SHORELINE PROTECTION FEASIBILITY STUDY FOR PRINCETON, PILLAR POINT

HALF MOON BAY, CALIFORNIA

Prepared For

SAN MATEO COUNTY HARBOR DISTRICT
1 Johnson Pier
El Granada, CA 94018

Prepared By

MOFFATT & NICHOL ENGINEERS
3000 Citrus Circle, Suite 230
Walnut Creek, CA 94598

September 2001
M&N FILE NO. 4852

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

1.1. BACKGROUND

This study was conducted for the San Mateo County Harbor District (District), as part of their ongoing efforts to update the Pillar Point Harbor Master Plan. Several segments of the shoreline within the Harbor are eroding due to various reasons. The project area investigated as part of this study includes the shoreline fronting Princeton, which is an unincorporated community within the Harbor. The study encompassed a coastal engineering assessment of the causes and severity of shoreline erosion at Princeton, preparing conceptual erosion protection measures along with implications to future public access plans, and analyzing potential impacts of proposed developments at Romeo Pier on the conceptual shore protection measures.

The project site is in Pillar Point Harbor, approximately four miles north of the City of Half Moon Bay in San Mateo County. The Princeton study area is about ½ mile long, and is located west of the Inner Harbor berthing area. The shoreline along Princeton community has been experiencing erosion since the time of the construction of the Pillar Point Inner and Outer breakwaters. The study area is focused on the reach of shoreline east of Romeo Pier, up to Broadway Avenue. The reach is comprised of privately owned parcels whose landowners have each attempted to protect their properties from erosion. As a result, the California Coastal Commission has requested assistance from the District in assessing the erosion problem and identifying possible comprehensive solutions.

1.2. PURPOSE

The objectives of this study are to assess causes, locations and severity of shoreline erosion, and to identify conceptual shore protection measures. The conceptual plans should also consider the District's proposed public access plans for the Princeton area, and incorporate those plans into the proposed shore protection measures. The District is also considering the replacement of Romeo Pier with a new pier that could provide public access as well as support commercial uses. The new pier would include a new federally sponsored channel, dredged to the new pier. The impacts of these activities on ongoing shoreline processes, and on the proposed shore protection measures should also be evaluated.

1.3. SCOPE OF WORK

The scope of work for the project consisted of the following tasks:

- Document existing conditions and review available data, including historic aerial photographs and surveys, available reports, and the proposed pier development and harbor dredging plans;
- Conduct preliminary coastal engineering analyses, assess the wave climatology, and evaluate erosion extents and mechanism in the study area;
- Develop concept level engineering solutions;
- Prepare study report summarizing findings.

2. ANALYSES OF SITE CONDITIONS

2.1. SITE RECONNAISSANCE

The study area is located inside the Pillar Point Harbor along the Princeton shoreline, east of Romeo Pier, as shown on Figure 1. The Harbor is protected by offshore breakwaters, with the entrance to the harbor located due south of the community of Princeton. The Princeton shoreline can be generally characterized as a narrow beach, backed by low sand dunes. The beach material is predominantly fine sand, with an average grain size between 0.10 mm and 0.15 mm. Earlier studies have shown that the deposits backing Half Moon Bay are poorly consolidated, which as a result of persistent oblique swell prior to the construction of the Outer breakwaters have eroded back to form a hook-shaped bay (USACE, 1996) resulting in the name "Half Moon Bay".

Many of the homeowners and commercial businesses along the shoreline between Boadway and Vassar have placed rip-rap, concrete rubble, or concrete seawalls to protect their property. An aerial photograph from February, 2000 is provided in Figure 2, and pictures of the site taken at about mean tide level on September 23rd are provided in Plates A1 through A10 in Appendix A. Discussions with local residents indicate that the embankment fronting the shoreline is frequently overtopped during high tides. Even the high embankment near Broadway, at the Conference Center, is overtopped during storm activity.

West Point To Vassar

Between West Point and Vassar Avenues, approximately 350 linear feet of the 500 foot long reach of shoreline has been armored with a concrete seawall and concrete rubble. Pictures of this reach are presented in Plates A1 through A3 in Appendix A. The beach exposed at high tide is narrow (about 10 feet wide, see Plate A1). Romeo Pier is located approximately 100 feet east of West Point. The reach just west of Vassar has an unprotected segment of shoreline where the beach is wider and erosion is ongoing (see Plate A2) .

Vassar To Columbia

Between Vassar and Columbia Avenues, the shoreline fronting the Yacht Club and the boat yard, is mostly armored as seen on Plates A4 through A8. The beach width transitions from a narrow beach at high tide near Vassar (see Plate A4) to almost none near Columbia (see Plate A7). The shoreline treatment varies from concrete rubble randomly placed, to a concrete seawall at the boat yard. Two parcels have constructed access ramps/stairs to the beach. Approximately 200 feet west of Columbia, a set of marine railways for a small boat repair yard extends into the water from the shore. A storm drain outlet has been installed near Vassar.

Columbia to Broadway

The shoreline between Columbia and Broadway Avenues fluctuates, where parcels protected by rip-rap protrude further into the Bay and adjacent areas have eroded back. No beach is visible, even at low tides. The shoreline is not accessible in this reach, except at Broadway. Pictures from this end are presented in Plates A9 and A10. East of Broadway, a small creek, Denniston Creek, flows out to the Bay. A delta has formed at the mouth of the creek from the sediments that are carried down. The delta is visible at low to mid tides.

2.2. Surveys and Aerial Photographs

Cross-section surveys at 5 locations from the top of bank to approximately the 12 foot depth contour were completed as part of this study by Tucker & Associates, sub-consultant to Moffatt & Nichol Engineers. The location of the sections, and the depth contours based on this survey, are provided in Figure 3. The sections are presented in Figure 4. Figure 3 also includes approximate assessor's parcel lot lines obtained from District files.

Aerial photographs were obtained to analyze shoreline changes to the coastline and to estimate shore recession rates. Photographs for the period between 1969 and 2000 were available, and used in the analysis. Copies of the aerial photographs showing the photo coverage and the study area are included in Appendix B.

Other data that were used in the analyses, and a summary of previous studies completed for the area, are noted in the following discussion. An annotated bibliography is provided for select references.

2.3. Literature Reviewed

The U.S. Army Corps of Engineers, San Francisco District (1998) prepared a reconnaissance report for Pillar Point Harbor. The objective of the study was to investigate the feasibility of providing Federal assistance for navigation in Pillar Point Harbor. The alternative that was to be carried forward included a new 200-foot wide channel, 13 feet deep, from the harbor entrance to Romeo Pier, with a turning basin near the pier. Estimated quantity of material to be removed was 43,100 cubic yards. It was noted in the reconnaissance study that the soils offshore consisted of a 2-foot sand unit underlain by clayey material. Approximately 19,500 cubic yards of material would be sandy. The study also included an analysis of shoaling in the harbor between 1947 and 1995, which showed that the net shoaling within the footprint of the Harbor reduced from about 19,000 cubic yards per year (CY/yr) prior to the outer breakwater construction, to about 15,000 CY/yr after construction of the breakwaters. In the vicinity of Princeton, the shoaling remained unchanged before and after construction of the breakwaters. However, the area used in the averaging was relatively large, which does not resolve near-shore accretion/erosion processes. A shoreline change analysis was not included in the study.

The County of San Mateo "Local Coastal Program", Policies document (June 1998) describes the minimum development standards for public access on beaches. For lateral access in areas without coastal bluffs, right of way for access to and along the beach during normal tides should be at least 25 feet in width between the mean high tide line and the first line of terrestrial vegetation.

In June 2001, Callandar Associates, consultants for the ~~Harbor District,~~ County prepared concept-level plans for public access to the shore at Vassar and Broadway Avenues. The conceptual public access plans are provided in Figures 5 and 6 for reference.

An engineering investigation of the shoreline retreat of the beachfront property located at parcels 20 through 25 and 27 through 31 (property located at end of Columbia Avenue), was prepared by Applied Earth Sciences, consultants to Mr. Christian Mickelsen (May 1999). Analysis of aerial photographs from 1943 through 1993 indicated that erosion rates increased from about 4 inches/year prior to breakwater construction to about 26 inches/year after breakwater construction. After construction of the inner breakwaters, the erosion rate reduced to about 13 inches/year.

Lajoie and Mathieson (Griggs and Savoy, 1985) described littoral processes along the California coast, including the area of Half Moon Bay. Prior to the construction of the Federal breakwaters for the harbor, the area was described as *"...constrained by headlands on the north (Pillar Point) and south (Miramontes point). Between these rocky headlands, loose nonresistant sand and gravels occur at the shoreline and are exposed to wave erosion... Sand periodically eroded from the soft cliffs accumulates to form a broad permanent beach that protects the cliffs from all but the largest storm waves which usually approach the coastline from the southwest."* Since the construction of the breakwaters, accelerated erosion has occurred in the Princeton area. Erosion rates increased from about 11 inches/year (period between 1908 and 1960) to about 16 inches/year (period between 1960 and 1983) at Columbia and about 40 inches/year at Broadway. At some locations along the Princeton shoreline, the erosion rate still averages about 33 inches/year.

2.4. ENVIRONMENTAL CONDITIONS

A coastal engineering analysis was conducted for the Half Moon Bay area, to assess the causes of erosion and to assist in developing conceptual shore protection schemes. Prior to the construction of the breakwaters, equilibrium conditions prevailed with the predominant northwest swells refracting around the Pillar Point headland resulting in wave energy distribution along the shoreline. Shoreline orientation and sediment budget was controlled by the predominant swells, with a small net southward longshore transport of sand. The erodible sea cliffs in the area were retreating at a rate of about 11 inches/year.

The construction of the breakwaters disrupted the natural state of equilibrium, and the long period swells from the northwest do not reach the shoreline within the Harbor. Under these conditions the local seas predominate, with no effective reversals in sediment supply to the beaches. Swells from the south and southwest directions transmit wave energy through the breakwater entrance, and also reach the Princeton shoreline. We believe it is a combination of transmitted wave energy and local seas which continues to cause erosion at Princeton. A preliminary wave analysis was conducted to estimate wave conditions due to wind blowing over the enclosed water body, and that transmitted through the breakwater entrance.

Water Levels

The water levels for the area are characterized as semi-diurnal tides with two unequal highs and lows each lunar day. Tidal planes for the study area were obtained from the USACE 1996 study, and are presented in Table 2.1. A Mean High Water (MHW) elevation of +4.65 feet (with reference to MLLW datum) was used in this study for the conceptual plans described in the Section 4.

Table 2.1: Tidal Bench Marks For Pillar Point Harbor
(Source: USACE, 1996)

Tidal Datum	Elevation (ft, MLLW)
Highest Estimated Tide (HET)	+8.0
Mean Higher High Water (MHHW)	+5.5
Mean High Water (MHW)	+4.7
Mean Tide Level (MTL)	+3.0
Mean Low Water (MLW)	+1.1
Mean Lower Low Water (MLLW)	0.0
Lowest Observed Water Level	-2.5

Wave Regime

The study area is protected from the predominant northwest ocean swells by the offshore breakwaters. However, due to the large body of water within the enclosed harbor, wind-generated waves occur frequently and reach the study area.

Data from several wind stations in the vicinity of the study area were reviewed, and analyzed. Figure 7 shows the locations of these wind stations.

1) Point Montara, where hourly data collected from February 1938 to November 1941 was analyzed by Department of Water Resource (DWR 1978). A wind rose (percent frequency of wind direction and speed), presented in Figure 8, was used in this study to assess prevailing wave conditions.

2) Pillar Point, where hourly data were collected from April 1988 to December 1988 by the Bay Area Air Quality Management District. The hourly data, analyzed by PG&E, and 50-year return period wind conditions were used as extreme wind conditions in this study.

3) NOAA Buoy 46012 at Half Moon Bay, where hourly data were collected from November, 1980 to December 2000 by National Data Buoy Center. These data were analyzed (see Figure 8) to determine prevailing wind and wave conditions at the study site.

Prevailing Wind Condition

Prevailing winds at Pillar Point Harbor were determined by reviewing the wind records from Point Montara and NOAA Buoy 46012. Figure 8 shows that the prevailing wind is from the northwest direction and the prevailing speed is between 5 and 15 miles per hour.

Extreme Wind Condition

The highest 1-minute wind speed (fastest mile) with a return period of 50-years is estimated to be 61 mph (PG&E, 1986). This extreme wind speed was used to analyze wind generated wave conditions within the harbor, and to develop shore protection measures.

Wind Wave Analysis

Wind-generated wave conditions within the harbor were developed from the 1994 bathymetry and extreme wind conditions. A spectral-contribution wave generation method was utilized, which is based on the technique described in the Shore Protection Manual (USACE, 1984) modified for short fetches. A south facing fetch, about 0.6 miles long, was used in the analysis. The significant wave height was estimated to be 1.7 ft, with a peak spectral period of about 2 seconds. Tidal variation did not seem to make much of a difference in wave conditions.

Transmitted Wave Analysis

Waves transmitted from the Pacific Ocean are mostly low frequency ocean swell. Wave diffraction around the tip of the west breakwater was analyzed using a typical incident wave period of 12 seconds. Since the natural promontory at Pillar Point and the west breakwater provides shelter from northwest through southwest wave approach directions, incident waves from the south were analyzed (150° through 180° compass directions). The diffraction coefficient K_d at the entrance to the Harbor was estimated as shown below.

Wave Period (seconds)	Wave Direction (degrees, north)	Diffraction Coefficient K_d
12	180	0.21
12	160	0.26
12	150	0.34

The K_d values shown above indicate that for waves approaching from the south, wave heights are reduced to about 21% of their offshore wave height at the entrance to the Harbor. Waves from the south-southeast are reduced to about 34% of their offshore wave height. As these waves propagate from the entrance, wave heights increase due to bottom friction (shoal) and eventually break at a limiting depth of water. For a wave period of 12 seconds, wave heights could increase by as much as 40% as they propagate from the harbor entrance towards the shore.

The above discussion indicates that long period swells from the southern hemisphere have a potential to transmit significant energy to the shoreline at Princeton, resulting in erosion. Under the pre-breakwater conditions, this erosion would be reversed by the predominant northwest waves which would move sand back to the shore. Under present conditions this reversal does not take place, and the sand remains offshore or is transported to the east via wind-generated waves

3. SHORE EROSION ANALYSIS

3.1. AERIAL PHOTO ANALYSIS

Shoreline changes were evaluated by comparing shoreline data using the following contact prints (9" x 9" aerial photos). Copies of the photographs, including a blow-up of the study area are provided in Appendix B. Typically, shoreline change analyses require low-altitude, large-scale photographs (1" = 400 feet or better) to estimate shoreline change rates. Low-altitude pictures were not available for this study, so it should be recognized that the change rates are approximate.

Description	Approx Scale
Oct. 1969, Black & White	1"= 1000'
May 1972, Black & White	1" = 1000'
Apr. 1975, Black & White	1" = 1000'
Jun 1981, Black & White	1" = 1000'
Jun 1989, Black & White	1" = 1000'
Jul 1991, Black & White	1" = 1000'
Aug 1993, Black & White	1" = 1000'
Sep 1995, Black & White	1" = 1000'
Jun 1997, Black & White	1" = 1000'
Aug 2000, Black & White	1" = 1000'

The following are pertinent observations of the aerial photographs listed above:

October 1969: Eight years after construction of the Federal outer breakwaters. Beach is visible between West Point and Columbia, although very narrow at Columbia. Seawall east of Romeo Pier and Yacht Club building can be observed. Creek west of West Point does not incise through the beach, possibly due to low run-off from marsh. About a third of the reach between Columbia and Broadway has a beach. Bank (top of dune) alignment is fairly straight between Columbia and Broadway, with no evidence of rip-rap.

May 1972: Similar to 1969, except a large delta visible at Denniston Creek, possibly exposed due to low tide. Evidence of some erosion near Broadway, in front of present-day Conference Center. Flow-line observed from Denniston creek mouth out to ocean.

April 1975: Shoreline between Columbia and Broadway eroded back. Creek west of West Point has incised a channel through the beach, probably due to winter run-off. Boat yard constructed. Difficult to determine location of Mean High Water line on photograph. Photograph not used in shoreline analyses.

June 1981: Large deltas visible at Denniston Creek and at mouth of creek west of West Point. Substantial shoreline erosion between Columbia and present-day Conference Center. Continues to erode between Columbia and Broadway.

June 1989: Low tide photo. Delta visible at Denniston Creek, although much smaller than 1981 photo. Bar at mouth of creek west of West Point. Conference Center built, and shoreline appears to have been protected in this location. Parcels to the west continue eroding, with no beach between Columbia and Broadway.

July 1991: No visible changes compared to 1989 photo, except unprotected shoreline between Conference Center and Columbia continues to erode.

August 1993: No significant changes compared from 1991 photo.

September 1995, June 1997: Delta deposits at Denniston creek not visible, appear to have eroded. Little to no beach at Columbia. Photographs taken possibly at high tides.

August 2000: Substantial rip-rap placed west of the Conference Center

The wetted bounds (textural change on the beach, indicating location of mean high water and shoreline) from the aerial photographs were digitized by scaling and orienting the photos using computer-aided rectification techniques. The top of bank for each year was also digitized, to assess changes. Distortions arising from elevation differences and corrections for tides are inherent in aerial photo analysis, and are not accounted for in this analysis.

3.2. SHORELINE CHANGE RATES

The various shorelines are shown on Figure 9, and the top of bank for each year is shown on Figure 10. The data, although approximate, indicate that erosion of up to 15 to 17 inches/year occurred in the area between Romeo and Vassar. The reach between Vassar and Columbia eroded at about 1 foot/year. Near Columbia, little to no beach exists. Observed erosion rates were about 7 inches/yr. The reach between Columbia and Broadway had eroded at about 45 inches/yr between circa 1968 and circa 1983 (Griggs and Savoy, 1985). The shoreline was anchored in the late 1980's by rip-rap, and is approximately at the same location since then except at the segment where rip-rap was used to build out the shoreline west of the Conference Center.

A summary of the shoreline change rates in the study area is presented below. If shoreline improvement plans are not implemented in the study area, it is expected that little to no beach will remain in the near future.

Reach	**Shoreline Retreat** (1969 to 2000)	**Beach Width** (August 2000)
Near Romeo	45 ft (17 in/yr)	10'
Near Vassar	38 ft (15 in/yr)	15'
Vassar to Columbia	31 ft (12 in/yr)	10'
Near Columbia	19 ft (7 in/yr)	5'
Columbia To Broadway	N/A (steep embankment)	0

4. SHORE PROTECTION / PUBLIC ACCESS CONCEPTS

If shoreline improvement plans are not implemented in the study area, it is expected that little to no beach will remain, and the non-engineered rip-rap will require ongoing maintenance to protect the banks from further retreat. Based on discussions with District staff and local residents, and the analyses described in the earlier sections, two alternatives were developed that provide shoreline stabilization as well as incorporate public access along the Princeton shoreline.

4.1. ALTERNATIVE 1 : REVETMENT

Alternative 1 envisions a rock revetment that would be constructed to protect the existing shoreline. The structure would anchor the shoreline at, or very close to, its present location. Figure 11 shows a typical section for the revetment. For construction, the revetment would be placed along the entire shoreline of the study area, tieing back into West Point at the west end and Denniston Creek at the east. The structure would closely follow the existing top of dune between Romeo Pier and Columbia. For the reach between Columbia and Broadway, the revetment would be located along straight segments rather than trying to follow the existing sinuous shoreline. A plan view of the proposed revetment is provided in Figure 12.

The revetment would consist of two layers of 200-pound angular quarry rock, with a geotextile and bedding to prevent erosion of the finer underlying material. The top of the structure would follow existing embankment height which varies from +12 feet at Vassar to about +18 feet near Denniston Creek. Some overtopping would occur during storm activity. The toe of the structure would be buried about 3 to 4 feet below beach elevation to prevent undermining.

The public access concepts developed for Vassar and Broadway by Callandar & Associates would be integrated into the revetment structure. A concrete cut-off wall would be required along both sides of the access ramp at Vassar, and the revetment would abut against the wall. The stairway at Broadway could be timber coming down over the revetment structure, or concrete built into the embankment. The existing beach between Broadway and Columbia is below tide levels; there is no existing continuous access on the beach. Therefore, at Broadway, lateral public access would be limited to the delta at Denniston Creek. Although this alternative would improve public access to the beach, material may continue to erode, lowering the beach to below high tide levels.

If the existing Romeo Pier is replaced with a new pier supporting public access, an additional stairway from the new pier to the beach could be constructed at the Vassar end to improve pedestrian traffic flow.

Construction costs are estimated to be about $200 per linear foot, assuming that some rock is available for reuse from the rip-rap near the Conference Center. Total project costs, including contingencies and engineering, are estimated to be about $400,000 for the reach from West Point to Broadway/Denniston Creek.

4.2. ALTERNATIVE 2: REVETMENT WITH BEACH FILL

Alternative 2 includes a revetment structure similar to Alternative 1, with a beach fill in front of it as presented in Figure 13. The perched beach would be designed to be above high tide levels to provide enhanced public access along the shoreline. Since the beach fill would continue eroding as described in the wave analysis section, a geotube would be located at the seaward edge of the fill in order to minimize losses and to stabilize the fill. Geotubes are large-diameter tubes (10 to 12 feet diameter) fabricated from geotextile material. They are usually filled hydraulically with a sand-water slurry. Water flows out the exit ports at the opposite end of the tube as it is filled. The geotube would also be placed at each end of the fill in order to contain the fill during placement. The geotube would be located along the right-of-way for Ocean Boulevard as shown on Figure 14.

Two sources of possible fill material were identified for the beach fill. The proposed channel improvements by the U.S. Army Corps of Engineers and Harbor District to the new Pier would provide approximately 19,500 cubic yards of sandy material. Additional material, if determined to be suitable for geotube fill, could also be utilized. This alternative was developed after giving due consideration to the potentially available material and volume.

Due to the relatively thin lens of sand that is available at the proposed channel location (about 2 feet), a hydraulic dredge is preferred over mechanical methods. The hydraulic dredge would pick up the material and pump it ashore to the area behind the geotubes. Some amount of fine material would exist in the pumped slurry, that will have to be removed. Some amount of fine material could also be used within the geo-tube.

A second source of material is the Pilarcitos Quarry in Half Moon Bay. Although the cost would be significantly higher than the reuse of the dredged material, the sand could be trucked to the site and placed with conventional construction equipment.

A beach fill often requires replenishment due to losses from wind and waves. Maintenance intervals will be dependent on the actual material used. The use of coarser material would extend the period of time between maintenance fills. We recommend using a coarser sand material for the top 1 to 2 feet of the beach fill.

The public access concepts would be similar to that described above in Alternative 1. The ramp or stairs for access would extend below the beach elevation so that fluctuations in the beach level would not prohibit access.

We have assumed some cost savings would be realized from a coincident channel improvement and a beach fill project. Assuming that the fill material in the geotubes and the beach fill are from the channel dredging project, construction costs to place the material would be approximately $75 per linear foot for the geotube and $100 per linear foot for the beach fill. The revetment costs would be similar to Alternative 1 ($200 per linear foot). Total project costs are anticipated to be about $700,000 including contingencies and engineering.

5.0 FINDINGS AND RECOMMENDATIONS

The Princeton shoreline is exposed to waves that are locally wind-generated and transmitted through the Harbor entrance. The wave energy has eroded the fine sandy material that comprises the native shoreline. Because the reach of shoreline for the study area is located within the protected Pillar Point Harbor, littoral and offshore material that once supplied sand to the beach is no longer available to the system.

Shoreline erosion rates determined from aerial photographs are estimated to range from 15 inches per year near Vassar, to 7 inches per year at Columbia. The beach would continue eroding if protection measures are not implemented, and the banks would continue to require maintenance.

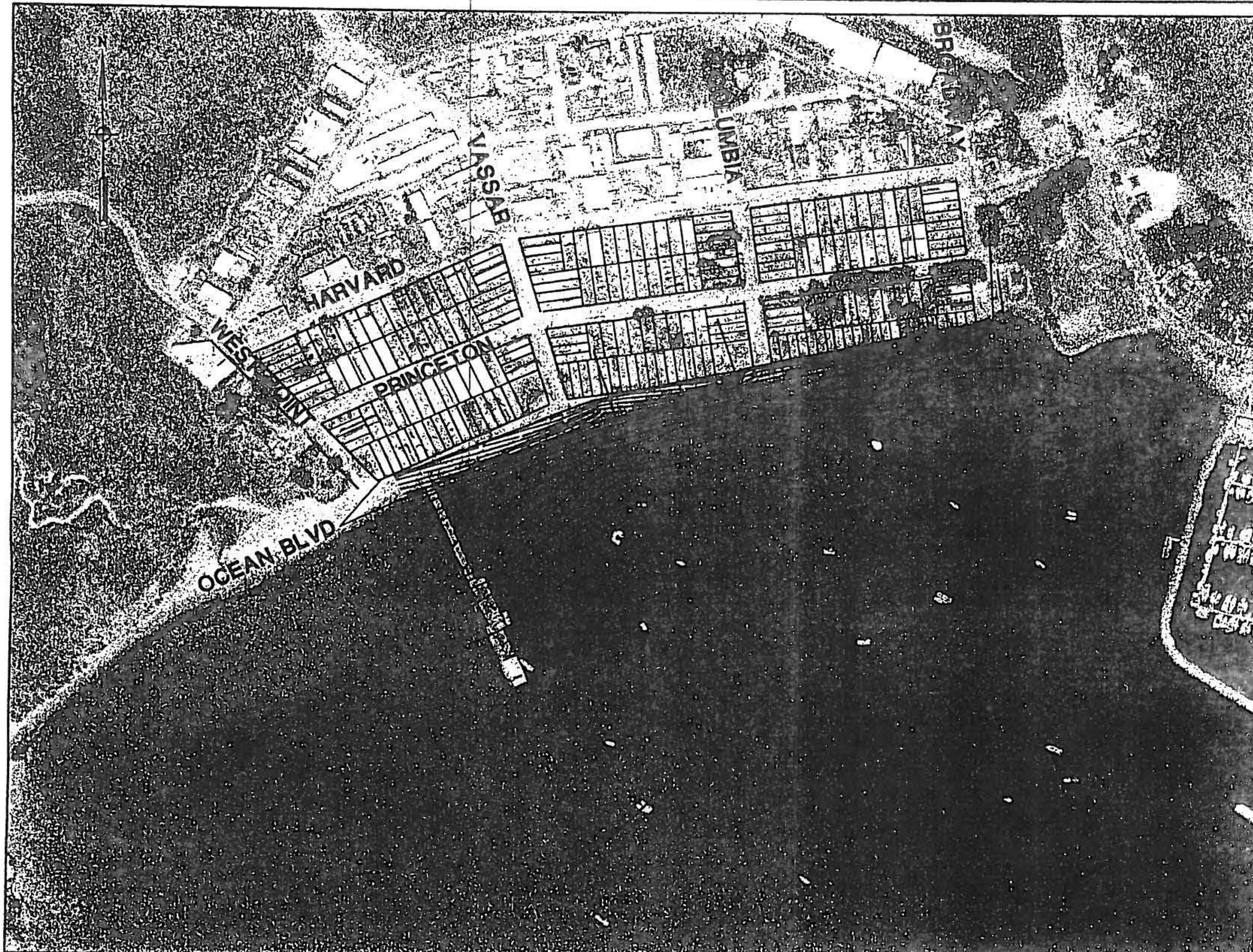
Much of the existing shoreline has already been armored with rock and concrete rubble that has been randomly dumped. In order to provide shore protection for the entire reach, a consistent solution should be implemented. It is recommended that as a minimum, a revetment structure should be constructed to anchor the shoreline at its present location. Improvements for public access to the beach can be accomplished at Broadway and Vassar, recognizing that limitations exist for lateral public access on the beach near Broadway.

If the existing Romeo Pier is to be replaced with a new pier supporting commercial fishing, public access, and other revenue generating uses, opportunities exist for enhanced public access along the Princeton shoreline. Coarse dredged material from the proposed channel could be pumped to the beach to increase beach width. Preliminary sediment grain size analysis indicate that about 20,000 cubic yards of sandy material could be available from the channel deepening. The beach fill alternative (Alternative 2) described in this report was developed after considering this available quantity.

We recommend that the District pursue Alternative 2, which would accomplish both the shore protection and public access goals. Additional opportunities may arise as part of the New Pier Feasibility Study, with respect to enhanced public uses in the area, which should be integrated with the shoreline planning process.

REFERENCES

1. Applied Earth Sciences Consultants, A Bank Retreat Investigation, prepared for Christian Mickelsen, April 1999.
2. Callander & Associates, June 2001, Public Access Improvements, Five Coastal Sites, prepared for County of San Mateo.
3. County of San Mateo, Local Coastal Program, Policies document, June 1998.
4. Department of Water Resources, Wind In California, Bulletin No. 185, January 1978.
5. Kenneth Lajoie and Scott Mathieson, San Francisco to Ano Nuevo, Living With The California Coast, Gary Griggs and Lauret Savoy, editors, Sponsored by the National Audubon Society, Duke University Press, 1985.
6. Pacific Gas & Electric Company, Extreme Winds In Northern And Central California, Meteorology Services, Jan 1990.
7. Treadwell & Rollo, Draft Geotechnical Investigation , Pillar Point Harbor Deepening Project, prepared for San Mateo County Harbor District, Dec 1997.
8. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Shore Protection Manual, 1984.
9. U.S. Army Corps of Engineers, San Francisco District, Pillar Point Harbor, San Mateo County, California, Reconnaissance Report, March 1996.



LEGEND

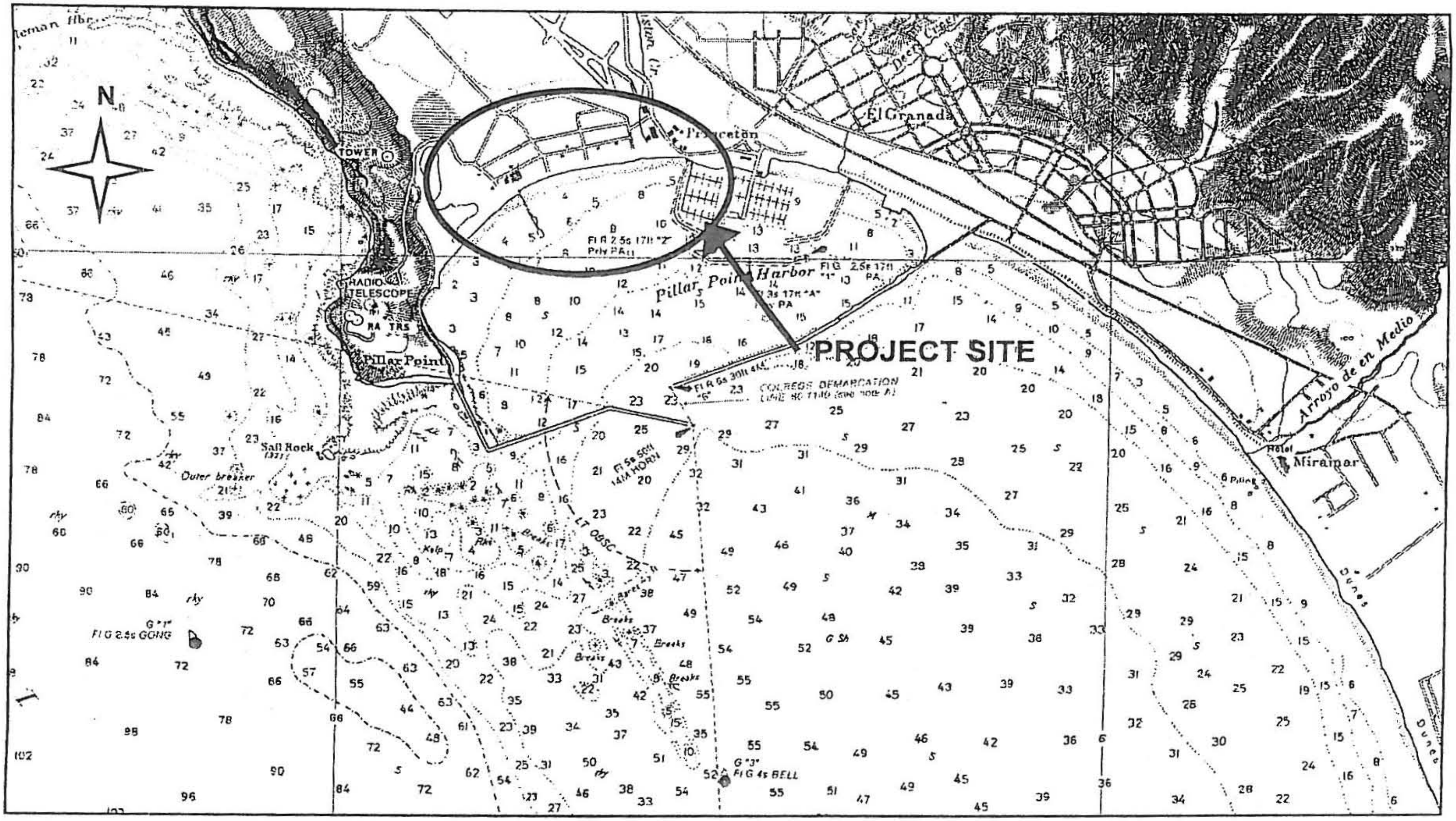
(A) RANGE LINE SURVEYED (7/01) SEE FIGURE 3

SITE PLAN (1"=400')

NOTES:
1. CONTOURS ARE SHOWN BASED ON SURVEY CONDUCTED BY TUCKER & ASSOCIATES (JULY 2001).
2. DEPTHS ARE BASED ON FEET MLLW DATUM.
3. PARCEL BOUNDARIES ARE APPROXIMATE.

MOFFATT & NICHOL ENGINEERS

FIGURE 3

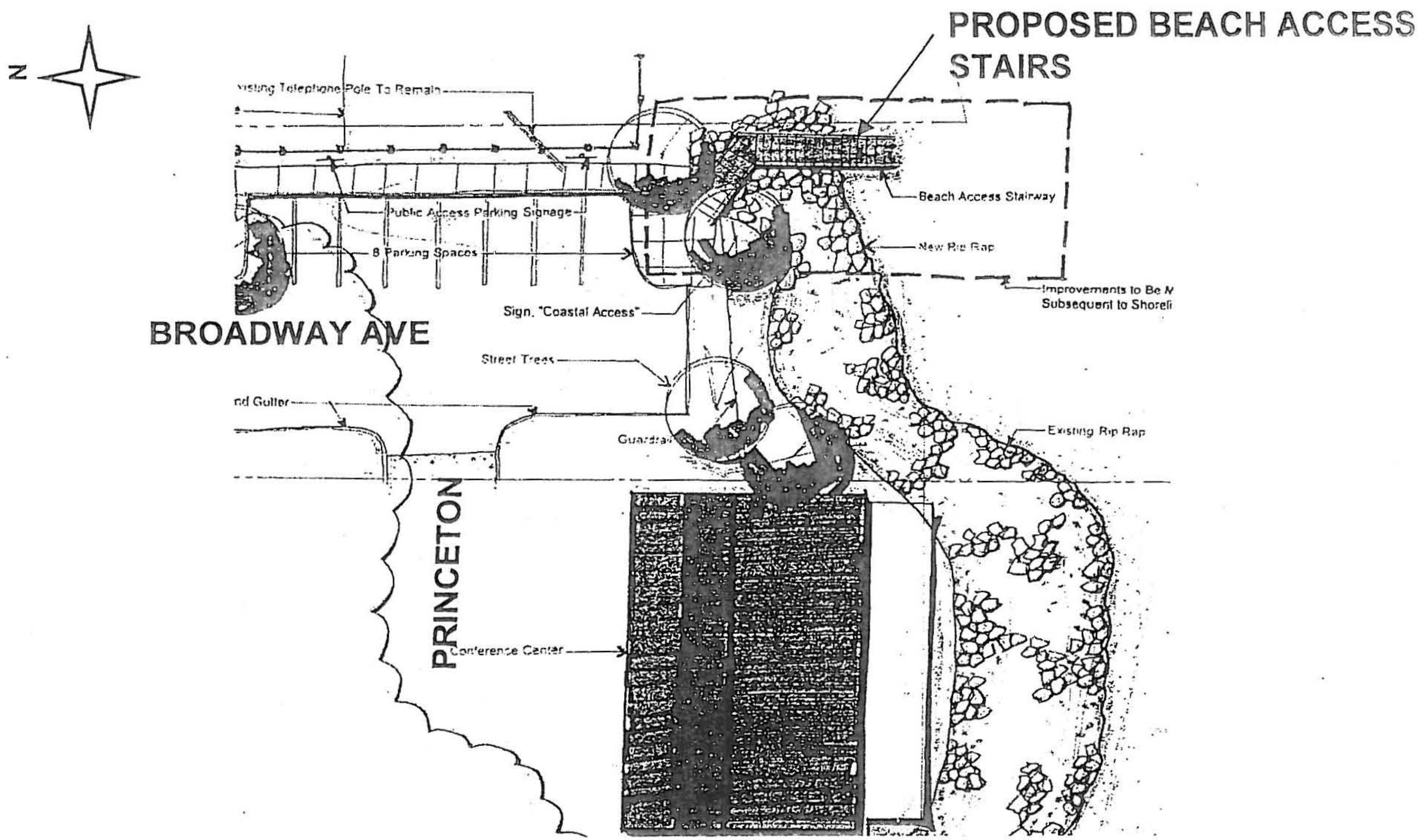


VICINITY MAP

RCE: NOS, NOAA HYDROGRAPHIC NAVIATION CHART, NO. 18682 (APPROX. SCALE 1" = 9700')

MOFFATT & NICHOL
ENGINEERS

FIGURE1

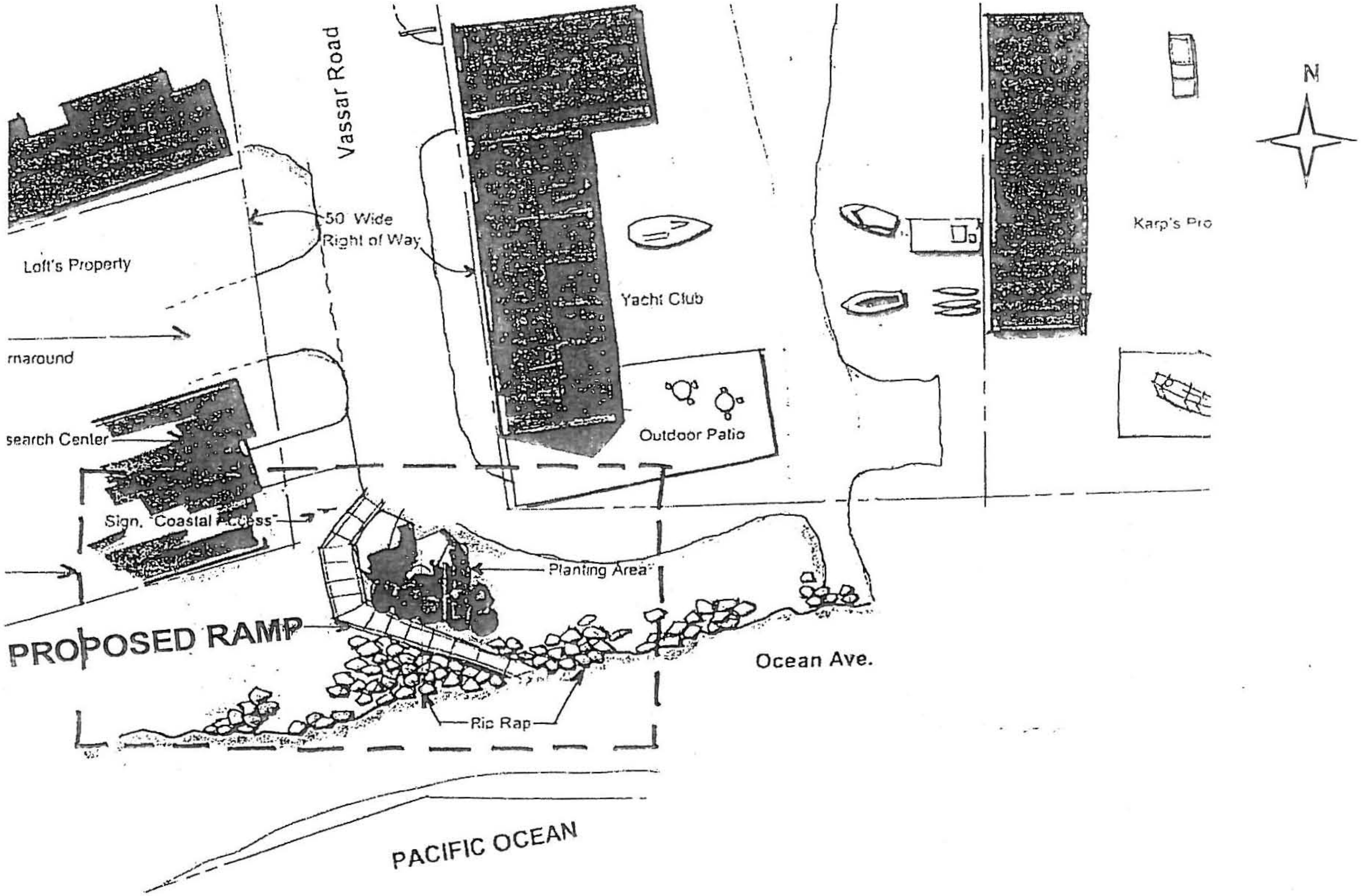


PUBLIC ACCESS PLAN AT BROADWAY

SOURCE: CALLANDAR & ASSOCIATES (APRIL 2001)

MOFFATT & NICHOL
ENGINEERS

FIGURE 5

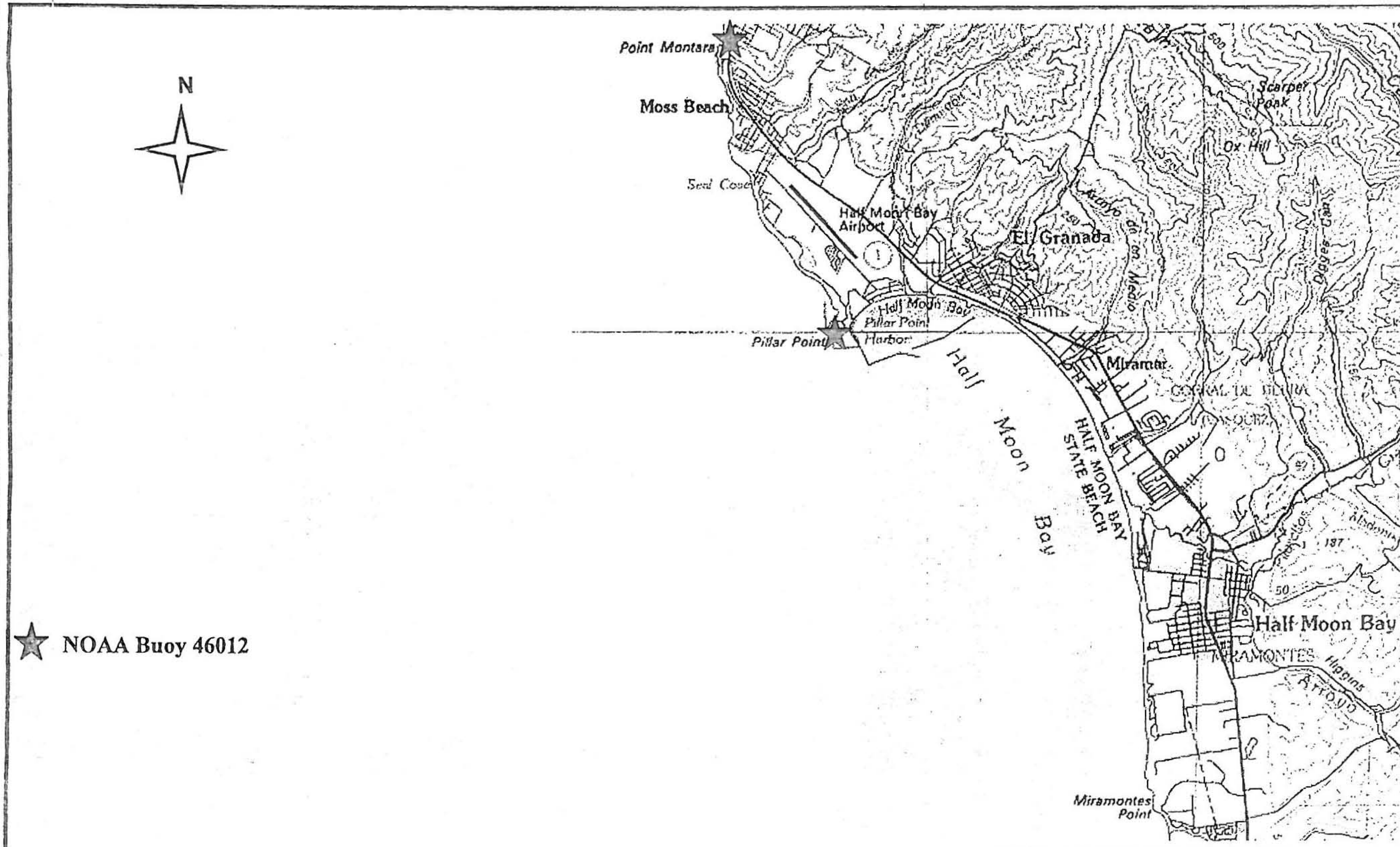


PUBLIC ACCESS PLAN AT VASSAR

MOFFATT & NICHOL ENGINEERS

FIGURE 6

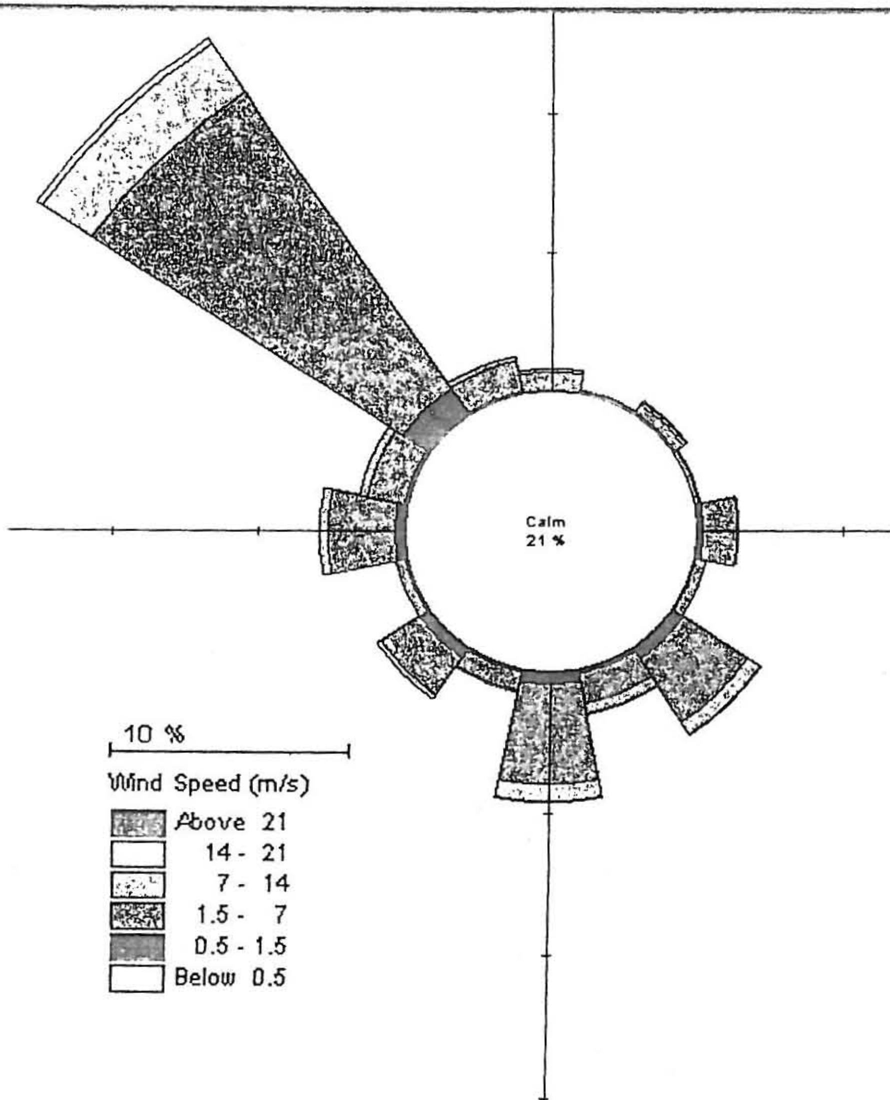
SOURCE: CALLANDAR & ASSOCIATES (APRIL 2001)



LOCATION MAP OF WIND STATIONS

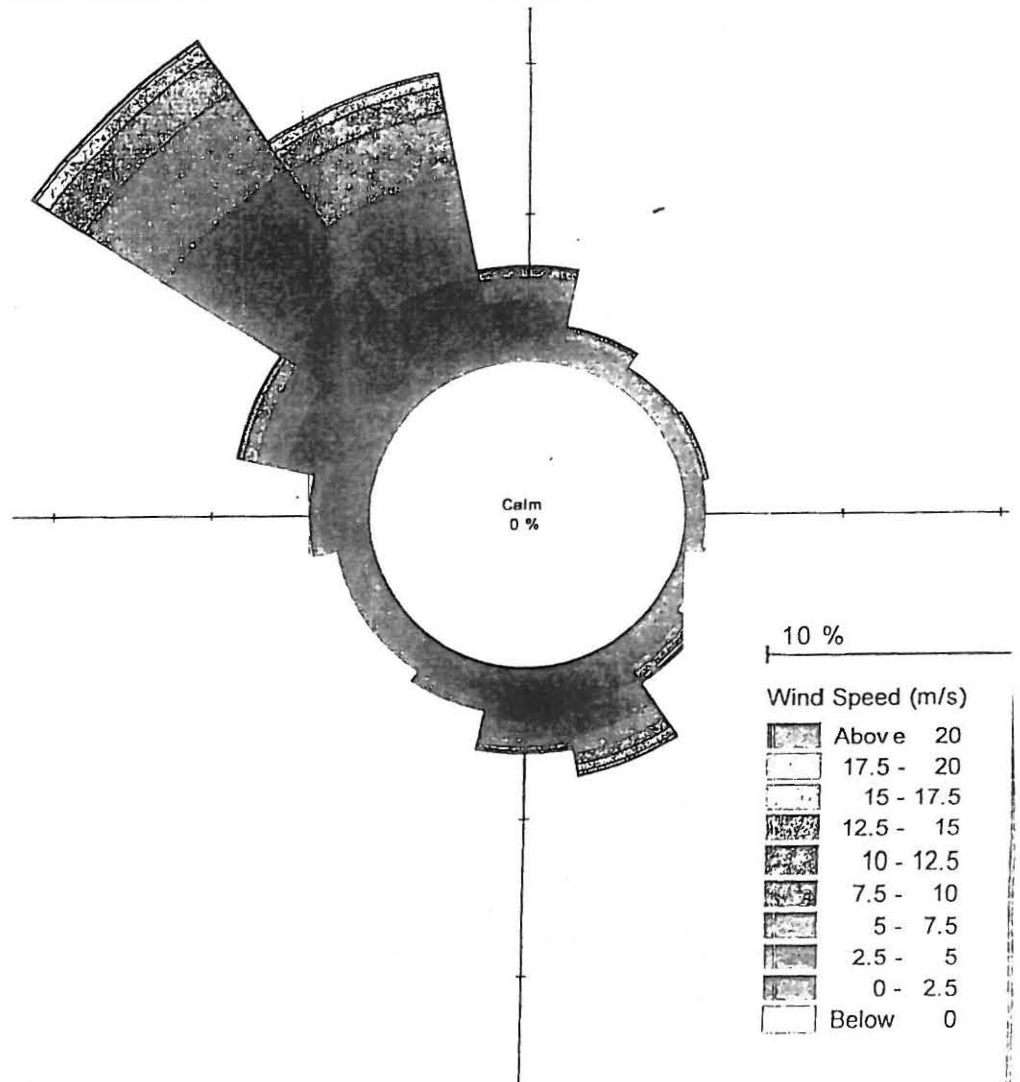
MOFFATT & NICHOL ENGINEERS

FIGURE 7



WIND ROSE AT POINT MONTARA

(RECORDING PERIOD: 1938-1941)

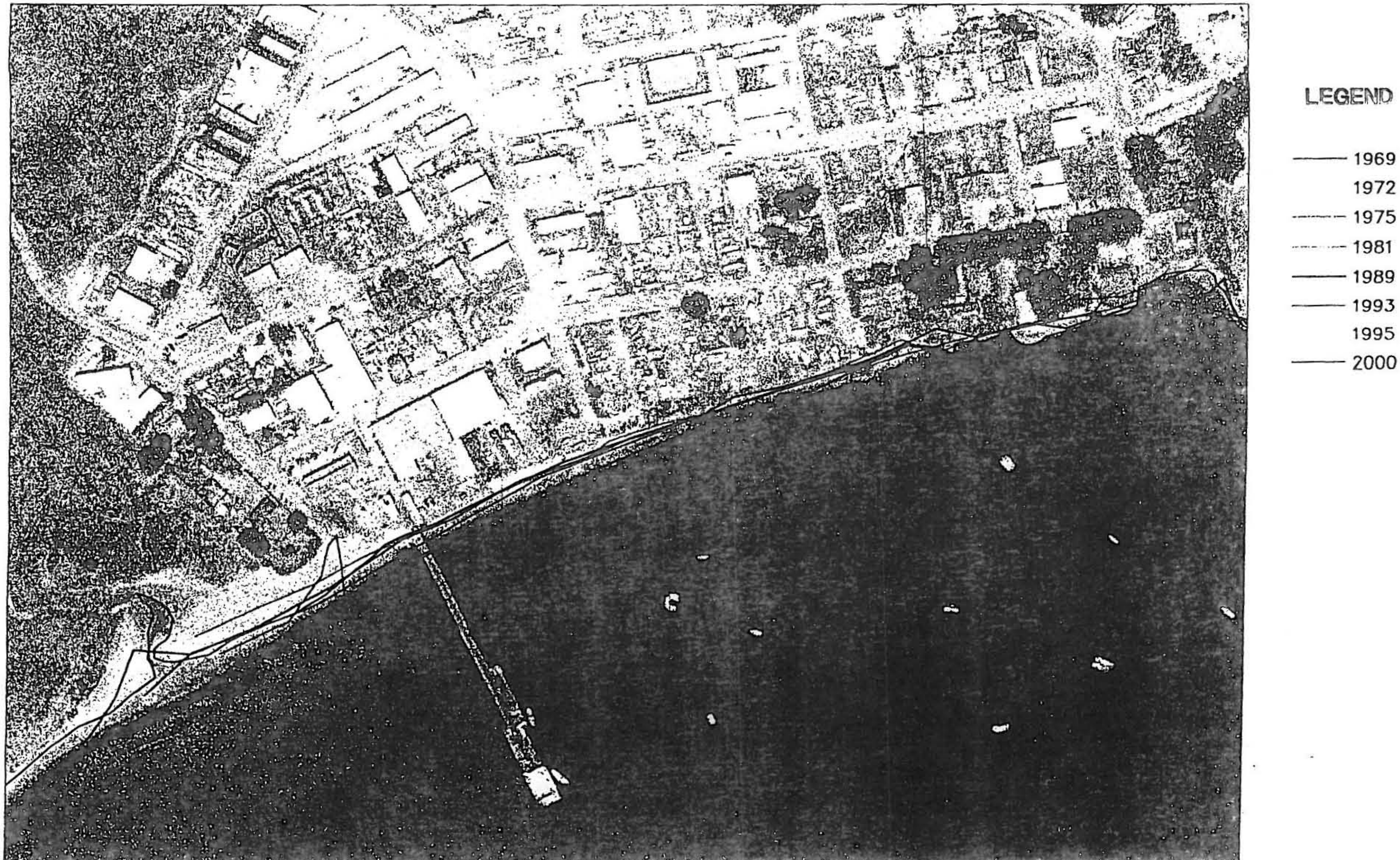


WIND ROSE AT NOAA BUOY 46012

(RECORDING PERIOD: 1980-2000)

MOFFATT & NICHOL ENGINEERS

FIGURE 8

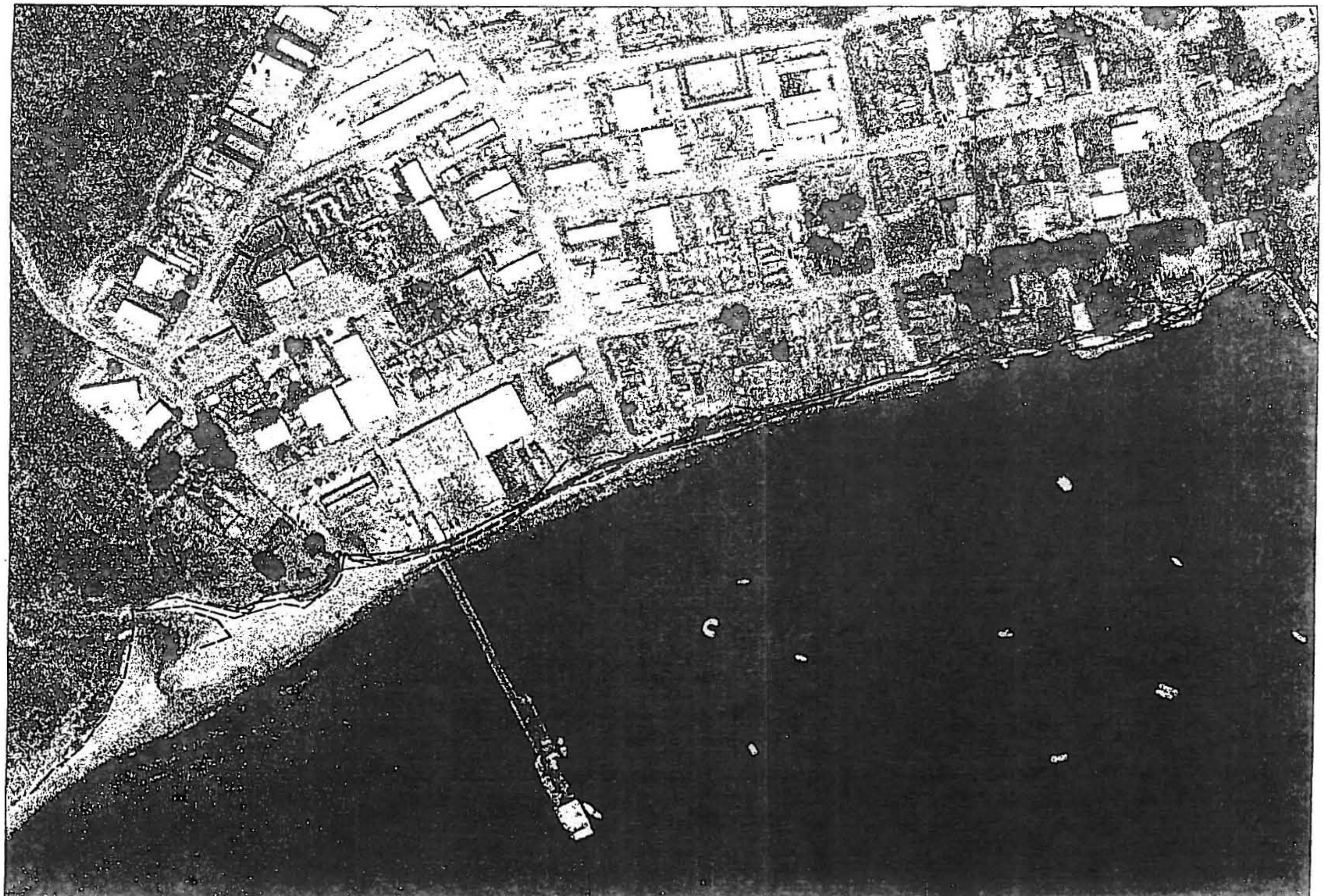


HISTORIC SHORELINES ANALYSIS USING AERIAL PHOTOGRAPHS
(SCALE: 1" = 300')

MOFFATT & NICHOL ENGINEERS

FIGURE 9

NOTE: LINES INDICATE WETTED BOUND (APPROXIMATELY MEAN HIGH WATER LINE) FOR EACH YEAR

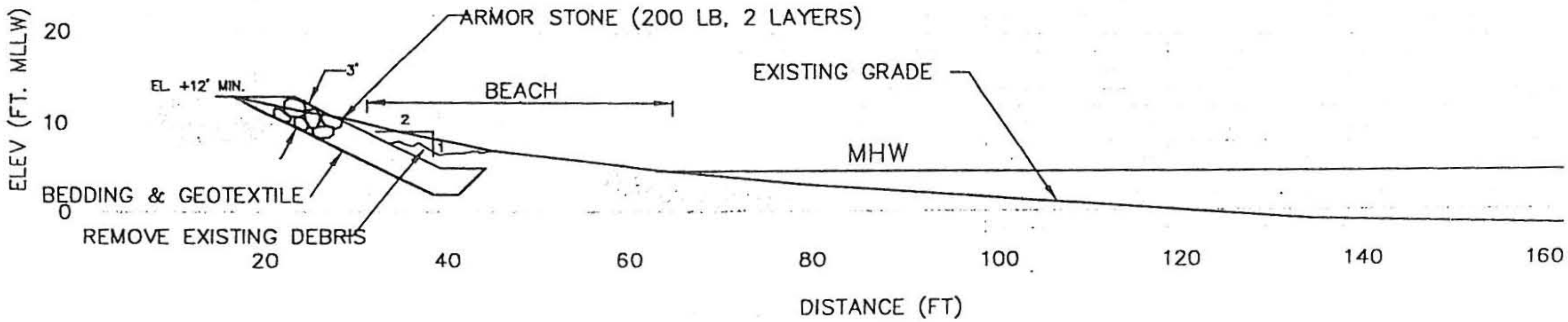


HISTORIC BANK RETREAT ANALYSIS USING AERIAL PHOTOGRAPHS
(SCALE: 1" = 300')

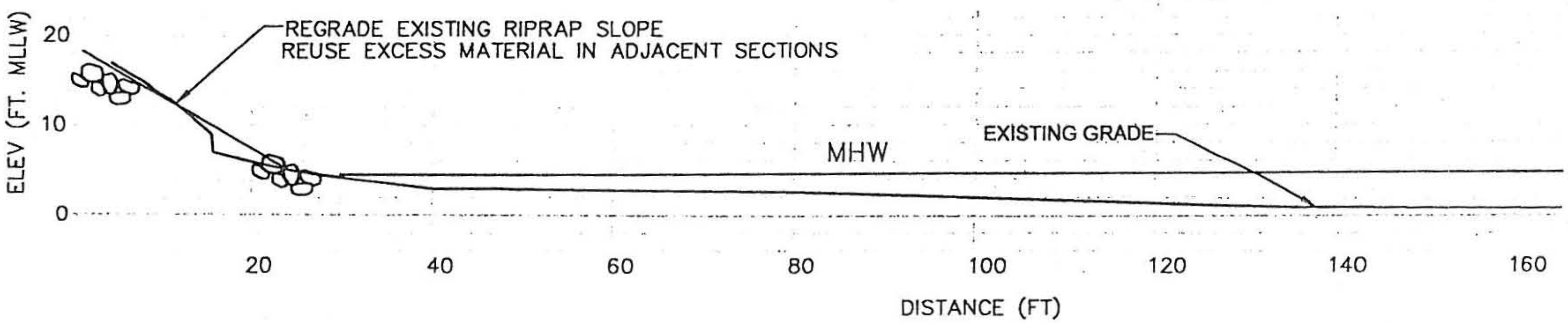
MOFFATT & NICHOL
ENGINEERS

FIGURE 10

NOTE: LINES INDICATE VEGETATION LIMITS ALONG TOP OF BANK FOR EACH YEAR



NEAR VASSAR



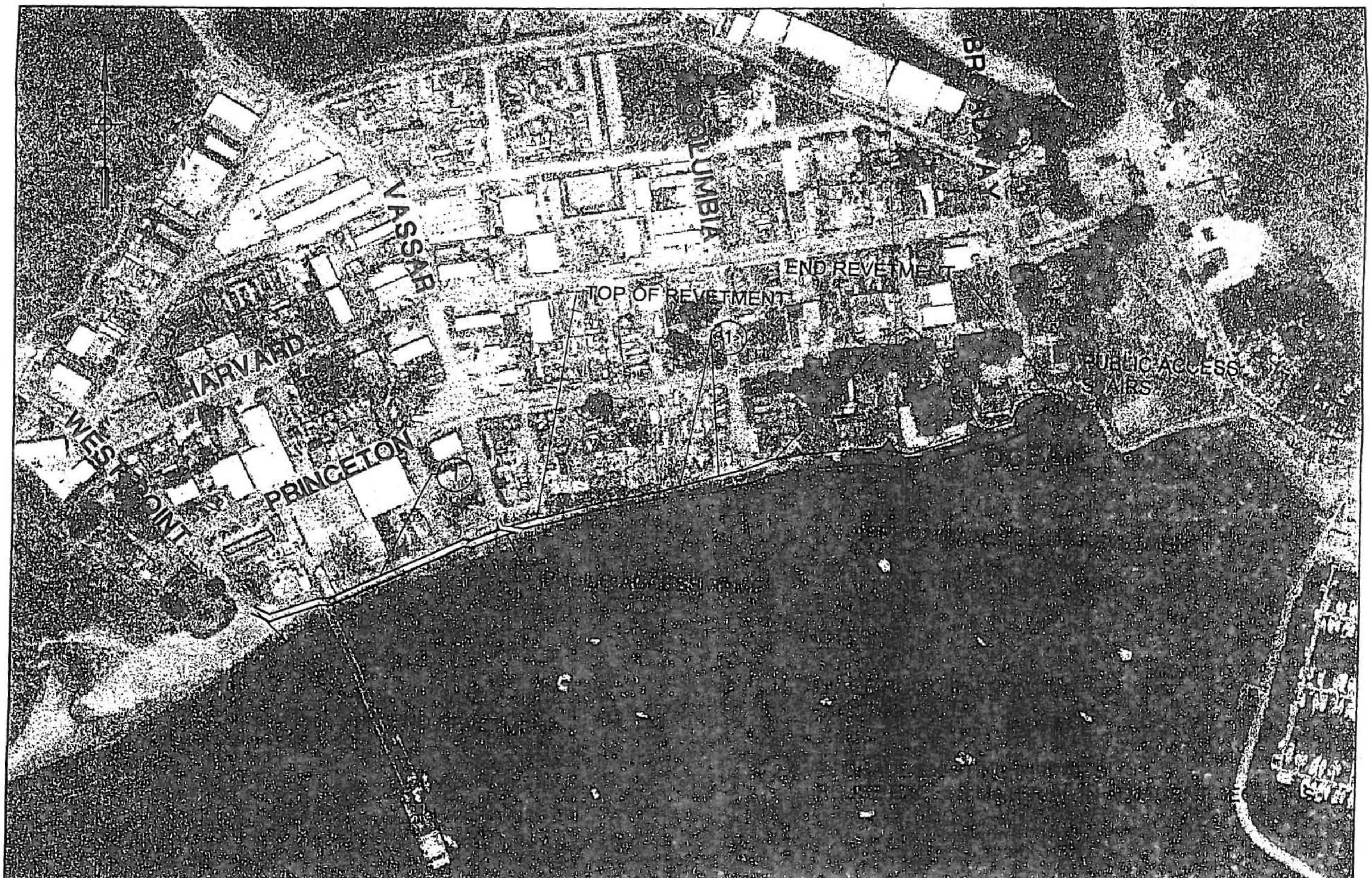
BETWEEN COLUMBIA AND BROADWAY

ALTERNATIVE 1: REVETMENT ONLY
SCALE: 1" = 20'

MOFFATT & NICHOL
ENGINEERS

FIGURE 11

P:\4852\DWG\SITEPLAN.DWG



ALTERNATIVE 1 - PLAN (1"= 300')

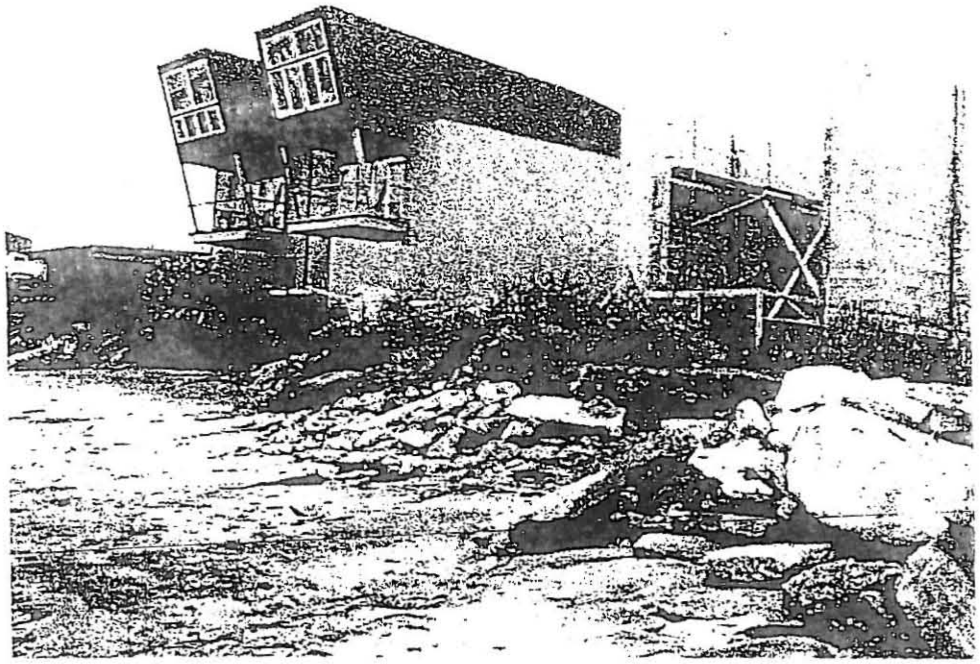
MOFFATT & NICHOL ENGINEERS

FIGURE 12

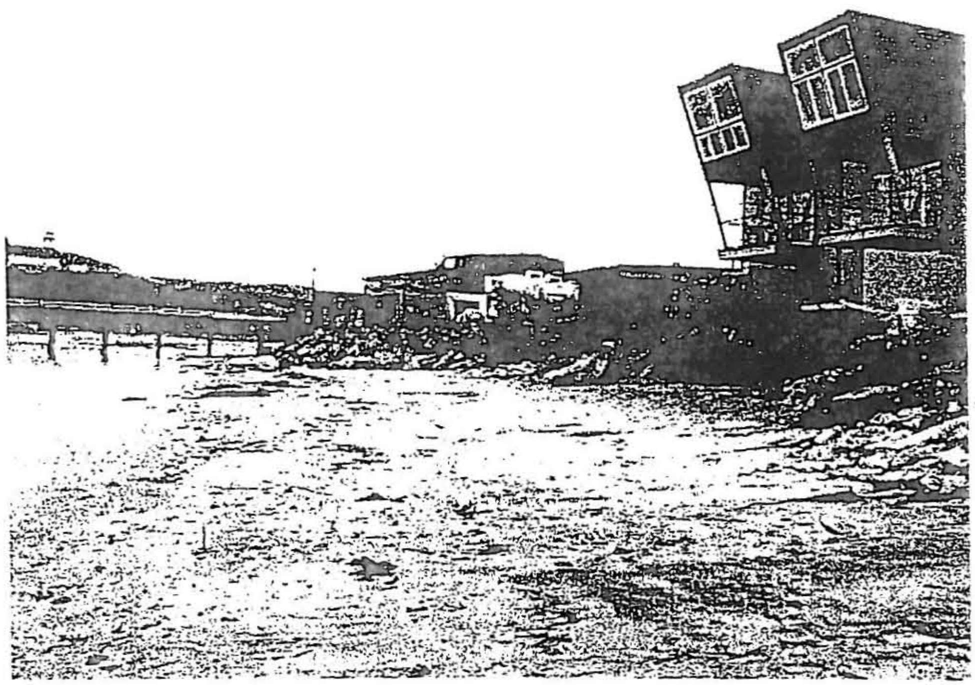
APPENDIX A

Photographs From Site Visits
(September 23, 2001 – Approx. Mean Tide Level)

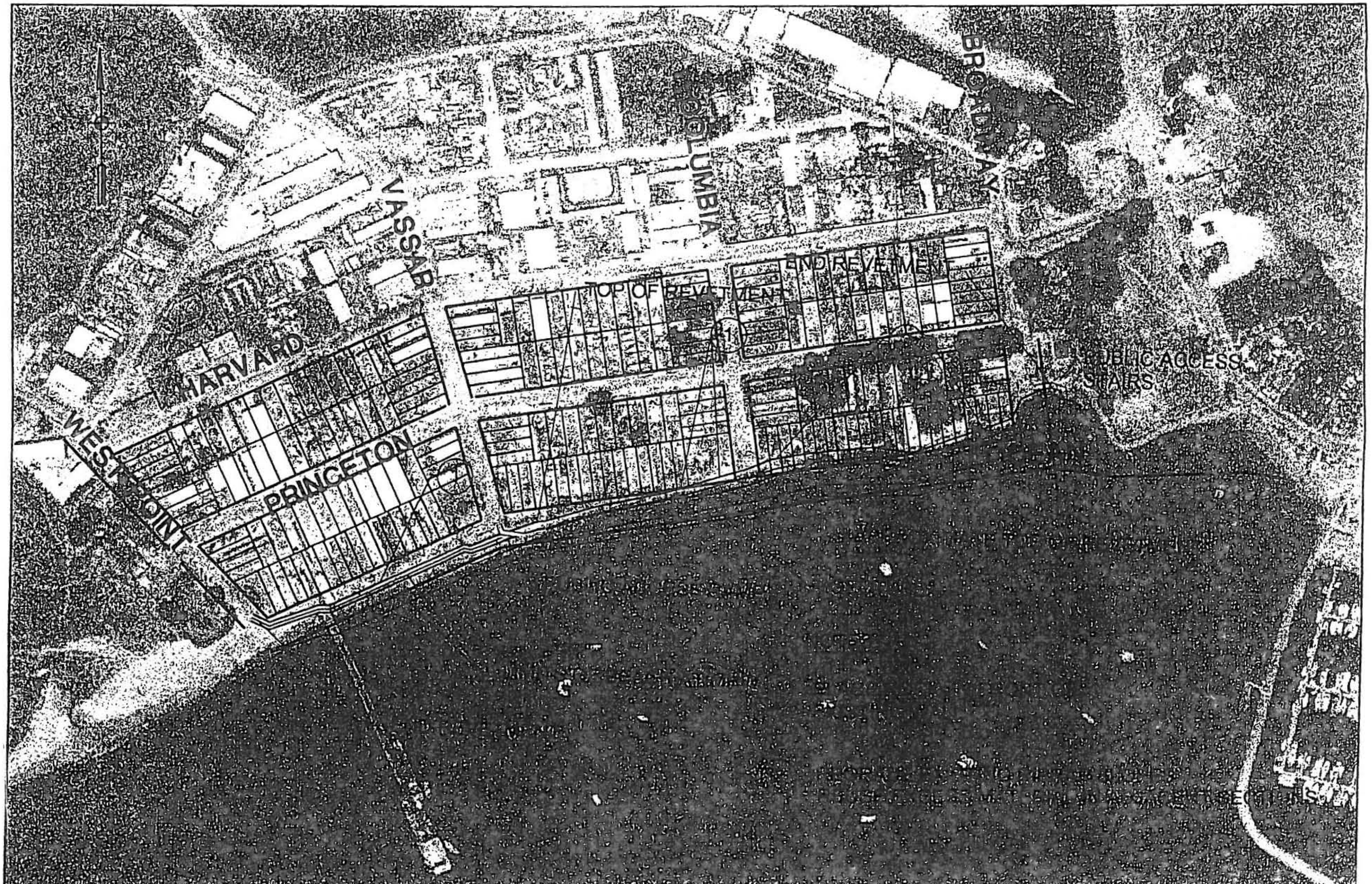
Plate A2



Approx. 200' West of Vassar



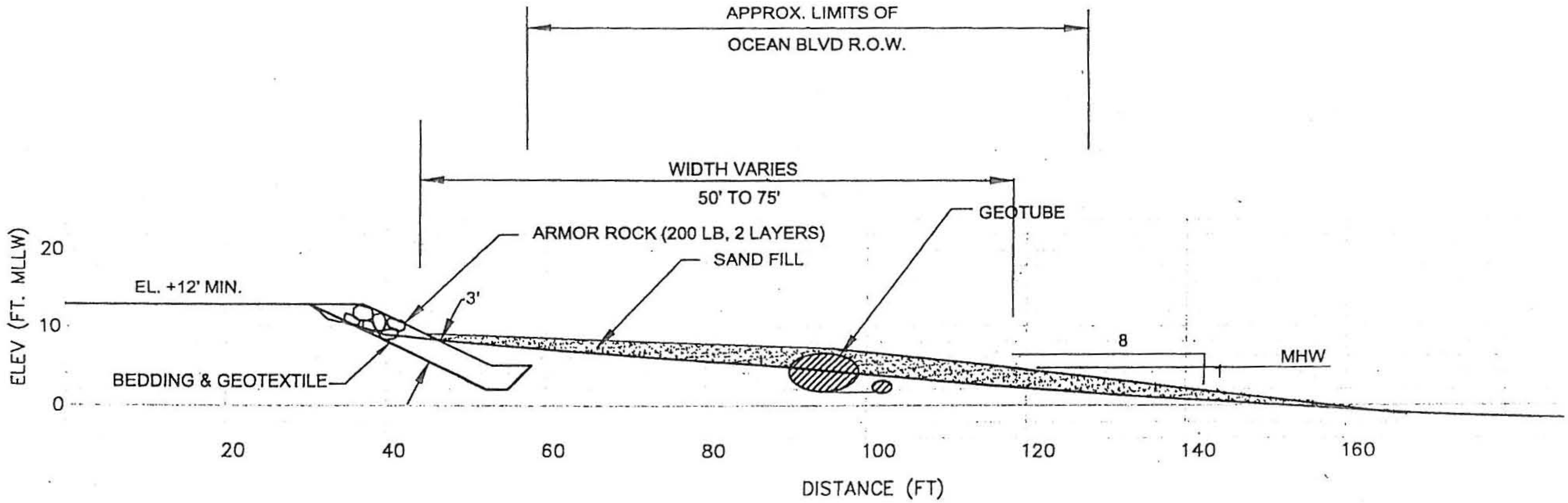
Approx. 200' West of Vassar



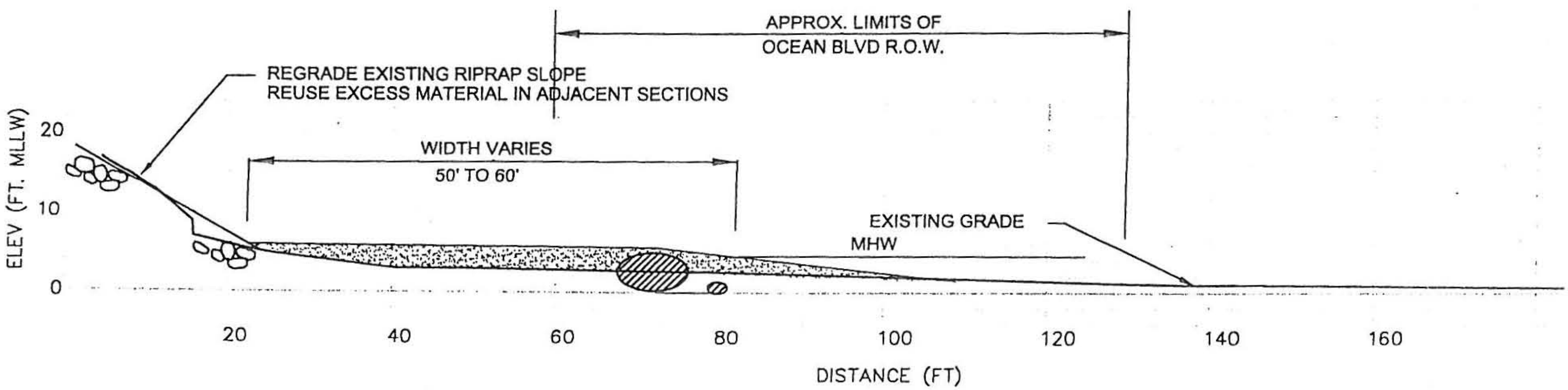
ALTERNATIVE 2 - PLAN (1"= 300')

MOFFATT & NICHOL ENGINEERS

FIGURE 14



NEAR VASSAR



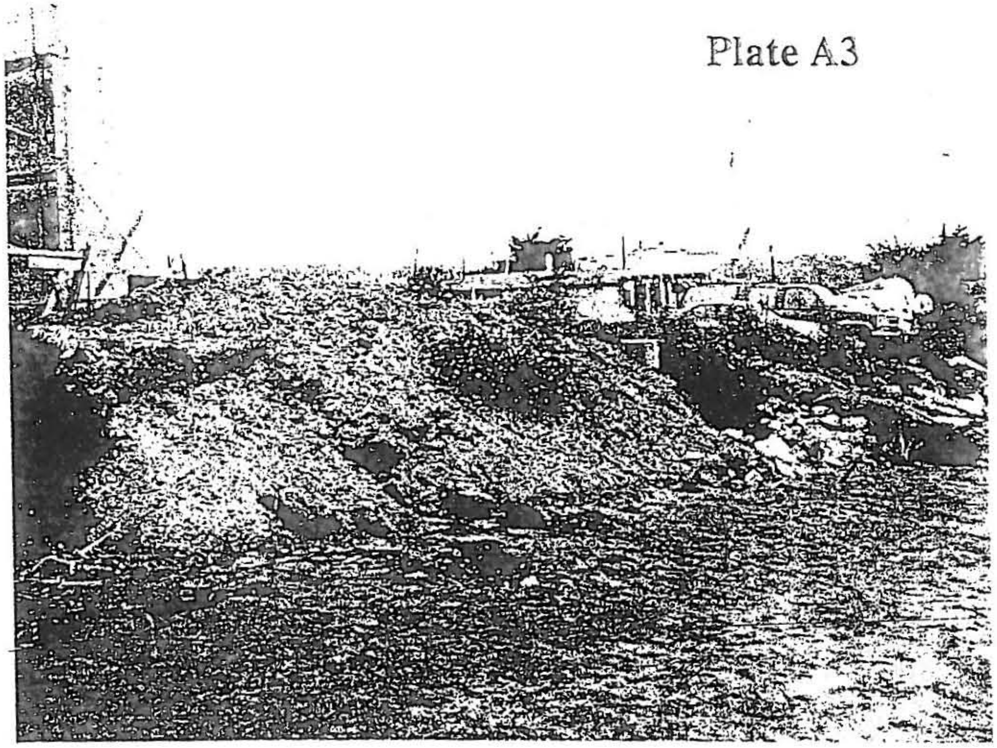
NEAR BROADWAY

ALTERNATIVE 2: REVETMENT AND BEACH FILL

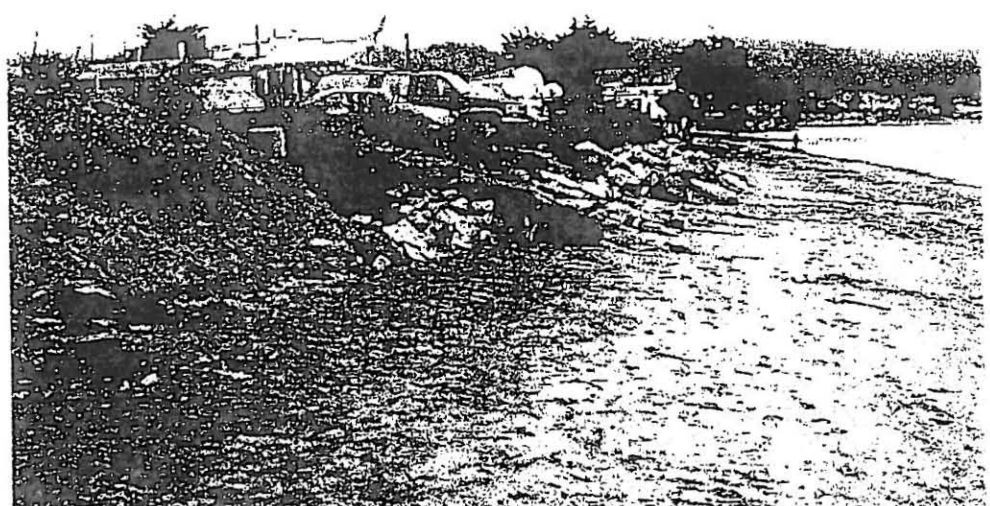
MOFFATT & NICHOL ENGINEERS

FIGURE 13

Plate A3



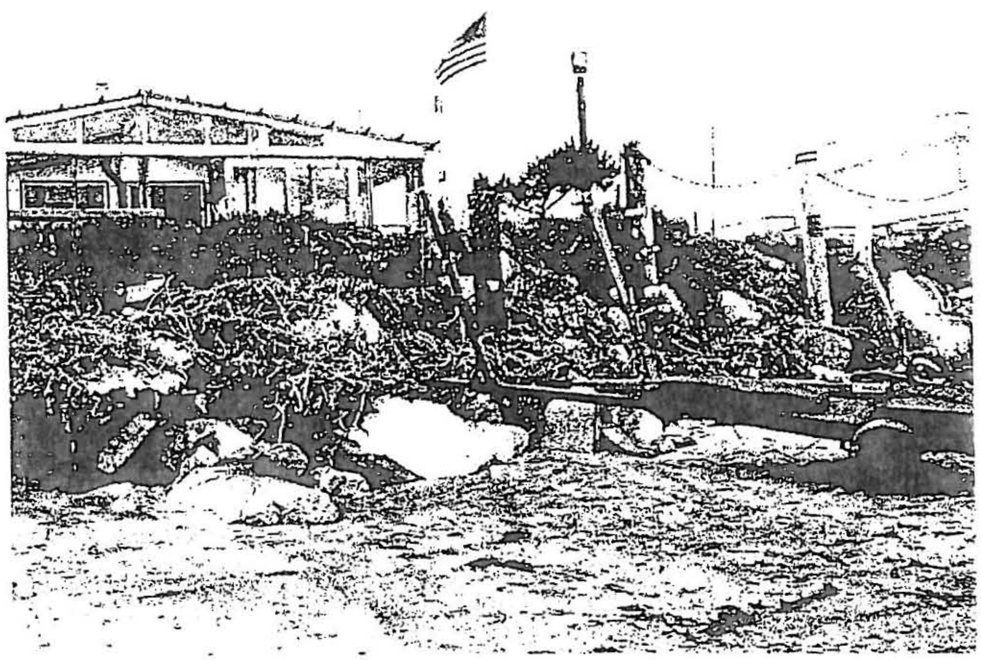
Exposed Bank (approx. 200' west of Vassar)



Rubble at end of Vassar

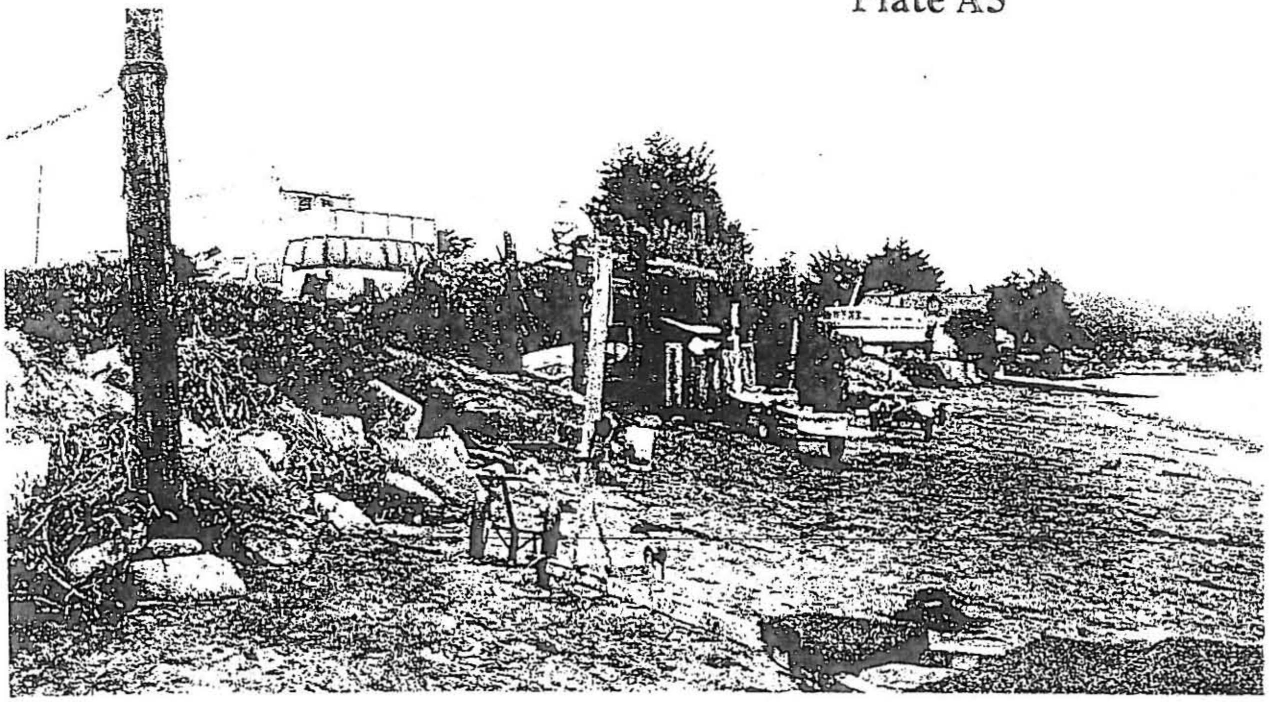
Plate A4

Storm Drain Outlet at Vassar

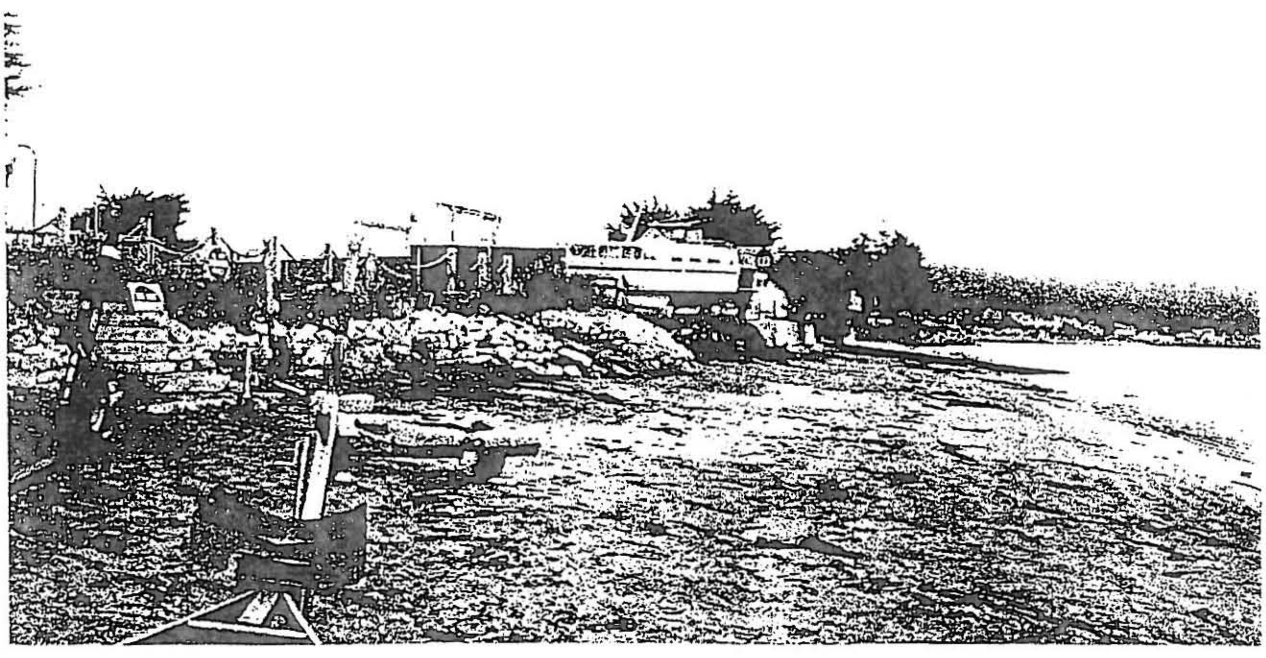


Near Yacht Club

Plate A5



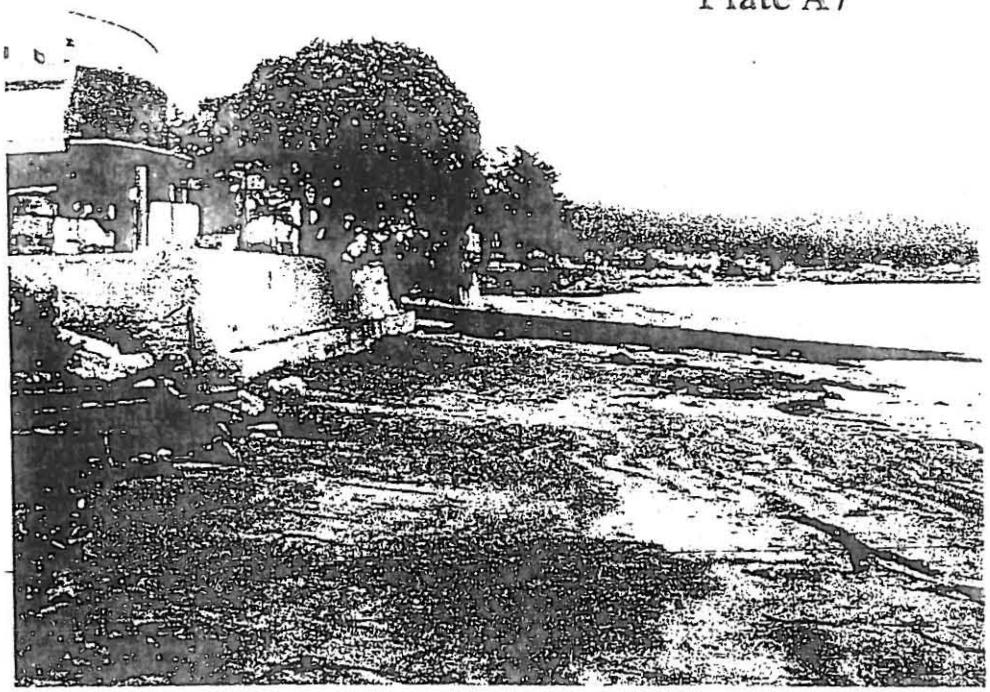
Near Yacht Club, East of Vassar



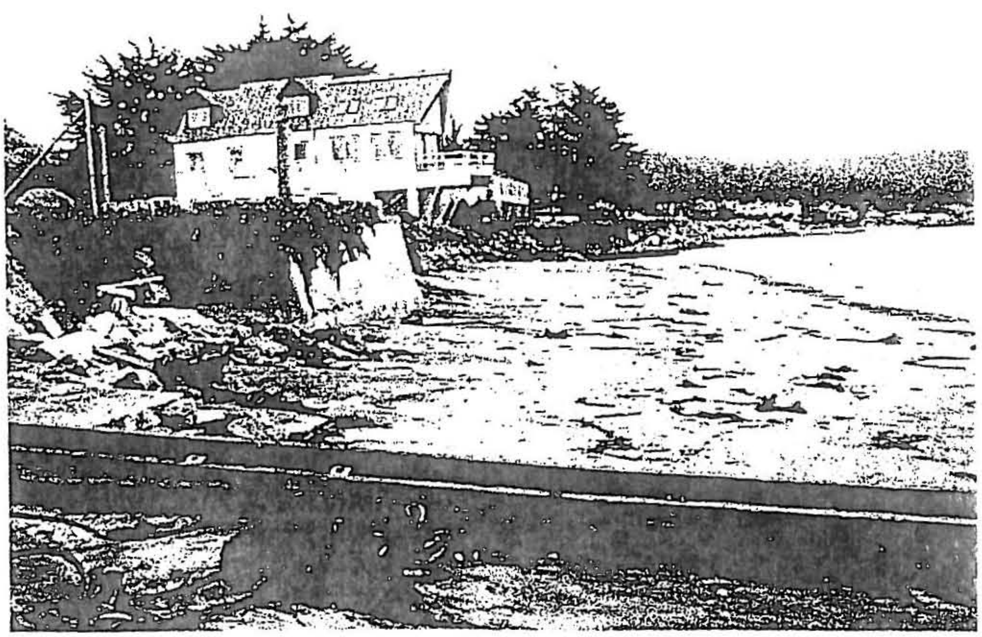
East of Boat Yard

West of Boat Yard

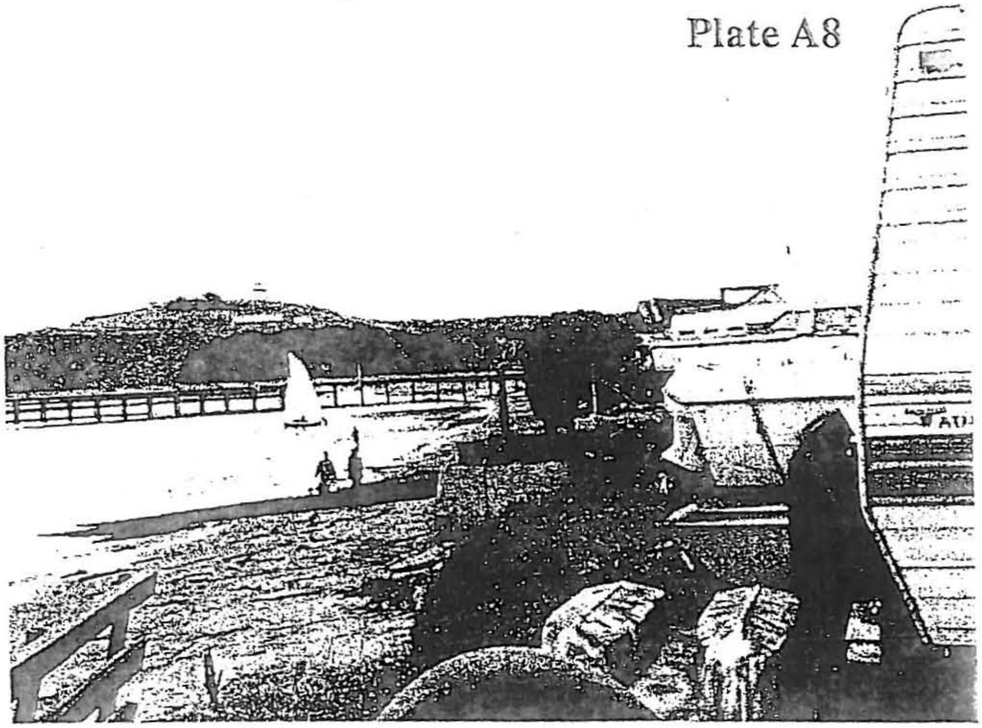
West of Boat Yard



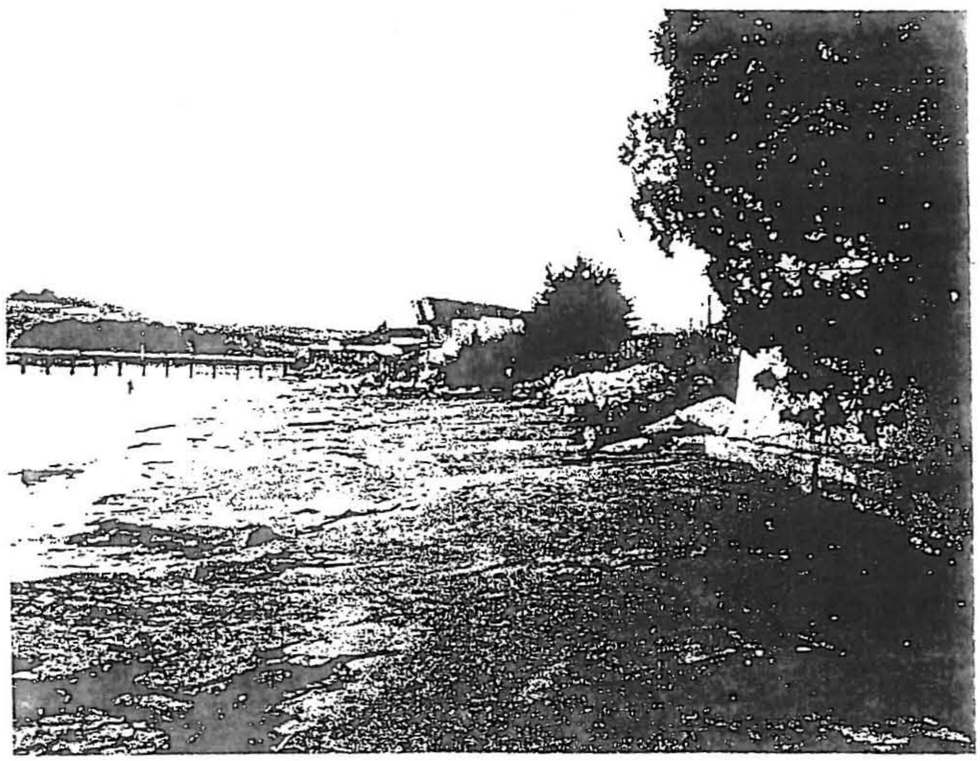
Wall in front of boat yard



Marine railway for boat yard



From atop dune at end of Broadway.
Marine railways visible in background

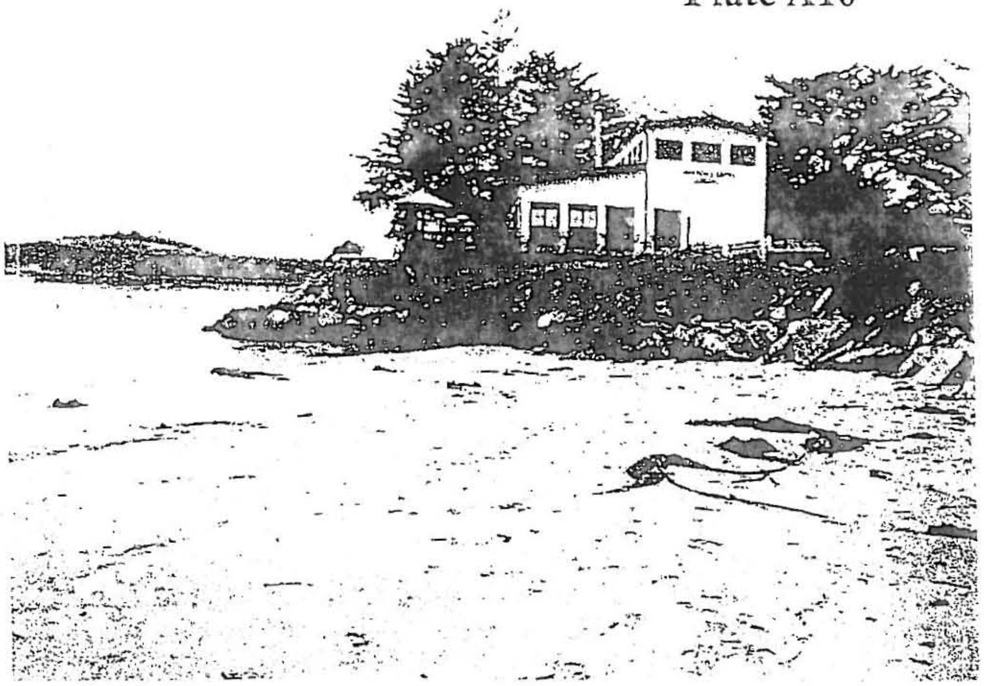


Looking west from marine railway

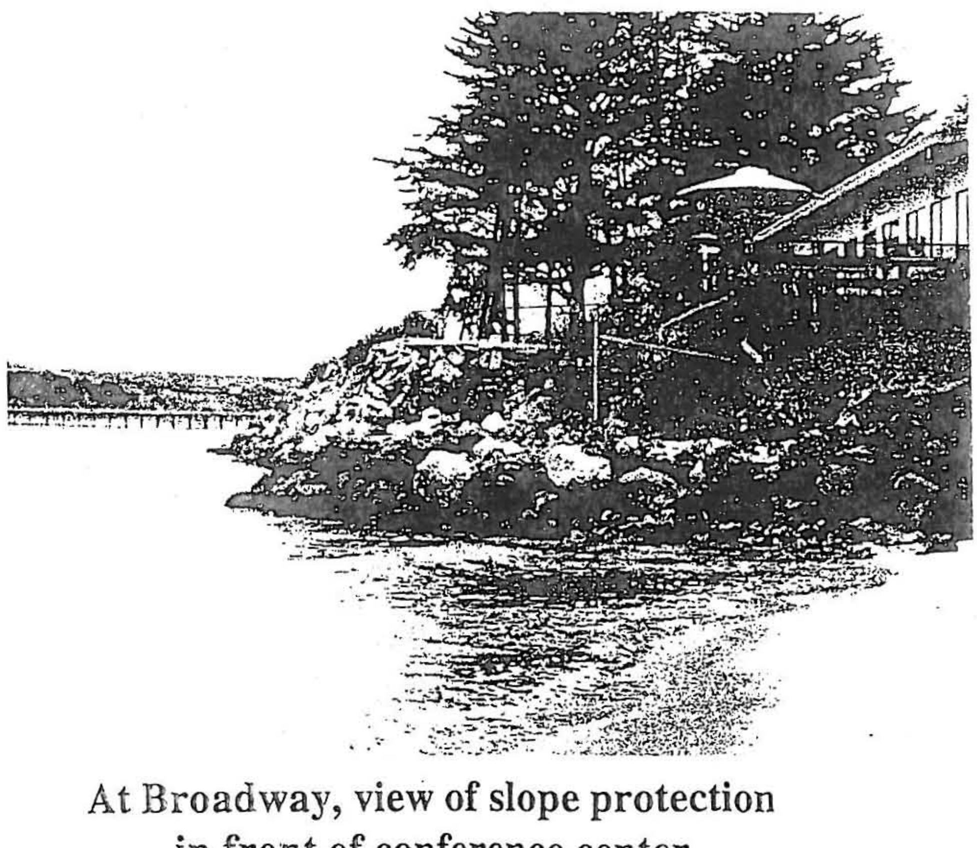
Plate A9

At Broadway, looking east

Denniston Creek, looking upstream



At Broadway, looking west.
Conference Center visible

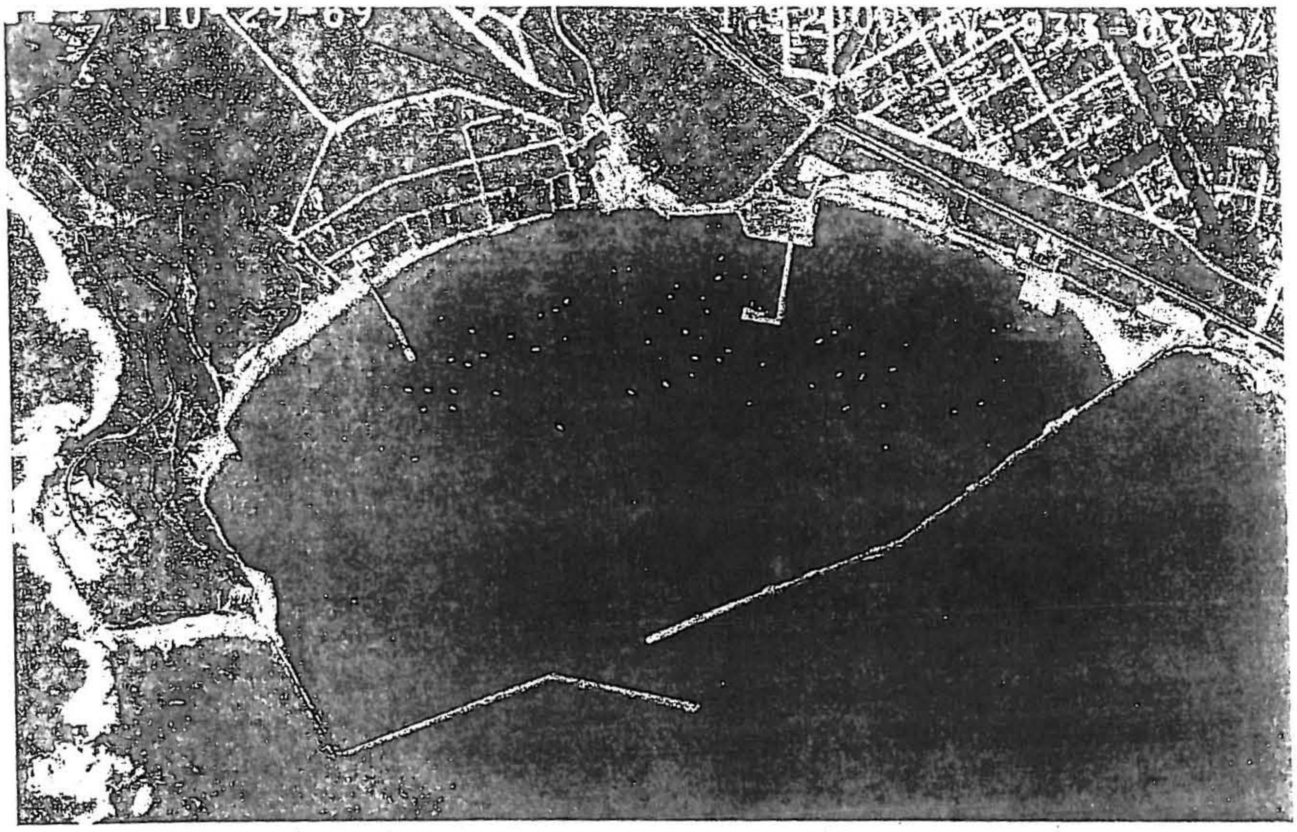


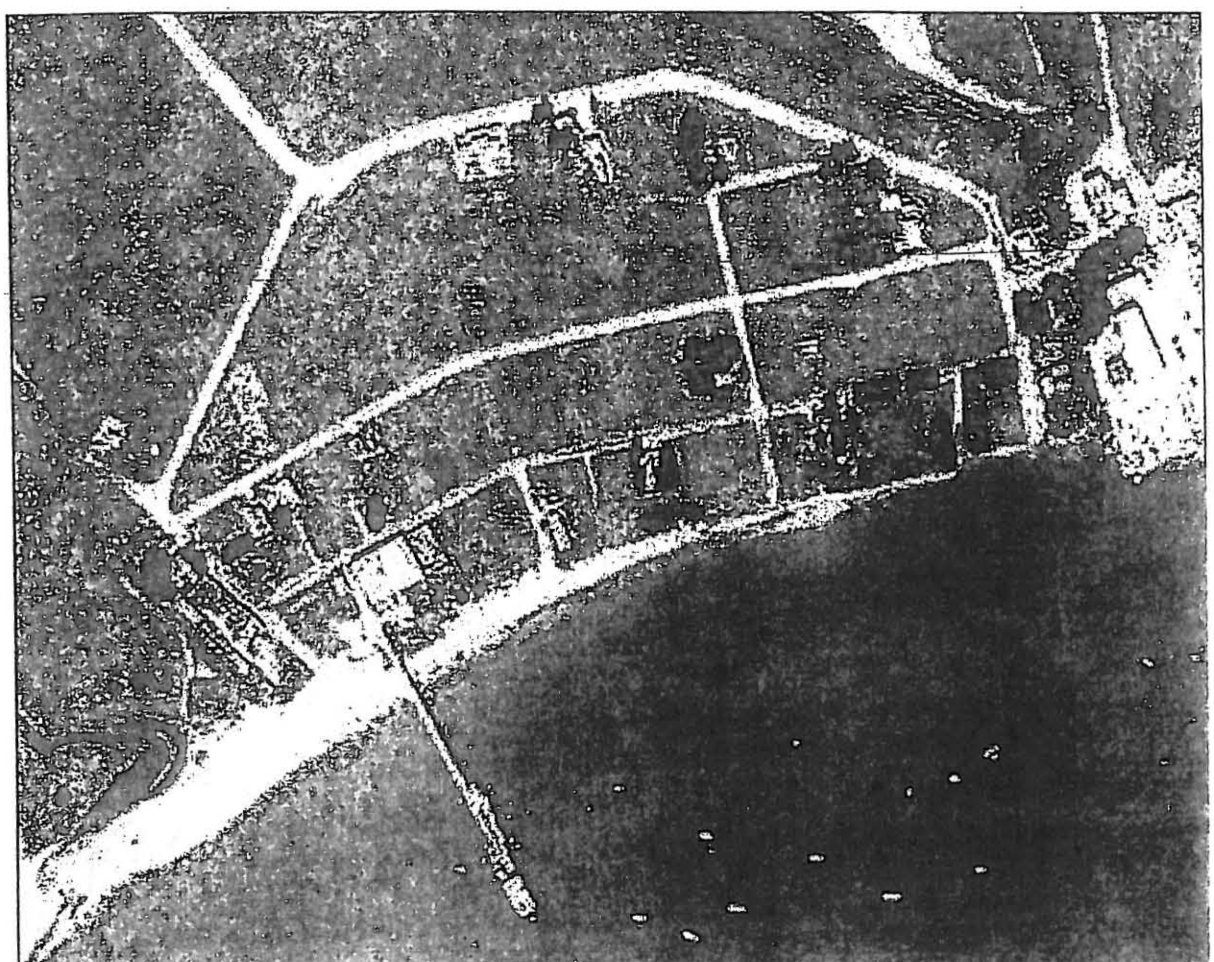
At Broadway, view of slope protection
in front of conference center.

APPENDIX B

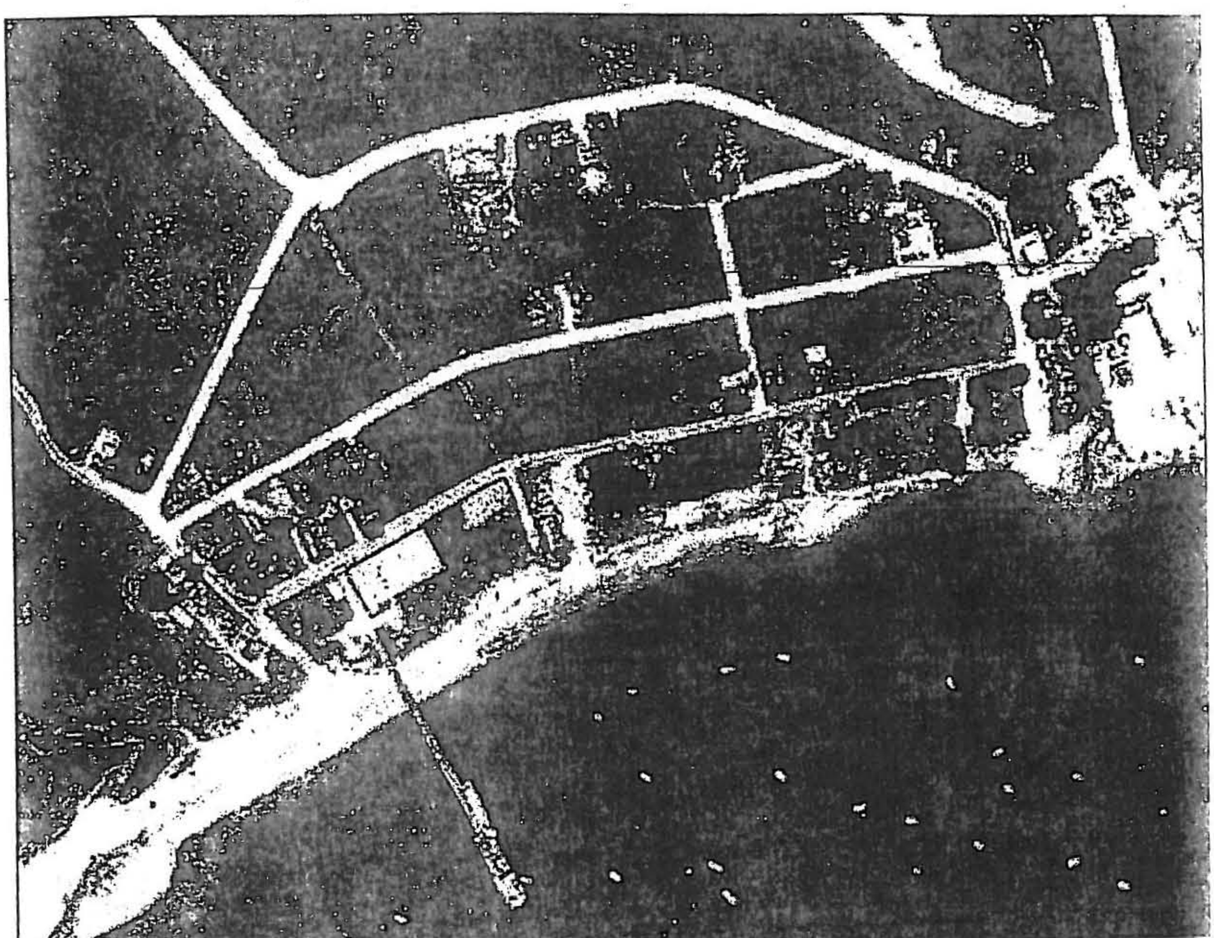
Aerial Photographs Used in Analysis

October, 1969

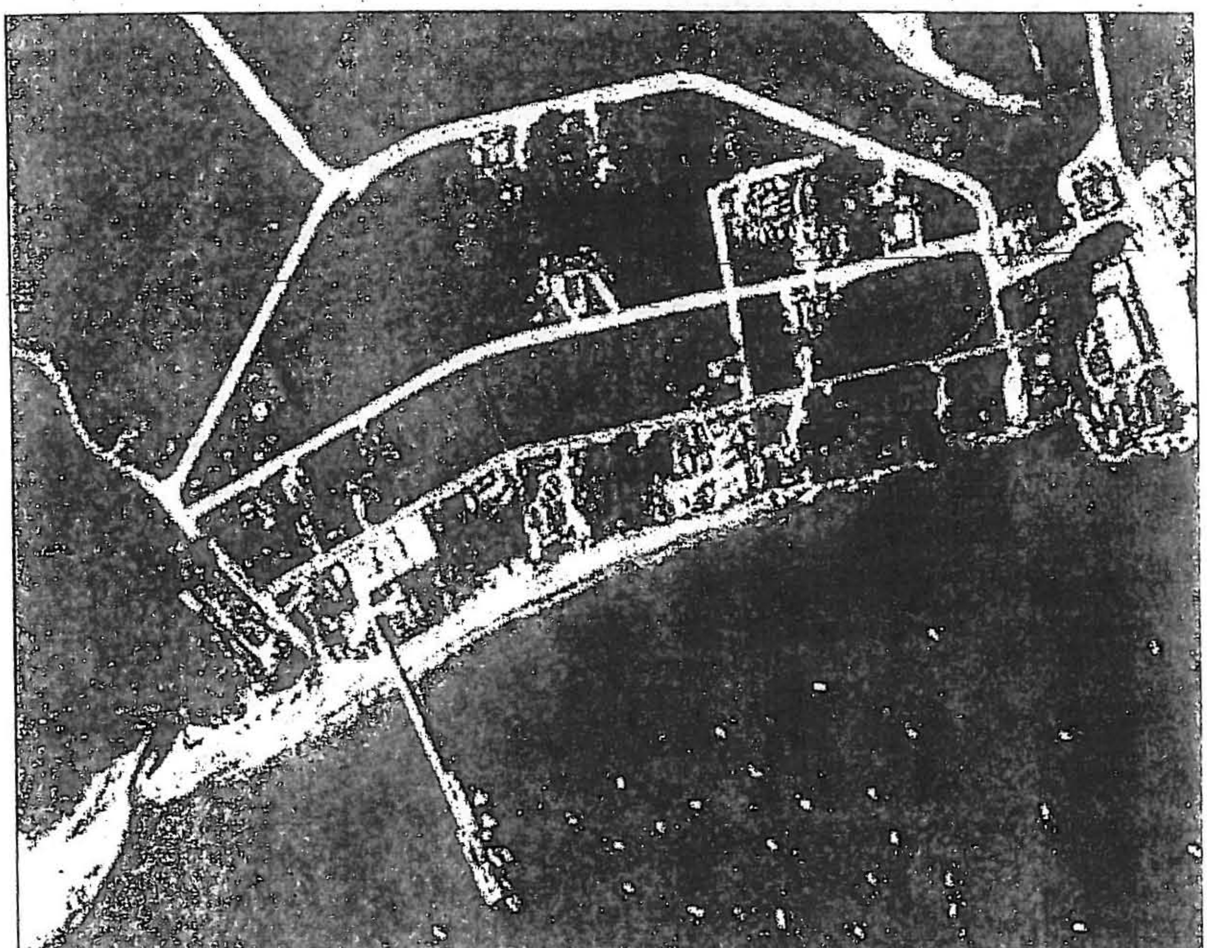




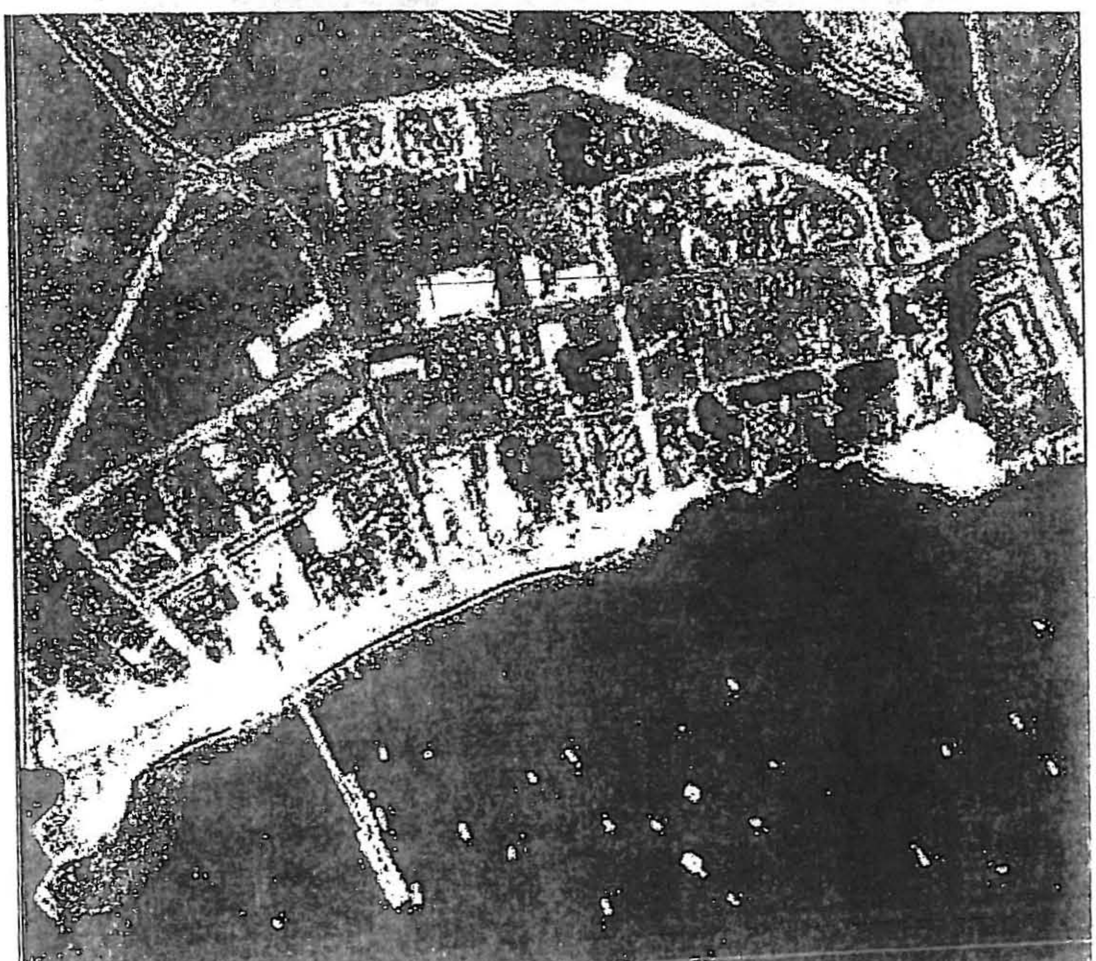
May, 1972



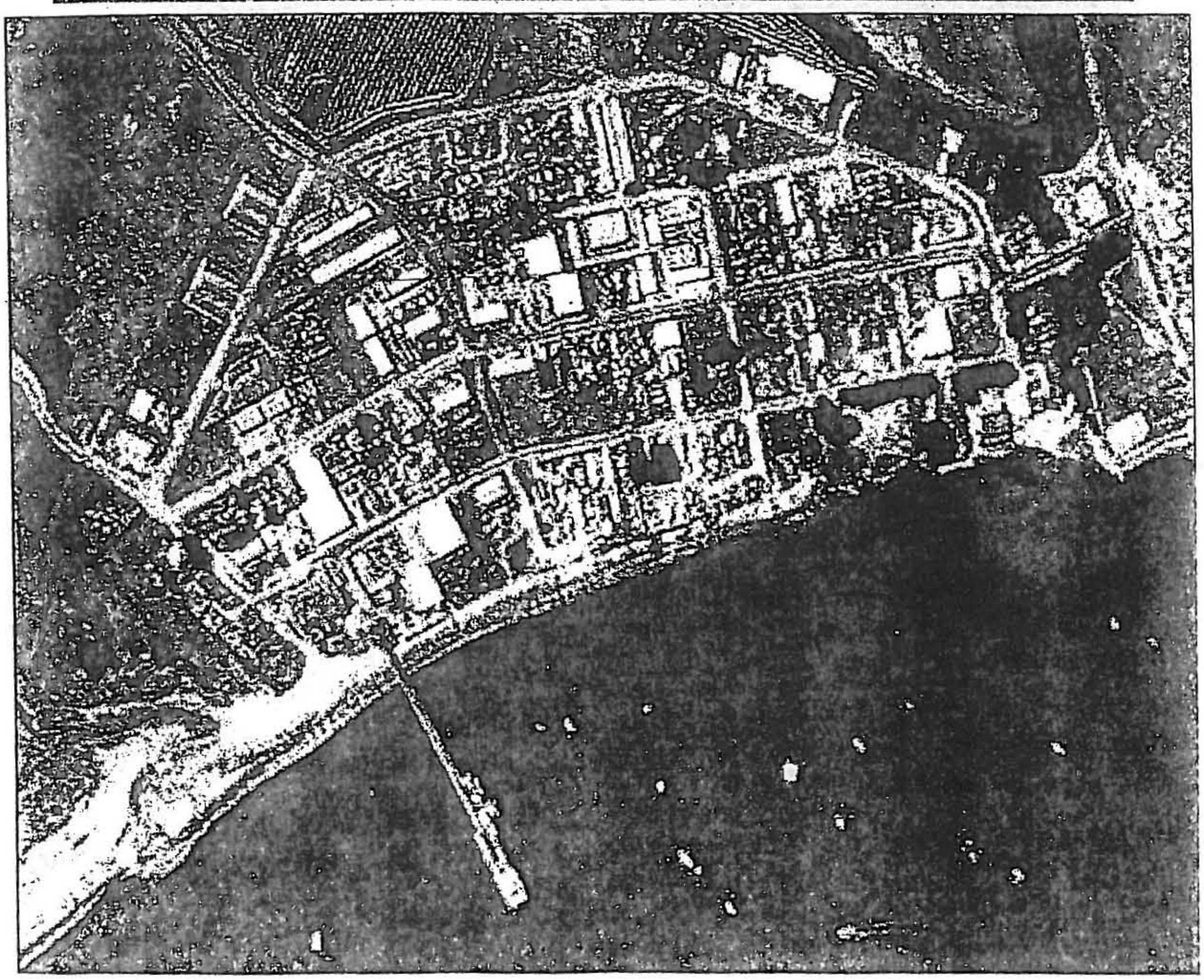
April, 1975



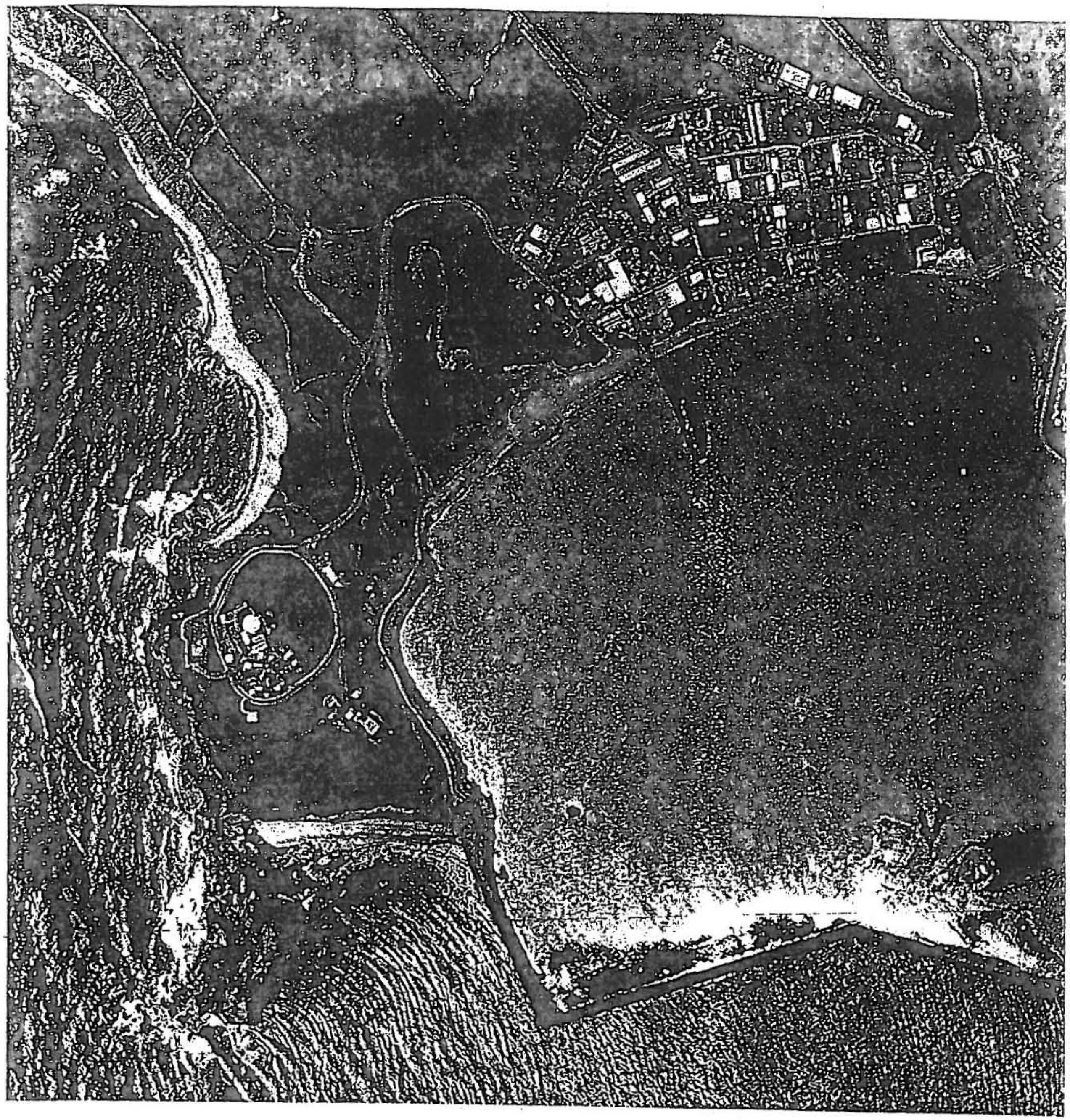
June, 1981



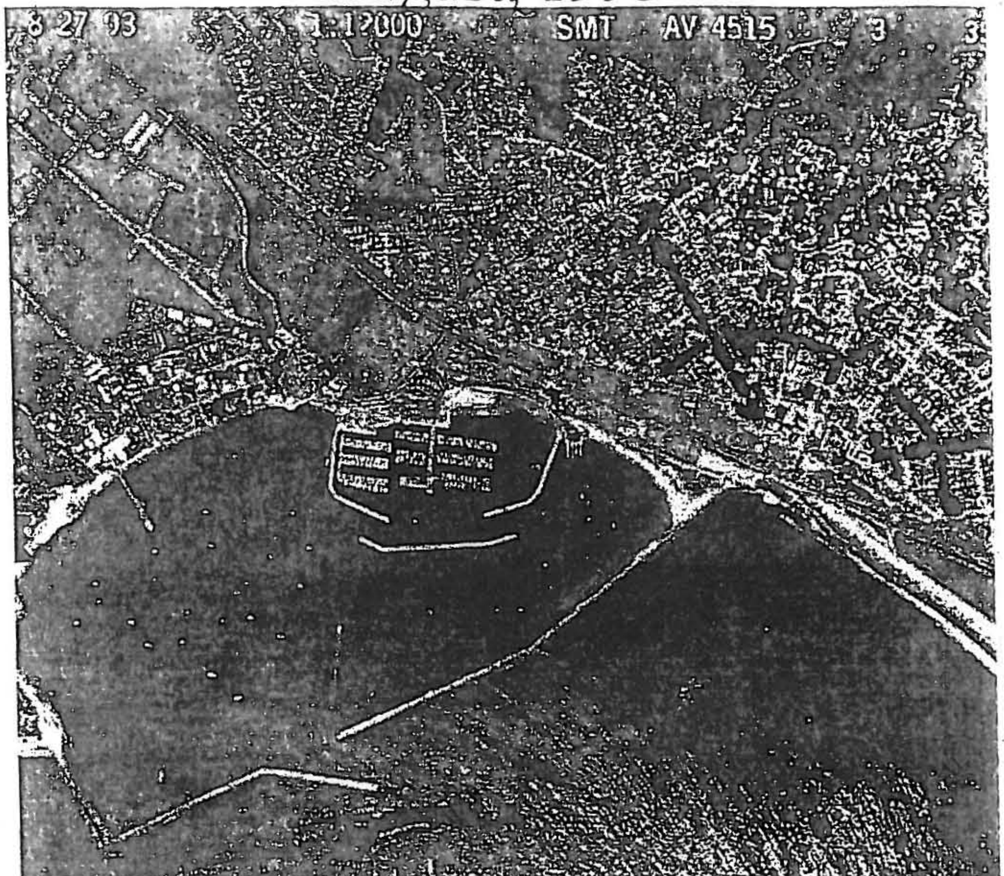
June, 1989



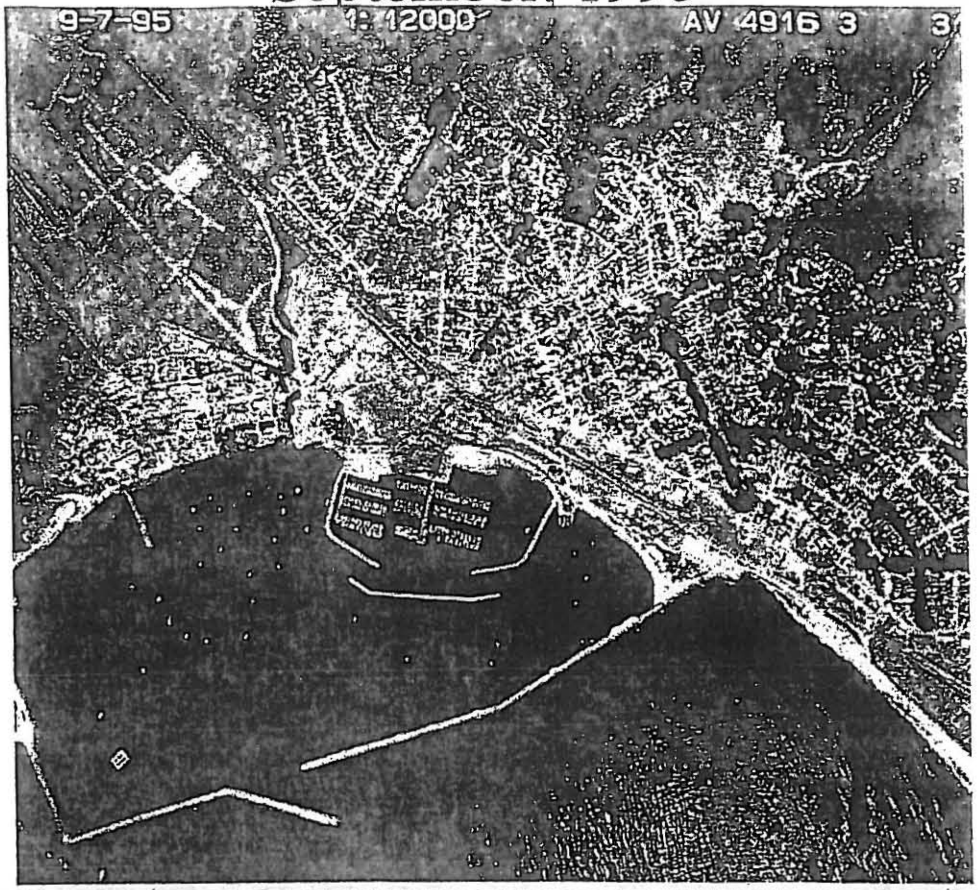
July, 1991



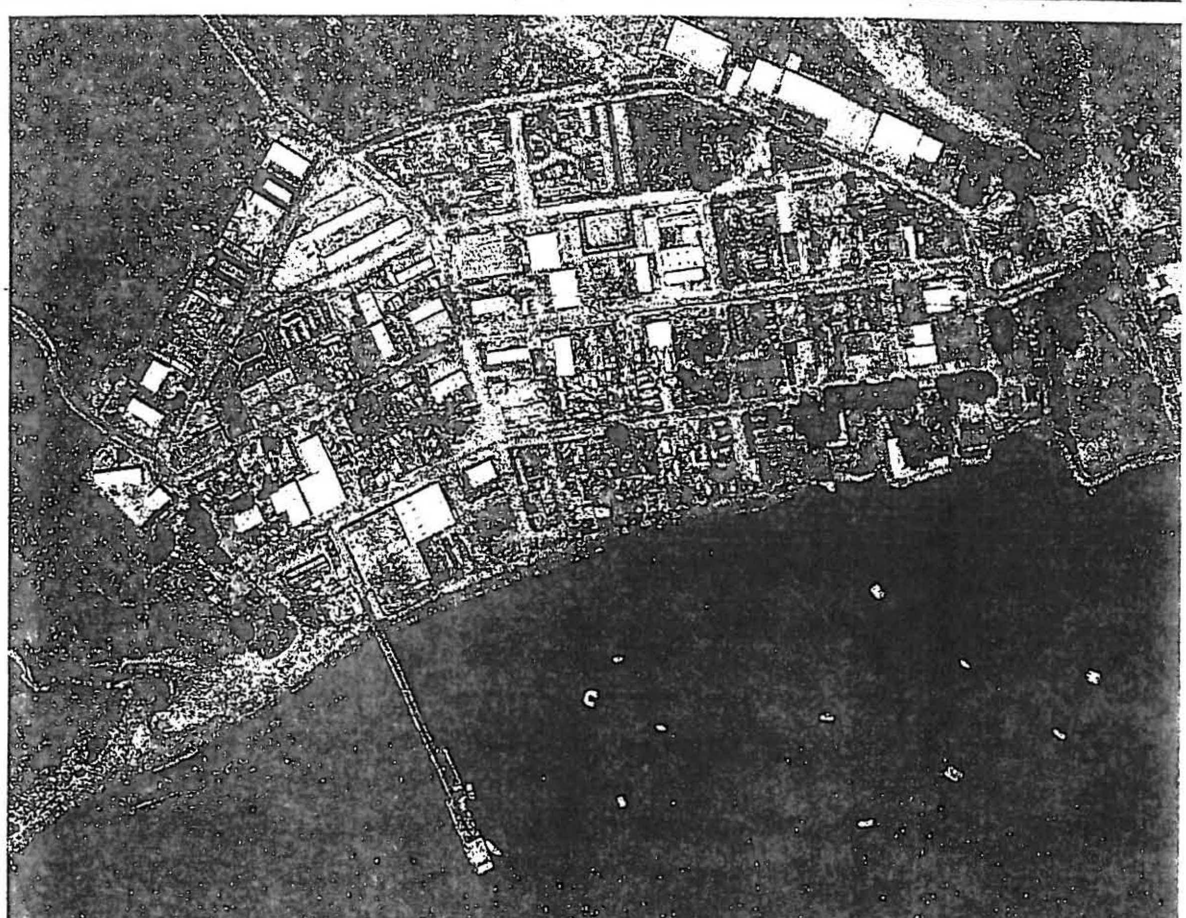
August, 1993



September, 1995



August, 2000



June, 1997

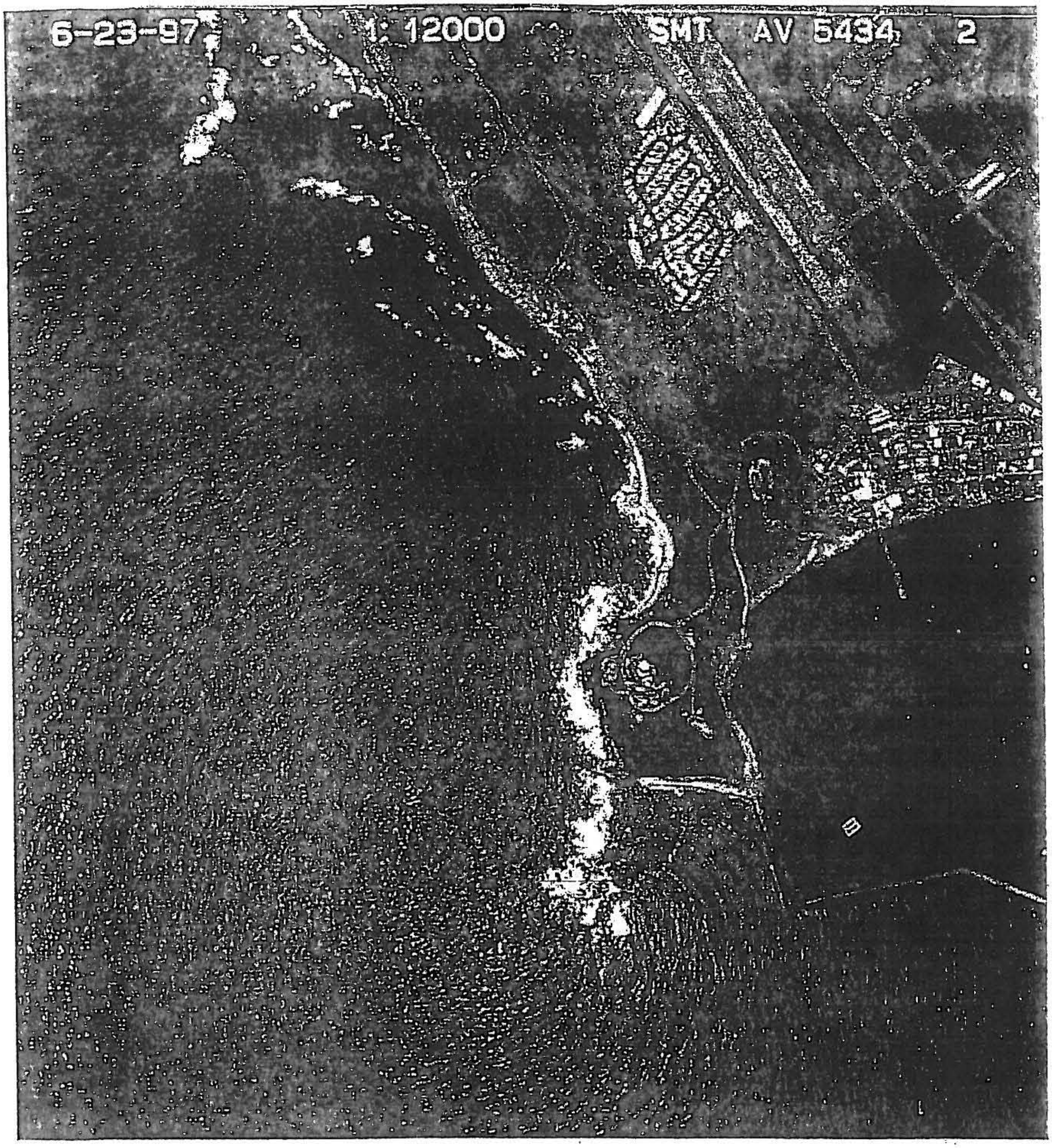


FIGURE 2: SITE CONDITIONS
(FEB 2000, APPROX SCALE 1"=100')