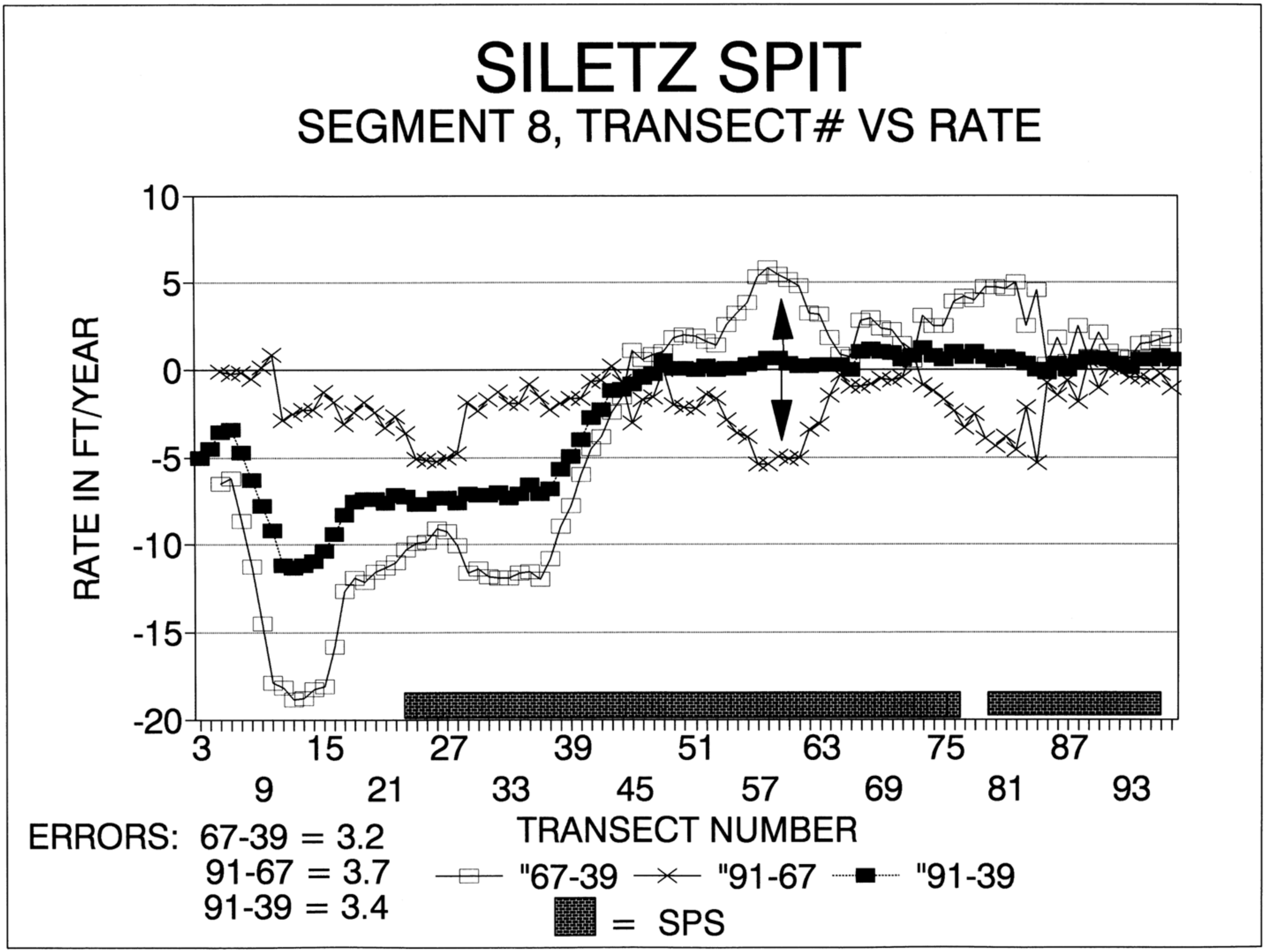
SEGMENT 6, TRANSECT# VS RATE



ERRORS: 67-39 = 1.2
91-67 = 1.4
91-39 = 1.3
BLUFF = .07


LINCOLN CITY AREA
SEGMENT 6, TRANSECT# VS RATE
RATE IN FT/YEAR
1.5
1
0.5
0
-0.5
-1
-1.5
-2
191
197
203
209
215
221
227
233
239
245
251
257
263
269
275
281
TRANSECT NUMBER
ERRORS: 67-39 = 1.2
91-67 = 1.4
91-39 = 1.3
BLUFF = .07
"67-39
"91-67
"91-39
BLUFF
= SPS

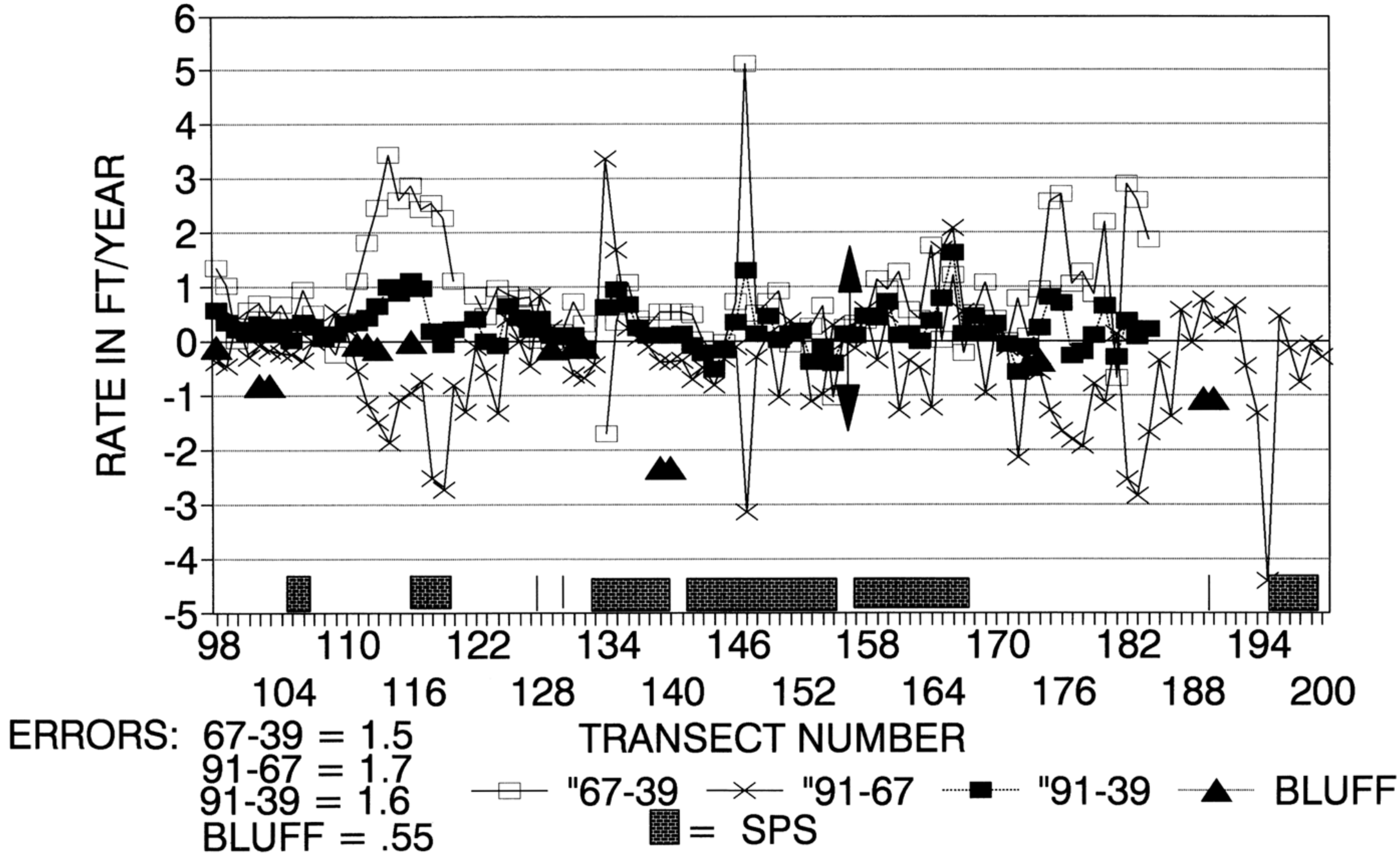

NORTH SIDE SILETZ BAY MOUTH
SEGMENT 7, TRANSECT# VS RATE
RATE IN FT/YEAR
1.5
1
0.5
0
-0.5
-1
-1.5
284
287
290
293
296
299
302
305
308
311
TRANSECT NUMBER
ERRORS: 67-39 = 7.4
91-67 = 8.6
91-39 = 7.9
BLUFF = .08
"67-39
"91-67
"91-39
BLUFF
= SPS



SILETZ SPIT
SEGMENT 8, TRANSECT# VS RATE
RATE IN FT/YEAR
10
5
0
-5
-10
-15
-20
3
9
15
21
27
33
39
45
51
57
63
69
75
81
87
93
TRANSECT NUMBER
ERRORS: 67-39 = 3.2
91-67 = 3.7
91-39 = 3.4
"67-39
"91-67
"91-39
= SPS

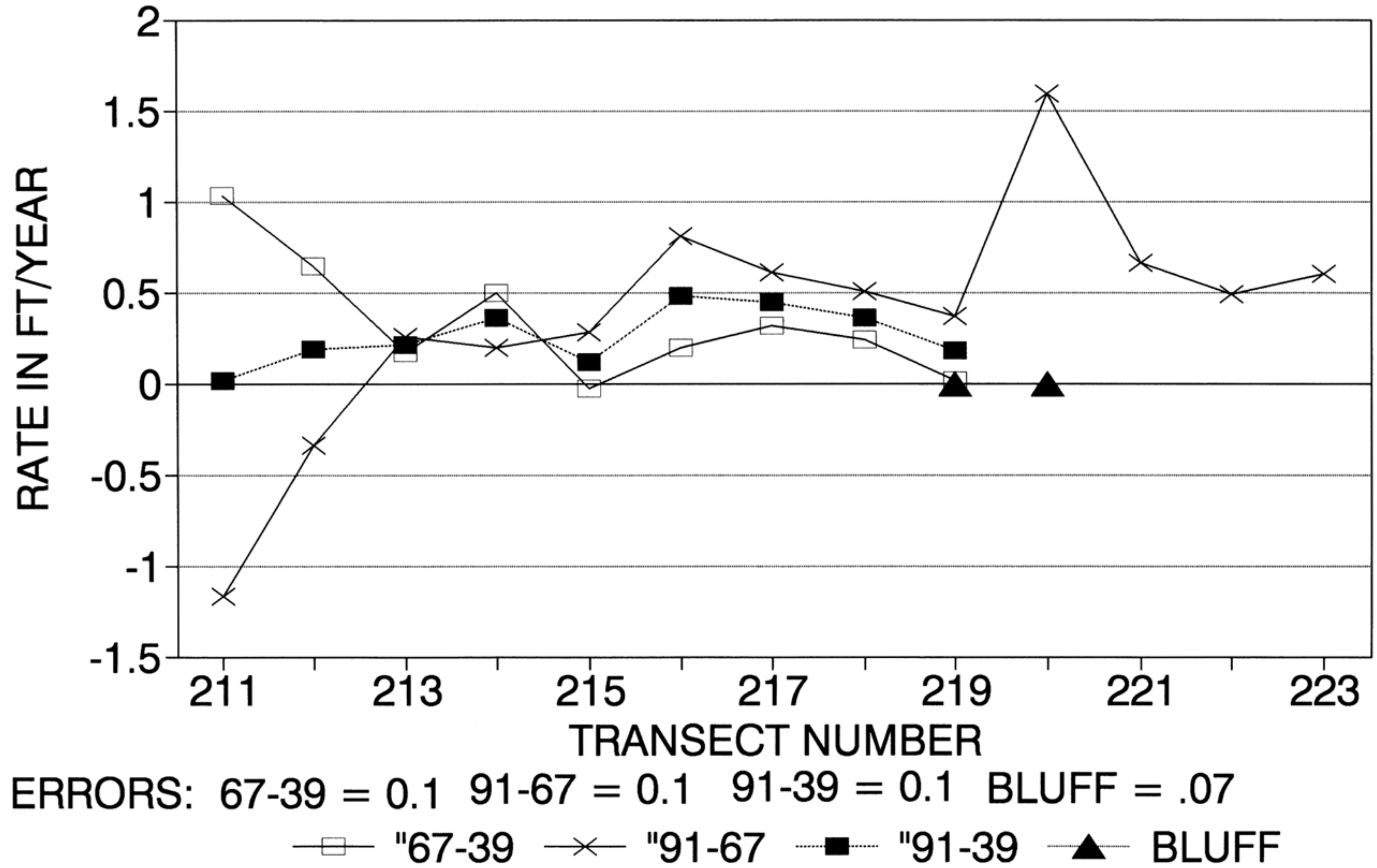
GLENEDEN BEACH TO FISHING ROCK

SEGMENT 9, TRANSECT# VS RATE



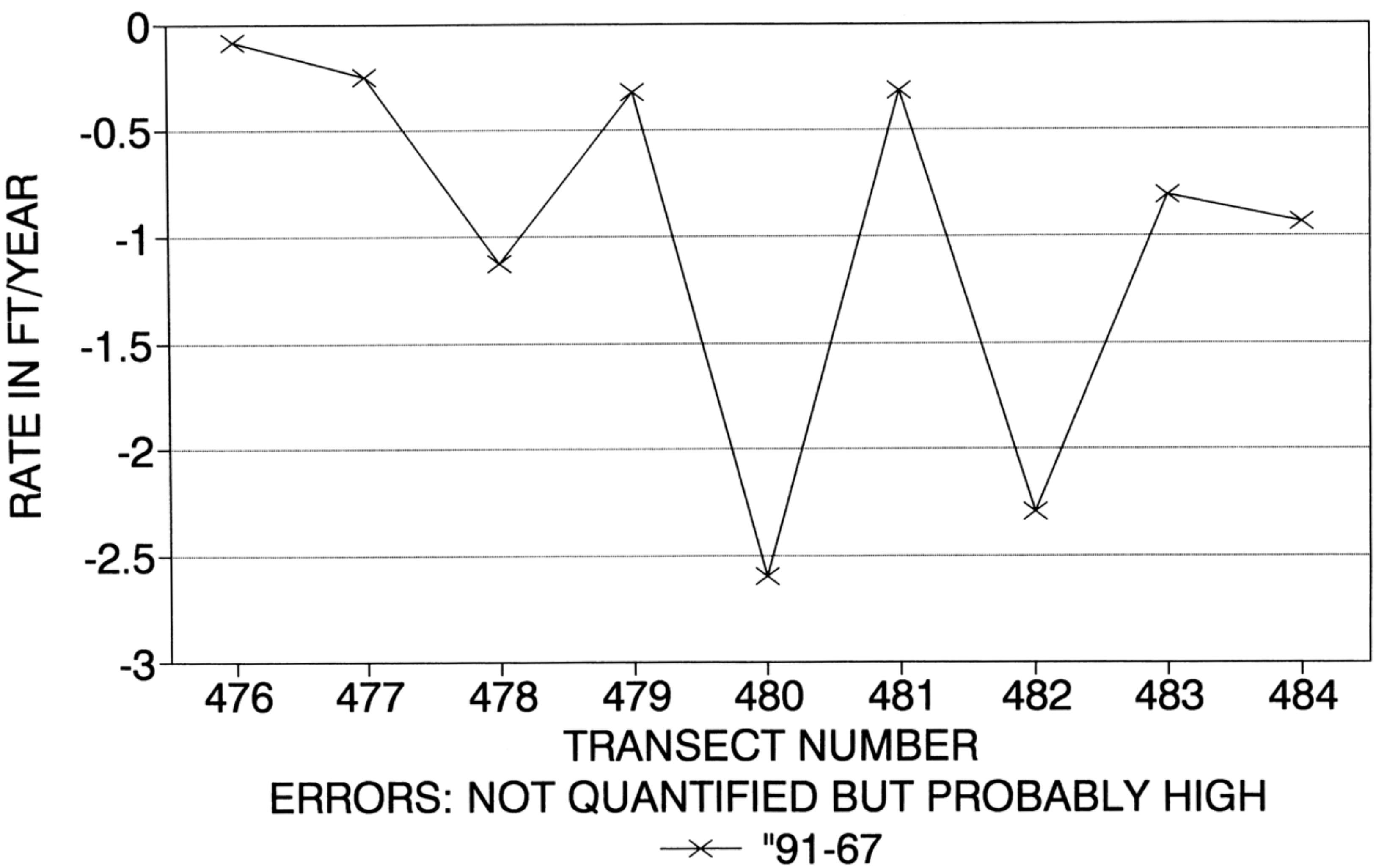
FOGARTY CREEK POCKET BEACH

SEGMENT 11, TRANSECT# VS RATE

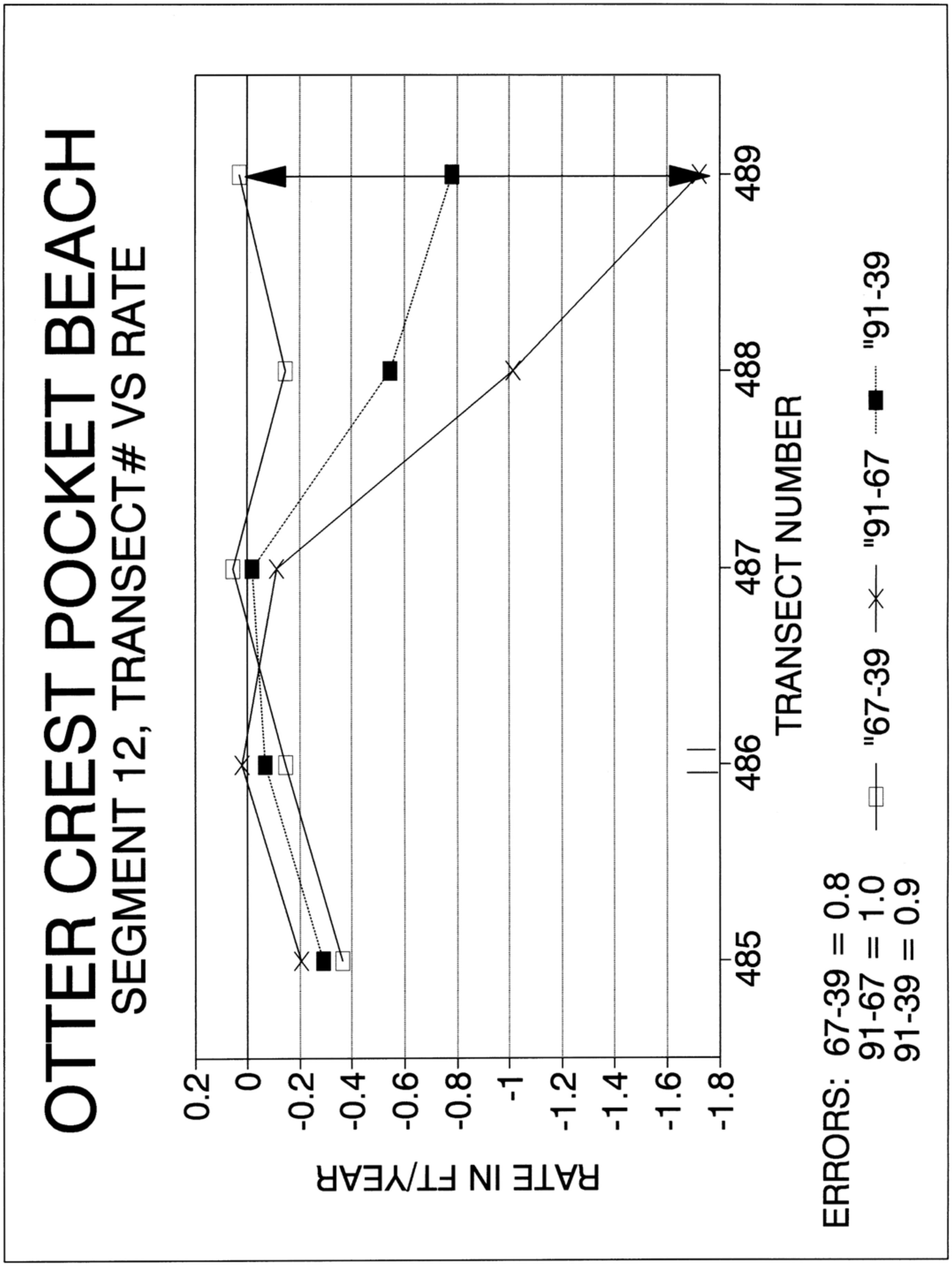


OTTER CREST

SEGMENT 11.5, TRANSECT# VS RATE



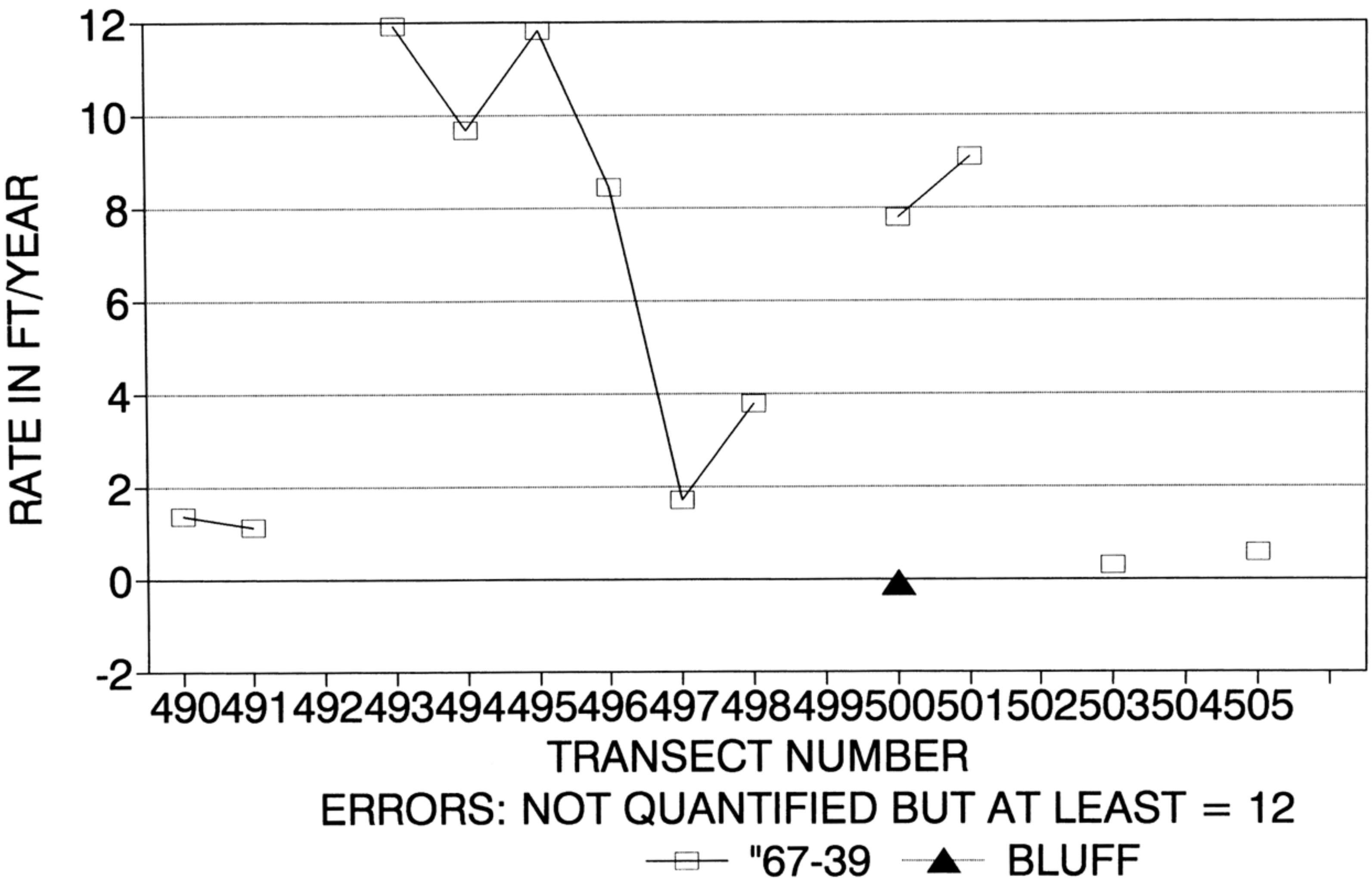
ERRORS: NOT QUANTIFIED BUT PROBABLY HIGH

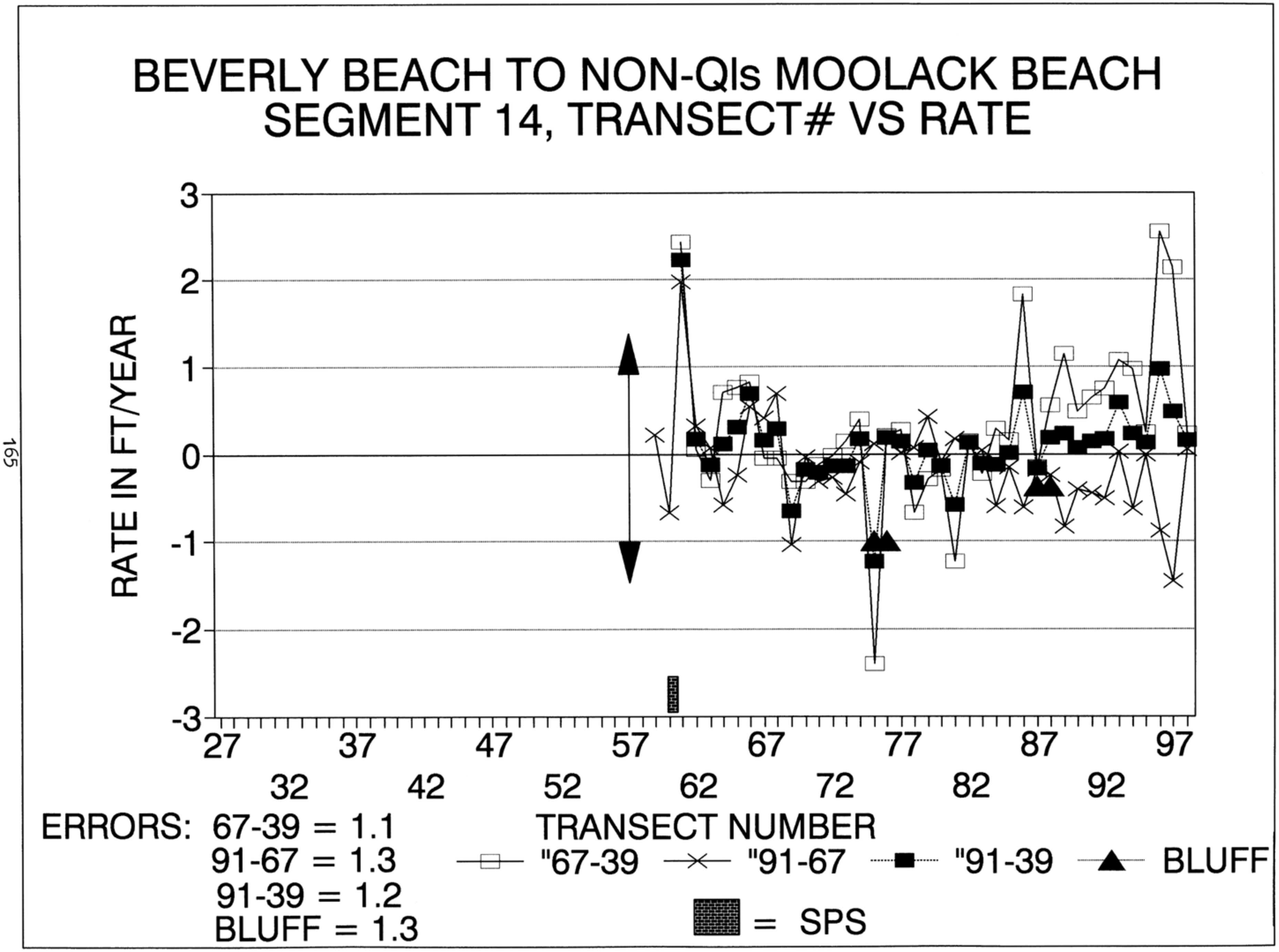


OTTER CREST POCKET BEACH
SEGMENT 12, TRANSECT# VS RATE
RATE IN FT/YEAR
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
485
486
487
488
489
TRANSECT NUMBER
ERRORS: 67-39 = 0.8
91-67 = 1.0
91-39 = 0.9
"67-39
"91-67
"91-39

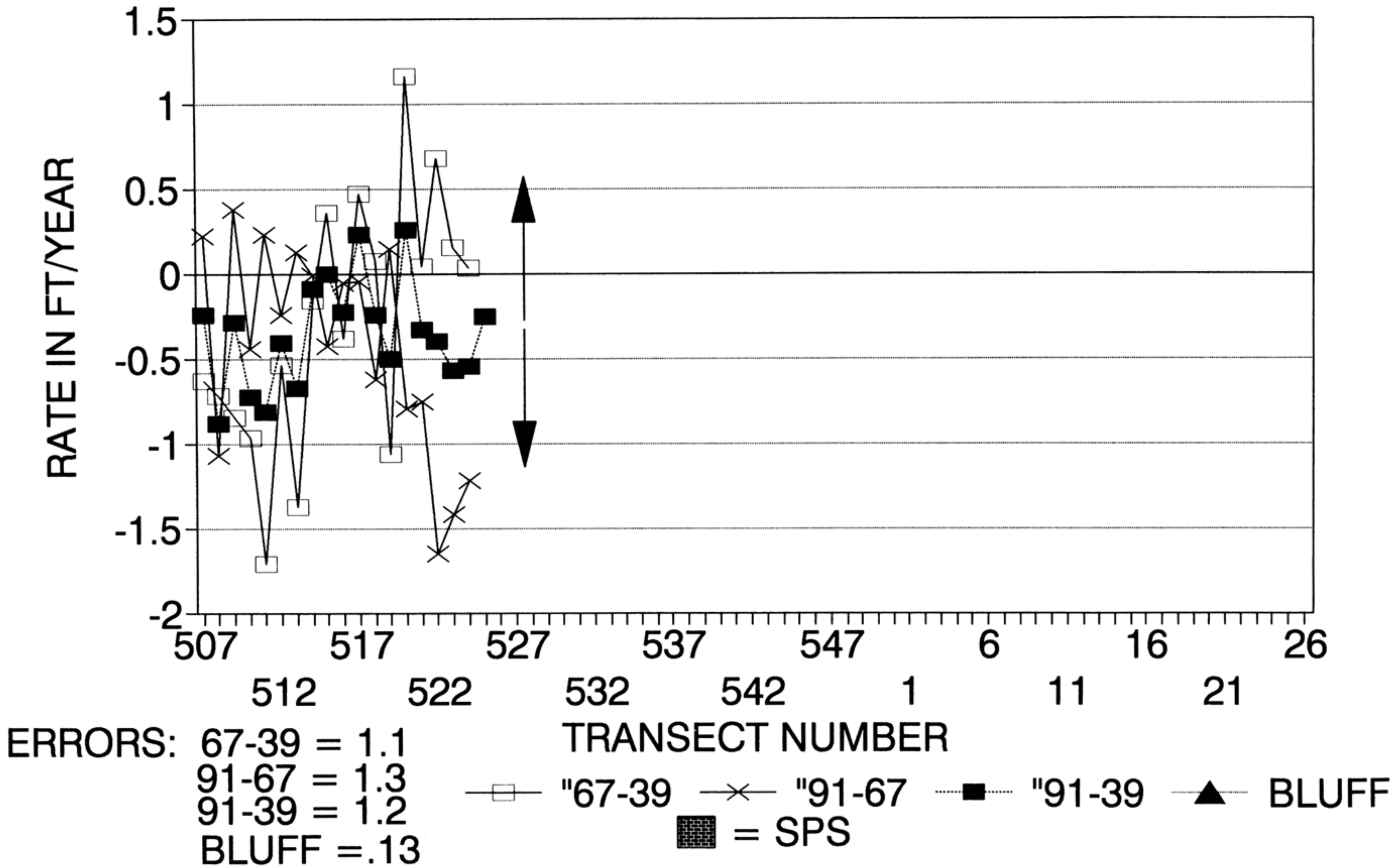
DEVILS PUNCH BOWL HEADLAND

SEGMENT 13, TRANSECT# VS RATE

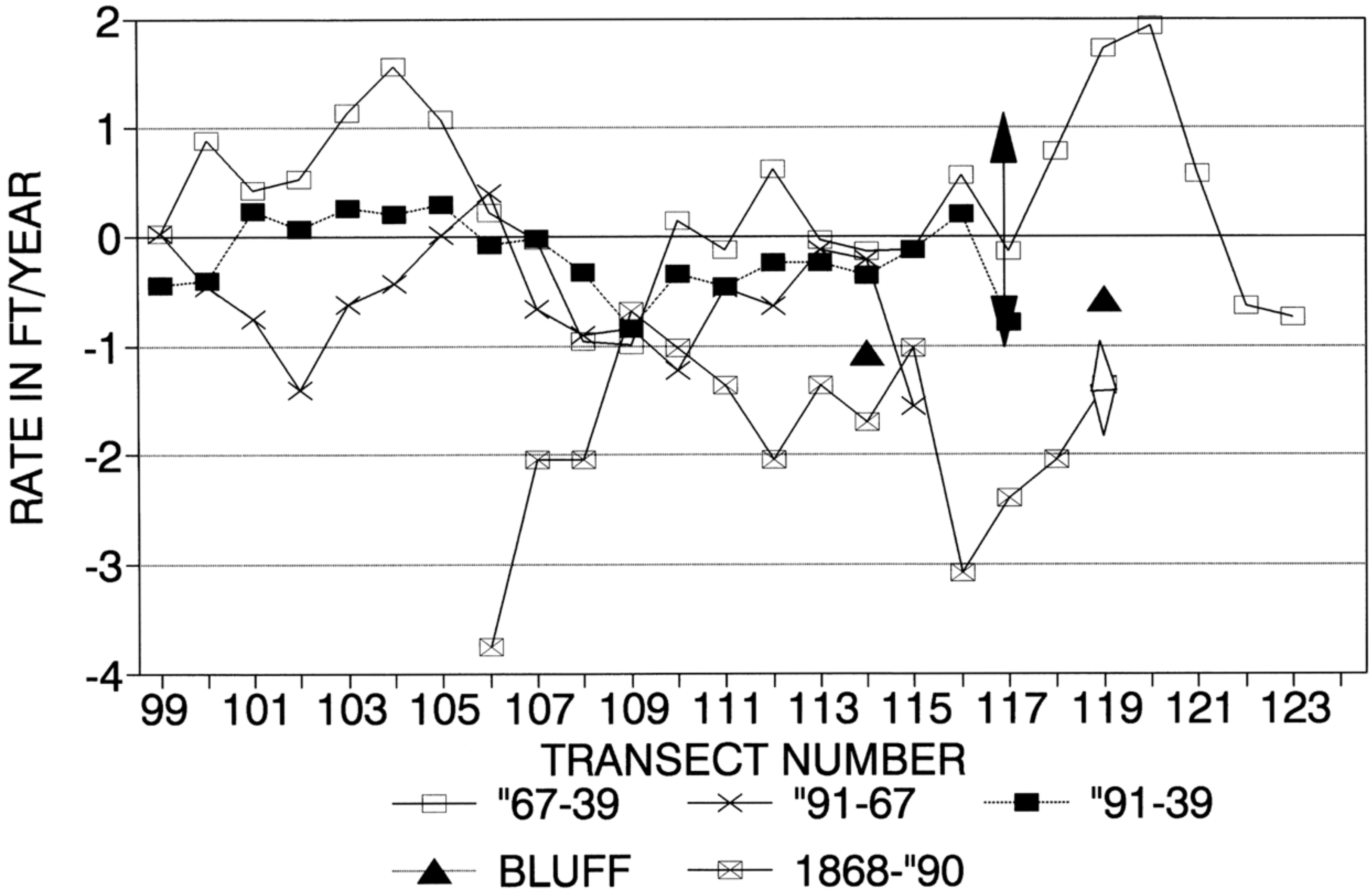



BEVERLY BEACH TO NON-QIs MOOLACK BEACH
SEGMENT 14, TRANSECT# VS RATE
RATE IN FT/YEAR
3
2
1
0
-1
-2
-3
27
32
37
42
47
52
57
62
67
72
77
82
87
92
97
TRANSECT NUMBER
ERRORS: 67-39 = 1.1
91-67 = 1.3
91-39 = 1.2
BLUFF = 1.3
"67-39
"91-67
"91-39
BLUFF
= SPS

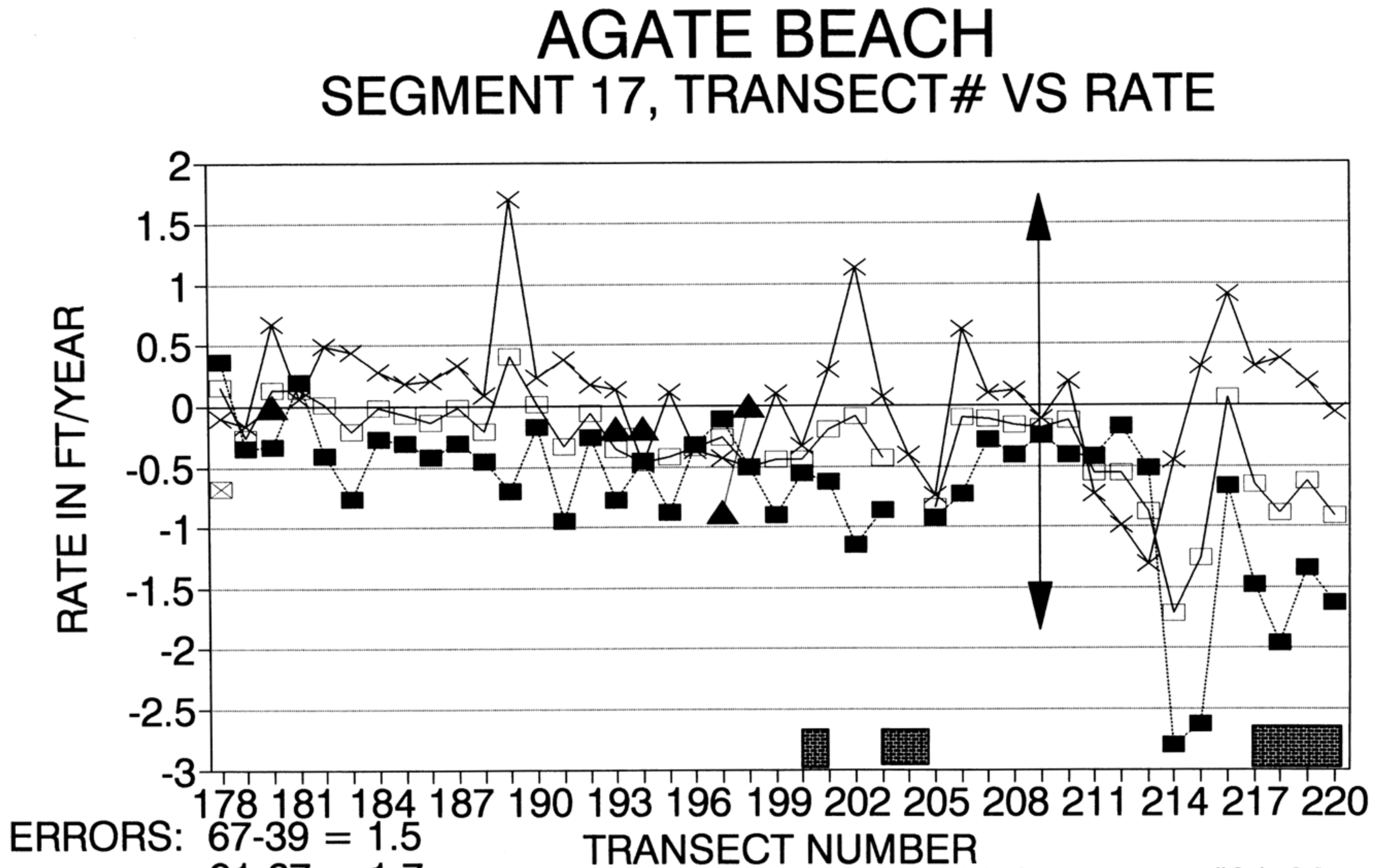
BEVERLY BEACH TO NON-QIs MOOLACK BEACH
SEGMENT 14, TRANSECT# VS RATE



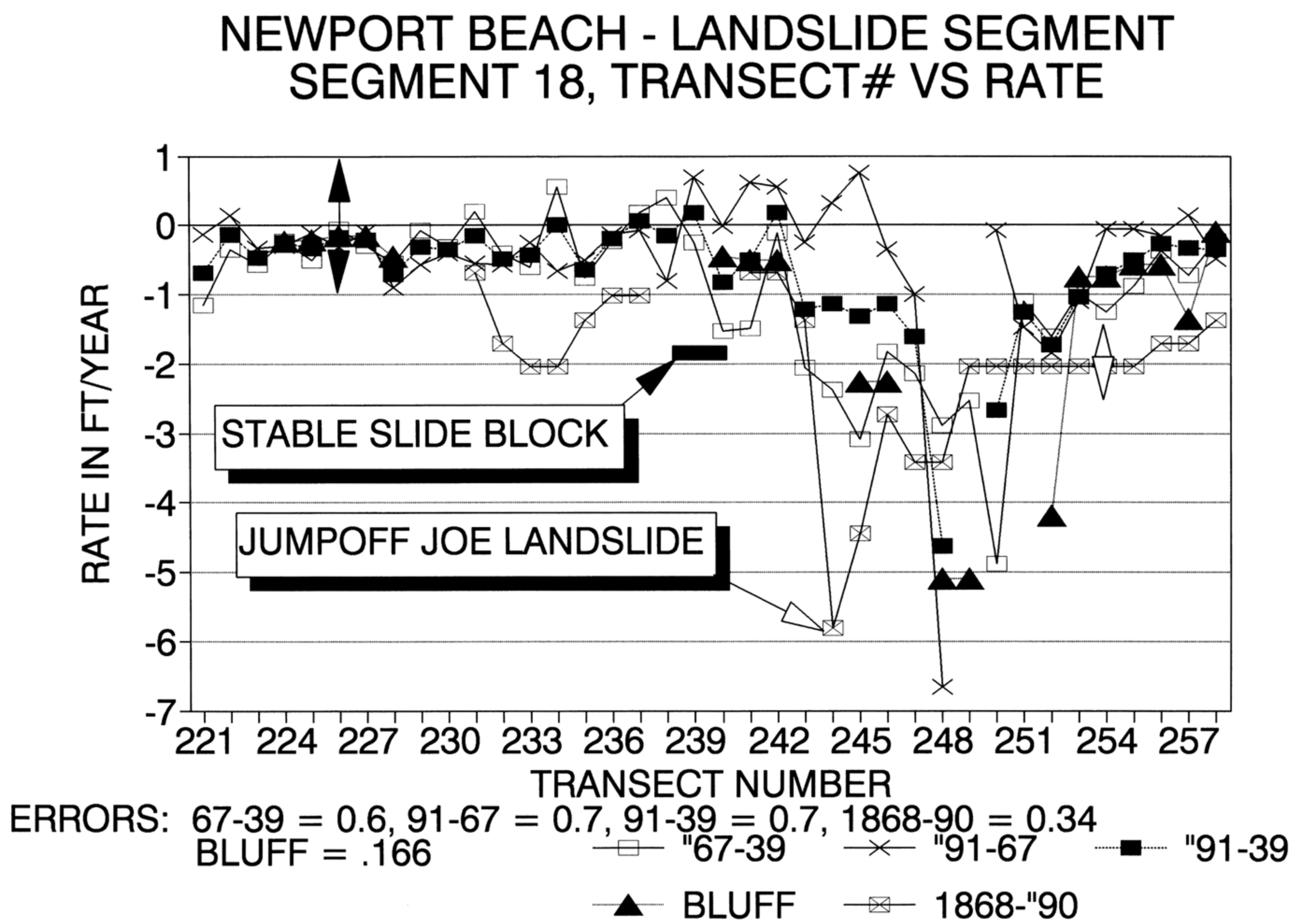
LANDSLIDE AREAS OF MOOLACK BEACH SEGMENT 15, TRANSECT# VS RATE



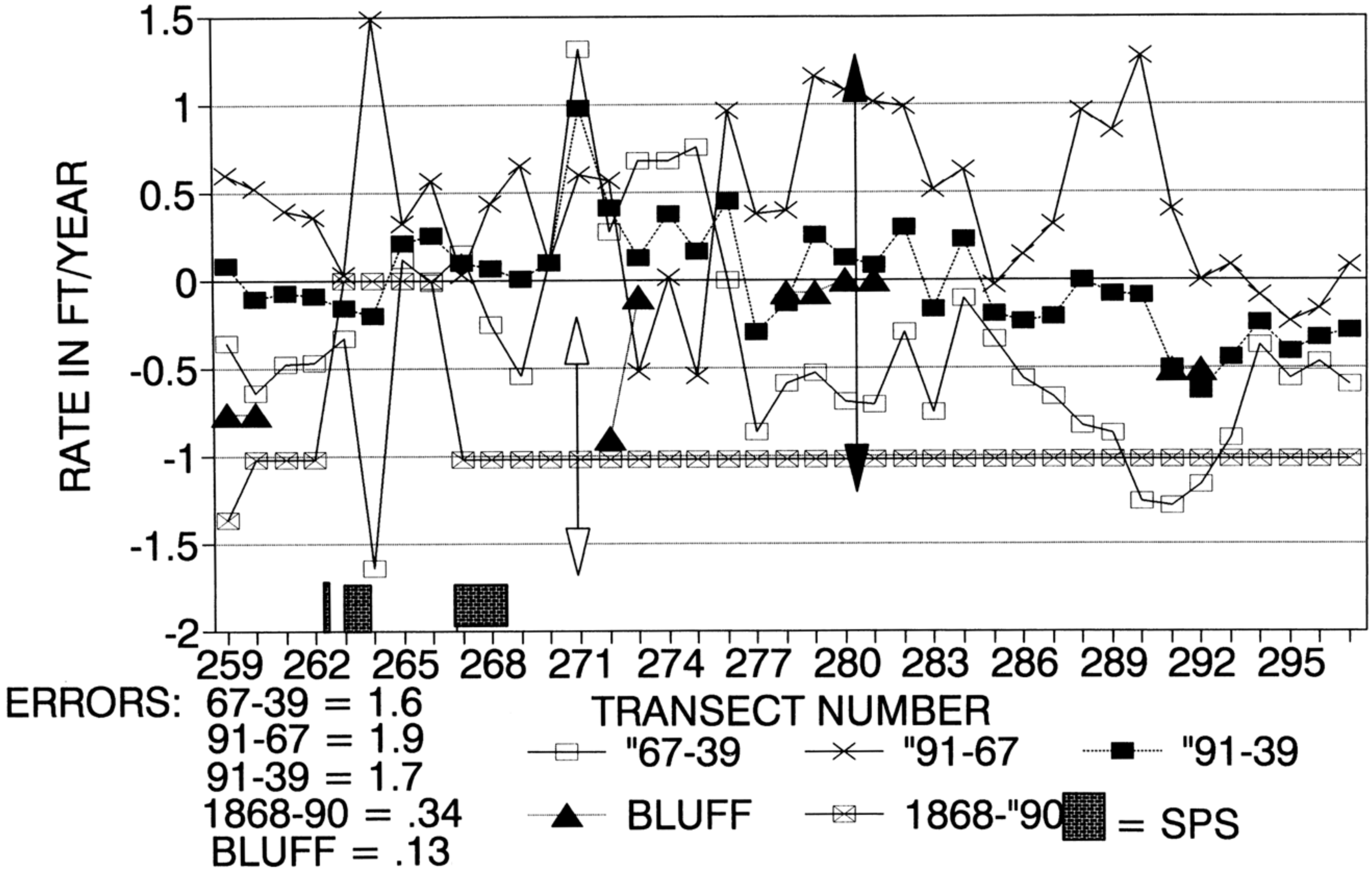
ERRORS: 67-39 = 0.9 91-67 = 1.191-39 = 1.0 1868-90 = 0.34 BLUFF = 0.08



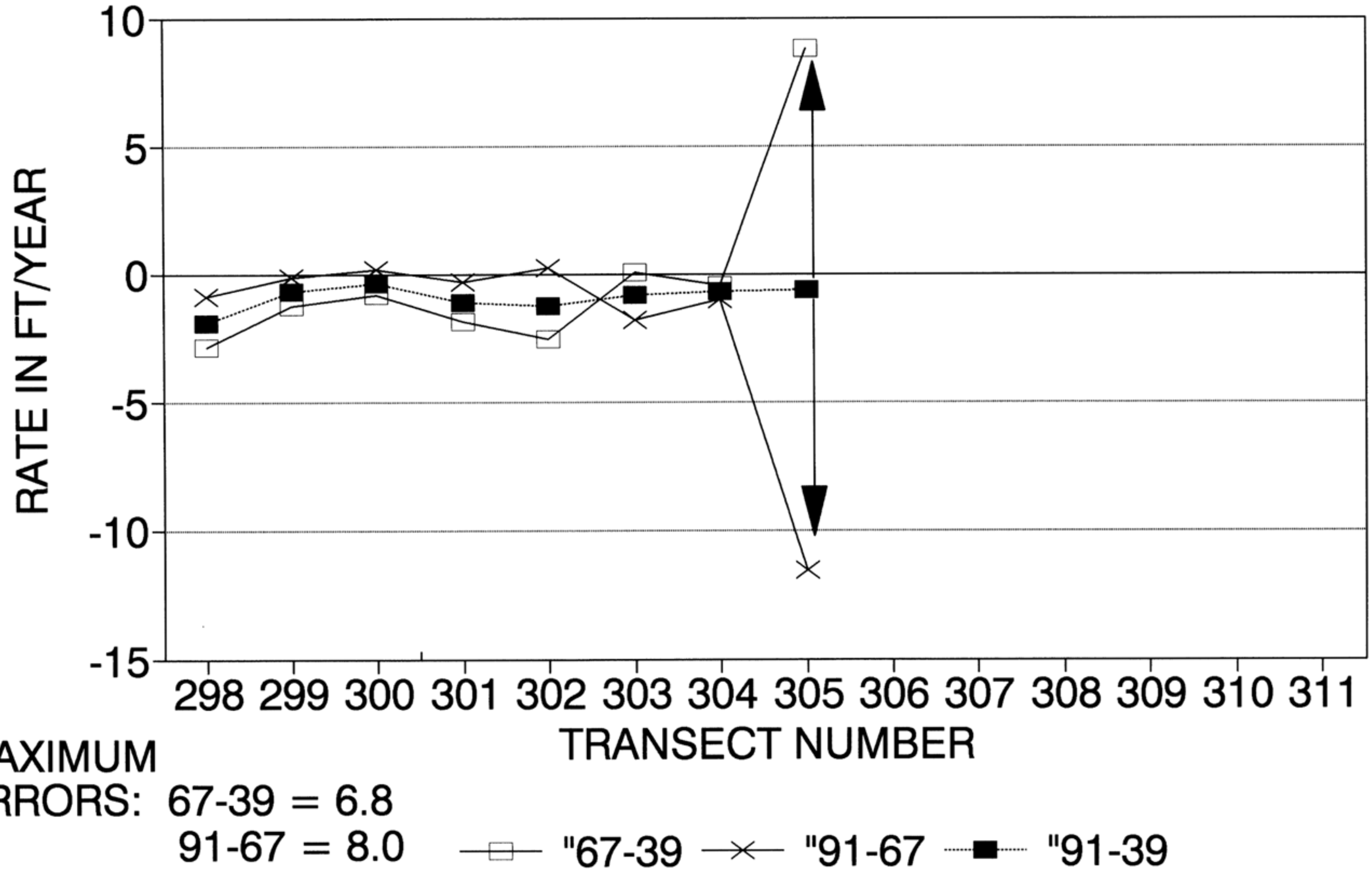
ERRORS: 67-39 = 1.5
91-67 = 1.7
91-39 = 1.6
1868-91 = 0.34
BLUFF = .126


NEWPORT BEACH - LANDSLIDE SEGMENT
SEGMENT 18, TRANSECT# VS RATE
RATE IN FT/YEAR
1
0
-1
-2
-3
-4
-5
-6
-7
221
224
227
230
233
236
239
242
245
248
251
254
257
TRANSECT NUMBER
STABLE SLIDE BLOCK
JUMPOFF JOE LANDSLIDE
ERRORS: 67-39 = 0.6, 91-67 = 0.7, 91-39 = 0.7, 1868-90 = 0.34
BLUFF = .166
"67-39
"91-67
"91-39
BLUFF
1868-"90

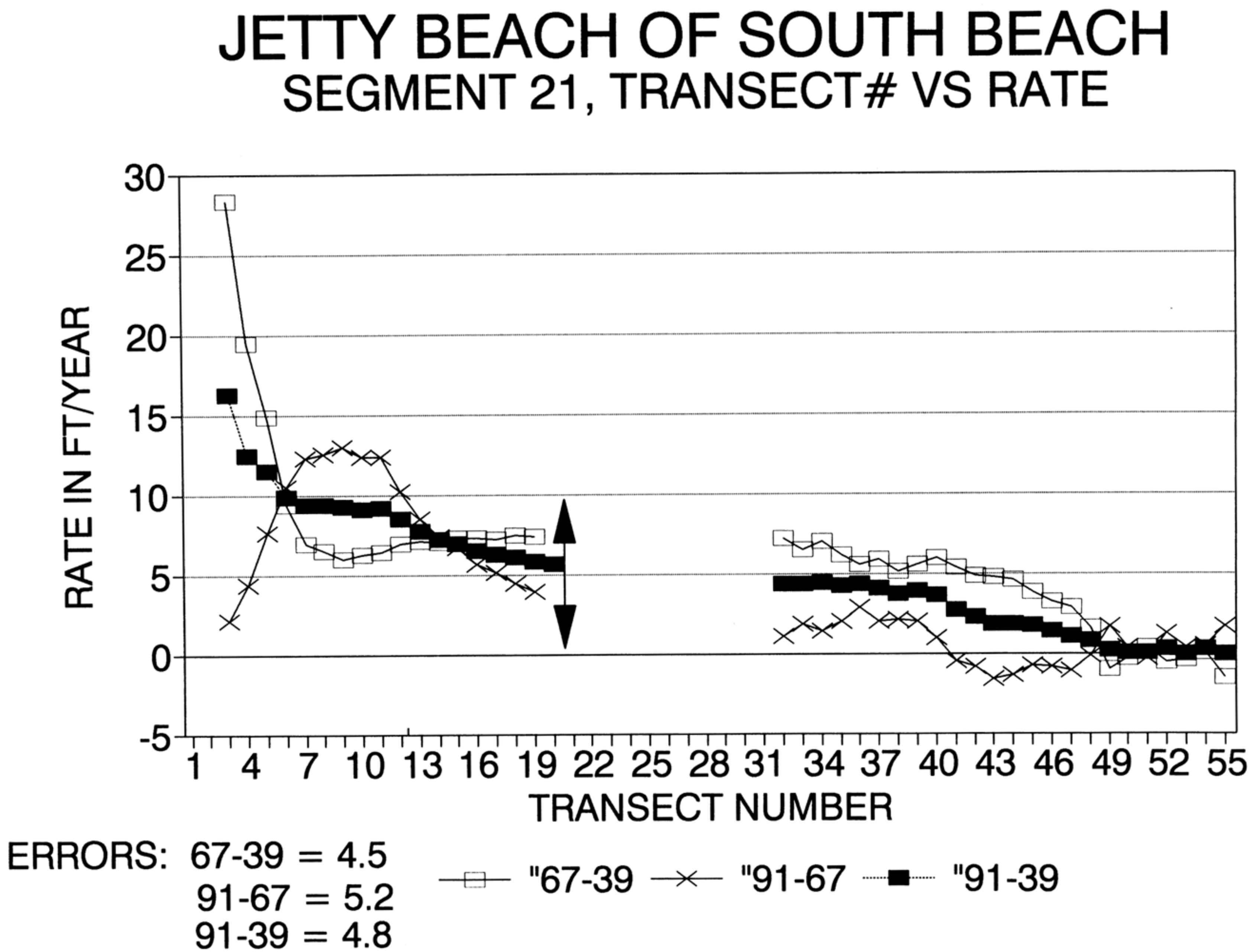
NEWPORT BEACH SOUTH - FEW QIs
SEGMENT 19, TRANSECT# VS RATE



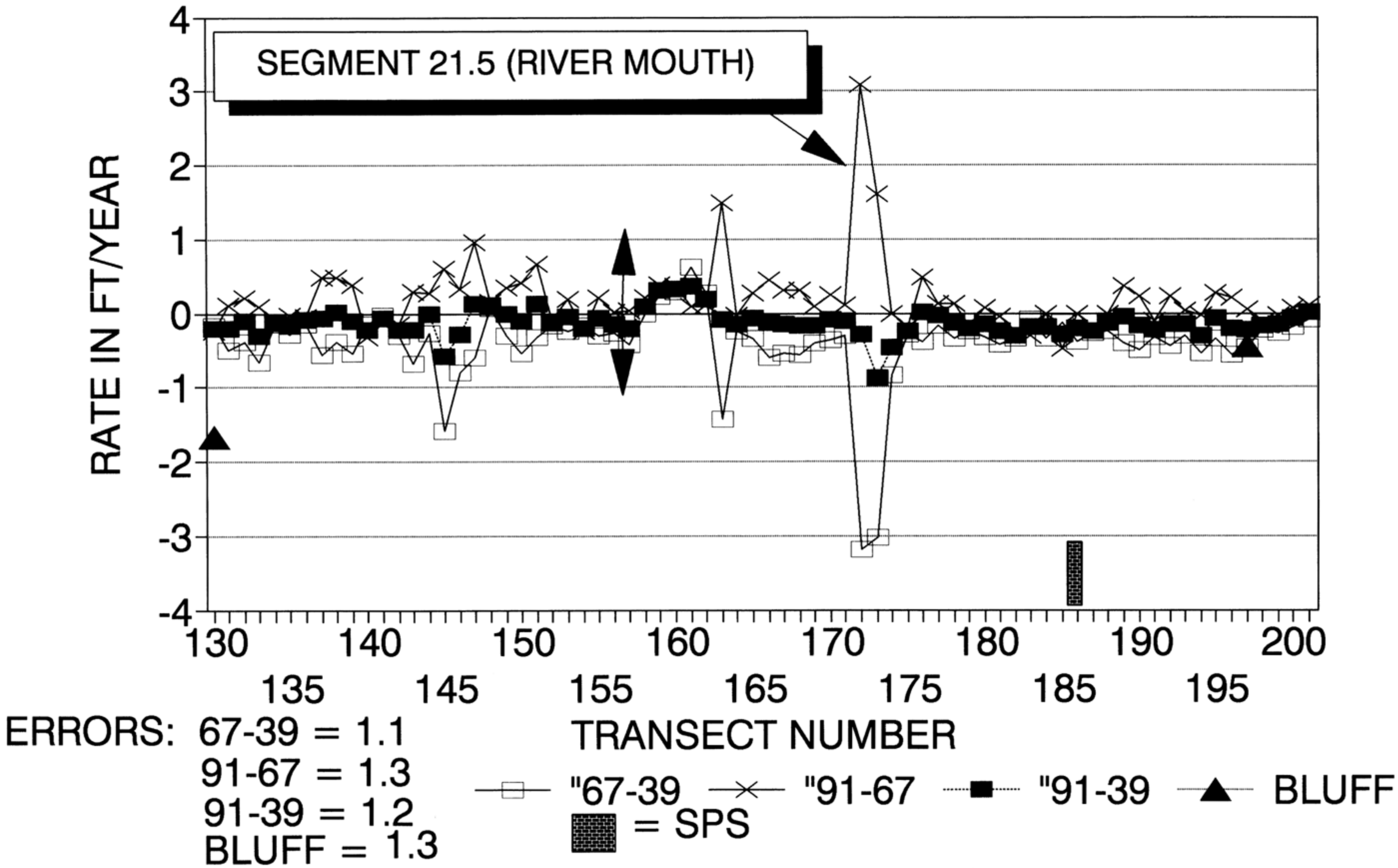
YAQUINA JETTY BEACH NORTH
SEGMENT 20, TRANSECT# VS RATE

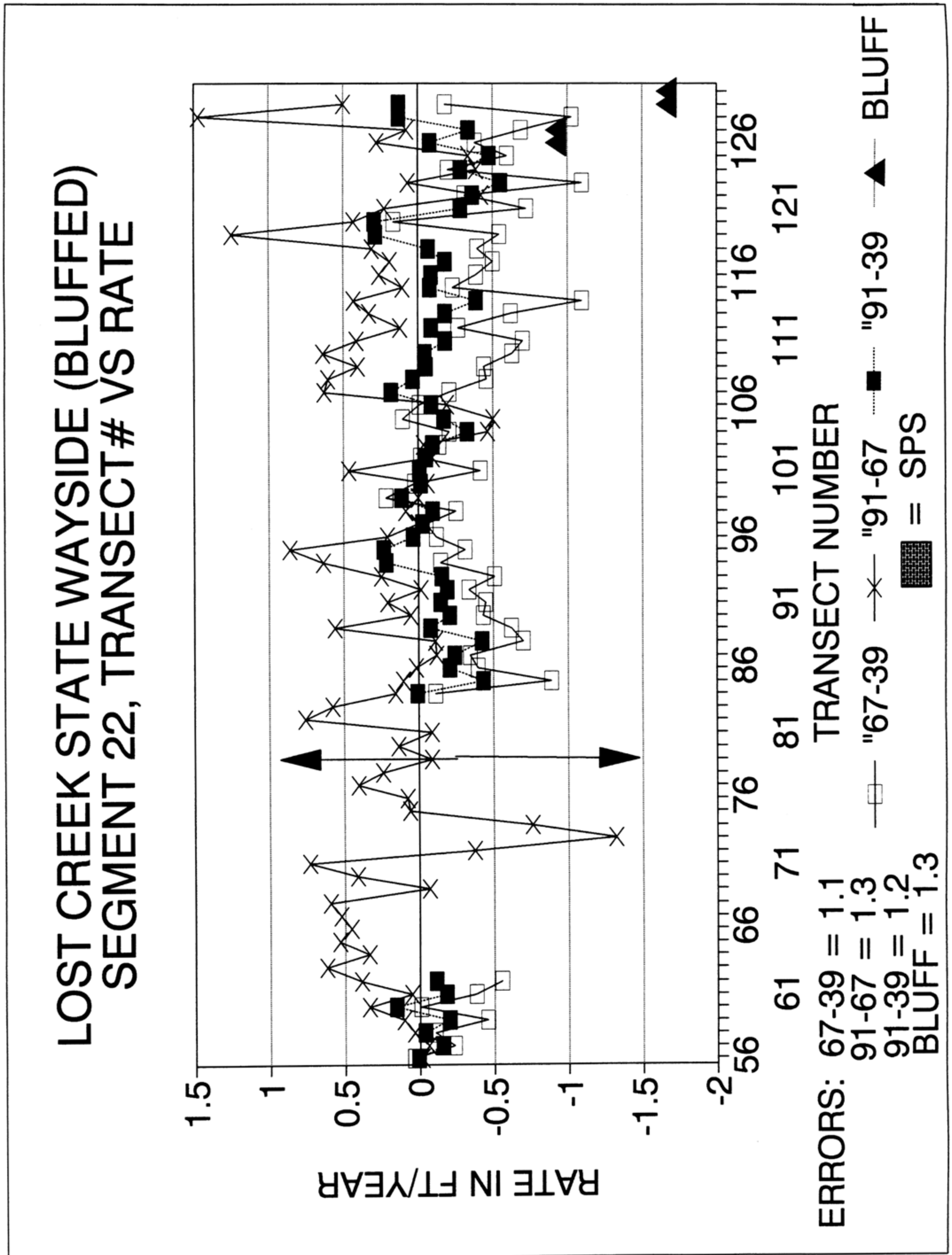


MAXIMUM
ERRORS: 67-39 = 6.8
91-67 = 8.0
91-39 = 7.3

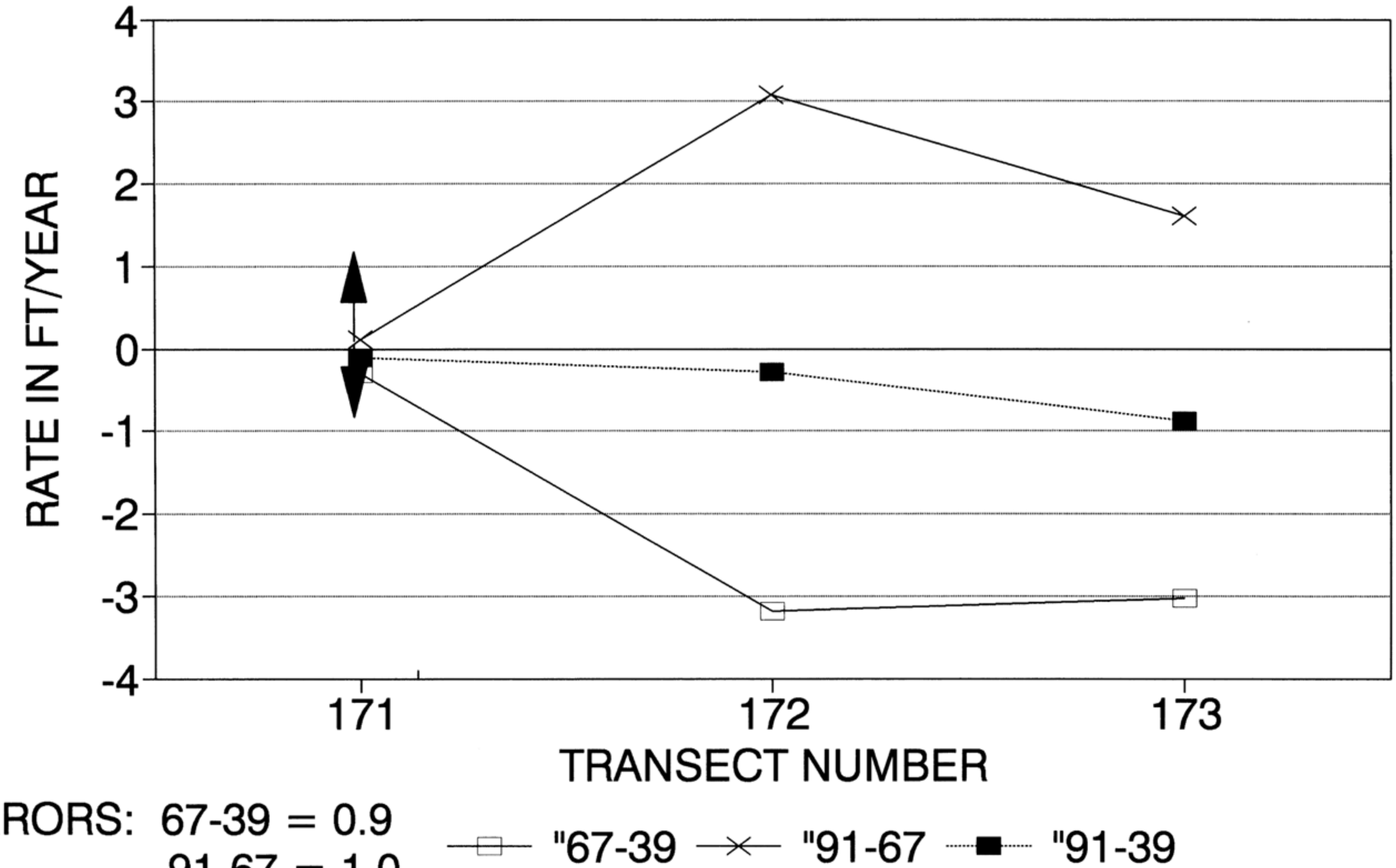

JETTY BEACH OF SOUTH BEACH
SEGMENT 21, TRANSECT# VS RATE
RATE IN FT/YEAR
30
25
20
15
10
5
0
-5
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55
TRANSECT NUMBER
ERRORS: 67-39 = 4.5
91-67 = 5.2
91-39 = 4.8
"67-39
"91-67
"91-39

LOST CREEK STATE WAYSIDE (BLUFFED)
SEGMENT 22, TRANSECT# VS RATE



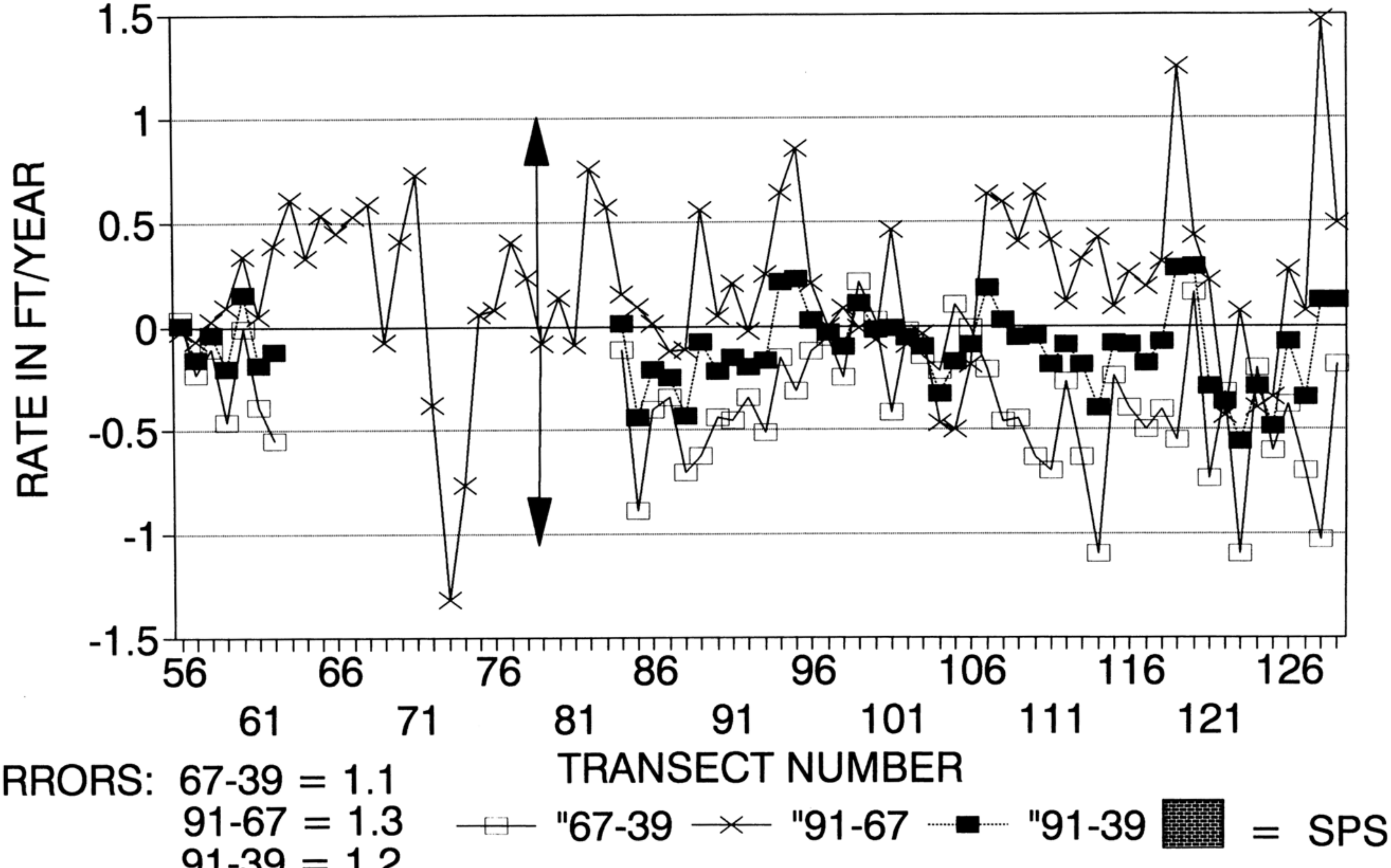

LOST CREEK STATE WAYSIDE (BLUFFED)
SEGMENT 22, TRANSECT# VS RATE
RATE IN FT/YEAR
1.5
1
0.5
0
-0.5
-1
-1.5
-2
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
TRANSECT NUMBER
ERRORS: 67-39 = 1.1
91-67 = 1.3
91-39 = 1.2
BLUFF = 1.3
"67-39
"91-67
"91-39
BLUFF
= SPS

DUNED RIVER MOUTH AT LOST CREEK
SEGMENT 21.5, TRANSECT# VS RATE



ERRORS: 67-39 = 0.9
91-67 = 1.0
91-39 = 1.0

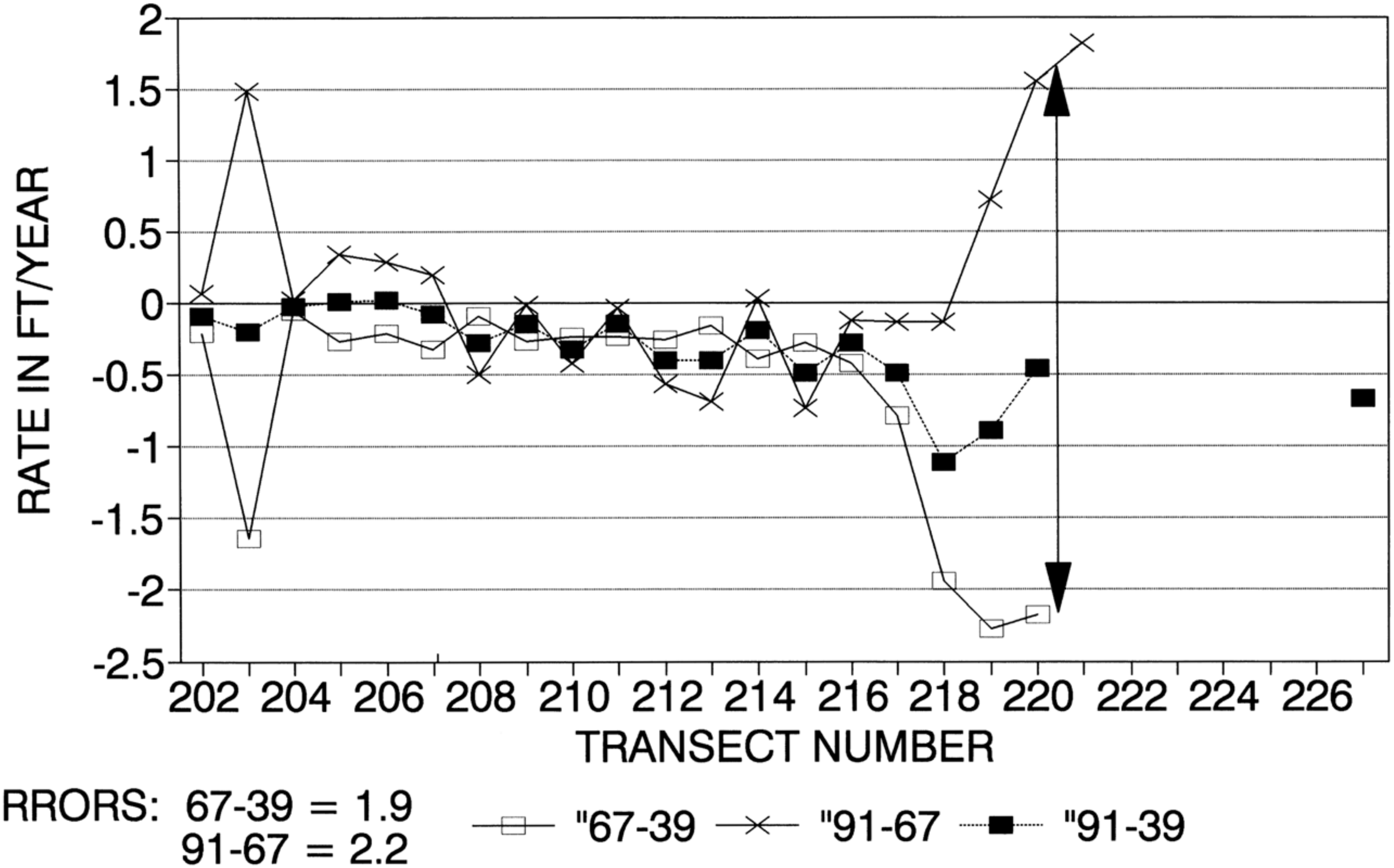
LOST CREEK STATE WAYSIDE (BLUFFED)
SEGMENT 22, TRANSECT# VS RATE



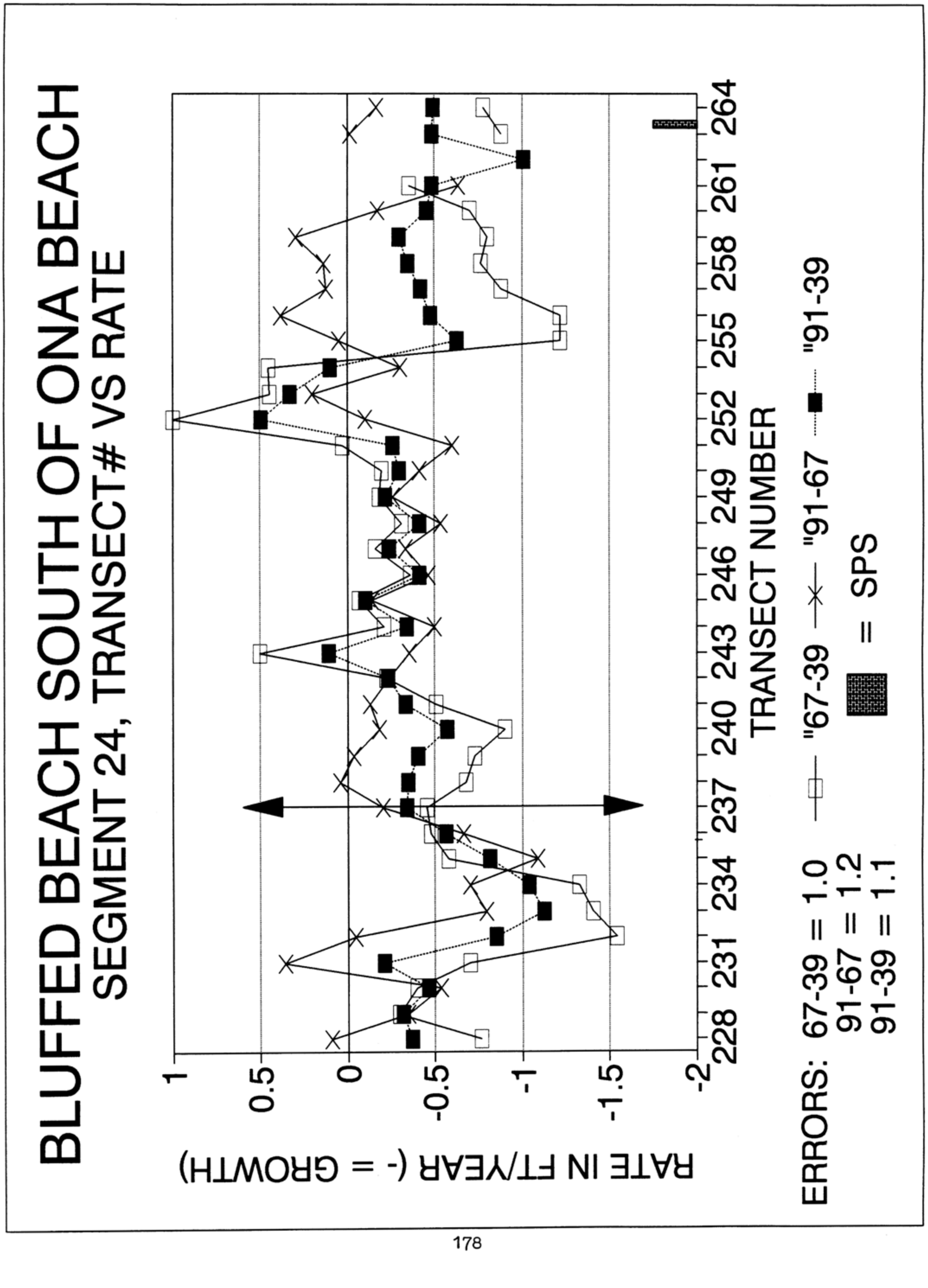
ERRORS: 67-39 = 1.1
91-67 = 1.3
91-39 = 1.2

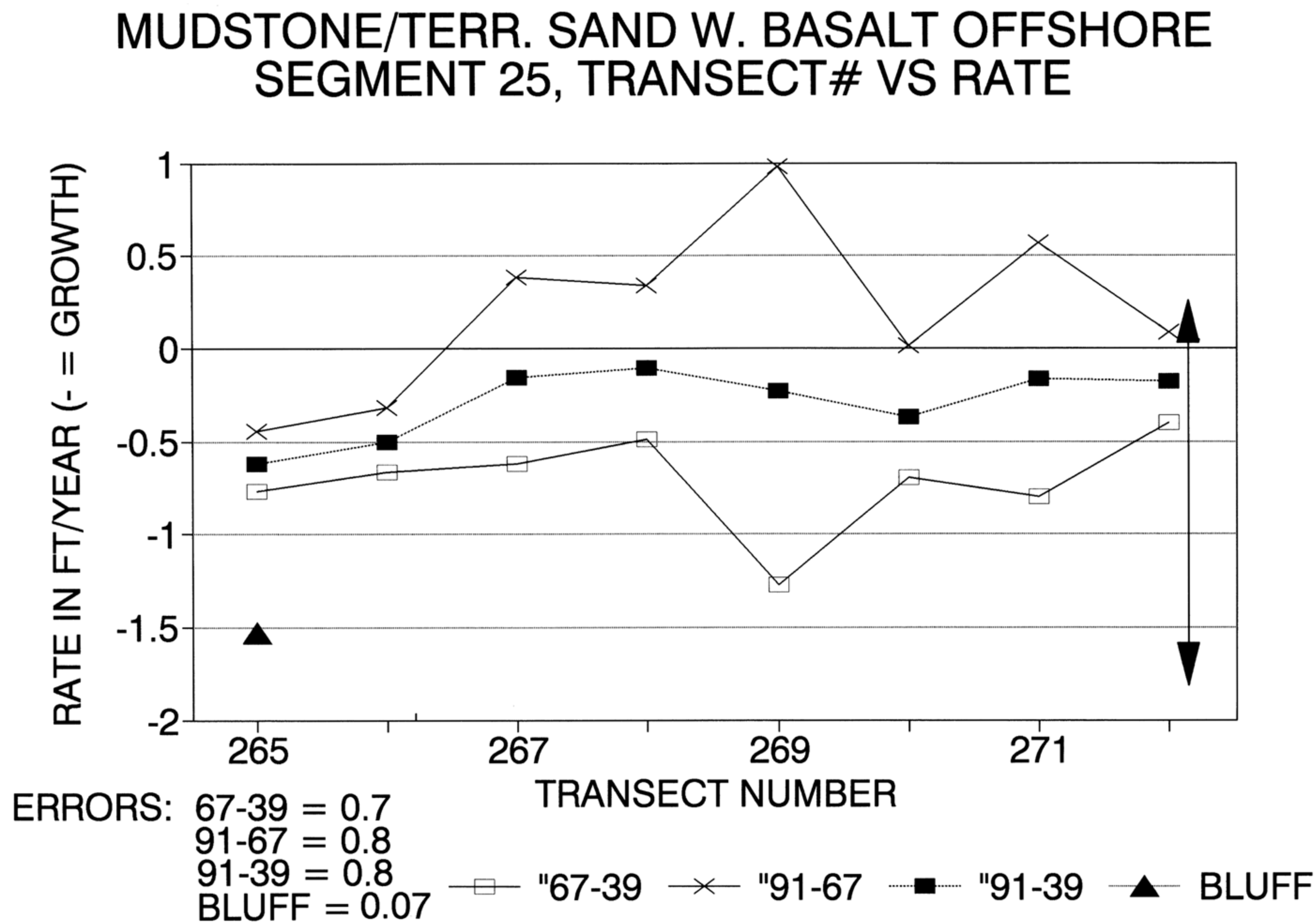
BEAVERCREEK DUNED RIVER MOUTH

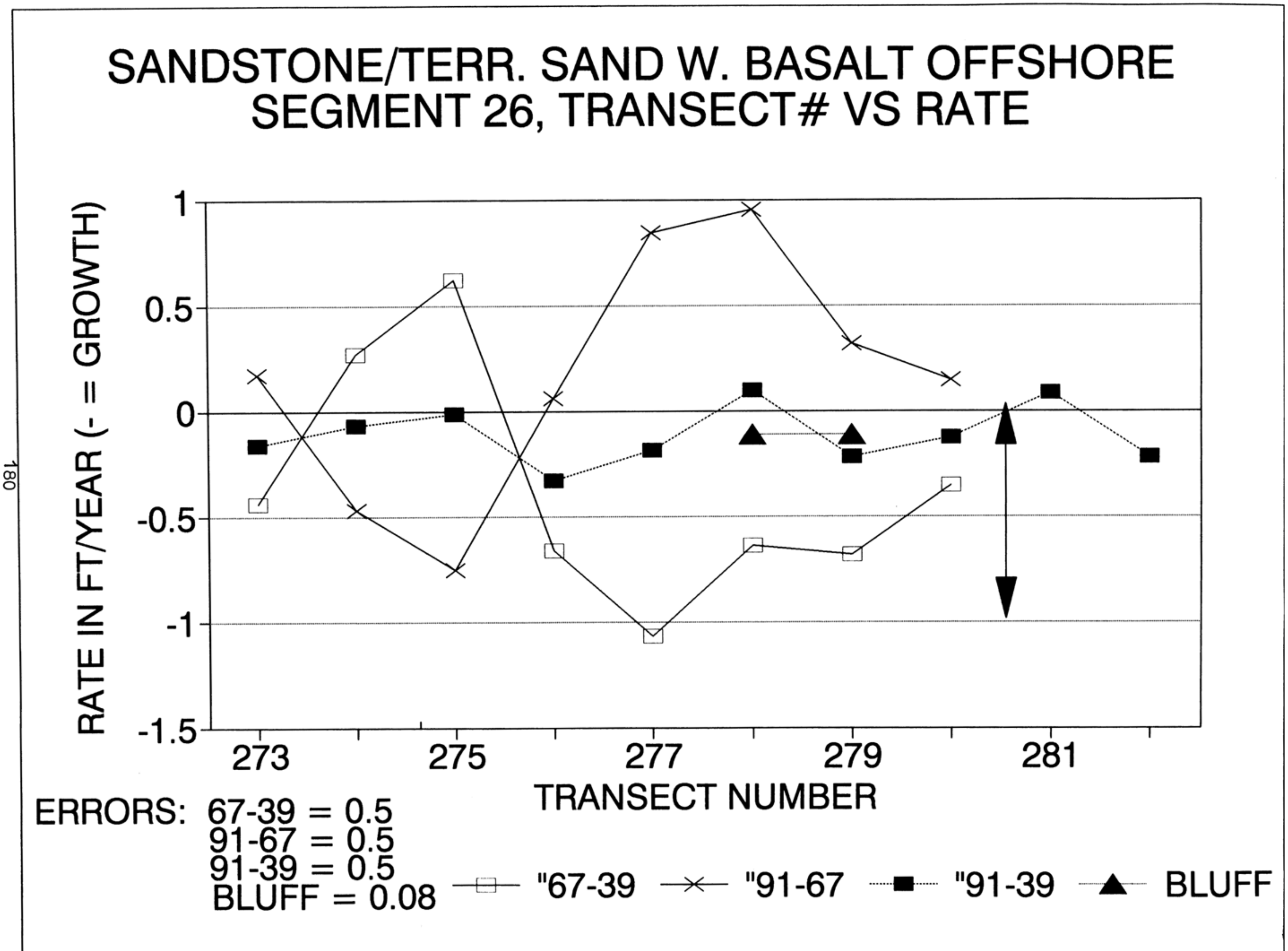
SEGMENT 23, TRANSECT# VS RATE



ERRORS: 67-39 = 1.9
91-67 = 2.2
91-39 = 2.0


BLUFFED BEACH SOUTH OF ONA BEACH
SEGMENT 24, TRANSECT# VS RATE
RATE IN FT/YEAR (- = GROWTH)
1
0.5
0
-0.5
-1
-1.5
-2
228
231
234
237
240
243
246
249
252
255
258
261
264
TRANSECT NUMBER
"67-39
"91-67
"91-39
= SPS
ERRORS: 67-39 = 1.0
91-67 = 1.2
91-39 = 1.1


MUDSTONE/TERR. SAND W. BASALT OFFSHORE
SEGMENT 25, TRANSECT# VS RATE
RATE IN FT/YEAR (- = GROWTH)
1
0.5
0
-0.5
-1
-1.5
-2
265
267
269
271
TRANSECT NUMBER
ERRORS: 67-39 = 0.7
91-67 = 0.8
91-39 = 0.8
BLUFF = 0.07
"67-39
"91-67
"91-39
BLUFF


SANDSTONE/TERR. SAND W. BASALT OFFSHORE
SEGMENT 26, TRANSECT# VS RATE
RATE IN FT/YEAR (- = GROWTH)
1
0.5
0
-0.5
-1
-1.5
273
275
277
279
281
TRANSECT NUMBER
ERRORS: 67-39 = 0.5
91-67 = 0.5
91-39 = 0.5
BLUFF = 0.08
"67-39
"91-67
"91-39
BLUFF

APPENDIX E

Coastal Erosion Database Development Project

Erosion Pilot Study
Utilizing Historical Data

Completed for DOGAMI 9/14/92
by
Andrea C. Ansevin
Scott Allen
&
Christine E. Valentine

Introduction

This project was part of a DOGAMI program that was developed to determine what types of erosion measurement methods would be applicable to the coastal bluffs and cliffs of Oregon's shoreline. Erosion rates must be reliable enough to be used as a basis for coastal construction setback regulations and other land use planning needs. Because the erosion rates are generally low, it is difficult to get accurate information over a time period of a few years. Yet, the farther back in time that erosion rates are measured, the lower the availability of valid, scientific data that support those rates.

In an attempt to look at longer erosion periods, anecdotal information on bluff/cliff locations was examined for accuracy and accessibility. Three different sources of information on bluff erosion were examined, with some positive results. Task 1 included the use of tax maps and other historical map data. Examination revealed that the tax maps were unacceptable as a source of erosion rates. The other historic maps, including survey and plat maps, were very useful when used in conjunction with Task 3 data. Task 2 involved the use of State Parks and Recreation Department (SPRD)/Department of State Lands (DSL) Beach Construction Permit files which document requests for shore protection structures (SPSs). However, very few erosion rates were given, and not all rates were reliable. This method was inconclusive and will not be useful until stricter standards are used for permit applications. Task 3 was the most successful, comparing 1967 Oregon Department of Transportation (ODOT) aerial photos to 1992 field measurements as well as historic information from Task 1. This method was reasonably accurate and gave consistent results. Further refinements would make this quite a viable option for Oregon's bluff erosion rate determinations.

Task 1

The primary goal of Task 1 was to acquire present-day and historic tax maps and analyze the maps for changes in locations of shoreline features. Since tax lot numbers are the identification system used in the database, a complete set of small scale tax maps for the study area was required. Acquisition of present day tax maps involved selection of tax maps in the study area and the purchase of tax map copies at the Lincoln County Tax Assessor's office.

The next step in map analysis was to locate and acquire copies of historical Lincoln County tax maps. Unexpectedly, it was discovered that the assessor's office does not store old maps. Tax maps are disposed of as new versions are drafted; the county has no practical use for the old tax maps. Historical tax maps for some of the study area were located at Security Title, an insurance company located in Newport, OR. We were allowed to look through all of the insurance company's maps in order to locate ones in the study area and borrowed those maps for the duration of the project. A major problem with the historic maps that the insurance company possessed was the lack of clear dates on many of the maps. Without this, it is impossible to derive an accurate erosion rate.

Further analysis of tax maps showed that only maps with vegetation and/or bluff lines drawn on them could be useful in erosion rate determinations. Inquiry into how the location of these map features were calculated was directed to the tax assessors office. The response was that these features were not accurately surveyed, were not updated when maps were updated, and were considered mainly as a "graphic" as opposed to a useful indicator. It was also noted that the tax map features do not appear to be remeasured whenever a map is updated. Instead, only new structures are added to already existing maps. This finding rendered the tax maps completely useless for erosion rate information.

Once it was determined that tax maps would not provide useful or accurate data on erosion rates, the search for historical maps was extended to include any available old maps. Approximately one hour was spent at the Lincoln County Historical Society Museum in Newport, OR looking through old maps which were primarily of the Newport area. Only a few maps contained applicable shoreline features. Problems with the use of these maps included determining measurement error recorded in the maps and finding dates of drafting. The artistic license taken in these older maps makes high error levels probable.

Another attempt to locate useful, historical maps led to inquiry at the Lincoln County Surveyor's Office in Newport, OR. The surveyors office had the original plat maps for development on the coast, and many included a bluff line. Surveys for taxlots were also looked at, and those that included a structure along with a bluff line were copied. This information was used in conjunction with information compiled in Task 3 (to be discussed later). Yet, it must be noted that the surveyors office reported that for maps drawn before 1980, the surveyors were not required to accurately map the location of the bluff line, and errors may be as high as 50 ft. After 1980, surveyors were required to accurately map the bluff line, and errors should be of the order of a few feet or less. We assumed that for any pre-1980 survey maps which were of only one lot and included a structure outline, the level of error would only be moderate.

Task 2

Task 2 consisted of the review of all SPRD permit files for SPS within the project study area and extraction of any information that would aid in erosion rate calculations. Permit files were available for the time period of 1967 to present. Approximately 175 files were reviewed.

The permits reviewed did not follow an established format and lacked erosion rate information for the most part. It appears that SPRD did not require landowners to obtain a professional and objective estimate of erosion of their property. Those few files that contained actual quotes of erosion amounts or rates were usually estimated by property owners or engineers planning on constructing the SPS, with very few estimated by State Parks. The methods used to arrive at these estimates are not known and therefore, the reliability of these data are not known. In the database, the error level is measured as high, medium, or low depending on the source of the quote. A State Parks estimate would be given a low error rating, a private engineer's or geologist's report a medium rating, and the owner's estimate a high error rating. This method was the easiest to use under the circumstances.

Engineers maps of areas proposed for SPS were found in some permit files. The bluff line was marked on some of these maps, and its location was compared to information gathered in Task 3. It is not known what the errors in the engineers maps are or how accurately the bluff lines in particular were mapped. It was hypothesized that accurate measurements would be needed in order for SPS to be constructed and therefore that these maps were reliable.

Overall, permit files do not appear to contain information that is useful in erosion rate calculations. The use of SPRD permit files will not be helpful for erosion studies in Oregon either now or in the future unless a standard format, which includes a professional and objective estimate of property loss, is adopted.

Task 3

For Task 3, measurements of the distance between structures and the bluff edge were taken from 1967 ODOT photomosaics and were compared to 1992 field data. The ODOT photographs were at a scale of one in. = 100 ft. and were not available in stereo for stereoscopic viewing. Measurements were taken directly from the photographs with an estimated error of 1.25 ft., assuming the photos are without distortion. The amount of distortion is unknown and would have to be determined in order to give a further estimate of measurement error.

Due to the low budget and short duration of this project, technical methods of field measurement could not be used. The method used was as follows: field location of structures present on ODOT photos, measurement from the corners(or any other points readily visible on the photographs) of the structure to the bluff/cliff edge using a two person/tape measure system, and recording of any other supplemental observations. Field measurement error was 0.5 ft., resulting in a maximum error of 1.75 ft. for this method (assuming zero photo distortion).

Field measurements were taken in particular areas for this study. Because of the short time involved , only certain tax lots were measured based on specific criteria. The structures measured on the 1967 ODOT photos had to be within 150 ft. of the bluff and still exist in a recognizable form (i.e. no extensive remodeling) in 1992. Areas of the coast which were not developed in 1967 could not be measured during Task 3. The bluff/cliff edge was not always discernable on the ODOT photos, and therefore, field measurements were only taken in areas where the edge could be readily distinguished on the photos. The last criteria was that SPSs must not have been installed before 1987 if long-term erosion rates were to be calculated. It was assumed that SPSs alter the natural processes of the sea bluffs and cliffs, hence not giving an accurate measure of erosion. With more time for analysis, the roads could be used as a reference in non-landslide areas, as long as the road improvements could be researched and included in the measurements.

The ODOT and field measurements were also compared to the survey and historical maps collected at the Lincoln County Surveyor's office. These maps often gave a longer time period to measure erosion, but were not always accurate. The older plat maps with no buildings to measure distances from were especially unreliable and hard to correlate to the ODOT photos. These maps could not be compared to field measurements. Survey maps, especially the more recent ones, were compared to the ODOT photos with relatively good results.

There were a few rates which actually indicated accretion of the bluff. It is believed that these rates are in error. Possible sources of error include hard to distinguish bluff lines on the ODOT photos, field measurement errors due to unnoticed remodelling of buildings, and measurements in regions of landsliding. There were six out of 43 field measurements that indicated accretion with an average of 5.8 ft. over 25 years. Overall, calculated rates indicated erosion, and many of the rates were consistent, demonstrating that the method utilized generally works.

The error for Task 3 erosion rates was again stated as high, medium, or low. Error determination was based on the age/reliability of the map and the ability to locate clear reference points on the maps. High error was assumed with older maps, shorter time periods between various measurements, or when calculated values indicated accretion. Low error was inferred for survey maps dated after 1980 and for field data comparisons. Some of the more recent survey maps were actually used in place of field measurements for comparison with ODOT data.

All ODOT and field data were entered into the database. This information was then compared to data collected in Tasks 1 and 2 of the project in order to analyze the accuracy of the methods. It must be noted that some of the data points that were entered in the historical map section cover a time period of 10 years or less. These erosion rates, etc. are not intended for use with this study; rather they are there for future use.

Conclusions

Out of the three tasks completed, the one which provided the most available and accurate data was Task 3, comparing

1967 aerial photos to 1992 field data. The supplements from plat and survey maps rounded out this area of the project, although the error level for the older plat maps was considerably higher than for the other methods utilized in Task 3. The supplemental data was easily obtained at the county surveyor's office, and the field measurements were done rather simply.

The other two tasks, tax map comparison and permit data analysis, will not prove to be useful in measuring erosion along the Oregon coast in the near future. The lack of accurate, up-to-date bluff data on tax maps and the failure of the county assessor's office to retain old tax maps, mean that this method is useless as an erosion measure in Lincoln County, and possibly for the entire Oregon shoreline. The permit file review was almost as ineffective, and until SPRD requires a objective, professionally-determined erosion rate estimate for every application, this will not be a useful method.

In summary, we believe that the methods utilized in Task 3 of this project appear to be the best way to measure erosion rates for the coastal bluffs and cliffs of the Oregon coast. With further analysis of the distortion of the photomosaics and/or use of stereo photos, the error level can be decreased. The field data collection does not require highly skilled labor or expensive equipment. As long as the criteria (previously discussed) are followed and measurement locations are accurately determined, the result will be quality data. Further research into the availability and accuracy of survey maps could provide more data and at a low cost. All of this information can then be used as a basis for establishment of sound land use regulations for the Oregon coast.

Expense and Labor Breakdown

Total Labor Expense:	**$2,750**
Total Capital Outlay Costs	**$197.65**
Total Travel Costs	**$663.00***
Cost per Erosion Rate, overall	**$33.74**
Total Man Hours:	**328**

Breakdown:

Task 1

Man Hours:	50	
Travel Costs:	$63.00*	
Capital Outlay		
Tax Maps	$48.40	
Copy Costs	$42.25	
TOTAL	$90.65	
Total for Task 1		**$572.65**

Task 2

Man Hours:	23	
No other expenses		
Total for Task 2		**$192.74**

Task 3

Man Hours	175	
Travel Costs:	$600*	
Capital Outlay		
1967 ODOT photos	86.00	
Total for Task 3		**$2152.50**

Other

Man Hours	80	
Capital Outlay		
Small tax maps	$21.00	
Total for Other		**$691.40**

* - Final financial statement not available, estimates on the travel costs.

Comments: The number of manhours shown under Task 3 can be reduced now that a set of criteria exists for establishing the location of field measurements. However, the work of Jim Good was invaluable for the Siletz littoral cell. Hours of extra reference work was saved by the use of his database. Also note that much of the man hours from Task 1 were at the Lincoln County Surveyors office, and results were applied primarily in Task 3.

Erosion Rate Database Description

Field	Name	Type	Width	Description
1	PARC_ID	N	9	Identifier for the tax lot. First two digits - littoral cell, second two - project assigned map number, last five - tax lot.
2	TAXLOT	C	5	Tax lot number
3	TWNSP	C	3	Township
4	RANGE	C	3	Range
5	SECTION	C	2	Section
6	SUBSECTION	C	2	Alphabetic subsection identifier
7	NS_ORDER	N	4	North to south order of the lots. (Note: the north-south order in the Newport littoral cell only holds for the project data)
8	SPC_X	N	7	Oregon State Plane Coordinate System, X-coordinate, of NW corner
9	SPC_Y	N	7	Oregon State Plane Coordinate System, Y-coordinate, of NW corner
10	BZL_SHT67	C	11	Beach Zone Line 1967 photomosaic sheet on which this tax lot appears
11	DEV_NAME	C	20	Common name of the development, subdivision, park, etc.
12	ST_ADDR	C	25	Street address of the tax lot
13	CITY	C	5	City

LICIT	*Lincoln City*
DEPOE	*Depoe Bay*
GLBCH	*Gleneden Beach*
LIBCH	*Lincoln Beach*
NEWPT	*Newport*
SOBCH	*South Beach*
SEALR	*Seal Rock*

14	COUNTY	C	5	County
	LINCO	*Lincoln County*		
15	BEACH	C	15	Beach which the tax lot faces
16	LIT_CELL	C	6	Littoral cell
17	AV_EROS_RT	N	4	The average erosion rate for this tax lot, calculated with erosion rates that are greater than 10 years and have a med-low error possibility. (Those taxlot for which this was not true have 99.99 as the rate)
18	ERROR_RT	C	3	Error rate for the av_eros_rt, given as hi, med, low, or n/a if erosion rates had a high possibility of error.
19	TYPE_RATE	C	18	Type of erosion measured
20	BUILT_ON	L	1	There is (Y) or is not (N) a structure on the tax lot
21	BUILT_YR	N	2	When the structure was built
22	HARD_SPS	L	1	There is (Y) or is not (N) a hard structure installed as shore protection
23	TYPE_HARD	C	3	The type of hard structure

Bw	*Vertical timber pile, other wood, or sheet steel bulkhead.*
Cr	*Reinforced concrete seawall, vertical or sloped*
Cb	*Concrete block seawall, usually vertical*
Rr	*Rip-rap rock revetment; engineered of not*
Rc	*Concrete rubble structure*
Gu	*Gunnite/sprayed concrete over wire*
As	*Access stairs*
Ar	*Access Ramp*
Pi	*Pipeline*
Gr	*Groin or jetty*
Oth	*Some other type of hard structure to prevent erosion*

24	YR_SPS_CON	N	2	Year the hard structure constructed (if more than one permit on a parcel, give latest one's data)
25	SPS_PERMIT	L	1	The lot had (Y) or did not have (N) a shore protection structure

				application WITH an erosion rate quoted
26	SPRD_NUM	N	8	If permit was issued, the State Parks and Recreation Department permit #, e.g., BA-120-77
27	DSL_NUM	N	6	If permit was issued, the Division of State Lands permit #, e.g., SP 3421
28	PR_RATE	N	6	Erosion rate stated in the permit application
29	TIME_PR	N	2	Time period over which the erosion was measured
30	SRCE_PR_RT	C	18	Source of the erosion quote
31	ERROR2	C	3	Possible error range on the erosion rate, depends primarily on the source of the quote
32	COMMENTS2	C	50	Additional information on the erosion rate
33	STRUC_67	L	1	This taxlot the same structure as in the 1967 ODOT photos AND was used as a field measurement
34	LOC_MEAS1	C	15	Location of the first measurement, relative to the house
35	MEAS1_67	N	5	Measurement from the ODOT photos
36	MEAS1_92	N	5	Measurement from the field
37	EROS_RT3	N	4	Erosion rate based on measurement 1
38	LOC_MEAS2	C	15	Location of the second measurement, relative to the house
39	MEAS2_67	N	5	Measurement from the ODOT photos
40	MEAS2_92	N	5	Measurement from the field
41	EROS_RT4	N	4	Erosion rate based on measurement 2
42	LOC_MEAS3	C	15	Location of the third measurement, relative to the house
43	MEAS3_67	N	5	Measurement from the ODOT photos
44	MEAS3_92	N	5	Measurement from the field

45	EROS_RT5	N	4	Erosion rate based on measurement 3
46	ERROR_RT3	N	3	Possible error for the field/ODOT measurements
47	COMMENTS3	C	50	Comments for the field data
48	HIS_MAP	L	1	This taxlot did (Y) or did not (N) have a historical or survey map which was used to find an erosion rate
49	REF1_OLD	C	20	The type of map used for the older bluff measure
50	DATE1_OLD	N	4	The date for the older reference
51	REF1_YOUNG	C	20	The type of map used for the younger bluff measure
52	DATE1_YOUN	N	4	The date for the younger reference
53	TIME_DIF1	N	3	The time difference between the references
54	EROS_MEAS2	N	5	The erosion measured between the maps at one point
55	EROS_MEAS3	N	5	The erosion measured between the maps at a second point (if this point was NOT measured, a 999 will appear instead of a 0)
56	EROS_RT6	N	4	The erosion rate as calculated by the averaging of the two erosion measures
57	REF2_OLD	C	20	The type of map used for the older bluff measure
58	DATE2_OLD	N	4	The date for the older reference
59	REF2_YOUNG	C	20	The type of map used for the younger bluff measure
60	DATE2_YOUN	N	4	The date for the younger reference
61	TIME_DIF2	N	3	The time difference between the references
62	EROS_MEAS4	N	5	The erosion measured between the maps at one point

63	EROS_MEAS5	N	5	The erosion measured between the maps at a second point (if this point was NOT measured, a 999 will appear instead of a 0)
64	EROS_RT7	N	4	The erosion rate as calculated by the averaging of the two erosion measures
65	ERROR_RT4	C	3	The error possible for this type of measurement, determined by the age of map and the ability to find clear reference points.
66	COMMENTS4	C	50	Comments on the historical/survey map erosion rates
67	GEOMOR_SET	C	20	Geomorphic setting of the taxlot
68	BASE_ROCK	C	20	Base rock in the bluff
69	SECOND_RC	C	20	Second level of rock in the bluff
70	THIRD_RC	C	20	Third highest rock type
71	TOP_RC	C	20	Fourth rock type
72	SEAWAR_DIP	N	4	Degree of seaward dip of units
73	LAWN	C	10	Observations of the lawn vegetation taken during field measurements
74	BLUFF_EDGE	C	15	Observations of the edge of bluff, including notes on vegetation
75	BLUFF_FACE	C	15	Vegetative state of the bluff face
76	BLUFF_HEIG	N	4	Estimated height of bluff
77	BCH_WI_MHW	C	4	Beach width in front of property

Tax Map Identification Numbers

Siletz Littoral Cell - Number 17

Township	Range	Section	Subsection	Map Id Number
06N	11W	23	XX	11
06N	11W	22	XX	12
06N	11W	27	AX	13
06N	11W	27	DA	14
06N	11W	27	DD	15
06N	11W	34	AA	16
06N	11W	34	AD	17
06N	11W	34	DA	19
06N	11W	34	DD	20
07N	11W	03	XX	21
07N	11W	03	DA	22
07N	11W	03	DC	23
07N	11W	10	AA	24
07N	11W	10	AC	25
07N	11W	10	DB	26
07N	11W	10	DC	27
07N	11W	15	AB	29
07N	11W	15	AC	31
07N	11W	15	DB	32
07N	11W	15	DC	33
07N	11W	22	BA	34
07N	11W	22	BD	35
07N	11W	22	CA	36
07N	11W	22	CD	37
07N	11W	27	BA	38
07N	11W	27	BD	39
07N	11W	27	CA	40
07N	11W	27	CD	41
07N	11W	34	BA	42
07N	11W	34	AB	43
07N	11W	34	BD	44
07N	11W	34	CB	45
07N	11W	34	CC	46
08N	11W	03	BB	47
08N	11W	03	BC	48
08N	11W	03	CB	49
08N	11W	03	CC	50
08N	11W	09	AA	51
08N	11W	09	AD	52
08N	11W	09	DA	53
08N	11W	09	DD	54
08N	11W	16	AB	55
08N	11W	16	AC	56
08N	11W	16	DB	57
08N	11W	16	DC	58
08N	11W	21	AB	59
08N	11W	21	AC	60
08N	11W	21	CA	61
08N	11W	21	CD	62

Township	Range	Section	Subsection	Map Id Number
08N	11W	28	BA	63
08N	11W	28	BC	64
08N	11W	28	CB	65
08N	11W	29	DX	66
08N	11W	29	DD	67
08N	11W	32	DB	68
08N	11W	32	DC	69
08N	11W	32	XX	70
Newport Littoral Cell - Number 18				
09N	11W	05	BX	01
09N	11W	05	CA	02
09N	11W	05	CD	03
09N	11W	08	BA	04
09N	11W	08	BD	05
09N	11W	08	CA	06
09N	11W	08	CB	07
09N	11W	07	DD	08
09N	11W	18	XX	09
09N	11W	18	AA	10
09N	11W	18	AD	11
09N	11W	17	BC	12
09N	11W	17	CB	13
09N	11W	19	AD	14
09N	11W	19	DA	15
09N	11W	20	XX	16
09N	11W	29	XX	17
09N	11W	29	BC	18
09N	11W	29	CD	19
09N	11W	32	XX	20
09N	11W	32	BD	21
09N	11W	32	DB	22
10N	11W	05	DC	23
10N	11W	08	AB	24
10N	11W	08	AC	25
10N	11W	17	AB	26
10N	11W	17	CA	27
10N	11W	17	CD	28
10N	11W	20	BB	29
10N	11W	20	BC	30
10N	11W	20	CB	31
10N	11W	19	DX	32
10N	11W	30	AA	33
10N	11W	30	AD	34
10N	11W	29	BC	35
10N	11W	29	CA	36
10N	11W	29	CD	37
10N	11W	32	AB	38
10N	11W	32	AC	39
10N	11W	32	DB	40
10N	11W	32	DC	41
11N	11W	05	BA	42

Township	Range	Section	Subsection	Map Id Number
11N	11W	05	BC	43
11N	11W	05	CB	44
11N	11W	05	CC	45
11N	11W	08	BB	46
11N	11W	08	BC	47
11N	11W	08	CB	48
11N	11W	08	CC	49
11N	11W	17	XX	50
11N	11W	17	CA	51
11N	11W	17	CD	52
11N	11W	20	XX	53
11N	11W	29	XX	54
11N	11W	30	AD	56
11N	11W	30	DA	57
11N	11W	30	DD	58
11N	11W	31	AA	59
11N	11W	31	AD	60
11N	11W	31	DA	61
11N	11W	31	DD	62
12N	11W	06	AB	63
12N	11W	06	CA	64
12N	11W	07	CX	65
12N	11W	18	XX	66
12N	11W	18	BA	67
12N	11W	19	BB	68
12N	11W	19	BC	69
12N	11W	19	CX	70
12N	12W	25	AA	71
12N	12W	25	AD	72
12N	12W	25	DA	73
12N	12W	25	DD	74
12N	12W	36	AA	75
12N	12W	36	AD	76

APPENDIX F

Report to
The Oregon Department
of Geology and Mineral Industries

PHOTOGRAPHIC EVIDENCE FOR SEA CLIFF EROSION AND BEACH CHANGES ALONG THE OREGON COAST

Paul D. Komar

College of Oceanography
Oregon State University
Corvallis, Oregon 97331-5503

December 1992

INTRODUCTION

Sea cliff erosion is an important problem along the Oregon coast, one that threatens homes and other facilities within communities built on uplifted marine terraces. Impacts from cliff erosion have been significant in the area of Lincoln City, the stretch of coast extending from Cascade Head on the north to Government Point (Depoe Bay) to the south (Figures 1 and 2). That area of coast is highly developed, including the communities of Lincoln City and Gleneden Beach, with many homes, motels, restaurants and other structures having been built along the cliff edge. Another area experiencing significant cliff erosion is the stretch of coast between Cape Foulweather and Yaquina Head, with the impacts being to Highway 101 as well as to private developments. Landsliding has been an important factor along that stretch of sea cliffs, and also at Newport to its immediate south, areas where the cliffs are composed mainly of mudstones that dip in the seaward direction. Shoreline protection structures are being installed with increasing frequency to protect the sea cliffs from wave attack.

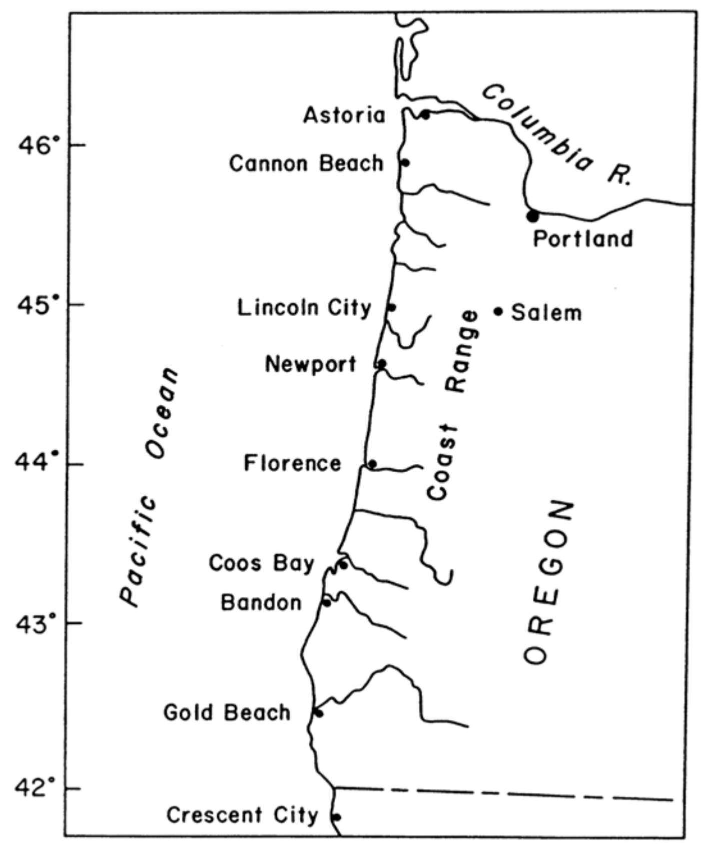


Figure 1: Location map for the Oregon coast.

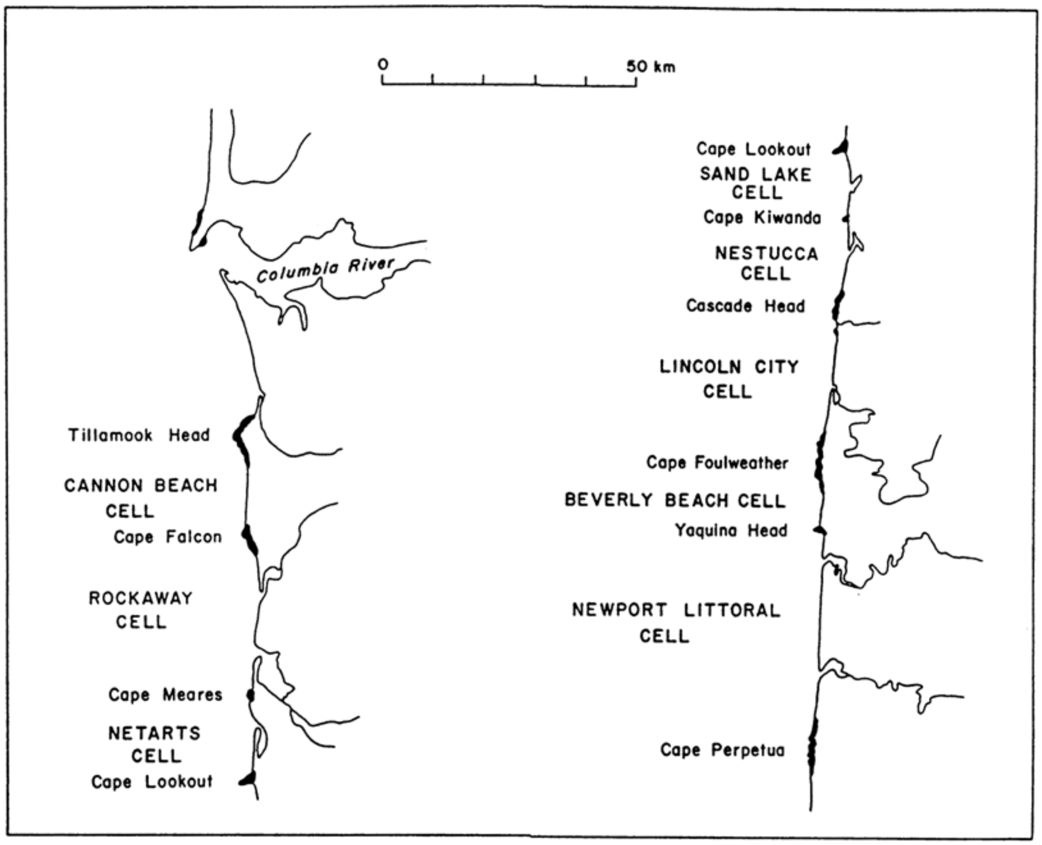


Figure 2: The Oregon coast consists of a series of littoral cells, stretches of beach isolated between rocky headlands.

Areas of sandy shorelines along the Oregon coast are also undergoing change. This can involve the total quantity of sand on the beach, reflected in the beach width, or in the sand spits and dune areas immediately backing the beach. These sandy areas have been particularly susceptible to episodic occurrences of erosion, with some losses of private and public properties.

We have recently completed a study of sea cliff erosion on the Oregon coast, sponsored by Sea Grant (Shih, 1992; Komar and Shih, 1991, in press). The objectives of that study related mainly to the processes of erosion and causes of spatial and temporal variability in bluff erosion along the coast. We found that old photographs, many dating back to early in the century, were an extremely valuable source of information regarding long-term changes in the coastal bluffs, and in a few cases permitted rough assessments of cliff recession. The objective of the present investigation is to undertake a more thorough search for old photographs of the Oregon coast that document the extent of coastal erosion. The primary focus continues to be on sea-cliff recession, but photographs were also sought that demonstrate long-term changes in the sandy areas of the Oregon coast. A number of photographs were also obtained that document extreme erosion events in the past, the earliest dating back to 1913. These contain valuable information regarding extreme but rare events; in some cases the old photographs show that certain areas of the coast have suffered from wave attack in the distant past, but have experienced little or no wave erosion within the latter half of this century. In the management of our coastal zone, it is important to be aware of such extreme but rare events that have the potential for impacting developments along the coast.

METHODS OF STUDY

Photographs have been obtained from the following collections:

The Oregon Historical Society (Portland)
Delano Photos (Portland)
The State Department of Transportation (Salem)
The Lincoln County Historical Society (Newport)
Mrs. Betty Troxel private collection (Newport)
The North Lincoln County Historical Society (Lincoln City)
Tillamook County Pioneer Museum (Tillamook)
The University of California, Berkeley, archives

Information regarding these sources and their collections is provided in Appendix I. The oldest photographs are found in the historical societies, particularly in the Oregon Historical Society which has an extensive collection. However, it was found that relatively few of these very old photographs are dated, as most were taken by tourists and other private citizens. One can often judge the approximate age by the styles of clothing and dates of automobiles, and sometimes by the photograph technology, but the dating remains imprecise. The photographs of the State Department of Transportation are all dated, but the oldest were taken in the 1970s and therefore do no provide a long-term comparison. Most of these State photographs are oblique aerials. The photos from Delano are also dated, at least to the year, but the main part of the collection again dates back to the 1970s with a few from the 1960s and 50s. Delano also has the Brubaker photo collection taken in the 1920s and 30s, which are dated as to the year. Both the Delano and Brubaker collections are high-altitude obliques photographs; although their photos permit some general assessments of the degrees of coastal change, detailed comparisons with the modern beach and cliff morphologies are not possible. The photographs from the

University of California were taken during World War II studies along the Oregon coast. The photographs obtained from these sources have been supplemented with photographs that I have taken during the past 22 years while involved in various coastal investigations, and by recent photographs taken in attempts to match the views seen in the old photographs.

In searching for old photographs, it was decided to focus on the northern half of the Oregon coast as this is the most highly developed area, has experienced the greatest erosion problems, and has the best photographic coverage. As depicted in Figure 2, the north Oregon coast can be considered as consisting of a series of littoral cells between rocky headlands. The headlands are highly resistant, all being composed of basalt except for Cape Kiwanda which is made up of hard sandstones. There are many old photographs available of these headlands, but as expected, due to their extreme resistance they show virtually no change. Therefore, I have not compiled photographs of the rocky headlands. The littoral cells between the headlands consist of stretches of beach backed by sea cliffs, dunes or sand spits. The sea cliffs vary in composition from cell to cell, but typically consist of Tertiary mudstones and/or Pleistocene marine terrace sands. These are far less resistant than the basalt headlands, and accordingly have been eroded back to form the embayments between the headlands.

The headlands extend into deep water and are effective in confining littoral sands to within the embayments with little or no exchange between adjacent cells (Clemens and Komar, 1988). Because of their isolation together with varying sand sources, the individual littoral cells differ in the quantities of sand on the fronting beach. This is an important factor in determining the occurrence and degree of erosion of the sea cliffs and sand spits within the littoral cells, since the beaches act as buffers between the erosive storm waves and coastal properties. Furthermore, analyses have shown that there is a systematic variation in tectonic uplift north-south along the Oregon coast (Vincent, 1989), and this pattern also has had an effect on the degree of erosion (Shih, 1992; Komar and Shih, 1991, in press). The tectonic rise along the southern half of the Oregon coast has exceeded the global rise in sea level during at least the past century, and this has minimized the erosional impacts. In contrast, along the northern half of the coast the global rise in sea level is greater than the tectonic uplift, and this is an important factor in the more extensive erosion along the north coast. However, even along the north coast the relative rise in sea level (relative to land-level changes) progressively decreases toward the north, becoming essentially zero as measured in the tide gauge at Astoria on the Columbia River. Therefore, one would expect to see decreasing long-term erosion toward the north, and our completed investigations of sea-cliff erosion support this hypothesis (Shih, 1992; Komar and Shih, 1991, in press) as do the old photographs collected as part of the present investigation.

INTERPRETATIONS OF PHOTOGRAPHS

The photographs obtained from the various sources have been organized in reference to the series of littoral cells of Figure 2. This is a convenient approach, and one that is particularly appropriate in view of the differing degrees of erosion experienced from cell to cell as discussed in the preceding section. The photographs are contained within files for the series of littoral cells, the files that accompany this report, and are discussed below in sequence from south to north along the length of the north Oregon coast.

Newport Cell

The southernmost littoral cell included in this search for old photographs is the Newport Cell which extends from Cape Perpetua on the south to Yaquina Head on the north (Figure 2). The principal communities within this cell are Newport and Waldport. These communities are centered respectively on Yaquina Bay and Alsea Bay, the bays particularly having been the focus of activities earlier in this century. However, there was an ocean-oriented community beginning early in the century centered in the Nye Beach area of Newport, consisting of facilities for summer visitors. As a result, there is a concentration of old photographs of the Nye Beach area, more so than for anywhere else on the Oregon coast. Scenic attractions such as the original Jump-Off Joe promontory and sea arch were so frequently photographed by tourists that we can document in detail its changes through the years, beginning as a promontory, eroding into a picturesque sea arch, and finally being reduced to small sea stacks after the arch collapsed (Figure 3). This rapid erosion implied by Jump-Off Joe is atypical, however, as it was part of a massive landslide (Byrne, 1963; North and Byrne, 1965; Sayre and Komar, 1988). Large-scale landsliding has occurred in the Nye Beach area because the sea cliff consists of Tertiary mudstones having a significant seaward dip of its layers. The extensive erosion apparent in the old photographs, Figure 3, and still evident in the Jump-Off Joe area, therefore has resulted from wave attack of the toe of the landslide which had been pushed out into the surf. This process of toe erosion is evident in the photographs spanning more than a century.

Excluding the rapidly eroding Jump-Off Joe landslide, cliff recession has been otherwise negligible in the Newport area. There is a large number of photographs available of the Nye Beach community to the immediate south of the Jump-Off Joe landslide; I have obtained representative copies for the accompanying files. Reference positions are provided by the houses built along the bluff edge, and in particular by the old hotel (now the Sylvia Beach Hotel). There has been no significant change in the condition of the bluff during this century, evident in the comparison of Figure 4 of a photograph taken early this century and one taken as part of this study. The cliff has remained vegetated throughout that time. There has also been no discernible change in the width or elevation of the beach.

1880

c. 1915

1978

Figure 3: A series of old photographs showing the erosion of Jump-Off Joe in Newport. The erosion was initially part of the toe retreat of a large landslide, but left the sea arch in the surf zone which continued to erode. Recent bluff erosion in this area has similarly involved the cutting back of the toe of a large landslide, one that was most active during the 1940s (Sayre and Komar, 1988).

Figure 4: Historic and recent photographs of the Nye Beach area of Newport, showing that changes in the sea cliff have been negligible during this century. See the Newport Littoral Cell file for originals of photographs.

Historic photographs are also available further to the south along the ocean shores of Newport, closer to the inlet of Yaquina Bay. The main object of the photography was the old lighthouse. Photographs from early in the century show a sea cliff relatively devoid of vegetation, Figure 5, indicating the existence of some erosion at that time, probably due to the close proximity of the bay inlet. The sea cliff in this area is now heavily vegetated, including large trees (Figure 5). The fronting beach is wide, with sizable sand dunes having built up at the back of the beach along the base of the sea cliff. These changes undoubtedly resulted from construction of the jetties at the bay mouth early in the century. A study of surveys associated with jetty construction demonstrated that sand accumulated to the immediate north and south of the jetties (Komar et al., 1976), and this beach accretion would have resulted in the protection of the sea cliffs from additional wave attack as well as the growth of sand dunes.

Beverly Beach Cell

This is the relatively small littoral cell between Yaquina Head and Cape Foulweather (Figure 2). Motels, condominiums, and a large RV park are found at the south end of the pocket beach, and the small community of Otter Rock is located at the north end. Most of this length of coast is backed by Highway 101 near the cliff edge. Steep cliffs are cut into Tertiary mudstones that are susceptible to slow mass movement, in some cases consisting of large intact masses of cliff sliding seaward at rates up to 10 cm/year. The coastal highway has been particularly affected by the ground instability.

Most of the old (pre-1950s) photographs of this littoral cell are from the Otter Rock area at the north end of the littoral cell. Many of the photos are broad scenic views taken from the top of Cape Foulweather, or shots of rock formations such as the "elephant rock" sea arch within the intertidal zone. In some photos the sea cliffs and beach along the main part of the cell can be seen in the distant background. They do not show dramatic changes, and are too distant to permit detailed analyses.

The poor photographic coverage of the Beverly Beach cell is unfortunate in that it apparently has a significant rate of sea cliff erosion due to the small quantity of sand on the fronting beach and low elevation of the beach relative to high tides and wave run-up (Peterson et al., 1991; Komar and Shih, 1991, in press; Shih, 1992). However, interpretation of the photographs would be potentially difficult as much of the cliff erosion in this littoral cell involves the cutting away of large blocks that are slowly sliding in the seaward direction.

Figure 5: Historic and recent photographs of the old Newport lighthouse and fronting sea cliff. The cliff has developed a heavy cover of vegetation during this century, and an extensive field of dunes has been established fronting the cliff. See the Newport Littoral Cell file for originals of photographs.

The Lincoln City Littoral Cell

The Lincoln City littoral cell extends from the Government Point portion of Cape Foulweather on the south to Cascade Head on the north (Figure 2). Development is high, including the communities of Lincoln City, Gleneden Beach and Lincoln Beach. High cliffs of Pleistocene terrace sands back the beach over much of its length. Cliff erosion is locally significant and represents a management problem due to the concentrated development along the bluff edge. The sea cliffs within the Lincoln City cell consist of Pleistocene terrace sands — uplifted semi-lithified dune, beach and shallow-water sands. These cliffs tend to erode uniformly, with only minor development of landslides, vertical sloughing being more common.

It was my intention to focus on this littoral cell in the collection of old photographs due to the important management problems there and because other research efforts are centered on this stretch of coast. However, my endeavors have not been particularly successful, at least in obtaining pre-1950 photographs. The earliest community in this area was centered at Taft, developed primarily along the north shore of Siletz Bay. Beach activities occurred within the bay and at the inlet. At best the early-century photographs might show a portion of the sea cliff along Taft in the distant background. A series of photographs is available of the ocean shore of Taft dating from the 1920s (undated, but the photographer is known to have been active during that decade). These photos provide one of the rare instances where estimates of the long-term cliff recession rate can be make due to a house and its stone wall that are central to one photograph, Figure 6. Comparisons with the present day cliff demonstrate that the recession adjacent to the wall has been at most 1 meter in some 70 years; a long-term average rate of only 1 to 2 cm/year. This very low recession rate is somewhat surprising in that the general perception is that erosion along Taft has been greater than in most areas of the Oregon coast. A recent episode of erosion occurred during the winter of 1977-78 (Komar, 1978). However, that erosion removed only the accumulated talus and had almost no direct impact on the cliff face itself. Furthermore, the erosion may in part have been in response to whole-scale log removal from the fronting beach, the log accumulations possibly having helped in buffering the sea cliff from wave attack.

The largest rates of erosion within the Lincoln City littoral cell are undoubtedly experienced along Siletz Spit and Gleneden Beach (Komar and Rea, 1976; Komar, 1983; Shih, 1992; Komar and Shih, in press). We have shown that this is due to the beach sand being coarser along this stretch of the littoral cell, and the resulting steeper beach permits more frequent wave attack. Furthermore, rip currents are particularly important in cutting the beach back to the coastal properties and allowing the waves to locally attack the sand spit or sea cliffs. This role of rip currents in the process makes the erosion highly variable, both

Figure 6: A photograph of Taft dating from the 1920s, compared with a more modern view. There has been little retreat of the bluff top relative to the stone wall during some 70 years. See the Lincoln City Cell file for originals of photos.

spatially and temporally. This variability makes it difficult to establish a representative erosion rate for this area. In particular, the foredunes on Siletz Spit have periodically been cut back locally by rip currents combined with storm waves, but it has been documented that the foredunes subsequently build back out to their former extent. Siletz Spit undergoes episodes of extreme erosion and dune retreat, followed by a decade of dune accretion and reformation, the long-term net effect being no change in the average dune edge position at the back of the beach. Photographs of Siletz Spit taken over the years document these cycles, but do not permit an assessment of any long-term net recession (or even to establish whether there has been a net recession). Perhaps more important is the documentation of the nature and processes of the spit erosion. The foredune on the spit is high, which in general prevents wave overtopping and overwash. Instead, the erosion proceeds as undercutting of the dunes to form a high scarp. Houses that have been lost on the spit were undermined by the undercutting process.

Old (pre-1950) photographs are not generally available of the sea cliff area of Gleneden Beach immediately south of Siletz Spit. The more recent photographs, mostly from the 1970s to the present, document episodes of cliff erosion, in some cases where the waves first removed the accumulated talus but then directly attacked the cliff itself. As on Siletz Spit, rip currents are important to the process, so that the cliff erosion during any given episode is very local, generally affecting only three or four properties. The recent photographs document these processes, and provide a rough assessment of how much cliff recession can occur during any one episode, but do not permit evaluations of the long-term recession rate of the cliff as a whole along the community of Gleneden Beach.

Cliff recession along the northern half of the Lincoln City littoral cell is certainly far less than in Gleneden Beach toward the south. This is shown by the post-1970 photo coverage which establishes that there has been essentially no change in the bluff morphology. Wave erosion has been negligible during the past three or more decades, and when it occurs it acts only to remove some talus without attacking the cliff itself (Komar and Shih, in press). However, a 1939 photograph (Figure 7) shows strong wave action against the cliff (protected by a small sea wall) in the Nescott area of north-central Lincoln City. Photographs of that 1939 storm have been found for several sites along the coast, in many cases with the waves reaching areas that have not been attacked by waves in several decades. That storm undoubtedly represents a very extreme condition of high water levels and severe wave energies. These photographs document that although many areas of the Oregon coast have not experienced significant wave attack and erosion in several decades, there is the potential for such an extreme event.

Figure 7: A 1939 photograph of the Nescott area of north Lincoln City, showing strong wave action against the bluff in an area that has not experienced wave attack in recent decades. See the Lincoln City Cell file for original photo.

Nestucca Cell

This is the littoral cell between Cascade Head and Cape Kiwanda (Figure 2). Most of the beach is backed by sand dunes and Nestucca Spit. The stretch of sea cliff close to Cape Kiwanda is heavily vegetated and fronted by dunes, suggesting that a long period of time has elapsed since the last episode of cliff attack by waves.

I have not located any old photographs of this area to document long-term changes. However, included in the file are photographs of the erosion along Nestucca Spit that occurred during the winter of 1977-78, leading to the breaching of the spit. These photos are from the State Department of Transportation and from my own collection. The ocean wave and tide conditions during spit breaching have been documented by Komar (1978), demonstrating that it involved a combination of unusually high tides (perigean spring tides) plus severe storm-wave energies. Erosion in the Pacific City area just south of Cape Kiwanda involved wave undercutting of the foredunes, like that described above for the erosion on Siletz Spit. It is believed that the breach similarly involved extensive wave undercutting of the dunes on the spit, rather than wave overtopping or washover being the dominant process. A number of homes in a new development in Pacific City were threatened by the 1977-78 erosion, requiring their protection by large riprap revetments. Of interest, in the years since that erosion event, sand has returned to such a degree that the riprap is now completely covered and the houses have problems with sand encroachment.

Sand Lake Cell

The small littoral cell between Cape Kiwanda and Cape Lookout on the north (Figure 2). There is minimal development with only a few houses along the southern half of the cell. The sea cliff is vegetated, indicating that there has not been significant sea cliff erosion in recent years. I have been unable to locate any pre-1970 photos of this littoral cell. However, the post-1970 photographs and the morphology and vegetation cover of the cliffs suggest that erosion has been negligible.

Netarts Cell

The littoral cell between Cape Meares and Cape Lookout (Figure 2). Most of this cell is occupied by Netarts Spit, but stretches of sea cliff backing beaches exist along the north and south portions of the cell. Cliff recession was minimal prior to 1982, but the exceptional wave conditions associated with the 1982-83 El Niño induced erosion of the sea cliffs south of the spit as well as attacking the spit itself (Komar et al., 1986). Cliff erosion has not taken place along the northern half of the cell within historic times. This is evident in old photographs of the community of Oceanside, Figure 8, which show the same bluff line as present today, at all times covered with dense vegetation. The bluff in this area is protected by a natural accumulation of cobbles at its base which acts to protect the cliff from wave attack (Komar and Shih, in press).

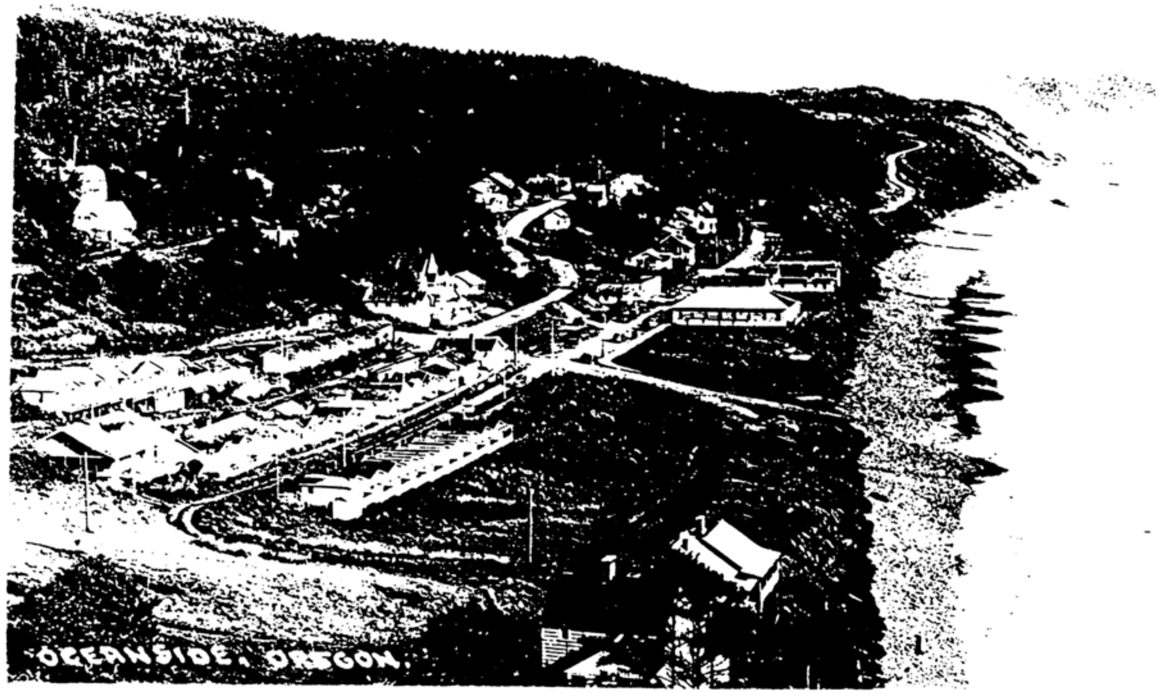


Figure 8: A historic photograph of Oceanside at the north end of the Netarts littoral cell. Although there has been extensive development of this area subsequent to this old photograph, there has been no discernible change in the bluff position. See the Netarts Cell file for the original photograph.

Rockaway Cell

This cell consists mainly of Nehalem and Bayocean Spits, and the dune backed shore in between. Sea cliffs are found only at the far north and south, close to the headlands. Cliff recession has been negligible, except to the south of Bayocean Spit where it occurred during the first half of this century in response to jetty construction on the inlet to Tillamook Bay (Terich and Komar, 1974). Cliff recession has been negligible since the mid-1970s after the second jetty was completed, as this tended to stabilize the shoreline.

Good collections of old photographs are available, but they are virtually all of Bayocean Spit, the development of the vacation community on the spit early in the century and its subsequent erosion. That erosion resulted from the construction of a single north jetty at the entrance to Tillamook Bay, which caused sand accumulation in the bars at the inlet mouth while at the same time producing erosion along the length of the spit. Significant shoreline and foredune erosion occurred during that period, documented in the old photographs that focused on the destruction of various buildings in the resort community (in particular, the natatorium and hotel). Although the ultimate cause of the erosion was jetty construction and the loss of beach-sand volume, specific episodes of erosion resulted from normal processes of storm waves and nearshore currents. The photographs show that the dune erosion along the spit was in the form of undercutting rather than overwash, except perhaps in the low-lying stretch of the spit which happened to also be its narrowest point and where it finally breached in 1952. Construction of the south jetty was completed during the 1970s, and this has helped to stabilize the shoreline along Bayocean Spit as the jetty in effect created a pocket beach between it and Cape Meares to the south. However, by the 1950s the vacation community had disappeared so there are few ground photographs to document shoreline changes during more recent years.

A number of photographs were found relating to wave attack at Barview on the north shore within the inlet to Tillamook Bay (Figure 9). Specific erosion events occurred during 1913 and 1915, which is prior to construction of the jetties on the inlet. Apparently large waves traveled up the deep water of the inlet to strike the shoreline along Barview. This has happened at several natural inlets (those without jetties), demonstrating that shorelines within and immediately adjacent to bay inlets are particularly susceptible to wave attack and in some cases have experienced erosion as the inlet mouth shifts position.

Figure 9: Wave attack at Barview along the north shore of the inlet to Tillamook Bay. See the Rockaway Cell file for the original photograph.

The Cannon Beach Littoral Cell

This littoral cell includes the stretch of sea cliffs backing the beach between Cape Falcon and Tillamook Head (Figure 2). This cell includes the communities of Cannon Beach and Arch Cape. Much of the cliff consists of debris from ancient landslides and alluvial slopes of the adjacent Coast Range. Cliff recession is minimal, occurring locally due to ground water seepage. The only old photographs of note show intensive wave attack during 1939 along the ocean shoreline. This must have been an event represented by extreme water elevations, as some photographs show standing water in streets within Cannon Beach. It is unclear how much cliff recession resulted from this episode. Of interest is the fact that the water and surf reached the sea cliff with such intensity, as I am unaware of a comparable occurrence during the 22 years of my work on the coast, or of reports of cliff erosion by wave attack since that 1939 event.

The Clatsop Plains Shoreline

The Clatsop Plains is the sandy area north of Tillamook Head to the Columbia River. The main communities are Seaside and Gearhart along the beach near the headland. It is clear that the entire Plains area has been produced by sand transported to the coast by the Columbia River, and accreted during the past 3 to 4 thousand years (Rankine, 1983).

There is a large number of old photographs available from the Seaside area as this has been a resort center since the turn of the century. The photographs are centered mainly on the Trials End turn around and adjacent boardwalk backing the beach. The oldest photos, Figure 10, show this as a true "board" walk, and also show that in the early days there was a pier extending out into the surf from the turn around. At a later date the pier was removed, and the board walk was replaced with the concrete walkway presently found along Seaside. Of particular interest is the obvious changes in the extent of the beach from the turn of the century to the present. In the early photographs, Figure 10, the sandy beach is narrow compared with the present wide beach, and a cobble high-tide ridge is seen at the back of the beach along the boardwalk. Today cobbles are visible on the beach only in close proximity to Tillamook Head, not anywhere near the Trails End turn around. Sand appears to have continued to accumulate since the construction of the concrete walkway, as the elevation of the structure above the level of the sand has decreased with time. It is apparent from this sequence of photographs that there has been a significant increase in the quantities of beach sand in the Seaside area, and a substantial increase in the width of the beach. A number of old photographs were found showing waves breaking against the turn around and boardwalk, Figure 10, and this was probably a frequent occurrence since the beach was narrow at that time. At present, with a wide beach, the waves never come close to the concrete seawall and boardwalk.

There is similar evidence for increased quantities of sand along Gearhart just to the north of Seaside. In the absence of a boardwalk, some of the sand has blown in from the beach and accumulated as extensive foredunes covered with dune grasses. The growth of these dunes through time is evident in the photographs.

It is possible that the accumulations of sand in the Seaside-Gearhart area reflect the continued sediment contributions from the Columbia River. It is certain that most of the Columbia River sand moves north onto the beaches of the Long Beach Peninsula in Washington, as the accretion there has been very substantial (Komar and Li, 1992). The situation along the Clatsop Plains is more problematic in that there has been some shoreline reorientation in response to construction of jetties at the mouth of the Columbia River. With the extension of the jetties, shoreline recession occurred near the jetty, progressively decreasing southward to a nodal point some 10 miles south of the jetty, and then reverted to accretion south of the nodal point. Therefore, some of the accumulation of sand at Seaside and Gearhart could represent this slight rotation of the shoreline rather than new sand having been contributed to the beach by the Columbia River.

Figure 10: Historic photographs of Seaside, showing a narrow sandy beach with the exposure of gravels along the board walk, and the occurrence of waves breaking against the turn around. The area is now characterized by a wide sandy beach. See the Clatsop Plains file for originals of these photos.

SUMMARY

Extensive collections of photographs are available of the Oregon coast. The several historical societies have photographs that date back to the late-1800s, increasing in number for the early twentieth century. However, their distribution is very uneven along the coast as there were few communities at that time. The highest concentrations of photographs were found from Newport, including Nye Beach, and from Seaside; these were resort areas even in those early days, and most of the photographs were taken by summer tourists. Unfortunately, most of these early photographs are undated. However, they are still useful as approximate indicators of very long-term coastal changes. In most cases they reveal that there has been relatively little change in the Oregon coast in nearly a century. Except for landslide areas like Jump-Off Joe in Newport, the sea cliffs show essentially no recession. The principal change noted in Seaside is the significant growth of the sandy beach, which may be attributed to the continued supply of sand from the Columbia River or a slight rotation of the beach along the Clatsop Plains resulting from the construction of jetties at the mouth of the Columbia.

There is a large number of photographs from the 1960s to the present, available in the Delano collection and at the Oregon Department of Transportation. For the most part these are oblique aerials rather than ground photographs. Spanning only a quarter of a century, they show relatively little change in the coast resulting from beach and cliff erosion. They better document the high rate of development along the coast, together with the proliferation of shoreline stabilization structures.

In general, the collections of old photographs substantiate the conclusions of Shih (1992) and Komar and Shih (1991, in press) regarding the variations of cliff erosion in the series of littoral cells along the coast, conclusions reached primarily on the basis of the morphologies of the cliffs and degrees of vegetation cover. As expected, sea cliffs that are presently highly vegetated are shown by the old photographs to have undergone essentially no change throughout this century. More significant is the finding that areas such as Taft, where bare cliffs are known to have experienced wave attack in recent years, have actually undergone only a small recession during more than half a century. It was my initial impression that these cliffs must be receding at greater rates, but the old photographs suggest that this is not the case. Areas such as Gleneden Beach likely have experienced greater long-term recession rates, but unfortunately oblique aerial photos of that area are available only beginning in the 1950s, and ground photos from the 1970s. These photographs substantiate that there is a great deal of spatial variability and episodic occurrence due to the erosion being governed by rip currents plus storm waves, but the coverage is insufficient to suggest a long-term average recession rate for this stretch of sea cliffs.

The old photographs collected as part of this study, therefore, have been most informative in establishing areas of the coast that have experienced essentially no erosion during this century. In summary, these areas include:

- The sea cliffs of Newport, including Nye Beach but excluding the localized area of the Jump-Off Joe landslide.
- The Roads End area of Lincoln City.
- The bluff line along the Sand Lake littoral cell.
- The sea cliff along Oceanside at the north end of the Netarts cell.
- Seaside and Gearhart at the south end of the Clatsop Plains, where extensive beach and dune accretion has occurred during this century.

Quantitatively, the long-term net recession rates in the above areas can be placed at essentially zero. The assessment of a recession rate of 1 to 2 cm/year in Taft, based on a comparison between the present bluff with photographs from the 1920s, is likely applicable on average to the remainder of the Lincoln City bluff, although there may be localized areas of greater erosion due to concentrations of groundwater flow from streets and culverts. This small rate is probably also applicable on average to the bluff in the Cannon Beach littoral cell where some recession has occurred, but it is apparent that the overall distance of cliff retreat and thus the rates are very small.

The photo collections also have been informative as to the nature of the erosion processes along the coast, and in providing evidence for extreme wave conditions during the past that have not been experienced in recent decades. In particular, an extreme storm that occurred during 1939 was photographed at several sites along the coast, in each case documenting intense wave attack in areas that have not experienced erosion during recent decades (probably not since 1939). In the management of our coastal zone, it is important to be aware of such extreme but rare events that have the potential for impacting the increasing development of the coast.

REFERENCES

Byrne, J.V. (1963) Coastal erosion, northern Oregon: In *Essays in Marine Geology in Honor of K.O. Emery*, University of Southern California Press, Los Angeles, California, p. 11-33.

Clemens, K.E., and P.D. Komar (1988) Oregon beach sand compositions produced by the mixing of sediments under a transgressing sea: *Journal of Sedimentary Petrology*, 58: 519-529.

Komar, P.D. (1978) Wave conditions on the Oregon coast during the winter of 1977-78 and the resulting erosion of Nestucca Spit: *Shore & Beach*, 46: 3-8.

Komar, P.D. (1983) The erosion of Siletz Spit, Oregon: In *Handbook of Coastal Processes and*

Erosion, CRC Press, Boca Raton, Fla.

Komar, P.D., and C.C. Rea (1976) Erosion of Siletz Spit, Oregon: *Shore & Beach*, v. 44, p. 9–15.

Komar, P.D., J.R. Lizarraga-Arciniega, and T.A. Terich (1976) Oregon coast shoreline changes due to jetties: *Journal of Waterways, Harbors and Coastal Engineering*, Amer. Soc. Civil Engrs., 102 (WW1): 13-30.

Komar, P.D., J.W. Good, and S.-M. Shih (1988) Erosion of Netarts Spit, Oregon: Continued impacts of the 1982-83 El Niño: *Shore & Beach*, 57: 11-19.

Komar, P.D., and Z. Li (1991) Black-sand placers at the mouth of the Columbia River, Oregon and Washington: Marine Mining, v. 10, p. 171-187.

Komar, P.D., and S.-M. Shih (in press) Cliff erosion along the Oregon coast: A tectonic-sea level imprint plus local controls by beach processes: *Journal of Coastal Research*.

North, W.B., and J.V. Byrne (1965) Coastal landslides in northern Oregon: *The Ore Bin*, Dept. of Geology and Mineral Industries, Portland, Oregon, 27: 217-241.

Peterson, C.D., D.J. Pettit, M.E. Darienzo, P.L. Jackson, C.L. Rosenfeld, and A.J. Kimerling, (1991) Regional beach sand volumes of the Pacific Northwest, USA. Coastal Sediments '91, ASCE, 1503-1517.

Rankin, D.K. (1983) Holocene geologic history of the Clatsop Plains foredune ridge complex: MS thesis, Portland State University, Portland, OR., 148 pp.

Sayre, W.O., and P.D. Komar (1988) The Jump-Off Joe landslide at Newport, Oregon: History of erosion, development and destruction: *Shore & Beach*, 56: 15-22.

Shih, S.-M. (1992) Processes of sea cliff erosion on the Oregon coast: Neotectonics to wave runup: Ph.D. thesis, College of Oceanography, Oregon State University, Corvallis.

Terich, T.A., and P.D. Komar (1974) Bayocean Spit, Oregon: History of development and erosional destruction: *Shore & Beach*, 42: 3-10.

Vincent, P. (1989) Geodetic deformation of the Oregon Cascadia margin: M.S. dissertation, University of Oregon, Eugene, 86 pp.

APPENDIX I: SOURCES OF OREGON COAST PHOTOGRAPHS

The Oregon Historical Society (Portland)

By far the most important and extensive collection of historic photographs for the Oregon coast. The collection is well organized into a series of files. The cost per photograph is modest; $6 for a 5 by 7 inch print, $10 for a 8 by 10 print, etc. (see attached price listing). There is an additional change if the photo is used in a publication, the rate depending on the circulation, and they require that a credit line be included with the published photo.

Delano Photos (Mrs. Delano, 15890 SE Wallace, Portland, OR)

A very large collection of oblique aerials. The main part of the collection dates back to the 1970s with a few from the 1960s and 50s. Delano also has the Brubaker photo collection taken in the 1920s and 30s. All photos are dated as to the year, the first two numbers of the ID number being the year. Being in Mrs. Delano's basement, the collection is somewhat disorganized and it takes a long time to obtain copies of the photos needed. The initial cost is high, based on a confusing scale that depends on how many photos are ordered. However, there is no subsequent charge for use of the photo in a publication, but it is requested that a general credit statement be included.

The State Department of Transportation (Salem)

A professionally obtained collection of oblique aerials, of high quality. The oldest photos were taken in the 1970s and therefore do not provide a long-term comparison. The organization of the collection is good.

The Lincoln County Historical Society (Newport)

Minimal collection and poorly organized. I quickly learned that Betty Troxel is a better source of historic photos for the Newport area.

Mrs. Betty Troxel private collection (6049 Evergreen Lane, Newport, OR 97365)

Formerly had a photo studio in Newport, and over the years has made an extensive collection of historic photographs. The photos are limited to roughly Waldport north to Otter Rock, with most from Newport.

The North Lincoln County Historical Society (Lincoln City)

A new organization having only a small collection of historical photographs. The photos are in boxes with little semblance of order. At this time it is only possible to obtain photocopies, not glossy prints.

Tillamook County Pioneer Museum (Tillamook)

A good collection of historical photographs, and the collection is well organized. However, the part of the collection relevant to the present study was limited, mainly being photographs of the development of Bayocean Spit and its subsequent erosion.

The University of California, Berkeley, archives

The few photos included in the files from this collection were obtained a number of years ago. They represent photos taken during World War II studies along the Oregon coast. There are both ground and oblique aerial photographs. The photos I have are mainly of Bayocean Spit, with a few additional scattered sites along the northern coast. Access to the original collection is very difficult, as the photos are contained in a series of file cabinets in a warehouse at a small airport outside of Berkeley.